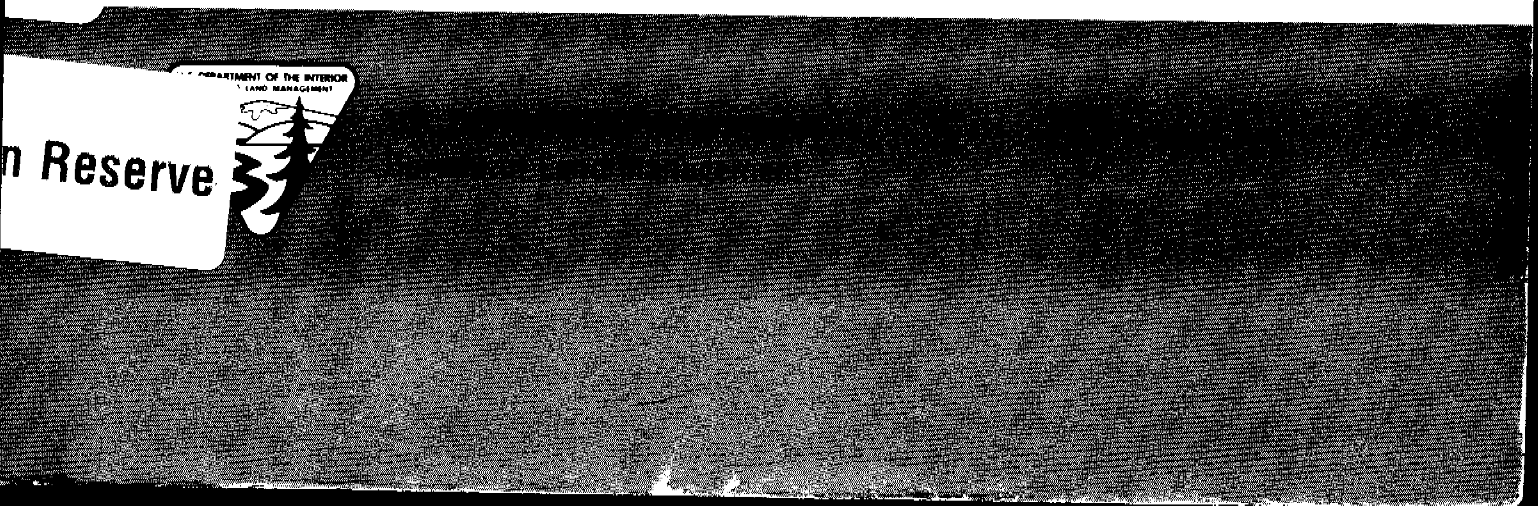
Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1979

Volume V. Receptors — Microbiology Contaminant Baselines

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration



VOLUME I	RECEPTORS -- MAMMALS BIRDS
VOLUME II	RECEPTORS -- BIRDS
VOLUME III	RECEPTORS -- FISH, LITTORAL, BENTHOS
VOLUME IV	RECEPTORS -- FISH, LITTORAL, BENTHOS
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Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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Bureau of Land Management

DISCLAIMER

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RECEPTORS -- MICROBIOLOGY

CONTENTS

ANNUAL REPORT

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development on the Outer Continental Shelf of Alaska

RU #29

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Prepared for:

Outer Continental Shelf Energy
Assessment Program
National Oceanic and Atmospheric
Administration

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Research Technicians:	Anne Bronner Ramneek Mohan Larry Figgs
Consultants:	Micah Krichevsky Elaine Krichevsky

I. Objectives - Summary

The main objectives of this study were to characterize microbial populations in Lower Cook Inlet, and the Beaufort Sea, to determine microbial hydrocarbon biodegradation potentials in Lower Cook Inlet, and the Beaufort Sea, to study denitrification potentials in the Beaufort Sea and to study degradation of petroleum in sediment in the Beaufort Sea. *In situ* experiments were sampled in Elson Lagoon to determine the fate of oil trapped in sediment. A Most Probable Number Procedure was used for enumeration of hydrocarbon utilizing microorganisms. Hydrocarbon utilizers in Cook Inlet were found in especially high numbers in several bays on the west side of the Inlet. The numbers of viable heterotrophs enumerated in Cook Inlet were low compared to the Beaufort Sea. The diversities of heterotrophic bacterial communities in Cook Inlet were generally high, indicative of a pristine area. Denitrification potentials were high in areas of apparent nutrient enrichment in the Beaufort Sea. Nitric oxide appears to be a major denitrification product in these areas.

II. Introduction - Scope of Work

This study is a continuation of an effort to characterize microbial populations and the ability of microorganisms to biodegrade petroleum hydrocarbons in proposed Alaskan OCS oil and gas lease areas. The approach has been to determine the distribution and population levels of several microbiological groups, e.g., hydrocarbon degraders within a geographic area, to extensively characterize selected microorganisms and using numerical taxonomy to determine the diversity of the microbial community and an inventory of the dominant microbial taxa within the geographic area. During this year microbial populations were characterized within Cook Inlet and the Beaufort Sea. Studies were begun to develop a probabilistic identification matrix for bacterial populations in Alaskan OCS areas.

As part of this study intensive surveys have been conducted to determine the biodegradation potentials of indigenous microbial populations for petroleum hydrocarbons. During the past year hydrocarbon biodegradation potentials were estimated within Cook Inlet and the Beaufort Sea. Denitrification potentials were also determined for sediment samples collected in the Beaufort Sea. In addition to surveys to determine hydrocarbon biodegradation potentials, intensive studies were continued in the Beaufort Sea to follow the chemical changes in crude oil as it undergoes biotic (biodegradation) and abiotic (physical and chemical) weathering in sediment.

III. Current State of Knowledge

The state of knowledge concerning microbial populations and hydrocarbon biodegradation in Alaskan OCS areas has been summarized in previous annual reports. A summary of some past data and new information developed from this project are described below.

IV. Study Area

The sampling sites used during this year are shown in Figures 1 and 2.

V. Methods and Rationale of Data Collection

Enumeration

The rationale of data collection for characterization of microbial populations was to sample surface water and sediment at a series of stations within a geographic area. Microbial populations were enumerated from each sample using direct count and viable plate count procedures. These procedures have been described in previous reports. A Most Probable Number (MPN) method was used in these studies. Most Probable Number estimates of hydrocarbon utilizers were performed as follows: Dilutions of samples were added to 60 ml stoppered serum vials containing 10 ml autoclaved Bushnell Haas broth (Difco) with 3% added NaCl, and 50 μl filter sterilized (0.2 μm Millipore filter) crude oil spiked with 1-^{14}C *n* hexadecane (s.p. act. = 0.9 μCi/ml oil). Cook Inlet oil was used for Cook Inlet studies; Prudhoe Bay crude oil was used for Beaufort Sea studies. The procedure has been described in detail in previous reports.

Taxonomic Characterization

Microorganisms selected at random from marine agar 2216 enumeration plates were considered as representative heterotrophic microorganisms. These organisms were extensively characterized. Approximately 300 phenotypic characteristics were determined for each strain. Characterization included morphological, physiological, biochemical, and nutritional testing. A comprehensive list of tests was supplied in a previous annual report. Following testing, the data was analysed by cluster analysis. Cluster analyses were performed using Jaccard coefficients and unweighted average linkage sorting. Taxonomic groupings or clusters were recognized at greater than 70% similarity. The diversity of bacterial populations was estimated using the Shannon diversity index. The formula $\overline{H} = C/N\ (N \log_{10} N - \Sigma n_i \log_{10} n_i)$ was used where $C = 3.3219$, N = total number of individuals and n_i = total number of individuals in the i^{th} taxonomic grouping.

The feature frequencies for the organisms forming a cluster were examined for evidence of adaptation and functional capacity of the organisms in a cluster. The features also were examined to determine the separation values of each feature. Features with maximal separation values, i.e., ability to differentiate one taxa from another, are being determined to develop a probabilistic identification matrix. This will greatly reduce the number of tests that would be needed in future monitoring efforts to taxonomically characterize the microbial populations in Alaskan OCS areas.

Hydrocarbon Biodegradation Potential

Hydrocarbon biodegradation potentials were determined as previously described. The method measures the production of $^{14}CO_2$ from a radiolabelled hydrocarbon (either hexadecane, pristane, naphthalene, or benzanthracene) within a crude oil.

Denitrification Potentials

A slurry of each sediment sample was used to inoculate replicate 30 ml serum vials containing either 5 ml of Rila marine salts mix, 5 ml of Rila salt mix + 0.1% KNO_3, or 5 ml Rila salt mix + 0.1% KNO_3 + 0.3% beef extract + 0.5% peptone. All vials and solutions had been sterilized by autoclaving at 121 C for 15 min., and had been cooled to 5 C before inoculation with sediment samples. The vials were aseptically recapped with rubber stoppers and purged with argon for 15 min. After purging, 5 ml of the headspace gas was removed with a syringe and replaced with 5 ml of acetylene generated from calcium carbide. The serum stoppers were covered with silicon rubber cement to prevent leakage through the needle punctures. Incubation was at 5 C. After 24 and 240 hours incubation, 0.5 ml saturated KOH solution was injected into each replicate to stop biological activity. Vials were maintained at 5 C until the headspace gases could be analysed in the laboratory. All tests were performed in triplicate.

Headspace gases in each vial were analysed using a Hewlett-Packard 5700 gas chromatograph equipped with a Carle thermal conductivity detector. The conditions for gas chromatography were injector temperature 100 C, oven temperature 50 C, carrier gas 22 c per minute helium column Poropak Q-6 m x 0.3 m. The injection size was 250 μl of headspace gas. Dilutions of pure gases and argon were used for calibration. A Hewlett-Packard 5992 gas chromatograph-mass spectrometer was used to confirm the identities of compounds detected with the gas chromatograph. Minimum levels of NO and N_2O detection were 25 nmoles/g dry wt./day and 40 nmoles/g dry wt./day, respectively.

In situ Biodegradation

Intensive *in situ* hydrocarbon biodegradation studies were conducted in the Beaufort Sea at a site in Elson Lagoon. The site was chosen because of its accessability for diving operations, and because it is representative of the nearshore ecosystems likely to be the initial sites for oil development in the Beaufort Sea.

Oil was exposed *in situ* in sediment. Two hundred ml Prudhoe Bay crude oil was placed in 0.0625 m^2 Plexiglas trays. Freshly collected sediment was added to the trays to a depth of 5 cm. The trays were replaced *in situ*. Replicate trays were collected after 2, 7, 14, 21, 28, 120, 240, and 360 days exposure.

Oil has been recovered from the sediment using sequential solvent extraction with diethyl ether, benzene and methylene chloride. The oil residues were analysed by gas liquid chromatography and mass spectrometry. A 30 m SP2100 glass capillary column was used for analyses. A temperature program of 100 C to 250 C was used. Both alkanes and aromatic compounds including 4 membered ring structures can be detected and identified in these analyses. A Hewlett-Packard 5830 gas chromatograph and 5992 GC-MS were used for these analyses. Repeated instrumental problems with the GC-MS unit have delayed completion of analyses and only preliminary analyses are available for this report. It appears that Hewlett-Packard has been able to repair the unit satisfactorily and that future analyses will proceed in a timely fashion.

The intercalibration NOAA sediment sample was extracted and has been analysed. The results are being forwarded to Dr. John Calder, NOAA, Boulder.

VI. Results

Enumeration

All enumeration results have been reported in previous quarterly and annual reports. Enumeration data are on file in the NIH computer system. Table 1 describes the files containing enumeration data. Table 2 is a listing of selected enumeration data contained in those files. These enumeration files contain data produced under RU #29 and RU #190. These data files are accessible through NODC. All data contained in these files can be transmitted to a computer facility in Boulder and plotted on maps meeting BLM-NOAA specifications. On specific request such maps will be produced for BLM-NOAA purposes.

Hydrocarbon Biodegradation Potentials

Hydrocarbon biodegradation potentials have been reported in previous quarterly and annual reports. Data on hydrocarbon biodegradation potentials have now been placed in enumeration files within the NIH computer. A listing of hydrocarbon biodegradation potentials is included in Table 2. As with the enumeration data, the hydrocarbon biodegradation potentials can be mapped through the computer facility in Boulder upon request of BLM-NOAA.

Denitrification Potentials

The rates of denitrification were below threshhold detection levels unless the sediment samples were supplemented with nitrate. No N_2O was detected from unamended samples even after 10 days incubation despite the fact that many samples had relatively high concentrations of fixed forms of nitrogen. When supplemented with nitrate, denitrification potentials could be assayed. Table 3 shows the rates of production of nitrous oxide and nitric oxide from sediments amended with nitrate with and without added organic compounds.

The most striking result was the relatively high rates of production of nitric oxide produced from several sediment samples, especially when supplemented with organic matter. In several cases production of nitric oxide was greater than production of nitrous oxide. The most active areas of nitric oxide production appeared to be in an are of known nutrient upwelling (near Stations 630 and 631), and in a region east of the mouth of the Colville River where nutrients are probably deposited. High rates of NO production were also detected at Station 634, an area not known as a region of nutrient enrichment.

Most sediment samples exhibited nitrous oxide production. Addition of organic matter resulted only in a modest increase in N_2O production. The range of N_2O production without addedmatter was 0-220 nmoles/g dry wt./day. For comparative purposes, rates of denitrification in Japanese coastal sediments have been reported in the range of 0.1-0.7 μg atoms nitrogen/g dry wt./hour, and from sediments collected near Denmark in the range of 0.04-0.1 μmoles nitrogen/ml/day. The Japanese studies were conducted near 20 C, the Danish studies near 5 C. Our results are within these ranges.

It is evident from the data reported above that the indigenous microorganisms in the Beaufort Sea marine sediments are capable of denitrification activities. Despite the apparent geographic relation of NO production and nutrient enrichment, there were no statistically significant correlations between the denitrification potential and the nutrient concentrations of the sediment samples.

Concurrent studies indicated that rates of nitrogen fixation were less than 0.25 μmoles/g dry wt. sediment/day. Addition of organic matter, as may occur with development offshore oil resources, would probably increase losses of nitrogen from sediment due to denitrification.

Taxonomic Studies

Numerical taxonomic testing has been completed on all isolates from previous cruises in Cook Inlet and the Beaufort Sea. Cluster analyses and feature frequency analyses have been performed on most of these isolates. Rather than include within this report the rather large dendograms and feature frequency tables generated in those analyses, Table 4 lists the files of these analyses presently available within the NIH computer. Printouts of these files can be obtained by request through NODC.

In addition to the general taxonomic surveys conducted in Cook Inlet and the Beaufort Sea, a model experiment was run to determine the effects of crude oil on diversity of bacterial populations in nearshore Arctic marine waters. Results of this study are shown in Table 5. Application of crude oil indeed caused a dramatic reduction in the diversity of bacterial populations.

In situ Oil Biodegradation Studies

The analyses of crude oil recovered from the *in situ* tray experiments being conducted in Elson Lagoon have been hampered by malfunctions of the GC-MS instrument. The problems have centered on electronic failures of the unit, leaks in the injection system, and software problems that precluded effective stripping of background. These problems have greatly increased the difficulty of quantifying and identifying the complex structure hydrocarbon mixtures recovered from the oil sediment trays. At present most of these analytical difficulties have been overcome and results are rapidly being obtained. Tables 6 and 7 show the concentrations of identified hydrocarbons recovered from the trays during 28 days of winter exposure. Additional analyses are presently being performed on the longer term exposures. Also, identification of other resolved structures will lead to more detailed analyses in future reports.

It appears from the data in Table 6 and Table 7 that the oil is patchily distributed within the sediment. The oil was originally added at a concentration of 1% by weight. This saturated the system as would likely occur as a result of a major acute oil spill. The apparent increases in concentration of hydrocarbons at 21 days is undoubtedly due to the patchiness of oil distribution. The lack of significant change in the pristane-heptadecane ratio and the phytane-octadecane ratio indicate a lack of biodegradation during this 28 day exposure. There would appear to be decrease by 28 days in the concentrations of light cyclic compounds. However, light aromatic compounds including substituted benzene and naphthalene compounds were still present after 28 days.

VII. Discussion and Interpretation of Results

The enumeration data continued to reveal a curious paradox. Viable counts of microorganisms in Cook Inlet in the Gulf of Alaska are lower by orders of magnitude than viable counts of bacteria in surface waters of the Beaufort Sea. The reasons for this phenomenon are unknown. Cruises planned for the next few months in the Bering Sea should answer the question of whether there is a gradual rise in viable bacterial populations between the Aleutian Islands and Point Barrow, or whether there is a large increase in the bacterial populations at some point north of the Aleutian Islands.

The Most Probable Number determinations of hydrocarbon utilizers coupled with the hydrocarbon biodegradation potential determinations have pinpointed areas which appear to have been contaminated with hydrocarbons. In Cook Inlet these areas include Kachemak Bay, Upper Cook Inlet near Kalgin Island, and the west side of Cook Inlet within Three Bays just north of Kamishak Bay. The area north of Kalgin Island may be receiving hydrocarbons from drilling operations in Upper Cook Inlet. A cruise is planned during May in Upper Cook Inlet to more accurately define the distributions of hydrocarbon utilizing microorganisms in relation to present drilling operations. The concentrations of hydrocarbon utilizing microorganisms within the Bays on the west side of Cook Inlet are indicative of a chronic source of hydrocarbons perhaps from a natural seepage. The abundance of hydrocarbon utilizers in these Bays may be indicative of proximal petroleum reserves. In the Beaufort Sea similar indications of the likely presence of petroleum hydrocarbons was found in the vicinity of Demarcation Bay, north of the Kuparuk River and north of Canning River. The data suggests a high probability of future petroleum development in these regions or of naturally occuring seepages of hydrocarbon into these areas. The low degradation potentials for complex polynuclear aromatics, e.g., benzanthracene, indicates that such compounds will likely accumulate in sediments should contamination occur as a result of petroleum development.

The denitrification potentials raise the question of why nitric oxide accumulated together with nitrous oxide in some cases. It is possible that denitrification at some locations in the Beaufort Sea is naturally blocked at nitric oxide and that nitric oxide rather than nitrous oxide or molecular nitrogen is the abundant terminal product of denitrification. The ratio of nitric oxide to nitrous oxide production may reflect the generic composition of the microbiota in a given sediment sample. There is an indication in our study that added organic compounds select for nitric oxide production over nitrous oxide production. This is indicated both by the geographic occurrence of nitric oxide evolution in areas of nutrient enrichment and by the stimulation of nitric oxide evolution by adding organic matter *in vitro*. The greatest rates of nitric oxide evolution were detected in an area of nutrient upwelling near Barter Island and northeast of the Colville River, where there is natural nutrient enrichment. The studies indicate the potential for markedly increased rates of denitrification if organic compounds are added to sediments in the Beaufort Sea as a result of petroleum development. Increased rates of denitrification could decrease the availability of fixed forms of nitrogen which are required by primary producing plankton and macroorganism populations. Thus, stimulated denitrification could reduce the overall carrying capacity of affected regions.

The taxonomic studies have continued to indicate that microbial populations in Alaskan OCS areas are taxonomically distinct from previously described marine microorganisms. Microbial populations in Alaskan OCS areas exhibit adaptive features such as the ability to grow at low temperatures and a high incidence of pigmentation in areas receiving intense solar radiation. The data bases generated by the taxonomic studies have proven to be quite flexible and amenable to additional analyses beyond those originally contemplated. For example, it has been possible to calculate diversities of microbial populations in Alaskan OCS areas. Our studies represent the first studies on bacterial populations that have permitted calculations of taxonomic diversities. The diversities of microbial populations appear to be a sensitive indicator of environmental stress. As indicated in this report, microbial diversity responds to the presence of pollutants such as petroleum hydrocarbons. We have also found that microbial diversity responds to natural environmental stress. Diversities are lower in waters of the Beaufort Sea, which are subject to severe stress due to ice formation, than in waters in the Gulf of Alaska and Cook Inlet. Diversities are normally quite high in sediments of these regions. The diversities in surface waters are low in areas of low current exchange. The microbial populations appear to be less diverse in areas of low current exchange and within gyres. Thus, the microbial populations are less diverse within the so-called null zone within Cook Inlet and within the gyre near Kayak Island in the northeast Gulf of Alaska. As a general rule, diversities calculated by the Shannon Index of less than 3.0 are indicative of environmental stress. The stress may be natural, such as ice formation or low current movement, or may be the result of human activities, such as introduction of pollutants.

The taxonomic data bases also provide a resource which can be used in further analyses. We are currently developing probabilistic identification matrices which will aid in future studies including monitoring efforts. We are also contemplating further analyses of the data by factor analysis and principal component analysis to identify the principal environmental factors that are associated with the occurrence of specific microbial populations in a given region.

The *in situ* oil biodegradation studies indicate a prolonged retention of low molecular weight hydrocarbons that become entrained within the sediment. Analyses indicate a probable patchy distribution for these hydrocarbons in sediment. The question of long term persistence of hydrocarbons in these sediments is presently being addressed and continuation of these studies is contemplated. Within the first month of exposure within sediment, biodegradation does not appear to be a major factor in reducing concentrations of petroleum hydrocarbons that become incorporated into the sediment. All data to date indicate that exposures of petroleum hydrocarbons in the Beaufort Sea will persist for long periods of time, and that light toxic compounds, such as substitute benzenes and naphthalenes, will be retained.

VIII. Summary of Fourth Quarter Activities

Activities during the final quarter have consisted mainly of extracting and analysing hydrocarbons from the *in situ* experiments and preparing for upcoming cruises in Upper Cook and the Bering Sea. Additionally, the intercalibration sediment sample has been extracted and analysed. Results of these analyses indicate the presence of 110 compounds in the alkane fraction and 76 compounds in the aromatic fraction. The alkanes include light hydrocarbons. The aromatics include heavy polynuclear aromatics.

TABLE 1

ENUMERATION FILES DESCRIPTION
MARCH 31, 1979

188 ENUMERATION DATASET: BEAUFORT & GULF, AUG SEPT OCT 1975 CRUISE
AND WINTER 1976 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0188
QUERY-SEARCHABLE FILE: WLH1EJK.Q0188

236 ENUMERATION DATASET: BEAUFORT, AUG SEPT 1976 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0236
QUERY-SEARCHABLE FILE: WLH1EJK.Q0236

237 ENUMERATION DATASET: COOK INLET , OCT 1976 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0237
QUERY-SEARCHABLE FILE: WLH1EJK.Q0237

254 ENUMERATION DATASET: COOK INLET APRIL 1977 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0254
QUERY-SEARCHABLE FILE: WLH1EJK.Q0254

259 ENUMERATION DATASET: COOK INLET NOV 1977 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0259
QUERY-SEARCHABLE FILE: WLH1EJK.Q0259

306 ENUMERATION DATASET: COOK INLET MAY 1978 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0306
QUERY-SEARCHABLE FILE: WLH1EJK.Q0306

307 ENUMERATION DATASET: BEAUFORT, SEPT 1977 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0307
QUERY-SEARCHABLE FILE: WLH1EJK.Q0307

309 ENUMERATION DATASET: BEAUFORT SEPT 1978 CRUISE
RKC CARD IMAGE FILE : HAE1MIK.F0309
QUERY-SEARCHABLE FILE: WLH1EJK.Q0309

TABLE 2

FORM NUMBER = 100188 BEAUFORT & GULF, AUG/SEPT/OCT 1975 CRUISE AND WINTER 1976 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
#BBP1													
#BB0001	71	21.2	156	32.2	3.7		3.0	3.81	0.00	0.00			
#BB0002	71	21.2	156	32.2	2.3		3.2						
#BB0003	71	25.0	156	20.0	9.3								
#BB0004	71	15.7	156	0.0	2.0	22.80							
#BB0005	71	19.0	156	15.8	3.3	17.00	2.0						
#BB0006	71	15.7	156	0.0	3.3		1.5						
#BB0007	71	21.5	156	21.1	11.3								
#BB0008	71	22.1	156	21.7	8.0								
#BB0009	70	30.6	149	34.2	2.0		2.9						
#BB0010	70	26.5	149	3.1	2.0		1.8	0.00	0.00	0.00			
#BB0011	70	19.1	148	19.3	2.0	19.20	-0.8						
#BB0012	70	20.3	148	20.0	2.3	19.80	-0.4						
#BB0013	70	20.9	148	23.9	2.7	19.80	-0.2						
#BB0014	70	20.1	148	26.0	1.7	17.50	-0.2						
#BB0015	71	21.2	156	32.2	2.3								
#BB0016	71	21.5	156	26.2	2.0								
#BB0017	71	21.5	156	21.1	11.3								
#BB0018	71	22.1	156	21.7	8.0								
#BB0019	70	19.1	148	19.3	2.7	19.50	1.0						
#BB0020	70	20.3	148	20.0	3.3	20.00	1.5						
#BB0021	70	24.5	148	22.3	3.0	21.00	1.0						
#BB0022	70	26.6	148	23.5	7.7	22.50	0.0						
#BB0023	70	21.8	148	27.5	1.7	17.50	2.3						
#BB0024	70	20.9	148	23.9	2.3	19.30	2.2						
#BB0025	70	20.0	148	22.1	2.7	18.50	2.2						
#BB0025A	71	21.2	156	32.2	1.0	20.00	0.4						
#BB0026	70	22.9	148	21.4	1.7	19.20	1.8						
#BB0027	70	24.5	148	22.3	6.7	21.50	0.3						
#BB0027A	71	21.5	156	26.2	2.0	20.50	-0.5						
#BB0028	70	26.6	148	23.5	6.3	21.30	0.0						
#BB0029	70	24.6	148	26.0	5.0	19.20	0.6						
#BB0030	70	23.6	148	27.3	2.3	20.20	1.5						
#BB0031	71	21.2	156	32.2	2.0		-0.5						
#BB0032	71	21.5	156	26.2	2.3		-0.5						
#BB0033	71	21.5	156	21.1	2.3		-0.5						
#BB101	71	23.0	155	56.0	6.0		0.0						
#BB102	71	23.0	155	26.0	6.0		0.0						
#BB103	71	23.0	154	54.0	7.0		0.0						
#BB104	71	21.4	156	27.0	5.0		0.0						
#BB105	71	21.6	156	21.0	5.0		0.0						
#BB106	70	32.0	148	22.0	8.0		0.0						
#BB107	70	31.0	147	24.0	14.0		0.0						
#BB108	70	28.0	147	30.0	3.5		0.0	0.00	0.00	0.90			

```
*BB109   70 47.0  147  0.0    26.0          0.0
*BB110   70 22.5  148 20.0     2.0          0.0
*BB111   71 26.0  152 22.0    50.0          0.0
*BB112   71 19.0  152 33.0    30.0          0.0
*BB113   71  8.0  152 55.0     9.0          0.0
*BB114   71 23.0  153 50.0    22.0          0.0
*BB115   71 23.0  154 22.0    13.0          0.0
*BI101   71 31.0  156  6.0     0.0          0.0
*BI102   71 34.5  155 35.0     0.0          0.0
*BI103   71 39.0  155  4.0     0.0          0.0     0.00      0.00      0.00
*BI104   71 21.6  156 21.0     0.0          0.0
*BI105   71 23.0  155 56.0     0.0          0.0     0.00      0.00      0.00
*BI106   71 23.0  155 26.0     0.0          0.0     0.00      0.00      0.00
*BI107   71 23.0  154 54.0     0.0          0.0     0.00      0.00      0.00
*BI108   71 21.4  156 27.0     0.0          0.0
*BI109   71 21.6  156 21.0     0.0          0.0
*BI110   71  8.0  146 30.0     0.0  3.20    0.0     0.00      0.00      0.00
*BI111   70 32.0  148 22.0     0.0          0.0     0.00      0.00      0.00
*BI112   70 31.0  147 24.0     0.0          0.0     0.00      0.00      0.00
*BI113   70 28.0  147 30.0     0.0          0.0     0.00      0.00      0.00
*BI114   70 47.0  147  0.0     0.0 23.80    0.0     0.00      0.00      0.00
*BI115   70 22.5  148 20.0     0.0  1.00    0.0     0.00      0.00      0.00
*BI116   71 36.0  152 12.0     0.0  6.00    0.0     0.00      0.00      0.00
*BI117   71 46.0  151 52.0     0.0  2.50    0.0     0.00      0.00      0.00
*BI118   71 26.0  152 22.0     0.0 11.00    0.0     0.00      0.01      0.00
*BI119   71 19.0  152 33.0     0.0  8.50    0.0     0.00      0.00      0.00
*BI120   71  8.0  152 55.0     0.0  3.50    0.0     0.00      0.00      0.00
*BI121   71 23.0  153 50.0     0.0  5.00    0.0     0.00      0.00      0.00
*BI122   71 23.0  154 22.0     0.0  5.00    0.0     0.00      0.00      0.00
*BI123   71 34.5  155 35.0     0.0  4.00    0.0     0.00      0.00      0.00
*BW0001 71 21.2  156 32.2     1.0 26.00    3.0
*BW0002 71 21.2  156 32.2     1.0 26.50    3.2     0.01      0.00      0.00
*BW0003 71 25.0  156 20.0     1.0 23.80   -0.5     0.00      0.00      0.00
*BW0004 71 15.7  156  0.0     1.0 22.50    2.0     0.01      0.00      0.00
*BW0005 71 20.8  156 35.2          0.00
*BW0006 71 19.0  156 15.8     1.0 17.00    2.0     0.00      0.00      0.00
*BW0006A71 21.2  156 32.2     1.0 20.10    3.0     0.00      0.00      0.00
*BW0007 71 15.7  156  0.0     1.0 21.00    1.5     0.00      0.00      0.00
*BW0007A71 21.5  156 26.2     1.0 21.00    2.5     0.00      0.00      0.00
*BW0008 71 21.0  156 42.2     1.0 25.50    2.0     0.00      0.00      0.00
*BW0009 71 21.5  156 21.1     1.0 20.00   -0.2     0.00      0.00      0.01
*BW0009A71 21.5  156 21.1     1.0 20.00    2.0     0.00      0.00      0.00
*BW0010 71 22.1  156 21.7     1.0 20.50   -0.2     0.00      0.00      0.00
*BW0011 70 30.6  149 34.2     1.0 12.10    1.9     0.00      0.00      0.00
*BW0011A71 19.7  156 40.9     1.0
*BW0011B71 22.1  156 21.7     1.0 25.00    3.0     0.00      0.00      0.00
*BW0012 70 26.5  149  3.1     1.0 18.80    1.8
*BW0012A71 19.7  156 40.9     1.0 31.00    3.0
*BW0013 70 20.0  148 22.1     1.0 20.00    1.5     0.00      0.00      0.00
*BW0013A71 19.7  156 40.9     1.0  0.50
*BW0013B71 19.7  156 40.9     1.0 23.00    2.0
*BW0014 70 19.1  148 19.3     1.0 11.80   -0.8     0.00      0.00      0.00
*BW0014A71 19.7  156 40.9     1.0 23.00    3.0
*BW0015 70 20.3  148 20.0     1.0 11.10   -0.8     0.00      0.00      0.00
*BW0016 70 20.3  148 20.0     2.3 19.80   -0.4     0.00      0.00      0.00
*BW0017 70 20.9  148 23.9     1.0 11.40   -0.5     0.00      0.00      0.00
*BW0018 70 20.1  148 26.0     1.0  9.00   -0.4     0.00      0.00      0.00
*BW0019 71 21.2  156 32.2     1.0 18.30   -0.5     0.01      0.00      0.00
*BW0019A71 20.8  156 35.2     1.0 25.00    2.0
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*BW0020 71 21.5  156 26.2    1.0 18.20   0.0    0.00    0.00    0.00
*BW0021 71 21.5  156 21.1    1.0 18.50   0.0    0.00    0.00    0.00
*BW0022 71 22.1  156 21.7    1.0 18.80   0.0    0.00    0.00    0.00
*BW0023 70 19.1  148 19.3    1.0 14.50   1.0    0.00    0.00    0.00
*BW0024 70 20.3  148 20.0    1.0 16.00   1.5    0.00    0.00    0.00
*BW0024A71 21.0  156 42.2    1.0 25.50   2.0
*BW0025 70 21.7  148 20.8    1.0 19.50   1.5    0.00    0.00    0.00
*BW0026 70 24.5  148 22.3    1.0 20.00   1.0    0.00    0.00    0.00
*BW0026A71 21.2  156 32.2    1.0 20.00   0.4    0.01    0.00    0.00
*BW0027 70 26.6  148 23.5    1.0 21.50   0.5    0.00    0.00    0.00
*BW0028 70 21.8  148 27.5    1.0 17.80   2.5    0.00    0.01    0.00
*BW0028A71 21.5  156 26.2    1.0 20.50  -0.5    0.00    0.00    0.00
*BW0029 70 20.0  148 22.1    1.0 18.10   1.9    0.00    0.00    0.00
*BW0030 70 22.9  148 21.4    1.0 16.20   2.2    0.00    0.00    0.00
*BW0031 70 24.5  148 22.3    1.0 18.50   1.5    0.00    0.00    0.00
*BW0032 70 26.6  148 23.5    1.0 20.20   0.3    0.00    0.00    0.00
*BW0033 70 24.6  148 26.0    1.0 16.00   1.9    0.00    0.00    0.00
*BW0034 70 23.6  148 27.3    1.0 15.80   2.3    0.00    0.00    0.00
*BW0035 71 21.2  156 32.2    1.0 22.00  -0.5    0.00    0.00    0.00
*BW0036 71 21.5  156 26.2    1.0 22.20  -0.5    0.00    0.00    0.00
*BW0037 71 21.5  156 21.1    1.0 22.20  -0.5    0.01    0.00    0.00
*BW0038 71 17.2  156 48.5         0.00
*BW0039 71 17.9  156 46.3         0.00
*BW0040 71 18.8  156 43.4         0.00
*BW0041 71 20.9  156 35.2    0.0 27.00  -1.0    0.00    0.00    0.00
}*BW0042 71 20.8  156 35.2    0.0 25.50  -1.0    0.01    0.00    0.00
*BW0043 71 23.1  156 29.2    0.0 26.00  -1.2    0.01    0.00    0.00
*BW0079 71 19.7  156 40.9    1.0 25.50   2.0
*BW0080 71 20.8  156 35.2    1.0 25.20   2.0
*BW0081 71 20.8  156 35.2    1.0 25.00   1.5
*BW0082 71 20.8  156 35.2    1.0  1.20
*BW0083 71 20.8  156 35.2    1.0  0.50
*BW0084 71 20.8  156 35.2    1.0  2.00
*BW0091 71 20.9  156 35.2    1.0 25.00  -1.0
*BW0092 71 20.8  156 35.2    1.0 26.00  -1.0
*BW0093 71 20.8  156 35.2    1.0  9.00          0.00    0.00    0.00
*BW0094 71 20.8  156 35.2    1.0  6.00          0.00    0.00    0.00
*BW0095 71 20.8  156 35.2    1.0 26.00   2.0    0.01    0.00    0.00
*BW101  71 30.0  156  6.0    1.0 28.00  -1.6    1.83    0.00    0.01
*BW102  71 34.5  155 35.0    1.0 22.00  -2.0    1.67    0.00    0.01
*BW103  71 39.0  155  4.0    1.0 19.20  -2.0    0.00    0.00    0.00
*BW104  71 21.6  156 21.0    1.0 24.50  -2.0    0.00    0.03    0.01
*BW105  71 23.0  155 56.0    1.0 25.00  -2.0
*BW106  71 23.0  155 26.0    1.0 22.00  -2.0
*BW107  71 23.0  154 54.0    1.0 17.00  -2.0
*BW107A 71 21.6  156 21.0    1.0 25.00  -2.0
*BW108  71 21.4  156 27.0    1.0 31.00  -2.0    0.00    0.00    0.00
*BW109  71 21.6  156 21.0    1.0 29.00  -2.0    0.00    0.00    0.01
*BW110  71  8.0  146 30.0    1.0 23.00  -2.0    0.00    0.00    0.00
*BW111  70 32.0  148 22.0    1.0 28.00  -1.5    0.00    0.00    0.00
*BW112  70 31.0  147 24.0    1.0 28.00  -2.0    0.00    0.00    0.00
*BW113  70 28.0  147 30.0    1.0 29.00  -1.5    0.00    0.00    0.00
*BW114  70 47.0  147  0.0    1.0 17.00  -2.0    0.00    0.00    0.00
*BW116  71 36.0  152 12.0    1.0 24.00  -2.0    0.00    0.00    0.01
*BW117  71 46.0  151 52.0    1.0 20.50  -2.0    0.00    0.00    0.01
*BW118  71 26.0  152 22.0    1.0 19.00  -2.0    0.00    0.00    0.00
*BW119  71 19.0  152 33.0    1.0 19.80  -2.0    0.00    0.00    0.00
*BW120  71  8.0  152 55.0    1.0 25.50  -2.0    0.00    0.00    0.01
*BW121  71 23.0  153 50.0    1.0 28.00  -2.0    0.00    0.00    0.01
*BW122  71 23.0  154 22.0    1.0 29.00  -2.0    0.00    0.00    0.01
*BW123  71 34.5  155 35.0    1.0 28.00  -1.5    0.00    0.00    0.01
*GR0101 59 18.6  152 23.5   91.0 30.76   9.3
*GR0121 56 43.6  155 28.0  230.5 33.49   4.7
*GR0134 55 33.6  158 39.9  154.0
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
*GB0146	54	49.5	161	11.8	75.0	31.73	7.8			
*GB0148	54	23.7	160	49.2	109.7	32.50	5.5			
*GB201										
*GB202	59	50.3	149	30.4	190.0	32.41	4.3			
*GB203	59	24.6	149	4.2	183.0	32.75	4.6			
*GB204	58	58.8	148	39.5	217.0	33.80	5.0			
*GB206	59	17.2	147	15.6	251.8	33.77	5.3			
*GB207	59	45.5	146	31.0	70.5	32.25	4.3			
*GB210	59	23.3	146	54.5	302.3	32.55	4.9			
*GB211	59	32.5	147	0.6	308.6	32.72	5.1			
*GB212	60	8.8	145	2.0	45.8	31.91	3.7			
*GB213	59	47.0	145	10.2	158.1	32.27	4.6			
*GB214	59	54.3	143	52.3	75.9	32.10	4.4			
*GB216	59	16.7	142	56.9	2282.1	34.62	2.1			
*GB217	59	45.9	142	44.0	127.8	32.17	4.8			
*GB218	59	44.2	141	29.0	40.3	31.87	4.2			
*GB219	59	27.1	141	48.5	174.9	33.17	5.8			
*GB220										
*GB223	59	26.7	140	19.0	226.4	33.11	5.8			
*GB224	59	18.4	140	29.6	124.0	32.79	5.6			
*GB225										
*GB226										
*GW0101	59	18.6	152	23.5	2.0	30.76	9.1			
*GW0102	59	10.1	152	4.4	2.0	29.46	9.2			
*GW0103	59	0.5	151	48.1	2.0	28.68	9.3			
*GW0104	58	50.0	151	26.1	2.0	32.02	8.4			
*GW0105	58	40.1	151	7.3	2.0	31.97	8.4			
*GW0106	58	28.7	150	49.3	2.0		7.7			
*GW0119	57	6.0	156	0.6	2.0	29.56	8.6			
*GW0124	56	7.0	154	39.9	2.0	31.78	8.3			
*GW0133	55	44.8	158	49.3	2.0	30.76	8.8			
*GW0137	54	55.0	157	58.5	2.0	31.25	8.6			
*GW0145	55	1.0	161	19.8	2.0	31.40	8.0			
*GW0148	54	23.7	160	49.2	2.0	31.92	7.8			
*GW0156	54	29.0	165	11.4	2.0	31.71	6.4			
*GW0159	53	52.0	164	33.7	2.0	31.95	7.5			
*GW201					0.0	31.41	2.0			
*GW202	59	50.3	149	30.4	2.0	31.67	3.0	0.00	0.00	0.01
*GW203	59	24.6	149	4.2	2.0	32.23	3.5	0.00	0.00	0.02
*GW204	58	58.8	148	39.5	2.0	32.26	3.5	0.00	0.00	0.02
*GW205	59	38.3	147	48.0	1.0	32.10	3.5	0.00	0.00	0.02
*GW206	59	17.2	147	15.6	2.0	32.16	4.0	0.00	0.00	0.02
*GW207	59	45.5	146	31.0	2.0	32.11	4.0	0.00	0.00	0.02
*GW208	60	4.7	146	44.4	1.0	31.90	4.0	@ 0.00	0.00	0.02
*GW209					0.0	31.10	3.0	0.00	0.00	0.01
*GW210	59	23.fh	146	54.5	2.0	31.83	3.0			
*GW211	59	32.5	147	0.6	2.0	31.81	3.0	0.00	0.00B	0.02
*GW212	60	8.8	145	2.0	2.0	31.78	3.2	0.00	0.00	0.02
*GW213	59	47.0	145	10.2	2.0	31.84	3.4	0.00	0.00	0.02
*GW214	59	54.3	143	52.3	2.0	32.08	4.1	0.00	0.00	0.02
*GW215	59	38.1	144	2.0	1.0	32.20	3.0	0.00	0.00	0.02
*GW216	59	16.7	142	56.9	2.0	32.46	4.5	0.00	0.00	0.02
*GW217	59	45.9	142	44.0	2.0	32.13	4.5	0.00	0.00	0.02
*GW218	59	44.2	141	29.0	2.0	31.72	3.8	0.00	0.00	0.02
*GW219	59	27.1	141	48.5	2.0	32.16	4.5	0.00	0.00	0.02
*GW220	59	44.7	140	7.5	0.0	30.76	3.0	0.00	0.00	0.02
*GW221	59	33.2	139	48.8	0.0	30.80	4.0	0.00	0.00	0.02
*GW222	59	34.5	140	6.6	2.0	31.97	4.2			
*GW223	59	26.7	140	19.0	2.0	32.19	4.7	0.00	0.00	0.02
*GW224	59	18.4	140	29.6	2.0	32.17	4.8			
*GW225	60	20.8	146	38.4	0.0	31.12	5.0	0.00	0.00	0.01
*GW226	60	20.6	146	38.5	0.0	30.74	5.0	0.00	0.00	0.01
*GW227	60	21.4	146	37.4	0.0	31.28	3.2			

Z

FORM NUMBER = 100188 BEAUFORT & GULF, AUG/SEPT/OCT 1975 CRUISE AND WINTER 1976 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
#BBP1		1.10E+03							
#BB0001		1.00E+04							
#BB0002		5.40E+04							
#BB0003		5.30E+04							
#BB0004		6.80E+05							
#BB0005		4.50E+04							
#BB0006		3.10E+04							
#BB0007		1.90E+05							
#BB0008		7.80E+05							
#BB0009		8.70E+04							
#BB0010		5.40E+04							
#BB0011	5.70E+06	6.20E+04							
#BB0012	9.70E+06	4.40E+04							
#BB0013	1.40E+07	3.40E+04							
#BB0014	5.10E+06	1.20E+05							
#BB0015	5.50E+06	2.20E+05							
#BB0016	4.80E+08	1.30E+05							
#BB0017	5.90E+07								
#BB0018	3.00E+08	2.40E+05							
#BB0019	3.10E+07	2.70E+05							
#BB0020	7.30E+06	2.30E+05							
#BB0021	3.70E+07	4.10E+04							
#BB0022	9.20E+07	3.20E+04							
#BB0023	9.20E+07	1.80E+06							
#BB0024	5.20E+07	6.80E+04							
#BB0025	2.60E+07	1.30E+05							
#BB0025A									
#BB0026	4.10E+07	4.00E+05							
#BB0027	1.70E+07	6.80E+04							
#BB0027A									
#BB0028	2.30E+06	9.70E+04							
#BB0029	1.10E+07	1.10E+05							
#BB0030	1.70E+07	2.90E+05							
#BB0031	2.50E+07	1.00E+05							
#BB0032	8.30E+07	1.10E+05							
#BB0033	1.90E+07	6.50E+03							
#BB101	1.10E+10	2.80E+05					2.50E+03		
#BB102	4.40E+09	1.90E+06					1.10E+04		
#BB103	5.50E+09	2.00E+05					2.20E+00		
#BB104	1.90E+09	6.40E+05					9.50E+03		
#BB105	1.30E+09	1.10E+05					1.70E+03		
#BB106	3.20E+07	6.30E+04					5.00E+03		
#BB107	5.30E+07	3.40E+04					6.60E+03		
#BB108	7.20E+08	1.90E+05					4.10E+03		
#BB109	1.40E+10	1.10E+05							
#BB110	1.40E+08	5.40E+04					2.50E+03		
#BB111	2.30E+08	7.70E+04					8.00E+03		
#BB112	2.20E+08	1.40E+04					3.50E+03		
#BB113	2.30E+08	7.60E+03					2.60E+03		
#BB114	7.50E+07	2.70E+04					2.50E+03		
#BB115	1.40E+08	1.80E+03					1.60E+03		

*BI101			
*BI102			
*BI103	1.00E+05	3.70E+01	
*BI104	1.90E+05	7.30E+01	
*BI105	1.60E+05	1.60E+01	1.20E+03
*BI106	8.50E+04	1.10E+01	2.70E+03
*BI107	7.80E+04	3.00E-01	2.10E+03
*BI108	7.00E+04	1.60E+01	2.40E+03
*BI109	1.90E+05	7.70E+01	2.20E+03
*BI110	8.50E+04	0.00E+00	1.80E+03
*BI111	1.50E+05	5.50E+02	1.20E+03
*BI112	7.80E+04	9.90E+00	1.50E+02
*BI113	1.30E+05	4.00E+01	
*BI114	7.80E+04	6.00E+01	3.00E+03
*BI115	1.10E+05	2.90E+02	
*BI116	4.60E+04	3.80E+01	4.00E+02
*BI117	5.40E+04	6.30E+01	3.30E+02
*BI118	7.80E+04	5.70E+00	5.30E+02
*BI119	9.30E+04	1.00E+01	2.30E+03
*BI120	7.80E+04	0.00E+00	1.20E+02
*BI121	7.80E+04	1.60E+00	8.60E+02
*BI122	1.00E+05	5.00E+00	3.40E+02
*BI123	4.60E+04	2.00E+01	2.30E+02
*BW0001		1.90E+02	
*BW0002		7.00E+01	
*BW0003		4.80E+03	
*BW0004		1.80E+04	
*BW0005		6.00E+02	
*BW0006		4.00E+03	
*BW0006A			
*BW0007		2.40E+03	
*BW0007A			
*BW0008		7.70E+02	
*BW0009	5.40E+05	8.40E+02	
*BW0009A			
*BW0010	1.40E+06	1.50E+03	
*BW0011	2.30E+06	1.00E+04	
*BW0011A			
*BW0011B			
*BW0012	1.40E+06	6.70E+03	
*BW0012A			
*BW0013	5.60E+05	1.00E+04	
*BW0013A			
*BW0013B			
*BW0014	7.60E+05	1.80E+04	
*BW0014A			
*BW0015	4.10E+06	2.20E+04	
*BW0016	8.70E+05	1.60E+04	
*BW0017	1.00E+06	2.60E+04	
*BW0018	7.10E+05	1.80E+04	
*BW0019	7.50E+05	6.10E+03	
*BW0019A			
*BW0020	5.80E+05	3.10E+03	
*BW0021		5.10E+03	
*BW0022	2.10E+05	1.30E+03	
*BW0023	6.80E+05	2.70E+04	
*BW0024	4.20E+05	2.10E+04	
*BW0024A			
*BW0025	5.90E+05	1.40E+04	
*BW0026	4.10E+05	9.60E+03	
*BW0026A			
*BW0027	3.80E+05	9.70E+03	
*BW0028	4.90E+05	2.60E+04	

*BW0028A			
*BW0029	2.30E+05	2.90E+04	
*BW0030	6.70E+05	1.90E+04	
*BW0031	2.40E+05	9.20E+03	
*BW0032	4.30E+05	5.90E+03	
*BW0033	7.40E+05	1.80E+04	
*BW0034	1.20E+06	2.30E+04	
*BW0035	3.10E+05	3.50E+03	
*BW0036	4.10E+05	1.40E+03	
*BW0037	3.40E+05	7.10E+02	
*BW0038	8.10E+05	3.30E+03	
*BW0039	1.30E+06	2.30E+04	
*BW0040	1.20E+06	3.10E+02	
*BW0041	1.10E+06	2.30E+03	
*BW0042	7.20E+05	9.80E+02	
*BW0043		1.70E+03	
*BW0079			
*BW0080			
*BW0081			
*BW0082			
*BW0083			
*BW0084			
*BW0091			
*BW0092			
*BW0093			
*BW0094			
*BW0095			
*BW101			
*BW102			
*BW103	6.40E+05	1.30E+01	
*BW104	6.20E+04	2.00E+01	
*BW105	7.00E+04	4.70E+01	1.30E+04
*BW106	1.60E+05	5.00E+01	1.00E+04
*BW107	1.00E+05	4.00E+01	1.40E+04
*BW107A			
*BW108	2.80E+05	1.40E+03	1.10E+03
*BW109	3.60E+05	6.10E+02	4.00E+03
*BW110	1.70E+05	5.70E+00	
*BW111	1.50E+05	6.20E+01	6.80E+03
*BW112	2.80E+05	3.00E+01	4.40E+03
*BW113	1.10E+05	3.30E+01	4.30E+03
*BW114	7.00E+04	2.00E+01	
*BW116	2.30E+05	1.00E+01	1.60E+03
*BW117	1.20E+05	9.10E+03	1.90E+03
*BW118	7.80E+04	8.30E+00	3.40E+03
*BW119	1.60E+05	7.10E+02	1.00E+03
*BW120	9.30E+04	1.30E+01	1.90E+03
*BW121	9.30E+04	3.30E+00	1.50E+03
*BW122	1.60E+05	1.20E+01	2.80E+03
*BW123	1.60E+05	1.30E+01	2.10E+03
*GB0101		1.00E+04	
*GB0121		1.10E+06	
*GB0134		1.40E+06	
*GB0137		6.20E+05	
*GB0146			
*GB0148		2.00E+04	
*GB201	1.10E+06	1.80E+05	1.20E+04
*GB202	3.30E+09	5.20E+05	4.20E+03
*GB203	6.20E+09	1.10E+05	7.00E+03
*GB204	2.50E+09	6.70E+04	3.90E+03
*GB206	2.70E+09	2.40E+04	3.30E+03
*GB207	3.30E+09	4.20E+05	1.90E+03
*GB210	2.80E+09	3.00E+06	4.00E+03

*GB211	5.20E+09	1.50E+05	
*GB212	3.30E+09	1.70E+05	4.80E+03
*GB213		1.70E+05	5.30E+03
*GB214	1.90E+09	1.10E+06	
*GB216	8.20E+08	3.70E+03	3.40E+03
*GB217	1.60E+09	1.50E+05	6.60E+03
*GB218	4.00E+08	5.80E+03	8.00E+03
*GB219	5.60E+09	1.10E+05	2.00E+00
*GB220	6.10E+07	1.50E+03	2.50E+03
*GB223	1.80E+09	1.20E+05	7.20E+03
*GB224	1.80E+09	4.40E+05	7.30E+03
*GB225	4.10E+09	4.00E+06	5.70E+03
*GB226	3.40E+09	9.00E+06	3.10E+03
*GW0101	1.20E+05	5.50E+01	
*GW0102	3.00E+05	5.00E+01	
*GW0103	1.40E+05	2.00E+01	
*GW0104	4.30E+05	5.00E+01	
*GW0105	3.80E+05	6.00E+01	
*GW0106	1.80E+05	6.50E+01	
*GW0119	3.60E+05	3.50E+01	
*GW0124	3.30E+05	9.70E+01	
*GW0133	3.80E+05	9.20E+01	
*GW0137	1.00E+05	1.20E+02	
*GW0145	2.80E+05	1.30E+02	
*GW0148	2.10E+05	1.90E+02	
*GW0156	5.00E+05	2.50E+02	
*GW0159	4.70E+05	2.20E+02	
*GW201	2.60E+05	2.20E+04	1.10E+04
*GW202	9.30E+04	3.30E+01	7.30E+03
*GW203	3.30E+05	2.10E+01	5.40E+03
*GW204	3.00E+05	3.10E+01	8.00E+03
*GW205			
*GW206	9.30E+04	1.40E+01	8.70E+03
*GW207	1.00E+05	9.70E+00	4.00E+03
*GW208			
*GW209	2.70E+05	1.00E+03	
*GW210	4.60E+04	5.90E+01	5.20E+03
*GW211	9.30E+04	3.60E+01	5.60E+03
*GW212	2.40E+05	7.20E+01	6.00E+03
*GW213		3.10E+01	4.30E+03
*GW214	5.40E+04	1.00E+02	6.70E+03
*GW215			
*GW216	6.20E+04	3.20E+01	2.90E+03
*GW217	1.60E+05	2.30E+01	5.50E+03
*GW218	1.50E+05	3.30E+01	6.00F+03
*GW219	1.20E+05	1.20E+01	5.30E+03
*GW220	4.60E+04	3.80E+02	3.10E+03
*GW221	1.20E+05	3.00E+01	3.40E+03
*GW222	1.00E+05	1.50E+01	4.80E+03
*GW223	7.00E+04	6.00E+00	4.60E+03
*GW224	3.10E+04	3.00E+01	1.10E+03
*GW225	1.00E+05	7.70E+02	3.30E+03
*GW226	2.20E+05		3.20E+03
*GW227	7.80E+04		5.60E+03

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FORM NUMBER = 100188  BEAUFORT & GULF, AUG/SEPT/OCT 1975 CRUISE AND WINTER 1976 CRUISE

*BBP1      041676BEAUFORT BEACH ELSON STA.03A
*BB0001    082075BEAUFORT ELSON LAGOON ST01 SEDIMENT
*BB0002    082075BEAUFORT ELSON LAGOON ST01 SEDIMENT
*BB0003    082875BEAUFORT ELSON LAGOON ST10 SEDIMENT
*BB0004    082875BEAUFORT PT BARROW ST12 SEDIMENT
*BB0005    083175BEAUFORT ELSON LAGOON ST11 SEDIMENT
*BB0006    083175BEAUFORT PT BARROW ST12 SEDIMENT
*BB0007    090575BEAUFORT ELSON LAGOON ST03 SEDIMENT
*BB0008    090575BEAUFORT PLOVER PT ST04 SEDIMENT
*BB0009    090575BEAUFORT OLIGTOK PT ST30 SEDIMENT
*BB0010    090575BEAUFORT PRUDHOE BAY ST40 SEDIMENT
*BB0011    090875BEAUFORT PRUDHOE BAY ST53 SEDIMENT
*BB0012    090875BEAUFORT PRUDHOE BAY ST55 SEDIMENT
*BB0013    090875BEAUFORT PRUDHOE BAY ST51 SEDIMENT
*BB0014    090875BEAUFORT PRUDHOE BAY ST54 SEDIMENT
*BB0015    091175BEAUFORT ELSON LAGOON ST01 SEDIMENT
*BB0016    091175BEAUFORT ELSON LAGOON ST02 SEDIMENT
*BB0017    091175BEAUFORT ELSON LAGOON ST03 SEDIMENT
*BB0018    091175BEAUFORT ELSON LAGOON ST04 SEDIMENT
*BB0019    091275BEAUFORT PRUDHOE BAY ST53 SEDIMENT
*BB0020    091275BEAUFORT PRUDHOE BAY ST55 SEDIMENT
*BB0021    091275BEAUFORT PRUDHOE BAY ST70 SEDIMENT
*BB0022    091275BEAUFORT PRUDHOE BAY ST71 SEDIMENT
*BB0023    091375BEAUFORT PRUDHOE BAY ST50 SEDIMENT
*BB0024    091375BEAUFORT PRUDHOE BAY ST51 SEDIMENT
*BB0025    091375BEAUFORT PRUDHOE BAY ST52 SEDIMENT
*BB0025A   090275 STA 1 OLD SAMPLE 25 LOCATION B
*BB0026    091375BEAUFORT PRUDHOE BAY ST57 SEDIMENT
*BB0027    091375BEAUFORT PRUDHOE BAY ST70 SEDIMENT
*BB0027A   090575 STA 2 OLD SAMPLE 27 LOCATION B
*BB0028    091375BEAUFORT PRUDHOE BAY ST71 SEDIMENT
*BB0029    091475BEAUFORT PRUDHOE BAY ST72 SEDIMENT
*BB0030    091475BEAUFORT PRUDHOE BAY ST73 SEDIMENT
*BB0031    091775BEAUFORT ELSON LAGOON ST01 SEDIMENT
*BB0032    091775BEAUFORT ELSON LAGOON ST02 SEDIMENT
*BB0033    091775BEAUFORT ELSON LAGOON ST03 SEDIMENT
*BB101     040776BEAUFORT SEDIMENT BARROW STA.13
*BB102     040776BEAUFORT SEDIMENT BARROW STA.14
*BB103     040776BEAUFORT SEDIMENT BARROW STA.15
*BB104     041076BEAUFORT SEDIMENT ELSON STA.02
*BB105     041076BEAUFORT SEDIMENT ELSON STA.03
*BB106     041276BEAUFORT SEDIMENT PRUDHOE STA.74
*BB107     041276BEAUFORT SEDIMENT PRUDHOE STA.81
*BB108     041276BEAUFORT SEDIMENT PRUDHOE STA.80
*BB109     041476BEAUFORT SEDIMENT PRUDHOE STA.83
*BB110     041476BEAUFORT SEDIMENT PRUDHOE STA.56
*BB111     041676BEAUFORT SEDIMENT PITT PT STA.22
*BB112     041676BEAUFORT SEDIMENT PITT PT STA.21
*BB113     041876BEAUFORT SEDIMENT PITT PT STA.20
*BB114     041876BEAUFORT SEDIMENT BARROW STA.17
*BB115     041876BEAUFORT SEDIMENT BARROW STA.16
*BI101     040576BEAUFORT ICE BARROW STA.13A
*BI102     040576BEAUFORT ICE BARROW STA.14A
*BI103     040576BEAUFORT ICE BARROW STA.15A
*BI104     040776BEAUFORT ICE ELSON STA.03
*BI105     040776BEAUFORT ICE BARROW STA.13
*BI106     040776BEAUFORT ICE BARROW STA.14
*BI107     040776BEAUFORT ICE BARROW STA.15
*BI108     041076BEAUFORT ICE ELSON STA.02
*BI109     041076BEAUFORT ICE ELSON STA.03
*BI110     041476BEAUFORT ICE PRUDHOE STA.85
*BI111     041476BEAUFORT ICE PRUDHOE STA.74
*BI112     041476BEAUFORT ICE PRUDHOE STA.81
*BI113     041476BEAUFORT ICE PRUDHOE STA.80
*BI114     041476BEAUFORT ICE PRUDHOE STA.83
*BI115     041476BEAUFORT ICE PRUDHOE STA.56
*BI116     041676BEAUFORT ICE PITT PT STA.24
*BI117     041676BEAUFORT ICE PITT PT STA.23
*BI118     041676BEAUFORT ICE PITT PT STA.22
*BI119     041676BEAUFORT ICE PITT PT STA.21
*BI120     041876BEAUFORT ICE PITT PT STA.20
*BI121     041876BEAUFORT ICE BARROW STA.17
*BI122     041876BEAUFORT ICE BARROW STA.16
*BI123     041876BEAUFORT ICE BARROW STA.14A
*BW0001    082075BEAUFORT ELSON LAGOON ST01 WATER
*BW0002    082075BEAUFORT ELSON LAGOON ST01 WATER
*BW0003    082875BEAUFORT ELSON LAGOON ST10 WATER
*BW0004    082875BEAUFORT POINT BARROW ST12 WATER
*BW0005    083075CHUKCH1 BARROW ST05B ICE
*BW0006    083175BEAUFORT ELSON LAGOON ST11 WATER
*BW0006A   082175 STA 1 OLD SAMPLE 6 LOCATION B
*BW0007    083175BEAUFORT POINT BARROW ST12 WATER
*BW0007A   082175 STA 2 OLD SAMPLE 7 LOCATION 3
*BW0008    083175CHUKCH1 BARROW ST06 WATER
*BW0009    090575BEAUFORT ELSON LAGOON ST03 WATER
*BW0009A   082175 STA 3 OLD SAMPLE 9 LOCATION B
*BW0010    090575BEAUFORT PLOVER PT. ST04 WATER
*BW0011    090575BEAUFORT OLIGTOK PT. ST30 WATER
*BW0011A   082475 STA 7 OLD SAMPLE 11ALOCATION B
*BW0011B   082175 STA 4 OLD SAMPLE 11 LOCATION B
*BW0012    090575BEAUFORT PRUDHOE BAY ST40 WATER
*BW0012A   082675 STA 7 OLD SAMPLE 12 LOCATION B
*BW0013    090575BEAUFORT PRUDHOE BAY ST52 WATER
*BW0013A   082775 STA 7 OLD SAMPLE 13ALOCATION B
*BW0013B   082875 STA 7 OLD SAMPLE 13 LOCATION B
*BW0014    090875BEAUFORT PRUDHOE BAY ST53 WATER
*BW0014A   082775 STA 7 OLD SAMPLE 14 LOCATION B
*BW0015    090875BEAUFORT PRUDHOE BAY ST55 WATER
*BW0016    090875BEAUFORT PRUDHOE BAY ST55 WATER
*BW0017    090875BEAUFORT PRUDHOE BAY ST51 WATER
*BW0018    090875BEAUFORT PRUDHOE BAY ST54 WATER
*BW0019    091175BEAUFORT ELSON LAGOON ST01 WATER
*BW0019A   083075 STA 5B OLD SAMPLE 19 LOCATION B
*BW0020    091175BEAUFORT ELSON LAGOON ST02 WATER
*BW0021    091175BEAUFORT ELSON LAGOON ST03 WATER
*BW0022    091175BEAUFORT ELSON LAGOON ST04 WATER
*BW0023    091275BEAUFORT PRUDHOE BAY ST53 WATER
*BW0024    091275BEAUFORT PRUDHOE BAY ST55 WATER
*BW0024A   090275 STA 7 OLD SAMPLE 24 LOCATION B
*BW0025    091275BEAUFORT PRUDHOE BAY ST56 WATER
*BW0026    091275BEAUFORT PRUDHOE BAY ST70 WATER
*BW0026A   090575 STA 1 OLD SAMPLE 26 LOCATION B
*BW0027    091275BEAUFORT PRUDHOE BAY ST71 WATER
*BW0028    091375BEAUFORT PRUDHOE BAY ST50 WATER
*BW0028A   090575 STA 2 OLD SAMPLE 28 LOCATION B
*BW0029    091375BEAUFORT PRUDHOE BAY ST52 WATER
*BW0030    091375BEAUFORT PRUDHOE BAY ST57 WATER
*BW0031    091375BEAUFORT PRUDHOE BAY ST70 WATER
*BW0032    091375BEAUFORT PRUDHOE BAY ST71 WATER
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*BW0033	091475BEAUFORT PRUDHOE BAY ST72 WATER
*BW0034	091475BEAUFORT PRUDHOE BAY ST73 WATER
*BW0035	091775BEAUFORT ELSON LAGOON ST01 WATER
*BW0036	091775BEAUFORT ELSON LAGOON ST02 WATER
*BW0037	091775BEAUFORT ELSON LAGOON ST03 WATER
*BW0038	092375CHUKCH1 BARROW ST09A ICE
*BW0039	092375CHUKCH1 BARROW ST09B ICE
*BW0040	092375CHUKCH1 BARROW ST09C ICE
*BW0041	092375BEAUFORT ELSON LAGOON ST05A WATER
*BW0042	092375CHUKCH1 BARROW ST05B WATER
*BW0043	092575CHUKCH1 BARROW ST08 WATER
*BW0079	091675 STA 7 OLD SAMPLE 79 LOCATION B
*BW0080	091675 STA 5B OLD SAMPLE 80 LOCATION B
*BW0081	091775 STA 5B OLD SAMPLE 81 LOCATION B
*BW0082	091675 STA 5B OLD SAMPLE 82 LOCATION B
*BW0083	091675 STA 5B OLD SAMPLE 83 LOCATION B
*BW0084	091675 STA 5B OLD SAMPLE 84 LOCATION B
*BW0091	092075 STA 5A OLD SAMPLE 91 LOCATION B
*BW0092	092075 STA 5B OLD SAMPLE 92 LOCATION B
*BW0093	092075 STA 5B OLD SAMPLE 93 LOCATION B
*BW0094	092075 STA 5B OLD SAMPLE 94 LOCATION B
*BW0095	092175 STA 5B OLD SAMPLE 95 LOCATION B
*BW101	040576 TIME1400 STA 13A
*BW102	040576 TIME1500 STA 14A
*BW103	040576 TIME1600 STA 15A
*BW104	040576BEAUFORT WATER ELSON STA.03
*BW105	040776BEAUFORT WATER BARROW STA.13
*BW106	040776BEAUFORT WATER BARROW STA.14
*BW107	040776BEAUFORT WATER BARROW STA.15
*BW107A	040976 TIME1400 STA 3
*BW108	041076BEAUFORT WATER ELSON STA.02
*BW109	041076BEAUFORT WATER ELSON STA.03
*BW110	041476BEAUFORT WATER PRUDHOE STA.85
*BW111	041276BEAUFORT WATER PRUDHOE STA.74
*BW112	041276BEAUFORT WATER PRUDHOE STA.81
*BW113	041276BEAUFORT WATER PRUDHOE STA.80
*BW114	041476BEAUFORT WATER PRUDHOE STA.83
*BW116	041676BEAUFORT WATER PITT PT STA.24
*BW117	041676BEAUFORT WATER PITT PT STA.23
*BW118	041676BEAUFORT WATER PITT PT STA.22
*BW119	041676BEAUFORT WATER PITT PT STA.21
*BW120	041876BEAUFORT WATER PITT PT STA.20
*BW121	041876BEAUFORT WATER BARROW STA.17
*BW122	041876BEAUFORT WATER BARROW STA.16
*BW123	041876BEAUFORT WATER BARROW STA.14A
*GB0101	101475GULF OF ALASKA ST101 SEDIMENT
*GB0121	101375GULF OF ALASKA ST121 SEDIMENT
*GB0134	101275GULF OF ALASKA ST134 SEDIMENT
*GB0137	101275GULF OF ALASKA ST137 SEDIMENT
*GB0146	101175GULF OF ALASKA ST146 SEDIMENT
*GB0148	101175GULF OF ALASKA ST148 SEDIMENT
*GB201	031576 GULF ALASKA SEDIMENT KODIAK BEACH
*GB202	031876 GULF ALASKA SEDIMENT STATION 01
*GB203	031876 GULF ALASKA SEDIMENT STATION 04
*GB204	031876 GULF ALASKA SEDIMENT STATION 07
*GB206	031976 GULF ALASKA SEDIMENT STATION 59
*GB207	032076 GULF ALASKA SEDIMENT STATION 57
*GB210	032176 GULF ALASKA SEDIMENT STATION 53A
*GB211	032176 GULF ALASKA SEDIMENT STATION 53B
*GB212	032176 GULF ALASKA SEDIMENT STATION 52
*GB213	032276 GULF ALASKA SEDIMENT STATION 50
*GB214	032276 GULF ALASKA SEDIMENT STATION 42
*GB216	032376 GULF ALASKA SEDIMENT STATION 37
*GB217	032376 GULF ALASKA SEDIMENT STATION 41
*GB218	032476 GULF ALASKA SEDIMENT STATION 30
*GB219	032476 GULF ALASKA SEDIMENT STATION 32
*GB220	032576 GULF ALASKA SEDIMENT NYAKITAT BEACH
*GB223	032576 GULF ALASKA SEDIMENT STATION 28
*GB224	032676 GULF ALASKA SEDIMENT STATION 27
*GB225	032676 GULF ALASKA SEDIMENT HILDENBACH BCH
*GB226	032676 GULF ALASKA SEDIMENT PRINCEWILL BCH
*GW0101	101475GULF OF ALASKA ST101 WATER
*GW0102	101475GULF OF ALASKA ST102 WATER
*GW0103	101475GULF OF ALASKA ST103 WATER
*GW0104	101575GULF OF ALASKA ST104 WATER
*GW0105	101575GULF OF ALASKA ST105 WATER
*GW0106	101575GULF OF ALASKA ST106 WATER
*GW0119	101475GULF OF ALASKA ST119 WATER
*GW0124	101375GULF OF ALASKA ST124 WATER
*GW0133	101275GULF OF ALASKA ST133 WATER
*GW0137	101275GULF OF ALASKA ST137 WATER
*GW0145	101175GULF OF ALASKA ST145 WATER
*GW0148	101175GULF OF ALASKA ST148 WATER
*GW0156	101075GULF OF ALASKA ST156 WATER
*GW0159	101075GUF OF ALASKA ST159 WATER
*GW201	031576 GULF ALASKA WATER KODIAK BEACH
*GW202	031876 GULF ALASKA WATER STATION 01
*GW203	031876 GULF ALASKA WATER STATION 04
*GW204	031876 GULF ALASKA WATER STATION 07
*GW205	031876 TIME2145 STA 68
*GW206	031976 GULF ALASKA WATER STATION 59
*GW207	032076 GULF ALASKA WATER STATION 57
*GW208	031976 TIME1940 STA 55
*GW209	032076 GULF ALASKA WATER SEWARD BEACH
*GW210	032176 GULF ALASKA WATER STATION 53A
*GW211	032176 GULF ALASKA WATER STATION 53B
*GW212	032176 GULF ALASKA WATER STATION 52
*GW213	032276 GULF ALASKA WATER STATION 50
*GW214	032276 GULF ALASKA WATER STATION 42
*GW215	032276 TIME1130 STA 44
*GW216	032376 GULF ALASKA WATER STATION 37
*GW217	032376 GULF ALASKA WATER STATION 41
*GW218	032476 GULF ALASKA WATER STATION 30
*GW219	032476 GULF ALASKA WATER STATION 32
*GW220	032576 GULF ALASKA WATER N YAKITAT BEACH
*GW221	032576 GULF ALASKA WATER S YAKITAT BEACH
*GW222	032576 GULF ALASKA WATER STATION 29
*GW223	032576 GULF ALASKA WATER STATION 28
*GW224	032676 GULF ALASKA WATER STATION 27
*GW225	032676 GULF ALASKA WATER HILDENBACH BEACH
*GW226	032676 GULF ALASKA WATER PRINCE WILLBEACH
*GW227	032676 GULF ALASKA WATER PRINCE WILLBEACH

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FORM NUMBER = 100236 BEAUFORT, AUG/SEPT 1976 CRUISE

SAMPLE#	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
*BB201	70	36.0	148	12.0	16.0	30.32	-1.4						
*BB203	70	32.0	147	33.0	25.0	31.72	0.6						
*BB204	70	39.0	147	37.0	25.0	39.21	-1.6						
*BB205	70	57.0	149	33.0	30.0								
*BB206	70	57.0	149	33.0	30.0	31.62	-1.1						
*BB207	71	8.0	151	19.0	34.0	30.73	-0.6						
*BB208	71	43.0	151	47.0	1700.0	34.85	-0.2						
*BB212	71	22.0	152	20.0	74.0	32.22	-0.9						
*BB214	71	19.0	152	32.0	52.0	31.47	-0.3						
*BB215	71	8.0	152	57.0	40.0	30.09	0.3						
*BB216	71	23.0	154	21.0	22.0	29.38	2.1						
*BB217	71	36.0	155	32.0	171.0	32.00	0.2						
*BB219	71	21.0	156	32.0	2.0	24.50	2.0						
*BB220	71	21.0	156	26.0	2.0	25.50	2.0						
*BW201	70	36.0	148	12.0	1.0	10.04	-0.2	0.00	0.00	0.00			
*BW202	70	36.0	148	12.0	1.0	10.04	-0.2	0.00	0.00	0.00			
*BW203	70	32.0	147	33.0	1.0	6.02	-1.3	0.00	0.00	0.00			
*BW204	70	39.0	147	37.0	1.0	5.05	0.3	0.00	0.00	0.00			
*BW205	70	57.0	149	33.0	1.0	10.75	0.3	0.00	0.00	0.00			
*BW206	70	57.0	149	33.0	1.0	7.64	0.4	0.00	0.00	0.00			
*BW207	71	8.0	151	19.0	1.0	19.05	0.7	0.00	0.00	0.00			
*BW208	71	43.0	151	47.0	1.0	10.18	0.3	0.00	0.00	0.00			
*BW209	71	43.0	151	47.0	15.0	29.54	-1.0	0.00	0.00	0.00			
*BW210	71	33.0	152	3.0	1.0	13.00	0.4	0.00	0.00	0.00			
*BW211	71	33.0	152	3.0	15.0	22.00	0.4	0.00	0.00	0.00			
*BW212	71	22.0	152	20.0	1.0	15.71	0.5	0.00	0.00	0.00			
*BW213	71	22.0	152	20.0	15.0	28.84	2.7	0.00	0.00	0.00			
*BW214	71	19.0	152	32.0	1.0	17.36	0.3	0.00	0.00	0.00			
*BW215	71	8.0	152	57.0	1.0	20.47	1.8	0.00	0.00	0.00			
*BW216	71	23.0	154	21.0	1.0	17.40	1.2	0.00	0.00	0.00			
*BW217	71	36.0	155	32.0	1.0	8.35	0.1	0.00	0.00	0.00			
*BW218	71	36.0	155	32.0	15.0	28.48	-0.7	0.00	0.01	0.00			
*BW219	71	21.0	156	32.0	1.0	24.50	2.0	0.00	0.00	0.00			
*BW220	71	21.0	156	26.0	1.0	25.50	2.0	0.00	0.00	0.00			

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FORM NUMBER = 100236  BEAUFORT, AUG/SEPT 1976 CRUISE

SAMPLE  DIRECT    MARINE    MPN      nC16      PRISTANE  BENZANTHR nC16      PRISTANE  BENZANTHR
 #      COUNT     AGAR 4C   HC UTIL  POTENTIAL POTENTIAL POTENTIAL POTENTIAL POTENTIAL POTENTIAL
                                     NON-NUTR  NON-NUTR  NON-NUTR  NATURAL   NATURAL   NATURAL
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#BB201  1.60E+09  1.60E+06                                         9.50E+02
#BB203  2.60E+09  3.10E+06                                         9.30E+02
#BB204  1.90E+09  3.20E+06                                         2.10E+03
#BB205  1.10E+09  2.10E+06                                         1.40E+03
#BB206  1.90E+09  1.50E+06                                         1.50E+02
#BB207  1.60E+09  6.20E+06                                         1.50E+02
#BB208  1.90E+09  3.50E+04                                         7.80E+02
#BB212  1.50E+09  1.20E+07                                         3.70E+02
#BB214  1.00E+09  5.50E+06                                         7.80E+02
#BB215  1.10E+09  1.20E+07                                         3.60E+02
#BB216  3.60E+09  4.50E+07                                         9.80E+02
#BB217
#BB219  6.90E+09  2.50E+06                                         5.20E+02
#BB220  7.60E+08  1.70E+07                                         2.10E+03
#BW201  9.30E+05  3.70E+04                                         1.90E+02
#BW202  6.00E+05  3.20E+04                                         1.70E+03
#BW203  4.50E+05  2.40E+04                                         1.60E+02
#BW204  2.60E+05  1.80E+05                                         2.70E+02
#BW205  3.40E+05  2.60E+04                                         5.00E+01
#BW206  4.00E+05  7.20E+04                                         2.10E+03
#BW207  2.10E+06  2.10E+04                                         2.00E+02
#BW208  3.70E+05  3.60E+04                                         3.70E+02
#BW209  4.50E+05  3.70E+03                                         9.50E+01
#BW210  4.20E+05  1.20E+05                                         7.70E+02
#BW211  2.60E+05  1.90E+03                                         7.50E+01
#BW212  6.50E+05  1.00E+05                                         1.00E+03
#BW213  5.70E+05  9.20E+03                                         1.10E+02
#BW214  5.30E+05  7.70E+04                                         2.60E+02
#BW215  3.10E+05  2.20E+04                                         8.70E+02
#BW216  3.20E+05  8.70E+04                                         1.10E+03
#BW217  2.80E+05  1.20E+05                                         4.40E+02
#BW218  6.00E+05  8.70E+03                                         4.50E+02
#BW219  2.90E+05  1.70E+04                                         3.00E+02
#BW220  3.10E+05  1.00E+04                                         1.20E+02
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 FORM NUMBER = 100236  BEAUFORT, AUG/SEPT 1976 CRUISE

#BB201     082476BEAUFORT PRUDHOE BAY SEDIMENT STA 74
#BB203     082576BEAUFORT PRUDHOE BAY SEDIMENT STA 80
#BB204     082676BEAUFORT PRUDHOE BAY SEDIMENT STA 81
#BB205     082776BEAUFORT COLVILLE R. SEDIMENT STA 41
#BB206     082776BEAUFORT COLVILLE R. SEDIMENT STA 41
#BB207     082876BEAUFORT COLVILLE R. SEDIMENT STA 31
#BB208     082976BEAUFORT PITT PT. SEDIMENT STA 24
#BB212     083076BEAUFORT PITT PT. SEDIMENT STA 22
#BB214     083176BEAUFORT PITT PT. SEDIMENT STA 21
#BB215     090176BEAUFORT PITT PT. SEDIMENT STA 20
#BB216     090276BEAUFORT PT. BARROW SEDIMENT STA 16
#BB217     090276BEAUFORT PT. BARROW SEDIMENT STA 15
#BB219     090876BEAUFORT ELSON LAGOONSEDIMENT STA 01
#BB220     090876BEAUFORT ELSON LAGOONSEDIMENT STA 02
#BW201     082376BEAUFORT PRUDHOE BAY WATER STA74
#BW202     082476BEAUFORT PRUDHOE BAY WATER STA74
#BW203     082576BEAUFORT PRUDHOE BAY WATER STA80
#BW204     082676BEAUFORT PRUDHOE BAY WATER STA81
#BW205     082776BEAUFORT COLVILLE R. WATER STA41
#BW206     082776BEAUFORT COLVILLE R. WATER STA41
#BW207     082876BEAUFORT COLVILLE R. WATER STA31
#BW208     082976BEAUFORT PITT PT. WATER STA24
#BW209     082976BEAUFORT PITT PT. 15 WATER STA24
#BW210     083076BEAUFORT PITT PT. WATER STA23
#BW211     083076BEAUFORT PITT PT. 15 WATER STA23
#BW212     083076BEAUFORT PITT PT. WATER STA22
#BW213     083076BEAUFORT PITT PT. 15 WATER STA22
#BW214     083176BEAUFORT PITT PT. WATER STA21
#BW215     090176BEAUFORT PITT PT. WATER STA20
#BW216     090276BEAUFORT PT. BARROW WATER STA16
#BW217     090276BEAUFORT PT. BARROW WATER STA15A
#BW218     090276BEAUFORT PT. BARROW15WATER STA15A
#BW219     090876BEAUFORT ELSON LAGOONWATER STA01
#BW220     090876BEAUFORT ELSON LAGOONWATER STA02
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FORM NUMBER = 100237 COOK INLET, OCT 1976 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
#GB301	59	6.0	152	47.0	148.0		8.5		371.00			0.50	4.40
#GB303	59	20.0	152	44.0	73.0	27.00	10.0						
#GB304	59	33.0	153	24.0	28.0	26.00	8.4	85.00	245.00	4.40	24.70	0.40	4.40
#GB308	59	44.0	153	21.0	0.0		6.5		18.00	32.70	3.00	0.40	4.10
#GB311	59	15.0	153	40.0	31.0	23.20	9.1	56.00	245.00	9.70	58.30	0.60	9.10
#GB312	59	38.0	152	33.0	75.0	26.00	10.0		3.00	6.70	0.80	0.20	0.90
#GB313	59	42.0	151	9.0	28.0	26.00	9.3	14.00	121.00	14.30	3.90	1.00	10.20
#GB318	59	34.0	151	44.0	88.0	28.00	9.5	117.00	295.00	29.20	27.20	1.30	10.70
#GB319	59	33.0	152	9.0	45.0	28.00	9.5	13.00	105.00			0.40	2.00
#GB320								41.00	249.00	44.70	17.50	0.50	7.60
#GB325	59	50.0	153	16.0	0.0		6.0						
#GB327	59	21.0	153	15.0	44.0	26.00	9.0						
#GB328	59	10.2	153	8.5	84.0	27.00	9.0						
#GB329	59	15.0	153	40.0	34.0	26.50	9.8						
#GB333	58	59.7	152	52.8	170.0	22.50	7.0						
#GB335	58	46.0	151	10.0	120.0	28.00	7.5						
#GW301	59	6.0	152	47.0	1.0	27.50	9.0						
#GW302	59	20.0	152	12.0	1.0	27.00	9.5						
#GW303	59	20.0	152	44.0	1.0	27.00	9.5						
#GW304	59	33.0	153	24.0	1.0	25.00	8.4						
#GW305	59	38.8	153	25.0	1.0	23.30	8.0						
#GW306	59	38.8	153	25.0	1.0	23.30	8.0						
#GW307	59	44.2	153	21.5	1.0	22.50	5.5						
#GW308	59	44.0	153	21.0	0.0	22.00	6.5						
#GW309	59	22.0	153	59.0	0.0	21.00	12.0						
#GW310	59	22.0	153	59.0	0.0	20.50	12.0						
#GW311	59	15.0	153	40.0	1.0	28.00	5.5						
#GW312	59	38.0	152	33.0	1.0	26.20	9.5						
#GW313	59	42.0	151	9.0	1.0	24.00	8.5						
#GW314	59	34.7	151	11.1	1.0	25.00	10.0						
#GW315	59	35.0	151	11.0	0.0	24.00	9.5						
#GW316	59	36.4	151	24.0	1.0	24.00	12.0						
#GW317	59	36.0	151	25.0	0.0	23.00	12.0						
#GW318	59	34.0	151	44.0	1.0	27.00	9.5						
#GW319	59	33.0	152	9.0	1.0	27.00	9.5						
#GW320	60	0.0	152	10.0	1.0	26.00	9.0						
#GW321	60	2.3	151	45.9	1.0	20.50	9.0						
#GW322	60	40.0	151	26.0	1.0	21.00	8.5						
#GW323	60	31.0	151	50.0	1.0	19.50	9.0						
#GW324	59	50.3	153	15.0	1.0	16.30	6.5						
#GW325	59	50.0	153	16.0	0.0	17.00	6.0						
#GW326	59	50.4	152	59.5	1.0	23.00	8.0						
#GW327	59	21.0	153	15.0	1.0	26.00	9.0						
#GW328	59	10.2	153	8.5	1.0	27.50	9.0						
#GW329	59	15.0	153	40.0	1.0	25.00	9.5						
#GW330	59	20.8	152	43.7	1.0	28.00	9.5						
#GW331	58	15.9	154	16.4	1.0	18.00	2.0						
#GW332	58	15.9	154	16.4	1.0	18.00	-1.5						
#GW333	58	59.7	152	52.8	1.0	23.70	8.0						
#GW334	59	2.7	151	58.7	1.0	24.00	7.5						
#GW335	58	46.0	151	10.0	1.0	25.50	9.0						
#GW336	58	50.2	151	21.3	1.0	27.50	8.0						
#GW337	58	55.3	152	0.1	1.0	27.50	5.0						

Z

FORM NUMBER = 100237 COOK INLET, OCT 1976 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
*GB301	5.00E+08	8.90E+05					1.00E+01		
*GB303	5.40E+08	8.70E+05					2.00E+01		
*GB304	1.10E+09	2.60E+06					1.70E+01		
*GB308	6.10E+08	1.70E+07							
*GB311	2.60E+09	2.30E+06					1.10E+01		
*GB312		2.90E+04					1.70E+03		
*GB313	2.90E+09	6.00E+06					1.40E+01		
*GB318	8.40E+08	6.90E+06					1.40E+02		
*GB319	3.70E+08	1.00E+04					7.00E+00		
*GB320									
*GB325	2.70E+08	8.40E+05							
*GB327	5.90E+08	6.50E+05					1.50E+02		
*GB328									
*GB329	7.10E+09	2.10E+07					9.50E+01		
*GB333									
*GB335	1.20E+09	1.50E+05					1.20E+01		
*GW301	2.70E+05	1.20E+01					0.00E+00		
*GW302	4.30E+05	3.30E+01					2.60E+01		
*GW303	1.70E+05	1.00E+01					6.00E+00		
*GW304	1.50E+05	9.00E+01					2.80E+01		
*GW305									
*GW306									
*GW307									
*GW308	1.70E+05	1.00E+04					1.30E+02		
*GW309	1.90E+05	4.20E+03					2.80E+01		
*GW310	2.10E+05	1.10E+04					1.00E+02		
*GW311	3.80E+05	1.60E+02					1.50E+01		
*GW312	2.50E+05	5.00E+00					7.00E+00		
*GW313	2.20E+05	2.00E+02					2.00E+01		
*GW314									
*GW315	2.30E+05	1.00E+03					1.10E+02		
*GW316									
*GW317	4.40E+05	1.10E+05					1.30E+02		
*GW318	2.60E+05	7.70E+01					9.30E+01		
*GW319	6.20E+04	9.30E+01					0.00E+00		
*GW320	2.20E+05	1.10E+02					1.40E+01		
*GW321									
*GW322	1.10E+06	2.20E+02					8.00E+00		
*GW323	1.50E+05	6.10E+02					9.00E+00		
*GW324									
*GW325	1.10E+06	2.90E+04					1.90E+02		
*GW326									
*GW327	2.60E+05	1.10E+02					0.00E+00		
*GW328									
*GW329	1.20E+07	4.70E+02					3.20E+01		
*GW330									
*GW331									
*GW332									
*GW333									
*GW334									
*GW335	1.90E+05	3.00E+01					7.00E+00		
*GW336									
*GW337									

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Z
 FORM NUMBER = 100237    COOK INLET, OCT 1976 CRUISE

*GB301     101876COOK INLET SEDIMENT STA.205
*GB303     101976COOK INLET SEDIMENT STA.215
*GB304     102076COOK INLET SEDIMENT STA.212
*GB308     102076COOK INLET SEDIMENT STA. M BEACH
*GB311     102176COOK INLET SEDIMENT STA.204LOW TIDE
*GB312     102276COOK INLET SEDIMENT STA.225
*GB313     102276COOK INLET SEDIMENT STA.229
*GB318     102276COOK INLET SEDIMENT STA.227
*GB319     102376COOK INLET SEDIMENT STA.226
*GB320     10 76COOK INLET SEDIMENT STA.245
*GB325     102476COOK INLET SEDIMENT STA. L BEACH
*GB327     102576COOK INLET SEDIMENT STA.214
*GB328     102576 TIME0130 STA 206
*GB329     102576COOK INLET SEDIMENT STA.204HIGH TIDE
*GB333     102776 TIME2200 STA 207
*GB335     102876COOK INLET SEDIMENT STA.105
*GW301     101876COOK INLET WATER STA.205
*GW302     101976COOK INLET WATER STA.216
*GW303     101976COOK INLET WATER STA.215
*GW304     102076COOK INLET WATER STA.212
*GW305     102076 TIME1130 STA R
*GW306     102076 TIME1130 STA R
*GW307     102076 TIME1245 STA M
*GW308     102076COOK INLET WATER STA. M BEACH
*GW309     102176COOK INLET WATER STA. I BEACH ON
*GW310     102176COOK INLET WATER STA..I BEACH OFF
*GW311     102176COOK INLET WATER STA.204LOW TIDE
*GW312     102276COOK INLET WATER STA.225
*GW313     102276COOK INLET WATER STA.229
*GW314     102276 TIME1000 STA J
*GW315     102276COOK INLET WATER STA. J BEACH
*GW316     102276 TIME1130 STA K
*GW317     102276COOK INLET WATER STA. K BEACH
*GW318     102276COOK INLET WATER STA.227
*GW319     102376COOK INLET WATER STA.226
*GW320     102376COOK INLET WATER STA.245
*GW321     102376 TIME1245 STA 246
*GW322     102476COOK INLET WATER STA.266
*GW323     102476COOK INLET WATER STA.265
*GW324     102476 TIME1420 STA L
*GW325     102476COOK INLET WATER STA. L BEACH
*GW326     102476 TIME1524 STA Q
*GW327     102576COOK INLET WATER STA.214
*GW328     102576 TIME0130 STA 206
*GW329     102576COOK INLET WATER STA.204HIGH TIDE
*GW330     102576 TIME1000 STA 215
*GW331     102676 TIME1530 STA P
*GW332     102676 TIME1530 STA P
*GW333     102776 TIME2200 STA 207
*GW334     102876 TIME0230 STA 106
*GW335     102876COOK INLET WATER STA.105
*GW336     102876 TIME1030 STA O
*GW337     102876 TIME1030 STA O
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FORM NUMBER = 100254 COOK INLET, APRIL 1977 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
*GB401	57	39.0	152	31.0	0.0	16.50	6.5						
*GB410	60	9.5	152	25.0	39.0	30.20	2.3	74.00		21.00	28.00		
*GB411	60	12.7	152	36.5	3.0	15.00	6.0	76.00	362.00		17.00		
*GB412	60	13.7	152	46.8	0.0	22.00	4.0	61.00	432.00		137.00		
*GB420	59	33.5	151	36.4	89.0	31.50	4.4						
*GB421	59	36.1	151	25.0	3.0			49.00	161.00	0.06	0.30		
*GB425	59	37.6	151	18.0	67.0	31.30	4.1	10.00	110.00	1.80	1.30		
*GB428	59	33.5	152	18.7	60.0	31.50	4.7						
*GB429	59	31.4	152	41.5	39.0	31.50	4.4						
*GB430	59	30.0	153	13.2	33.0	30.98	3.1						
*GB431	59	18.2	153	14.3	49.0	31.10	3.3	5.30	117.00	1.92	1.10		
*GB432	59	14.2	153	39.7	36.0	30.91	2.9	25.00	70.00		15.00		
*GB434	59	32.4	153	21.8	27.0	30.70	2.5	25.00	161.00	6.04	3.70		
*GB435	59	21.9	152	48.7	76.0	31.50	4.6						
*GB436	59	33.4	153	24.5	22.0	30.70	2.4						
*GB437								11.00	43.00	5.94	7.60		
*GB438	59	6.3	152	43.1	148.0	32.10	5.4						
*GB440	58	53.0	152	54.0	172.0			13.00	151.00	1.20	0.40		
*GB442	58	50.0	151	20.0	118.0	32.60	7.5	13.00	65.00	2.04	0.50		
*GB444	58	28.6	153	10.0	168.0			2.40	22.00	0.13	0.30		
*GB445	58	2.0	153	29.0	95.0	32.00	5.0	1.30	15.00	0.18	0.00		
*GW401	57	39.0	152	31.0	0.0	16.50		1.22	1.00	1.10	0.21		
*GW402	60	41.2	151	25.0	1.0	21.00	1.0	1.55	1.94	14.30	0.21		
*GW403	60	34.3	151	51.4	1.0	27.40	1.0	1.66	1.81	16.10	0.05		
*GW404	60	9.6	152	15.0	56.0	30.21	2.2						
*GW405	60	6.8	152	14.0	1.0	26.00	2.9	1.46	1.44	15.70	0.17		
*GW406	60	10.7	152	36.0	1.0	24.50	2.8	1.27	1.75	10.50	0.30		
*GW407	60	10.7	152	36.0	0.0	24.00	4.5						
*GW408	60	9.3	152	38.0	0.0	25.00	2.8	1.71	1.22	16.30	0.19		
*GW409	60	9.3	152	38.0	0.0	25.00	4.0	1.75	1.90	16.10	0.23		
*GW410	60	9.5	152	25.0	0.0	30.19	2.3						
*GW411	60	12.7	152	36.5	1.0	15.00	6.0						
*GW412	60	13.7	152	46.8	0.0	22.00	4.0	1.43	1.88	12.70	0.24		
*GW413	60	13.7	152	46.8	0.0	23.00	2.0	2.29	4.01	16.30	0.23		
*GW414													
*GW415	60	9.5	152	25.0	1.0	30.10	2.3						
*GW416	60	9.5	152	25.0	33.0	30.08	2.3						
*GW417	60	3.0	151	46.2	1.0	25.50	2.5	1.65	3.30	15.90	0.28		
*GW418	59	40.8	152	38.6	40.0	30.60	2.8	3.36	4.00	14.10	0.57		
*GW419	59	40.9	151	14.1	48.0	31.41	4.1	2.00	2.97	15.70	0.24		
*GW420	59	33.5	151	36.4	1.0	31.40	4.4						
*GW421	59	36.1	151	25.0	1.0	25.30	5.3						
*GW422	59	36.1	151	25.0	0.0	26.00	5.0	1.31	1.72	16.50	0.14		
*GW423	59	35.3	151	10.7	0.0	26.80	4.6		2.50	15.20	0.57		
*GW424	59	35.3	151	10.7	0.0	25.00	5.0		1.58	16.00	0.53		
*GW425	59	37.6	151	18.0	1.0	31.30	4.2	1.67	1.58	14.30	0.43		
*GW426	59	18.2	152	14.1	1.0	31.50	5.0						
*GW427	59	27.0	152	23.2	74.0	31.47	4.6		1.03	15.40	0.33		
*GW428	59	33.5	152	18.7	1.0	31.50	4.7		1.15	15.60	0.29		

*GW429	59 31.4	152 41.5	1.0	31.30	3.7				
*GW430	59 30.0	153 13.2	33.0	30.98	3.1	0.52	1.50	0.10	0.10
*GW431	59 18.2	153 14.3	1.0	31.10	3.3				
*GW432	59 14.2	153 39.7	1.0	30.80	2.7	1.91		10.50	0.15
*GW433	59 9.8	153 8.2	1.0	31.50	4.9	1.72	3.62	10.00	0.19
*GW434	59 32.4	153 21.8	1.0	30.60	2.3	2.10	2.68	12.40	0.25
*GW435	59 21.9	152 48.7	1.0	31.20	3.4				
*GW436	59 33.4	153 24.5	22.0	30.68	2.4				
*GW437	59 14.7	152 45.5	104.0	31.62	4.9	1.15	0.28	7.80	0.06
*GW438	59 6.3	152 43.1	1.0	31.60	5.0	1.82	1.67	10.70	0.13
*GW439	58 59.9	152 52.0	1.0	31.70	4.8				
*GW440	58 53.0	152 54.0	1.0	26.50	4.6				
*GW441	59 0.4	152 0.0	1.0	31.50	4.7	1.42	2.26	15.10	0.28
*GW442	58 50.0	151 20.0	1.0	27.80	4.6	1.36	2.33	12.10	0.22
*GW443	58 48.8	152 11.9	122.0	31.74	4.7				
*GW444	58 28.6	153 10.0	1.0	24.40	4.7	1.48	1.75	14.30	0.23
*GW445	58 2.0	153 29.0	1.0	26.30	4.5	1.51	2.23	8.20	1.71

%

FORM NUMBER = 100254 COOK INLET, APRIL 1977 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
*GB401									
*GB410	4.30E+07	4.50E+05		5.80E+03	5.00E+02	1.50E+02	2.00E+02	5.00E+01	0.00E+00
*GB411	4.50E+07	1.60E+07	1.10E+03	4.10E+03	0.00E+00	1.40E+02	0.00E+00	0.00E+00	0.00E+00
*GB412									
*GB420	5.20E+07	1.10E+07	2.10E+02	1.20E+04	1.20E+03	0.00E+00	1.10E+03	0.00E+00	4.00E+01
*GB421	7.20E+07	1.10E+08	4.60E+02	4.30E+03	1.50E+02	3.70E+02	6.50E+02	1.50E+02	1.50E+02
*GB425	4.70E+07	1.30E+07	1.50E+03	3.00E+03	4.40E+02	0.00E+00	2.00E+02	2.50E+02	0.00E+00
*GB428	1.40E+08	5.10E+04	1.10E+02	4.50E+03	2.00E+02	1.40E+02	6.50E+02	2.00E+02	2.60E+02
*GB429	5.00E+07	3.80E+05	6.40E+00	5.20E+03	1.50E+02	7.00E+01	1.10E+02	0.00E+00	0.00E+00
*GB430									
*GB431	9.30E+07	1.00E+06	2.10E+01	2.90E+03	4.50E+02	1.70E+02	1.20E+03	3.10E+02	1.40E+02
*GB432				6.00E+03	2.00E+02	4.00E+02	3.40E+02	1.80E+02	1.30E+02
*GB434	1.60E+08	3.90E+05	2.80E+00	3.50E+03	2.50E+02	1.00E+02	3.20E+02	1.50E+02	0.00E+00
*GB435	5.00E+07	1.40E+05	2.80E+00	3.90E+03	1.80E+02	0.00E+00	1.20E+03	1.50E+02	0.00E+00
*GB436									
*GB437									
*GB438	8.30E+07	1.60E+05	4.30E+00	5.00E+03	1.40E+02	3.40E+02	3.70E+02	1.20E+02	0.00E+00
*GB440	1.00E+08	6.00E+05	7.00E-02	2.50E+03	1.80E+02	2.00E+02	7.00E+02	2.10E+02	1.00E+02
*GB442	6.80E+07	5.90E+05	2.10E+02	2.60E+03	3.00E+02	1.80E+02	1.80E+03	1.10E+02	3.00E+02
*GB444		2.50E+06							
*GB445		2.10E+06							
*GW401									
*GW402	3.20E+04	1.20E+03	2.00E+01	6.00E+03	1.20E+03	0.00E+00	7.50E+01	0.00E+00	0.00E+00
*GW403	2.00E+04	5.80E+02	2.00E+01	6.30E+03	2.20E+03	0.00E+00	3.00E+02	0.00E+00	0.00E+00
*GW404									
*GW405	2.10E+04	4.70E+02	1.10E+00	6.30E+03	1.60E+02	0.00E+00	3.50E+02	1.00E+02	0.00E+00
*GW406	3.10E+04	8.80E+02	2.00E+01	7.50E+03	2.20E+02	0.00E+00	2.00E+02	0.00E+00	0.00E+00
*GW407	2.80E+04	5.60E+02	2.00E+01	5.50E+03	1.20E+02	0.00E+00	2.50E+02	7.00E+01	0.00E+00
*GW408									
*GW409									
*GW410									
*GW411	2.20E+04	1.90E+03	7.50E+01	9.70E+03	0.00E+00	0.00E+00	6.60E+02	0.00E+00	0.00E+00
*GW412									
*GW413									
*GW414									

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*GW416
*GW417   2.70E+04  1.30E+03  2.80E+00  2.40E+03  0.00E+00  0.00E+00  3.50E+02  0.00E+00  0.00E+00
*GW418
*GW419
*GW420   2.30E+04  1.80E+02  4.00E+00  7.00E+03  1.20E+02  0.00E+00  7.00E+02  0.00E+00  0.00E+00
*GW421   2.40E+04  6.10E+02  2.10E+02  1.30E+02  2.90E+02  0.00E+00  0.00E+00  0.00E+00  0.00E+00
*GW422
*GW423
*GW424
*GW425   5.60E+04  1.10E+02  1.10E+03  6.00E+03  1.20E+02  0.00E+00  5.70E+02  0.00E+00  0.00E+00
*GW426   1.90E+04  7.20E+01  2.80E+00  3.70E+03  3.10E+02  0.00E+00  1.20E+03  9.00E+02  1.40E+02
*GW427
*GW428   1.70E+04  6.40E+01  1.20E+02            2.50E+02  1.70E+02  6.40E+02  2.50E+02  1.60E+02
*GW429   2.30E+04  5.40E+01  2.80E+00  5.80E+02  0.00E+00  3.00E+01  1.70E+02  0.00E+00  0.00E+00
*GW430
*GW431   2.50E+04  7.40E+01  2.00E+00  2.50E+03  2.00E+03  3.80E+02  7.00E+02  5.50E+02  1.40E+02
*GW432   1.40E+04  6.40E+01  2.10E+01  6.00E+03  2.70E+02  1.10E+02  4.00E+02  1.50E+02  1.10E+02
*GW433   2.00E+04  2.80E+01  2.80E+00  6.00E+03  9.00E+02  3.50E+02  2.10E+02  0.00E+00  1.20E+02
*GW434   4.00E+04  1.90E+02  1.40E+00  2.80E+02  1.20E+03  2.20E+02  3.50E+02  2.50E+02  6.00E+01
*GW435   1.90E+04  3.20E+01  2.00E+00  2.10E+02  1.80E+02  0.00E+00  6.00E+02  0.00E+00  0.00E+00
*GW436
*GW437
*GW438   1.50E+04  1.20E+02  1.40E+00  5.00E+03  0.00E+00  3.80E+02  3.70E+02  0.00E+00  0.00E+00
*GW439             1.20E+02  1.10E+00  4.00E+02  6.00E+02  5.00E+02  6.50E+02  1.20E+02  0.00E+00
*GW440   2.40E+04  4.80E+01  7.00E-02  8.00E+03  2.40E+02  0.00E+00  1.80E+02  1.40E+02  0.00E+00
*GW441   1.90E+04  9.30E+02  9.30E+01  3.50E+02  0.00E+00  1.20E+02  7.00E+02  0.00E+00  1.20E+02
*GW442   2.50E+04  2.40E+02  9.30E+01  1.00E+03  0.00E+00  0.00E+00  3.60E+02  0.00E+00  0.00E+00
*GW443
*GW444             2.80E+01  1.10E+00            1.40E+02  1.60E+02  4.80E+02  1.10E+02  1.10E+02
*GW445             9.80E+01

%
 FORM NUMBER = 100254  COOK INLET, APRIL 1977 CRUISE

*GB401    SEDIMENT STA.D
*GB410    040677COOK INLET SEDIMENT STA.242
*GB411    040777COOK INLET SEDIMENT STA.U OFF
*GB412    SEDIMENT STA.V
*GB420    040977COOK INLET SEDIMENT STA.227
*GB421    040977COOK INLET SEDIMENT STA.K
*GB425    040977COOK INLET SEDIMENT STA.229
*GB428    041077COOK INLET SEDIMENT STA.226
*GB429    041077COOK INLET SEDIMENT STA.225
*GB430    SEDIMENT STA.213
*GB431    041077COOK INLET SEDIMENT STA.214
*GB432    SEDIMENT STA.204
*GB434    041177COOK INLET SEDIMENT STA.212
*GB435    041177COOK INLET SEDIMENT STA.215
*GB436    SEDIMENT STA.212
*GB437    SEDIMENT STA. 208
*GB438    041277COOK INLET SEDIMENT STA.205
*GB440    041377COOK INLET SEDIMENT STA.395
*GB442    041477COOK INLET SEDIMENT STA.105
*GB444    041477COOK INLET SEDIMENT STA.388
*GB445    041477COOK INLET SEDIMENT STA.378
*GW401    040377 TIME1400 STA D
*GW402    040577COOK INLET WATER STA.266
*GW403    040577COOK INLET WATER STA.265
*GW404    040677 TIME0700 STA 244
*GW405    040677COOK INLET WATER STA.245
*GW406    040677COOK INLET WATER STA.S OFF
*GW407    040677COOK INLET WATER STA.S
*GW408    040677 TIME1500 STA T
*GW409    040677 TIME1500 STA T
*GW410    040677 TIME1315 STA 242
*GW411    040777COOK INLET WATER STA.U OFF
*GW412    040777 TIME1412 STA V
*GW413    040777 TIME1410 STA V
*GW414    04 77 TIME STA
*GW415    040777COOK INLET WATER STA.242
*GW416    040777 TIME1905 STA 242
*GW417    040877COOK INLET WATER STA.246
*GW418    040977 TIME1325 STA 235
*GW419    041077 TIME0340 STA 236
*GW420    040977COOK INLET WATER STA.227
*GW421    040977COOK INLET WATER STA.K OFF
*GW422    041077 TIME0950 STA K
*GW423    041077 TIME1050 STA J
*GW424    041077 TIME1115 STA J
*GW425    040977COOK INLET WATER STA.229
*GW426    041077COOK INLET WATER STA.216
*GW427    041177 TIME0315 STA 217
*GW428    041077COOK INLET WATER STA.226
*GW429    041077COOK INLET WATER STA.225
*GW430    041177 TIME1200 STA 213
*GW431    041077COOK INLET WATER STA.214
*GW432    041077COOK INLET WATER STA.204
*GW433    041077COOK INLET WATER STA.206
*GW434    041177COOK INLET WATER STA.212
*GW435    041177COOK INLET WATER STA.215
*GW436    041277 TIME1100 STA 212
*GW437    041277 TIME1445 STA 208
*GW438    041277COOK INLET WATER STA.2
*GW439    041277COOK INLET WATER STA.2
*GW440    041377COOK INLET WATER STA.3
*GW441    041377COOK INLET WATER STA.1
*GW442    041477COOK INLET WATER STA.1
*GW443    041277 TIME2045 STA 398
*GW444    041477COOK INLET WATER STA.3
*GW445    041477COOK INLET WATER STA.3
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FORM NUMBER = 100259 COOK INLET, NOV 1977 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
*GB501	57	47.2	151	48.8	75.0	32.20	7.1	95.00	124.00	17.80	12.90	1.00	5.90
*GB502	58	4.8	151	42.0	166.0	32.90	6.0	51.00	63.00			1.50	11.30
*GB506	59	36.5	151	25.5	1.5	29.00	3.5	18.00	119.00	15.40	1.70	2.30	27.80
*GB507	58	39.5	153	23.5	75.0	31.40	7.4	8.00	73.00			0.60	6.80
*GB508	58	17.2	154	2.3	128.0	32.30	7.3					0.80	8.00
*GB509	57	57.0	154	41.3	225.0	33.10	5.4	19.00	71.00	16.00	1.10	1.20	11.40
*GB510	57	31.4	155	32.8	185.0	32.90	5.9	33.00	34.00	15.80	13.90	0.90	10.90
*GB511	57	27.5	155	14.5	234.0	33.50	5.0	20.00	52.00	16.00	1.10	1.90	15.20
*GB512	57	18.4	154	57.0	175.0	33.10	5.4	6.00	289.00	10.00	16.30	1.20	10.40
*GB513	57	50.1	154	25.0	211.0	33.40	5.0	19.00	56.00			1.00	11.10
*GB514	58	1.6	153	29.0	85.0	32.30	7.0	31.00	79.00	20.80	8.90	2.00	10.30
*GB515	58	10.8	153	45.0	189.0	33.10	5.5	48.00	130.00	52.00	2.40	1.30	12.00
*GB516	58	27.0	152	57.5	214.0	32.90	5.8	13.00	213.00		17.00		
*GB517	58	33.4	153	14.3	178.0	32.70	6.4						
*GB518	59	42.4	152	59.7	99.0	32.50	6.6	54.00	102.00			0.70	6.50
*GB519	58	53.3	153	11.5	163.0	32.60	6.7	24.00	92.00			0.40	4.20
*GB520	58	53.3	152	54.0	159.0	32.80	6.1	39.00	78.00	14.30	2.80	0.90	8.10
*GB523	59	32.5	153	21.2	17.0	30.10	5.7	23.00	122.00		9.30	0.80	5.50
*GB524	59	26.1	153	37.3	16.0	30.30	5.6	85.00	206.00	6.70	22.60	1.50	8.70
*GB525	59	29.4	153	12.7	37.0	29.90	6.0	23.00	93.00	19.40	1.20	0.60	6.10
*GB526	59	17.8	153	14.0	50.0	30.50	6.6	46.00	62.00	32.70	2.40		
*GB527	59	6.2	153	29.1	44.0	30.50	5.5	12.00	103.00	0.90	5.70	1.30	9.80
*GB528												0.90	6.80
*GB529	59	14.3	153	38.5	33.0					12.60	13.30		
*GB532	58	59.8	152	52.9	167.0	32.70	6.4	25.00	275.00			1.00	6.90
*GB538	59	33.5	151	36.1	75.0	31.10	7.4	32.00	124.00	5.00	5.00	1.50	13.40
*GB545	59	42.1	152	38.0	36.0	30.10	6.1						
*GB549	60	12.8	152	36.1	3.0	27.00	2.0	14.00	87.00	3.00	2.40	0.80	6.10
*GB550	60	13.7	152	45.7	1.5	28.00	2.0						
*GB552	60	9.0	152	25.5	31.0	29.40	5.4						
*GB554	59	50.4	152	56.5	26.0			31.00	79.00	19.30	1.20	0.40	5.00
*GB557	59	40.4	151	14.3	16.0	30.80	5.6	30.00	54.00	16.90	3.60	1.10	3.20
*GB558	59	37.5	151	17.8	72.0	31.10	7.0	31.00	114.00	4.40	3.90	1.30	13.80
*GW501	57	47.2	151	58.8	1.0	31.70	7.1	1.45	1.42	9.30	0.35		
*GW502	58	4.8	151	42.0	1.0	32.00	6.4	1.71	0.83	15.00	0.28		
*GW503	58	17.5	151	25.8	1.0	32.20	6.4	1.89	1.48	15.80	0.24		
*GW504	58	48.9	152	11.6	1.0	32.00	7.0	1.58	0.90	13.90	0.24		
*GW505	59	35.5	151	10.5	1.0	29.00	7.5	1.61	3.00	9.10	0.50		
*GW506	59	36.5	151	25.5	1.0	29.00	3.5	1.36	2.71	9.50	0.40		
*GW507	58	39.5	153	23.5	1.0	29.90	4.8	1.23	1.45	9.60	0.34		
*GW508	58	17.2	154	2.3	1.0	30.20	5.2	1.18	1.13	9.00	0.31		
*GW509	57	57.0	154	41.3	1.0	30.70	7.0	1.17	0.85	8.80	0.31		
*GW510	57	31.4	155	32.8	1.0	30.50	6.7	1.19	1.10	8.80	0.31		
*GW511	57	27.5	155	14.5	1.0	31.90	6.1	1.38	1.01	11.30	0.13		

*GW512	57 18.4	154 57.0	1.0	31.80	6.3				
*GW513	57 50.1	154 25.0	1.0	31.90	6.1				
*GW514	58 1.6	153 29.0	1.0	31.20	6.4	1.30	0.82	10.60	0.24
*GW515	58 10.8	153 45.0	1.0	31.30	7.0	1.32	0.92	11.50	0.24
*GW516	58 27.0	152 57.5	1.0	31.30	7.3	1.22	0.62	8.80	0.35
*GW517	58 33.4	153 14.3	1.0	30.90	7.3				
*GW518	58 42.4	152 59.7	1.0	31.00	7.4	1.29	0.62	10.00	0.29
*GW519	58 53.3	153 11.5	1.0	30.20	5.1	1.22	1.12	8.50	0.32
*GW520	58 53.3	152 54.0	1.0	31.90	7.1	1.49	1.36	13.30	0.27
*GW521	59 6.2	152 41.3	1.0	31.00	7.8	1.18	0.55	9.20	0.33
*GW522	59 9.4	153 7.1	1.0	30.30	6.6	1.21	0.95	9.40	0.31
*GW523	59 32.5	153 21.2	1.0	30.10	5.7	1.18	0.93	8.80	0.33
*GW524	59 26.1	153 37.3	1.0	30.30	5.6	1.22	1.05	8.80	0.33
*GW525	59 29.4	153 12.7	1.0	29.90	6.0	0.99	0.58	6.30	0.26
*GW526	59 17.8	153 14.0	1.0	30.00	6.2	1.21	1.66	9.60	0.36
*GW527	59 6.2	153 29.1	1.0	30.30	5.1	1.30	1.35	9.10	0.30
*GW528	59 12.8	153 52.4	1.0			1.19	1.48	9.20	0.30
*GW529	59 14.3	153 38.5	1.0		6.7	1.22	1.27	9.10	0.26
*GW530	59 21.1	153 48.8	1.0	30.60	6.5	1.26	1.03	9.50	0.35
*GW531	59 15.0	152 44.9	1.0	31.00	7.0	1.20	0.65	9.90	0.32
*GW532	58 59.8	152 52.9	1.0	31.40	7.0	1.38	1.31	11.90	0.22
*GW533	59 18.0	152 15.0	1.0	31.40	7.8	1.35	0.99	11.70	0.21
*GW534	59 27.7	152 22.9	1.0	31.50	7.6	1.36	0.85	11.80	0.23
*GW535	59 31.5	152 41.9	1.0	31.30	7.1	1.30	0.62	11.00	0.29
*GW536	59 33.3	152 18.6	1.0	31.30	7.2	1.35	0.80	11.10	0.29
*GW537	59 32.9	151 53.4	1.0			1.33	1.05	10.10	0.38
*GW538	59 33.5	151 36.1	1.0	31.00	7.2				
*GW539	59 51.3	152 2.1	1.0	30.80	6.3	1.18	1.70	9.30	0.39
*GW540	60 2.5	151 47.5	1.0	30.70	2.2	1.12	1.50	8.60	0.30
*GW541	60 41.2	151 25.6	1.0	23.00	4.4	1.45	1.11	12.90	0.07
*GW542	60 33.6	151 51.6	1.0			1.26	1.47	10.70	0.39
*GW543	60 19.9	151 45.9	1.0	28.80	5.4	1.37	1.49	11.20	0.12
*GW544	59 50.5	152 56.5	1.0	29.80	5.9	1.25	1.45	10.20	0.35
*GW545	59 42.1	152 38.1	1.0	30.00	6.1	1.28	1.25	9.80	0.35
*GW545A	59 42.1	152 38.1	20.0	30.10	6.1				
*GW546	59 37.6	152 55.8	1.0	30.40	6.3				
*GW547	60 6.7	152 14.5	1.0	29.40	5.3	1.25	1.15	10.20	0.34
*GW548	60 6.8	152 36.0	1.0						
*GW549	60 12.8	152 36.1	1.0	27.00	2.0	0.91	1.23	10.60	0.44
*GW550	60 13.7	152 45.7	1.0	28.00	2.0	1.18	1.25	10.20	0.43
*GW551	60 6.8	152 36.0	1.0						
*GW552	60 9.0	152 25.5	1.0	29.30	5.1				
*GW553	59 56.0	152 37.1	1.0						
*GW554	59 50.4	152 56.5	1.0						
*GW555	59 29.4	153 12.7	1.0	30.30	5.6				
*GW556	59 41.3	152 14.1	1.0	31.40	7.0	1.52	1.26	11.70	0.23
*GW557	59 40.4	151 14.3	1.0	30.70	5.5	1.43	1.75	10.40	0.39
*GW558	59 37.5	151 17.8	1.0	30.90	6.2	1.41	1.67	10.30	0.46
*GW559	59 0.6	152 1.4	1.0	31.50	7.0	1.43	1.78	13.00	0.16
*GW560	58 49.8	151 17.8	1.0	31.20	6.5	1.32	0.95	10.70	0.10

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FORM NUMBER = 100259 COOK INLET, NOV 1977 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
#GB501	4.80E+08	1.30E+06	2.00E+04	5.20E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
#GB502	7.50E+08								
#GB506	1.10E+09	4.60E+07	2.30E+04	1.70E+02	5.60E+02	0.00E+00	1.20E+03	3.50E+02	8.00E+01
#GB507									
#GB508									
#GB509									
#GB510	8.90E+08	1.10E+06	1.50E+04	1.60E+02	0.00E+00	0.00E+00	5.30E+02	1.20E+01	5.00E+02
#GB511	6.70E+08	3.20E+05	4.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
#GB512	4.70E+08	7.10E+05	4.00E+03	1.20E+03	2.50E+01	0.00E+00	0.00E+00	2.50E+01	0.00E+00
#GB513	7.90E+08	2.20E+06	4.00E+03						
#GB514	4.40E+08	4.50E+05	4.00E+03						
#GB515	6.90E+08	5.40E+05	4.00E+03						
#GB516									
#GB517									
#GB518	2.50E+08	7.70E+04	4.00E+03	3.10E+02	0.00E+00	0.00E+00	1.50E+01	0.00E+00	0.00E+00
#GB519									
#GB520	5.00E+08	5.40E+05	4.00E+03						
#GB523	3.90E+08	6.40E+04	4.00E+03	2.00E+02	1.00E+01	0.00E+00	2.20E+02	8.50E+01	0.00E+00
#GB524	4.70E+08	2.30E+06	1.50E+05	1.70E+02	0.00E+00	0.00E+00	8.30E+02	0.00E+00	0.00E+00
#GB525									
#GB526									
#GB527									
#GB528									
#GB529	4.50E+08	7.30E+05	7.00E+03			0.00E+00			0.00E+00
#GB532									
#GB538	5.40E+08		4.00E+03	9.50E+02	0.00E+00	0.00E+00	1.20E+02	1.20E+02	0.00E+00
#GB545	2.80E+08	7.30E+04	4.00E+03	4.80E+02	2.00E+02	0.00E+00	1.00E+03	7.00E+01	0.00E+00
#GB549	6.20E+08	1.00E+07	2.40E+05	4.80E+02	0.00E+00	0.00E+00	8.60E+02	3.00E+01	0.00E+00
#GB550									
#GB552									
#GB554									
#GB557	6.40E+08	4.40E+06	2.40E+06	4.20E+02	0.00E+00	0.00E+00	1.10E+03	0.00E+00	0.00E+00
#GB558	8.30E+08	4.70E+06	1.10E+06	0.00E+00	0.00E+00	0.00E+00	2.80E+02	0.00E+00	9.00E+01
#GW501	3.00E+04	6.10E+02	2.00E+02	9.00E+01	1.50E+01	1.50E+01	2.00E+02	0.00E+00	0.00E+00
#GW502	4.10E+04								
#GW503	4.00E+04								
#GW504	2.50E+04	4.30E+01	4.00E+01						
#GW505	4.10E+04	3.40E+02	2.30E+02						
#GW506	3.50E+04	1.40E+03	4.60E+04	2.00E+03	4.30E+02	0.00E+00	2.70E+02	8.30E+01	3.40E+01
#GW507									
#GW508									
#GW509	3.70E+04								
#GW510	4.10E+04	1.50E+02	2.40E+03	3.60E+02	7.70E+02	0.00E+00	1.10E+02	6.80E+01	8.50E+01
#GW511	4.10E+04	2.30E+02	4.00E+01	4.20E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
#GW512	3.50E+04	1.00E+01	2.30E+02	7.20E+02	2.00E+01	0.00E+00	2.00E+02	0.00E+00	4.30E+02
#GW513	4.10E+04	2.00E+01	3.00E+01						
#GW514	3.80E+04	6.70E+00	4.00E+01						
#GW515	3.40E+04	3.00E+00	1.10E+02						

*GW516									
*GW517									
*GW518	3.70E+04	7.00E+01	4.00E+01	1.20E+02	0.00E+00	0.00E+00	1.10E+02	0.00E+00	0.00E+00
*GW519									
*GW520	3.30E+04	2.00E+01	4.00E+01						
*GW521	5.30E+04	5.30E+01	9.30E+02	0.00E+00	2.30E+02	5.00E+01	0.00E+00	0.00E+00	0.00E+00
*GW522	9.30E+04	1.70E+01	9.00E+01	5.50E+01	0.00E+00	4.50E+01	2.00E+02	5.00E+01	2.80E+02
*GW523	8.30E+04	1.30E+01	4.00E+01	1.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*GW524	5.20E+04	3.70E+01	9.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+01
*GW525									
*GW526									
*GW527									
*GW528	5.90E+04	1.30E+02	4.00E+01	3.60E+02	0.00E+00	0.00E+00	2.50E+02	0.00E+00	0.00E+00
*GW529	5.80E+04	1.00E+02	1.10E+02	3.40E+02	0.00E+00	0.00E+00	2.50E+02	0.00E+00	0.00E+00
*GW530	6.00E+04	4.70E+01	4.00E+01	1.30E+02	0.00E+00	0.00E+00	9.00E+01	0.00E+00	1.00E+01
*GW531	6.80E+04	4.00E+01	4.00E+01	0.00E+00	0.00E+00	2.90E+02	8.00E+01	0.00E+00	0.00E+00
*GW532	4.70E+04	2.20E+03	3.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*GW533	4.80E+04	6.30E+01	7.00E+01	5.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*GW534	3.60E+04	8.30E+01	4.00E+01	7.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*GW535	3.70E+04	6.00E+01	4.00E+01	4.80E+02	0.00E+00	1.30E+02	0.00E+00	0.00E+00	0.00E+00
*GW536	7.50E+04	4.10E+02	9.00E+01	2.60E+02	0.00E+00	0.00E+00	1.40E+02	0.00E+00	0.00E+00
*GW537									
*GW538	7.70E+04	4.10E+02	4.30E+02	5.40E+02	0.00E+00	0.00E+00	5.40E+02	2.50E+01	0.00E+00
*GW539	4.90E+04	5.50E+02	2.30E+02	3.50E+02	0.00E+00	0.00E+00	9.00E+01	0.00E+00	0.00E+00
*GW540	5.00E+04		4.00E+01	9.50E+02	0.00E+00	0.00E+00	1.20E+02	0.00E+00	0.00E+00
*GW541	1.10E+05		4.00E+01	1.60E+02	6.50E+01	0.00E+00	4.30E+02	0.00E+00	0.00E+00
*GW542	6.30E+04	1.60E+02	4.30E+01	3.80E+02	4.00E+02	0.00E+00	1.10E+02	6.00E+01	0.00E+00
*GW543	5.80E+04		4.30E+02	3.40E+02	0.00E+00	0.00E+00	3.00E+02	0.00E+00	1.00E+01
*GW544			9.00E+01	1.90E+02	6.00E+01	0.00E+00	2.30E+02	0.00E+00	0.00E+00
*GW545	6.50E+04	9.00E+01	7.00E+01	2.60E+02	6.00E+01	0.00E+00	1.40E+02	0.00E+00	0.00E+00
*GW545A	6.20E+04	2.40E+02	1.50E+02	2.10E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+01
*GW546									
*GW547	9.00E+04	4.60E+02	7.00E+01	1.00E+03	0.00E+00	0.00E+00	1.70E+02	0.00E+00	0.00E+00
*GW548									
*GW549	9.60E+04	5.80E+02	2.40E+03						
*GW550	1.30E+05		9.30E+02	1.20E+03	0.00E+00	0.00E+00	3.40E+02	0.00E+00	0.00E+00
*GW551									
*GW552	8.20E+04		2.30E+02	5.00E+02	0.00E+00	0.00E+00	7.50E+02	1.00E+01	0.00E+00
*GW553									
*GW554									
*GW555									
*GW556	6.70E+04		9.00E+01	1.40E+02	0.00E+00	0.00E+00	4.00E+02	0.00E+00	0.00E+00
*GW557	8.70E+04	2.00E+02	4.60E+03	5.70E+02	0.00E+00	3.00E+01	3.20E+02	0.00E+00	0.00E+00
*GW558	4.80E+04	3.00E+02	7.50E+02	0.00E+00	1.40E+02	0.00E+00	2.80E+02	0.00E+00	2.00E+01
*GW559		3.70E+01	9.00E+01	5.60E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*GW560	1.00E+05	1.00E+01	4.00E+01	2.50E+01	0.00E+00	1.10E+02	3.00E+02	0.00E+00	0.00E+00

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 FORM NUMBER = 100259  COOK INLET, NOV 1977 CRUISE

*GB501   1177 COOK INLET SEDIMENT ST.429            *GW518   1177 COOK INLET WATER ST.394
*GB502   1177 COOK INLET SEDIMENT ST.418            *GW519   1177 COOK INLET WATER ST.390
*GB506   1177 COOK INLET SEDIMENT ST. K BEACH       *GW520   1177 COOK INLET WATER ST.395
*GB507   COOK INLET SEDIMENT ST 380                 *GW521   1177 COOK INLET WATER ST.205
*GB508   1177 COOK INLET SEDIMENT ST.370            *GW522   1177 COOK INLET WATER ST.206
*GB509   COOK INLET SEDIMENT ST 360                 *GW523   1177 COOK INLET WATER ST.212
*GB510   1177 COOK INLET SEDIMENT ST.350            *GW524   1177 COOK INLET WATER ST.211
*GB511   1177 COOK INLET SEDIMENT ST.354            *GW525   1177 COOK INLET WATER ST.213
*GB512   1177 COOK INLET SEDIMENT ST.358            *GW526   1177 COOK INLET WATER ST.214
*GB513   1177 COOK INLET SEDIMENT ST.364            *GW527   1177 COOK INLET WATER ST.203
*GB514   1177 COOK INLET SEDIMENT ST.378            *GW528   1177 COOK INLET WATER ST.201
*GB515   1177 COOK INLET SEDIMENT ST.374            *GW529   1177 COOK INLET WATER ST.204
*GB516   COOK INLET SEDIMENT ST 388                 *GW530   1177 COOK INLET WATER ST.215
*GB517   COOK INLET SEDIMENT ST 384                 *GW531   1177 COOK INLET WATER ST.208
*GB518   1177 COOK INLET SEDIMENT ST.394            *GW532   1177 COOK INLET WATER ST.207
*GB519   COOK INLET SEDIMENT ST 390                 *GW533   1177 COOK INLET WATER ST.216
*GB520   1177 COOK INLET SEDIMENT ST.395            *GW534   1177 COOK INLET WATER ST.217
*GB523   1177 COOK INLET SEDIMENT ST.212            *GW535   1177 COOK INLET WATER ST.225
*GB524   1177 COOK INLET SEDIMENT ST.211            *GW536   1177 COOK INLET WATER ST.226
*GB525   COOK INLET SEDIMENT ST 213                 *GW537   COOK INLET WATER ST 228
*GB526   COOK INLET SEDIMENT ST 214                 *GW538   1177 COOK INLET WATER ST.227
*GB527   COOK INLET SEDIMENT ST 203                 *GW539   1177 COOK INLET WATER ST.249
*GB528   1177 COOK INLET SEDIMENT ST.201            *GW540   1177 COOK INLET WATER ST.246
*GB529   1177 COOK INLET SEDIMENT ST.204            *GW541   1177 COOK INLET WATER ST.266
*GB532   COOK INLET SEDIMENT ST 207                 *GW542   1177 COOK INLET WATER ST.265
*GB538   1177 COOK INLET SEDIMENT ST.227            *GW543   1177 COOK INLET WATER ST.255
*GB545   COOK INLET SEDIMENT ST 235                 *GW544   COOK INLET WATER ST 248
*GB549   1177 COOK INLET SEDIMENT ST. U BEACH       *GW545   1177 COOK INLET WATER ST.235
*GB550   1177 COOK INLET SEDIMENT ST. V BEACH       *GW545A  1177 COOK INLET WATER ST.235 >20M
*GB552   1177 COOK INLET SEDIMENT ST.242            *GW546   1177 COOK INLET WATER ST.234
*GB554   COOK INLET SEDIMENT ST 233                 *GW547   1177 COOK INLET WATER ST.245
*GB557   1177 COOK INLET SEDIMENT ST.229A           *GW548   COOK INLET WATER ST 241
*GB558   1177 COOK INLET SEDIMENT ST.229            *GW549   1177 COOK INLET WATER ST. U BEACH
*GW501   1177 COOK INLET WATER ST.429               *GW550   1177 COOK INLET WATER ST. V BEACH
*GW502   1177 COOK INLET WATER ST.418               *GW551   COOK INLET WATER ST 241
*GW503   1177 COOK INLET WATER ST.417               *GW552   1177 COOK INLET WATER ST.242
*GW504   1177 COOK INLET WATER ST.398               *GW553   COOK INLET WATER ST 247
*GW505   1177 COOK INLET WATER ST. J BEACH          *GW554   COOK INLET WATER ST 233
*GW506   COOK INLET WATER ST K BEACH                *GW555   COOK INLET WATER ST 213
*GW507   COOK INLET WATER ST 380                    *GW556   1177 COOK INLET WATER ST.236
*GW508   COOK INLET WATER ST 370                    *GW557   1177 COOK INLET WATER ST.229A
*GW509   1177 COOK INLET WATER ST.360               *GW558   1177 COOK INLET WATER ST.229
*GW510   1177 COOK INLET WATER ST.350               *GW559   1177 COOK INLET WATER ST.106
*GW511   1177 COOK INLET WATER ST.354               *GW560   1177 COOK INLET WATER ST.105
*GW512   1177 COOK INLET WATER ST.358
*GW513   1177 COOK INLET WATER ST.364               ------------------------------------------
*GW514   1177 COOK INLET WATER ST.378
*GW515   1177 COOK INLET WATER ST.374
*GW516   1177 COOK INLET WATER ST.388
*GW517   COOK INLET WATER ST 384
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FORM NUMBER = 100306 COOK INLET, MAY 1978 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
#GB601								38.60	171.00	7.10	13.00		
#GB602	56	46.0	154	20.3	52.0	32.10	3.5	13.00	141.00	2.00	2.30		
#GB603	57	4.2	155	1.2	188.0	32.40	4.5	9.60	47.00	1.30	1.40		
#GB604	57	18.1	154	56.0	148.0	32.40	4.5	5.20	56.00	2.30	1.10		
#GB605	57	31.2	155	33.8	265.0	32.50	4.6	9.10	115.00	2.60	1.40		
#GB606	57	56.2	154	40.6	228.0	32.40	4.5	15.40	139.00		0.90		
#GB607	57	43.9	154	9.0	53.0	32.30	4.4	8.70	111.00	2.10	1.10		
#GB608								25.90	186.00		5.70		
#GB609	58	17.2	154	1.9	11.2	32.00	4.7	9.50	100.00	5.40	10.00		
#GB610	58	38.9	154	1.9	166.0	31.50	4.0	6.10	80.00	13.80	2.80		
#GB611	58	40.9	153	0.5	153.0	32.30	4.7	9.50	101.00	3.00	0.80		
#GB612	58	27.2	152	58.0	215.0	32.40	4.6	13.80	53.00	2.30	1.10		
#GB613	58	53.2	152	54.9	166.0	32.20	4.7	9.40	113.00	2.90	1.10		
#GB614	58	59.9	152	53.3	166.0	32.10	4.8	44.70	184.00	2.00	0.20		
#GB616	59	39.9	151	14.8	38.0	31.70	4.2	9.10	109.00	2.10	3.00		
#GB625	59	49.7	152	56.0	15.0	31.00	3.9	7.90	120.00	9.80	0.60		
#GB627	59	6.3	153	27.8	41.0	31.10	4.0	8.70	78.00	42.60	1.20		
#GB628	59	12.5	153	52.9	20.0	30.70	4.3	6.80	117.00	34.40	1.20		
#GB629	59	14.1	153	39.5	34.0	31.20		13.00	125.00	40.30	2.10		
#GB630	59	17.9	153	13.2	53.0	31.70		0.00	106.00	2.90	1.40		
#GB631								29.60	246.00	15.50	7.60		
#GB632	59	32.7	153	20.9	26.0	31.30	4.0	5.50	85.00	23.90	0.90		
#GB633	60	13.4	152	45.6	26.0			7.50	111.00	16.70	1.30		
#GB634	60	12.8	152	36.0	26.0								
#GB636	59	29.6	153	13.9	33.0	31.40	4.2	12.40	57.00		2.30		
#GB644	58	53.4	153	11.6	62.0	32.10	5.0						
#GB649	59	38.0	153	37.8	201.0			17.50	227.00	1.70	1.00		
#GB650	59	43.3	153	22.6	201.0			9.00	265.00	1.90	1.70		
#GB652	59	37.8	151	18.4	64.0	31.80	4.3	62.40	273.00		16.10		
#GB653	59	13.7	153	40.1	31.0	31.40	4.4						
#GB654	59	16.6	153	20.3	36.0			8.00	93.00	4.70	5.30		
#GB660	59	35.4	151	45.9	51.0	31.80	5.1	17.40	136.00	25.30	18.70		
#GB669	59	36.5	151	25.5	51.0				628.00	1.10	1.40		
#GB677	60	28.2	152	12.2	37.0	30.70		6.70	37.00	72.70	0.30		
#GW601	56	22.3	154	17.9	1.0	32.20	4.5	1.00	2.58	5.40	0.23		
#GW602	56	46.0	154	20.3	1.0	32.10	3.5	1.83	1.66	17.10	0.71		
#GW603	57	4.2	155	1.2	1.0	31.90	4.9	1.02	0.78	5.90	0.39		
#GW604	57	18.1	154	56.0	1.0	32.10	4.5	1.48	2.38	12.80	0.26		
#GW605	57	31.2	155	33.8	1.0	31.90	4.4	1.60	2.13	14.90	0.64		
#GW606	57	56.2	154	40.6	1.0	31.80	4.4	1.50	1.36	13.50	0.36		
#GW607	57	43.9	154	9.0	1.0	32.10	4.6	1.34	1.22	12.00	0.46		
#GW608	58	1.3	153	29.6	1.0	32.10	4.9	0.70	1.13	1.70	0.26		
#GW609	58	17.2	154	1.9	1.0	31.50	4.0	1.49	2.38	15.00	0.24		

*GW610	58 38.9	153 24.7	1.0	31.40	3.9	1.54	1.38	15.70	0.49
*GW611	58 40.9	153 0.5	1.0	31.90	4.6	1.67	1.23	15.60	0.42
*GW612	58 27.2	152 58.0	1.0	32.00	4.9	1.24	0.98	9.30	0.27
*GW613	58 53.2	152 54.9	1.0	31.90	4.7	1.60	1.30	14.70	0.26
*GW614	58 59.9	152 53.3	1.0	32.00	4.8	1.62	1.95	15.40	0.20
*GW615	58 52.7	153 11.1	1.0	31.30	3.8	1.57	1.27	15.30	0.19
*GW616	59 39.9	151 14.8	1.0	31.60	4.7	0.78	1.43	3.10	0.16
*GW617	59 51.3	152 1.6	1.0		4.7	1.28	1.25	9.40	0.13
*GW618	60 5.5	151 45.7	1.0		5.0	1.09	1.50	6.30	0.17
*GW619	60 42.7	151 25.5	1.0		4.2	1.29	1.37	14.80	0.25
*GW620	60 34.9	151 41.9	1.0		4.1	1.52	1.59	12.80	0.34
*GW621	60 19.3	151 46.5	1.0	30.00	3.3	1.48	1.19	15.60	0.34
*GW622	60 9.0	152 25.7	1.0	30.80	3.7				
*GW623	60 6.3	152 15.5	1.0	30.60	3.8	1.41	1.45	11.90	0.29
*GW624	59 58.1	152 34.4	1.0	30.70	4.0	1.54	1.17	15.10	0.20
*GW625	59 49.7	152 56.0	1.0	31.20	3.9	1.59	2.19	16.30	0.32
*GW626	59 50.1	152 24.2	1.0	30.90	3.8	1.54	1.60	15.10	0.38
*GW627	59 6.3	153 27.8	1.0	30.00	4.1	1.45	1.66	14.30	0.26
*GW628	59 12.5	153 52.9	1.0	30.70	4.3				
*GW629	59 14.1	153 39.5	1.0	31.20		1.61	1.70	15.60	0.22
*GW630	59 17.9	153 13.2	1.0	31.50		1.59	1.42	15.20	0.17
*GW631	59 26.1	153 37.0	1.0	31.30	4.0	1.76	2.52	16.20	0.42
*GW632	59 32.7	153 20.9	1.0	31.20	4.0	1.65	1.66	16.00	0.42
*GW633	60 13.4	152 45.6	1.0	30.50	4.0	0.86	0.99	14.00	0.28
*GW634	60 12.8	152 36.0	1.0	29.00	4.0				
*GW635	59 37.8	152 55.8	1.0	31.30	4.1	1.70	1.42	15.80	0.40
*GW636	59 29.6	153 13.9	1.0	31.40	4.2				
*GW637	59 31.5	152 39.6	1.0	31.70	4.4	1.59	1.28	15.40	0.19
*GW638	59 42.6	152 37.3	1.0	31.20	4.1	1.62	2.51	15.40	0.41
*GW639	59 41.7	152 14.2	1.0	31.90	4.8	1.70	1.60	15.90	0.50
*GW640	59 32.8	152 18.3	1.0	31.90	4.7	1.75	1.73	16.40	0.29
*GW641	59 18.1	152 15.4	1.0	31.90	4.8	1.66	1.52	14.80	0.22
*GW642	59 6.7	152 40.0	1.0	31.90	4.8	1.61	2.13	13.70	0.21
*GW643	59 8.7	153 5.0	1.0	31.90	4.8	1.62	1.97	14.20	0.48
*GW644	58 53.4	153 11.6	1.0	31.50					
*GW645	58 49.0	152 12.3	1.0	32.20	5.1	1.40	1.68	11.40	0.23
*GW646	58 49.7	151 19.3	1.0	32.10	5.0	1.65	1.70	0.20	0.33
*GW647	59 0.6	152 1.2	1.0	31.90	4.9	1.48	2.01	12.30	0.31
*GW648	59 39.5	153 16.5	1.0	28.00					
*GW649	59 38.0	153 37.8	1.0	27.20	5.5				
*GW650	59 43.3	153 22.6	1.0	27.60	8.0	0.57	1.92	9.50	0.29
*GW651	59 34.6	151 11.0	1.0	31.20					
*GW652	59 37.8	151 18.4	1.0	31.40	6.0	0.32	1.63	12.30	0.19
*GW653	59 13.7	153 40.1	1.0	31.40	4.4				
*GW654	59 16.6	153 20.3	1.0						
*GW655	59 19.9	153 58.3	1.0			1.73	2.74	14.30	0.76
*GW656	59 23.3	152 38.7	1.0			1.49	2.35	13.40	0.60
*GW657	59 25.6	152 19.4	1.0			1.48	2.52	13.50	0.47
*GW658	59 29.9	152 0.6	1.0			1.43	1.83	11.60	0.53
*GW659	59 35.4	151 45.9	1.0	31.80	5.6	0.89	1.46	0.90	0.06
*GW660	59 35.4	151 45.9	1.0	31.80	5.3	0.91	2.13	3.80	0.50
*GW661	59 35.4	151 45.9	1.0	31.80	5.8	0.35	1.44	4.00	0.34

#GW662	59	27.6	151	43.2	1.0	29.50	5.0	1.20	1.88	9.50	0.17
#GW663	59	35.4	151	45.9	1.0	31.80	5.3	0.85	1.49	3.50	0.14
#GW664	59	35.4	151	45.9	1.0	31.80	5.8	0.87	1.27	0.60	0.24
#GW665	59	35.4	151	45.9	1.0	31.70	5.4	0.80	0.61	4.00	0.47
#GW666	59	35.4	151	45.9	1.0	31.80	5.9	0.56	1.08	0.90	0.11
#GW667	59	35.4	151	45.9	1.0	31.80	5.4	0.91	2.31	4.40	0.36
#GW668	59	35.4	151	45.9	1.0	31.80	5.5	0.50	1.86	3.00	0.17
#GW669	59	36.5	151	25.5	1.0	29.00	6.0	0.56	1.70	0.30	0.10
#GW670	60	31.5	151	30.9	1.0	29.50	4.3	1.42	1.08	15.20	0.14
#GW671	60	31.5	151	30.9	1.0			1.45	0.80	16.20	0.17
#GW672	60	31.5	151	30.9	1.0	29.60	4.2	1.50	0.78	15.40	0.22
#GW673	60	31.5	151	30.9	1.0	29.30	4.4	1.42	1.22	15.00	3.39
#GW674	60	31.5	151	30.9	1.0	29.50	4.2	1.43	1.36	15.30	0.20
#GW675	60	28.2	152	12.2	1.0	30.70	4.7	1.39	1.13	13.60	0.19
#GW676	60	28.2	152	12.2	1.0	30.40	4.7	1.42	1.17	13.90	0.14
#GW677	60	28.2	152	12.2	1.0	30.50	4.9	1.43	1.32	13.60	0.16
#GW678	60	28.2	152	12.2	1.0	30.50		1.42	1.20	14.00	0.16
#GW679	60	28.2	152	12.2	1.0	30.60		1.34	2.43	13.60	0.23
#GW680	60	28.2	152	12.2	1.0	30.20		1.39	0.95	13.60	0.18
#GW681	60	28.2	152	12.2	1.0	30.50		1.39	1.02	12.30	0.17
#GW682	60	28.2	152	12.2	1.0	30.40		1.42	0.85	14.10	0.23
#GW683	60	28.2	152	12.2	1.0	30.50		1.40	1.03	12.60	0.24

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FORM NUMBER = 100306 COOK INLET, MAY 1978 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
#GB601									
#GB602	3.30E+08	3.30E+06	2.10E+03	1.20E+03	1.00E+02	0.00E+00			
#GB603	6.50E+08	3.80E+06	2.10E+03	1.00E+02	3.20E+02	0.00E+00			
#GB604		6.80E+05	2.00E+02	4.50E+02	6.00E+02	8.00E+02			
#GB605	8.20E+08	2.20E+06	1.10E+05	6.00E+02	6.00E+02	3.80E+02			
#GB606	4.90E+08	2.80E+05	3.00E+02	3.50E+02	3.50E+02	2.00E+02			
#GB607	4.60E+08	1.40E+05	3.00E+02	4.00E+02	4.00E+02	1.00E+02			
#GB608									
#GB609	6.40E+08	1.20E+06	2.10E+04	7.00E+02	4.00E+02	4.00E+02			
#GB610	5.00E+08	1.20E+06	3.00E+02	2.20E+03	1.20E+02	0.00E+00			
#GB611	4.00E+08	4.70E+04	1.00E+03	1.50E+02	3.30E+02	2.00E+02			
#GB612		1.30E+05	2.10E+02	3.00E+02	4.00E+02	2.00E+02			
#GB613	5.80E+08	1.10E+05	2.10E+02	3.00E+02	1.00E+03	5.00E+02			
#GB614	3.70E+08	1.80E+06	2.50E+02	6.50E+02	1.00E+03	2.30E+02			
#GB616		1.10E+06	6.40E+02	2.20E+03	1.30E+03	0.00E+00			
#GB625	4.80E+08	7.00E+05	2.00E+02	1.80E+03	1.20E+03	1.00E+02			
#GB627	7.90E+08	1.40E+06	2.50E+00	1.30E+03	9.00E+02	5.00E+02			
#GB628	5.80E+08	7.90E+06	3.00E+02	5.00E+03	8.00E+02	0.00E+00			
#GB629									
#GB630									
#GB631									
#GB632		4.60E+04	2.40E+05	8.00E+02	7.50E+02	5.00E+01			
#GB633	4.40E+08	6.80E+06		2.50E+03	2.50E+03	6.00E+02			
#GB634	4.80E+08	8.50E+06	1.50E+02	1.00E+03	8.00E+02	6.00E+02			
#GB636	2.30E+08		2.10E+04	4.00E+02	3.00E+02	7.00E+02			
#GB644	3.50E+08	8.70E+05	9.00E+02						
#GB649	7.00E+08		2.40E+05	3.60E+03	1.40E+03	1.60E+03			
#GB650	3.10E+08		2.40E+05	4.90E+03	9.60E+02	0.00E+00			
#GB652	5.50E+08		1.00E+03	1.50E+03	8.00E+02	5.00E+01			
#GB653	4.30E+08		5.00E+04	9.00E+02	1.30E+03	6.00E+02			

*GR654						
*GR660	3.40E+08	6.90E+06	1.10E+02	2.00E+02	2.00E+02	3.00E+02
*GR669			6.40E+02	1.40E+03	2.20E+03	1.00E+02
*GR677	3.80E+08			4.00E+02	2.20E+03	4.00E+02
*GW601	1.10E+05	1.20E+03	3.00E-01	1.50E+02	1.00E+03	5.50E+02
*GW602	9.30E+04	3.10E+02	1.40E+00	1.00E+03	5.00E+02	7.90E+02
*GW603	8.20E+04	3.20E+02	1.50E-01	2.20E+02	3.00E+02	0.00E+00
*GW604	8.30E+04	1.40E+02	2.30E+03	1.20E+03	2.10E+03	2.70E+02
*GW605	6.00E+04	2.50E+01	7.00E-01	4.50E+02	2.00E+02	3.00E+02
*GW606	8.20E+04	6.00E+01	3.00E+00	4.00E+02	4.80E+02	5.20E+02
*GW607	8.50E+04	1.80E+01	1.20E+01	4.40E+02	1.80E+02	0.00E+00
*GW608	1.10E+05	2.40E+03		3.70E+02	1.30E+02	1.50E+02
*GW609	5.20E+04	2.40E+01	3.00E+00	3.60E+02	2.70E+02	1.00E+02
*GW610	5.60E+04	6.90E+01	7.00E-01	8.70E+01	4.00E+02	6.00E+02
*GW611	9.50E+04	7.30E+00	9.00E-01	4.60E+02	7.00E+02	1.30E+03
*GW612	6.20E+04	1.40E+02	4.00E+00	0.00E+00	8.20E+01	0.00E+00
*GW613	3.90E+04	8.80E+00	2.10E+00	4.50E+02	3.40E+02	1.00E+02
*GW614	1.20E+05	5.40E+01	1.10E+00	1.30E+02	4.40E+02	2.40E+02
*GW615	8.50E+04	4.40E+01	1.10E+00	3.40E+02	7.60E+02	1.60E+03
*GW616	7.80E+04	7.50E+02	2.40E+02	1.20E+03	1.40E+03	4.40E+02
*GW617	6.60E+04	1.10E+03	1.10E+00	3.10E+02	0.00E+00	0.00E+00
*GW618	4.90E+04	8.20E+02	2.40E+03	2.50E+02	5.10E+02	1.80E+02
*GW619	1.10E+05	2.20E+02	2.40E+03	1.80E+03	2.20E+02	5.40E+02
*GW620	1.10E+05	4.20E+02	1.10E+03	1.70E+03	7.00E+02	3.90E+02
*GW621	1.60E+05	3.20E+02	4.60E+01	5.80E+02	1.50E+02	6.60E+02
*GW622	8.20E+04	2.10E+02	4.00E-01	1.70E+03	1.70E+03	1.00E+02
*GW623	6.40E+04	1.70E+02	4.00E-01	0.00E+00	1.70E+02	0.00E+00
*GW624	4.90E+04	3.50E+02		3.20E+02	1.60E+02	9.00E+02
*GW625	9.30E+04	7.70E+01	1.20E+01	1.90E+03	1.30E+03	1.30E+03
*GW626	6.80E+04	8.00E+01	4.60E+02	1.60E+03	1.00E+02	5.00E+02
*GW627	9.90E+04	6.20E+01	3.00E+00	1.70E+03	2.70E+03	5.90E+02
*GW628	1.20E+05	9.80E+02	2.40E+03	4.80E+02	5.30E+02	2.60E+02
*GW629						
*GW630						
*GW631	8.20E+04	9.50E+01	2.10E+01	8.20E+02	1.00E+02	2.90E+02
*GW632	6.20E+04	7.50E+01	2.10E+01	3.00E+02	1.40E+03	1.40E+03
*GW633	1.10E+05	5.90E+03	3.00E+00	9.30E+02	4.90E+02	0.00E+00
*GW634	1.20E+05	4.50E+03	1.10E+03	7.00E+02	1.20E+03	9.00E+02
*GW635	9.70E+04		2.10E+01	6.70E+02	4.30E+02	7.00E+02
*GW636	1.10E+05		2.10E+01	1.70E+03	8.10E+02	2.50E+02
*GW637	6.60E+04					
*GW638	9.70E+04	9.50E+02	1.10E+03	1.40E+03	1.20E+03	1.70E+02
*GW639	7.00E+04		2.40E+03	2.80E+02	5.50E+02	1.40E+02
*GW640	8.90E+04		1.10E+01	9.00E+01	5.60E+02	1.80E+03
*GW641	6.00E+04			2.30E+02	5.60E+02	4.50E+02
*GW642	1.10E+05	1.50E+03	9.00E+00	1.60E+03	1.90E+03	3.80E+02
*GW643	9.30E+04		3.00E+00	3.90E+02	3.10E+02	3.80E+02
*GW644						
*GW645	5.00E+04		9.00E+02	5.00E+02	5.00E+02	7.10E+02
*GW646	1.40E+05	1.50E+03	2.40E+03	7.10E+02	4.80E+02	0.00E+00
*GW647	7.60E+04	6.40E+03	2.10E+01	9.10E+02	7.70E+02	2.50E+02

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*GW648
*GW649   6.00E+04            2.40E+03  1.80E+03  2.30E+03  9.60E+02
*GW650   8.90E+04            2.40E+03  2.30E+03  7.70E+02  9.20E+02
*GW651   6.40E+04            2.40E+03  1.30E+03  4.10E+02  3.60E+02
*GW652   6.20E+04            2.40E+03  3.00E+02  4.30E+02  2.50E+02
*GW653   7.80E+04  2.80E+04  1.50E+00  2.40E+03  0.00E+00  4.60E+02
*GW654   7.40E+04  2.00E+04  2.40E+03  2.40E+03  2.30E+02  2.40E+02
*GW655   6.40E+04            1.20E+02  4.10E+02  8.00E+01  0.00E+00
*GW656   7.60E+04            3.00E+00  3.40E+03  5.30E+02  0.00E+00
*GW657   6.60E+04            3.00E+00  2.20E+02  6.30E+02  1.50E+02
*GW658   5.40E+04            3.00E+00  4.40E+02  3.00E+01  1.80E+02
*GW659   1.80E+05  1.20E+04  1.40E+00  3.40E+02  7.20E+02  5.00E+02
*GW660   7.40E+04  6.00E+03  1.10E+03  1.10E+03  2.60E+02  1.10E+03
*GW661   7.20E+04  4.50E+04  4.60E+02  1.80E+02  1.00E+02  7.70E+02
*GW662   6.80E+04            1.10E+00  7.30E+02  1.40E+03  4.00E+02
*GW663   1.00E+05            7.00E+00  2.80E+02  2.80E+02  0.00E+00
*GW664   1.40E+05            2.10E+01  5.70E+02  2.00E+02  1.10E+03
*GW665   4.50E+04            2.40E+01  3.40E+02  9.20E+02  4.20E+02
*GW666   7.20E+04            2.40E+03  6.50E+02  0.00E+00  2.00E+02
*GW667   3.70E+04            2.40E+00  4.00E+02  4.00E+01  2.80E+02
*GW668   4.90E+04            4.00E+00  1.80E+02  2.80E+02  0.00E+00
*GW669   5.40E+04
*GW670   8.20E+04            3.00E+00  1.20E+02  5.00E+01  0.00E+00
*GW671   7.50E+04                      1.60E+03  7.30E+02  1.20E+03
*GW672   8.90E+04            2.00E+00  4.00E+02  0.00E+00  2.30E+02
*GW673   1.70E+05            2.10E+01  4.00E+02  5.80E+02  4.00E+02
*GW674   4.30E+04            2.00E+00  1.00E+02  2.30E+02  5.00E+01
*GW675   6.20E+04            1.10E+02  1.00E+00  0.00E+00  0.00E+00
*GW676   1.00E+05            2.10E+01  1.20E+03  2.00E+02  1.40E+03
*GW677   4.90E+04
*GW678   7.60E+04
*GW679   1.30E+05
*GW680   6.80E+04
*GW681   5.60E+04
*GW682   6.40E+04
*GW683   9.10E+04
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 FORM NUMBER = 100306  COOK INLET, MAY 1978 CRUISE

*GB601    0578 COOK INLET SEDIMENT ST 330
*GB602    0578 COOK INLET SEDIMENT ST 331
*GB603    0578 COOK INLET SEDIMENT ST 333
*GB604    0578 COOK INLET SEDIMENT ST 358
*GB605    0578 COOK INLET SEDIMENT ST 350
*GB606    0578 COOK INLET SEDIMENT ST 360
*GB607    0578 COOK INLET SEDIMENT ST 368
*GB608    0578 COOK INLET SEDIMENT ST 378
*GB609    0578 COOK INLET SEDIMENT ST 370
*GB610    0578 COOK INLET SEDIMENT ST 380
*GB611    0578 COOK INLET SEDIMENT ST 394
*GB612    0578 COOK INLET SEDIMENT ST 388
*GB613    0578 COOK INLET SEDIMENT ST 395
*GB614    0578 COOK INLET SEDIMENT ST 207
*GB616    0578 COOK INLET SEDIMENT ST 229
*GB625    0578 COOK INLET SEDIMENT ST 233
*GB627    0578 COOK INLET SEDIMENT ST 203
*GB628    0578 COOK INLET SEDIMENT ST 201
*GB629    COOK INLET SEDIMENT ST 204
*GB630    COOK INLET SEDIMENT ST 214
*GB631    0578 COOK INLET SEDIMENT ST 211
*GB632    0578 COOK INLET SEDIMENT ST 212
*GB633    0578 COOK INLET SEDIMENT ST V BEACH
*GB634    0578 COOK INLET SEDIMENT ST U BEACH
*GB636    0578 COOK INLET SEDIMENT ST 213
*GB644    0578 COOK INLET SEDIMENT ST 390
*GB649    0578 COOK INLET SEDIMENT ST AW BEACH
*GB650    0578 COOK INLET SEDIMENT ST M BEACH
*GB652    0578 COOK INLET SEDIMENT ST CB8
*GB653    0578 COOK INLET SEDIMENT ST CB1
*GB654    COOK INLET SEDIMENT ST CB2
*GB660    0578 COOK INLET SEDIMENT ST CB7 0930 HRS
*GB669    0578 COOK INLET SEDIMENT ST K BEACH
*GB677    0578 COOK INLET SEDIMENT ST CB9 1300 HRS
*GW601    0578 COOK INLET WATER ST 330
*GW602    0578 COOK INLET WATER ST 331
*GW603    0578 COOK INLET WATER ST 333
*GW604    0578 COOK INLET WATER ST 358
*GW605    0578 COOK INLET WATER ST 350
*GW606    0578 COOK INLET WATER ST 360
*GW607    0578 COOK INLET WATER ST 368
*GW608    0578 COOK INLET WATER ST 378
*GW609    0578 COOK INLET WATER ST 370
*GW610    0578 COOK INLET WATER ST 380
*GW611    0578 COOK INLET WATER ST 394
*GW612    0578 COOK INLET WATER ST 388
*GW613    0578 COOK INLET WATER ST 395
*GW614    0578 COOK INLET WATER ST 207
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*GW615	0578 COOK INLET WATER ST 390
*GW616	0578 COOK INLET WATER ST 229
*GW617	0578 COOK INLET WATER ST 249
*GW618	0578 COOK INLET WATER ST 246
*GW619	0578 COOK INLET WATER ST 266
*GW620	0578 COOK INLET WATER ST 265
*GW621	0578 COOK INLET WATER ST 255
*GW622	0578 COOK INLET WATER ST 242
*GW623	0578 COOK INLET WATER ST 245
*GW624	0578 COOK INLET WATER ST 247
*GW625	0578 COOK INLET WATER ST 233
*GW626	0578 COOK INLET WATER ST 248
*GW627	0578 COOK INLET WATER ST 203
*GW628	0578 COOK INLET WATER ST 201
*GW629	0578 COOK INLET WATER ST 204
*GW630	COOK INLET WATER ST 214
*GW631	0578 COOK INLET WATER ST 211
*GW632	0578 COOK INLET WATER ST 212
*GW633	0578 COOK INLET WATER ST V BEACH
*GW634	0578 COOK INLET WATER ST U BEACH
*GW635	0578 COOK INLET WATER ST 234
*GW636	0578 COOK INLET WATER ST 213
*GW637	0578 COOK INLET WATER ST 225
*GW638	0578 COOK INLET WATER ST 235
*GW639	0578 COOK INLET WATER ST 236
*GW640	0578 COOK INLET WATER ST 226
*GW641	0578 COOK INLET WATER ST 216
*GW642	0578 COOK INLET WATER ST 205
*GW643	0578 COOK INLET WATER ST 206
*GW644	COOK INLET WATEWATERT 390
*GW645	0578 COOK INLET WATER ST 398
*GW646	0578 COOK INLET WATER ST 105
*GW647	0578 COOK INLET WATER ST 106
*GW648	COOK INLET WATEWATERT AA BEACH
*GW649	0578 COOK INLET WATER ST AW BEACH
*GW650	0578 COOK INLET WATER ST M BEACH
*GW651	COOK INLET WATEWATERT J BEACH
*GW652	0578 COOK INLET WATER ST CB8
*GW653	0578 COOK INLET WATER ST CB1
*GW654	0578 COOK INLET WATER ST CB2
*GW655	0578 COOK INLET WATER ST CB3
*GW656	0578 COOK INLET WATER ST CB4
*GW657	0578 COOK INLET WATER ST CB5
*GW658	0578 COOK INLET WATER ST CB6
*GW659	0578 COOK INLET WATER ST CB7 0330 HRS
*GW660	0578 COOK INLET WATER ST CB7 0930 HRS
*GW661	0578 COOK INLET WATER ST CB7 1530 HRS
*GW662	0578 COOK INLET WATER ST AB BEACH
*GW663	0578 COOK INLET WATER ST CB7 2230
*GW664	0578 COOK INLET WATER ST CB7 0331
*GW665	0578 COOK INLET WATER ST CB7 1015
*GW666	0578 COOK INLET WATER ST CB7 1600
*GW667	0578 COOK INLET WATER ST CB7 2200
*GW668	0578 COOK INLET WATER ST CB7 0400
*GW669	0578 COOK INLET WATER ST K BEACH
*GW670	0578 COOK INLET WATER ST CB10 2100 HRS
*GW671	0578 COOK INLET WATER ST CB10 0230 HRS
*GW672	0578 COOK INLET WATER ST CB10 0830 HRS
*GW673	0578 COOK INLET WATER ST CB10 1515 HRS
*GW674	0578 COOK INLET WATER ST CB10 2101 HRS
*GW675	0578 COOK INLET WATER ST CB9 2100 HRS
*GW676	0578 COOK INLET WATER ST CB9 0320 HRS
*GW677	0578 COOK INLET WATER ST CB9 0930 HRS
*GW678	0578 COOK INLET WATER ST CB9 1530
*GW679	0578 COOK INLET WATER ST CB9 2100
*GW680	0578 COOK INLET WATER ST CB9 0300 HRS
*GW681	0578 COOK INLET WATER ST CB9 0900 HRS
*GW682	0578 COOK INLET WATER ST CB9 1500 HRS
*GW683	0578 COOK INLET WATER ST CB9 2100 HRS

%
FORM NUMBER = 100309 BEAUFORT, SEPT 1978 CRUISE

SAMPLE #	DEG LAT	MIN LAT	DEG LONG	MIN LONG	DEPTH	SALINITY	TEMP	PHOSPH	AMMONIA	NITRATE	NITRITE	TON	TOC
*BB609	70	36.0	147	38.7	21.0	21.29	-0.7						
*BB610	70	29.0	147	23.0	25.0	21.11	-0.3						
*BB611					5.0	25.50	-2.5						
*BB612	70	22.0	148	8.0	5.0	26.20	-2.5						
*BB613	70	21.9	146	51.7	22.0	22.47	-0.1						
*BB614	70	10.0	145	56.0	3.0	26.40	-2.5						
*BB615	70	13.0	147	17.0	1.0	25.50	4.0						
*BB616	70	14.5	145	51.5	23.0	23.65	0.4						
*BB617	70	10.5	145	55.0	1.0	26.30	1.5						
*BB618	70	5.0	145	29.0	2.0	24.70	1.5						
*BB619	69	59.0	144	54.0	2.5	27.04	3.5						
*BB620	70	13.0	143	20.0	25.0	26.28	2.6						
*BB621	70	9.0	143	21.0	3.0	29.30	2.0						
*BB622	69	59.0	142	16.0	18.0	28.51	4.1						
*BB623	69	56.0	142	19.0	5.0	28.10	2.0						
*BB624	69	57.0	142	20.0	1.0	27.50	2.0						
*BB626	69	47.0	141	26.0	21.0	29.00	3.4						
*BB627	69	41.0	141	16.0	3.0	25.99	6.0						
*BB628	69	49.0	141	51.0	5.0		5.0						
*BB629	70	8.0	142	49.0	19.0	28.11	3.0						
*BB630	70	26.0	143	42.0	54.0	25.60	4.4						
*BB631	70	28.0	143	42.0	60.0	26.25	4.2						
*BB632	70	13.0	143	54.0	30.0	27.35	2.9						
*BB633	70	9.0	144	47.5	20.0	25.13	2.3						
*BB634	70	19.3	146	30.3	22.0	26.08	-1.0						
*BB635	71	1.4	147	54.8	50.0	15.93	-0.2						
*BB636	70	46.0	148	34.0	24.0	10.35	0.1						
*BB637	70	35.8	148	4.0	22.0	16.94	-0.5						
*BB638	70	26.0	148	24.0									
*BB639	70	20.5	148	19.0									
*BB640	70	47.0	149	36.5	24.0	10.48	-0.5						
*BB641	71	14.3	149	33.5	67.0	27.26	1.4						
*BB642					27.0	25.66	-0.6						
*BB643	70	31.5	149	34.0	1.5		2.0						
*BB644	70	33.0	150	0.0	3.5		3.0						
*BB645	70	30.0	150	14.0	2.0		4.0						
*BB646	71	1.0	150	25.0	25.0	26.57	-1.0						

*BWI-9					1.0		
*BW609	70	36.0	147	38.7	1.0	21.29	-0.7
*BW610	70	29.0	147	23.0	1.0	21.11	-0.3
*BW611					1.0	25.50	-2.5
*BW612	70	22.0	148	8.0	1.0	26.20	-2.5
*BW613	70	21.9	146	51.7	1.0	22.47	-0.1
*BW614	70	10.0	145	56.0	1.0	26.40	-2.5
*BW615	70	13.0	147	17.0	1.0	25.50	4.0
*BW616	70	14.5	145	51.5	1.0	23.65	0.4
*BW617	70	10.5	145	55.0	1.0	26.30	1.5
*BW618	70	5.0	145	29.0	1.0	24.70	1.5
*BW619	69	59.0	144	54.0	1.0	27.04	3.5
*BW620	70	13.0	143	20.0	1.0	26.28	2.6
*BW621	70	9.0	143	21.0	1.0	29.30	2.0
*BW622	69	59.0	142	16.0	1.0	28.51	4.1
*BW623	69	56.0	142	19.0	1.0	28.10	2.0
*BW624	69	57.0	142	20.0	1.0	27.50	2.0
*BW626	69	47.0	141	26.0	1.0	29.00	3.4
*BW627	69	41.0	141	16.0	1.0	25.99	6.0
*BW628	69	49.0	141	51.0	1.0		5.0
*BW629	70	8.0	142	49.0	1.0	28.11	3.0
*BW630	70	26.0	143	42.0	1.0	25.60	4.4
*BW631	70	28.0	143	42.0	1.0	26.25	4.2
*BW632	70	15.0	143	48.0	1.0	27.35	2.9
*BW633	70	9.0	144	47.5	1.0	25.13	2.3
*BW634	70	19.3	146	30.3	1.0	26.08	-1.0
*BW635	71	1.4	147	54.8	1.0	15.93	-0.2
*BW636	70	46.0	148	34.0	1.0	10.35	0.1
*BW637	70	35.8	148	4.0	1.0	16.94	-0.5
*BW638	70	26.0	148	24.0			
*BW639	70	20.5	148	19.0			
*BW640	70	47.0	149	36.5	1.0	10.48	-0.5
*BW641	71	14.3	149	33.5	1.0	27.26	1.4
*BW642					1.0	25.66	-0.6
*BW643	70	31.5	149	34.0	1.0		2.0
*BW644	70	33.0	150	0.0	1.0		3.0
*BW645	70	30.0	150	14.0	1.0		4.0
*BW646	71	1.0	150	25.0	1.0	26.57	-1.0

%

FORM NUMBER = 100309   BEAUFORT, SEPT 1978 CRUISE

SAMPLE #	DIRECT COUNT	MARINE AGAR 4C	MPN HC UTIL	nC16 POTENTIAL NON-NUTR	PRISTANE POTENTIAL NON-NUTR	BENZANTHR POTENTIAL NON-NUTR	nC16 POTENTIAL NATURAL	PRISTANE POTENTIAL NATURAL	BENZANTHR POTENTIAL NATURAL
*BB609	1.60E+09	5.70E+05	3.00E+02	6.70E+01	0.00E+00	0.00E+00			
*BB610	1.30E+09	2.60E+05	2.80E+03	9.60E+02	0.00E+00	0.00E+00			
*BB611	5.40E+08	1.20E+07	2.80E+03	1.00E+02	7.40E+02	2.40E+02			
*BB612	1.90E+09	2.50E+07	1.10E+05	6.00E+01	8.00E+01	4.00E+02			
*BB613	1.30E+09	1.70E+06	1.10E+05	2.00E+01	3.00E+01	1.30E+02			
*BB614	2.00E+09	9.40E+05	2.10E+04	1.00E+02	4.00E+01	1.00E+01			
*BB615	1.00E+09	6.80E+06	2.80E+03						
*BB616	1.70E+09		4.00E+03	3.00E+02	8.70E+02	3.50E+01			
*BB617	2.40E+09	3.00E+07	4.00E+03	1.00E+04	3.00E+03	4.00E+01			
*BB618	2.00E+09		1.50E+04	0.00E+00	8.00E+01	0.00E+00			
*BB619	2.20E+09	1.40E+07	2.10E+04	8.20E+02	2.30E+03	1.70E+03			
*BB620	1.10E+09	1.30E+05	1.40E+01						
*BB621									
*BB622	2.80E+09	1.80E+07	4.00E+02	9.80E+02	7.20E+02	9.50E+02			
*BB623			7.00E+02						
*BB624	3.10E+09	1.80E+06	2.10E+05	1.80E+02	1.60E+03	2.50E+02			
*BB626	9.90E+08	3.40E+05	4.00E+03	1.20E+03	1.70E+02	5.00E+02			
*BB627	9.70E+08	1.90E+06	7.00E+02	1.70E+02	6.00E+02	2.50E+01			
*BB628									
*BB629									
*BB630	1.60E+09	6.40E+06	2.80E+03	2.50E+01	1.00E+02	2.50E+01			
*BB631	2.20E+09	2.20E+06	1.10E+03	1.70E+02	6.90E+02	1.00E+02			
*BB632	1.20E+09	7.80E+05	4.30E+03	9.20E+02	3.40E+03	2.50E+03			
*BB633	2.00E+09	3.30E+06	1.10E+03	5.00E+02	5.30E+02	4.30E+02			
*BB634	1.40E+09	1.50E+06	7.00E+03	1.50E+03	1.00E+01	1.00E+01			
*BB635	1.60E+09		2.40E+05	8.50E+01	0.00E+00	9.00E+01			
*BB636	1.00E+09	3.50E+05	2.10E+02	2.50E+01	7.00E+01	9.00E+01			
*BB637									
*BB638	1.80E+09	1.90E+06							
*BB639				2.50E+03	1.50E+03	4.00E+01			
*BB640	2.90E+09	3.70E+06	1.10E+03	1.30E+02	2.00E+02	3.50E+01			
*BB641	2.80E+08	1.60E+05	3.00E+03	6.00E+01	0.00E+00	4.00E+01			
*BB642	1.90E+09	2.80E+05	4.30E+03	2.00E+02	2.30E+02	6.80E+02			
*BB643	1.00E+09	2.30E+06	7.50E+03	7.50E+01	2.70E+02	3.00E+02			
*BB644	1.40E+09	3.70E+06	3.00E+03	1.10E+02	3.00E+01	5.50E+01			
*BB645	1.60E+09	2.90E+06	2.60E+03	8.50E+01	2.40E+02	4.00E+01			
*BB646									

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*BW1-Y   2.30E+05
*BW609   2.00E+05  6.20E+03  3.00E+00  5.00E+01  5.00E+01  0.00E+00
*BW610   3.90E+05  5.80E+03  2.80E+00  9.70E+02  4.70E+02  6.60E+01
*BW611             1.30E+04  1.40E+00
*BW612   4.50E+05  9.70E+03  1.20E+02  6.50E+02  1.00E+01  3.50E+02
*BW613   2.20E+05  1.80E+04  2.40E+03  1.00E+03  1.30E+02  1.20E+02
*BW614   5.80E+05            2.80E+00  0.00E+00  0.00E+00  1.10E+02
*BW615   7.80E+05  8.60E+03  3.00E+00
*BW616   6.10E+05            7.00E+00  1.00E+01  1.00E+02  1.00E+01
*BW617   8.70E+05  1.80E+03  4.60E+01  4.00E+03  0.00E+00  1.20E+02
*BW618   7.50E+05  1.30E+04  1.10E+01  3.10E+02  0.00E+00  4.10E+02
*BW619   4.80E+05  4.00E+02  2.80E+00  3.00E+01  1.20E+02  0.00E+00
*BW620   4.60E+05  4.00E+02  3.00E+00
*BW621   9.20E+05            1.20E+01  1.50E+03  7.60E+02  3.10E+02
*BW622   5.30E+05  1.40E+03  1.10E+00  1.00E+01  1.30E+03  1.30E+03
*BW623   5.60E+05  2.30E+03  2.40E+03  1.10E+03  6.20E+02  8.30E+02
*BW624   4.70E+05  7.30E+01  3.90E+01
*BW626   5.50E+05  8.60E+02  2.10E+02  2.60E+02  6.30E+02  6.20E+01
*BW627   1.00E+06  3.50E+03  2.40E+01  2.40E+02  1.10E+02  3.00E+01
*BW628   6.80E+05  9.00E+02  7.00E-01  4.00E+02  2.50E+02  0.00E+00
*BW629   5.90E+05  8.30E+01
*BW630   6.60E+05  5.40E+02  3.00E+01  4.00E+01  0.00E+00  1.20E+02
*BW631   7.60E+05  1.40E+03  2.80E+01  1.50E+02  2.50E+02  1.60E+01
*BW632   8.00E+05  1.90E+03  4.60E+01  9.50E+02  1.30E+02  3.00E+01
*BW633   6.60E+05  1.60E+03  1.10E+01  1.30E+02  6.00E+02  2.50E+01
*BW634   1.00E+06  2.10E+03  1.10E+01  1.20E+02  5.10E+01  3.50E+01
*BW635   5.50E+05  1.20E+03  2.80E+01  0.00E+00  6.50E+01  0.00E+00
*BW636   7.30E+05  3.90E+03  2.10E+01  2.00E+02  1.00E+01  0.00E+00
*BW637   8.00E+05  8.60E+03  3.00E+00  1.10E+02  2.30E+02  8.50E+01
*BW638   1.10E+06  3.00E+03  3.00E+00  5.00E+01  6.50E+01  1.50E+02
*BW639   5.40E+05  9.70E+01  2.10E+01  5.00E+01  1.00E+02  2.40E+02
*BW640   4.90E+05  6.00E+03  3.00E+00  1.20E+02  2.00E+02  3.50E+01
*BW641   5.90E+05  1.00E+03  3.00E+00  3.00E+01  1.10E+02  5.50E+01
*BW642   5.70E+05  1.90E+03  2.10E+02  2.00E+02  2.30E+02  6.80E+02
*BW643   9.70E+05  1.30E+03  1.10E+01  5.50E+01  3.00E+02  5.00E+01
*BW644   1.10E+06  3.70E+02  1.40E+01  9.00E+01  1.10E+02  1.00E+02
*BW645   1.20E+06  1.00E+02  2.00E+01  0.00E+00  1.00E+01  1.00E+01
*BW646   8.50E+05  2.80E+02  1.10E+01
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%
 FORM NUMBER 00309  03/79  17:17

*BB609    0978 BEAUFORT SEA SEDIMENT ST.14
*BB610    0978 BEAUFORT SEA SEDIMENT ST.16
*BB611    0978 BEAUFORT SEA SEDIMENT ST.
*BB612    0978 BEAUFORT SEA SEDIMENT ST.
*BB613    0978 BEAUFORT SEA SEDIMENT ST.17
*BB614    0978 BEAUFORT SEA SEDIMENT ST.
*BB615    0978 BEAUFORT SEA SEDIMENT ST.
*BB616    0978 BEAUFORT SEA SEDIMENT ST.18
*BB617    0978 BEAUFORT SEA SEDIMENT ST.
*BB618    0978 BEAUFORT SEA SEDIMENT ST.
*BB619    0978 BEAUFORT SEA SEDIMENT ST.
*BB620    0978 BEAUFORT SEA SEDIMENT ST.19
*BB621    0978 BEAUFORT SEA SEDIMENT ST.
*BB622    0978 BEAUFORT SEA SEDIMENT ST.20
*BB623    0978 BEAUFORT SEA SEDIMENT ST.
*BB624    0978 BEAUFORT SEA SEDIMENT ST.
*BB626    0978 BEAUFORT SEA SEDIMENT ST.22
*BB627    0978 BEAUFORT SEA SEDIMENT ST.
*BB628    0978 BEAUFORT SEA SEDIMENT ST.
*BB629    0978 BEAUFORT SEA SEDIMENT ST.
*BB630    0978 BEAUFORT SEA SEDIMENT ST.23
*BB631    0978 BEAUFORT SEA SEDIMENT ST.24
*BB632    0978 BEAUFORT SEA SEDIMENT ST.25
*BB633    0978 BEAUFORT SEA SEDIMENT ST.26
*BB634    0978 BEAUFORT SEA SEDIMENT ST.27
*BB635    0978 BEAUFORT SEA SEDIMENT ST.28
*BB636    0978 BEAUFORT SEA SEDIMENT ST.30
*BB637    0978 BEAUFORT SEA SEDIMENT ST.31
*BB638    0978 BEAUFORT SEA SEDIMENT ST.
*BB639    0978 BEAUFORT SEA SEDIMENT ST.
*BB640    0978 BEAUFORT SEA SEDIMENT ST.32
*BB641    0978 BEAUFORT SEA SEDIMENT ST.33
*BB642    0978 BEAUFORT SEA SEDIMENT ST.34
*BB643    0978 BEAUFORT SEA SEDIMENT ST.
*BB644    0978 BEAUFORT SEA SEDIMENT ST.
*BB645    0978 BEAUFORT SEA SEDIMENT ST.
*BB646    0978 BEAUFORT SEA SEDIMENT ST.35
*BW608    0978 BEAUFORT SEA WATER ST.
*BW609    0978 BEAUFORT SEA WATER ST.14
*BW610    0978 BEAUFORT SEA WATER ST.16

*BW611    0978 BEAUFORT SEA WATER ST.
*BW612    0978 BEAUFORT SEA WATER ST.
*BW613    0978 BEAUFORT SEA WATER ST.17
*BW614    0978 BEAUFORT SEA WATER ST.
*BW615    0978 BEAUFORT SEA WATER ST.
*BW616    0978 BEAUFORT SEA WATER ST.18
*BW617    0978 BEAUFORT SEA WATER ST.
*BW618    0978 BEAUFORT SEA WATER ST.
*BW619    0978 BEAUFORT SEA WATER ST.
*BW620    0978 BEAUFORT SEA WATER ST.19
*BW621    0978 BEAUFORT SEA WATER ST.
*BW622    0978 BEAUFORT SEA WATER ST.20
*BW623    0978 BEAUFORT SEA WATER ST.
*BW624    0978 BEAUFORT SEA WATER ST.
*BW626    0978 BEAUFORT SEA WATER ST.22
*BW627    0978 BEAUFORT SEA WATER ST.
*BW628    0978 BEAUFORT SEA WATER ST.
*BW629    0978 BEAUFORT SEA WATER ST.
*BW630    0978 BEAUFORT SEA WATER ST.23
*BW631    0978 BEAUFORT SEA WATER ST.24
*BW632    0978 BEAUFORT SEA WATER ST.25
*BW633    0978 BEAUFORT SEA WATER ST.26
*BW634    0978 BEAUFORT SEA WATER ST.27
*BW635    0978 BEAUFORT SEA WATER ST.28
*BW636    0978 BEAUFORT SEA WATER ST.30
*BW637    0978 BEAUFORT SEA WATER ST.31
*BW638    0978 BEAUFORT SEA WATER ST.
*BW639    0978 BEAUFORT SEA WATER ST.
*BW640    0978 BEAUFORT SEA WATER ST.32
*BW641    0978 BEAUFORT SEA WATER ST.33
*BW642    0978 BEAUFORT SEA WATER ST.34
*BW643    0978 BEAUFORT SEA WATER ST.
*BW644    0978 BEAUFORT SEA WATER ST.
*BW645    0978 BEAUFORT SEA WATER ST.
*BW646    0978 BEAUFORT SEA WATER ST.35
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TABLE 3. Production of nitrous and nitric oxide from Beaufort Sea sediments with and without added carbon sources.

Station	N_2O PRODUCED nmoles/g dry wt./d		NO PRODUCED nmoles/g dry wt./d	
	with NO_3^-	with NO_3^- + organics	with NO_3^-	with NO_3^- + organics
645	20	60	0	0
644	50	110	0	0
643	150	180	240	1390
640	320	1620	0	1880
642	0	30	0	1430
641	0	0	0	1360
636	220	150	200	1140
635	140	120	150	790
612	190	150	0	0
609	140	260	0	0
610	40	80	0	0
613	10	60	0	0
634	100	160	180	950
616	60	40	0	0
617	150	430	0	0
618	190	510	0	0
619	100	80	0	0
630	180	260	150	1370
631	180	280	280	1470
622	90	200	0	0
624	10	40	0	0
626	30	40	0	0
627	120	210	0	0

TABLE 4

TAXONOMIC FILES DESCRIPTION
MARCH 30, 1979

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185     BEAUFORT 4 C ISOLATES  04/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0185
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0185
        WLH1EJK.185.REPORT                  -  5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.185.SVALUE       -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.185.RERUN                -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
186     BEAUFORT 20C ISOLATES  04/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0186
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0186
        WLH1EJK.186.REPORT                  -  5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.186.SVALUE       -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.186.RERUN                -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
187     BEAUFORT 4 C ISOLATES  08/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0187
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0187
        WLH1EJK.187.REPORT                  -  5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.187.SVALUE       -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.187.RERUN                -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
190     GULF 4 C ISOLATES  10/75 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0190
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0190
        WLH1EJK.REPORT.190.5SEQ             -  5 SEQUENCE QUERY REPORT
        WLH1EJK.SJ.MATRIX.190.5SEQ          -  DATA MATRIX IN CLUSTER ANALYSIS SJ ORDER
        WLH1EJK.NT.RESULTS.190.UNCOMPRESSED -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.190.RERUN                -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
191     GULF 20 C ISOLATES  09/75 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0191
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0191
        WLH1EJK.191.REPORT.5SEQ             -  5 SEQUENCE QUERY REPORT
        WLH1EJK.SVALUE.191.5SEQ             -  DATA MATRIX IN CLUSTER ANALYSIS SJ ORDER
        WLH1EJK.S.VALUE.191.UCOMPRESSED     -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.191.5SEQ.RERUN           -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
192     BEAUFORT 4 C ISOLATES  09/75 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0192
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0192
        WLH1EJK.192.REPORT.5SEQ             -  5 SEQUENCE QUERY REPORT
        WLH1EJK.SVAL.192.5SEQ               -  DATA MATRIX IN CLUSTER ANALYSIS SJ ORDER
        WLH1EJK.S.VALUE.192.UCOMPRESSED     -  CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.192.5SEQ.RERUN           -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
------------------------------------------------------------------------------------------
212     GULF 5 C ISOLATES  03/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0212
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0212
        WLH1EJK.212.REPORT                  -  5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.SED212           -  CLUSTER ANALYSIS ON  SEDIMENT ISOLATES
        WLH1EJK.NT.RESULTS.WATER212         -  CLUSTER ANALYSIS ON  WATER ISOLATES
        WLH1EJK.FF.SED212.RERUN             -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
        WLH1EJK.FF.WATER212.RERUN           -  FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
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213     GULF 20 C ISOLATES  03/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0213
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0213
        WLH1EJK.213.REPORT                         - 5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.SED213                  - CLUSTER ANALYSIS ON  SEDIMENT ISOLATES
        WLH1EJK.NT.RESULTS.WATER213                - CLUSTER ANALYSIS ON  WATER ISOLATES
        WLH1EJK.FF.SED213.RERUN                    - FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
        WLH1EJK.FF.WATER212.RERUN                  - FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
---------------------------------------------------------------------------------------------------------
238     TCBS   09/75 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0238
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0238
        WLH1EJK.238.REPORT                         - 5 SEQUENCE QUERY REPORT
         WLH1EJK.NT.RESULTS.238.SVALUE              - CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.238.RERUN                       - FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
---------------------------------------------------------------------------------------------------------
239     AMPHIPODS    04/76 CRUISE
        RKC CARD IMAGE  FILE : HAE1MIK.F0239
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0239
        WLH1EJK.239.REPORT                         - 5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.239                     - CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.239.RERUN                       - FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
-----------------------------------------------------------------------------------------------
240     BEAUFORT  5C 08/78 CRUISE
        RKC CARD IMAGE FILE :  HAE1MIK.F0240
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0240
---------------------------------------------------------------------------------------------------------
245     COOK INLET 4 C ISOLATES 10/76
        RKC CARD IMAGE  FILE : HAE1MIK.F0245
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0245
        WLH1EJK.245.REPORT.NO.TCBS                 - 5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.RESULTS.245                     - CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.245.RERUN                       - FEATURE FREQUENCY OUTPUT WITH CURRENT FORMAT
---------------------------------------------------------------------------------------------------------
250     HYDROCARBON AUG & SEP 1976 CRUISE
        5 C AND 10 C , BARROW CHUKCHI SOURCE
        RKC CARD IMAGE  FILE : HAE1MIK.F0250
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0250
        WLH1EJK.250.REPORT                         - 2 SEQUENCE HYDROCARBON QUERY REPORT
        WLH1EJK.NT.RESULTS.250.WITH.NO.HYDROCARBONS -CLUSTER ANALYSIS OUTPUT
        WLH1EJK.NT.RESULTS.250                     - CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.250                             - FEATURE FREQUENCY OUTPUT NOT CURRENT FORMAT
        WLH1EJK.FF.250.BY.STRAIN.CLUSTER           - FEATURE FREQ RUN ON 9 GROUPS EXTRACTED
                                                     BY SELECTED STRAIN DESIGNATION
----------------------------------------------------------------------------------------------  ----
251     HYDROCARBON 10/76 & 08/75 CRUISE, ERDAPLOT, ETC
        RKC CARD IMAGE  FILE : HAE1MIK.F0251
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0251
        WLH1EJK.251.REPORT                         - 2 SEQUENCE HYDROCARBON QUERY REPORT
        WLH1EJK.NT.RESULTS.250.NO.HYDROCARBONS- CLUSTER ANALYSIS OUTPUT
        WLH1EJK.NT.RESULTS.251                     - CLUSTER ANALYSIS OUTPUT
        WLH1EJK.FF.251.BY.STRAIN.CLUSTER           - FEATURE FREQUENCY OUTPUT NOT CURRENT FORMAT,
                                                     RUN ON 8 GROUPS EXTRACTED BY SELECTED STRAIN DESIGNATIONS.
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252    HYDROCARBON BEAUFORT, 03/76, 08/76, 09/76,10/76 CRUISE(S)
       RKC CARD IMAGE  FILE : HAE1MIK.F0252
       QUERY-SEARCHABLE FILE: WLH1EJK.Q0252
       WLH1EJK.252.REPORT                  - 2 SEQUENCE HYDROCARBON QUERY REPORT
       WLH1EJK.NT.RESULTS.252.BEAU.SED     - CLUSTER ANALYSIS OUTPUT EXTRACTED ON SOURCE=BEAU AND SEDIMENT
        WLH1EJK.NT.RESULTS.252.BEAU.WATER   - CLUSTER ANALYSIS OUTPUT EXTRACTED ON SOURCE=BEAU AND WATER
       WLH1EJK.NT.RESULTS.252.CO2          - CLUSTER ANALYSIS OUTPUT EXTRACTED ON SOURCE=CO2
       WLH1EJK.NT.RESULTS.252.NOCO2        - CLUSTER ANALYSIS OUTPUT EXTRACTED ON NOT SOURCE=CO2
       WLH1EJK.NT.RESULTS.252GULF          - CLUSTER ANALYSIS OUTPUT EXTRACTED ON SOURCE=GULF
       WLH1EJK.FF.252.BEAU.SED             - FEATURE FREQUENCY NOT CURRENT FORMAT
       WLH1EJK.FF.252.BEAU.WATER           - FEATURE FREQUENCY NOT CURRENT FORMAT
       WLH1EJK.FF.252.CO2                  - FEATURE FREQUENCY NOT CURRENT FORMAT
       WLH1EJK.FF.NOCO2                    - FEATURE FREQUENCY NOT CURRENT FORMAT
       WLH1EJK.FF.252.GULF                 - FEATURE FREQUENCY NOT CURRENT FORMAT
       WLH1EJK.FF.252.BY.SOURCE            - FEATURE FREQUENCY OUTPUT NOT CURRENT FORMAT
----------------------------------------------------------------------------------------
253    CRAB DATA, 01/76, 03/76 TANNER CRAB CHINIAK BAY, 10/75 DUNGENESS CRAB CHINIAK BAY, ETC.
       RKC CARD IMAGE  FILE : HAE1MIK.F0253
       QUERY-SEARCHABLE FILE: WLH1EJK.Q0253
------------------------------------------------------------------------------------------
256    COOK INLET 4 C 04/77 CRUISE
       RKC CARD IMAGE  FILE : HAE1MIK.F0256
       QUERY-SEARCHABLE FILE: WLH1EJK.Q0256
       WLH1EJK.256.REPORT                  -  5 SEQUENCE QUERY REPORT
       WLH1EJK.NT.RESULTS.256              -  CLUSTER ANALYSIS OUTPUT
----------------------------------------------------------------------------------------
257    COOK INLET  20 C 04/77   TCBS CULTURES
       RKC CARD IMAGE  FILE : HAE1MIK.F0257
       QUERY-SEARCHABLE FILE: WLH1EJK.Q0257
       WLH1EJK.257.REPORT                  -  5 SEQUENCE QUERY REPORT
       WLH1EJK.NT.RESULTS.257              -  CLUSTER ANALYSIS OUTPUT
------------------------------------------------------------------------------------------
258    COOK INLET 5 C 11/77 CRUISE
       RKC CARD IMAGE FILE  : HAE1MIK.F0258
       QUERY-SEARCHABLE FILE: WLH1EJK.Q0258
       WLH1EJK.REPORT.258.FEATURE LIST    -  FEATURE LIST/COLUMNS FOR REPORT.258
       WLH1EJK.REPORT.258                 -  5 SEQUENCE QUERY REPORT
       WLH1EJK.REPORT.258.GP1             -  AS ABOVE, EXTRACTED ON SOURCE=MA AND (ST265 OR ST235 OR ST354 OR ST394)
       WLH1EJK.REPORT.258.GP2             -  AS ABOVE, EXTRACTED ON SOURCE=OA OR BA
       WLH1EJK.REPORT.258.GP3             -  AS ABOVE, EXTRACTED ON SOURCE=MA AND NOT(ST265 OR ST235 OR ST354 OR ST394)
       WLH1EJK.NT.RESULTS.258.GP1         -  CLUSTER ANALYSIS OUTPUT, AS EXTRACTED ABOVE
       WLH1EJK.NT.RESULTS.258.GP2         -  CLUSTER ANALYSIS OUTPUT, EXTRACTED AS ABOVE
       WLH1EJK.NT.RESULTS.258.GP3         -  CLUSTER ANALYSIS OUTPUT, EXTRACTED AS ABOVE
       WLH1EJK.GPSTAT.258.GP1             -  INTRA GROUP STATISTICS, EXTRACTED AS ABOVE
       WLH1EJK.GPSTAT.258.GP2             -  INTRA GROUP STATISTICS, EXTRACTED AS ABOVE
       WLH1EJK.GPSTAT.258.GP3             -  INTRA GROUP STATISTICS, EXTRACTED AS ABOVE
       WLH1EJK.FF.258                     -  FEATURE FREQUENCE ON TOTAL SET CURRENT FORMAT
       WLH1EJK.258.GP1                    -  FEATURE FREQUENCY DESIGNATED CLUSTERS, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.258.GP2                    -  FEATURE FREQUENCY DESIGNATED CLUSTERS, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.258.GP3                    -  FEATURE FREQUENCY DESIGNATED CLUSTERS, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.GP1         -  FEATURE FREQUENCY TOTAL SET, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.GP2         -  FEATURE FREQUENCY TOTAL SET, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.GP3         -  FEATURE FREQUENCY TOTAL SET, EXTRACTED AS ABOVE, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.MARINE AGAR -  FEATURE FREQUENCY TOTAL SET EXTRACTED ON MARINE AGAR, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.MARINE OIL  -  FEATURE FREQUENCY TOTAL SET EXTRACTED ON MARINE OIL, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.SED.ISOLATES -  FEATURE FREQUENCY TOTAL SET EXTRACTED ON SEDIMENT ISOLATES, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.WATER.ISOLATES- FEATURE FREQUENCY TOTAL SET EXTRACTED ON WATER ISOLATES , CURRENT FORMAT
       WLH1EJK.EDITMAT.258.FEAT.TOTALS.MARINE.AGAR - FEATURE FREQUENCY TOTAL SET EXTRACTED ON MARINE AGAR,CURRENT FORMAT
       WLH1EJK.EDITMAT.258TAB.OIL.AGAR     -  FEATURE FREQUENCY TOTAL SET EXTRACTED ON OIL AGAR, CURRENT FORMAT
       WLH1EJK.EDITMAT.TAB258.BUSHNELL.HAAS -  FEATURE FREQUENCY TOTAL SET EXTRACTED ON BUSHNELL.HAAS, CURRENT FORMAT
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308     COOK INLET 5 C 04/78 CRUISE, ELSON 01/78 CRUISE
        RKC CARD IMAGE FILE  : HAE1MIK.F0308
        QUERY-SEARCHABLE FILE: WLH1EJK.Q0308
        WLH1EJK.REPORT.308                   -  5 SEQUENCE QUERY REPORT
        WLH1EJK.NT.REPORT.308.1              -  5 SEQUENCE QUERY REPORT FOR RUN ONE STRAINS
        WLH1EJK.NT.REPORT.308.2              -  5 SEQUENCE QUERY REPORT FOR RUN TWO STRAINS
        WLH1EJK.NT.REPORT.308.3              -  5 SEQUENCE QUERY REPORT FOR RUN THREE STRAINS
        WLH1EJK.NT.REPORT.308.4              -  5 SEQUENCE QUERY REPORT FOR RUN FOUR STRAINS
        WLH1EJK.NT.REPORT.308.5              -  5 SEQUENCE QUERY REPORT FOR RUN FIVE STRAINS
        WLH1EJK.NT.REPORT.308.6              -  5 SEQUENCE QUERY REPORT FOR RUN SIX STRAINS
        WLH1EJK.NT.RESULTS.100308.RUN.ONE   -  CLUSTER ANALYSIS ON STRAINS DESIGNATED AS RUN ONE
        WLH1EJK.NT.RESULTS.100308.RUN.TWO   -  CLUSTER ANALYSIS ON STRAINS DESIGNATED AS RUN TWO
        WLH1EJK.NT.RESULTS.100308.RUN.FIVE  -  CLUSTER ANALYSIS ON STRAINS DESIGNATED AS RUN FIVE
        WLH1EJK.NT.RESULTS.100308.RUN.SIX   -  CLUSTER ANALYSIS ON STRAINS DESIGNATED AS RUN SIX
        WLH1EJK.EDITMAT.308.RANKED.STRAIN.FEATURES  - FEATURE TOTALS WITH STRAINS RANKED FOR INPUT SEQUENCE TO NT RUN
------------------------------------------------------------------------------------------------------------------
MANIPULATED AND CONCATENATED FILES
=================================
1, WLH1EJK.NT.RESULTS.COMPOSITE
       CLUSTER ANALYSIS ON SELECTED STRAINS OF FILES 185, 186, 187, 191 AND 192.
2, ORANGE PIGMENT ORGANISMS
        WLH1EJK.NT.RESULTS.ORANGE    CLUSTER ANALYSIS OUTPUT
        WLH1EJK.SVALUE.MATRIX.NT.RESULTS.ORANGE    DATA MATRIX IN SJ ORDER OF CLUSTER ANALYSIS
        WLH1EJK.ORANGE.REPORT      5 SEQUENCE QUERY REPORT
3, HYDROCARBON UTILIZERS 250, 251, 252
                                          (POSITIVE FOR ANY ONE HYDROCARBON UTILIZATION FEATURE)
;WLH1EJK. NT.RESULTS.250.251.252.LOW   CLUSTER ANALYSIS OUTPUT(15% THRU 57% RANKING OF FEATURES AS INPUT STRAIN SEQUENCE TO NT RUN)
 WLH1EJK.NT.RESULTS.250.251.252.TOP  (56% THRU 70% RANKING OF FEATURES AS INPUT STRAIN SEQUENCE TO NT RUN)
  WLH1EJK.FF.TOP ------------------------;
  WLH1EJK.FF.LOW                         ;  FEATURE FREQUENCY
  WLH1EJK.FF.250.251.252.ALL.STRAINS     ;  NOT CURRENT FORMAT
  WLH1EJK.FF.HYDROCARBON.UTILIZERS.251----;
3, CLUSTER ANALYSIS ON CLUSTERS OF SED212 SED213 WATER212 WATER 213
        WLH1EJK.NT.RESULTS.CLUSTERS.212.213.SVALUE
4, REPORT.ALL.ENUMERATION.FILES  -  REPORT OF 188, 236, 237, 254, 259, 306, 307, 309
                                    UTILIZING REPORT SPECIFICATIONS FOR ENUMERATION FILES.
```

TABLE 5. Diversity of surface water bacterial populations of the Beaufort Sea exposed to Prudhoe Bay crude oil.

Exposure	Diversity
control	3.8
oil 2 wks	3.9
oil 4 wks	2.2
oil 6 wks	2.0

TABLE 6. Quantitation of selected major components based on gas chromatography. Identification based on mass spectrometry and retention time.

Compound	Concentration (μg/g sed dry wt.) 2 Days	7 Days	14 Days	21 Days	28 Days
decane	5.4	1.5	13.5	21.1	5.8
undecane	7.7	3.3	7.3	11.7	7.7
naphthalene	0.5	0.2	0.8	2.5	0.7
dodecane	8.1	2.6	6.9	10.1	6.7
methyl naphthalene	0.7	-	0.8	0.9	0.7
methyl naphthalene	0.8	-	-	1.3	0.8
tridecane	10.2	2.2	7.4	18.4	7.8
dimethyl naphthalene	0.5	-	0.3	1.0	0.9
tetradecane	8.0	3.0	6.7	22.7	5.7
pentadecane	7.0	2.9	4.6	14.7	4.3
hexadecane	5.7	1.8	3.7	11.8	3.5
heptadecane	4.5	1.5	3.3	11.2	2.9
pristane	2.9	0.7	2.1	8.7	1.0
octadecane	3.6	0.8	2.6	9.4	2.1
phytane	1.5	0.3	1.1	5.0	0.9
nonadecane	2.3	0.6	2.2	8.6	1.8
eicosane	3.8	1.5	1.9	6.1	1.6
uncosane	3.2	1.0	1.5	4.5	1.2
docosane	1.7	0.5	1.2	3.4	1.2
tricosane	1.6	0.9	1.5	2.3	0.9
$\frac{\text{pristane}}{\text{heptadecane}}$ ratio	0.6	0.5	0.6	0.8	0.7
$\frac{\text{phytane}}{\text{octadecane}}$ ratio	0.4	0.4	0.4	0.5	0.4

TABLE 7. Quantitation and identification of selected light cyclic compounds based on mass apectrometry.

Compound	Concentration (ng/g sed dry wt.) 2 Days	7 Days	14 Days	21 Days	28 Days
ethyl benzene	336	295	-	3589	450
dimethyl benzene	673	477	-	2241	335
propyl benzene	2791	434	63	1534	255
o + m ethyl toluene	3990	517	53	2383	321
p ethyl toluene	1959	1105	68	2505	378
trimethyl benzene	2692	513	181	2340	326
n butyl benzene	3384	435	139	1606	253
t butyl benzene	2688	360	226	1623	256
propyl toluene	3108	366	-	1540	272
tetramethyl benzene	3175	382	-	1646	275
pentyl benzene	2237	412	214	1431	220
butyl toluene	2016	290	126	1338	258
ethyl cyclohexane	8212	-	-	2802	311
propyl cyclohexane	5266	-	53	-	334
butyl cyclohexane	2229	68	89	1844	-
pentyl cyclohexane	1897	380	167	1084	172
dicyclohexane	520	105	296	-	-

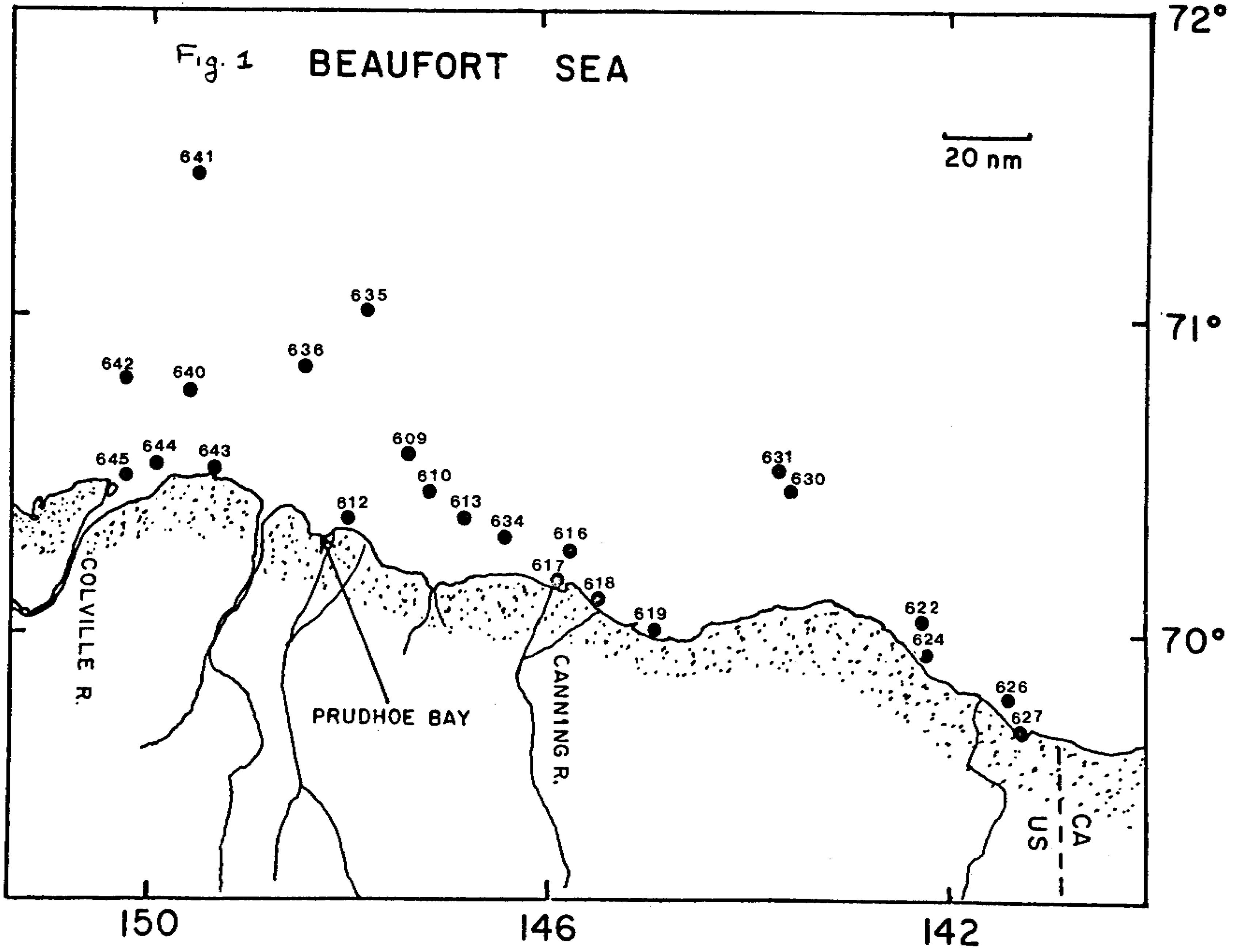

Fig. 1

BEAUFORT SEA
20 nm
72°
71°
70°
150
146
142
641
635
636
642
640
645
644
643
609
610
612
613
634
616
617
618
619
631
630
622
624
626
627
COLVILLE R.
PRUDHOE BAY
CANNING R.
US
CA

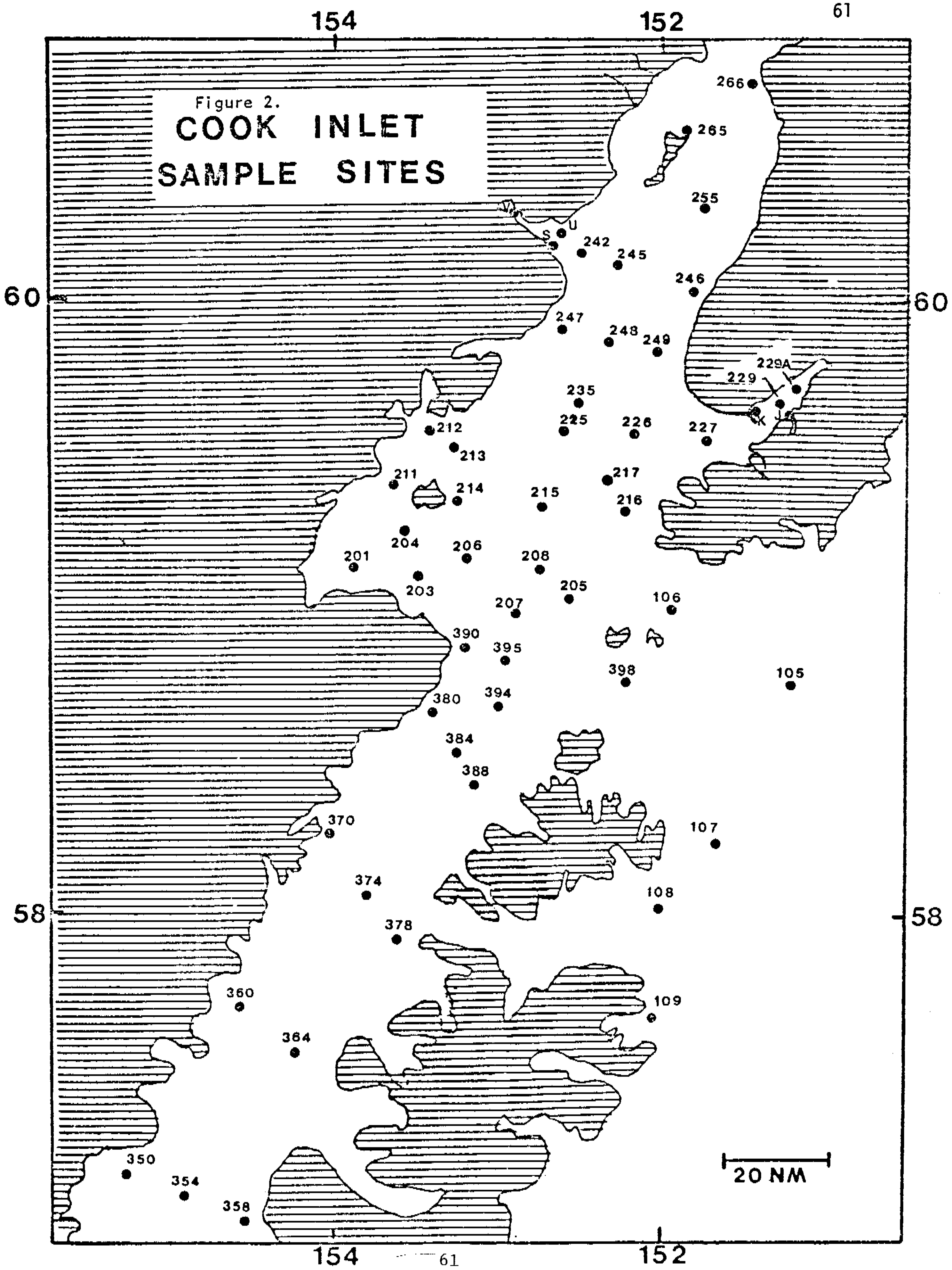

Figure 2.
COOK INLET SAMPLE SITES

Fourth Annual Report

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Study of Microbial Activity and Crude Oil-Microbial Interactions in the Waters and Sediments of Cook Inlet and the Beaufort Sea

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March 31, 1979

TABLE OF CONTENTS

I. Summary of objectives, conclusions, and implications with respect to OCS oil and gas development.

A. Objectives

In general terms, our main objectives during the last year were to obtain information about marine microbial function in the Beaufort Sea and Cook Inlet, Alaska and to obtain information about the effects of crude oil on specific processes. The microbial functions, that we were primarily concerned with, were relative microbial activity and respiration (mineralization) in surface waters and sediments and rates of nitrogen fixation in the sediments. Employing both field and laboratory observations, we were to estimate the effects of crude oil on these processes.

In addition, we were to extend our effects studies to include long-term crude oil affects on a number of microbial processes which, up to this time, had not been measured. In order to achieve this objective, we were to perfect the appropriate methodologies and to establish a field laboratory at which these observations were to be made.

B. Conclusions and Implications

1. We have further substantiated the fact that the presence of crude oil decreases the rate at which natural marine microbial populations take up and mineralize (respire) nutrients. Crude oil thus acts as an environmental stress on this segment of the biosphere. This conclusion has been substantiated by recent observations made by Dr. Altas (RU #30).

2. We have also observed that crude oil significantly reduces both protozoan growth rates and the rates of bacterial ingestion (cropping rate). This means that the presence of crude oil could greatly reduce the rate by which nutrients are passed through the detrital food chain from sediments to higher trophic levels via the transformation of dissolved organic matter into bacterial cells which, in turn, are eaten by protozoan. The protozoans are then eaten by higher forms.

3. Corexit 9527 is a dispersant which is currently stockpiled in Alaska to be used to disperse crude oil slicks in the Cook Inlet. We have tested the effect of Corexit 9527 by itself and in combination with crude oil on heterotrophic activity (nutrient uptake and respiration (mineralization) rates) in natural microbial populations and the effects on protozoan growth rates and cropping rates. Corexit by itself at a concentration of 15 ppm has about the same adverse effect on heterotrophic activity as does crude oil. At higher concentrations, the effects are more severe. The same effect was observed in both protozoan growth rates and in their feeding rates when cropping bacteria. A combination of crude oil and Corexit greatly reduces all of these rates. In many cases, the observed rates under these conditions were only 10% of that found in untreated controls.

4. We are now starting to see significant changes in microbial populations that have been exposed to crude oil for three months or longer. The total concentration of adenylates in Beaufort Sea sediments treated with crude oil is only 1-10% of that found in non-oiled controls. Since the total concentration of adenylates directly reflect the total biomass in sediments, it would appear that certain organisms that would normally be present in these sediments are not present in trays containing oiled sediment. Either they were killed by the oil and/or they tend to avoid the oiled sediments. The absence of these organisms could signify that the food web is interupted in oiled sediments.

5. We have also observed that the degree to which crude oil affects nutrient uptake and respiration in seawater microbial populations varies with geographical area. Waters which are most probably impacted by chronic crude oil or petroleum input are those in which the effect of crude oil on substrate uptake is minimal. It is thus likely that the degree to which crude oil effects uptake in natural microbial populations may relfect the degree to which those populations had previously been exposed to crude oil or petroleum products.

6. In summary, crude oil appears to have adverse effects on natural microbial populations on both an acute and chronic basis. More research needs to be done to determine which of many possible long term effects will have the greatest potential effect on the ecosystem. To date, one of the important long term effects that has been noted is the reduction of total adenylate concentrations in marine sediments. The greatest impact of crude oil in marine sediments may come in the form of altered microbial and function that will, in turn, alter the physical and chemical properties of the sediment. These changes along with direct effects on the benthic community may greatly alter the basic components of the food web. It should also be kept in mind that the dispersant Corexit 9527, seems to intensify the impact of crude oil on microbial processes.

II. Introduction

A. General nature and scope of the study

Our main objective has been to study the natural levels of relative microbial heterotrophic activity, respiration percentages and nitrogen fixation rates in natural microbial populations found in the Beaufort Sea and Cook Inlet under contrasting seasonal conditions. Our other objectives have been to evaluate the effects of crude oil on microbial activity and nitrogen fixation rates. These studies have been interpreted in light of other data that has also been collected on the same samples. These data include inorganic nutrient data, sample temperature, salinity and location; as well as direct counts, plate counts and crude oil degradation potential data collected by Dr. Atlas, (RU #30).

B. Specific Objectives

1. Cook Inlet

a. To continue studies of relative microbial activity and respiration (mineralization) of natural microbial populations found in water and sediment samples. These studies were to fill some of the data gaps which still exist from past studies in this region. These data may also be used in the future to estimate the degree of perturbation caused by chronic crude oil input.

b. To characterize water masses using microbial measurements which might be used to follow the movement of water masses within the Inlet.

c. To evaluate the extent of nitrogen fixation in the sediments.

d. To provide nutrient data on all water and sediment samples taken by both microbiological groups. These data are important in evaluating other data collected by us, especially data on N_2 fixation and denitrification.

e. To coordinate our sampling with the hydrocarbon chemists during a Cook Inlet cruise so that comparisons could be made between our data and theirs.

f. To initiate a study which would be designed to determine the long-term effects of crude oil on microbial function in marine sediments.

2. Beaufort Sea

a. To obtain information concerning the effects of added crude oil on the natural microflora of the sediments. These studies were to include crude oil effects on microbial function as measured by uptake and respiration characteristics using two labeled compounds. These studies were also to include the study of nitrogen fixation and the effects of crude oil on this process.

b. To continue collecting data on relative microbial activity and respiration percentages in this region during the August-September, 1978 Norhwind cruise in this region. Nitrogen fixation rates were also to be estimated on sediment samples collected at the same time.

c. To provide nutrient data on all water and sediment samples collected by both Dr. Atlas and ourselves.

3. General

To coordinate our sampling efforts and experimentation with that of Dr. Atlas and this associates at the Unviersity of Louisville. This will minimize duplication of effort and maximize the usefulness of the resulting data.

4. Laboratory studies

To establish the methodology required to conduct tests of the long-term effect of crude oil on microbial function in marine seidments. This study was to be conducted at the Kasitsna Bay laboratory in Alaska.

C. Relevance to problems of petroleum development

Our major area of concern is the interaction between the crude oil that might be accidently spilled during the course of petroleum production in potential lease areas and the microorganisms present that might be perturbed by such a spill. Our studies will produce information about microbial function in these areas before extensive perturbation has occurred.

We are also determining what effect crude oil has on specific microbial function. These data will provide information about those types of microbial function which are most likely to be impacted by a crude oil spill. In addition, field studies on the effects of crude oil on microbial function will provide information about which geographical areas are most likely to be impacted. These data along with data provided by other investigators can be used to locate areas which are particularly sensitive to crude oil perturbation. These data, in turn, can be used by planners and managers in both government and industry to better assess the potential risks involved and better forecast those measures which must be taken to minimize risks to the environment.

Long term effects studies are being initiated which should identify key microbial functions which are perturbed in the presence of crude oil. Once these functions are identified, it will be easier to assess the extent of environmental perturbation as well as recovery rates in the event of an extensive oil spill.

III. Current state of knowledge

Since our last annual report, an aritcle by Knowles and Wishart (1977) has come to our attention which has relevance to our study. They studied the effects of crude oil on nitrogen fixation rates in Beaufort Sea sediments. They, like ourselves, have not seen any short-term negative effects of crude oil on nitrogen fixation rates.

IV. Study areas

During the past year, we have participated in two cruises and have conducted three field studies at NARL, Barrow, AK and one field study at the Kasitsna Bay laboratory. During the April, 1978 Cook Inlet cruise, we collected and analyzed samples at the stations illustrated on Fig. 1. In addition, we collected samples during three time-series stations in a coordinated study with the hydrocarbon chemists. During the August, 1978 Beaufort Sea cruise on board the North Wind, samples were collected at the stations illustrated on Fig. 2.

The three field studies at NARL were conducted in April and August, 1978 and in January, 1979. The samples analyzed during those studies were oiled sediments taken from trays which were placed on the bottom of Elson Lagoon. During the first field study in Kasitsna Bay laboratory, 17 sediment and 7 water samples were collected near the laboratory and within Kachemak Bay.

V. Methods

A. Sampling procedures

1. Cook Inlet Cruise

The water samples were taken in sterile Niskin plastic water sample bags fitted in Niskin "butterfly" water samplers. All water samples were taken within two meters of the surface and were processed within two hours after they were collected.

All sediment samples except those taken at the beach stations were obtained by a box or Haps corer. Approximately 150 grams of surface sediment were taken from the top two to four cm. Portions of these samples were used to determine percent respiration, relative microbial activity and nitrogen fixation rates within four hours of their collection.

2. Beaufort Sea (North Wind cruise)

Sediment samples wre taken using a Smith-McIntyre grab. The subsamples were taken as described above.

3. Beaufort Sea (Elson Lagoon, Jan., 1978).

Water samples were taken through hole drilled through the ice using a Niskin "butterfly" water sampler. The samples were kept at *in situ* temperature while they were transported back to the Naval Arctic Research Laboratory (NARL). The samples were processed within 5 hours after they were collected. Sediment samples were taken directly from the bottom by divers.

B. Relative microbial activity and percent respiration determinations

The procedure used in these studies involved adding a U-^{14}C compound to identical subsamples which were contained in 50 ml serum bottles.

After addition of subsamples, the 50 ml serum bottles that were used for reaction vessels were sealed with rubber serum bottle caps fitted with plastic rod and cup assemblies (Kontes Glass Co., Vineland, N. J.: K-882320) containing 25 x 50 mm strips of fluted Whatman #1 chromatography paper. The samples were incubated in the dark within 0.5 C of the *in situ* temperature. After the incubation period, the bottles were injected through the septum with 0.2 ml of 5N H_2SO_4 in order to stop the reaction and release the $^{14}CO_2$. After the addition of the acid, 0.15 ml of the CO_2 absorbent, β-phenethylamine, was injected onto the filter paper. The bottles were then shaken on a rotary shaker at 200 rpm for at least 45 minutes at room temperature to facilitate the absorption of CO_2. The filter papers containing the $^{14}CO_2$ were removed from the cup assemblies and added to scintillation vials containing 10 ml of toluene based scintillation fluor (Omiflour, New England Nuclear).

The subsamples were filtered through a 0.45 μm membrane filter (Millipore). The trapped cells on the filter were washed with three

10 ml portions of seawater at 0-3 C. The filters were dried and then added to scintillation vials containing 10 ml of the above mentioned fluor. The vials were counted in a Beckman model LS-100 C liquid scintillation counter located in our laboratory at Oregon State University.

In the sediment samples, a 10.0 ml subsample was diluted 1,000 times (v/v) with a 32 o/oo (w/v) solution of sterile artificial seawater. Ten ml subsamples of the sediment slurry were dried and weighed to determine the dry weights. These dry weights were used to calculate the observed uptake rates in terms of grams dry weight of sediment.

U-^{14}C L-glutamic acid with a specific activity of 237 mCi/mmole (Amersham-Searle) was used in all water samples giving a final concentration of 5.4 μg/liter. Glutamic acid with a lower specific activity (10 mCi/mmole) was used in all sediment samples except those collected at Elson Lagoon in January, 1979. In these sediments, the higher specific activity glutamic acid was used. U-^{14}C D-glucose with a specific activity of 328 mCi/mmole (Amersham-Searle) was used in all water and sediment samples. The final concentration used was 3.8 μg/liter.

Triplicate subsamples were analyzed for each sample and the results reported here are the means of the observed values. The channels ratio method for determining counting efficiencies was used. The observed CPM was converted to DPM before the mean value was calculated. The percent respiration was calculated by dividing the amount of labeled carbon taken up by the cells (both cell and CO_2 radioactivity) and multiplying this ratio by 100. All samples were incubated in the dark at a temperature within 0.5 C of the *in situ* temperature.

C. Crude oil effects on uptake and respiration of labeled organic compounds

Field observations of crude oil effects were made on samples collected during the recent August 1978 and January 1979 Elson Lagoon studies, on samples collected during the April, 1978 Cook Inlet cruise and samples collected during the August, 1978 North Wind cruise.

Since our last annual report, we have modified the technique used to determine the effects of crude oil on substrate uptake by marine microflora. It was determined that only 10 μl of crude oil per 10 ml of reaction mixture was required to obtain maximum effect therefore this amount is routinely used in the effects experiments. It was also observed that even at these low concentrations and when a toluene wash was used, there was still significant quenching of the cell fraction so that nondetectable errors were generated. To circumvent this problem, we subsampled 1/2 of the 10 ml reaction mixture using a syringe which allows removal of fluid from underneath the surface oil slick. The amount of radioactivity associated with these subsamples were doubled in our calculations so that the resulting counts could be compared with the controls.

D. Nitrogen fixation in sediments

Nitrogen fixation in the sediments was determined in the field by using the acetylene reduction method (Stewart *et al*, 1967). Ten ml subsamples of sediment were added to respective 50 ml serum bottles: one control and two duplicate samples were used for each analysis. After the bottles were sealed with a rubber stopper, the samples were gassed for one min. with He at a flow rate of 10 cc/sec. Ten ml of acetylene was then added to each bottle and the bottles were allowed to incubate for 24 hr before incubation was terminated with one ml of saturated $HgCl_2$ solution. The controls were treated in the same way before incubation and were used to determine the amount of ethylene that was released abiotically. After the incubation was terminated, the tops of the rubber stoppers were sealed with silicone cement. The bottles were kept at or below 4 C until they could be assayed for ethylene in our laboratory at Oregon State University. The analysis for ethylene was made on a Hewlett Packard model 5830A gas chromatograph. The column used was 1.9 meter of 1/8" stainless steel tubing packed with Porapak R 80-100 mesh and the oven temeprature was 40 C. The carrier gas was nitrogen flowing at a rate of 29 cc/min. The resulting levels of ethylene were normalized using incubation times and gram dry weight conversions. All rates were calculated in terms of pmoles nitrogen fixed per gram dry weight of sediment per hour. A conversion factor of 0.33 was used to calculate the amount of nitrogen fixed from the amount of ethylene produced.

E. Crude oil degradation experiments

1. In the field, 10 ml of sediment was added to a screw capped test tube to which 0.1 ml of crude oil was added. The sample was transported to our laboratory at OSU at or below the *in situ* temperature of the collection site. When the sample was received in the laboratory, 5 ml of an enriched mineral salts solution was added to the sample and the sample was allowed to incubate at 5 to 8°C for at least 4 weeks. The "Enriched Mineral Salts Solution" (EMSS) is the basal medium of Mulkins-Phillips and Stewart (1974).

2. The enrichment cultures were maintained by transfer of 1.0 ml of the original enrichment into 19.0 ml of EMSS containing 0.2 ml of crude oil. The enrichments were incubated in 125 ml French-square bottles. Beaufort Sea samples were enriched with Prudhoe Bay crude oil and the Cook Inlet samples were enriched with Cook Inlet crude oil.

3. The temperature effects study was designed to compare the effects of incubation temperature on crude oil degradation in a composite of several crude oil enrichment cultures. These cultures were made from sediment samples collected in the Beaufort Sea and in the Cook Inlet. Two composite enrichment cultures were established; the one from the Beaufort Sea (BS) contained 6 enrichment cultures and the one from the Cook Inlet (CI) contained 9 cultures. The composite enrichment cultures contained 1 ml from each of the original cultures, 200 ml of EMSS and 1.0 ml of the appropriate crude oil. These cultures were incubated at 8°C for 16 days by which time growth was evidenced by turbidity and

emulsification of the oil. From these cultures 1.0 ml inocula were added to duplicate subsamples containing 0.2 ml of crude oil, and 19.0 ml of EMSS. The BS culture contained Prudhoe Bay crude oil and the CI culture contained Cook Inlet crude oil. One uninoculated control was also used for each temperature. These cultures were incubated for 36 days at 0, 1.5, 5, 15 and 20°C. At the end of the experiment, the bottles were cooled to 0°C and extracted with 10 ml spectrograde benzene. The benzene layer was transferred to centrifuge tubes and centrifuged at 27,000 x g for 5 min at 0°C. Five ml of each supernatant was placed into their respective preweighed weighing dishes and each subsample was dried with approximately 0.5 g anhydrous Na_2SO_4 and sealed in 4 ml glass vials. These subsamples were used in the gas chromatographic analysis.

4. The benzene extracts were analyzed on a Hewlett Packard model HP 5830A gas chromatograph fitted with dual flame ionization detectors, 2 meter, 1/8" stainless steel columns packed with 3% OV-17 on 800/100 Chromosorb WHP. Operating conditions were as follows; column temperature, 50°C, isothermal for 6 min increasing at 6°C/min to a maximum temperature of 250°C then isothermal for 15 min. The detector temperature was 300°C, the injector temperature was 275°C and the carrier gas flow (nitrogen) was 25 ml/min. The sample injection volume was 1.0 µl. Results were compared with a mixture of known hydrocarbons for presumptive identification of some sample components. The signal from the second column was subtracted from the signal from the column on which the sample was placed to compensate for baseline drift. The results of each analysis were entered into a calculator from the gas chromatograph integrator using a digital data interface. Determinations were made on benzene alone, the control crude oil which had not been degraded, and the degraded samples. The calculator was used to correct for injection volume variations using the benzene peak as the standard. All peaks found in the benzene control were subtracted from the control and degraded sample. The corresponding peaks in the control and degraded samples were then compared and a percent degradation calculated from this comparison These comparisons were made on a peak by peak basis and by comparing total response areas over a range of retention times.

V. Methods

F. Analysis of Total Adenylate Pools in Marine Sediments

1. Adenylate Pool Extraction Procedure

The procedure used is a modification of Bullard (1978). One ml. of sediment was added to 8 ml. of extraction buffer (0.04 M Na_2HPO_4 adjusted to pH 7.70 with 0.02 M citric acid) and placed in a boiling water bath for 2 minutes. Evaporation was minimized by covering the extraction vessels (50 ml beakers) with a watch glass. Internal standards (0.1 ml of a *Vibrio* sp. culture or 0.1 ml of a known ATP concentration) were run both alone and in combination with sediments. Duplicate subsamples of each sediment were extracted. Following extraction, samples were removed to an ice bath, then added to centrifuge tubes, allowing a small volume distilled H_2O rinse to completely recover the extracted sample. After centrifuging at 8000 x g at 0 C for 10 min., the clear supernatant was removed to a screw cap vial, its volume brought up to 10.0 ml with distilled H_2O, and frozen at -20 C until the time of analysis.

2. Analysis of Extracted Adenylate Pools

For the analysis of ATP, 1.8 ml of extract was added to 0.72 ml of buffer 1 (0.55 g K_2SO_4 and 1.5 g $MgSO_4$ in 10.0 ml dist. H_2O) and 0.2 ml Tris-EDTA buffer (20 mM Tris; 2 mM EDTA; pH 7.75). For analysis of ATP plus ADP, 1.8 ml of extract was added to 0.72 ml of buffer 2 (buffer 1 with 5 mg phosphenol pyruvate added) and 0.2 ml pyruvate kinase solution (10 mg in 10 ml Tris-EDTA). For analysis of ATP plus ADP plus AMP, 1.8 ml of extract was added to 0.72 ml buffer 2, 0.2 ml pyruvate kinase, and 0.05 ml adenylate kinase solution (Sigma). Each mixture was held on ice during preparation, then incubated at 30 C for 15 min and returned to an ice bath.

The assay itself was run on an Aminco Photometer and Integrator-timer. A 575 µl volume of each mixture was transferred to a cuvette and placed in the photometer chamber. Integration of photon emissions over 3 sec intervals was begun at the instant at which 100 µl of a buffered luciferin-luciferase preparation (Dupont Instruments, No. 760145-902) was injected into the chamber through a septum. The maximum integrated count, usually occurring in the second interval, was used to calculate amounts of each adenylate present, using standard curves prepared from pure adenylate solutions.

G. Nutrient analysis

1. Water sample nutrients

a. Frozen samples were thawed in a warm water bath and then aspirated into a four channel Technicon Autoanalyzer system. The samples were subdivided with a stream divider into four sample flows which were used to analyze ammonia, phosphate, nitrate and nitrite concentrations.

b. The total concentrations of nitrate and nitrite were made following the procedures of Callaway et al. (1972). The following modifications were made to this procedure: sample, 0.8 cc/min; DDW diluture, 1.2 cc/min; ammonium chloride, 1.0 cc/min; sulfanilamide, 0.1 cc/min; N-1-naphylethylene 0.1 cc/min. The debubbler before the cadmium column is pumped out of the system (1.0 cc/min) with the remaining water forced through the cadmium column.

c. The nitrite concentration was determined using the same chemistry as the above analysis except there is no ammonium chloride, cadmium column, DDW diluter, or first air bubble. A 2.3 cm cc/min. sample tube was used.

d. The phosphate concentration determinations were made using the method of Calloway et al. (1972) without modification.

e. The ammonium ion concentration was made using the technique of Head (1971).

2. Sediment samples

a. Sediment samples were thawed in a warm water bath, mixed and then centrifuged for 30 min at 0°C and 8000 RPM.

b. Five to fifteen ml of the supernatant was removed and used in the nutrient analysis. Approximately 20 ml of the diluted sediment water was placed into quartz tubes with 0.3 ml of H_2O_2. These samples were then treated with UV light for 4 hours.

c. Soluble oxidizable nitrogen was determined as nitrate on the Autoanalyzer. Ther remainder of the diluted sediment water was diluted further for the ammonia determination.

d. When H_2S was present, approximately 0.15 ml of a 2% $CuSO_4$ solution was added to remove sulfide ions from solution which would interfere with the nutrient assays.

e. The total carbon content of the sediment was determined by the following procedure. A subsamples of the sediment was treated with HCl to remove all traces of inorganic carbon. The sediment was centrifuged and the supernatant removed. The sediment was dried and combusted using the technique of Pella and Columbo (1973).

3. Statistical analysis

The correlation coefficients used in this report were computed using the following equation:

$$r = \frac{N\Sigma XY-(\Sigma X)\ (\Sigma Y)}{[N\Sigma X^2-(\Sigma X)^2]-[(N\Sigma Y^2-(\Sigma Y)^2]}$$

The significance of differences between mean values were made using Student's "t" test. A critical value of 0.05 was used in these determinations. Whenever it is stated that there was a "significant" difference between two mean values, the difference fulfills the above conditions.

VI. Results

A. Location of sampling sites at which samples were collected

1. April, 1978 Cook Inlet Cruise

During this cruise, 83 water and 30 sediment samples were collected and analyzed from the locations given in Table 1 and Fig. 1. These samples included a series which was collected at the time series stations CB7, 9, and 10. The samples were collected in such a way as to maximize coordination with the chemists which were making observations at the same time.

2. August, 1978 Beaufort Sea Cruise on the North Wind.

During this cruise, 42 water and 38 sediment samples were collected and analyzed from the locations given in Table 2 and Fig. 2. These observations were made in conjunction with other marine biologists who were studying various aspects of the food web in the Beaufort Sea.

3. Elson Lagoon tray experiment

This is a continuation of the study initiated over a year ago with Dr. Atlas (RU #30). During this reporting period, samples from trays containing oiled-sediment were taken during three study periods, April, 1978, August, 1978 and January, 1979. Both water and sediment samples were analyzed during each field study period. Sediment samples were analyzed which had been exposed to crude oil for periods of from 24 hours to one year. The location of the sampling station is a few hundred meters south the tip of Point Barrow spit (our station #3).

B. Relative microbial activity and respiration percentages in water samples

1. Cook Inlet

a. In general the patterns of substrate uptake and respiration in the Cook Inlet area were the same as those we have observed in the past. The relative levels of microbial activity were higher in the northern section of Cook Inlet and within the bays (Fig. 3, Tables 3 and 4). There were, however, differences observed in certain details of surface water relative microbial activity. During the 1977 November cruise, the highest rates of microbial activity were observed along the western shore of the Shelikof Strait; during the April cruise, the reverse pattern was observed. These data suggest that the overall pattern of water mass movement in the Cook Inlet still followed the trends we have observed in the past; however, the movement of these waters through the Shelikof Strait may vary.

As we have seen in the past, the repiration percentages were lowest in the north-eastern section of Cook Inlet (Fig. 4). For some reason, the patterns were not as well defined as those observed in previous Cook Inlet cruises.

b. The pattern of relative microbial activity observed in the Cook Inlet sediments during the April cruise was similar to that observed before. The highest activity levels were found in the muddy sediments of inshore stations taken in the smaller bays (Fig. 5).

c. The relative microbial activity in the sediments along the western edge of Shelikof Strait were higher than those observed to the east. This is similar to the pattern normally found in the surface waters in this region. If our hypothesis is correct that the suspended matter observed in the northern waters of Cook Inlet ends up in the sediments of Kamishak Bay and the Shelikof Strait, then it can be assumed that the flow of most microbially active water is normally along the west shore. However, at the time of the April cruise, the more active waters were observed along the eastern side of the Shelikof Strait.

2. Beaufort Sea (August 1979, North Wind cruise).

a. Water samples

The relative levels of microbial activity in water samples collected during the summer, 1978 Beaufort Sea cruise showed some interesting trends (Table 5). Some of the highest values in both glucose and glutamic acid uptake were found in the regions near the Colville and Sagavanirktok Rivers (Figs. 6 and 7). It would appear that this high microbial activity is associated with the effluent from these rivers.

The average rate of glucose uptake in all water samples was 7.5 ng/liter/h. at a glucose concentration of 3.8 μg/liter (Table 5). This is slightly higher than the average of 5.1 ng/liter/h observed in water samples collected during the summer, 1976 Beaufort Sea cruise when the same substrate concentration was used. The average rate of glutamic acid uptake observed in water samples collected during the summer, 1978 Beaufort Sea cruise was 14.0 ng/liter/h at a substrate concentration of 5.4 μg/liter. During the summer, 1976 cruise the average value was 7.9 ng/liter/h; however, the substrate concentration used was exactly 1/2 that used in the 1978 study thus the rates at comparable concentrations would be roughly equal in the two studies. The average ratio of glucose to glutamic acid uptake (2.3) was also similar to what we have observed in past studies both in the Beaufort Sea and the Cook Inlet.

The average percent respiration in water samples exposed to glucose was 36. This is higher than the average of 27% observed in these waters in 1976 but lower than that observed in water samples collected during the April, 1978 cruise in the Cook Inlet (45%). The average percent respiration in water samples exposed to glutamic acid was 62. This is also higher than that observed in the Beaufort Sea in the summer of 1976 when the average was 46%. This is also lower than the average percent respiration observed during the April, 1978 Cook Inlet cruise.

The percent respiration when either glutamic acid or glucose was used as the substrate showed similar patterns near the mouths of the Colville and Sagavaniroktok Rivers (Figs. 8 and 9). In each case, the percent respiration observed in these water samples was lower than that observed in the surrounding water masses. These are the same waters in which the relative microbial activities were higher than those observed in the surrounding waters (Figs. 6 and 7).

b. Sediment samples

The patterns of glutamic acid uptake in the marine sediments of the Beaufort Sea are similar to those found in the water column (Fig. 10). In addition to the high microbial activity found near the mouths of the Colville and Sagavanirktok Rivers, high activity was observed in the sediment samples collected at stations 622 and 624. When glucose was used as the substrate, the highest value for microbial activity was also found at station 622 (Fig. 11). It is curious that this is also the only station where we found unusually high nitrogen fixation rates in the sediments.

The average rate of glutamate uptake in the sediments was 91 ng/g dry wt./h (Table 6). During our summer, 1976 cruise in the Beaufort Sea, we observed an average uptake of 150 ng/g dry wt./h. There was one value observed during that cruise that we feel was atypical of these sediments. If this value is removed from the average value, the resulting mean would be 80 ng/g dry wt./h which is very close to the value observed during the summer, 1978 cruise. The average value observed in sediments returned to us from the 1977 Glacier, Beaufort Sea cruise was 420 ng/g dry wt./h. Since these sediments were stored for up to six weeks before they were assayed, it is quite possible that this is an erroneously high value (all other measurements were made on fresh samples taken in the field). The average glucose uptake in the sediment samples was 8.5 ng/g dry wt./h which is higher than the average value of 4.2 ng/g dry wt./h observed in sediment samples collected during the summer, 1976 cruise and is slightly lower than that observed in the sediment samples collected during the 1977 Beaufort Sea cruise (10.1 ng/g dry wt./h).

The average percent respiration observed in sediments exposed to glutamic acid was 53 which is higher than that observed in 1976 (28%) and that observed in 1977 (38%). The average percent respiration observed in sediments exposed to glucose was 32 which is higher than that observed in 1976 (20%) and higher than that observed in 1977 (25%).

3. Elson Lagoon

a. April, 1978

During this field study, five sediment and three water samples were analyzed (Table 7). There did not appear to be any adverse effect of either short or longer term exposure to heterotrophic activity as measured by glucose or glutamic acid uptake. In sediment samples exposed to crude oil to period greater than 24 hours, there was an increase in the percent respiration.

b. August, 1978

During this field study, seven sediment and three water samples were analyzed (Tables 5 and 6). Of the sediment samples two (BB601 and BB607) were controls; the rest were exposed to crude oil for 2, 24, 72 hr., 4 or 7 months (BB 603, 604, 606, 602, and 605 respectively). No significant trends were observed in either heterotrophic activity or respiration in response to long term crude oil exposure.

c. January, 1979

During this field study period, six sediment and two water samples were analyzed (Table 8). In this study, both control sediments

(BB703 and 704) showed statistically significant higher heterotrophic activity than did all oiled samples. Also the percent respiration was lower in the nonoiled sediments.

C. Effects of crude oil, Corexit 9527, and a combination of the two on substrate uptake and respiration

1. Cook Inlet

During the April, 1979 Cook Inlet Cruise, the effects of Cook Inlet crude oil on glucose and glutamic acid uptake and respiration were measured in 31 and 35 water samples respectively (Tables 3 and 4; Fig. 12 and 13). The effects of crude oil on glucose and glutamic acid uptake and respiration were measured in 27 and 7 sediment samples respectivel (Tables 9 and 10). In addition to these studies, the effects of the dispersant Corexit 9527 both with and without crude oil was measured in a number of water and sediment samples (Table 11). The kinetics of glucose and glutamic acid uptake in water and sediment samples were also measured in the presence of crude oil (Table 12).

The average percent reduction in the rate at which glucose was taken up and respired in water samples exposed to crude oil was 45 (Table 13). When glutamic acid was tested under the same conditions, the average reduction was 33%. The reduction in each case was statistically significant. When the same observations were made in sediment samples, average reductions were 14 and 18% respecitvely. However, these differences were not statistically significant.

In seven water samples, the effects of crude oil, Corexit 9527 and a combination of the two on either glucose or glutamic acid uptake was also observed (Table 14). All three of these treatments had an adverse effect on the uptake of these substrates. The same type of measurement were made in five sediment samples where very little or no effect was noted.

2. Beaufort Sea, North Wind Cruise

a. Water samples:

A series of experiments was completed which was designed to determine the effects of crude oil and/or the dispersant Corexit 9527 on the uptake of glucose in both water and sediment samples collected during the 1978 Beaufort Sea cruise. As can be seen in Table 15, the average reduction in glucose uptake in the water samples exposed to fresh Prudhoe Bay crude oil was 52%. The average reduction observed in water samples exposed to 15 ppm Corexit 9527 was 58% and the average reduction in samples exposed to both crude oil and Corexit was 76%. If the levels of uptake under these conditions were compared with the nontreated samples, all differences here are statistically significant.

During these studies, we wanted to determine how crude oil and Corexit affected the uptake of glucose. To do this, we studied the kinetics of glucose uptake under the appropriate conditions (Table 16). The average maximum potential uptake of glucose (Vmax) in the water samples studied was 14.6 ng/liter/h. When exposed to crude oil, another set of subsamples gave an average of 3.7 ng/liter/h. Samples exposed to Corexit and Corexit with crude oil had averages of 2.7 and 1.5 ng/liter/h respectively. The Vmax values observed in the presence of crude oil, Corexit, and Corexit with crude oil were all significantly lower than in the nontreated samples.

The time required for the natural microbial population to utilize all of the naturally occurring glucose (T_t) was also measured in these same samples (Table 16). The average turnover time for the non-oiled samples was 177 hours. The average turnover time for samples exposed to crude oil, Corexit, and Corexit and crude oil was 492, 1145, and 1162 hours respectively. These values were all significantly higher than that observed in nontreated samples.

The transport constant plus the natural substrate concentration (K_t+S_n) was also measured in these samples (Table 16). In this case, there were differences noted but they were not statistically significant. Thus both the Vmax and the T_t values were altered by the presence of crude oil but the K_t+S_n values were not. In classical enzyme kinetics, this pattern would be attributed to noncompetitive inhibition.

The percent reduction in the rate of glucose taken up by microbial populations in the water samples exposed to crude oil showed an interesting trend (Fig. 14). The waters that were most greatly effected by the presence of crude oil were found in an area near the mouth of the Colville River.

b. Sediment samples

The effects of crude oil, Corexit 9527, and a combination of the two on glucose uptake by microbial populations in sediment samples collected in the Beaufort Sea during the summer, 1978 cruise were also measured (Table 17). The average percent reduction in glucose uptake rate was 30, 15, and 40 respectively for samples exposed to crude oil, Corexit, and crude oil plus Corexit. The reductions caused by Corexit and crude oil plus Corexit are statistically significant; the reduction caused by crude oil was not significant at the 95% confidence level.

In several of these samples, the effect of these compounds on the kinetics of glucose uptake in sediments was studied (Table 18). There were some differences in the Vmax values in the treated samples but they were not significantly different from the nontreated samples. Likewise, there was no significant differences observed in the T_t and K_t+S_n values in treated vs. nontreated sediment samples.

Fig. 15 shows the percent reduction of glucose uptake in crude oil treated sediment samples collected in various locations during the

Beaufort Sea cruise. The sediment samples that were collected off the Sagavanirktok River showed a relatively high susceptibility to the effects of crude oil whereas the sediment samples collected to the east of the Canning River and offshore from Prudhoe Bay showed relatively low susceptibility to the effects of crude oil.

D. Rates of nitrogen fixation in marine sediments

Nitrogen fixation rates were measured in sediments collected during both the Cook Inlet and Beaufort Sea cruises. During the Cook Inlet cruise, the average rate in the 29 samples studied was 0.4 ng nitrogen fixed per g dry weight per h. There was no significant short-term effect of crude oil on nitrogen fixation rates in either nontreated or in sucrose augmented samples. As we have observed in the past, the highest nitrogen fixation rates were observed in Kachemak Bay and in the Shelikof Strait (Fig. 16).

During the Beaufort Sea cruise, 32 sediment samples were measured for nitrogen fixation rates (Table 20). The average value observed in this study was 0.3 ng nitrogen fixed per g. dry wt. per h. This is very close to the average value observed in the Cook Inlet. It was however, lower than that observed in the Elson Lagoon near Barrow, AK during the study conducted in April, 1978; a value of 1.3 ng/g dry wt./h was observed in these samples. Again, there was no significant alteration in nitrogen fixation rates in sediments exposed to crude oil. There did not appear to be any significant geographical trends in relative rates of nitrogen fixation. The sediment from only one location (station 622) showed an unusually high rate of nitrogen fixation.

E. Concentrations of ATP, ADP, and AMP in marine sediments

During the August, 1978 Beaufort Sea study, ATP, ADP, and AMP measurements were made on four sediment samples collected in Elson Lagoon and four sediment samples collected during the North Wind cruise (Table 21). The energy charge ranged from 0.92 to 1.00 with the most dominant adenylate species being ATP. Of these samples, only two (BB602 and 603) had come from the oiled sediment tray experiment in Elson Lagoon. The level of total adenylates in these two sediments was roughly 1% of that found in the sediments collected near the trays that were not exposed to crude oil (BB601 and 607).

During the January, 1979 Elson Lagoon study, the energy charge was much lower than that observed during the August sampling period. In January, the range of values observed were from 0.15 to 0.38. i.e., there were very low levels of ATP relative to ADP and AMP. Also the total concentration of adenylates was much lower in the January sediments. In this series of samples, two came from trays that had been oiled for six and twelve months (there samples were BB701 and 702). The level of adenylates in these trays was much lower than that observed in nontreated controls (BB703 and 704). We were concerned that the crude oil itself might be interfering with the assay itself. We checked that possibility by adding crude oil to the controls (BB703 + oil and BB705) and conducting measurements on these. The crude oil did not interfere with the assay.

F. Inorganic and organic nutrient data

All of the available inorganic nutrient data measurements of total organic carbon (TOC) and total organic nitrogen (TON) are given in Tables 23 to 28. These data long with other cruise data have been submitted to NIH in the proper format to be included in that data base. The 1977 Beaufort Sea summer cruise data were placed into file number 100307 and 100309. The April, 1977 Lower Cook Inlet cruise data were placed into file number 100254; the November, 1977 and April, 1978 cruise data were placed into file numbers 100259 and 100306 respectively.

VII. Discussion

A. Glucose and glutamic acid uptake and respiration in water and sediment samples

1. Water samples

In our last annual report, we indicated that there were two different water masses in the Cook Inlet which showed different microbiological properties. One water mass to the north contains highly turbid water of low salinity which shows high levels of microbial activity and low respiration percentages. The other water mass which originates from the southeast, shows the opposite trends. The water masses between these two extremes showed intermediate values which indicated regions of mixing. During the April, 1979 cruise, we observed similar trends but they were not as well defined as those observed in the past (Fig. 3 and 4).

All of the information that we have concerning the water masses in the Cook Inlet indicate that the type of water present on the west side is much different from that found along the east side. The eastern water is essentially open ocean water and the water along the western coastline is dominated by the water mass that originates in the Upper Cook Inlet. In the final report for RU #417, Dennis Lees (1978) reports that the flora and fauna of the western side of Cook Inlet is much different than that found on the east side. The species found on the west side are similar in many ways to those species that are typically found in the Beaufort Sea. There is no apparent reason for this difference; however, the possibility does exist that the differences in the two water masses mentioned above could be a factor. The influence of terrestrial runoff in the western side of Cook Inlet may be similar to the condition along the southern Beaufort Sea.

During the summer, 1978 Beaufort Sea cruise we made some observations that suggest that terrestrial runoff may be an important organic nutrient source along the Beaufort Sea coast. The relative levels of microbial activity in water samples as measured using glucose, and glutamic acid were highest off the mouths of the most prominent rivers along this portion of the North Slope (Fig. 6 and 7). The size of the area of high microbial activity was roughly proportional to the size of the drainage system associated with the river in question, i.e. Colville > Sagavanirktok

> Canning. The waters off the mouths of the first two rivers also contain microbial populations which showed unusually low respiration percentages relative to that observed in the surrounding water mass (Fig. 8 and 9). We have now observed two geographically different areas which show similar patterns of microbial function in response to terrestrial input.

2. Sediment samples

During the Beaufort Sea cruise, sediment samples were also analyzed for microbial activity. The data illustrated in Fig. 10 and 11 suggest that organic nutrients from a terrestrial origin may be a prominent feature in the river delta regions as well. The terrestrial input of organic carbon from these rivers could be a very important factor in the carbon budget in this region. Since there are elevated levels of microbial activity in the sediments, it is quite likely that these areas are important to the input of organic carbon into the entire food chain through the food web. If crude oil is present, it is quite likely that the transfer of this energy source to higher trophic levels will be impaired. A recent study of the effects of crude oil in marine sediments and the associated water column in an actual oil spill off the coast of Sweden has shown that crude oil may change the environment near the sediment-water interface. This change could very well effect the food web.

The data collected by Dr. Atlas during the same cruise suggest that denitrification rates may be increased in the presence of organic carbon. It is also known that the denitrification processes itself is enhanced by anaerobic conditions. In areas where there is an unusually high level of organic carbon being transferred into the system, it is quite likely that the presence of crude oil may increase the metabolic activity to the point where denitrification rates are increased. If fixed nitrogen is limiting to energy transfer, then increased denitrification rates could alter this process.

The same types of observations were made in sediment samples collected during the Cook Inlet cruise (Fig. 5). The patterns of relative microbial activity were similar to those observed in past Cook Inlet studies. The highest values observed were found in sediments taken from Kamishak and and Kachemak Bays and one sediment taken to the west of Kalgin Island. This is the first time we have been able to obtain a muddy sediment sample near Kalgin Island. The extremely high value observed there most probably reflects the presence of terrestrial input from the rivers flowing into the Upper Cook Inlet. The high value observed in the Homer Boat Basin sediment most probably reflects the input of human waste products.

3. Observations made during the April Cook Inlet time series stations

After looking at the microbiological data from the time series stations at least two factors have emerged: (i) there was no significant correlation between tide state and any of the variables that we have analyzed (Table 28), and (ii) many of the surface water samples that we took at station CB7 appear to have been contaminated by the ship's effluent. We have come to this conclusion for two reasons. Those samples that appear to be contaminated have much higher microbial activity than one would anticipate at the location in question and the ratio of glucose to glutamic acid uptake is much lower than that normally found in natural marine waters (Table 28). For example, water samples number 661 and 662 were taken at about the same time and in locations that were not far apart (stations CB7 and AA respectively). From our past experience in this region, we would expect that the uptake rate and glutamic acid/glucose ratios would be about the same in these samples. As can be seen in Table 28, the uptake rates and glutamic acid/glucose ratio for sample 661 was more similar to sample 660 taken in the polluted Homer boat basin than to sample 662. Of the other surface water samples taken during this cruise, those that appear to be contaminated by the ship's effluent are samples numbered 601, 659, 660, 661, 663, 668, and 683. We felt that there are two reasons why many of the samples taken at station CB7 were contaminated whereas those taken during the time series at stations CB9 and CB10 were not. The first reason is that there was relatively poor coordination between the ship's engineers and the ship's operations during the initial time series. On at least one occasion, the ship's effluent was pumped just prior to a sampling sequence instead of just after a sequence. The sample that we took at that time was 661 which was one of the most contaminated samples that we collected. The second reason is that the tidal current at station CB7 was much less vigorous than that observed at stations CB9 and CB10. It is thus much more likely that the water column, if contaminated with ship's effluent, would remain near the ship where it could be sampled.

B. The effects of crude oil on marine microbial populations

1. Acute effects

It is now well documented through both the work of Hodson et al., (1977) and ourselves (Table 13) that the presence of crude oil adversely effects the uptake of labeled organic substrates by marine microbial populations. Of the two substrates measured by us (glucose and glutamate), the uptake of glucose appears to be affected the greatest. Microorganisms in the water column appear to be affected to a greater degree than those found in the sediment. Sediment samples collected in the Beaufort Sea showed a greater effect than those assayed in the Cook Inlet.

Since we were using the single concentration method of determining relative microbial activity, it was possible that the crude oil effects that we were seeing was due to an artifact of the assay system. That is, the crude oil might have contained some compound that was taken up by the cells in the same way that the labeled compound was taken up. One way to test this possibility is to run a series of kinetic experiments. We measured the kinetics of glucose uptake in five sediment samples that we transported to our lab at OSU after the January field trip to Barrow. The results of these studies were inconclusive (Table 12). In the sediment samples analyzed at Barrow during the April trip, there was a statistically significant difference between the V_{max} values observed in the oiled and non-oiled sediment samples exposed to labeled glucose. In the same samples, the turnover time did not vary significantly between these two groups. The transport constant and the natural substrate uptake concentration value (K_t+S_n) was generally lower in the oiled samples. Of the other samples that were studied, only the water samples collected in the Cook Inlet show a decrease in V_{max} values when the samples were exposed to crude oil. In this study the T_t values were generally higher in the oiled group than in the controls but this difference was not significant as determined by Student's t test.

During the North Wind cruise we measured the effects of crude oil on the kinetics of glucose uptake in both water and sediment samples. There were no significant effects observed in the sediment samples (Table 18); however, significant trends were observed in the water samples (Table 16). In these samples, there was a reduction in the V_{max} (maximum potential uptake rate) values and an increase in the turnover time; there was no significant change in the transport constant. This is the type of pattern one would expect in non-competitive inhibition. These data suggest that the crude oil is in some way interfering with the uptake mechanism for glucose.

During the course of this same series of experiments, we wanted to determine if the presence of crude oil affects the level of substrate binding as we have defined it in a recent article (Baross et al., 1975). If crude oil did affect binding or pooling, we should observe a proportionaly higher effect in cells that had not been treated with acid. (The samples that we normally assay have been acidified during preparation). This was not what we observed; in fact, the differences observed between oiled and non-oiled samples were greater in the acidified group.

We have recently conducted a series of tests which indicate that both protozoan cropping (feeding) rates on bacteria and protozoa growth rates are adversly effected by the presence of crude oil. Since this series of experiments was conducted on marine ciliates isolated from an Oregon coast sediment, we do not know if the same effects would be observed in protozoa isolated from Alaskan marine sediments. Studies are currently underway to determine if the same effects are noted in Alaskan sediments. If these same effects are observed it is probable that this potentially important step in the food web is affected by the presence of crude oil.

2. Chronic effects

From the data that is accumulating it would appear that the presence of crude oil is an environmental stress which acts to enrich for hydrocarbon utilizing bacteria but at the time acts to reduce the variation within a given population. This is the same type of pattern that is emerging from the diversity index data being generated by Dr. Atlas (RU #30). If microbial populations do adjust to the presence of crude oil, then populations that are constantly exposed to crude oil or petroleum products should not be as susceptible to the acute effects of crude oil as populations that are not exposed. Thus if one were to measure the effects of crude oil on an appropriate microbial function, one might have a method of assaying prior chronic exposure to crude oil. We are starting to accumulate data that suggest that the measurement of the effects of crude oil on the uptake of glucose by microbial populations may function as such an assay system. During both the Cook Inlet and the Beaufort Sea cruises, we calculated the percent reduction in the uptake of glucose or glutamic acid by natural marine microbial populations exposed to crude oil (Fig. 12, 13, 14 and 15).

In the Cook Inlet, the following trends were observed. The effects of crude oil glucose uptake were minimal in the stations taken nearest to the existing drilling platforms north of Kalgin Island (stations 266 and 265). In fact, the uptake rate in the water sample taken at station 266 was higher in the presence of crude oil than without oil. The effects of Cook Inlet crude oil on glutamic acid uptake were measured in all water samples taken during the time series stations at CB7, CB9 and CB10 (Fig. 12). The effect was significantly less at stations CB9 and CB10 than there were at CB7. Both of these stations are close to oil drilling rigs in the Upper Cook Inlet.

Another interesting feature of the distribution pattern seen in Fig. 12 is the comparison between the effects observed in the water sample taken in Oil Bay (station AA) and the sample taken in Cottonwood Bay (stations AW) as shown in Fig. 12 and 13. The effect of crude oil on the uptake of both glucose and glutamic acid was less in Oil Bay than in Cottonwood Bay. Oil Bay is so named because of a natural oil seep fund in that bay.

At one point in the cruise, we collected consecutive water samples along a track line running from Kamishak Bay within a 24 h period (Fig. 12). Moving from west to east, the percent reduction due to the presence of crude oil decreased as the samples were taken closer to the center of the shipping channel. At station CB5 the uptake was actually higher in the sample exposed to crude oil. As samples were taken further towards shore in the east side of the inlet, the effects became increasingly greater as the percent reduction increased. It is possible that the surface waters toward the center of the inlet may have been exposed to higher levels of petroleum hydrocarbons because of the constant input from passing freighters.

During the North Wind cruise, the following trends were observed. Most of the microbial populations in the water column showed approximately the same level of susceptability to crude oil exposure. In one water mass, however, the microbial population showed relatively high susceptability to crude oil exposure; the water mass close to mouth of the Colville River (Fig. 14). We have also examined the effects of crude oil on the uptake of glucose by bacteria associated with sediment samples. There is very little effect of crude oil on the uptake of glucose in sediments collected to the east of the Canning River (Fig. 15). These data suggest that these sediments may have been exposed to elevated levels of hydrocarbons for an extended period of time. We cannot tell, at this time, whether these hydrocarbons originated from natural crude oil seeps or from hydrocarbons produced by living organisms. Dr. Atlas (RU 29) measured the concentration of hydrocarbon utilizing bacteria in the same sediment samples. Although the correlation is far from perfect, four out of the five sediment samples that he found to contain an unusually high concentration of hydrocarbon utilizing bacteria were in the areas where we found the least effect of crude oil on glucose uptake. If there is a chronic input of hydrocarbons into these sediments, we would expect to find both a decrease in the effect of crude oil on the metabolism of these organisms and we would expect fo find elevated concentrations of hydrocarbon utilizing bacteria. We concur with Dr. Atlas' conclusion that more must be learned about the presence of hydrocarbons in these sediments.

We have also conducted preliminary studies which indicate that the presence of crude oil in marine sediments may effect more than the genetic diversity within the microbial population. We now have two sets of data showing that the total concentration of adenylates is lower in sediments that have been exposed to crude oil for several months than those that have not been exposed (Table 21). In the summer study, the two oiled trays (BB602 and BB605) had total adenylate concentrations that were about 1% of that in the controls (BB601 and BB607). In the January study, the oiled trays (BB701 and BB702) had adenylate concentrations that were 5 and 10% of that observed in the controls (BB703 and BB704). During these studies we also determined that the differences that we were observing were not due to an artifact of the assay system. This drastic difference in the adenylate concentrations probably reflects a reduction in a significant portion of the biomass normally present in these sediments. All we know at this time is that the fraction of the population that has not been reduced is the bacterial fraction. Although, for the first time since we started the tray experiments, we observed a reduction in the heterotrophic activity in the oiled sediments relative to the controls (Table 8). These data suggest that some major component of the food web may be missing in these oiled sediments. Support for this hypothesis comes from an unexpected result from an assay of cellulase activity in the sediments collected in January. We found that the cellulae activity in the oiled trays was higher than that found in the controls and that the level of activity was related to the length of time that the sediment had been exposed to crude oil. The question then arises; why should the cellulase activity increase in a system that is stressed with crude oil? The answer may come from a set of observations reported by Goodrich and Morita (1977). They reported that chitinase activity was very low in inshore sediments but higher offshore. They also reported very high levels of chitinase activity in the guts of fish. It would appear that most of the free chitin produced in the inshore environment was being consumed by higher forms and mineralized in their guts (by gut bacteria). In the offshore communities, more of the chitin found its way into the sediments and thus there was a microbial population present which produced chitinase. There may be an analogous situation in the oiled sediment trays. Higher organisms are normally present that would utilize the cellulose that come into contact with the sediments leaving very little to be utilized directly by sediment bacteria. If these organisms are eliminated by the presence of crude oil, more cellulose would be present in the sediments for utilization by the bacteria present. Of course there is also another simpler explanation and that is that the crude oil has selected for microbial population that just happens to produce unusually high levels of cellulase. Regardless of the mechanisms involved, the fact remains that the microbial population has been altered by the presence of crude oil.

C. The effects of the dispersant Corexit 9527 and/or crude oil on microbial function

Because the dispersant Corexit 9527 is stockpiled for possible use in the caes of an oil spill in Cook Inlet, we have conducted experiments designed to measure its effects on a number of microbial functions. The effects of Corexit and Corexit and crude oil on substrate uptake by marine microorganisms has been investigated during several studies (Tables 8, 11 and 14-18). These data can be summarized as follows. Corexit 9527 at 15 ppm had roughly the same adverse effect on glucose and glutamic acid uptake by marine microorganisms as did crude oil alone (Table 14). The combination of crude oil and Corexit decreased uptake even further in all cases. The effect of Corexit on uptake rates is concentration dependent; i.e., the effect at 150 ppm is greater than at 15 ppm (Table 11). The mode of action appears to be similar to that of crude oil (Table 11). Since Corexit by itself has an effect, the effect of Corexit and oil cannot be attributed to its action on the oil; i.e. increasing the contact between crude oil and the organisms present.

Similar observations have also been made on the effects of crude oil and Corexit on protozoan feeding rates and protozoan growth rates. There is an adverse effect which is concentration dependent. These data all suggest that this dispersant may have properties which would make its application under certain conditions undesirable.

D. Concentrations of ATP, ADP, and AMP in marine sediments

The concentration of ATP, ADP, and AMP were measured in eight sediment samples collected during the summer Beaufort Sea field study and in five sediment samples collected during the January, 1979 Elson Lagoon study (Table 21). Several trends were noted. As previously mentioned, the total concentration of adenylates was much higher in the nontreated control sediments than in the oiled sediments. The energy charge was much higher in the summer than in the winter indicating that the benthic organisms were metabolically more active in the summer than in the winter. This observation is what one would expect from everything that is known about seasonal differences in Beaufort Sea sediments. In our previous annual reports we have discussed this phenomenon in some detail. Not only was there a seasonal difference observed in the energy charge but there was also a difference observed in the total concentration of adenylates as well. In non-oiled Elson Lagoon summer sediments, the concentration of total adenylates was 10 times higher than that observed in the winter sediments from the same area. These data suggest that there are seasonal changes in the physiology and the total biomass within the benthic community.

E. Nitrogen fixation rates in marine sediments

The data that we have accumulated to date suggest that nitrogen fixation rates are not adversly affected by short-term exposure to crude oil. This is also the conclusion of Knowles and Wishart (1977). There were not consistant geographical patterns of nitrogen fixation rates observed in the Beaufort Sea sediments. However the average rate was close to the average rate observed in the Cook Inlet sediments. The pattern of nitrogen fixation rates in the Cook Inlet was similar to that which we have observed in the past (Fig. 16).

VIII. Conclusions

1. Crude oil has an adverse effect on the utilization of organic nutrients by heterotrophic microorganisms present in seawater. The mode of action is similar to classical non-competitive inhibition in enzyme systems. The presence of crude oil constitutes an environmental stress which probably reduces the diversity of the microbial population present. In the long run this would act to alter microbial function.

2. Crude oil also decreases both protozoan growth rates and feeding rates when cropping bacteria. This observation opens the possibility that crude oil may interfer with certain key components of the food chain.

3. Crude oil decreases the concentration of total adenylates (ATP, ADT, and AMP) in Elson Lagoon sediments exposed to crude oil for periods over 3 months. This observation also implies that crude oil may interfere with various components of the detrital food chain.

4. The dispersant Corexit 9527 by itself has an adverse effect on the utilization of organic nutrientes by heterotrophic microorganisms when applied at a concentration of 15 ppm. When the concentration is increased, the effect is increased. The mode of action appears to be similar to that observed in crude oil experiments. Corexit also has an adverse effect on protozoan growth and feeding rates. When marine microorganisms are exposed to both Corexit and crude oil, the above mentioned effects are intensified. More data needs to be accumulated to better define the effects of Corexit on microbial populations; however, from what we know now, we suggest that caution be used when this chemical is added to the environment.

5. The degree to which crude oil effects the uptake of glucose by microorganisms in seawater may reflect the prior exposure of that watermass to crude oil or petroleum products thus making it potentially useful as an assay technique.

6. Results from our work in the Beaufort Sea and the Cook Inlet suggest that measurements of relative microbial activity and percent respiration may be used to characterize water masses which are influenced by the presence of terrestrial runoff.

7. The different water masses on the east and west sides of Cook Inlet may, in part, cause the wide differences in flora and fauna found in these two areas.

8. The adenylate data that we have collected in Elson Lagoon sediments suggest that there are large seasonal changes in the total biomass and the degree of metabolic activity in the benthic community. Both the total biomass and the level of microbial activity in winter sediment was about 10% of that found in the summer. These data suggest that most biological activity is greatly reduced during the winter months in the Beaufort Sea.

IX. Needs for further study

A. Food web studies

During the last 6 months, our main effort has been directed toward establishing the methodology required to study the effects of crude oil on microbial function within the food web and establishing a laboratory at Kasistna Bay which would contain all of the equipment and supplies required to conduct these studies. During our first study period in Feb., 1979, we initiated these studies by putting down 18 trays containing treated sediment and by setting up four aquaria which also contained treated sediment. As things stand now, we are scheduled for only two more field studies (one in April and one in July-August). It is imperative that these studies be permitted to continue through FY80. The continuation of these studies will allow us to follow seasonal changes throughout at least one cycle and it will allow enough time to elapse so that changes which occur over an extended time period can be detected. If we are not permitted to continue these studies past the current fiscal year, most of the potentially useful information that this study is designed to provide will be lost.

We also recommend that the Elson Lagoon oiled tray experiment in the Beaufort Sea be funded to continue through FY80. Now that we have the capability to assay a large number of microbial functions, it would be very useful to analyze oiled sediments from the Beaufort Sea as well as those from the Cook Inlet. During the January, 1979 Elson Lagoon sampling period, we expanded our observations to include ATP, ADP, and AMP measurements and measurements of cellulase activity in these sediments. All of these measurements showed crude oil effects on the microbial populations that have never before been observed. As time progresses, we will make different types of measurements which will further clarify the effects of crude oil on marine sediment microbial populations collected from this extreme environment.

B. Studies of microbial function in Norton Sound and Bristol Bay

As of now, there is no information on the microbiology of these areas which are future potential lease sites. There is a cruise planned this summer in the Norton Sound but much more work will have to be continued after that initial study.

C. Studies on the effects of the dispersant Corexit 9527 on microbial function

We recommended that we be permitted to continue our studies on the effects of Corexit 9527 on microbial function in the marine environment. This is the dispersant that is currently stockpiled for use in both the Cook Inlet and Prince William Sound. Our preliminary experimental results indicate that this compound may adversely effect several microbial processes. We feel that the results of these preliminary studies justify continued investigation into the problem.

X. Summary of the January-March quarter

A. Field studies

During this quarter, we conducted one series of observations on the oiled sediments of Elson Lagoon in January and another set of observations on the samples collected near the Kasitsna Bay laboratory in Feb. While at NARL we analyzed 5 sediment samples and 3 water samples.

We conducted operations at the Kasitsna Bay laboratory for 6 weeks. During that time we set up the laboratory equipment and supplies, checked out our assays and the operation of all major equipment. We also put down a total of 18 trays of sediment which had been treated in various ways and we set up four aquaria containing sediment. These aquaria were connected to a seawater flow system which maintained the low temperature of the sediments and insured fresh supplies of O_2 and nutrients. Work at this facility will continue during the month of April.

B. Laboratory studies

During this quarter, we analyzed the data collected in the field during both field periods and we continued our preparation for the studies at the Kasitsna Bay laboratory. We also conducted tests on the effects of crude oil and Corexit on both feeding and growth rates in a population of marine ciliates. The results of these studies and the initial Kasitsna Bay work will be reported in the next quarterly report.

C. Scientific staff

Dr. Robert Griffiths, Co-Principal Investigator
Dr. Richard Y. Morita, Co-Principal Investigator
Mr. Thomas McNamara, Technician (Research Assistant, Unclassified)
Mr. Bruce Caldwell, " " " "

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Table 1. Summary of station numbers, station position, water column depth, and salinity and temperature measurements made during the April, 1978 Cook Inlet cruise.

Station #	Sample #	Temp.		Salinity		Lat.	Long.	Depth.
		Surf.	Bottom	Surf.	Bottom			
330	GW601	4.47	4.48	32.222	32.227	56 22.3	154 17.9	44
331	GW602	3.52	3.51	32.059	32.065	56 46.0	154 20.3	52
333	GW603	4.88	4.46	31.973	32.418	57 04.2	155 01.2	188
358	GW604	4.45	4.51	32.049	32.397	57 18.1	154 56.0	148
350	GW605	4.42	4.57	31.903	32.470	57 31.2	155 33.8	265
360	GW606	4.44	4.51	31.766	32.406	57 56.2	154 40.6	228
368	GW607	4.59	4.38	32.134	32.291	57 43.9	154 09.0	53
378	GW608	4.93	4.62	32.108	32.392	58 01.3	153 29.6	82
370	GW609	3.97	4.65	31.468	31.977	58 17.2	154 01.9	112
380	GW610	3.88	3.99	31.425	31.500	58 38.9	153 24.7	-
394	GW611	4.55	4.67	31.928	32.281	58 40.9	153 00.5	153
388	GW612	4.93	4.58	32.026	32.420	58 27.2	152 58.0	215
395	GW613	4.73	4.70	31.915	32.247	58 53.2	152 54.9	166
207	GW614	4.77	4.80	31.980	32.120	58 59.9	152 53.3	166
390	GW615	3.81	4.67	31.262	32.121	58 52.7	153 11.1	170
229	GW616	4.66	4.17	31.557	31.688	59 39.9	151 14.8	38
249	GW617	-	-	31.854	-	59 51.3	152 01.6	40
246	GW618	-	-	31.749	-	60 05.5	151 45.7	33
266	GW619	-	-	27.266	-	60 42.7	151 25.5	43
265	GW620	-	-	29.993	-	60 34.9	151 41.9	16
255	GW621	3.26	3.25	30.023	30.026	60 19.3	151 46.5	42
242	GW622	3.72	3.69	30.778	30.781	60 09.0	152 25.7	36
245	GW623	3.78	3.78	30.574	30.756	60 06.3	152 15.5	84
247	GW624	3.96	3.97	30.741	30.755	59 58.1	152 34.4	21
233	GW625	3.87	3.88	31.022	31.023	59 49.7	152 56.0	15
248	GW626	3.76	4.38	30.948	29.663	50 50.1	152 24.2	70
203	GW627	4.08	3.99	29.987	31.085	59 06.3	153 27.8	41
201	GW628	4.29	4.26	30.708	30.739	59 12.5	153 52.9	20
204	GW629	3.89	3.89	31.228	31.232	59 14.1	153 39.5	34
214	GW630	4.08	4.26	31.512	31.666	59 17.9	153 13.2	53
211	GW631	4.01	4.03	31.255	31.300	59 26.1	153 37.0	20
212	GW632	4.00	4.02	31.243	31.273	59 32.7	153 20.9	26
*V	GW633	4.0	-	30.5	-	60 13.4	152 45.6	-
*U	GW634	4.0	-	29.0	-	60 12.8	152 36.0	-
234	GW635	4.14	4.13	31.277	31.276	59 37.8	152 55.8	36
213	GW636	4.20	4.16	31.354	31.362	59 29.6	153 13.9	33
225	GW637	4.43	4.46	31.734	31.743	59 31.5	152 39.6	61
235	GW638	4.11	4.19	31.157	31.225	59 42.6	152 37.3	39
236	GW639	4.79	4.79	31.909	31.888	59 41.7	152 14.2	37
226	GW640	4.73	4.74	31.909	31.903	59 32.8	152 18.3	49
216	GW641	4.81	4.81	31.917	31.936	59 18.1	152 15.4	80
205	GW642	4.81	4.89	31.884	32.034	59 06.7	152 40.0	140
206	GW643	4.81	4.88	31.871	31.971	59 08.7	153 05.0	84
390	GW644	4.44	4.98	31.544	32.104	58 53.4	153 11.6	62
398	GW645	5.09	5.01	32.203	32.249	58 49.0	152 12.3	126

Table 1. (Cont'd)

Station #	Sample #	Temp. Surf.	Temp. Bottom	Salinity Surf.	Salinity Bottom	Lat.	Long.	Depth.
105	GW646	5.04	5.11	32.100	32.430	58 49.7	151 19.3	118
106	GW647	4.92	5.11	31.920	32.311	59 00.6	152 01.2	201
*AA	GW648	5.0	-	28.0	-	59 39.5	153 16.5	-
*AW	GW649	5.5	-	27.2	-	59 38.0	153 37.8	-
*M	GW650	8.0	-	27.6	-	59 43.3	153 22.6	-
*J	GW651	4.0	-	31.2	-	59 34.6	151 11.0	-
229A	GW652	5.99	4.29	31.426	31.778	59 37.8	151 18.4	64
CB1	GW653	4.40	4.37	31.368	31.369	59 13.7	153 40.1	31
CB2	GW654	-	-	-	-	59 16.6	153 20.3	36
CB3	GW655	-	-	31.875	-	59 19.9	152 58.3	-
CB4	GW656	-	-	31.940	-	59 23.3	152 38.7	-
CB5	GW657	-	-	31.965	-	59 25.6	152 19.4	-
CB6	GW658	-	-	31.850	-	59 31.9	512 00.6	-
CB7	GW659	5.60	4.84	31.774	31.836	59 35.4	151 45.9	51
CB7	GW660	5.32	5.13	31.765	31.790	59 35.4	151 45.9	51
CB7	GW661	5.76	4.92	31.778	31.836	59 35.4	151 45.9	51
*AB	GW662	5.0	-	29.5	-	59 27.6	151 43.2	-
CB7	GW663	5.30	5.11	31.769	31.790	59 35.4	151 45.9	51
CB7	GW664	5.73	4.87	31.776	31.832	59 35.4	151 45.9	51
CB7	GW665	5.42	5.15	31.688	31.790	59 35.4	151 45.9	51
CB7	GW666	5.87	4.97	31.809	31.839	59 35.4	151 45.9	51
CB7	GW667	5.37	5.20	31.766	31.796	59 35.4	151 45.9	51
CB7	GW668	5.54	5.08	31.798	31.826	59 35.4	151 45.9	51
*K	GW669	6.0	-	29.0	-	59 36.5	151 25.5	-
CB10	GW670	4.11	4.11	29.514	29.509	60 31.5	151 30.9	24
CB10	GW671	-	-	-	-	60 31.5	151 30.9	24
CB10	GW672	4.19	4.12	29.579	29.559	60 31.5	151 30.9	24
CB10	GW673	4.41	4.30	29.277	29.262	60 31.5	151 30.9	24
CB10	GW674	4.24	4.24	29.480	29.482	60 31.5	151 30.9	24
CB9	GW675	4.70	4.70	30.664	30.661	60 28.2	152 12.2	37
CB9	GW676	4.70	4.70	30.442	30.474	60 28.2	152 12.2	37
CB9	GW677	4.92	4.75	30.461	30.681	60 28.2	512 12.2	37
CB9	GW678	4.77	4.74	30.522	30.479	60 28.2	152 12.2	37
CB9	GW679	4.81	4.82	30.639	30.644	60 28.2	152 12.2	37
CB9	GW680	4.94	4.78	30.220	30.595	60 28.2	152 12.2	37
CB9	GW681	4.89	4.84	30.529	30.634	60 28.2	152 12.2	37
CB9	GW682	4.84	4.77	30.364	30.480	60 28.2	152 12.2	37
CB9	GW683	5.12	4.91	30.474	30.619	60 28.2	152 12.2	37

*Shore stations

Table 2. Station locations, surface water temperature and salinity and the water column depth at each station sampled during the North Wind cruise.

Station Number	Horner Station Number	Temp C°	Sample Number	Salinity o/oo	Water Depth (Meters)	Lat. North	Long. West
3		3.0	BW601	25.6	3	71 22	156 21
3		2.0	BW604	26.0	3	"	"
3		2.0	BW606	25.0	3	"	"
3		1.0	BW608	-	3	"	"
609		-0.7	BW609	21.5	21	70 36	147 38.7
610	16		BW610	23.5	25	70 29.6	147 23
611			BW611	19.8	5	70 28	147 58
612		2.5	BW612	-	5	70 22	148 08
613	17		BW613	23.9		70 21.9	146 51.7
614		3.0	BW614	26.5	3	70 19	147 35
615		4.0	BW615	27.0	3	70 13	147 17
616	18		BW616	25.5	23	70 14.5	145 51.5
617		1.5	BW617	27.0	1	70 10.5	145 55
618		1.5	BW618	25.0	2	70 05	145 29
619		3.5	BW619	26.3	2.5	69 59	144 54
620	19		BW620		24	70 13	143 20
621		2.0	BW621	28.2	3	70.09	143 21
622	20		BW622	27.1	3	69 59	142 16
623		2.0	BW623	24.0	5	69 56	142 19
624		2.0	BW624	26.0	9	69 57	142 20
625	21		BW625	24.1	2200	71 08	142 03
626	22		BW626	27.5	21	69 47	141 26
627		6.0	BW627	25.9	4	69 41	141 16
628			BW628	27.4	5	69 49	141 51
629		3.0	BW629	28.0	19	70 08	142 49
630	23	4.4	BW630	25.8	54	70 26	143 42
631	24		BW631	24.1	60	70 28	143 42
632	25		BW632	27.2	31	70 15	143 48
633			BW633	24.1	20	70 09	144 47.5
634	27		BW634	26.0	17	70 19	146 30
635	29		BW635	23.5	60	71 01	146 55
636	30		BW636	17.5	24	70 46	148 34
637	31	BW637	BW637	20.9		70 35.8	148 04
638		-05	BW638	28.3	4	70 26	148 24
639		2.5	BW639	18.2	1	70.20.5	148 19.0
640	32		BW640	12.8	24	70 47.0	149 36.4
641	33		BW641	27.0	290	17 14.3	140 33.5
642	34		BW64]	25.1	24	70 52	150 16
643		2.0	BW643	28.2	2	70 31.5	149 34
644		3.0	BW644	-	4	70 31	150 00
645		4.0	BW645	-	2	70 30	150 14
646	35		BW646	26.7	18	71 01.0	150 25.0

Table 3. Relative levels of microbial activity and percent respiration of glucose in water samples collected in the Cook Inlet during the April cruise. A comparison is made between samples that had been exposed to crude oil and those that were not exposed.

Sample number	Station number	*Glucose Uptake No Oil	Oil	Percent Respiration No Oil	Oil	@Tide State
GW601	330	30.9		32		
°GW602	331	0.5		29		
GW603	333	0.3		34		
GW604	358	0.8		40		
GW605	350	0.1		11		
GW606	360	0.7		28		
GW607	368	1.8		38		
GW608	378	4.9		37		
GW609	370	0.8		40		
GW610	380	0.3		36		
GW611	394	0.5		36		
GW612	388	9.3		38		
GW613	395	0.6		34		
GW614	207	0.6		42		
GW615	390	0.7		26		
GW616	229	3.1		44		
GW617	249	2.8	1.2	31	32	
GW618	246	2.6	1.5	30	35	
GW619	266	1.4	2.0	14	16	
GW620	265	2.9	2.6	15	15	
GW621	255	5.5	2.4	12	18	
GW622	242	1.4	0.7	19	24	
GW623	245	1.3	0.8	18	17	
GW624	247	3.5	1.1	14	26	
GW625	233	1.0	0.6	18	25	
GW626	248	1.3	0.6	16	21	
GW627	203	2.0	1.1	49	38	
GW628	201	6.4	3.7	31	31	
GW629	204	5.2	0.3	84	15	
GW630	214	0.5	0.2	24	18	
GW631	211	1.4	0.3	14	28	
GW632	212	0.7	0.3	14	17	
GW633	V	22.8	3.3	22	27	
GW634	U	1.3	0.4	18	29	
GW635	234	0.8	0.3	15	31	
GW636	213	0.5	0.3	17	20	
GW637	225	0.8	0.5	35	28	
GW638	235	0.1	0.2	17	10	
GW639	204	0.2	0.2	24	16	
GW640	226	0.1	0.2	17	7	

Table 3. (Cont'd) (glucose uptake)

Sample number	Station number	*Glucose Uptake No Oil	Oil	Percent Respiration No Oil	Oil	@T St
GW641	216	0.2	0.5	31	12	
GW642	205	0.1		49		
GW643	206	0.2		53		
GW644	390	0.5	0.4	28	15	
GW645	398	0.5	0.3	46	30	
GW646	105	0.2		51		
GW647	106	1.2		39		
GW648	AA	0.7	0.8	24	48	
GW649	AW	3.8	1.5	34	35	
GW650	M	75.6		23		
GW651	J	43.3	40.8	36	36	
GW652	229a	20.1	8.0	40	44	
GW653	CB1	1.3	0.6	14	23	
GW654	CB2	1.1		43		
GW655	CB3	4.0		38		
GW656	CB4	8.6		30		
GW657	CB5	0.9		19		
GW658	CB6	5.9		34		
GW659	CB7	23.8		50		H
°GW660	CB7	153		41		L
°GW661	CB7	102		46		H
GW662	AB	6.0		35		
GW663	CB7	24.6		49		L
°GW664	CB7	40.9		48		H
GW665	CB7	10.3		81		L
GW666	CB7	8.5		23		H
GW667	CB7	13.3		44		L
°GW668	CB7	53.3		47		H
GW669	K	109		38		
GW670	CB10	34.2		7		H
GW671	CB10	21.6		12		L
GW672	CB10	14.0		12		H
GW673	CB10	12.1		13		L
GW674	CB10					H
GW675	CB9					H
GW676	CB9	3.1		16		L
GW677	CB9	4.3		18		H

*Glucose uptake rates reported as ng glucose/liter/h.
°These samples appear to have been contaminated by the ship's effluent.
@The tide state reported for the time series stations only. H - high slack tide. L = low slack tide.

Table 4. Relative levels of microbial activity and percent respiration of glutamic acid in water samples collected in the Cook Inlet during the April cruise. A comparison is made between samples that had been exposed to crude oil and those that were not exposed.

Sample number	Station number	*Glutamate Uptake		Percent Respiration		@Tide state
		No Oil	Oil	No Oil	Oil	
°GW601	330	20.7		66		
GW602	331	1.0		67		
GW603	333	1.0		80		
GW604	358	0.5		80		
GW605	350	0.2		43		
GW606	360	1.5		73		
GW607	368	6.6		69		
GW608	378	7.0		60		
GW609	370	1.7		65		
GW610	380	0.4		65		
GW611	394	1.9		61		
GW612	388	8.1		70		
GW613	395	2.5		62		
GW614	207	1.9		71		
GW615	390	2.3		50		
GW616	229	4.8		64		
GW617	249	10.8		61		
GW618	246	2.9		64		
GW619	266	3.0		41		
GW620	265	11.2		32		
GW621	255	11.4		37		
GW622	242	2.4		43		
GW623	245	2.7		35		
GW624	247	12.7		33		
GW625	233	2.4		36		
GW626	248	4.2		32		
GW627	203	0.6		34		
GW628	201	6.1		45		
GW629	204	0.5		15		
GW630	214	1.7		49		
GW631	211	3.8		36		
GW632	212	3.8		32		
GW633	V	149		52		
GW634	U	3.7		58		
GW635	234	3.2		33		
GW636	213	3.5		33		
GW637	225	0.9		67		
GW638	235	0.3		50		
GW639	204	0.2		53		
GW640	226	0.1		32		

Table 4. (Cont'd)

Sample number	Station number	*Glutamate Uptake		Percent Respiration		@Tid sta
		No Oil	Oil	No Oil	Oil	
GW641	216	0.2		57		
GW642	205	0.2		52		
GW643	206	0.2		64		
GW644	390	0.9		66		
GW645	398	1.1		66		
GW646	105	0.2		41		
GW647	106	4.4		59		
GW648	AA	1.7	1.5	38	59	
GW649	AW	10.0	3.3	50	61	
GW650	M	143		50		
GW651	J	93.2	43.5	57	62	
GW652	229a	33.3	15.8	61	66	
GW653	CB1	2.5	1.3	52	57	
GW654	CB2	4.3	2.6	57	55	
GW655	CB3	7.2	4.3	59	49	
GW656	CB4	24.6	18.1	58	54	
GW657	CB5	6.8	10.0	66	51	
GW658	CB6	15.1	11.4	61	25	
GW659	CB7	10.0	5.6	66	74	H
°GW660	CB7	71.9	24.3	63	71	L
°GW661	CB7	63.3	27.8	65	77	H
GW662	AB	9.9	5.8	63	71	
GW663	CB7	17.7	6.5	64	75	L
GW664	CB7	17.2	12.7	67	74	H
GW665	CB7	13.4	9.7	82	84	L
GW666	CB7	10.2	7.1	50	53	H
GW667	CB7	20.2	10.9	64	73	L
°GW668	CB7	33.5	17.3	66	72	H
GW669	K	103	40.7	59	67	
GW670	CB10	58.3	51.0	39	37	H
GW671	CB10	61.1	34.2	33	40	L
GW672	CB10	69.4	40.5	33	42	H
GW673	CB10	81.2	62.3	32	37	L
GW674	CB10	94.8	83.4	31	31	H
GW675	CB9	21.7	21.7	30	33	H
GW676	CB9	9.7	9.5	36	22	L
GW677	CB9	15.1	5.8	41	43	H
GW678	CB9	21.0	23.5	37	40	L
GW679	CB9	15.0	11.4	41	47	H
GW680	CB9	9.7	4.1	51	58	L
GW681	CB9	2.5	2.3	59	60	H
GW682	CB9	4.6	4.4	48	48	L
°GW683	CB9	30.1	14.1	34	45	H

*Glutamic acid uptake rates reported as ng glutamate/liter/h.

°These samples appear to have been contaminated by the ship's effluent.

@The tide state reported for the time series stations only. H = high slack tide. L = low slack tide.

Table 5. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all water samples collected during the summer, 1978 Beaufort Sea field studies.

	Glucose		Glutamic Acid	
Sample Number	*Uptake	Percent Respiration	*Uptake	Percent Respiration
BW601	15.6	27	34.3	54
BW604	2.3	36	4.6	59
BW606	43.9	18	21.6	56
BW608	12.1	31	10.9	59
BW609	3.4	29	44.1	53
BW610	10.9	25	12.2	57
BW611	4.3	31	20.3	51
BW612	11.3	29	36.4	62
BW613	14.8	30	11.6	56
BW614	6.9	33	6.9	60
BW615	3.4	38	12.7	71
BW616	4.3	41	19.0	66
BW617	4.8	34	9.7	61
BW618	3.5	37	3.9	66
BW619	3.5	41	3.2	62
BW620	3.0	34	18.6	48
BW621	14.9	27	9.8	63
BW622	6.9	33	9.6	51
BW623	4.5	30	8.2	59
BW624	5.6	38	14.1	59
BW625	6.0	24	3.6	77
BW626	¢26.5		20.6	
BW627	¢13.0		0.7	
BW628	¢ 4.0		11.3	
BW629	3.3	42	1.5	59
BW630	0.9	19	5.4	69
BW631	2.1	29	6.3	71
BW632	3.5	47	4.8	81
BW634	3.1	54	4.8	65
BW635	0.6	51	3.0	73
BW636	4.2	26	11.4	64
BW638	1.7	57	3.2	73
BW638	3.1	57	3.2	73
BW639	4.0	48	8.1	60
BW640	7.7	45	16.4	69
BW641	2.4	42	9.6	64
BW642	5.3	44	15.6	66
BW643	4.3	26	38.7	44
BW644	26.2	29	40.9	53
BW645	18.1	22	38.7	44
BW646	9.9	40	13.2	67

* These values are reported as ng/liter/h.

¢ These are estimates of total uptake using cell data and average percent respiration.

Table 6. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all sediment samples collected during the summer, 1978 Beaufort Sea Field studies.

	Glucose		Glutamic Acid	
Sample Number	*Uptake	Percent Respiration	*Uptake	Percent Respiration
BB601	2.7	29	19	54
BB602	1.5	57	9	54
BB603	1.3	32	8	59
BB604	9.9	22	251	59
BB605	6.9	23	96	
BB606	9.5	24	84	46
BB607	13.2		161	46
BB608	8.4	26	187	45
BB609	6.7	24	58	49
BB610	0.2		19	49
BB611	7.5	36	129	52
BB612	7.4	31	113	47
BB613	4.6	29	35	59
BB614	4.2	33	75	49
BB615	23.4	23	113	46
BB616	3.2	28	32	60
BB617	14.1	27	20	75
BB618	4.7	40	65	67
BB619	4.6	29	197	49
BB622	49.2	35	188	64
BB624	31.8	41	155	62
BB626	¢ 6.5		45	
BB627	¢17.0		88	
BB630	7.7	25	143	56
BB631	1.3	24	86	56
BB632	1.6	32	16	46
BB633	18.0	36	104	64
BB634	1.5	40	17	48
BB635	2.2	35	45	48
BB636	0.7	30	7	34
BB638	2.8	27	38	40
BB640	13.8	36	139	50
BB641	3.7	26	161	46
BB642	18.1	39	99	53
BB643	9.7	21	262	52
BB644	23.8	28	179	47
BB645	3.7	28	54	50
BB646	3.7	26	161	46

* These values are reported at ng/g dry wt./h.

¢ These are estimates of total uptake using cell data and the average percent respiration.

Table 7. Relative levels of microbial activity and percent respiration of glucose and glutamic acid in sediment and water samples collected in Elson Lagoon in April, 1978.

A. Glucose

	*Substrate Uptake		Percent Respiration		
Sample number	No Oil	Oil	No Oil	Oil	Sample Treatment
BB501	3.2	2.7	29	28	Oiled 3 months
BB502	3.4	3.5	40	34	No oil control
BB503	12.2	9.4	19	19	Oil 0 time
BB504	1.7	3.7	43	38	Oil 24 hours
BB505	10.5	2.0	43	24	Oil 72 hours
BW501	0.3	0.3	43	35	
BW502	0.3	0.3	47	37	
BW503	0.1	0.1	42	31	

B. Glutamic acid

BB501	393	358	62	54	Oiled 3 months
BB502	128	160	52	44	No oil control
BB503	479	598	44	36	Oil 0 time
BB504	76	89	52	41	Oil 24 hours
BB505	95	72	60	60	Oil 72 hours
BW501	0.6	0.5	64	65	
BW502	0.4	0.4	60	60	

*Substrate uptake reported as ng substrate/unit/h. In sediment samples, the unit is one gram dry weight and in water it is one liter.

Table 8. Relative levels of microbial activity and percent respiration in samples collected in Elson Lagoon during the January, 1979 field study. The effects of crude oil and Corexit treatments were measured in all samples.

A. Glucose

Sample number	*Substrate Uptake No. Oil	Oil	Corexit	Corexit + Oil	Percent Respiration No Oil	Oil	Corexit	Corexit + Oil	Sample Treatment
BB701	0.76	0.72	0.54	0.51	71	66	79	88	Oiled 6 months
BB702	0.79	0.73	0.50	0.45	59	55	56	66	Oiled 12 months
BB703	2.38	2.08	1.92	1.44	49	36	46	42	Control
BB704	3.71	3.44	2.64	2.10	47	38	49	42	Control
BB705	0.55	0.40	0.39	0.29	50	56	55	69	BB704 + Oil (0 time)
BB706	0.96	1.26	0.81	0.60	61	44	57	53	BB704 + Oil (24 hr.)
BW701	0.178	0.056	0.053	0.00	26	47	6	0	
BW702	0.178	0.040	0.072	---	26	46	16	-	

B. Glutamic acid

Sample number	*Substrate Uptake No. Oil	Oil	Corexit	Corexit + Oil	Percent Respiration No Oil	Oil	Corexit	Corexit + Oil	Sample Treatment
BB701	1.83				90				Given above
BB702	3.02				81				
BB703	7.07				74				
BB704	7.86				78				
BB705	1.74				77				
BB706	3.71				77				
BW701	0.58				66				
BW702	2.72				88				

*Substrate uptake reported as ng substrate/unit/n. In sediment samples, the unit is one gram dry weight and in water it is one liter.

Table 9. Relative levels of microbial activity and percent respiration of glucose in sediment samples collected in the Cook Inlet during the April cruise. A comparison is made between samples that had been exposed to crude oil and those that were not exposed.

		*Glucose Uptake		Percent Respiration	
Sample number	Station number	No Oil	Oil	No Oil	Oil
GB602	331	0.3	0.9	22	20
GB603	333	0.3	0.3	28	20
GB604	358	0.2	0.3	28	22
GB605	350	0.2	0.8	32	4
GB606	360	1.5	2.6	66	16
GB607	368	1.1	0.8	32	33
GB609	370	2.8	1.8	42	36
GB610	380	0.8	0.8	27	27
GB611	394	0.3	0.4	43	30
GB612	388	0.1	0.7	26	30
GB613	395	0.5	0.9	24	11
GB614	207	2.2	0.9	30	31
GB616	229a	0.9	1.1	38	24
GB625	233	0.6	0.5	35	33
GB627	203	2.9	3.4	28	33
GB628	201	38.4	26.7	10	36
GB629	204	0.3	0.4	22	18
GB630	214	3.6	3.5	21	21
GB632	212	3.5	2.3	28	27
GB633	V	2.6	1.6	43	30
GB634	U	0.4	0.4	39	25
GB636	213	2.9	2.4	25	25
GB644	390	2.5	1.8	29	38
GB649	AW	16.4	14.5	27	31
GB650	M	17.8		33	
GB652	229	22.9	23.5	22	19
GB653	CB1	4.5	4.3	30	21
GB654	CB2	6.5		33	
GB660	CB7	4.9		26	
GB669	K	165		19	

*Glucose uptake reported in ng glucose/g dry wt. sediment/h.

Table 10. Relative levels of microbial activity and percent respiration of glutamic acid in sediment samples collected in the Cook Inlet during the April cruise. A comparison is made between samples that had been exposed to crude oil and those that were not exposed.

Sample number	Station number	*Glutamate Uptake No Oil	*Glutamate Uptake Oil	Percent Respiration No Oil	Percent Respiration Oil
GB602	331	7.7		55	
GB603	333	10.9		56	
GB604	358	6.0		61	
GB605	350	6.3		30	
GB606	360	24.3		66	
GB607	368	29		31	
GB609	370	20		43	
GB610	380	34		47	
GB611	394	8.9		41	
GB612	388	4.7		31	
GB613	395	15		45	
GB614	207	38		49	
GB616	229a	17		43	
GB625	233	10		49	
GB627	203	58		61	
GB628	201	495		43	
GB629	204	4.7		39	
GB630	214	67		41	
GB632	212	105		48	
GB633	V	126		51	
GB634	U	25		62	
GB636	213	56		43	
GB644	390	50		31	
GB649	AW	284	264	39	42
GB650	M	329		40	
GB652	229	380	427	42	36
GB653	CB1	48	41	46	47
GB654	CB2	67	51	49	52
GB660	CB7	92	54	56	59
GB669	K	1277	1374	51	43
GB677	CB9	595	229	41	43

*Glutamic acid uptake reported as ng glutamic acid/g dry wt sediment/h.

Table 11. The effects of crude oil and the dispersant Corexit on relative microbial activity in samples collected in Elson Lagoon April, 1978 and Cook Inlet April, 1978.

	Substrate						Percent Respiration		
Sample number	No Oil	Oil	Corexit (15ppm)	Corexit (150ppm)	Corexit (15ppm) + Oil	Corexit (150ppm) + Oil	No Oil	Corexit (15ppm) + Oil	Corexit (150ppm) + Oil
A. Elson Lagoon (Beaufort Sea) (Glucose)									
BB503	12.2	9.4	7.1	2.7	4.2	1.4	19	20	39
BB505	10.5	2.0	1.4	0.7	0.6	0.5	43	54	68
B. Elson Lagoon (Glutamic acid)									
BB503	479	598	612	410	327	112	44	40	64
BB505	95	72	45	14	54	35	60	53	65
C. Cook Inlet (Glutamic acid)									
GB652	380	427	496		416		42	34	
GB653	48	41	55		48		46	30	
GB669	1277	1374	1325		1325		51	43	
GB677	253	252	281		172		35	40	
GW649	10	3.3	2.0		1.2		50	53	
GW652	33	16	12		7		61	65	
GW672	69	41	49		26		33	43	
GW677	15.1	5.8	6.3		3.8		41	51	
GW682	4.6	4.4	4.4		2.5		48	59	
D. Cook Inlet (Glucose)									
GW648	0.7	0.8	0.1		0.2		24	8	
GW649	3.8	1.5	0.8		0.4		34	25	
GB649	16	14	18		21		27	23	

Table 12. Effects of crude oil on the kinetics of glucose and glutamic acid uptake in water and sediment samples.

A. Glucose (Elson Lagoon - Acidified cells)

	V_{max} (ng/unit/hr)		T_t (hour)		K_t+S_n (ng/unit/hr)	
Sample number	No Oil	Oil	No Oil	Oil	No Oil	Oil
BB501	8.2	7.3	2137	2115	17.6	16.9
BB502	9.6	7.3	1850	1458	17.9	10.7
BB503	3.5	7.1	345	407	4.7	2.9
BB504	8.6	6.8	1953	1534	16.9	10.5
BB505	9.3	2.1	786	2670	7.3	5.7
BW501	0.5	0.3	5617	2240	2.8	0.8
BW502	4.0	4.0	7319	5511	3.2	2.3
B. Glucose (Cook Inlet-Acidified Cells)						
GB649	30.7	24.6	234	299	7.2	7.4
GW648	1.4	1.2	3019	3258	4.5	4.0
C. Glutamic acid (Cook Inlet-Acidified Cells)						
GB649	210	160	149	86	31	14
GB652	250	220	198	105	50	23
GB653	40	30	23	95	1	3
GB669	590	660	32	37	19	25
GB677	170	190	119	123	20	23
GW649	9.7	5.8	97	674	1.0	3.9
GW652	79	21	94	121	7.5	2.5
GW672	150	80	45	71	6.8	5.6
GW677	19	11	103	262	2.0	3.0
GW682	9	9	559	527	4.9	4.6
D. Glutamic acid (Cook Inlet-Non Acidified cells)						
GB649	340	340	111	174	38	59
GB652	370	350	77	59	29	21
GB653	140	190	655	668	92	126
GB669	830	1050	12	18	10	19
GB677	300	350	124	111	37	38
GW648	5	4	1073	1715	5.8	7.1
GW649	10	6	97	674	0.9	3.9
GW652	110	90	31	58	3.4	5.3
GW672	180	130	20	24	3.6	3.2
GW677	30	30	72	120	2.4	3.6
GW682	20	10	93	120	2.0	1.6

Table 13. The effects of crude oil on the uptake and respiration of glucose and glutamic acid by natural marine microbial populations found in water and sediment samples taken from the Lower Cook Inlet and the Beaufort Sea. The percent reduction is reported as the mean value for all observations.

A. WATER

		GLUCOSE		GLUTAMIC ACID	
Study Area	Time	Percent Reduction	Number of Observations	Percent Reduction	Number of Observations
Beaufort	1/78	[¢]45	8		
Beaufort	4/78	0	3	0	2
Beaufort	9/78	52	40		
Lower Cook	11/77	[¢]41	21		
Lower Cook	4/78	45	32	33	35

B. SEDIMENT

Study Area	Time	Percent Reduction	Number of Observations	Percent Reduction	Number of Observations
Beaufort	9/77	[¢]35	20	[¢]33	20
Beaufort	4/78	24*	5	7*	5
Beaufort	9/78	32*	30		
Beaufort	1/79	12*	6		
Lower Cook	4/78	14*	26	18*	7

[¢] These values are for average percent reduction in respiration only.

[*] These differences were not significant at the 0.05 level.

In the Beaufort Sea studies, Prudhoe Bay crude oil was used and in the Lower Cook Inlet study, Lower Cook Inlet crude oil was used.

Table 14. The effects of crude oil, Corexit 9527, and crude oil plus Corexit 9527 on the uptake and respiration of glucose and glutamic acid in water and sediment samples collected in the Beaufort Sea and the Lower Cook Inlet. The final concentration of Corexit in these experiments was 15 ppm.

A. WATER

				AVERAGE PERCENT REDUCTION		
Study Area	Time	Number of Observations	Substrate	Crude Oil	Corexit 9527	Crude Oil + Corexit
Beaufort	9/78	14	glucose	52*	58*	76*
Lower Cook	4/78	2	glucose	30	83	80
Lower Cook	4/78	5	glutamate	40*	47*	74*
B. SEDIMENT						
Beaufort	4/78	2	glucose	52	65*	80*
Beaufort	4/78	2	glutamate	12	26	38
Beaufort	9/78	34	glucose	32*	15*	40*
Beaufort	1/79	6	glucose	12	26*	41*
Lower Cook	4/78	4	glutamate	4	0	8
Lower Cook	4/78	1	glucose	13	0	0

*These differences were significant at the 0.05 level.

Table 15. The percent reduction in glucose uptake in water samples collected in the Beaufort Sea during the summer, 1978 sampling season. The reductions were in response to the addition of Prudhoe Bay crude oil, Corexit 9527 at 15ppm or a combination of the two.

Sample Number	Crude Oil	Corexit 9527	Crude Oil + Corexit
BW601	58		
BW606	65	46	86
BW608	72	62	90
BW609	40		
BW610	28	54	88
BW611	39	38	69
BW612	50		
BW613	45		
BW614	59	78	91
BW615	51		
BW616	61	74	89
BW617	49		
BW618	55		
BW619	42		
BW620	38		
BW621	69	59	82
BW622	51		
BW623	68		
BW624	59	79	89
BW625	75		
BW626	61	65	72
BW627	71		
BW628	78	92	95
BW629	49		
BW630	41		
BW631	40	53	69
BW632	52		
BW633	-8		
BW634	60		
BW635	42	58	54
BW636	66		
BW637	31	48	71
BW638	61	59	80
BW640	86		
BW641	53		
BW642	40		
BW644	72		
BW645	88		
BW646	55		
	$\overline{X} = 52$	$\overline{X} = 58$	$\overline{X} = 76$
	$s = 20$	$s = 22$	$s = 20$
	$n = 40$	$n = 14$	$n = 14$

Table 16. The effects of crude oil, Corexit 9527, and a combination of the two on the kinetics of glucose uptake in water samples collected during the summer, 1978 Beaufort Sea field studies.

Sample Number		No Oil	Crude Oil	Corexit	Corexit + Oil
(1) Maximum Potential Uptake Rate (V_{max})					
BW611		12.4	4.3	3.8	2.5
BW614		10.8	3.7	3.1	1.2
BW616		5.7	2.1	1.2	0.9
BW619		8.1	2.7		
BW632		8.6	1.5		
BW644		38.7	6.6		
BW645		17.8	5.0		
	$\bar{x}$	14.6	3.7	2.7	1.5
(2) Turnover Time (T_t)					
BW611		306	597	1046	1337
BW614		286	480	1693	2000
BW616		429	689	697	1650
BW619		246	384		
BW644		58	35		
BW645		42	767		
	$\bar{x}$	177	492	1145	1662
(3) Transport Constant + Natural Substrate Concentration ($K_t + S_n$)					
BW611		3.8	2.6	4.0	3.4
BW614		3.1	1.8	5.2	2.5
BW616		2.5	1.5	0.9	1.5
BW619		2.0	1.1		
BW644		2.2	0.2		
BW645		0.8	3.9		
	$\bar{x}$	1.9	1.9	3.4	2.5

(1) = Values in ng/liter/h
(2) = Values in hours
(3) = Values in μg/liter

Table 17. The percent reduction in the amount of glucose taken up in sediment samples collected in the Beaufort Sea during the summer, 1978 sampling season. The reductions were in response to the addition of Prudhoe Bay crude oil, Corexit 9527 at 15 ppm or a combination of the two.

Sample Number	Crude Oil	Corexit 9527	Crude Oil + Corexit
BB601	28	28	23
BB602	3	18	9
BB603	0	26	0
BB604	18	21	20
BB605	9	20	34
BB606	15	19	21
BB607	11	33	37
BB608	21	9	9
BB611	58	5	60
BB612	43		
BB613	15		
BB614	14	27	48
BB615	83		
BB616	38	17	45
BB617	35		
BB618	48		
BB619	9		
BB622	6		
BB624	0	10	19
BB626	0	26	27
BB627	34		
BB630	52	21	36
BB631	46	6	49
BB632	9		
BB633	8		
BB634	36	38	45
BB635	12	4	13
BB636	53	20	60
BB638	68	0	62
BB640	2		
BB642	35		
BB643	25		
BB644	36		
BB645	33		
$\overline{X}$	32 ± 22 n = 34	15 ± 11 n = 12	40 ± 17 n = 12

Table 18. The effects of crude oil, Corexit 9527, and a combination of the two on the kinetics of glucose uptake in sediment samples collected during the summer, 1978 Beaufort Sea field studies.

(1) Maximum Potential Uptake Rate (V_{max})

Sample Number	No Oil	Crude Oil	Corexit	Corexit + Oil
BB601	7.9	4.6	5.1	5.1
BB602	6.1	3.7	4.2	4.2
BB605	31.2	36.0	26.8	17.6
BB607	59.9	42.6	41.3	42.4
BB611	21.1	10.0	19.8	11.8
BB614	15.1	12.8	9.6	5.5
BB616	7.4	3.5	11.1	4.3
BB632	4.3	3.4		
BB640	31.0	34.9		
BB645	8.6	3.0		
$\bar{X}$	22.8	16.3	16.8	13.0

(2) Turnover Time (T_t)

BB601	2490	2798	3552	3839
BB602	4598	3672	5149	4043
BB605	822	954	1025	1162
BB607	532	628	782	801
BB611	589	1132	582	1193
BB614	1589	1062	1869	2157
BB616	1033	1318	1987	1363
BB619	541	682		
BB632	2913	2337		
BB640	465	560		
BB644	224	264		
BB645	826	530		
$\bar{X}$	1385	1064	1666	1337

(3) Transport Constant + Natural Substrate Concentration

BB601	11.3	7.3	10.5	11.2
BB602	17.6	8.6	13.6	10.8
BB605	19.4	26.1	20.9	15.5
BB607	19.7	16.5	19.8	26.0
BB611	10.1	9.2	9.1	11.3
BB614	14.6	15.1	10.9	7.2
BB616	6.2	3.7	17.6	4.5
BB619	2.3	7.5		
BB632	7.3	4.8		
BB640	8.0	10.9		
BB644	12.2	7.2		
BB645	5.6	1.3		
$\bar{X}$	11.2	10.0	14.6	11.6

Table 19. Nitrogen fixation rates observed in sediment samples collected during the April, 1978 Cook Inlet cruise and the April, 1978 Elson Lagoon study.

A. Beaufort Sea, April, 1978 (Elson Lagoon)

	No Sucrose		Sucrose	
Sample #	No Oil	Oil	No Oil	Oil
BB501	1.9	1.7		
BB502	0.8	0.9		
BB503	1.4	0.6		
BB504	1.4	1.7		
BB505	0.9	0.9		
$\bar{x}$	1.3	1.2		

B. Cook Inlet, April, 1978

	No Sucrose		Sucrose	
Sample #	No Oil	Oil	No Oil	Oil
GB602	0.4	0.4	0.8	0.7
GB603	0.4	0.4	0.6	0.6
GB604	0.3	0.2		
GB605	0.8	0.6		
GB606	1.1	0.5	0.8	1.3
GB607	0.4	0.3		
GB609	0.3	0.2		
GB610	0.3	0.3	0.3	0.3
GB611	0.4	0.3		
GB612	0.3	0.4		
GB613	0.9	0.7		
GB614	0.6	0.4		
GB616	0.6	0.9	$ 2.6	0.5
GB625	0.1	0.1	0.3	0.1
GB627	<0.1			
GB628	<0.1			
GB629	<0.1			
GB630	0.15			
GB632	<0.1			
GB633	<0.1			
GB634	<0.1			
GB636	0.1			
GB644	0.15			
GB649	0.4			
GB652	1.1	1.2		
GB653	0.2			
GB654	0.5			
GB660	0.3	0.3		
GB669	2.2	2.1	1.3	1.1
$\bar{x}$	0.4	0.5	1.0	0.7

*All values reported as ng nitrogen fixed per g dry wt per h.
$This high value probably due to experimental error.

Table 20. Nitrogen fixation rates observed in sediment samples collected during the summer, 1978 Beaufort Sea cruise.

Sample Number	*No Oil	Oil
BB601	1.1	
BB602	0.4	
BB603	0.5	
BB604	0.4	
BB605	0.4	
BB606	0.3	
BB607	0.3	
BB608	0.5	0.6
BB609	0	
BB610	0	0
BB612	0.1	0.1
BB613	0.4	
BB615	0.1	
BB616	0.1	0
BB617	0.1	
BB619	0	0
BB622	1.4	
BB624	0.3	
BB626	0.1	0.1
BB627	0.1	0.1
BB630	0.3	
BB631	0.2	0.2
BB632	0.2	0.3
BB633	0.2	
BB634	0.1	
BB635	0.2	0.2
BB636	0.1	
BB640	0.2	0.2
BB641	0.1	0.1
BB642	0	
BB644	0.2	
BB645	0.1	0.1
Wood	4.9	4.2
$\bar{X}$	0.3 w/o wood	

* All values reported as ng nitrogen fixed per g dry wt. per h.

Table 21. Adenylate measurements made on sediment samples collected during the summer, 1978 Beaufort Sea study and in the Elson Lagoon in January, 1979.

A. Beaufort Sea, August, 1978

Sample Number	*ATP	*ADP	*AMP	Total Adenylate	Energy Charge
BB601	245	6	7	263	0.95
BB602	3.2	0	0	3.2	1.00
BB605	3.6	0.2	0	3.7	0.98
BB607	211	19	0	227	0.96
BB619	337	7	10	352	0.96
BB624	13.7	1.3	0.6	15.7	0.92
BB626	23.7	0.3	0	24.6	0.99
BB627	62.7	1.9	0.3	65.3	0.98

B. Elson Lagoon, January, 1979.

Sample Number	*ATP	*ADP	*AMP	Total Adenylate	Energy Change
BB701	0.2	0.08	0.28	0.4	0.24
BB702	0.33	0.54	1.01	1.9	0.38
BB703	0.28	4.0	13	17	0.25
BB703 + oil	0.63	5.4	17	23	0.27
BB704	0.07	1.9	11	13	0.15
BB705	0.17	3.0	11	14	0.19

* nMoles of adenylate x g. dry wt.$^{-1}$.

Table 22. Inorganic nutrient data in samples taken in the Cook Inlet and Beaufort Sea. All concentrations reported in μM.

A. Beaufort Sea (Elson Lagoon), January, 1978

Sample #	NH_3	NO_2	NO_3	TAN	PO_4
1. Water					
BW403	2.90	0.09	7.24		1.44
BW408	2.93	0.09	6.95		1.49
2. Sediment					
BB402	52.74	0.36	3.87		4.32
BB403	14.01	0.04	0.30	30.46	0.74
BB404	14.01	0.06	0.29	13.54	4.02
BB405	92.88	1.08	0.40	46.92	18.48
BB406	16.80	0.73		15.16	2.43
BB407	84.69	0.81	1.26		10.8
BB408	15.24	0.11	0.28	23.66	1.64
BB409		3.66			
BB410	23.34	0.17	0.16	95.20	8.40
B. Cook Inlet, April, 1977					
1. Water					
GW401	1.00	0.21	1.12	6.29	1.22
GW402	1.94	0.21	14.30	20.03	1.55
GW403	1.81	0.05	16.14	20.00	1.66
GW405	1.44	0.17	15.73	19.54	1.46
GW406	1.75	0.30	10.53	19.40	1.27
GW407				20.46	
GW408	1.22	0.19	16.31	21.35	1.71
GW409	1.90	0.23	16.05	19.09	1.75
GW412	1.88	0.24	12.74	15.17	1.43
GW413	4.01	0.23	16.34	21.55	2.29
GW417	3.30	0.28	15.92	20.92	1.65
GW418	4.00	0.57	14.10	18.91	3.36
GW419	2.97	0.24	15.74	18.02	2.00
GW422	1.72	0.14	16.53	20.20	1.31
GW423	2.50	0.57	15.22	18.92	
GW424	1.58	0.53	16.01	19.50	
GW425	1.58	0.43	14.33	18.04	1.67
GW427	1.03	0.33	15.43	17.91	
GW428	1.15	0.29	15.55	18.09	
GW430	1.50	0.10	0.10	8.09	0.52

Table 22. (Cont'd)

B. Cook Inlet, April, 1977

Sample #	NH_3	NO_2	NO_3	TAN	PO_4
1. Water					
GW432		0.15	10.46	27.84	1.91
GW433	3.62	0.19	10.01	16.2	1.72
GW434	2.68	0.25	12.35	11.6	2.10
GW437	0.28	0.06	7.76	12.6	1.15
GW438	1.67	0.13	10.71	9.5	1.82
GW441	2.26	0.28	15.05	20.2	1.42
GW442	2.33	0.22	12.13	15.6	1.36
GW444	1.75	0.23	14.34	20.4	1.48
GW439	2.23	1.71	8.22	13.8	1.51
2. Sediment					
GB410		28.2	20.77		73.5
GB411	>362	16.6			76.3
GB412	>432	137			60.5
GB421	>161	0.30	0.06	147.2	48.6
GB425	109.8	1.32	1.80	113.7	10.3
GB431	116.6	1.14	1.92	380.2	5.3
GB432	70.4	14.5			24.6
GB434	>161	3.74	6.04		24.9
GB437	42.7	7.56	5.94	197.2	11.2
GB440	150.8	0.42	1.20	420.7	12.5
GB442	64.7	0.54	2.04	83.5	13.4
GB444	22.2	0.31	0.13	13.9	2.40
GB445	14.6	0	0.18	22.7	1.25

C. Cook Inlet, November, 1977

1. Water					
GW501	1.42	0.35	9.34	14.7	1.45
GW502	0.83	0.28	15.04	19.2	1.71
GW503	1.48	0.24	15.80	20.4	1.89
GW504	0.90	0.24	13.90	16.2	1.58
GW505	3.00	0.50	9.10	13.9	1.61
GW506	2.71	0.40	9.46	14.2	1.36
GW507	1.45	0.34	9.59	11.5	1.23
GW508	1.13	0.31	8.98	12.4	1.18
GW509	0.85	0.31	8.84	11.8	1.17
GW510	1.10	0.31	8.78	10.1	1.19
GW511	1.01	0.13	11.25	1.4	1.38
GW514	0.82	0.24	10.55	12.4	1.30
GW515	0.92	0.24	11.53	13.8	1.32

Table 22. (Cont'd)

C. Cook Inlet, November, 1977

1. Water

	NH_3	NO_2	NO_3	TAN	PO_4
GW516	0.62	0.35	8.78	10.4	1.22
GW518	0.62	0.29	9.96	11.4	1.29
GW519	1.12	0.32	8.52	11.1	1.22
GW520	1.36	0.27	13.3	16.2	1.49
GW521	0.55	0.33	9.21	13.2	1.18
GW522	0.95	0.31	9.37	10.8	1.21
GW523	0.93	0.33	8.77	10.7	1.18
GW524	1.05	0.33	8.77	11.2	1.22
GW525	0.58	0.26	6.30	8.2	0.99
GW526	1.66	0.36	9.61	14.0	1.21
GW527	1.35	0.30	9.14	10.8	1.30
GW528	1.48	0.30	9.17	12.6	1.19
GW529	1.27	0.26	9.12		1.22
GW530	1.03	0.35	9.53	12.2	1.26
GW531	0.65	0.32	9.92	11.3	1.20
GW532	1.31	0.22	11.87	13.5	1.38
GW533	0.99	0.21	11.66	13.6	1.35
GW534	0.85	0.23	11.76	15.2	1.36
GW535	0.62	0.29	11.01	13.6	1.30
GW536	0.80	0.29	11.07	14.4	1.35
GW537	1.05	0.38	10.05	12.7	1.33
GW539	1.70	0.39	9.26	11.4	1.18
GW540	1.50	0.30	8.57	10.7	1.12
GW541	1.11	0.07	12.90	15.5	1.45
GW542	1.47	0.39	10.68	14.1	1.26
GW543	1.49	0.12	11.20	13.6	1.37
GW544	1.45	0.35	10.15	14.2	1.25
GW545	1.25	0.35	9.76	12.5	1.28
GW547	1.15	0.34	10.22	12.5	1.25
GW549	1.23	0.44	10.60	12.6	0.91
GW550	1.25	0.43	10.18	12.4	1.18
GW556	1.26	0.23	11.65	12.6	1.52
GW557	1.75	0.39	10.44	18.1	1.43
GW558	1.67	0.46	10.26	12.7	1.41
GW559	1.78	0.16	12.96	16.2	1.43
GW560	0.95	0.10	10.72	14.4	1.32

Table 23. The total organic nitrogen (TON) and total organic carbon (TOC) in sediment samples collected in Cook Inlet and the Beaufort Sea. The units used are mg/g. dry weight.

A. Elson Lagoon, January, 1978

Sample #	TOC	TON
BB402	21.3	1.9
BB403	38.3	1.7
BB404	32.4	2.3
BB405	39.5	1.6
BB406	34.6	1.4
BB407	30.6	1.8
BB409	34.2	1.8
BB410	34.9	1.6

B. Cook Inlet, April, 1977

Sample #	TOC	TON
GB401		
GB410	1.7	0.1
GB412	6.4	0.3
GB420	6.8	0.3
GB421	19.5	0.9
GB425	14.5	1.0
GB430	7.1	0.2
GB431	8.6	0.8
GB432	5.0	0.2
GB434	3.6	0.1
GB437	15.3	0.6
GB438	2.0	0.1
GB440	7.2	0.4
GB442	14.4	0.4
GB444	9.0	0.5
GB445	5.1	0.3

Table 24. Inorganic nutrient and TOC and TON concentrations in sediment samples collected during the October, 1976 Lower Cook Inlet cruise. The inorganic nutrient concentrations are reported in μM and the TOC and TON values are reported in units of mg/g. dry weight sediment. The inorganic nutrient data was measured on interstitial water only.

Sample #	NH_3	NO_2	NO_3	TAN	PO_4	TOC	TON
GB301	371			474		4.5	0.3
GB304	245	24.7	4.4	2060	85	4.9	0.2
GB308	18	3.0	32.7	45		4.3	0.1
GB311	245	58.3	9.7	619	56	10.3	0.3
GB312	3	0.8	6.7	2087		7.0	0.1
GB313	121	3.9	14.3	540	14	11.8	0.6
GB318	295	27.2	29.2	606	117		
GB319	105			760	13	1.5	0.1
GB320	249	17.5	44.7	566	41	8.9	0.3
GB327						5.6	0.5
GB333						9.5	0.9
GB334						2.5	0.2

Table 25. Measurements made on sediment samples collected during the November 1977 Lower Cook Inlet cruise. The same units as those given in Table 24 were used.

Sample #	NH_3	NO_3	NO_3	TAN	PO_4	TOC	TON
GB501	124	12.9	17.8	533	95	5.2	0.3
GB502	63			624	51	12.8	1.3
GB503						22.2	1.7
GB506	119	1.7	15.4	521	18	32.9	2.0
GB507	73			455	8	7.2	0.3
GB508				1450		8.5	0.4
GB509	71	1.1	16.0	345	19	12.5	0.7
GB510	34	13.9	15.8	235	33	12.3	0.6
GB511	52	1.1	16.0	250	20	16.4	1.2
GB512	289	16.3	10.0	127	6	11.8	1.0
GB513	56			259	19	12.3	0.6
GB514	79	8.9	20.8	290	31	8.3	0.5
GB515	130	2.4	52.0	220	48	13.6	1.0
GB516	213	17.0	low	108	13		
GB518	102			588	54	7.3	0.5
GB519	92			434	24	4.4	0.2
GB520	78	2.8	14.3	411	39	8.8	0.6
GB523	122	9.3	low	483	23	5.6	0.4
GB524	206	22.6	6.7	484	85	7.6	0.5
GB525	93	1.2	19.4	520	23	6.8	0.4
GB526	62	2.4	32.7	370	46		
GB527	103	5.7	0.9	186	12	11.0	1.0
GB528						6.9	0.4
GB529		13.3	12.6	123			
GB532	275			337	25	6.5	0.4
GB538	124	5.0	5.0	789	32	14.6	1.2
GB549	87	2.4	3.0	251	14	6.2	0.3
GB554	79	1.2	19.3	451	31	5.5	0.2
GB557	54	3.6	16.9	301	30	14.3	0.9
GB558	114	3.9	4.4	215	31	15.9	1.1

Table 26. Inorganic nutrient data observed in samples taken in the Cook Inlet during the April, 1978 cruise. All concentrations in μM.

A. Water samples

Sample #	NH_3	NO_2	NO_3	PO_4
GW601	2.58	0.23	5.4	1.00
GW602	1.66	0.71	17.1	1.83
GW603	0.78	0.39	5.9	1.02
GW604	2.38	0.26	12.8	1.48
GW605	2.13	0.64	14.9	1.60
GW606	1.36	0.36	13.5	1.50
GW607	1.22	0.46	12.0	1.34
GW608	1.13	0.26	1.7	0.70
GW609	2.38	0.24	15.0	1.49
GW610	1.38	0.49	15.7	1.54
GW611	1.23	0.42	15.6	1.67
GW612	0.98	0.27	9.3	1.24
GW613	1.30	0.26	14.7	1.60
GW614	1.95	0.20	15.4	1.62
GW615	1.27	0.19	15.3	1.57
GW616	1.43	0.16	3.1	0.78
GW617	1.25	0.13	9.4	1.28
GW618	1.50	0.17	6.3	1.09
GW619	1.37	0.25	14.8	1.29
GW620	1.59	0.34	12.8	1.52
GW621	1.19	0.34	15.6	1.48
GW623	1.45	0.29	11.9	1.41
GW624	1.17	0.20	15.1	1.54
GW625	2.19	0.32	16.3	1.59
GW626	1.60	0.38	15.1	1.54
GW627	1.66	0.26	14.3	1.45
GW629	1.70	0.22	15.6	1.61
GW630	1.42	0.17	15.2	1.59
GW631	2.52	0.42	16.2	1.76
GW632	1.66	0.42	16.0	1.65
GW633	0.99	0.28	14.0	0.86
GW635	1.42	0.40	15.8	1.70
GW637	1.28	0.19	15.4	1.59
GW638	2.51	0.41	15.4	1.62
GW639	1.60	0.50	15.9	1.70
GW640	1.73	0.29	16.4	1.75
GW641	1.52	0.22	14.8	1.66
GW642	2.13	0.21	13.7	1.61
GW643	1.97	0.48	14.2	1.62
GW645	1.68	0.23	11.4	1.40
GW646	1.70	0.33	0.2	1.65
GW647	2.01	0.31	12.3	1.48

Table 26. (Cont'd)

Sample #	NH_3	NO_2	NO_3	PO_4
GW650	1.92	0.29	9.5	0.57
GW652	1.63	0.19	12.3	0.32
GW655	2.74	0.76	14.3	1.73
GW656	2.35	0.60	13.4	1.49
GW657	2.52	0.47	13.5	1.48
GW658	1.83	0.53	11.6	1.43
GW659	1.46	0.06	0.9	0.89
GW660	2.13	0.50	3.8	0.91
GW661	1.44	0.34	4.0	0.35
GW662	1.88	0.17	9.5	1.20
GW663	1.49	0.14	3.5	0.85
GW664	1.27	0.24	0.6	0.87
GW665	0.61	0.47	4.0	0.80
GW666	1.08	0.11	0.9	0.56
GW667	2.31	0.36	4.4	0.91
GW668	1.86	0.17	3.0	0.50
GW669	1.70	0.10	0.3	0.56
GW670	1.08	0.14	15.2	1.42
GW671	0.80	0.17	16.2	1.45
GW672	0.78	0.22	15.4	1.50
GW673	1.22	3.39	15.0	1.42
GW674	1.36	0.20	15.3	1.43
GW675	1.13	0.19	13.6	1.39
GW676	1.17	0.14	13.9	1.42
GW677	1.32	0.16	13.6	1.43
GW678	1.20	0.16	14.0	1.42
GW679	2.43	0.23	13.6	1.34
GW680	0.90	0.18	13.6	1.39
GW681	1.02	0.17	12.3	1.39
GW682	0.85	0.23	14.1	1.42
GW683	1.03	0.24	12.6	1.40

B. Sediment samples (interstial water)					TAN	TOC	TON
GB601	171	13.0	7.1	38.6	190	0.9	0.1
GB602	141	2.3	2.0	13.0	94	12.2	1.4
GB603	47	1.4	1.3	9.6	66	10.6	1.3
GB604	56	1.1	2.3	5.2	109	26.0	1.8
GB605	115	1.4	2.6	9.1	130	31.5	2.1
GB606	139	0.9		15.4	133	9.0	0.9
GB607	111	1.1	2.1	8.7	93	18.1	3.1
GB608	186	5.7		25.9	170	4.0	0.5
GB609	100	10.0	5.4	9.5	89	17.1	0.9
GB610	80	2.8	13.8	6.1	85	4.6	0.5
GB611	101	0.8	3.0	9.5	124	5.5	1.2
GB612	53	1.1	2.3	13.8	48	10.5	2.1

Table 26. (Cont'd)

Sample #	NH_3	NO_2	NO_3	PO_4	TAN	TOC	TON
GB613	113	1.1	2.9	9.4	139	10.4	1.2
GB614	184	0.2	2.0	44.7	77	17.5	0.3
GB615	-	-	-	-	-	3.6	0.4
GB616	109	3.0	2.1	9.1	66	9.8	1.0
GB617	-	-	-	-	-	41.6	2.6
GB622	338	9.6	0	-		24.0	2.4
GB624	-	-	-	-	-	13.3	1.3
GB625	120	0.6	9.8	7.9	142	4.6	0.5
GB626	-	2.6	0	-	-	16.0	0.3
GB627	78	1.2	42.6	8.7	43	4.0	0.4
GB628	117	1.2	34.4	6.8	109	3.1	0.3
GB629	125	2.1	40.3	13.0	169	19.6	0.5
GB630	106	1.4	2.9	0.0	99	15.6	0.2
GB631	246	7.6	15.5	29.6	137	6.5	0.9
GB632	85	0.9	23.9	5.5	141	2.1	0.2
GB633	111	1.3	16.7	7.5	173	4.4	0.4
GB635	-	-	-	-	-	11.5	0.4
GB636	57	2.3		12.4	85		
GB640	-	-	-	-	-	10.8	1.1
GB649	227	1.0	1.7	17.5		7.3	0.6
GB650	265	1.7	1.9	9.0	241		
GB652	273	16.1		62.4	61	12.3	2.0
GB654	93	5.3	4.7	8.0	81	4.2	0.5
GB660	136	18.7	25.3	17.4	196		
GB669	628	1.4	1.1			60.0	3.2
GB677	37	0.3	72.7	6.7	130	5.4	0.5

Table 27. Inorganic nutrient and TOC and TON concentrations in sediment samples collected during the August, 1978 Beaufort Sea cruise. The same units are used as those described in Table 25.

A. Water samples

Sample #	NH_3	NO_2	NO_3	PO_4
BW604	3.7	0.29	18.8	0.36
BW606	10.6	2.53	17.3	0.91
BW608	4.2	0.11	0.28	0.60
BW610	0.34	0.02	0.26	0.62
BW611	0.75	0.04	0.24	0.73
BW613	0.34	0.06	0.11	0.61
BW615	0.70	0.06	0.28	0.45
BW617	0.29	0.01	0.34	0.73
BW618	0.50	0.01	0.28	0.62
BW619	0.46	0.01	0.33	0.66
BW620	---	0.01	0.30	0.78
BW621	0.38	0.03	0.28	0.71
BW622	0.85	0.06	0.28	0.40
BW623	0.67	0.11	0.22	0.66
BW624	0.52	0.05	0.25	0.68
BW625	---	0.04	0.21	0.69
BW627	0.28	0.25	0.24	0.52
BW628	---	0.09	0.25	0.69
BW629	0.50	0.06	0.14	0.72
BW630	0.82	0.03	0.21	0.64
BW631	0.21	0.01	0.16	0.59
BW632	0.22	0.02	0.24	0.76
BW633	0.68	0.04	0.33	0.66
BW634	0.80	0.05	0.23	0.66
BW635	0.28	0.07	0.22	0.40
BW636	0.48	0.01	0.10	0.50
BW638	0.79	0.03	0.34	0.81
BW639	0.72	0.06	0.36	0.35
BW640	0.35	0.02	0.20	0.33
BW641	0.60	0.02	0.23	0.54
BW642	---	0.20	0.72	0.66
BW646	0.59	---	---	0.73

Table 27 (cont'd)

B. Sediment samples

Sample #	NH_4	NO_2	NO_3	PO_4	TOC	TON
BB601	32	2.5	0	2.3	—	--
BB602					33.0	1.5
BB603	--	--	--	--	27.8	2.4
BB604	92	3.4	0	8.8	13.7	1.0
BB605	75	1.4	0.7	7.1	14.5	1.3
BB606	207	8.9	0	19.3	19.0	1.4
BB607	291	10.4	5.8	--	--	--
BB608	84	3.7	0	7.2	9.8	0.8
BB609	103	2.1	1.7	--	--	--
BB610	37	0.7	2.8	3.7	12.2	0.9
BB611	1	0.04	0.3	0.7	--	--
BB612	64	3.5	13.4	6.2	11.3	0.6
BB613	--	3.0	0.3	6.6	9.0	1.7
BB614	60	2.5	1.7	--	--	--
BB615	121	3.6	1.5	13.5	3.4	0.4
BB616	232	4.0	11.3	--	8.7	0.8
BB617	--	2.5	0	--	--	--
BB619	141	3.5	2.3	8.2	13.3	0.6
BB622	338	9.6	0	9.4	41.0	2.6
BB624	--	--	--	--	13.0	1.3
BB626	--	2.6	--	--	12.5	0.3
BB630	172	2.8	43.4	8.8	--	--
BB631	103	1.3	13.8	11.8	7.7	0.7
BB632	52	1.4	0.2	4.2	11.2	0.3
BB633	64	2.5	28.5	6.2	7.9	0.7
BB634	55	1.4	0.3	4.2	14.2	0.8
BB635	62	1.2	11.4	8.3	--	--
BB636	39	1.3	0.6	4.0	12.6	0.9
BB640	106	1.0	67.0	8.2	--	--
BB641	59	--	--	2.0	5.0	0.5
BB642	57	1.6	4.4	4.4	6.6	0.8
BB644	201	3.1	0	4.6	8.0	0.7
BB645	--	--	--	--	13.8	0.9

Table 28. The uptake of glucose and glutamic acid and the effects of crude oil on glutamic acid uptake at various tidal states during the time series.

Sample #	Station #	* Tide	@ DPM glucose	DPM glutamate	$\frac{\text{glutamate}}{\text{glucose}}$	°Percent reduction
659	CB7	H	896	432 ¢	0.5	44
660	"	L	5740	3045 ¢¢	0.5	66
661	"	H	3830	2682 ¢¢	0.7	56
663	"	L	923	749 ¢	0.8	63
664	"	H	1537	729 ¢¢	0.5	26
665	"	L	389	567	1.5	27
666	"	H	319	433	1.4	31
667	"	L	501	858	1.7	46
668	"	H	2006	1420 ¢¢	0.7	49
670	CB10	H	1284	2472	1.9	13
671	"	L	813	2590	3.2	44
672	"	H	525	2942	5.6	42
673	"	L	455	3442	7.6	23
674	"	H		4016		7
675	CB9	H		918		0
676	"	L	115	411	3.6	2
677	"	H	160	638	4.0	61
678	"	L		890		-12
679	"	H		636		24
680	"	L		409		57
681	"	H		108		11
682	"	L		195		5
683	"	H		1276 ¢		
601	330		1161	879 ¢¢	0.8	
669	K		4086	4383 ¢¢	1.1	
662	AB		225	419	1.9	

*Tide state: H = high slack L = low slack

@DPM = disintegrations per minute per hour incubation time.

¢Those samples that were probably contaminated to some degree by the ship's effluent.

¢¢Those samples that were probably grossly contaminated by the ship's effluent.

°Percent reduction in uptake in samples exposed to crude oil.

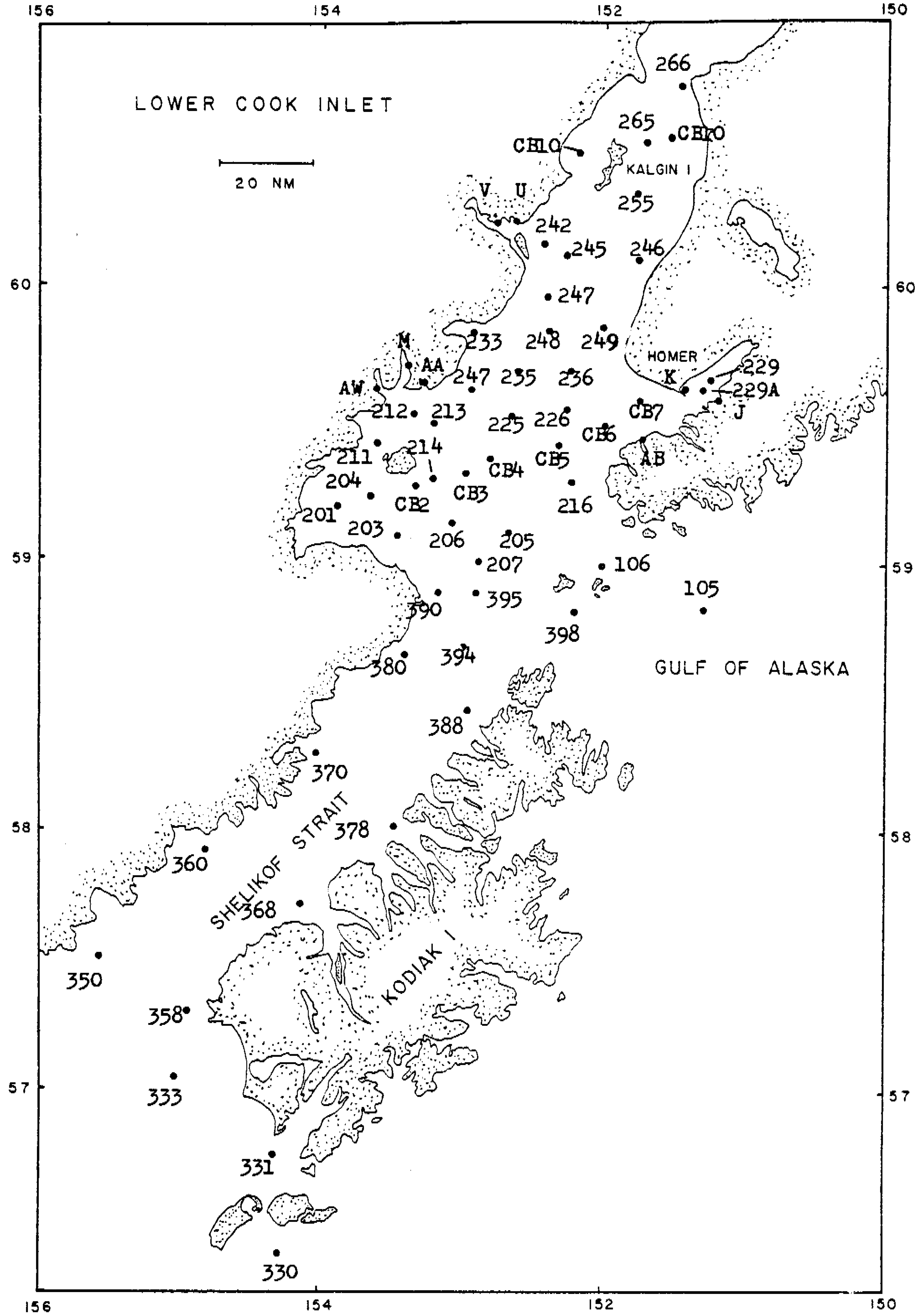


Figure 1. Location of stations sampled during the April, 1978 Cook Inlet cruise.

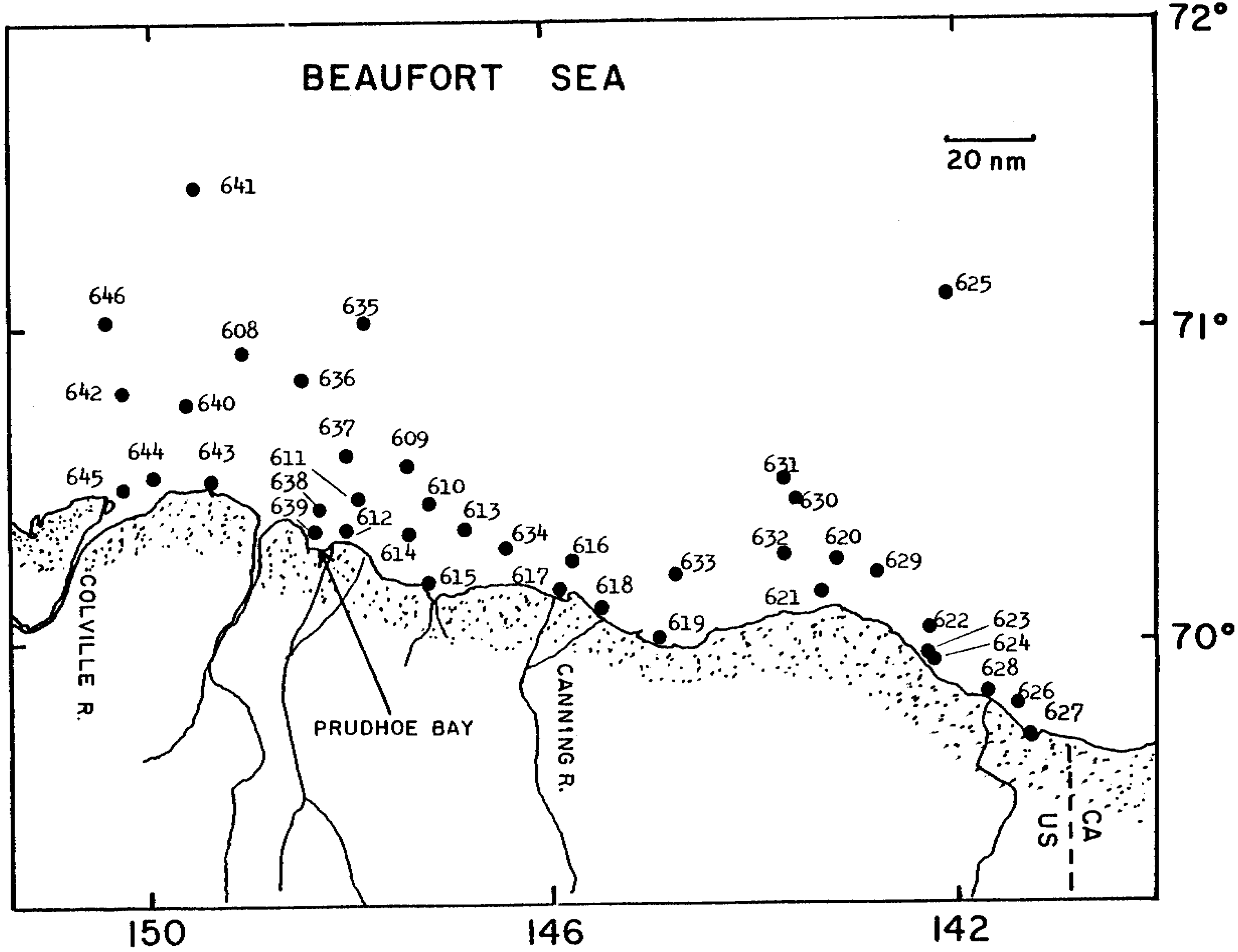


Figure 2. The location of stations where samples were collected during the summer, 1978 Beaufort Sea cruise.

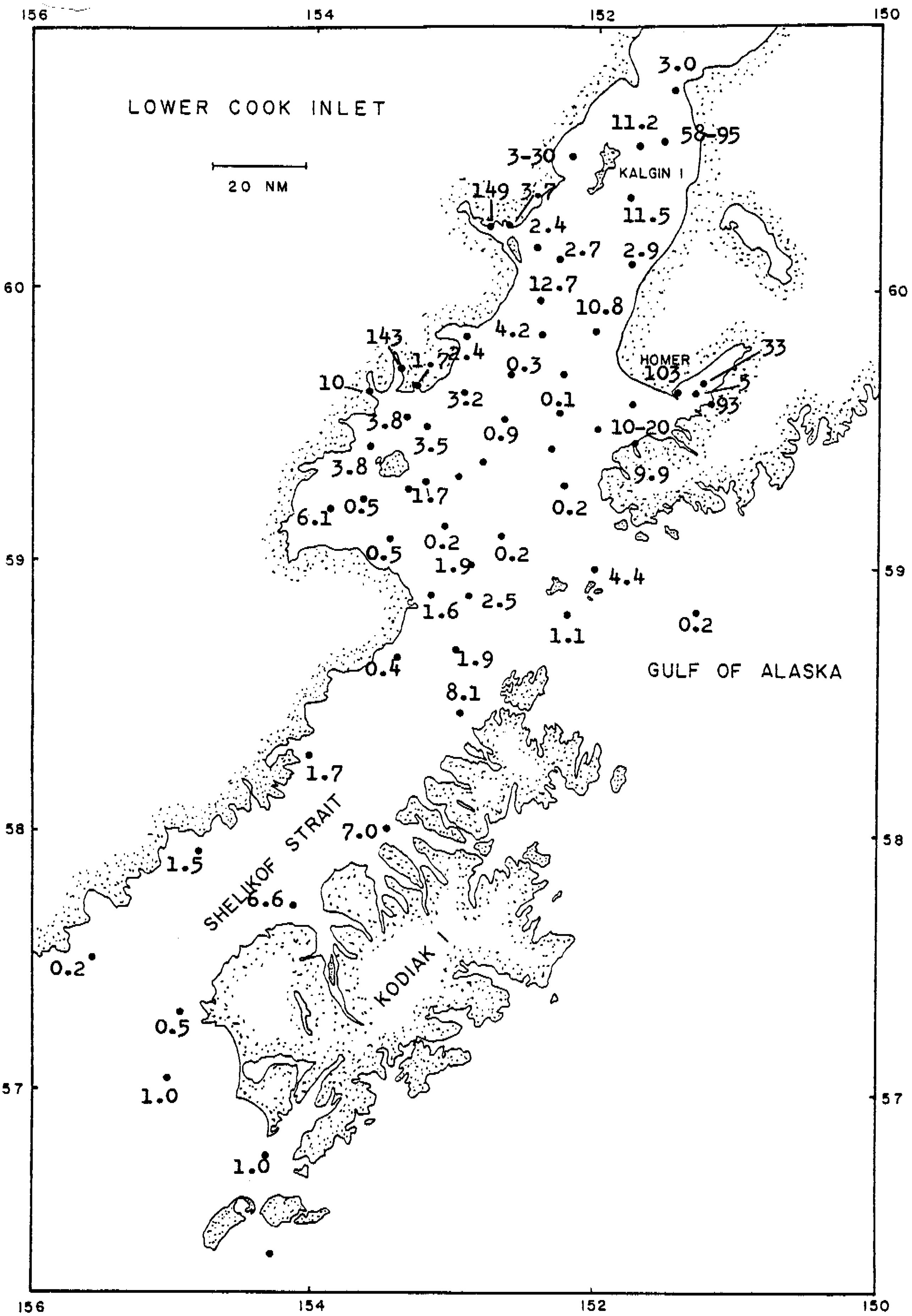


Figure 3. Relative microbial activity as measured using glutamic acid during the April, 1978 Cook Inlet cruise. The units are ng/l/h. Water samples only.

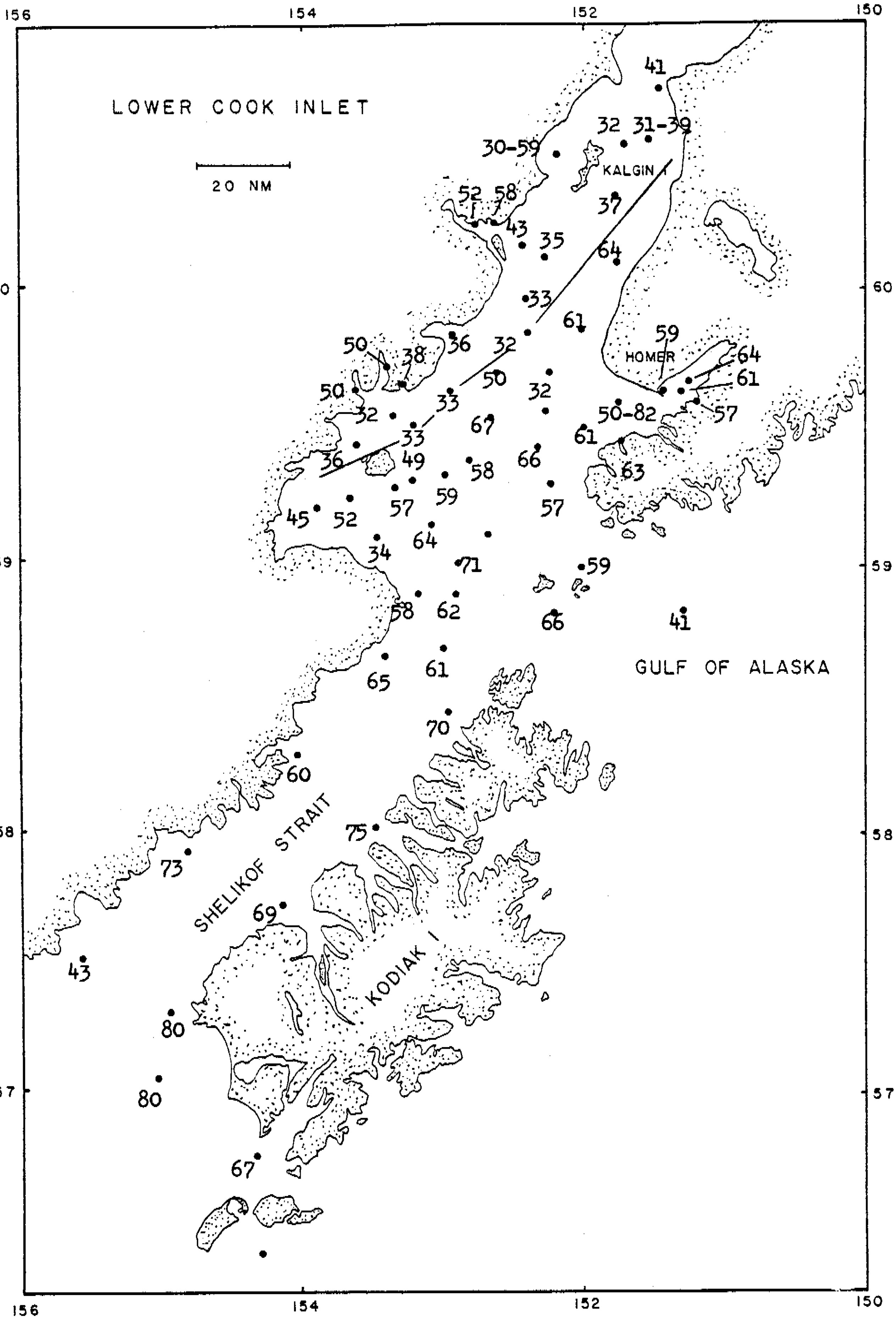


Figure 4. Percent respiration in water samples exposed to glutamic acid. These samples were collected during the April, 1978 Cook Inlet cruise.

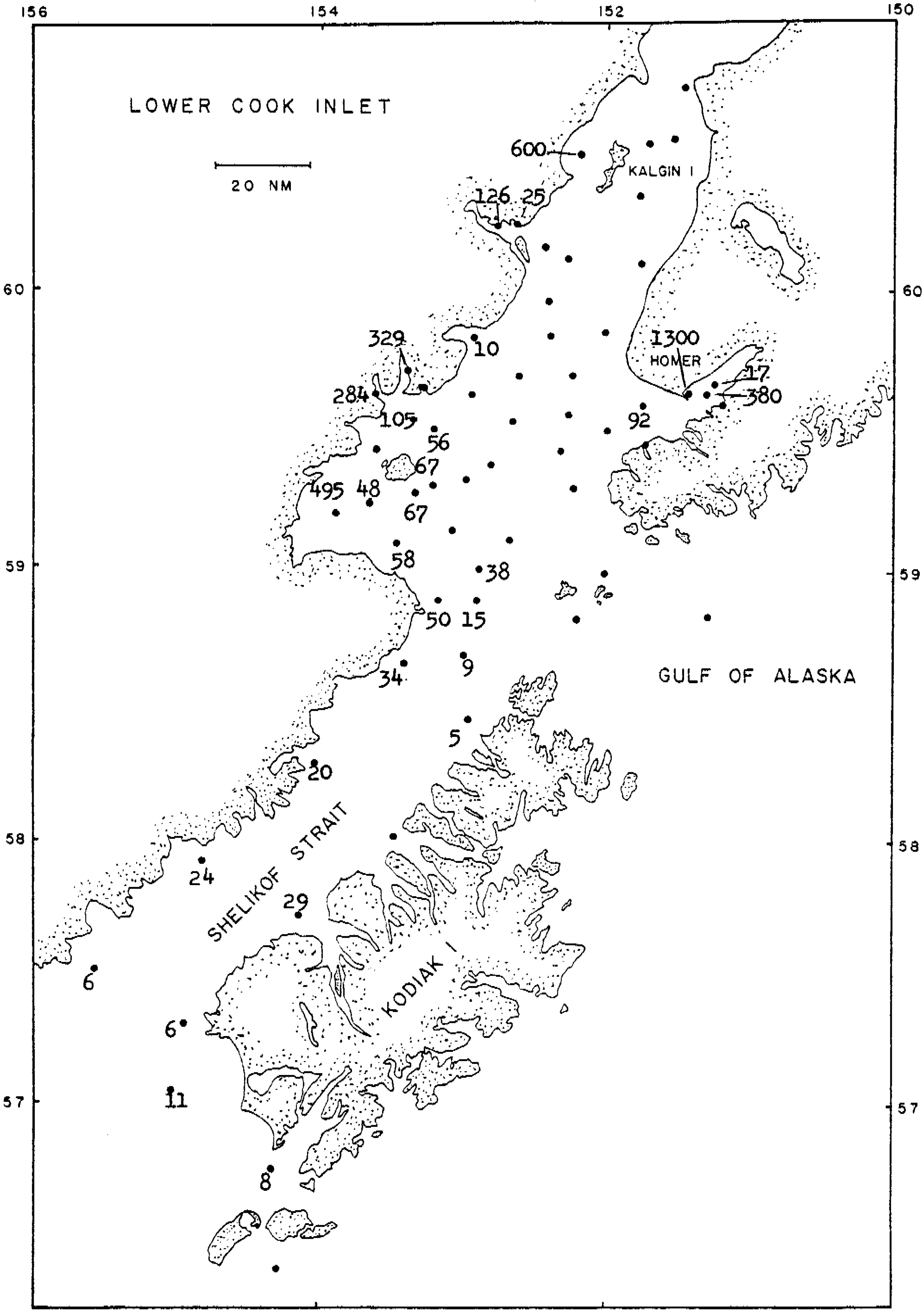


Figure 5. Relative microbial activity in the marine sediments collected during the April, 1978 Cook Inlet cruise. Units used are ng glutamate/g/h.

Figure 6. The rate of glutamic acid uptake observed in water samples reported in ng/ g dry wt./h.

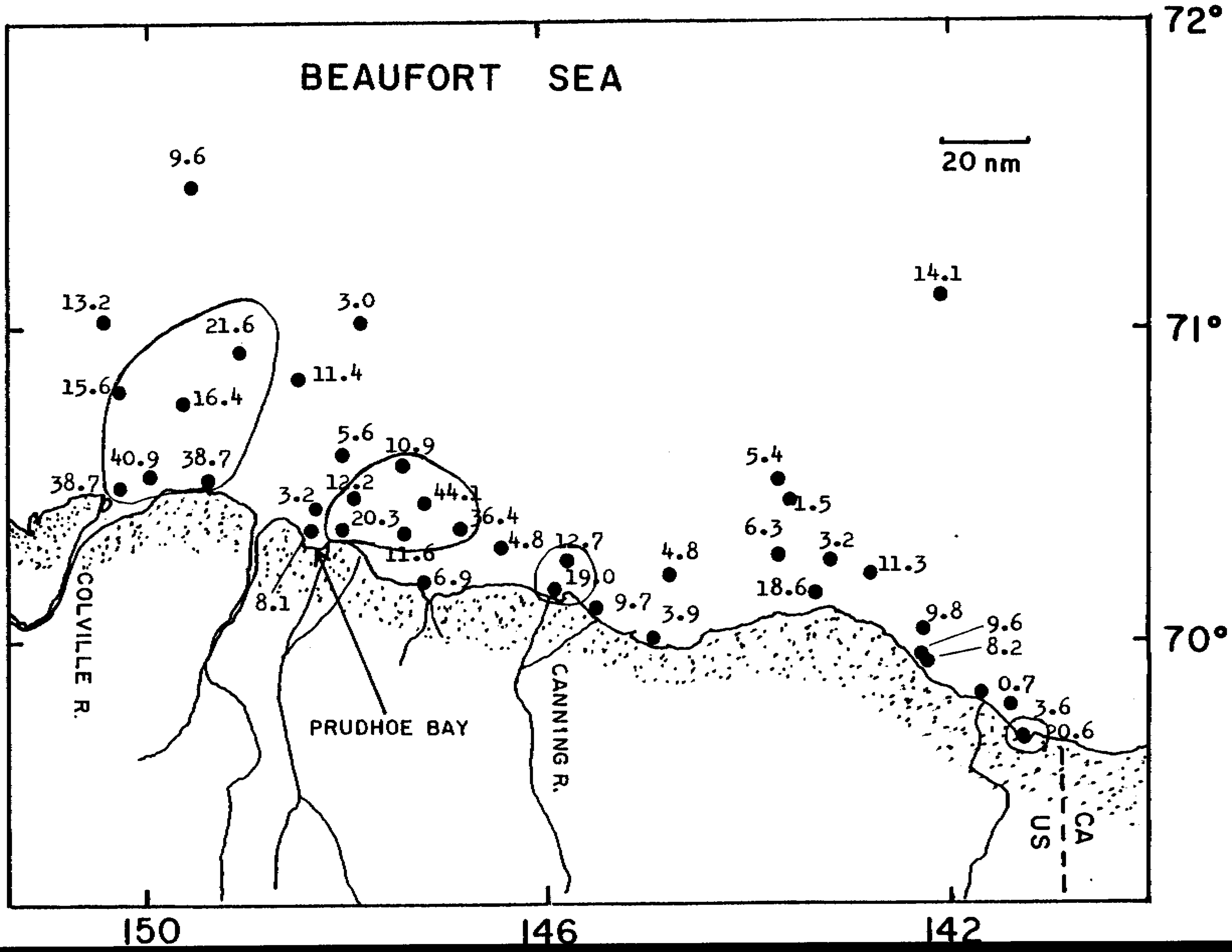


Figure 7. The rate of glucose uptake observed in water samples reported in ng/ g dry wt./h.

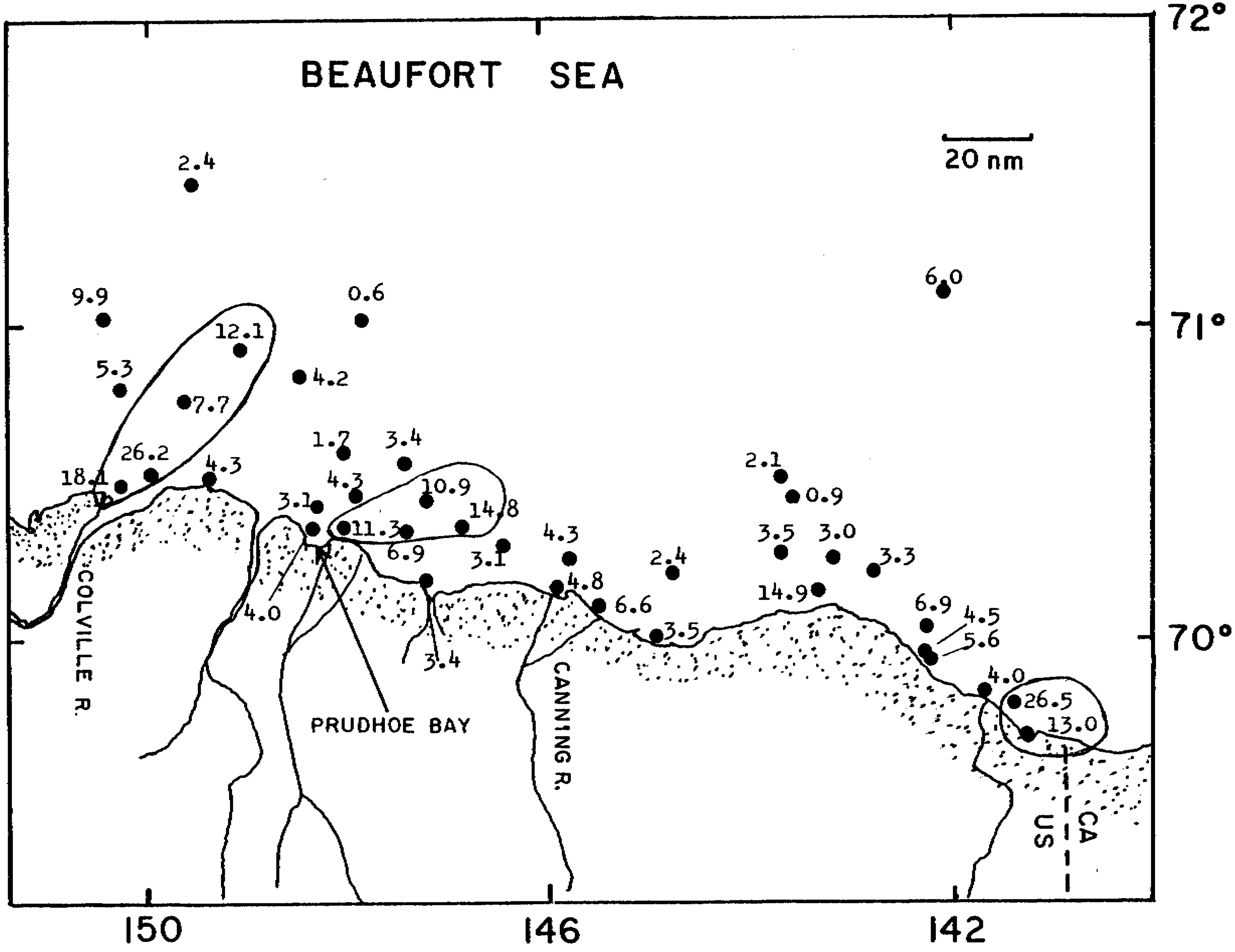


Figure 8. Percent respiration observed in water samples exposed to glutamic acid.

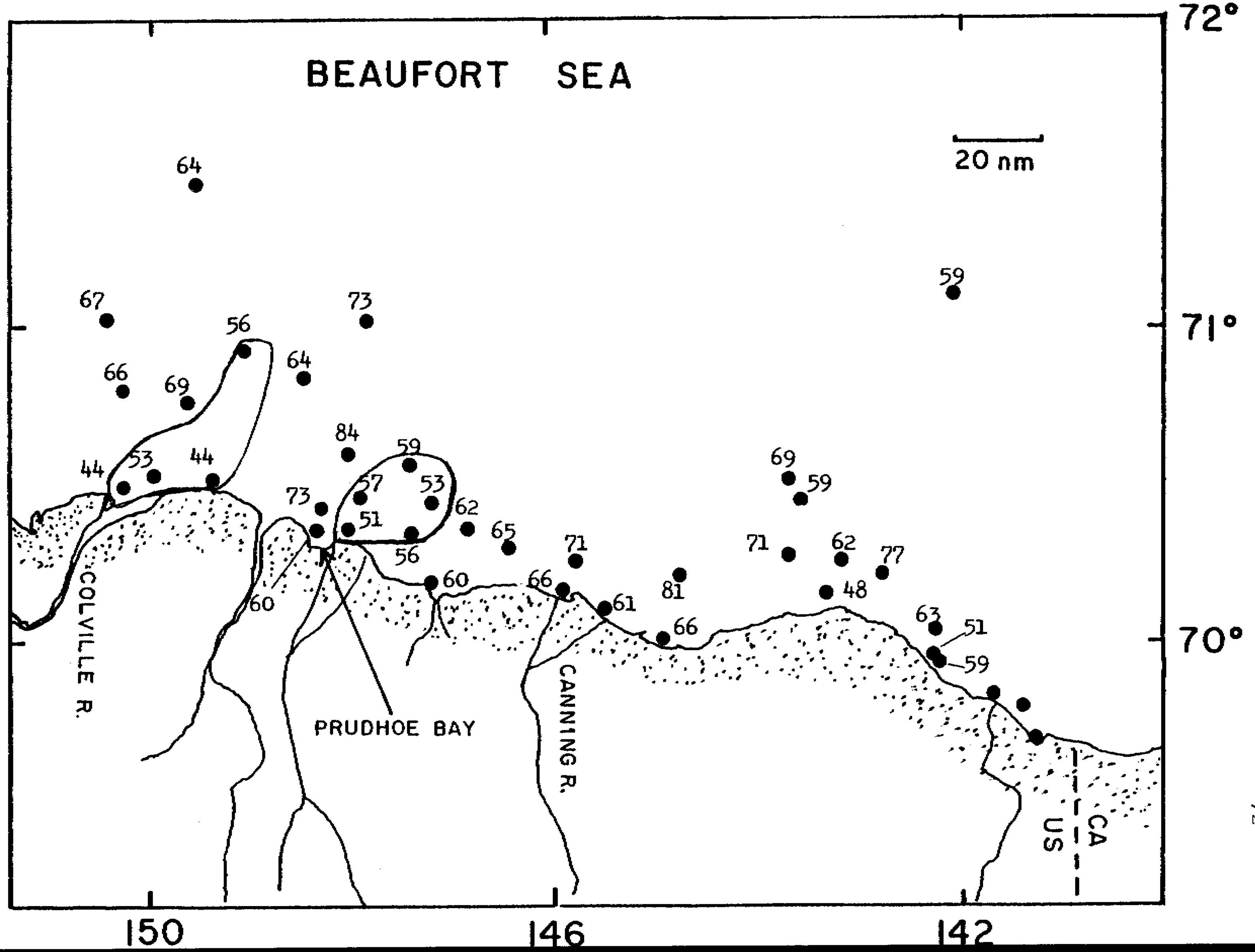


Figure 9. Percent respiration observed in water samples exposed to glucose.

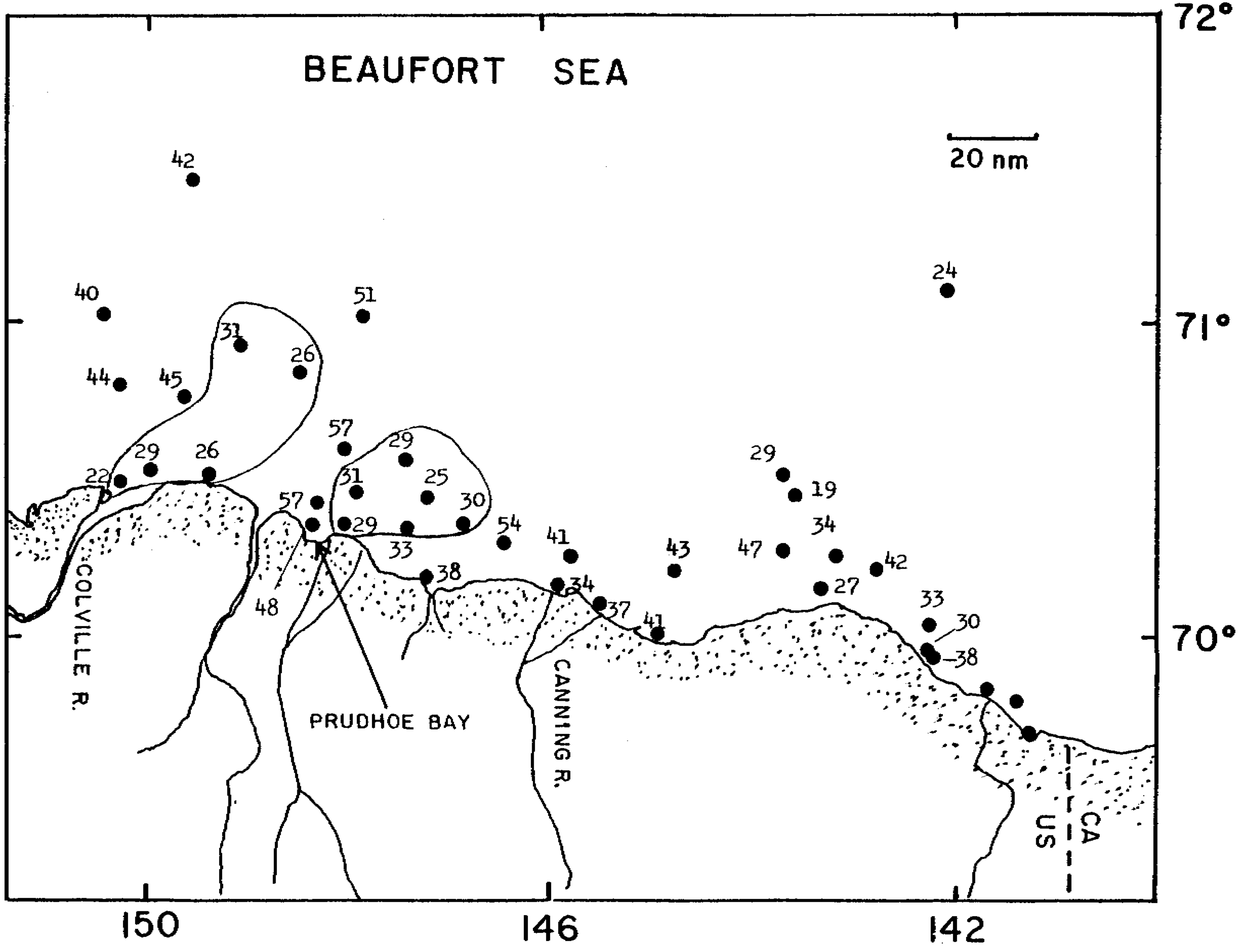


Figure 10. The rate of glutamic acid uptake observed in sediment samples reported in ng/g dry wt./h.

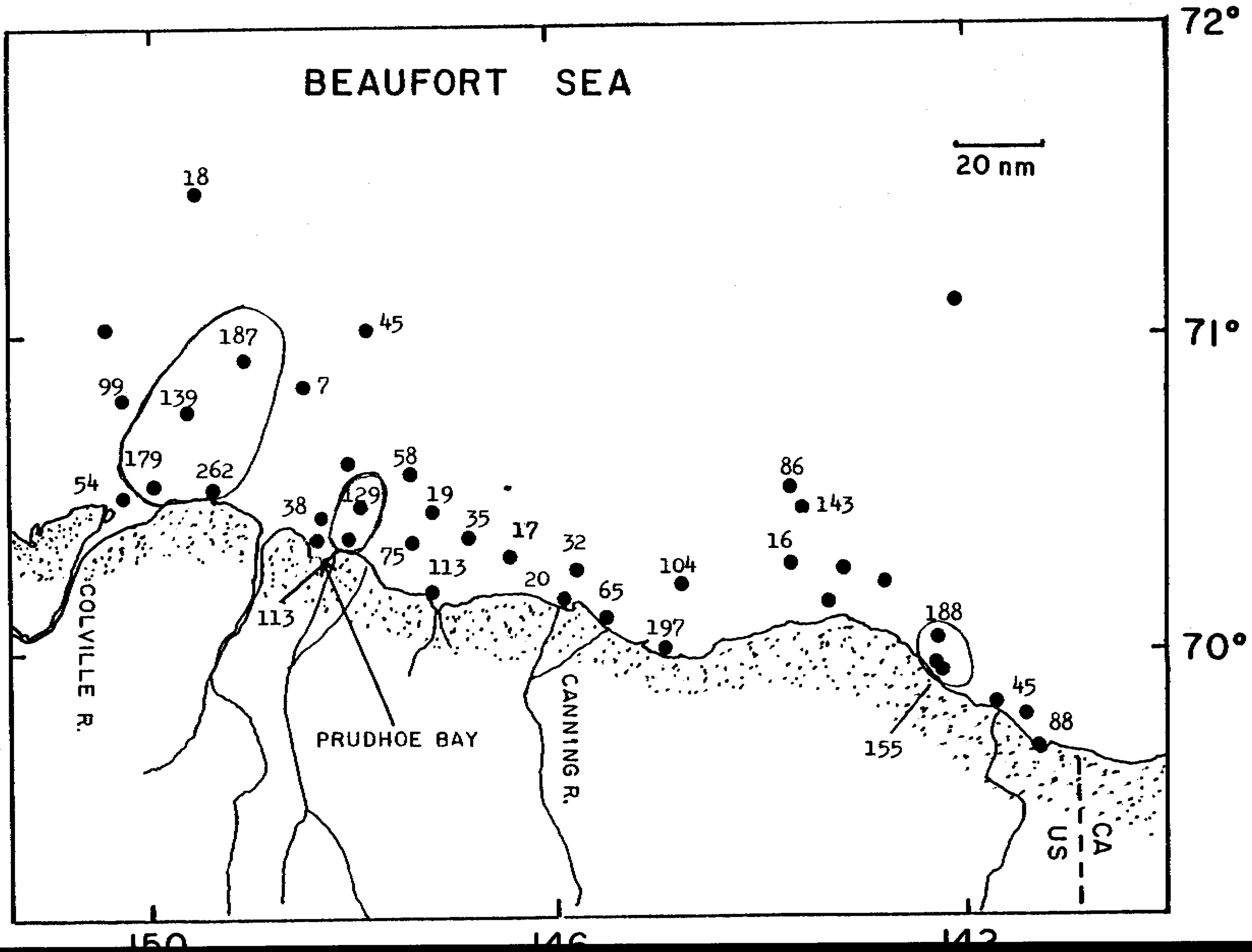
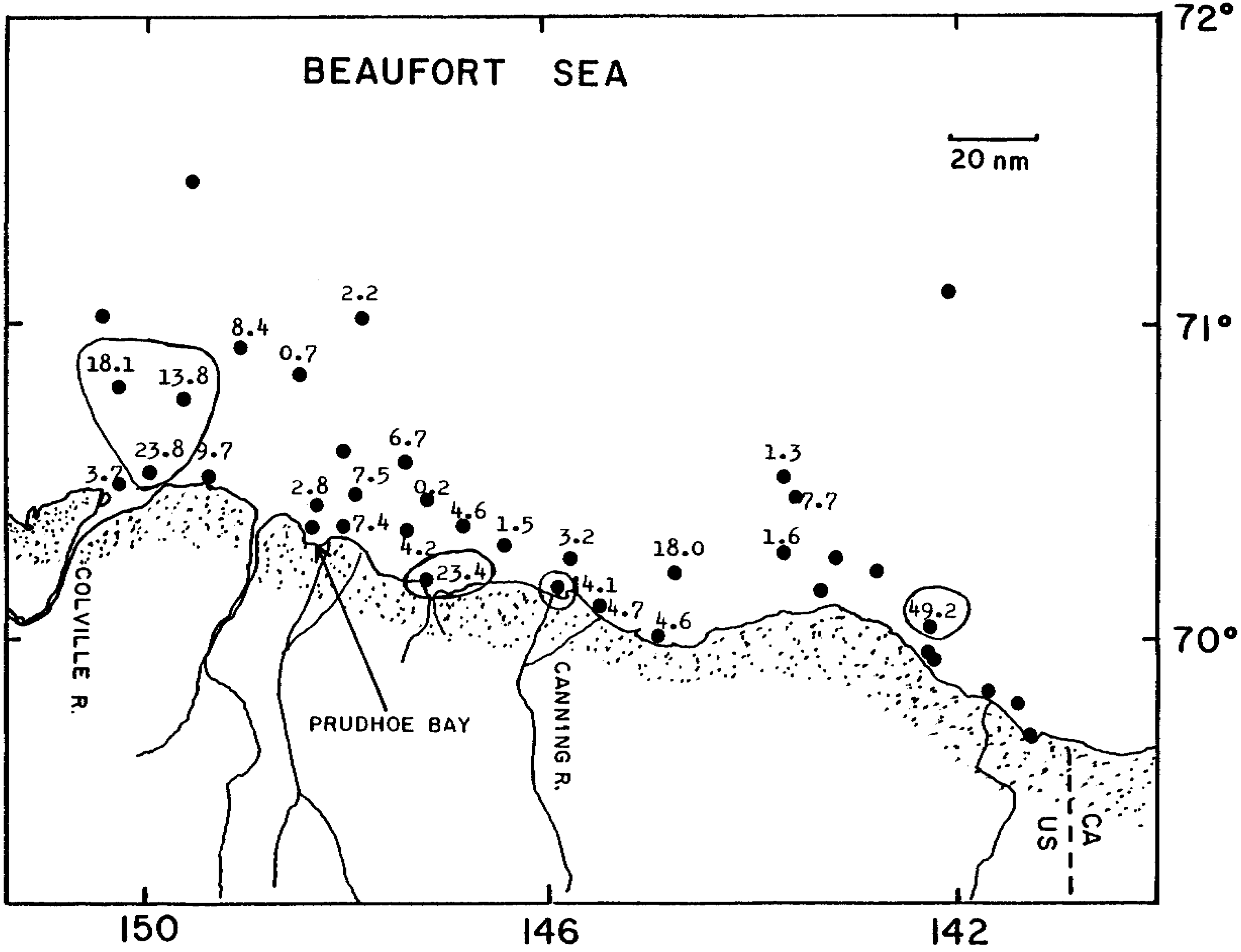


Figure 11. The rate of glucose uptake observed in sediment samples reported in ng/g dry wt./h.



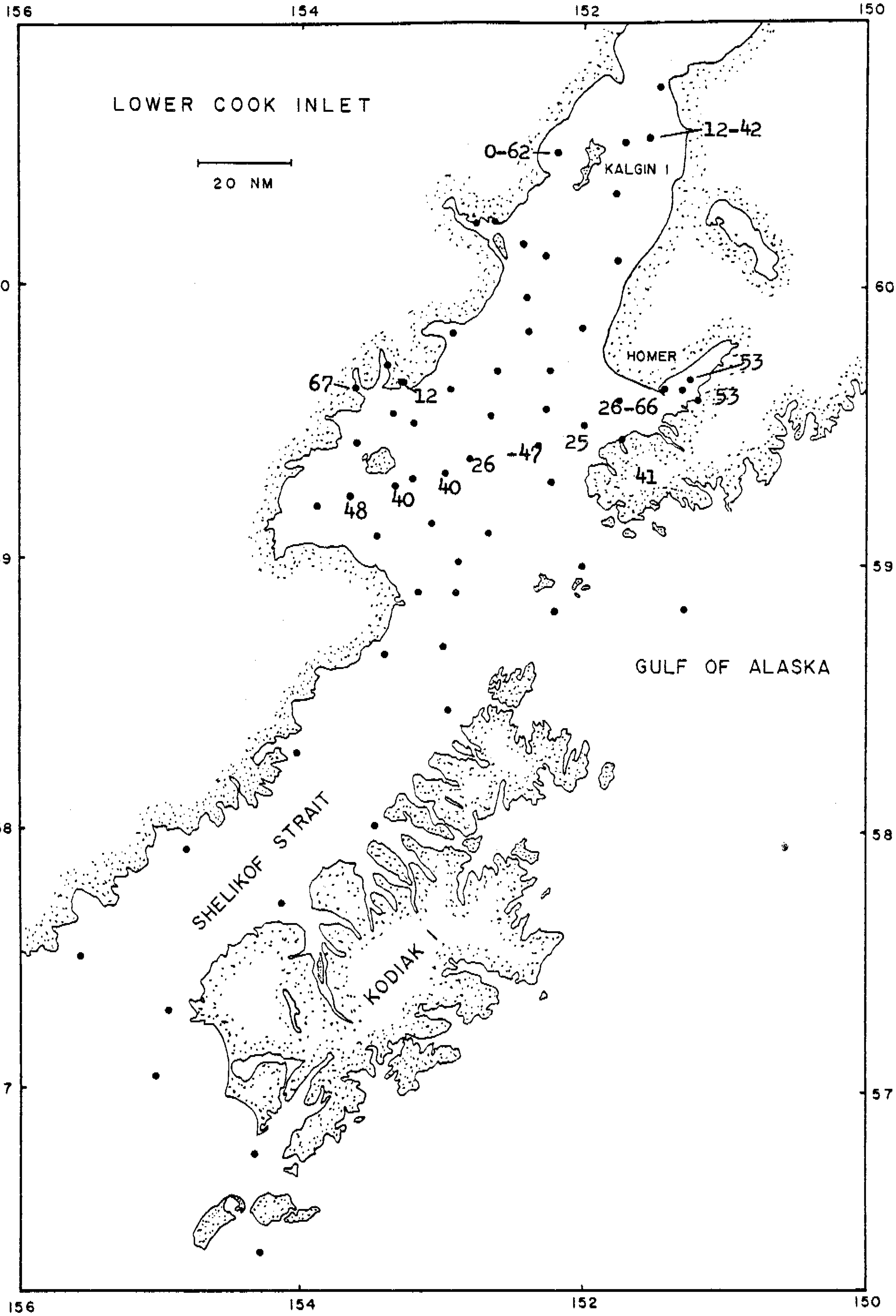


Figure 12. The percent reduction in glutamate uptake rates in water samples exposed to crude oil relative to nonoiled controls.

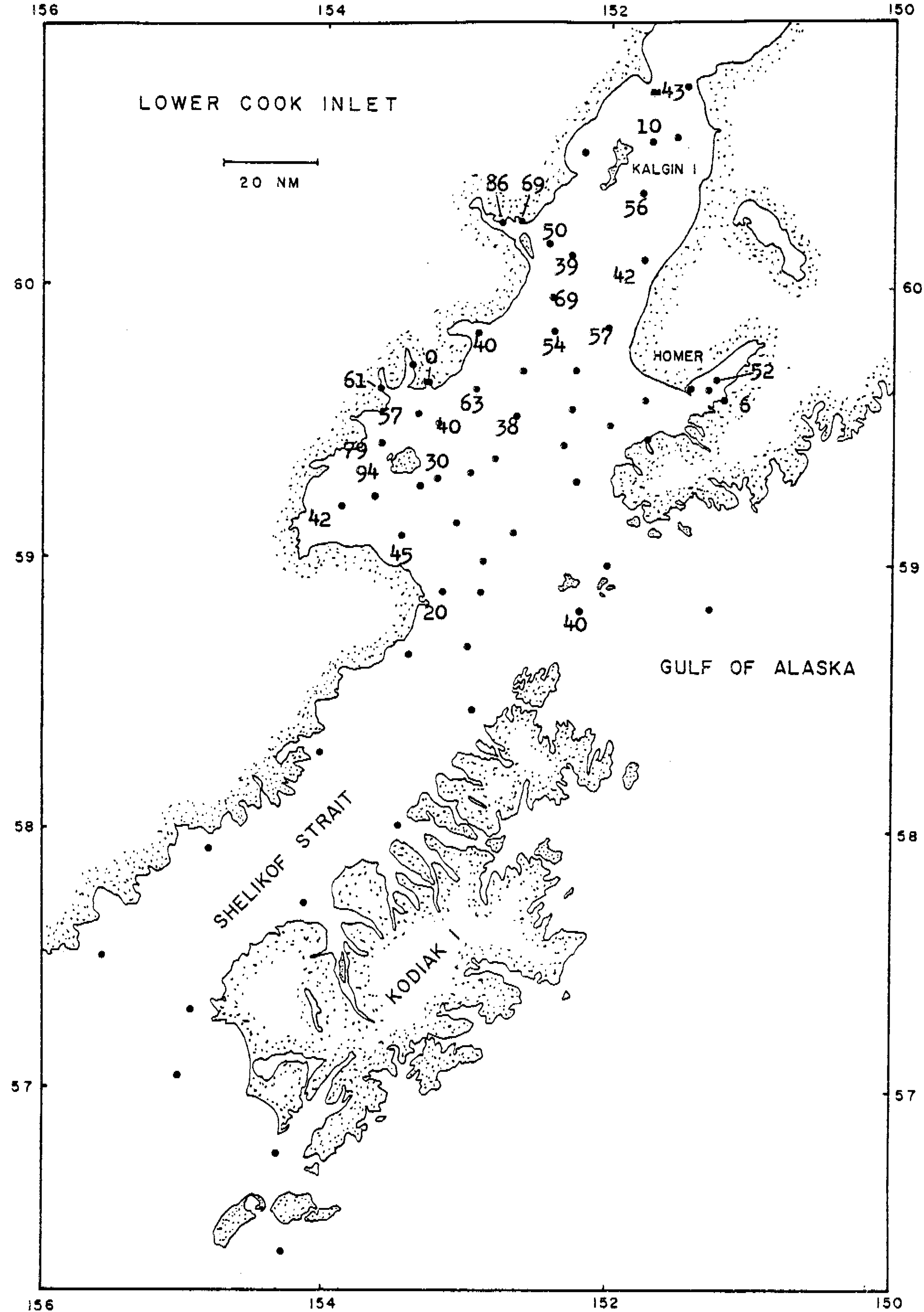


Figure 13. The percent reduction in glucose uptake rates in water samples exposed to crude oil relative to nonoiled controls.

Figure 14. Percent reduction in the rate of glucose uptake in water samples exposed to Prudhoe Bay crude oil when compared to nonoiled samples.

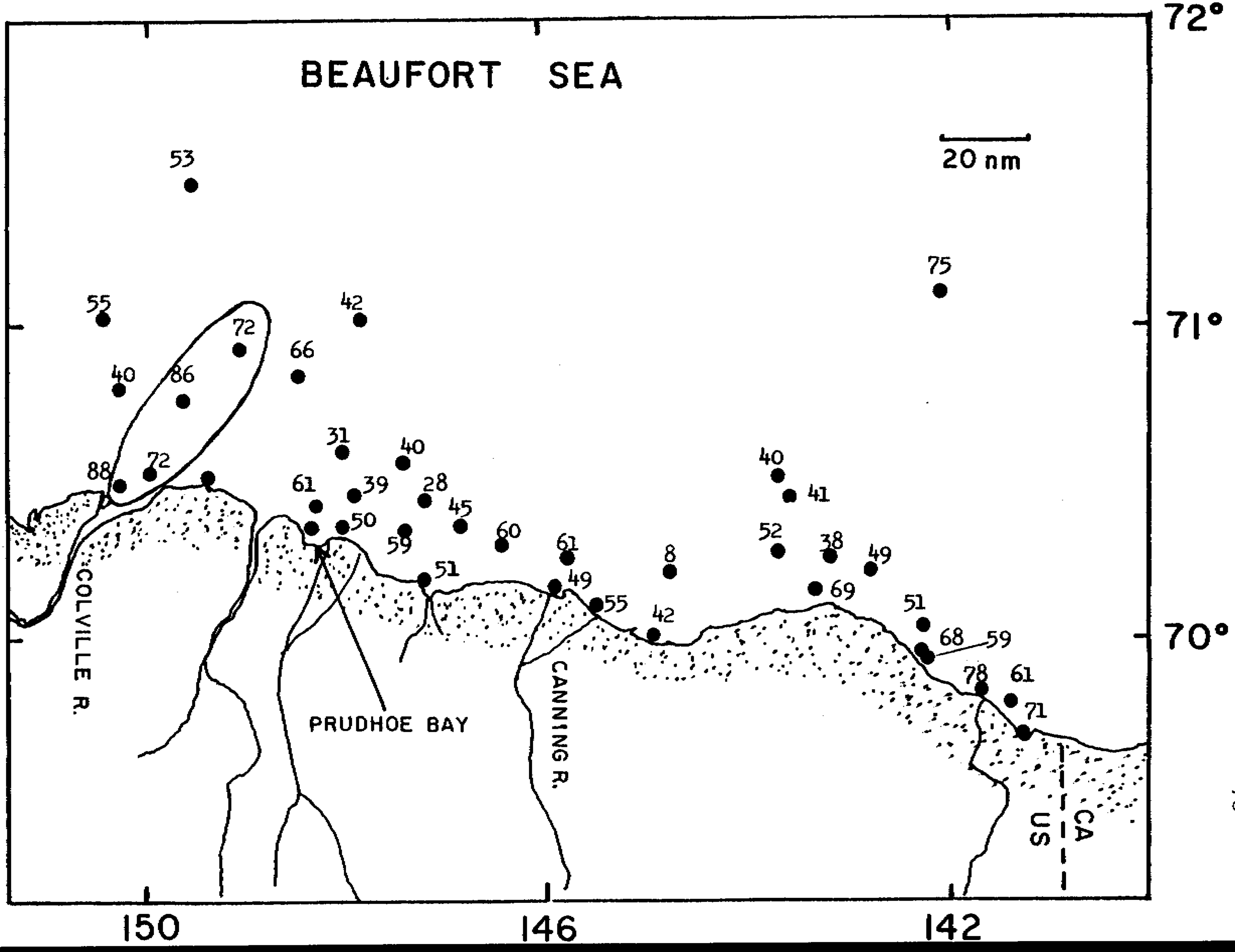
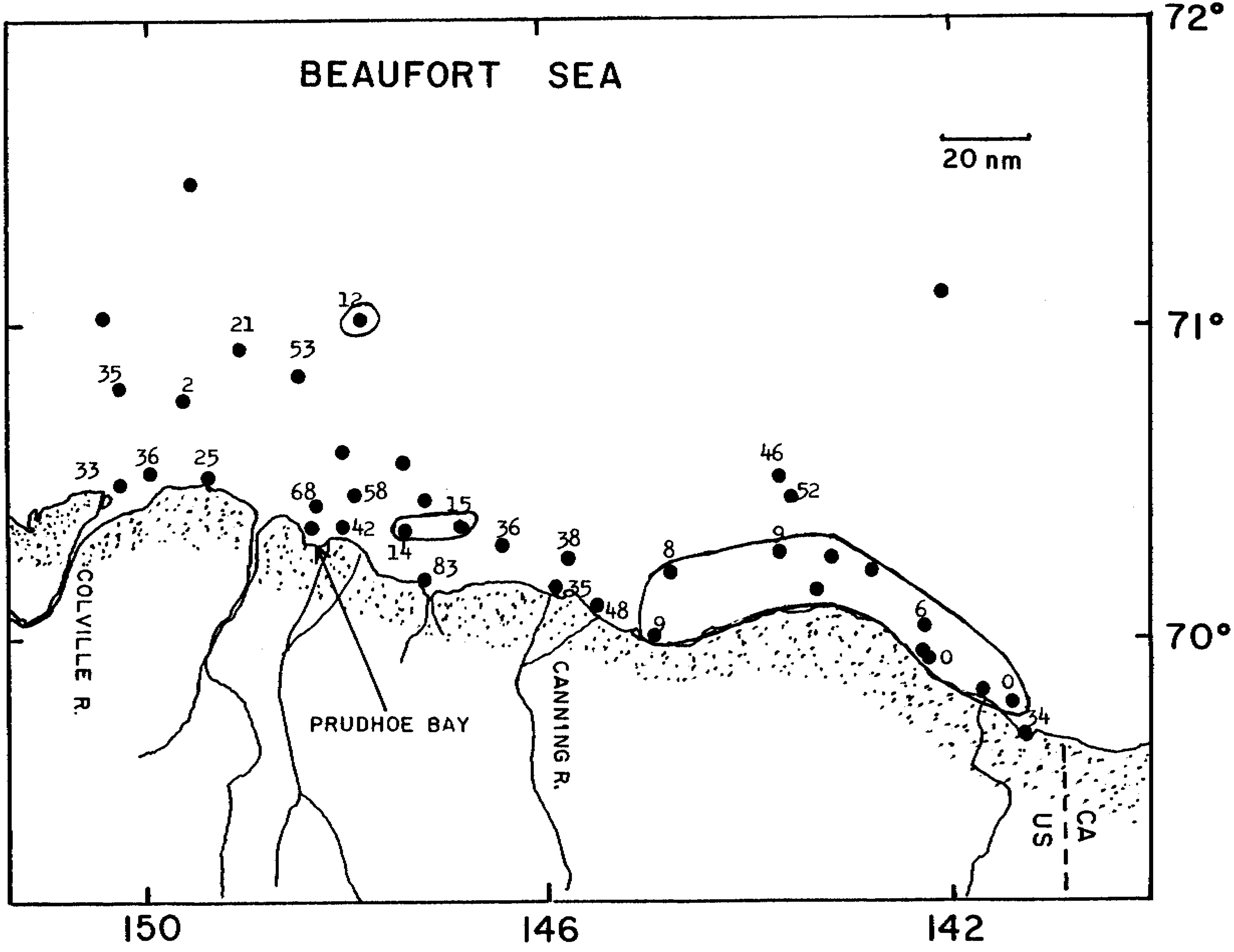


Figure 15. Percent reduction in the rate of glucose uptake in sediment samples exposed to Prudhoe crude oil when compared to nonoiled samples.



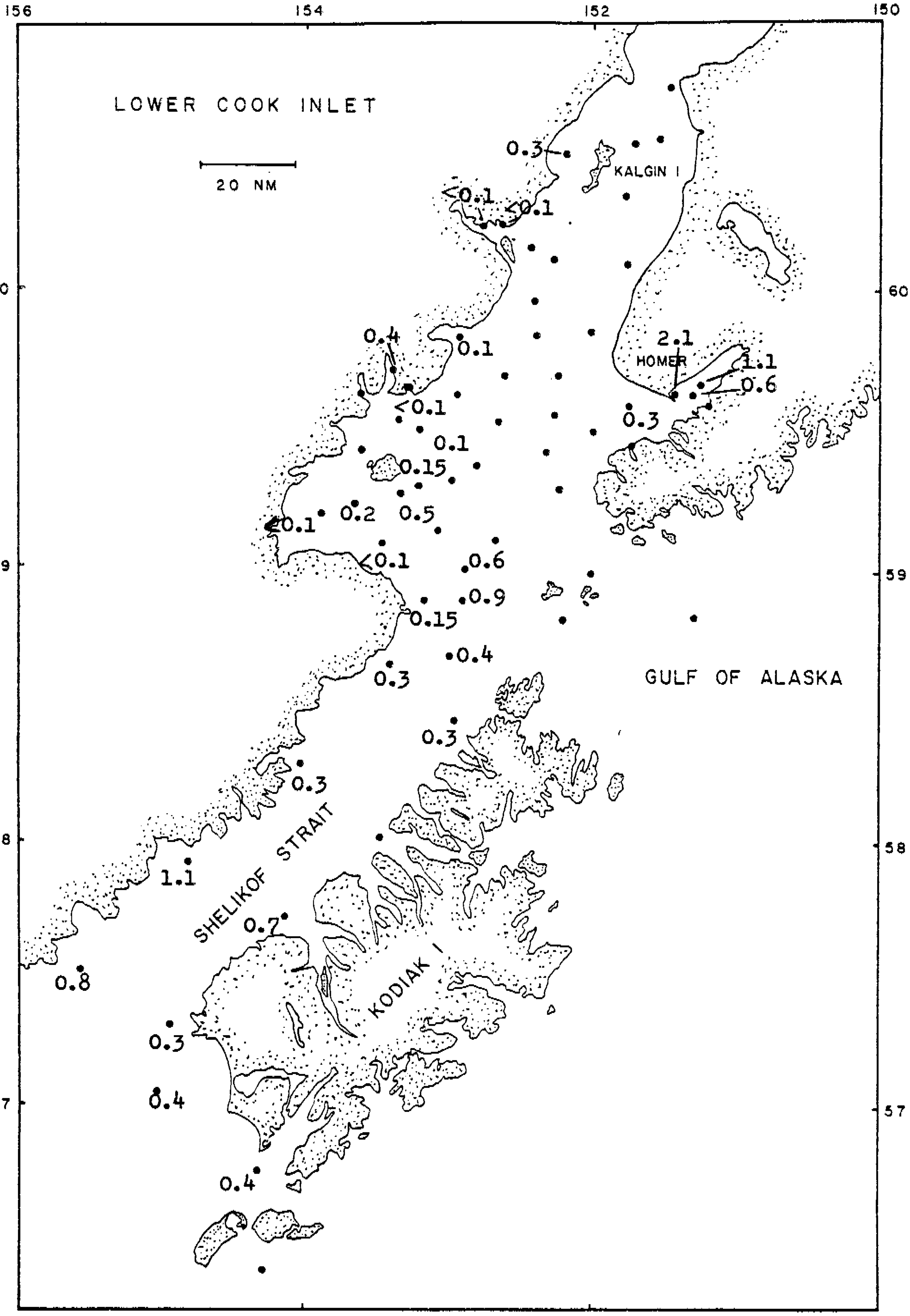


Figure 16. Nitrogen fixation rates in sediment samples collected during the April, 1978 Cook Inlet cruise. Units used are ng N_2/g dry wt./h.

IWR 79-11

ANNUAL REPORT

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NUTRIENT DYNAMICS IN NEARSHORE ALASKAN BEAUFORT SEA WATERS

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HIGHLIGHTS OF 1978 RESULTS AND CONCLUSIONS

Isotopic studies of marine organisms obtained from the Simpson Lagoon area indicate that up to 12 percent of the carbon in the organisms is derived from peat eroded into nearshore waters. Benthic isopods and amphipods contain the greatest amounts of peat carbon whereas arctic cisco and humpback whitefish showed no evidence of detrital carbon in their tissue. Four-horned sculpins taken from Simpson Lagoon reflected the isotopic composition of mysids and amphipods on which they feed.

Radiolabel experiments utilizing C-14 labeled cellulose and peat samples obtained from Simpson Lagoon showed active cellulose degradation by microflora in the water column and in the detrital peat. Amphipods and isopods captured in Elson Lagoon showed no ability to digest cellulose when fed radiolabeled cellulose either carrier-free or in the presence of detrital peat. It is concluded, therefore, that degradation of peat carbon by microflora and subsequent grazing of the bacteria and meiofauna by benthic crustacea are the principle pathways for the incorporation of peat carbon into higher animals.

Estimates of total carbon input to the Beaufort Sea via shoreline erosion processes have been revised downward to 1.1 x 10^8kg C/year out of a total of 5.4 x 10^8kg C/year. Primary production and fluvially transported organic matter supply the remainder. River transported modern carbon is the largest single source, 2.3 x 10^8kg C/year although the data base for this figure is poor and being revised. Since the pathways of energy transport in the nearshore foodweb are similar for eroded detritus and river transported detritus, the determination of peat carbon incorporation is also a means of estimating the total significance of allochthonous carbon input. This would indicate that up to 30-40 percent of the carbon in Simpson Lagoon benthic invertebrates is derived from terrestrial sources. This percentage may be even higher if averaged over the year as all organisms tested were collected in late summer and fall following the season of high primary production and thus biasing the C-14 content toward modern percentages.

Nutrient concentration data confirm that the offshore waters are strongly nitrogen limited with N:P ratios averaging near 7.5. In areas receiving large detrital and freshwater inputs, the reverse is true and a deficiency of phosphate is evident. Nitrogen and phosphorus analyses on peat samples from Simpson Lagoon yielded N:P ratios of about 110, and inputs of this organic matter may contribute to the observed depletions in the water column nearshore.

Ice algae populations sampled in Spring 1978 were apparently more responsive to turbidity in the ice column than to the nutrient concentrations in the underlying water. Data are insufficient at this time to comment on the effects of thermohaline convection as a supply of nutrients to ice algae in the nearshore zone. Turbidity within the ice is related to the process of ice formation and the entrainment of detritus particles into the ice sheet after being carried from the bottom to the underside of the ice presumably by ice crystals forming from supercooled water (See also R.U. 356). Ice turbidity was observed to be most active in stations where water depths ranged from 3 to 6m but much less in shallower water or outside of the barrier islands.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Objectives

The overall objective of RU 537 is to describe the principal processes supplying energy (i.e. fixed carbon) to the biota of the Beaufort Sea coastal zone and to relate the various nutrient chemistry regimes observed to this production of energy. Both terrestrially derived and offshore derived nutrient sources are considered. The information obtained is for integration into the overall structure of the LGL Barrier Island study group, RU 467. Their modelling effort will relate this information to: 1) description of the overall ecosystem, 2) possible OCS direct impacts on the nearshore biota by offshore oil and gas development, and 3) possible impacts on the nearshore biota caused by "upstream effects" on land which would change the character of terrestrial input of nutrients and/or carbon to the marine ecosystem via erosional processes or runoff.

Conclusions

The conclusions to date give evidence that the nearshore Beaufort Sea is decidedly different than more temperate Alaskan coastal zones with regard to the energy sources supporting the biota. The estimates of energy input to nearshore waters have been revised as new data obtained by this research unit and RU 530 are utilized to appraise the various input sources. These estimates show that over 50% of the carbon input to nearshore marine biota (within approximately 10 km of shore) is terrestrially derived from two primary processes, fluvial transport and coastline erosion. The rivers carry large quantities of organic matter during spring break-up and coastal erosion occurs during summer months, resulting in the deposition of large amounts of organic carbon along the shoreline. This carbon is composed primarily of peat-like material that has been accumulating on land for up to 12,000 years. Thus the nearshore marine biome is apparently a "fossil fuel" subsidized ecosystem wherein the meager annual primary production by ice algae and phytoplankton is supplemented by organic carbon eroded from coastal peat bluffs and transported by river flow into the coastal zone.

Implications with respect to oil and gas development.

The implications of oil and gas development on biological primary and secondary production are mostly indirect but potentially great. Development that would increase or decrease shoreline erosion or runoff characteristics could be expected to show corresponding impacts on the nearshore zone.

Similarly, developmentally caused changes in the nearshore sea-ice surface that would change freezing rates or transparency would be expected to change under-ice salinity and light characteristics with consequent biological effects. Refinement of our assessments as to the magnitude of these impacts is continuing.

II. INTRODUCTION

General nature and scope of study

This research unit originally proposed to look at a very specific aspect of the nearshore primary production regime, namely, the contribution of ice algae, and the effects of thermohaline convection in supplying nutrients to ice algae populations. Since that time the importance of detritus became more evident and this research unit began to consider the possible magnitude of its significance through the use of data collected previously by the author. These results, which have been refined and presented below, (See Figure 1) show the approximate magnitudes of carbon inputs to the Simpson Lagoon ecosystem and set forth an outline of isotopic techniques that allow determination of the relative inputs of peat carbon versus modern primary production carbon (Figure 2).

Specific objectives

The specific objectives of this research unit are to:

1. Establish mass balance relationships for particulate and dissolved nitrogenous nutrients beneath the winter ice cover in the nearshore Beaufort Sea.
2. Compare standing stocks of epontic algae in relation to under-ice water circulation.
3. Collect data delineating temporal and spatial variability in ice algae blooms in the nearshore Beaufort Sea.

The data requirements of the LGS-Barrier Island study group have identified and necessitated the inclusion of the following objectives relating to the nutrient and energy inputs to the coastal marine ecosystem.

4. Determine the total inputs of energy to the coastal ecosystem including allochthonous carbon and nitrogen entering the system via terrestrial runoff and coastal erosion.

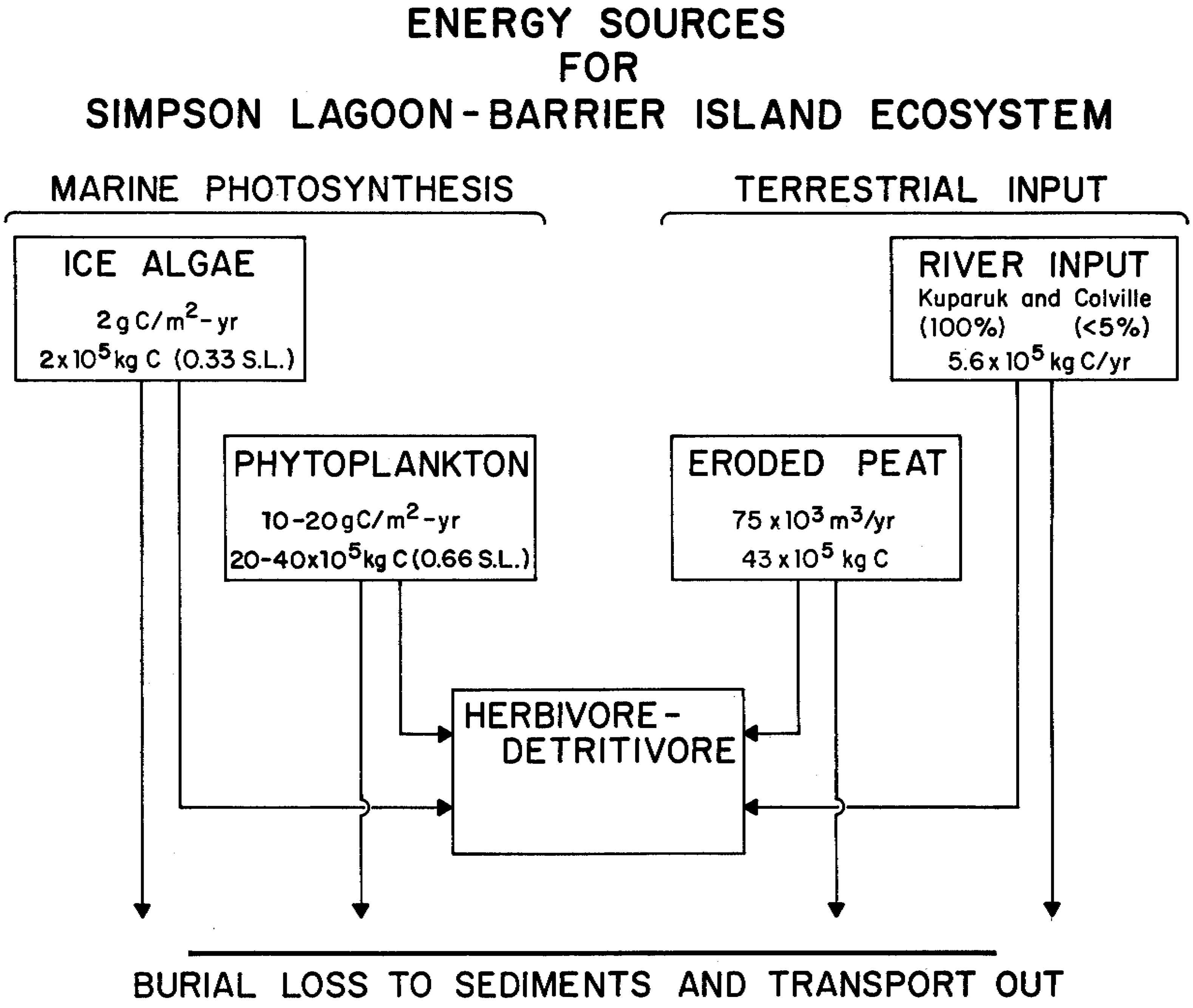


Figure 1. Energy sources for Simpson Lagoon-Barrier Island ecosystem

5. Relate the observed patterns in nutrient availability over the annual cycle to the heterotrophic utilization of detrital carbon within the coastal ecosystem.
6. Determine to what extent the detrital carbon is passed up the food chain and the relative significance of the various energy inputs to specific higher organisms in the coastal Beaufort Sea.

Relevance to problems of petroleum development

An ecosystem with a substantial detrital base along large portions of the Beaufort Sea could be readily altered directly or indirectly through OCS-related petroleum development. A summary of the specific impacts that might affect the various sources of energy into the ecosystem would include, by type:

Ice algae productivity:

1. Oil spills on or under the spring ice cover would diminish primary production through either phytotoxic effects or by attenuation of light passing through the ice sheet.
2. Alteration of bottom topography by dredging channels or constructing causeways could alter ice algae production by changing patterns of thermohaline convective flow beneath the ice cover. Prevention of brine drainage by closing off deeper channels would lead to brine accumulation on the bottom which could seriously impact both fauna and flora.

Phytoplankton production: Open water primary production would be most sensitive to such impacts as phytotoxicity resulting from oil spills. The rapid lateral flushing of water along the Beaufort Sea coast may, however, serve to minimize this aspect of potential impact.

Detrital-based production and heterotrophic productivity: Impacts upon the heterotrophic organisms that depend upon eroded and transported peat materials as their energy source would occur primarily through OCS-related developments that impinged upon the sources of detritus. Such procedures as shoreline stabilization could alter the food base by eliminating eroded materials. Causeway construction could change wave energy regimes and thus decrease shoreline erosion. Stabilization or channelizing of streambeds might add to or subtract from the total organic load carried by runoff waters. The present lack of knowledge concerning the role of detrital-based production in the overall food web of the Beaufort Sea makes assessment of the potential impacts difficult at this time.

III. CURRENT STATE OF KNOWLEDGE

Primary production

In comparison to the warmer waters along the more southern Alaskan coastlines, the Beaufort Sea supports a relatively sparse biota. No appreciable harvests of renewable marine resources are made, with the exception of small commercial fisheries operated principally by native communities in the estuaries along the coast, and seasonal harvesting of bowhead whales at Point Barrow. The zone of maximum biological productivity is confined to a relatively narrow strip along the coast wherein the interaction of terrestrial influences ameliorates and somewhat enhances the sparse oceanic regime.

The primary production supporting the pelagic community occurs in two distinct phases in the Beaufort Sea (and other polar waters). The initial algal bloom in the spring occurs well before the >2 m ice cover has begun to melt, but after the returning daylight reaches critical intensities sufficient to supply the necessary energy beneath the ice (Appolonio, 1965; Bunt, 1963). Attached, or epontic algal populations grow on the ice-water interface and thrive until the melt begins around the beginning of June. Estimates of the carbon fixed during this period range from about 1 gm/m^2-yr in the shallow Prudhoe Bay area (Horner et al., 1974) to 5 gm/m^2-yr off Point Barrow (Clasby et al., 1976). Little is known about spatial variability in ice algae production along the Beaufort Sea coast.

As the ice cover melts, phytoplankton production assumes the major role in energetic input, although the stability of the water column caused by the melting of the nutrient-poor ice cover hinders the advection of deep water nutrients to the photic zone. Only in limited areas near Barter Island has Hufford (1974) identified possible upwelling of deep waters. As a result, primary production by phytoplankton is low and estimates range from <10 g C/m^2-yr in the central Arctic Ocean (English, 1961) to about 20 g C/m^2-yr on the coastal zone near Barrow (Alexander et al., 1974).

Input of terrestrial carbon to the nearshore coastal zone

The enhancement of biological activity in the proximity of land has been long attributed to various factors among which are the provision of suitable habitat for both benthic flora and fauna, substrate for macrophytes and input of terrigenous nitrogen, phosphorus and carbon via runoff from land. The arctic coastline provides very limited habitat for macrophytes or benthic infauna due to the 2 m freeze depth, which effectively eliminates the shallow nearshore zone as a year-round environment for marine organisms. Again, in the deeper water, ice scouring creates sufficient habitat disturbance to account for the paucity of observed infauna.

Below the 2 m contour in the bays and lagoons, however, large standing stocks of invertebrates - amphipods, mysids and isopods - are common and the LGL-Barrier Island Study (RU 467) personnel are attempting to determine the biomass in Simpson Lagoon. These invertebrates are commonly found in close association with eroded organic material from the shoreline. Studies by Broad (RU 356) have shown that certain gammarid amphipods and isopods do ingest and degrade the peat. This ingestion is probably accompanied by the removal and digestion of heterotrophic microflora and microfauna that are attached to the peat particles.

Although it is known that the detrital material is ingested and that large numbers of invertebrates are associated with the organic material, no conclusive evidence has yet been found indicating that the peat carbon is being assimilated either directly by invertebrates capable of utilizing cellulosic material or by symbiotic cellulose-degrading microflora within the guts of invertebrates. To the contrary, evidence presented below shows that the predation of meiofauna by larger invertebrates is an essential step in translocating peat carbon up the food chain.

By using data obtained by Lewellen (1973) and the author during an earlier study of the Simpson Lagoon shoreline, (Schell, 1975) erosion rates and the resulting quantities of carbon and nitrogen washed into the lagoon were estimated for the shoreline between Oliktok Point and Beechey Point. These estimates have been expanded by Cannon and Rawlinson (RU 530) to include all of Simpson Lagoon and are presented in Section VI. Further estimates on the total input of allochthonous carbon to the Beaufort Sea have been made by the author and S. Rawlinson (RU 530), showing that most of the total carbon input is terrestrially derived. The implications of this compartmentalization of the energy input to the marine ecosystem are discussed in Section VI.

IV. STUDY AREA - BEAUFORT SEA - 100%

The study area for this project has been shifted from the originally proposed Elson Lagoon-Dease Inlet area near Pt. Barrow to Simpson Lagoon approximately 60 km west of Prudhoe Bay. This shift in siting was made to allow integration with the tasks being undertaken by the LGL-Barrier Island Study group. The principal data collection effort and detailed analyses on primary production and heterotrophic production will be made in this area. However, in conjunction with RU 530, estimates of terrestrial input of carbon along the entire Beaufort Sea coast via runoff and erosion will be undertaken on a much less detailed program.

Laboratory experiments seeking to determine the mechanisms by which trophic movement of peat carbon occurs were conducted at the Naval Arctic Research Laboratory at Point Barrow. The ready availability of amphipods and isopods in Elson Lagoon allowed controlled laboratory experiments on cellulose biooxidation with freshly collected animals.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Primary production by epontic ice algae

The sampling program for ice algae production and spatial distribution occurs during the spring months and involves sampling the ice-water interface before and after the ice algae bloom. The first sampling period is during early April and yields the water chemistry data representing the maximum nutrient concentrations and salinities of the annual cycle.

The second sampling trip of the spring, in late May, coincides with the maximum standing stocks of ice algae. Ice cores, water samples and nutrient samples are taken at this time to determine ice algae and phytoplankton particulate nitrogen and the remaining inorganic nitrogen in the water column. These data are useful in projecting primary production estimates for the lagoon area.

Analytical methods employed for nitrate, ammonia and phosphate analyses are similar to those utilized by Alexander et al. (1974) for their ice algae studies. Dissolved organic nitrogen was run using the ultraviolet photooxidation technique employed by Schell (1974). Particulate nitrogen analyses were run on glass fiber filters containing particulate material from melted ice cores or underlying water. The filters were burned and the evolved nitrogen gas measured using a Coleman Nitrogen Analyzer.

By establishing detailed nitrogen budgets for the water column and ice column before and after the epontic algal bloom, it is possible to determine two important facets of the nearshore productivity regime. First, the total standing stocks of ice algae (and assimilated nitrogen) can be quantitatively described for the nearshore zone, and the validity of extrapolating primary production measurements obtained by Clasby et al. (1976) at Point Barrow to include other areas of the Beaufort Sea coast can be determined. Second, by establishing budgets of nitrogen in the dissolved and particulate phase, the importance of thermohaline convective flow as a nutrient input in the nearshore zone can be estimated. This hypothesis states that enhanced primary production by ice algae can be expected in the 2-5 m depth zone in the late spring and the measurement of total particulate and inorganic nitrogen in the ice/water column offers the most direct test of whether or not this enhancement occurs.

Utilization of detrital carbon and transfer of detrital carbon in the food web

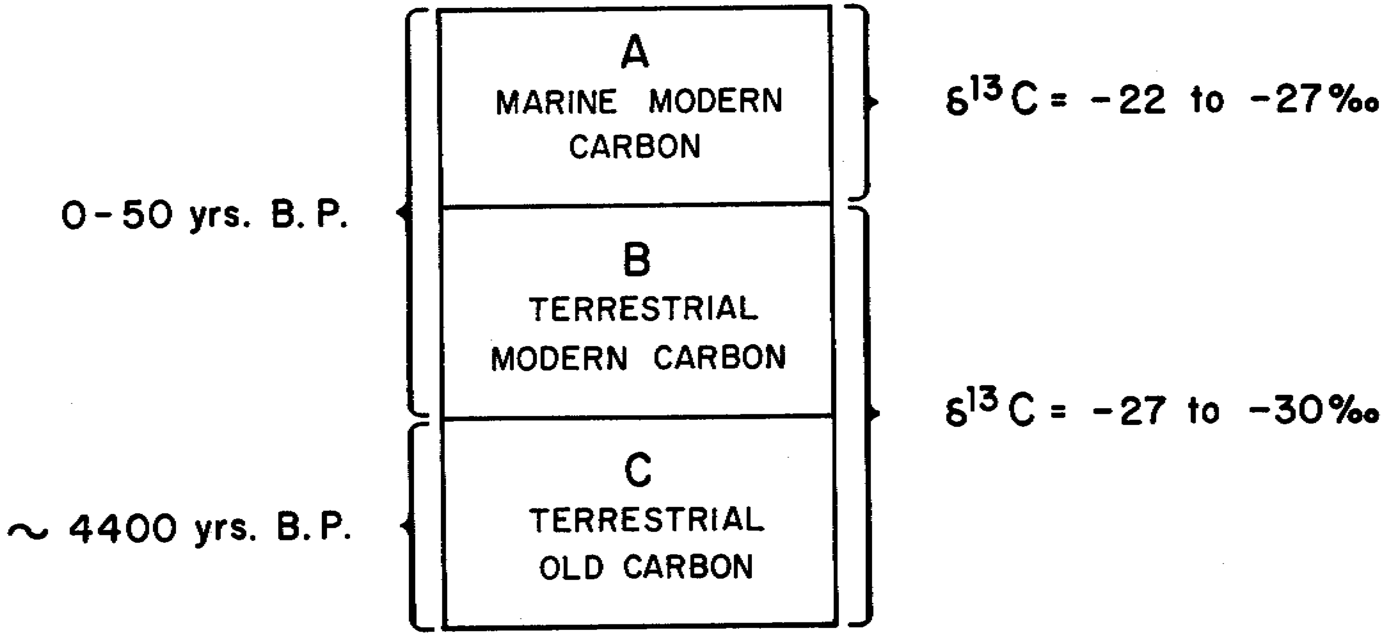
The magnitude of detrital carbon input to the nearshore zone of Simpson Lagoon (Fig. 1) required that the effects of this energy source be evaluated in respect to the inputs of primary production. Detrital input occurs through essentially two sources - coastal erosion and runoff from the tundra. Thus assessment of these inputs becomes a

DETERMINATION OF HERBIVORE-DETRITIVORE CARBON SOURCE

IS CARBON SOURCE RECENT OR OLD ?

HERBIVORE-DETRITIVORE BIOMASS

IS CARBON SOURCE MARINE OR TERRESTRIAL?



A
MARINE MODERN CARBON

B
TERRESTRIAL MODERN CARBON

C
TERRESTRIAL OLD CARBON

0-50 yrs. B. P.

~ 4400 yrs. B. P.

$\delta^{13}C = -22$ to $-27‰$

$\delta^{13}C = -27$ to $-30‰$

Figure 2A.

RADIOCARBON DATING

$$\% C = \left[\frac{\text{Mean peat age} - \text{Sample age}}{\text{Mean peat age}} \right] \times 100$$

$$\% A+B = 100 - C$$

= percent modern carbon (marine and terrestrial)

STABLE ISOTOPE RATIOS

$$\% A = \frac{{}^{12}C/{}^{13}C(\text{terr.}) - {}^{12}C/{}^{13}C(\text{sample})}{{}^{12}C/{}^{13}C(\text{terr.}) - {}^{12}C/{}^{13}C(\text{marine})} \times 100$$

$$\% B = 100 - (A+C)$$

= carbon derived from modern terrestrial sources.

Figure 2B. Isotopic techniques for carbon source determination.

geomorphological problem for the former source and a hydrological problem for the second. Chemical data on the eroded tundra have been previously obtained by Schell (1975) and have been refined through additional work since beginning this study. Vertical profiles of newly exposed permafrost shoreline bluffs at Milne Point and Pingok Island were obtained in August 1978 and are currently being analyzed for carbon, nitrogen, phosphorus and water content. Carbon analyses are being performed with a carbon analyzer which will give more accurate carbon content than the ashing technique used in previous work.

Refinements in shoreline erosion rates along the Beaufort coast are being determined by Cannon and Rawlinson (RU 530). Total organic carbon data for the Colville River waters have been kindly provided by the US Geological Survey (Charles Sloan, personal communication) and flow data are available from the literature (Arnborg et al., 1967; Walker, 1974). It is hoped that further organic carbon data from the river systems can be obtained in 1979 for both mass transport and isotopic analysis.

The utilization of detrital organic carbon by heterotrophs and the further transfer of this carbon into the food web has been investigated through the use of carbon isotope ratios in the various coastal marine living and nonliving organic materials. Figure 2A shows the three fractions that would comprise the organic carbon of a detritivore or the predators of detritivores. The analytical techniques employed to identify these fractions are shown in Figure 2B. If the carbon in the eroded peat materials of the shoreline are incorporated to a significant extent in the food web of heterotrophic microorganisms and these are then consumed and assimilated by benthic invertebrates such as amphipods, isopods and mysid shrimp, the isotopic abundances in the higher organisms should generally reflect the food source. Some species of these benthic invertebrates are known to comprise a large fraction of the diets of higher organisms found in the coastal Beaufort Sea and thus the potential exists for detrital carbon to constitute a significant fraction of the energy supply to the ecosystem.

Radiocarbon dating has been used to delineate the fraction of peat carbon in the organisms. Eroded peat in Simpson Lagoon has a mean radiocarbon age of about 4000-5000 years B.P. if the radiocarbon dates given by Lewellen (1973) are representative of the basal peat layer in the Simpson Lagoon area. This research unit has several samples of basal peats collected in 1978 that are currently being radiocarbon dated. These ages will be essential is establishing the mean ^{14}C activity in the "average" eroded shoreline carbon. An assumption as yet untested is that the accumulation rate of peat has been constant to date. As yet no radiocarbon age has been obtained for carbon transported by the Colville River, but the surficial nature of runoff in a permafrost environment such as the North Slope would suggest a modern date somewhat tempered by peat addition via riverbank erosion and collapse.

Stable isotope techniques allow the discrimination of food sources in ecosystems where the source materials (primary producers) have significantly different $^{12}C/^{13}C$ ratios. By comparing $^{12}C/^{13}C$ ratios of organisms at different trophic levels, the food sources of the higher organisms can be apportioned. This technique has been used by McConnaughey (1978) to study the detrital input of eelgrass beds in Izembek Lagoon to the fauna of the lagoon and nearshore Bering Sea. Application of this technique is shown in Figure 2B and was used as a method to separate terrestrial and marine contributions to the nearshore fauna. Although the method is acknowledged to be less sensitive than ^{14}C dating, the applicability to modern carbon sources increases its desirability. Analytical cost is low compared to ^{14}C dating.

Process studies to measure the rate of cellulose biodegradation in the under-ice waters of the Beaufort Sea were undertaken at the Naval Arctic Research Laboratory at Barrow. Water samples were collected at stations in Elson Lagoon, Smith Bay and Dease Inlet. A big-tired truck was used for transportation on Elson Lagoon and a Cessna 180 ski-equipped aircraft was used to sample the latter two locations.

A baited trap was set overnight in Elson Lagoon and, upon retrieval, approximately 200 amphipods were captured. These animals were used to investigate their ability to digest cellulose through a series of experiments employing ^{14}C-labeled cellulose mixed and peat samples obtained from Simpson Lagoon. Similarly, the microbial activity in the detrital peat was studies by measuring the production of radiolabeled CO_2 from added ^{14}C-labeled cellulose. Samples of seawater were incubated with ^{14}C-labeled cellulose and aliquots were taken at approximately 12-hour intervals. These aliquots were acidified and stripped with nitrogen to remove the carbon dioxide fraction, which was subsequently absorbed in phenethylamine liquid scintillation cocktail. These experiments, conducted at 0° and 20°, showed active microbial decomposition and oxidation of the labeled cellulose, with the fastest rates occuring at 20°.

To test the hypothesis that amphipods might possess intestinal microflora which would be active cellulose degraders (and thus be able to symbiotically contribute to the nutrition of the amphipods), an experiment was conducted usuing freshly captured animals fed on radiolabeled cellulose. Animals were offered both carrier-free and a mix of labeled cellulose and peat aged in seawater. A control of peat plus labeled cellulose without amphipods was used to determine the oxidation rate due to microflora alone. At 12 hour intervals, animals were sampled and aliquots of seawater stripped for radiolabeled carbon dioxide as described above.

Chemical analyses for total dissolved phosphorus and total and dissolved phosphate

Portions of bottom and surface water were analyzed for total and dissolved inorganic phosphate by the colorimetric method of Murphy and Riley (1962). The total phosphorus procedure involved a persulfate oxidation step to convert all of the phosphorus present to phosphate prior to colorimetric analysis (Gales et al., 1966). Total (persulfate labile) phosphorus was also determined on weighed portions of oven dried peat.

Radiophosphate uptake measurement

For analysis of radiophosphate (^{32}Pi) uptake rates in seawater, samples from Simpson Lagoon, 9 August 1978, and peat amended seawater, duplicate 250-ml subsamples were removed from five gallon carboys and placed into glass bottles which had been carefully washed and pre-rinsed with the appropriate water.

To the duplicate 250-ml subsamples, amounts to equal final concentrations of 0-2μM phosphate (^{31}Pi) plus 0.05-0.1 microcuries of ^{32}Pi were added (C. F. Rigler, 1966). Controls contained 3 drops of 10^{-2}M mercuric chloride under constant illumination. At intervals from 10 minutes to one day after the addition of ^{32}Pi and ^{31}Pi, ten-ml aliquots were removed and passed though 0.45 micrometer membrane filters using a constant suction of 400 mm Hg. The filters were placed in 10-ml of toluene-Triton X-100 counting cocktail, and the radioactivity was measured in a liquid scintillation counter to give, after correction for background radiophosphorus on the filter and subtraction from the total ^{32}Pi added, the amount of radiophosphorus in solution at different times after the addition.

Phosphate uptake rate determinations

The rate of ^{32}Pi uptake (v*) was determined as a function of either exponential (first order) or linear (zero order) ^{32}Pi removal from solution according to Brown et al. (1978). The rate of ^{31}Pi uptake (v) was then calculated from:

$$v = v^* \frac{Sn + A}{C} ,$$

where Sn was the indigenous ^{31}Pi level, A was the added ^{31}Pi level, A was the added ^{31}Pi level at time zero and C was the total added ^{32}Pi at time zero.

VI. RESULTS

Primary production by epontic ice algae.

The 1978 ice algae sampling effort was again hampered by poor flying weather but seven stations were occupied in the Simpson Lagoon area. Immediately apparent was the extreme variation in ice algae populations both on a local scale and on an area-wide basis. Station 8, approximately 1 mile off Long Island (see Figure 3) had the highest density of algae visible and the clearest ice. Inside of the barrier islands, the presence of algae was dependent upon the amount of detritus in the ice column and the depth of the overlying snow. At Stations 7, 3, 23, and 11, large amounts of detritus were incorporated into the ice and no algae were present in the bottom layer. At Station 1, off Milne Point, two cores cut approximately 10m apart gave evidence of local patchiness in that one core contained a visible ice algae layer whereas the other, cut beneath 0.4m of snow, contained only clear ice on the bottom. Such observations support the conclusions of Horner, et al. 1974, that ice algae growth is in direct response to light penetrating the ice and attenuation of this light by either detritus in the ice or snow drifts inhibits the growth of algae. Quantitation of the ice algae particulate nitrogen content is in progress and techniques for in situ chlorophyll determination using a Turner Design field fluorometer will be employed this spring for more detailed information on under-ice chlorophyll distribution. If algal populations are high at the Stefansson Sound intensive study site, calibration of ice algae recovery via coring versus diver obtained samples will be undertaken. To date, coring recoveries have been estimated from visual inspection of the

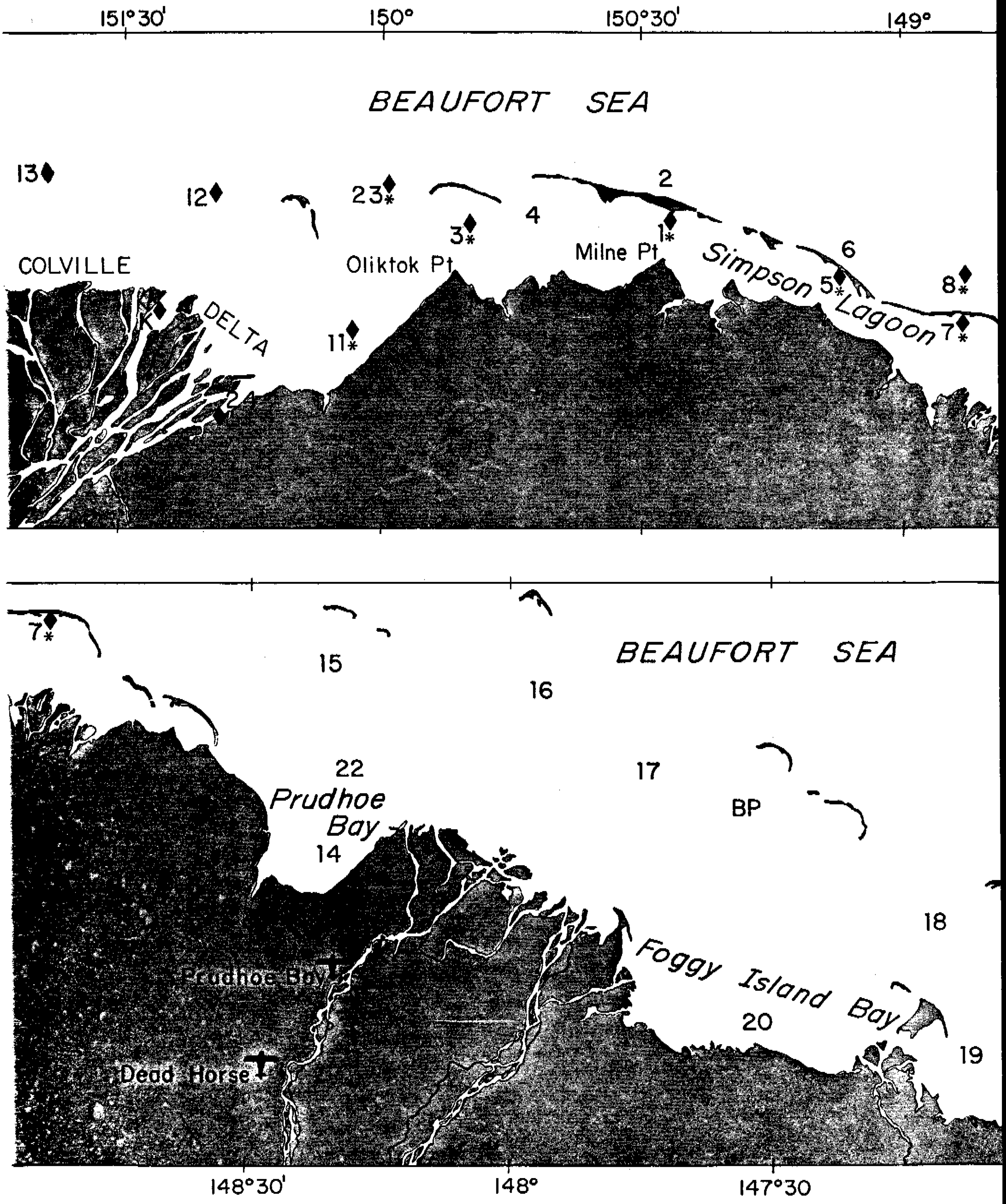


*Figure 3. Sampling stations, 1978. Numbered stations were sampled November, 1978; ◆ = sampled April, 1978; * = sampled May, 1978.*

recovered core to ascertain complete recovery of the water-ice interface and allowing for washout based on information obtained by Alexander, et al., 1974 in diver studies off Point Barrow.

Nutrient concentrations in coastal waters

The 1978 water sampling effort was successful in obtaining a good temporal and spatial coverage of the nutrient concentrations in the area of the Beaufort Sea lease sale. The field effort was divided into four sampling trips: 1) early April during maximum annual nutrient concentrations, 2) late May near maximum ice algae production, 3) summer sampling during break-up and the open water season, and 4) during November when photosynthetic activity ceases and winter salinity regimes return.

The overall nutrient concentrations increase over the winter months in response to regeneration processes, freeze concentration and resupply from deeper offshore waters. These late winter concentrations of nitrate, ammonium and phosphate ions in nearshore waters (within 10 km of shore) are compared with concentrations in the same locations in June and July, 1978 in Table 1. The sharp decrease in concentrations reflects the uptake by algal populations and the dilution of the coastal waters by melt and runoff. Samples obtained in November 1978 are in the process of being analyzed and data are not available at this time.

It is somewhat surprising to see appreciable concentrations of available nutrients present in summer waters. This may be the result of low uptake capabilities by phytoplankton in the turbid euryhaline nearshore zone or in part due to regeneration in samples being frozen under field conditions. The samples were frozen in an ice cellar at

TABLE 1. Nutrient and salinity concentration ranges in coastal Beaufort Sea waters, 1978

Date	Depth	S 0/00	Nitrate-N*	Phosphate-P*	Ammonia-N*
4-5 April	Surface (under-ice)	34.9-50.7[9] $\bar{x} = 41.0$	6.9-12.3[9] $\bar{x} = 9.05$	0.73-1.55[9] $\bar{x} = 0.96$	0.4-5.0[9] $\bar{x} = 2.7$
25 May	Surface (under-ice)	32.8-50.3[7] $\bar{x} = 39.9$	4.2-9.4[7] $\bar{x} = 7.2$	0.98-1.26[7] $\bar{x} = 1.15$	0.62-4.4[7] $\bar{x} = 2.02$
21-28 June	Surface	1.1-7.5[10] $\bar{x} = 2.55$	0.0-1.9[10] $\bar{x} = 0.52$	0.11-0.45[10] $\bar{x} = 0.27$	0.3-3.2[10] $\bar{x} = 1.5$
	Bottom	32.4-47.1[9] $\bar{x} = 40.8$	0.6-5.1[9] $\bar{x} = 3.0$	0.21-1.15[10] $\bar{x} = 0.54$	0.9-3.8[9] $\bar{x} = 1.7$
7 July	Surface	2.4-3.9[5] $\bar{x} = 3.14$	0.0-1.1[3] $\bar{x} = 0.35$	0.08-0.25[5] $\bar{x} = 0.13$	
	Bottom	3.05-5.89[5] $\bar{x} = 4.33$	0.0-1.3[7] $\bar{x} = 0.36$	0.10-1.14[5] $\bar{x} = 0.35$	
20-29 July	Surface	22.7-30.0[10] $\bar{x} = 26.5$	0.0-1.9[12] $\bar{x} = 0.72$	0.30-1.09[9] $\bar{x} = 0.66$	
	Bottom	23.4-32.3[10] $\bar{x} = 29.7$	0.0-3.1[9] $\bar{x} = 2.02$	0.28-1.19[9] $\bar{x} = 0.83$	

*Nutrient concentration ranges in μg-atoms/liter, [ ] = number of samples.

TABLE 2. Water and phosphorus content of coastal peat soils, Simpson Lagoon, Alaska

	Milne Point Soil Section 1		Pingok Island Soil Section 1	
Depth, cm	Percent moisture	Total P mg P/kg dry weight	Percent moisture	Total P mg P/kg dry weight
0-10	41.4	261	28.3	228
30-40	35.5	282	71.4	137
60-70	76.2	328	78.9	319
90-100	81.3	210	77.8	306
120-130	68.4	294	59.7	338
150(basal peat)	57.5	184	73.6	342
160-170	72.0	244	71.9	426
Sagavanirktok River basal peat	50.9	342		

Milne Point and often took about 48 hours to reach permafrost temperatures (∿ -10°C). These less than ideal conditons for nutrient sample storage may be responsible in part for the measured wide ranges in available nitrogen and phosphorus in surface samples. Future samples will be poisoned to 10^{-5}M $HgCl_2$ in addition to freezing to guard against possible microbial activity. The deeper samples (2.5 - 12m) show concentrations of nitrate that would be expected to support active photosynthesis in July. Ice cover persisted until mid-July and the reduced light penetration resulting from reflectance and turbidity may have been responsible for the slow apparent uptake at depth. Chlorophyll data are being processed to determine phytoplankton concentrations within the water column at these stations.

Phosphate uptake experiments - August, 1978

The results in Table 3 show the concentrations of dissolved inorganic phosphate (DIP) and total organic phosphorus (TOP) in Milne Point seawater. The phosphate uptake rates of Milne Point seawater samples and peat amended Milne Point seawater samples are shown in Tables 4 and 5. The peat amended seawater does take up phosphate at a significantly higher rate than seawater alone. The fact that the uptake rates in the $HgCl_2$ poisoned control and the autoclaved control were much lower than the peat amended seawater, indicates that the uptake was probably biological in nature versus a non-biological sorption (Table 5). Since the phosphate uptake rates in seawater did not increase significantly with concentration up to additions of 0.50μg atom P/l, and the indigenous concentration was 0.20μg atom P/l, the mechanisms responsible for uptake and release of phosphorus at these

TABLE 3. Phosphorus analyses - Milne Point Water

Station	Date	DIP* µg At P/l	TOP** µg At P/l
1(surface)	27 July 78	0.36	0.72
4(bottom)	27 July 78	1.07	1.55
1(surface)	7 Aug 78	0.20	0.49
4(bottom)	7 Aug 78	0.15	0.24
1 & 4(pooled)	8 Aug 78	0.12	

*DIP = dissolved inorganic phosphate
**TOP = total organic phosphorus

TABLE 4. Phosphate uptake by Milne Point Seawater

Phosphate Added * µg atom P/liter hr	Uptake Rate ng atom P/liter hr
carrier free ^{32}Pi	5.6
0.05	5.5
0.10	4.8
0.50	6.9
1.0	18.0
2.0	52.0

*ambient dissolved inorganic phosphate = 0.20 µg-atom P/liter

TABLE 5. Phosphate uptake by peat amended seawater

Sample	Total inorganic phosphate µg atoms P/g peat	Uptake Rate µg atoms P/g peat-hr
Peat & filtered Milne Point water	3.12	1.08
$HgCl_2$ poisoned	3.12	0.17
Autoclaved	3.12	0.03

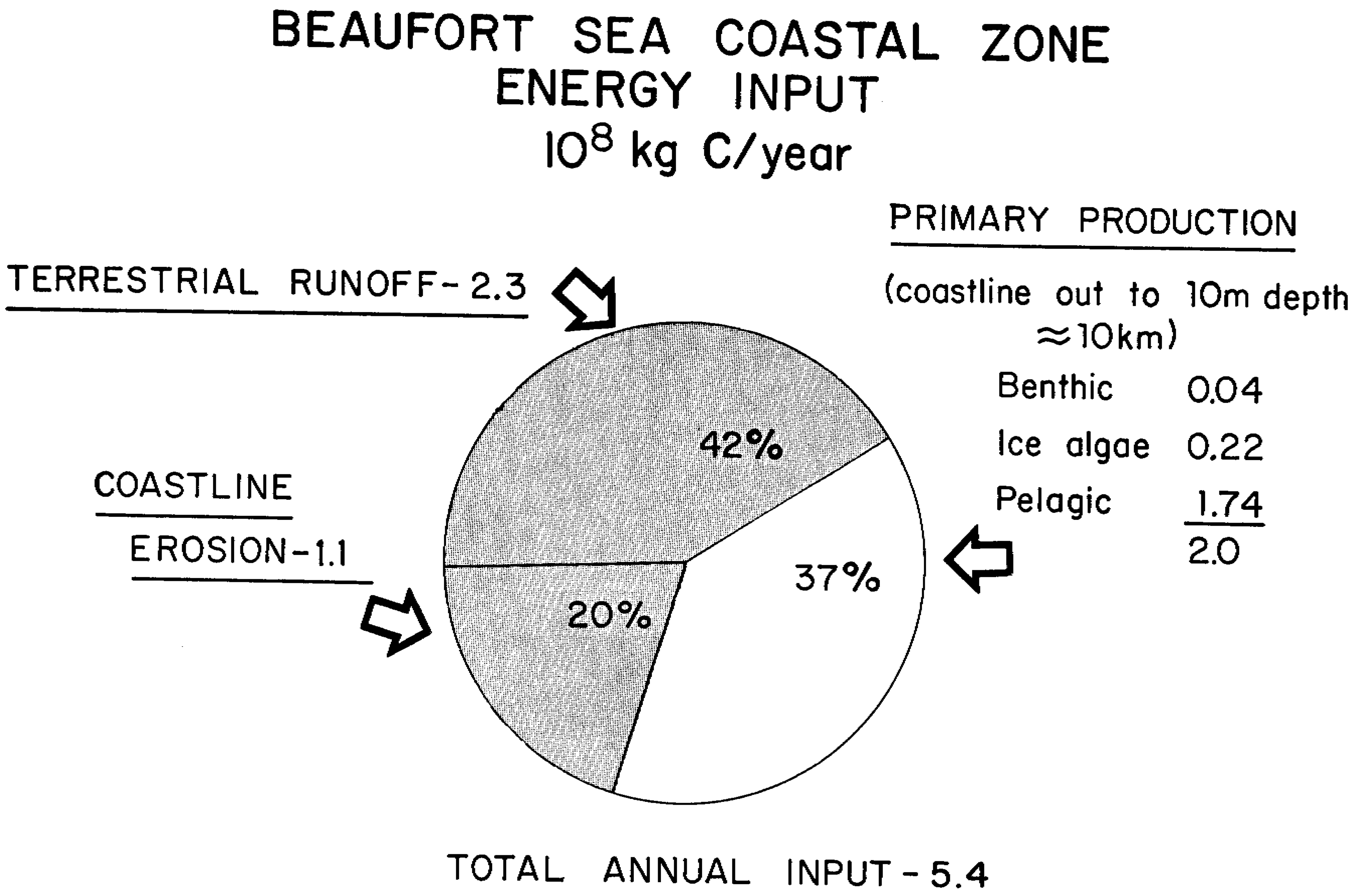

BEAUFORT SEA COASTAL ZONE
ENERGY INPUT
10^8 kg C/year
TERRESTRIAL RUNOFF - 2.3
COASTLINE EROSION - 1.1
PRIMARY PRODUCTION
(coastline out to 10m depth ≈ 10km)
Benthic 0.04
Ice algae 0.22
Pelagic 1.74
2.0
42%
20%
37%
TOTAL ANNUAL INPUT - 5.4

Figure 4.

lower concentrations were most likely in a steady state (Table 4). The increased uptake response to additions of higher concentrations of phosphate (1.0 and 2.0μg atom P/l) probably indicates a stimulation of biological phosphate incorporation above the steady state levels. A physical sorption studies of phosphate to peat are currently being done to validate this interpretation. In addition, more uptake studies with estimations of microbial biomass in the samples are being planned.

Trophic system energy flow

Reevaluation of erosion data obtained by R.U. 530 and new field data has led to a revision of carbon input quantities resulting from coastline erosion along the Alaskan Beaufort Sea. The carbon content of eroded soils has been revised downward to 1.1 x 10^8kg C/year from 4.6 x 10^8kg C/year following moisture analyses of soil sections obtained at Pingok Island and at Milne Point (Table 2) during 1978. The carbon input quantities from terrestrial runoff and from primary production remain the same pending additional sampling and analytical data. It is hoped that the Colville, Kuparuk and Sagavanirktok Rivers can be sampled over the 1979 hydrologic season to improve the terrestrial runoff data. The quantities of total eroded carbon carried by these rivers has been estimated from a very limited data base and need to be verified. The revised allocation of Beaufort Sea coastal zone (<10 km offshore) carbon inputs is shown in Figure 4. Similarly, the nitrogen and phosphorus inputs have been revised to reflect the changes in estimated peat volumes eroded the results indicate total N input equals 10.1 x 10^6kg/year and total phosphorus, 4 x 10^5kg/year. Table 2 lists the results of total phosphate analyses on samples collected in summer 1978. Using erosional estimates along the Simpson Lagoon perimeter (R.U. 530) the revised carbon inputs are shown in Figure 1 with benthic biomass ranges estimated by R.U. 467. These figures are the current "best estimates" and will be revised in the future as the analyses of the collected samples is completed.

Cellulose biodegradation studies.

The utilization of detrital peat materials as an energy source for benthic crustaceans could conceivably occur through two mechanisms. First, if the organisms possess the enzymatic systems in the digestive track to hydrolyze cellulose or symbiotic cellulose degrading microflora, direct consumption and digestion is possible. The second pathway assumes that the amphipods, mysids, etc., feed upon the microfauna and flora that are the primary consumers of the detrital carbon. To test which of these mechanisms is the predominant transfer process, laboratory feeding studies rising ^{14}C-labeled cellulose were conducted as described above. The results of these experiments are shown in Figures 5 and 6. Figure 5 gives the oxidation rates as measured by the production of $^{14}CO_2$ due to microbial populations in seawater taken from Elson Lagoon, Station 1 being approximately 1 mile off Brant Point in the channel behind Tegekakrok Bar and Station 2 in Eluitkak Pass. Oxidation rates were faster in Eluitkak Pass water and in both samples, faster at 20°C. The oxidation rates at 0°, 0.016 and 0.021 μg cellulose/liter-hr for Stations 1 and 2 respectively, yield a turnover time of 120 and 91 days for the 46 μg per liter of cellulose added. At 20°, these turnover times drop to 42 days for Station 1 and 39 days for Station 2 indicating active populations of

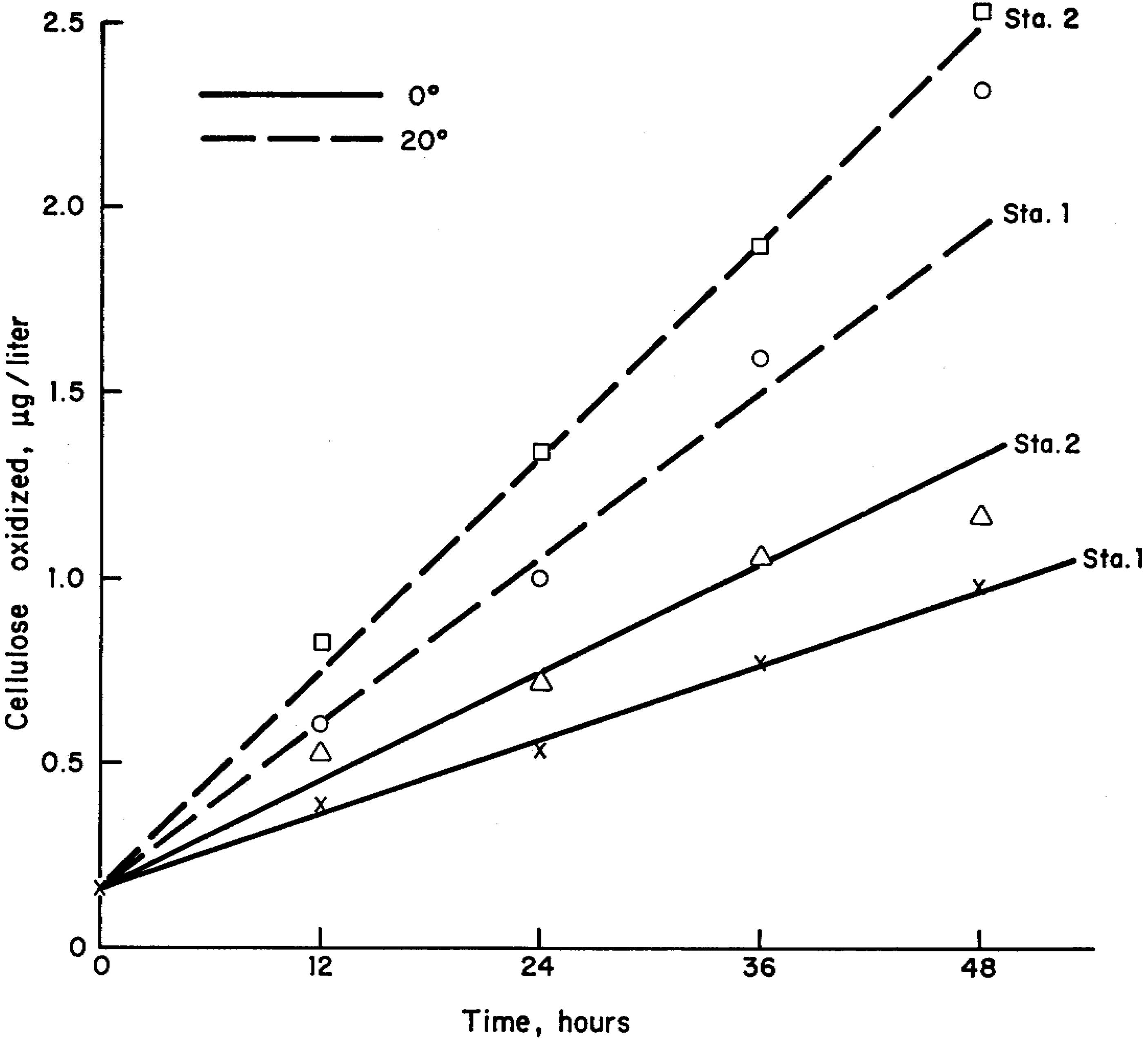


Figure 5. Carbon-14 cellulose oxidation in Elson Lagoon seawater.

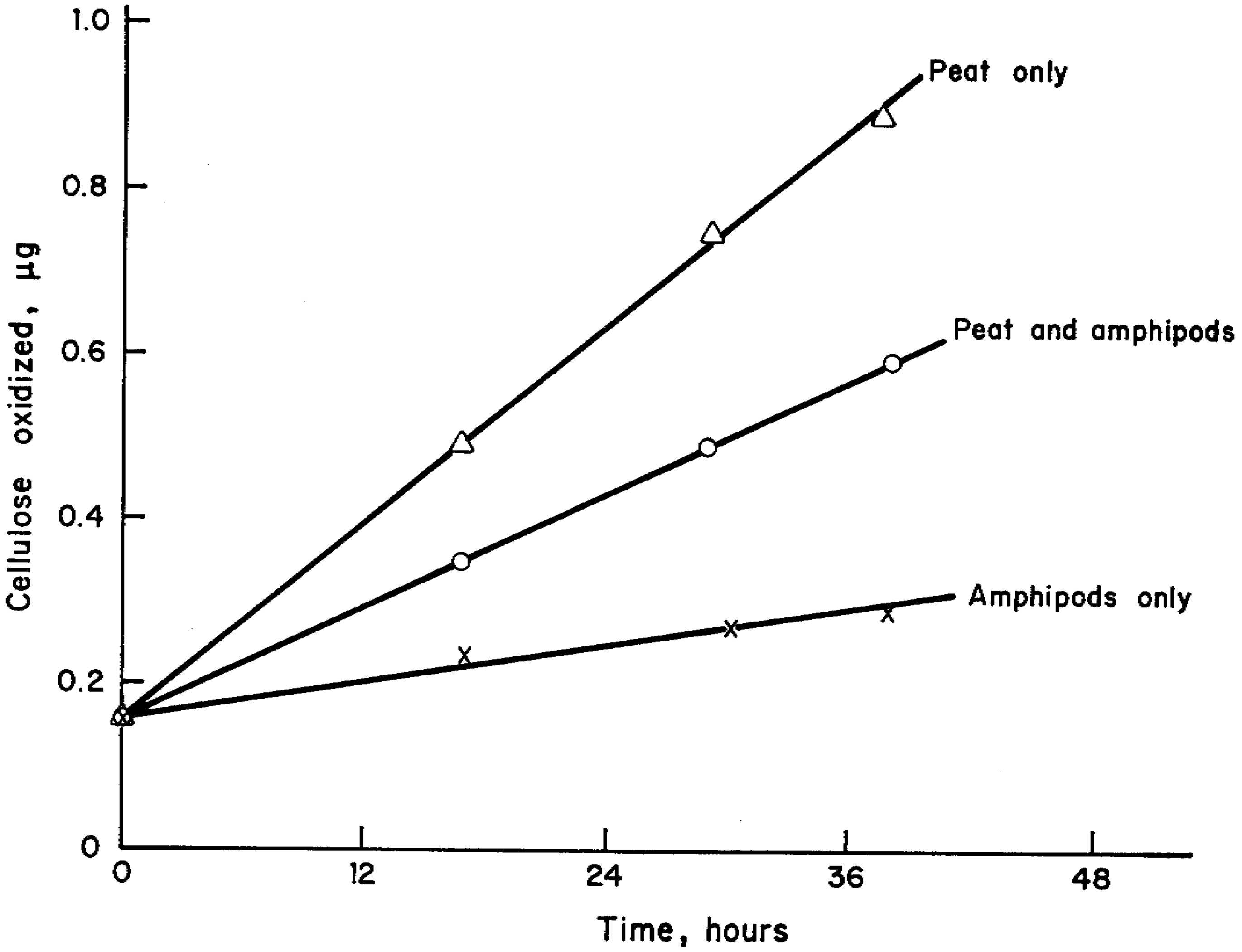


Figure 6. Oxidation rates of ^{14}C-cellulose in seawater with added peat and amphipods, 0°C.

cellulose degraders throughout the water column. The results of cellulose oxidation experiments at 0°C with amphipods (Onisimus and Boeckisimus *sp.*) are shown in Figure 6. The fastest oxidation rates were found in the seawater-wet peat control which had no amphipods. The amphipods which were given carrier free ^{14}C-cellulose (i.e. no peat) showed the lowest rate of oxidation which was probably due to the microflora in the water sample as there no evidence of measurable uptake by the amphipods over the course of the experiment. The sample containing peat and amphipods together yielded an intermediate rate of oxidation which may have been due to the grazing of meiofauna and microflora by the amphipods which were actively feeding throughout the experiment. Solubilization in scintillation cocktail of individual amphipods taken during the course of the experiment showed only very low amounts of radiolabeling indicating essentially no direct incorporation of radiocellulose carbon into animal tissue. Thus, at least for the amphipod species tested, the movement of peat carbon up the food chain must require a microbial intermediate with probable further transfers within the meiofauna.

Carbon isotope studies.

The hypothesis that a fraction of the peat carbon is being carried up the food chain to higher organisms has been tentatively confirmed by the first set of ^{14}C analyses on samples of Simpson Lagoon fauna. The ^{14}C isotope ratios relative to 95 percent activity/NBS oxalic acid, 1950 standard, and normalized for biochemical fractionation ($\delta^{13}C$ normalized) are shown in Figure 7 for the species tested to date. Since the samples of modern algae have not been dated as yet, the modern

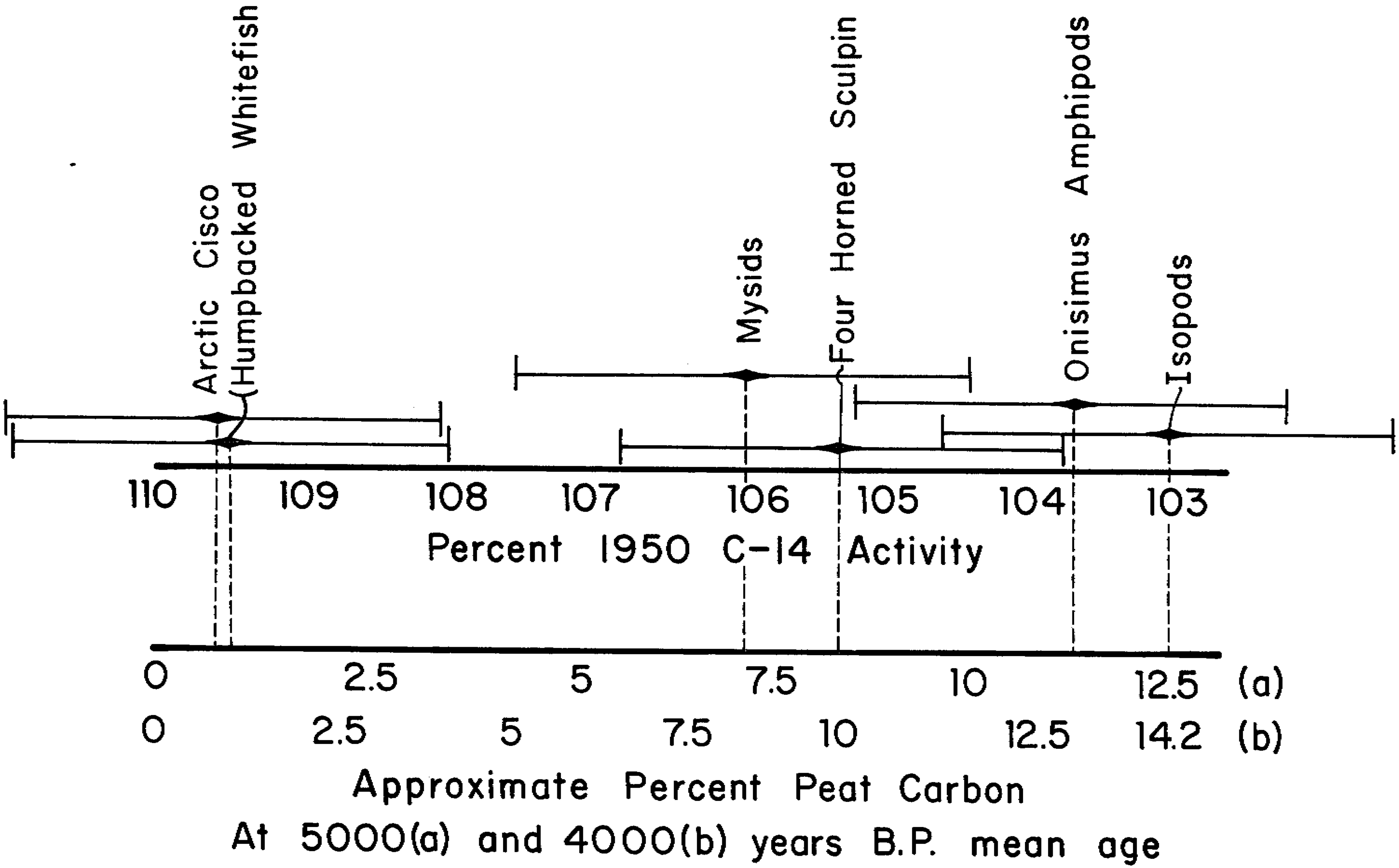


Figure 7. Carbon-14 activity in Simpson Lagoon marine organisms and approximate peat carbon content.

activity has been taken as 110 percent of 1950 standard. The mean age of the peat is taken as 5000 years BP which is based upon the approximate mean of two samples of basal peat obtained at Oliktok Point and Kavearak Point, Simpson Lagoon by Lewelllen (1973) which yielded dates of 8550 and 12,610 years B.P., respectively. The samples recently dated by Hopkins (R.U.'s 204 and 473) of basal peats from Harrison Bay lake sediments gave dates of much more recent origin namely 2930 and 3130 years B.P. and a similar type of sample from the bank of the Sagavanirktok River yielded an age 2,270 years B.P. Until the remaining basal peat samples from Simpson Lagoon are dated, there is some question as to the correct mean age of the peat eroding into the lagoon. To illustrate the effects of reducing the mean age of the peat on the observed carbon transfer percentages, the second scale shown in Figure 7 assumes a mean peat age of 4000 years B.P., (basal peat age of 8000 years B.P.) and results in an increase of about 2 percent of peat carbon in the isopods collected. The error bars shown represent ± 1 standard deviation judged upon the analytical data alone. The observed depressions indicate that peat carbon is being actively transfered up the food chain and, in the case of the four-horned sculpins (Myoxocephalus quadricornis) which prey upon mysids and amphipods in the lagoon, the isotopic composition is in excellent agreement with that of the food species. The arctic cisco (Coregonus autumnalis) and humpback whitefish (C. pidschian) however, show very little, if any, evidence of peat carbon present and this would seem to require a source of food derived from outside the area strongly influenced by the presence of "old" detrital carbon. These species are known to favor pelagic mysids as food (See R.U. 467) and the isotopic composition would strongly suggest that detrital carbon is not a significant fraction of their food source.

Figure 8 shows the $^{13}C/^{12}C$ isotope ratios for Simpson Lagoon marine organisms expressed as δC^{13}_{PDB} in parts per thousand, and compared with ranges found for similar types of organisms in the Bering Sea by McConnaughey, 1978. In general, the organisms fall within the expected ranges although the humpback whitefish and four horned sculpins are close to the values expected for benthic fish. Whether this reflects a terrestrial carbon detrital input is uncertain as the $^{14}C/^{12}C$ data for humpback whitefish indicate a totally modern carbon input, whereas the four-horned sculpins are similar to the $^{14}C/^{12}C$ isotope ratios of the mysids and onisimus amphipods. The possibility exists, however, that the humpback whitefish may derive a large portion of its food from the rivers and thus contain terrestiral modern carbon having a similar $^{13}C/^{12}C$ isotope signature to the peat materials in the lagoon, but with a modern $^{14}C/^{12}C$ ratio. The arctic cisco, however, is more pelagic in nature and the $^{13}C/^{12}C$ isotope ratios indicate a marine food source for this species.

VII. DISCUSSION

Nutrient chemistry and thermohaline convection effects.

The data obtained to date have confirmed many of the conclusions made earlier (Schell, 1975) regarding nutrient limitation and nutrient concentration ranges in the nearshore Beaufort Sea. The water column has a low nitrogen: phosphorus ratio in offshore waters, averaging about 7.5 in 1978 samples, but in areas impacted by freshwater runoff, the reverse is true. The mouth of the Colville River, although saline to

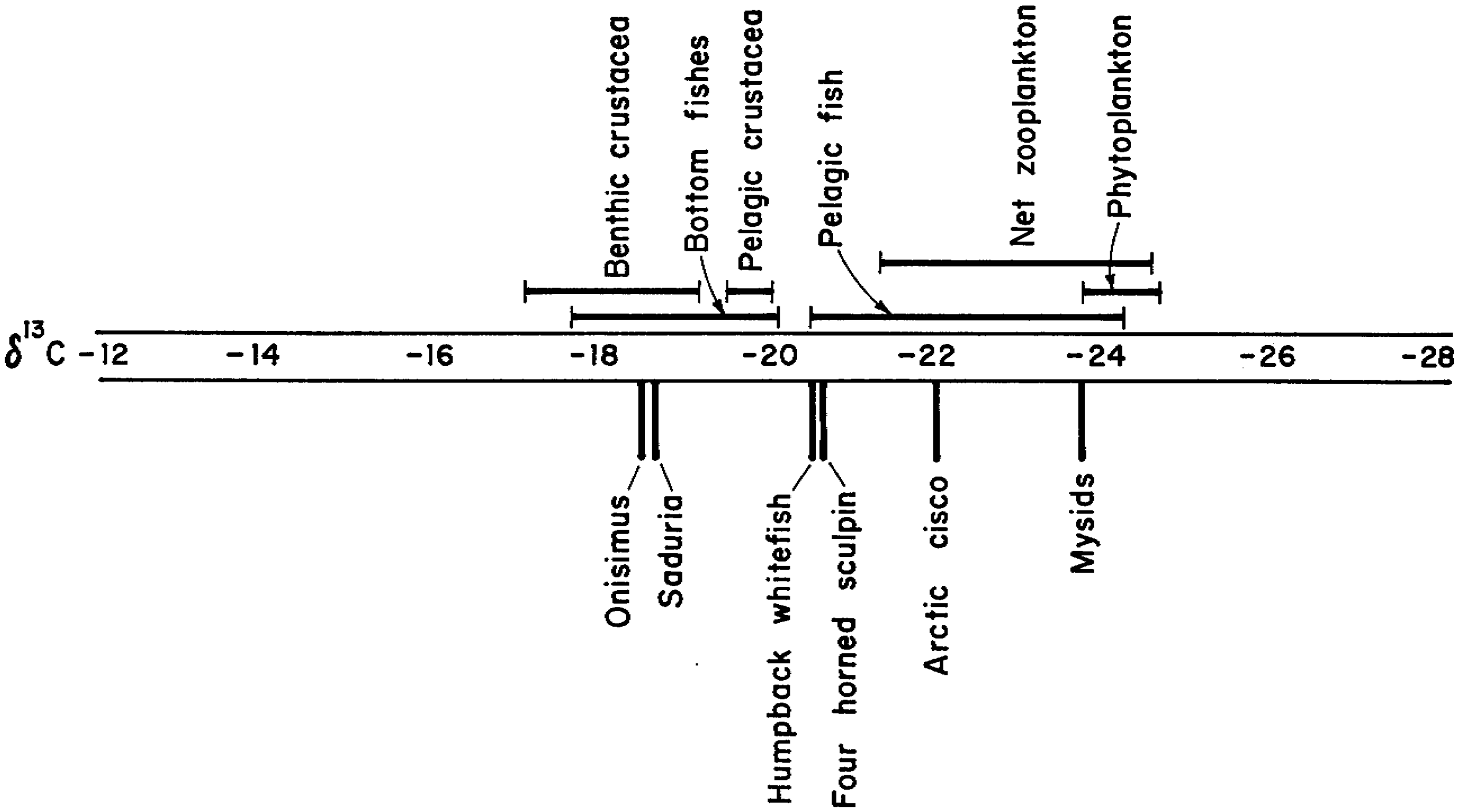


Figure 8. Values of δC^{13}_{PDB} for Simpson Lagoon organisms compared to ranges for Bering Sea marine fauna. (Bering Sea data from McConnaughey, 1978).

the extent of over 28 ppt in April 1978, had an N:P ratio in underice waters of about 30 reflecting the high nitrogen inputs coupled with very low phosphorus concentrations in terrestrial runoff.

No conclusions can yet be made regarding the enhancement of ice algae growth by thermohaline convection of offshore water onshore beneath the ice. The high sediment loads incorporated into the upper layers of the sea ice in the shallow waters of Harrison Bay and Simpson Lagoon during Fall, 1977 prevented the growth of algae at many locations and insufficient data exist to ascertain if this phenonenon is a common ocurrence. Ice algae sample cores collected in May 1979 will give additional indication as to how wide-spread turbidity is in the near-shore fast-ice sheet, and will serve to confirm a predicted lack of ice algae at stations found to have turbid ice in November 1978 (Figure 9).

Trophic system energetics.

The observed depressions in C-14 activity in organisms collected from Simpson Lagoon indicate that erosional input of peat carbon is an appreciable input to the energy flow within the ecosystem. Although the apparent percentage contribution is small (∿ 10 percent), two considerations concerning the data given are required: 1) the organisms tested were collected in late summer and fall, following the full summer season of primary production and thus may be biased toward modern carbon composition, 2) although the observed peat contribution is small, it is probably indicative of a similar input resulting from river-transported modern carbon which is indistinguishable from primary

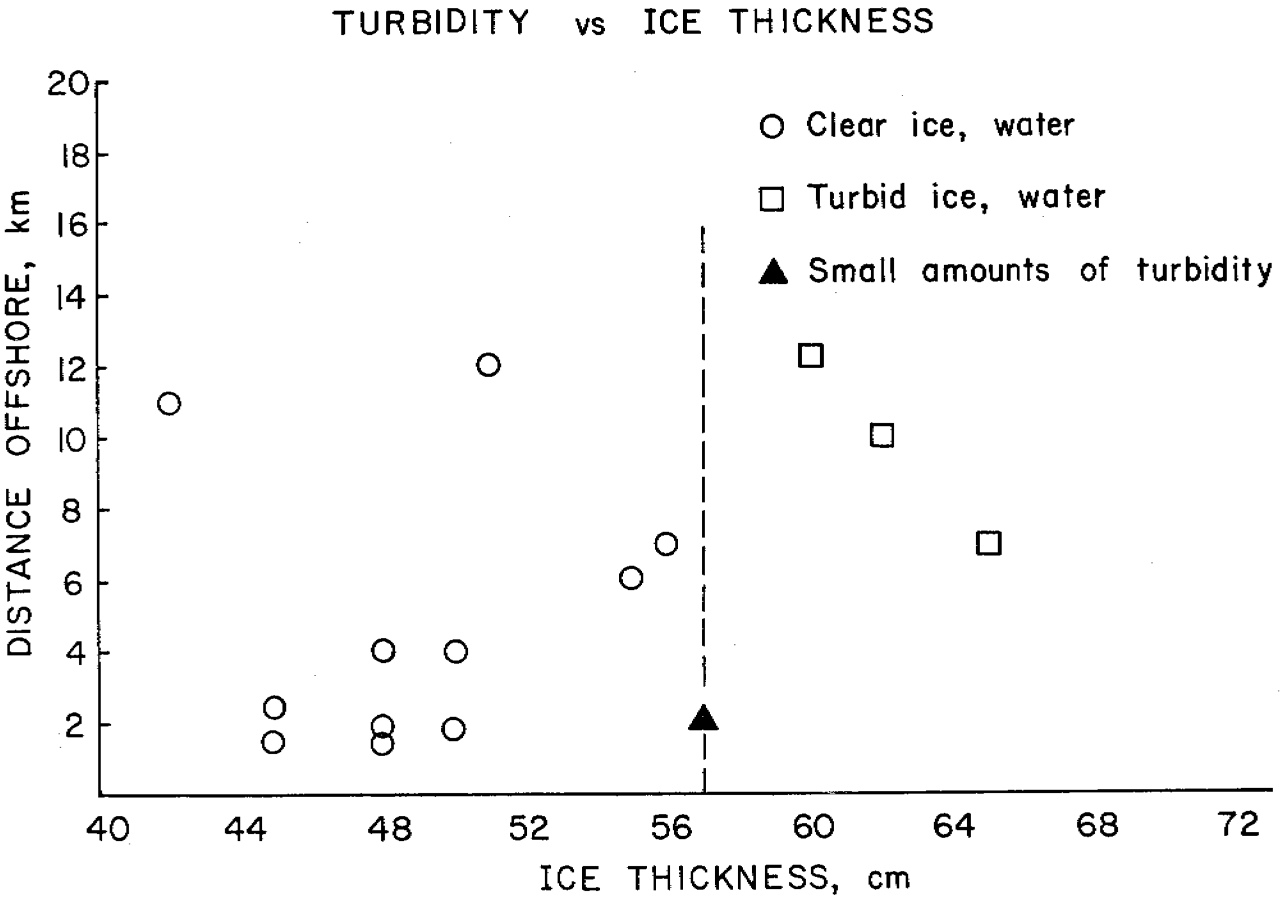


Figure 9. Turbidity versus ice thickness, 9-10 November, 1978.

production by C-14 dating. If the input fractions to the food chain are proportional to total input quantities and there is no obvious reason to suspect otherwise, the actual composition of the nearshore organisms due to allocthonous carbon is about three times the observed quantity indicated by C-14 measurements (See Figure 4). Thus the actual contributions of terrestrial carbon to nearshore invertebrates and their predators may be in the order of 30-40 percent without adjustment for seasonal bias. Conceivably, it may be higher, if seasonal variation is appreciable.

VIII. NEEDS FOR FURTHER STUDY

1) River carbon input quantity estimates must be improved by sampling the major rivers over a hydrologic season.
2) Organisms must be collected and analyzed for C-14 content prior to and following the summer season to test isotopic biasing due to summer primary production. This work has begun but needs expansion.
3) The peat thicknesses and basal peat ages from eroding bluffs need to be obtained along the entire Alaskan Beaufort Sea coastline. The rapid lateral wind-driven transport requires that the uniformity of the processes be ascertained. Such information would also increase the validity of extending processes described in the Simpson Lagoon area.
4) Ice algae populations should continue to be determined to ascertain year-to-year variability and response to ice turbidity.
5) Ice algae populations need to be measured offshore to ascertain the seaward extent of populations and differing responses to ice conditions.

IX. SUMMARY OF FOURTH QUARTER ACTIVITIES

Field activities.

A short trip was made to Prudhoe Bay to retrieve nutrient regeneration experiments set on the bottom of Stefansson Sound in November 1978. The experimental bottles were recovered by divers and the experiment terminated by poisoning of the water samples with mercuric chloride. The samples were then returned to Fairbanks for analysis.

Laboratory activities.

The receipt of the Turner Design Fluorometer in February will enable the completion of a large backlog of chlorophyll analyses. This work is now underway. Carbon-14 analyses are currently in progress with the data availability scheduled for April 1, 1979.

Meetings attended.

The American Society of Microbiology Conference on Aquatic Microbial Ecology, 7-10 February 1979 at Clearwater Beach, Florida. Seasonal Sea Ice Zone Workshop, 26 February - 1 March at the Naval Postgraduate School. Monterey, California.

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CONTAMINANT BASELINES

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CONTENTS

Annual Report

Research Unit #152

Reporting Period: 4/1/78-4/1/79

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COMPOSITION, TRANSPORT AND DEPOSITION OF SUSPENDED MATTER IN LOWER COOK INLET AND SHELIKOF STRAIT, ALASKA

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April 1, 1979

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I. Summary

The seasonal distributions, elemental compositions, and fluxes of suspended particulate matter in lower Cook Inlet were studied and compared with current patterns and bottom sediment distributions. In general, the suspended matter distributions appear to follow the pattern of circulation in lower Cook Inlet and Shelikof Strait. The inflowing clear saline Gulf of Alaska water, which is enriched in biogenic particles of marine origin, flows northward along the eastern coast until it reaches the region near Cape Ninilchik where it mixes with the outflowing brackish water. The outflowing turbid water, which contains terrigenous particles derived primarily from the Susitna, Matanuska, and Knik Rivers, moves seaward along the western side of the inlet past Augustine Island and Cape Douglas into Shelikof Strait where it mixes with the oceanic water and is dispersed. Comparisons of physical characteristics and sedimentation rates of suspended particles and sediments from the central basin indicate that net sedimentation of fine-grained suspended particles is minimal. However, net sedimentation is occurring in several of the embayments along the coast. Chemical analysis of the particulate matter reveals that: (1) fine-grained aluminosilicate minerals comprise about 80-95% of the suspended matter with biogenic material making up the rest; (2) Kachemak Bay is characterized by trace element enrichments in the organic phases of the particulate matter; (3) Kalgin Island region is characterized by trace element enrichments in the Fe-Mn oxyhydroxide phases; and (4) lower Cook Inlet and Shelikof Strait are linked by biogeochemical processes involving Mn and organic matter. These studies lead to the speculation that bioaccumulation of certain trace elements could occur in Kachemak Bay if it were to receive a sudden massive insult of these dissolved trace elements.

II. Introduction

The development of petroleum and natural gas resources on the Alaskan outer continental shelf will undoubtedly result in an increased potential for crude oil contamination of its coastal waters. Of particular concern are the major accidents which cause massive oil spills, such as the ARGO MERCHANT oil spill on Fishing Rip near Nantucket (NOAA Special Report, 1977). However, chronic release of oil through minor spills and localized transfer operations may be more important over the long term.

Oil spilled onto the surface of the ocean is acted upon by several physical processes, including evaporation, solution, emulsification, and injection into the atmosphere (Kreider, 1971; McAuliffe, 1966, 1969; Baier, 1970). With respect to the oceanic environment, only the solution and emulsification processes represent important mechanisms by which spilled oil becomes entrained in the water column, thus increasing its potential for impacting marine organisms.

Since crude oil is sparingly soluble in seawater, it tends to form emulsions when introduced into marine waters, especially under intense wave action. The emulsions have a high affinity for particles and tend to be adsorbed rapidly. Recent studies of oil spills in coastal waters containing high suspended loads have indicated rapid dispersal and removal of the oil by sorption onto particles along frontal zones (Forrester, 1971 and Klemas and Polis, 1977). These zones are regions where turbid brackish water contacts seawater. At the interface downwelling occurs in most cases, causing the inorganic material from the rivers and any associated contaminants to be carried down into the water column. Similarly, laboratory studies involving the interaction between Prudhoe Bay and Cook Inlet crude oils and river-derived inorganic suspended matter have indicated that significant amounts of oil may be accommodated by suspended material, and that the quantity of oil retained on the particles is dependent upon the isoelectric point of oil and sediment particles, particle size, temperature, and the concentration of oil relative to that of the suspended material (Baker et al., 1978; Feely et al., 1978). Since these processes play a major role in the dispersal and deposition of petroleum hydrocarbons, this report addresses the spatial and temporal variations of the distribution, chemical composition, and dispersal of suspended material in lower Cook Inlet and Shelikof Strait.

III. Current State of Knowledge

Previous studies of the distribution of suspended material in lower Cook Inlet have been limited to observations of LANDSAT satellite and aircraft photographs, augmented with sea-truth measurements in some cases. These studies have provided useful information about near-surface suspended matter dispersal patterns, particularly in the region surrounding Kalgin Island where concentration gradients have been observed to be extremely high.

Sharma et al. (1974) used density-sliced LANDSAT photographs and sea truth measurements to study suspended matter distributions in Cook Inlet during late summer of 1972 and early spring of 1973. Suspended matter concentrations ranged from 100 mg/L near The Forelands to 1-2 mg/L near the entrance to the inlet. Large temporal variations were observed which were related to tidal variations in water circulation and seasonal variations in river runoff.

Gatto (1976) studied the dispersal of sediment plumes from coastal rivers as affected by tidal currents in the inlet. Turbid plumes from the Drift, Big, McArthur, and Tuxedni Rivers on the west side of the inlet and the Kenai, Kasilof, and Ninilchik Rivers on the east side formed distinct surface layers, riding over and mixing with the saline water from the south. During flood tide, the plumes migrated northward along the coast. On ebb tide, the plumes migrated back again to the south and west. Occasionally, relict plumes were observed far offshore which indicated that at least some plumes of sediment-laden water were capable of maintaining their identity for several tidal cycles.

Burbank (1977) used LANDSAT imagery to study suspended matter dispersal patterns in Kachemak Bay. Suspended material in Kachemak Bay is derived from in situ production of organic material and from runoff from the Fox, Bradley, and Martin Rivers. Sediment plumes from inner Kachemak Bay were observed along the northwest shore of the bay. These plumes were diverted around Homer Spit and into the outer Kachemak Bay by a counterclockwise rotating gyre. In the outer bay, the plumes move to the west and north under the influence of a second counterclockwise gyre.

IV. The Study Area

Cook Inlet is a large tidal estuary in south central Alaska. It lies on a northeast-southwest axis and is about 150 nautical miles long and 50 nautical miles wide at the mouth. Physiographically, the inlet is divided into three sections. At the head of the inlet, it separates into Knik and Turnagain Arms, which are 45 and 43 nautical miles long, respectively. Near the middle, upper Cook Inlet is separated from lower Cook Inlet by two geographic constrictions, the East and West Forelands.

The inlet receives freshwater from four major rivers: the Matanuska and Knik Rivers at the head of Knik Arm and the Susitna and Beluga Rivers to the northwest. These rivers supply about 70% to 80% of the freshwater input (Rosenberg and Hood, 1967). In addition, numerous streams containing large concentrations of glacial flour drain into the lower inlet from both sides. Included in this category are the Kenai, Kalisof, Nihilchik, and Anchor Rivers on the eastside and the McArthur, Big, Drift, and Tuxedni Rivers which discharge into the inlet from the west.

Water circulation in lower Cook Inlet has been described by several authors (Kinney et al., 1970; Wright et al., 1973; Gatto, 1976; Burbank, 1977; and Muench et al., 1978). The last reference provides the most completed description of water circulation in lower Cook Inlet. Circulation in the inlet is characterized by a net inward movement of oceanic water up the eastern shore and a net outward movement of a mixture of oceanic water and runoff water along the western shore. In the vicinity of The Forelands, the water masses are vertically mixed due to the turbulent action of tidal currents. However, lateral separation of the water masses is apparent, resulting in a shear zone between the incoming saline water on the eastside and the outgoing less saline water on the west. Coastal upwelling occurs in the vicinity of the Chugach Islands, from the region west of Elizabeth Island to Cape Starichkof.

The distribution and composition of bottom sediments in lower Cook Inlet have been studied (Sharma and Burrell, 1970; Bouma and Hampton, 1976; Hein et al., 1979). The sediments are primarily composed of medium-to-fine grain sands; however, occasionally silt and clay-sized sediments have been observed. The deposits in the northern part of the inlet are winnowed Pleistocene-early Holocene gravels, with many of the sand-sized and smaller particles being removed and redeposited to the south. In addition to the relict sands and gravels, the sediments also contain a very thin cover of fine-grained silts and clays which are modern. Hein et al. (1979) state that the clay mineral deposits in lower Cook Inlet are dominated by clay mineral suites from two distinct sources. A chlorite-rich suite dominates the clay mineral fraction in deposits from the region around the Barren Islands to Kachemak Bay. The Copper River appears to be the major source of this material as it discharges chlorite-rich fine grained material into the northeast Gulf of Alaska which is diverted to the west and southwest by the coastal long shelf currents (Feely et al., 1979). Apparently, some of this material reaches Kennedy Entrance and is transported into lower Cook Inlet along with the inflowing Gulf of Alaska water.

The region to the west and north of Kachemak Bay is dominated by an illite-rich suite which has the Susitna River in upper Cook Inlet as its major source. These authors further state that the distribution of clay minerals in the bottom sediments in lower Cook Inlet reflects the dispersal routes for suspended material in the overlying water. Thus, fine-grained particles from these two sources follow the general pattern of water circulation in the inlet and form the bulk of the mud deposits in the quiet embayments along the shore and throughout Shelikof Strait.

V. Sources, Methods and Rationale of Data Collection

In order to obtain information about the seasonal variations of the distribution and composition of suspended matter, we have conducted five cruises in lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977; Cruise Acona-245, 28 June-12 July 1977; Cruise RP-4-Di-77C, 3-12 October 1977; Cruise RP-4-Di-78A-III, 4-17 May 1978 and Cruise RP-4-Di-78B-II, 22 August-6 September 1978) during 1977-78. The field studies have been intergrated with the physical oceanography program so that concomitant information about water mass structure has been obtained.

In addition to the seasonal studies, we have conducted a number of high frequency (hourly) time series studies at selected locations in the inlet. This has provided valuable information about the variability of the distribution and chemical composition of suspended matter that may be due to the influence of tidal currents and/or variations of primary productivity in surface waters and resuspension of sediments in near-bottom waters.

Another aspect of the suspended matter program was concerned with the vertical fluxes and composition of settling material in areas of contrasting sedimentation and productivity. To this end, self-closing sediment traps were deployed on three moorings along a transect line extending from Kamishak Bay to Kachemak Bay. The materials recovered by the traps were subjected to extensive gravimetric and chemical analyses, designed to determine the sedimentation rates for particulate material and the partitioning of trace elements among major solid phases.

A. Sampling Methods

1. Particulate Matter

Water samples were collected from preselected depths in General Oceanics 1070 10-L PVC Top-Drop Niskin bottles. Nominally these depths included: 0-2 m 10 m, 20 m, 40 m, 60 m, 80 m, and 5 meters above the bottom. Aliquots were drawn within one-half hour after collection from each sample and vacuum filtered through preweighed 0.4 μm pore diameter Nuclepore polycarbonate filters for total suspended matter concentration determinations and multielement particulate composition analyses. Samples were also filtered through 0.45 μm pore diameter Selas silver filters for particulate carbon and nitrogen analyses. All samples were rinsed with three 10 mL aliquots of deionized and membrane filtered water, placed in individual petri dishes with lids slightly ajar for a 24-hour desiccation period over sodium hydroxide, and then sealed and stored (silver filters frozen) for subsequent laboratory analysis.

2. Bottom Sediments

Bottom sediment samples were collected with a Shipek grab sampler, a three-inch gravity corer equipped with a plastic core liner, and a HAPS corer. Twelve gravity corer samples and all HAPS corer samples were sectioned into 1 cm segments upon collection and frozen in individual plastic bags. All remaining bottom sediment samples were immediately frozen and returned to the laboratory intact.

3. Nephelometry

The vertical distribution of suspended matter was determined with a continuously recording integrating analog nephelometer. The instrument was interfaced with the ship's CTD system using the sound velocity channel (14-16 KHz). Continuous vertical profiles of forward light scattering were obtained in analog form on a Hewlett Packard 7044 X-Y recorder.

4. Conductivity (Salinity), Temperature, and Depth

These standard hydrographic data were acquired with a Plessy Model 9040 Environmental Profiling System (CTD probe) and a Model 8400 digital data logger using 7-track, 200 B.P.I. magnetic tape. Temperature and salinity calibration data were provided by NOAA ship personnel from discrete water samples utilzing reversing thermometers and a bench salinometer, respectively. Signals from the CTD system and the nephelometer were also simultaneously interfaced with the ship's data acquisition system. This resulted in computer listings of continuous (uncorrected) data for conductivity, temperature, depth, salinity, sigma-t, and light scattering for all vertical sampling stations.

5. Sediment Trap/Vertical Particulate Flux Studies

During Cruise RP-4-MF-78A-II (19 May-4 June 1978) three moorings, each supporting one set of tandem sediment traps located 10 m above the bottom, were deployed along a transect line extending from Kamishak Bay to Kachemak Bay in lower Cook Inlet. The sediment trap capture period was set (trap closure to be activated by self-contained timers approximatly 85 days after deployment) to obtain a long-term average of the particulate vertical flux mass (rate) and composition. Recovery of the sediment traps occurred in October 1978 (DISCOVERER Cruise RP-4-DI-78C-V).

B. Analytical Methods

1. Gravimetry

Total suspended matter concentrations were determined gravimetrically. Volumetric total suspended matter samples were collected on 47 mm, 0.4 μm pore diameter Nuclepore® filters which were weighed on a Cahn® Model 4700 Electrobalance before and after filtration. The suspended matter loadings were then determined by difference. The weighing precision (2 σ = ± .011 mg) and volume reading error (± 10 mL) yield a combined coefficient of variation in suspended matter concentration (mg/L) at mean sample loading and volume (2.057 mg and 2 L, respectively) of approximately 1%. However, preliminary investigations of sampling precision (coef. of var.: 25%) suggest that the actual variability in the particulate matter concentrations of these waters is much greater than the above analytical precision.

2. Gas Chromatography

Analysis of total particulate carbon and nitrogen in suspended matter was performed with a Hewlett Packard Model 185B C-H-N analyzer. In this procedure, particulate carbon and nitrogen compounds are combusted to CO_2 and N_2 (micro Pregl-Dumas method), chromatographed on Poropak® Q, and detected sequentially with a thermal conductivity detector. NBS acetanilide is used for standardization. Analyses of replicate surface samples yield coefficients of variation ranging from 2% to 10% for carbon and 7% to 14% for nitrogen.

3. X-ray Secondary Emission Spectrometry

The major (Mg, Al, Si, K, Ca, Ti, and Fe) and trace (Cr, Mn, Ni, Cu, Zn, and Pb) element chemistry of the suspended particulate matter samples was determined by x-ray secondary emission (fluorescence) spectrometry utilizing a Kevex® Model 0810A-5100 x-ray energy spectrometer and the thin-film technique (Baker and Piper, 1976). The inherent broad band of radiation from a Ag x-ray tube was used to obtain a series of characteristic emission lines from a single element secondary target which then more efficiently excited the thin-film sample. Fe, Se and Zr secondary targets were used to analyze the samples for both major and trace elements. Standards were used to analyze the samples for both major and trace elements. Standards were prepared by passing suspensions of finely ground USGS standard rocks (W-1, G-2, GSP-1, AGV-1, BCR-1, PCC-1) and NBS trace element standards through a 37 μm mesh polyethylene screen followed by collection of the size fractionated suspensates on Nuclepore filters identical to those used for sample acquisition. The coefficient of variation for 10 replicate analyses of a largely inorganic sample of approximately mean mass was less than 3% for the major constituents and as high as 5% for the trace elements. However, when sampling precision is considered, the coefficients of variation increase, averaging 12% and 24% for major and trace elements, respectively.

4. Atomic Absorption Spectrophotometry

The suspended matter samples from lower Cook Inlet are being analyzed for peroxide extractable, weak acid extractable, and total Al, Fe, Mn, Cr, Cu, Ni, Zn, and Pb. The first extraction procedures involve the use of hydrogen peroxide to release organically-bound trace metals. The second treatment utilizes 0.3 N hydrochloric acid to release trace metals which are weakly bound to inorganic phases. The details and validity of these procedures are outlined below.

a. H_2O_2 Treatment

Crecelius et al. (1974) have demonstrated that 30% hydrogen peroxide efficiently oxidizes particulate organic matter and thus removes certain trace metals from sediments. Landing (1978) has shown that the modification of this procedure, as described below, efficiently removes organic carbon and nitrogen from suspended matter. The release of trace metals from suspended matter during this procedure is attributed to the dissolution of organically bound trace metals.

Procedure. Dilute 30% ULTREX (J. T. Baker) hydrogen peroxide to 10% with the addition of quartz distilled water (Q-H_2O). Combine 5 mLs of 10% H_2O_2 with 100-500 mg of sample material in a precleaned centrifuge tube equipped with a nonsealing cap. The volume and mass of extractant and sample, respectively, may vary within the above limits depending on the relative magnitude of the organic fraction in the sample. We are currently using polypropylene centrifuge tubes and caps. Heat the extractant-sediment solution in a water bath at approximately 50°C for 48 hours. During the final 24 hours of heating, vigorously sonicate the solution to assist in dispersal and breakdown of the organic matter. Centrifuge the tube contents at 2000 rpm for 1 hour. Decant the supernate into a precleaned and tared polyethylene (CPE) bottle. Rinse the residual particulate matter with one 10 mL aliquot of quartz-distilled water. Centrifuge, as above, after the rinse and combine all supernates in the polyethylene bottle. Since the centrifugation separation is not complete, filter the samples through a 0.4 µm Nuclepore filter. Determine the weight of the supernate by difference.

b. 0.3 N HCl Treatment

Malo (1977) has shown that leaching with hot 0.3 N HCl is the most effective method for dissolving trace metals associated with surface coatings. In this study, this method was modified by heating the sediment-0.3 N HCl mixture to 75°C instead of 100°C. The time required for completion of the reaction was determined by leaching subsamples for different lengths of time. The results of this kinetic study (Fig. 1) indicate that no additional Cu is released after the first 2 hours while Ni and Zn continue to be leached for 12 hours. Therefore, the sediment-acid mixture was heated for 24 hours to insure that the reaction was complete. A high efficiency for this reaction was confirmed by analyzing the amount of Cu and Mn released on a subsequent 0.3 N HCl leach (Table 1).

Procedure. Dilute ULTREX (J. T. Baker) HCl to 0.3 N with Q-H_2O. Add 8 mLs of 0.3 N HCl to 100-500 mg of sample which has been treated with H_2O_2. Heat the mixture to 75°C for 24 hours while sonicating. Centrifuge the mixture at 2000 rpm for 1 hour. Decant the supernate into a precleaned and tared polyethylene bottle. Add 8 mLs of 0.3 N HCl to the residual sediment. Shake this mixture, then centrifuge as

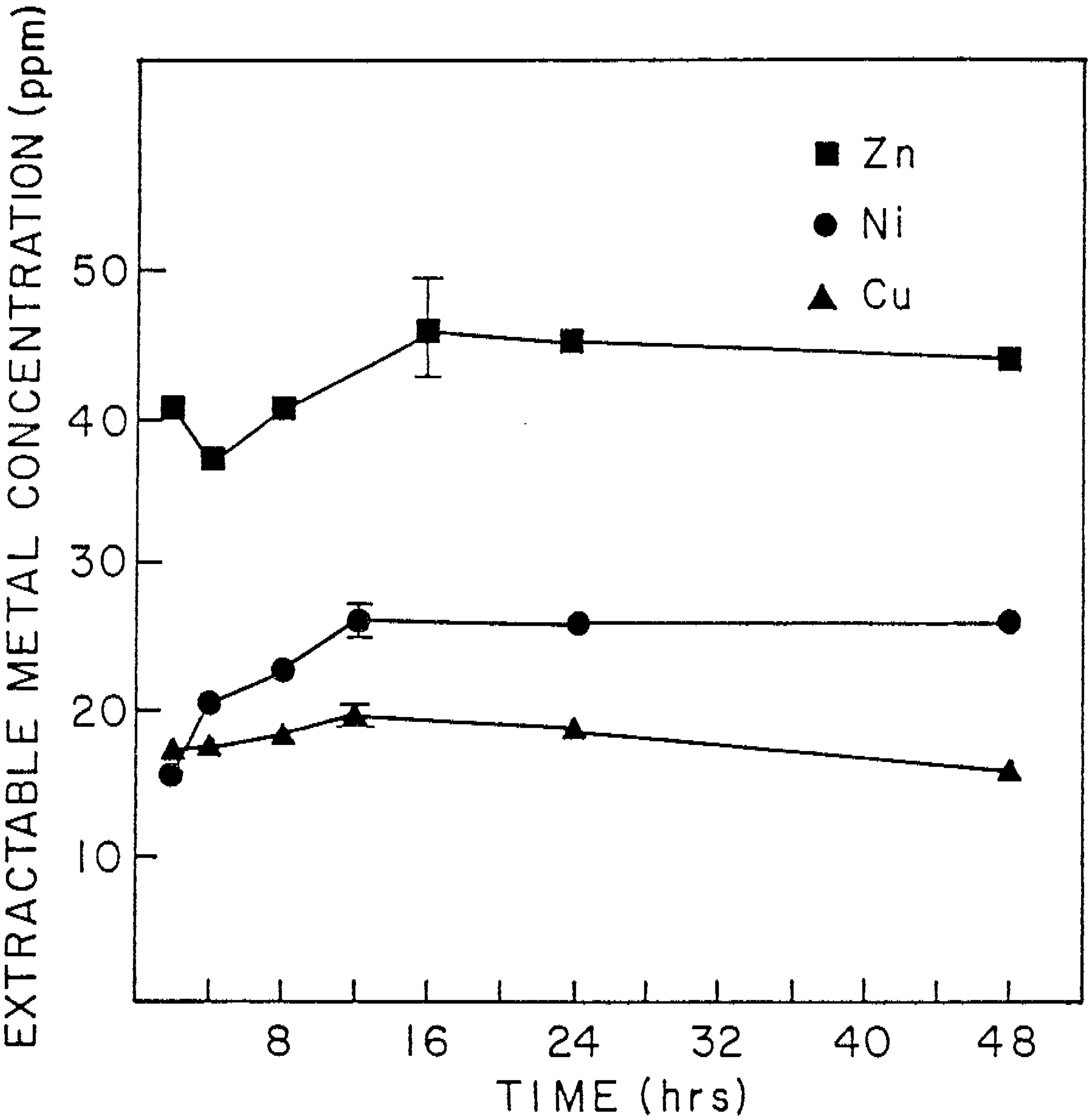

Figure 1. Extractable metal concentration versus time in contact with 0.3 N HCl for Zn, Ni, and Cu. The range of values is given for duplicate samples at 12 hrs.

above and decant the supernate into the bottle. Repeat the rinsing of the residual sediment once. Filter the combined supernates through a 0.4 μm Nuclepore filter. Determine the weight of the final supernate by difference.

Table 1. Efficiency of successive 0.3 N HCl treatments

	Mn (ppm)	Cu (ppm)
First Treatment (n=3)	911 ± 78	49.3 ± 2.5
Second Treatment (n=3)	6.7 ± 0.3	0.7 ± 0.1

c. Bulk Elemental Analysis

Elemental composition of suspended matter was determined using a modification of the method of Eggimann and Betzer (1976).

Procedure. If the sediment is refractory, grind the dry sediment in a boron carbide mortar and pestle. Weigh out approximately 2 mg and place in a digestion bomb (Bombco, Inc.). Add 0.75 mL of 12 N HCl (ULTREX) and seal the bomb tightly and place in boiling water for 45 minutes. Cool for 45 minutes in a freezer. Add 0.25 mL of 16 N HNO_3 (ULTREX), seal, and place in boiling water for 45 minutes. Cool for 45 minutes in freezer. Add .05 mL of concentrated HF (ULTREX), seal, and place in boiling water for 90 minutes. Cool for 90 minutes. Quantitatively transfer the contents of the digestion bomb to a wide mouth bottle and rinse the bomb with Q-H_2O. Dilute the sample to 20 gm with Q-H_2O.

d. Atomic Absorption Spectrophotometry Analysis

Flameless atomic absorption measurements were made using a Perkin-Elmer 603 spectrophotometer equipped with an HGA-2200 furnace control, deuterium arc background corrector, AS-1 automatic sampler and a Model 54 recorder. The normal instrument parameters are listed in Table 2. Baker AAS standards are diluted in a matrix similar to the samples. The instrument was calibrated using this standard which covered the absorbance range of the samples. The total dissolution analysis for Al was done by the standard addition method.

Table 2. Summary of the analytical parameters utilized in the flameless atomic absorption determinations. Analyses conducted with a Perkin-Elmer 603 AAS, D-2 Arc Background Corrector, HGA-2200 Flameless Atomizer, AS-1 Automatic Sampler. Pyrolitically-coated tubes used for all elements. Std. Add. = Standard Additions.

Element	Wavelength (nm)	Slit (nm)	Volume (μl)	Dry Cycle Time/Temp	Ash Cycle Time/Temp	Atomize Cycle Time/Temp	Gas	Flow Units	Bkg. Cor.	Comment
Al	257	0.2	10	30/100	22/1300	5/2600	Ar	40	No	Std. Add.
Fe	347	0.2	10	30/100	22/1050	5/2600	N_2	40	No	
Mn	280	0.2	10	30/100	22/1000	5/2600	N_2	55	No	
Cr	358	0.7	10	30/100	22/1000	5/2600	Ar	45	No	
Cu	325	0.7	10	30/100	22/ 800	5/2500	Ar	35	No	
Ni	232	0.2	20	40/100	32/ 900	5/2500	Ar	35	Yes	
Pb	217	0.7	20	40/100	32/ 600	5/2500	Ar	35	Yes	
Zn	214	0.7	10	30/100	22/ 500	5/2500	Ar	40	Yes	

VI and VII. Results and Discussion

A. Particulate Matter Distributions and Transport

To date we have completed five cruises in lower Cook Inlet and Shelikof Strait which have been scheduled for FYs 77 and 78. The first cruise was conducted during early spring of 1977 (4-16 April); the second, in summer of the same year (28 June-12 July); the third, in fall (3-12 October); the fourth, in spring of 1978 (4-17 May); and the fifth cruise was conducted in late summer of 1978 (22 August-6 September). Horizontal surveys of the entire region were obtained on the first two cruises and vertical sections between Kachemak Bay and Kamishak Bay were obtained on all five cruises. The station locations for the first two cruises are shown in Figures 2 and 3. The vertical sections for the first three cruises were obtained at stations 24 through 29. The station locations for the last two cruises are shown in Figures 4 and 5. Vertical sections were obtained at stations CB1 through CB8 in lower Cook Inlet and stations SS2, SS3, SS6, SS8, SS9, SS10, and SS12 in Shelikof Strait (Fig. 5).

Figures 6 through 9 show the distributions of salinity, temperature, sigma-t, and suspended matter at the surface and 5 m above the bottom for the April and July 1977 cruises in lower Cook Inlet and Shelikof Strait. As shown in Figures 6 and 8, the surface particulate matter distributions are characterized by unusually high horizontal gradients. On the eastern side particulate concentrations were relatively low, ranging from 0.5 mg/L near Cape Elizabeth to about 5.0 mg/L near Cape Ninilchik. On the western side suspended loads increased rapidly from concentrations around 5.0 mg/L in the vicinity of Kamishak Bay to concentrations greater than 100 mg/L north of Tuxedni Bay. The salinity and temperature data (Figs. 6 and 8) for these cruises show very similar horizontal distribution patterns, illustrating the predominance of the inflowing relatively clear saline Gulf of Alaska water on the eastern side and

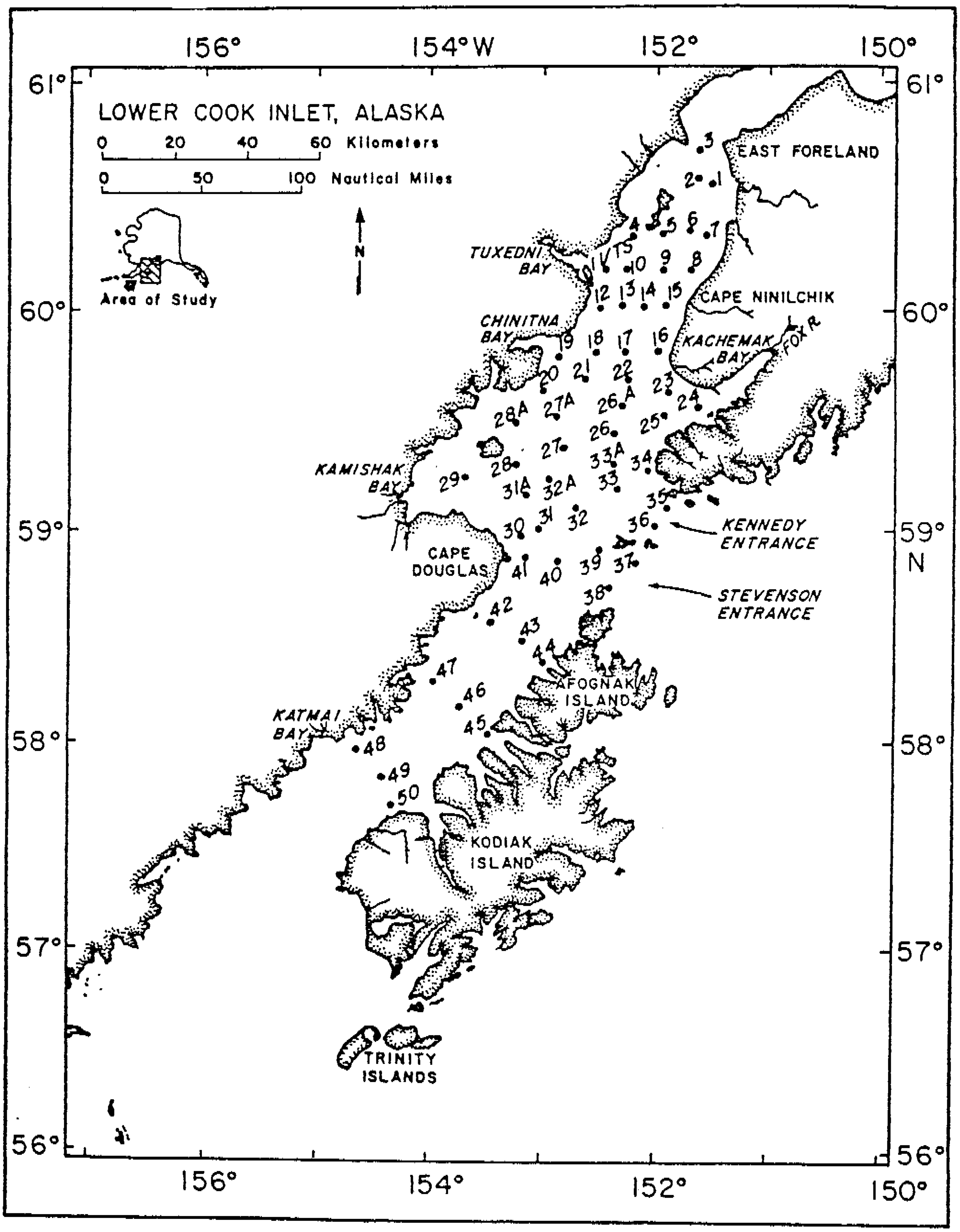

Figure 2. Locations of suspended matter stations in lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

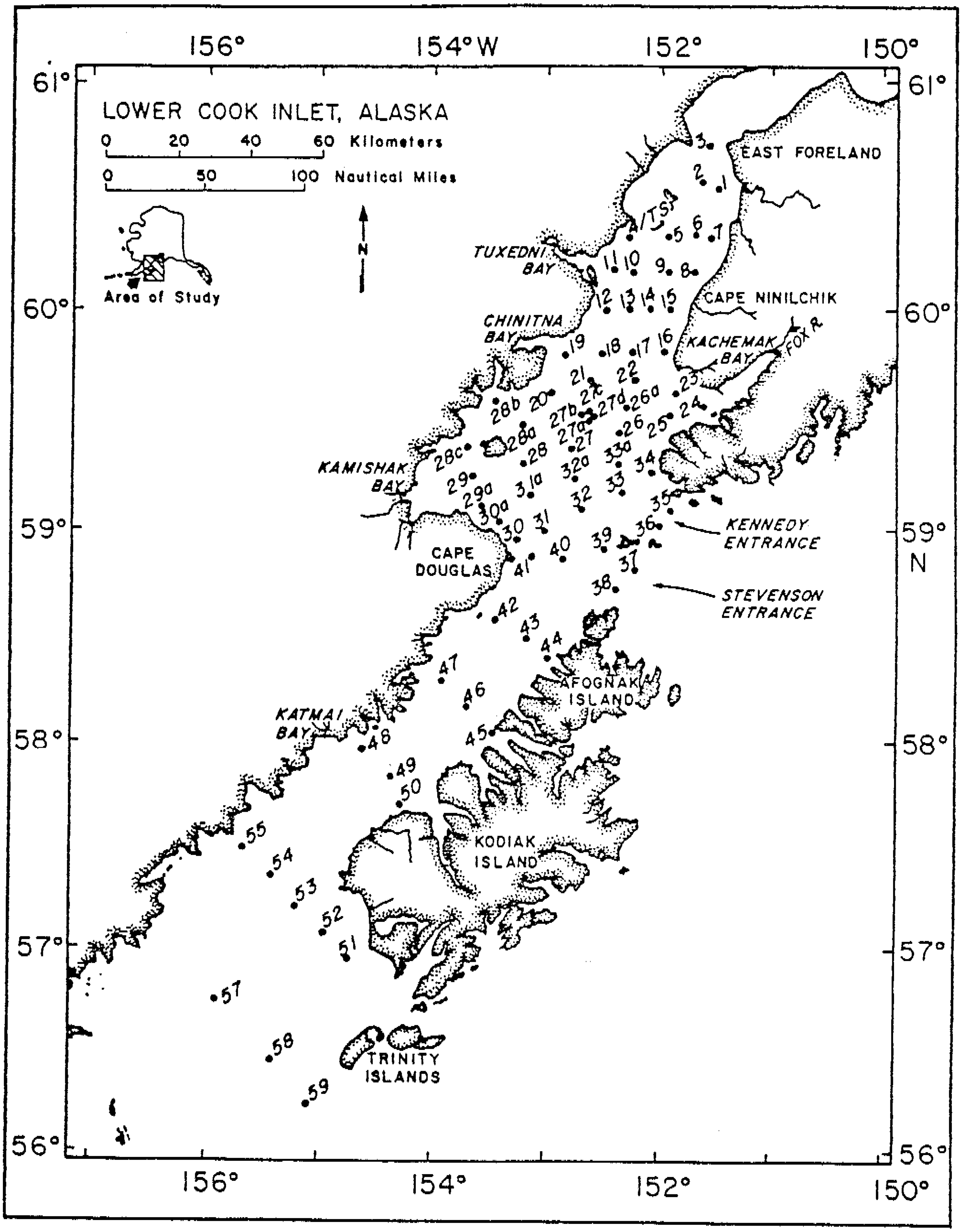

Figure 3. Locations of suspended matter stations in lower Cook Inlet and Shelikof Strait (Cruise Acona-245, 28 June - 12 July 1977).

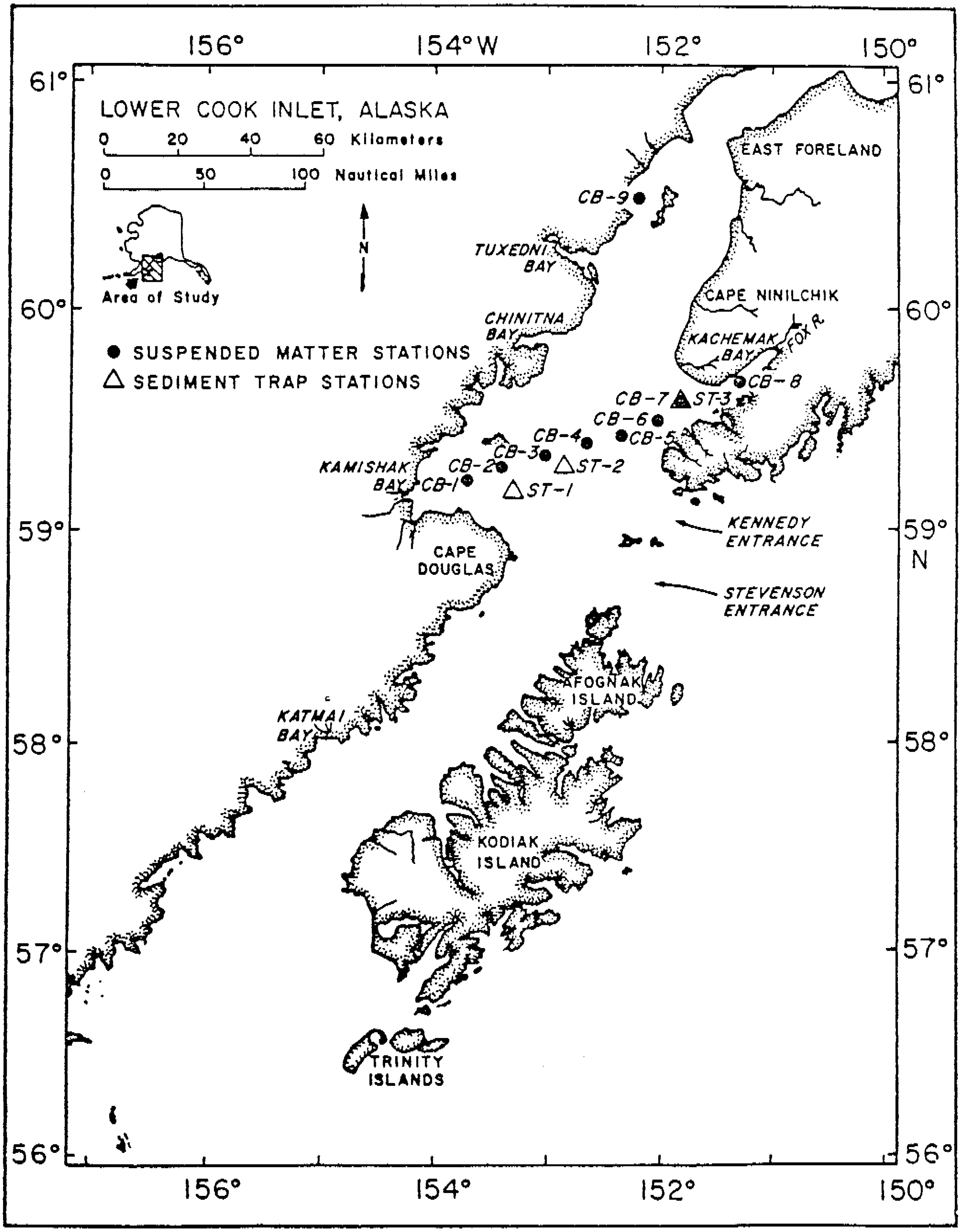

Figure 4. Locations of suspended matter and sediment trap stations in lower Cook Inlet (Cruise RP-4-Di 78A-III, 4-17 May 1978).

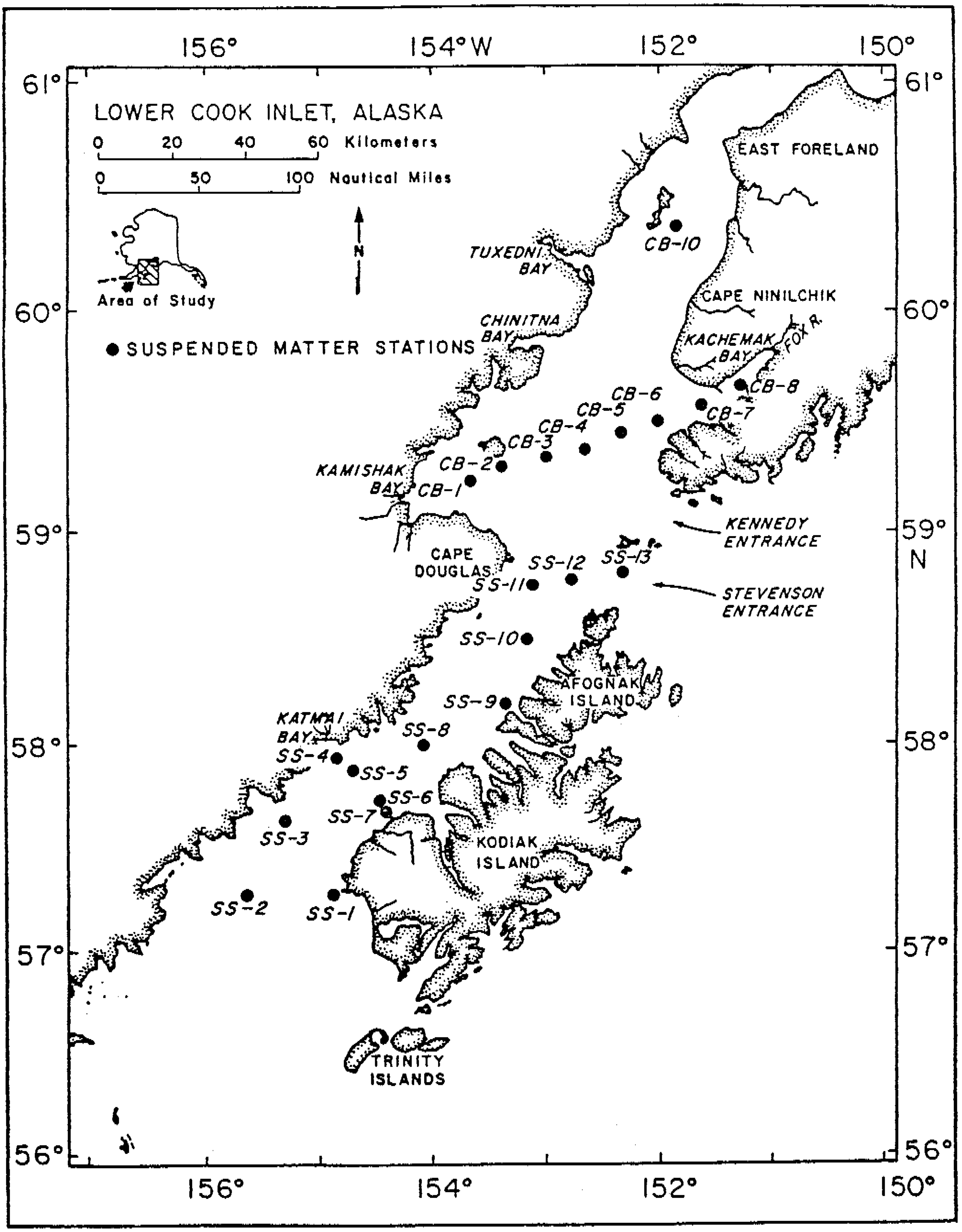

Figure 5. Locations of suspended matter stations in lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

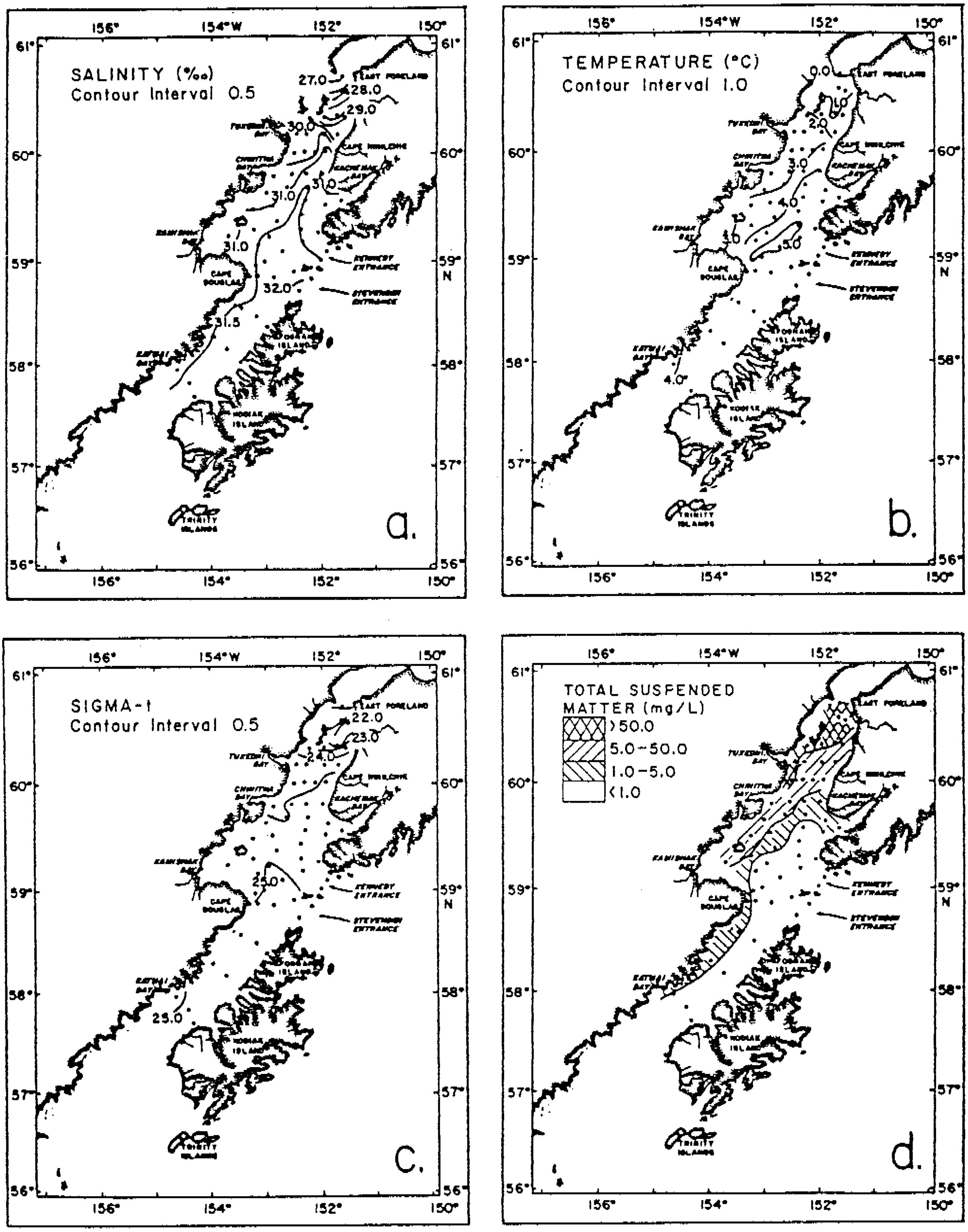

Figure 6. Distribution of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter at the surface (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

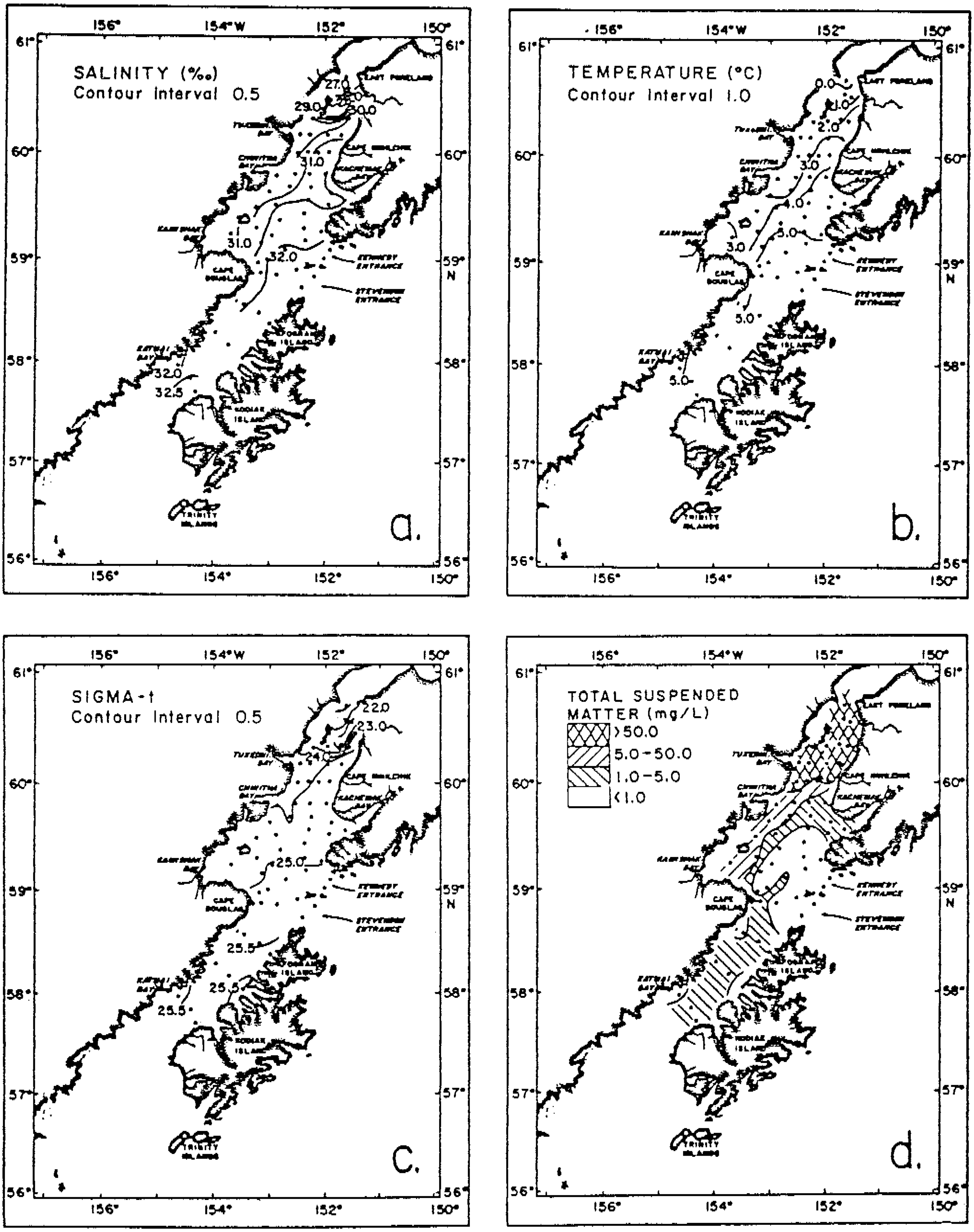

Figure 7. Distribution of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter 5 m above the bottom (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

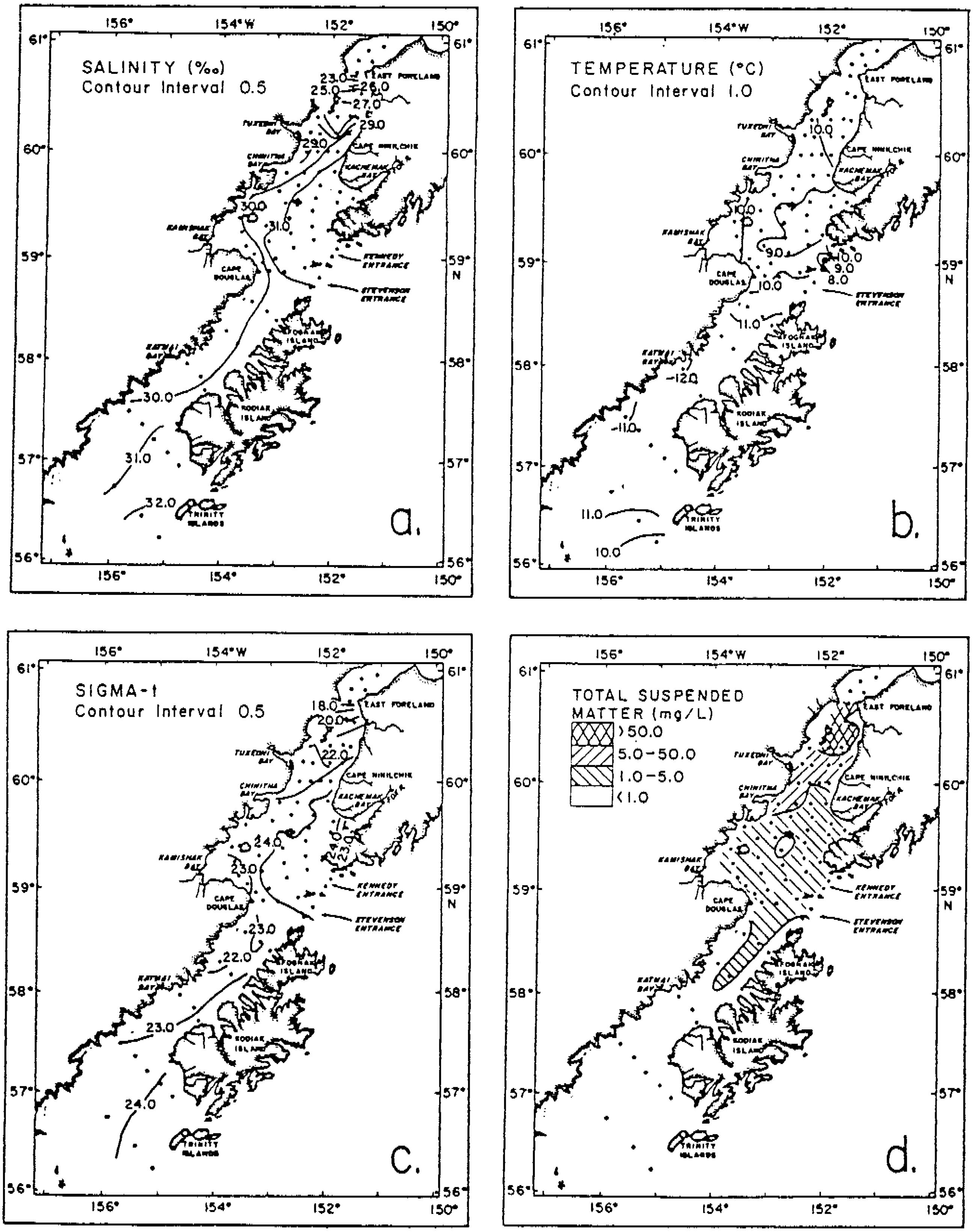

Figure 8. Distribution of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter at the surface (Cruise Acona-245, 28 June - 12 July 1977).

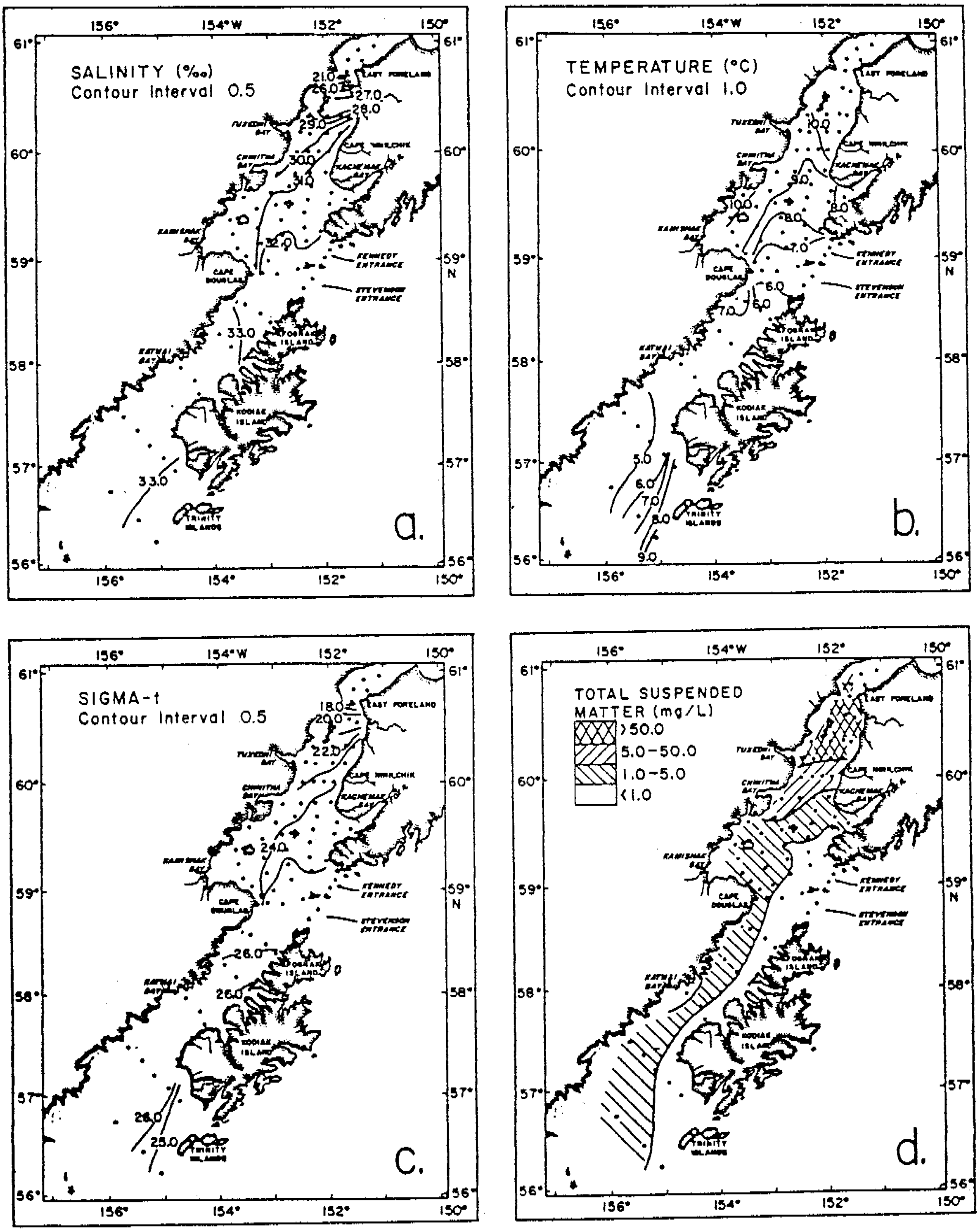

Figure 9. Distribution of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter 5 m above the bottom (Cruise Acona-245, 28 June - 12 July 1977).

the outflowing turbid low salinity water from upper Cook Inlet on the western side. The outflowing turbid water is transported to the southwest past Augustine Island and Cape Douglas into Shelikof Strait where it continues to mix with the oceanic water and the suspended matter is dispersed. The near-bottom suspended matter distributions (Figs. 7 and 9) are very similar to the surface distributions, suggesting that cross-channel gradients in the suspended matter distributions exist throughout the water column. In apparent agreement with this, the vertical cross-sections of the distribution of suspended matter from Kachemak to Kamishak Bay (Figs. 10 through 14) show large cross-channel variations which can be utilized to identify three distinct water masses. On the west side (stations 28 and 29 for the 1977 data and stations CB1 through CB3 for the 1978 data) the water properties are low salinity ($29.8\text{-}31.6^{\circ}/oo$) and high suspended matter concentrations (0.9-8.2 mg/L). The water is virtually unstratified from top to bottom. These properties are characteristic of the outward flowing brackish water which originates from upper Cook Inlet and flows south along the western coast. This water mass contains significant amounts of terrigenous rock debris from the rivers which drain into upper Cook Inlet. The central region (stations 25 and 26 for the 1977 data and stations CB5 and CB6 for the 1978 data) contain water which is more saline ($31.4\text{-}31.8^{\circ}/oo$) and less turbid (0.4-1.4 mg/L). This water is characteristic of the inflowing Gulf of Alaska water which flows north along the east side of the inlet. In Kachemak Bay (station 24 from the 1977 data and stations CB7 and CB8 from the 1978 data), the waters are relatively warmer, less saline ($27.3\text{-}31.4^{\circ}/oo$) and more turbid (0.9-2.8 mg/L) than the water in the central region of the inlet. These waters are moderately stratified, with the freshwater from the Fox and Martin Rivers extending as far as station CB7.

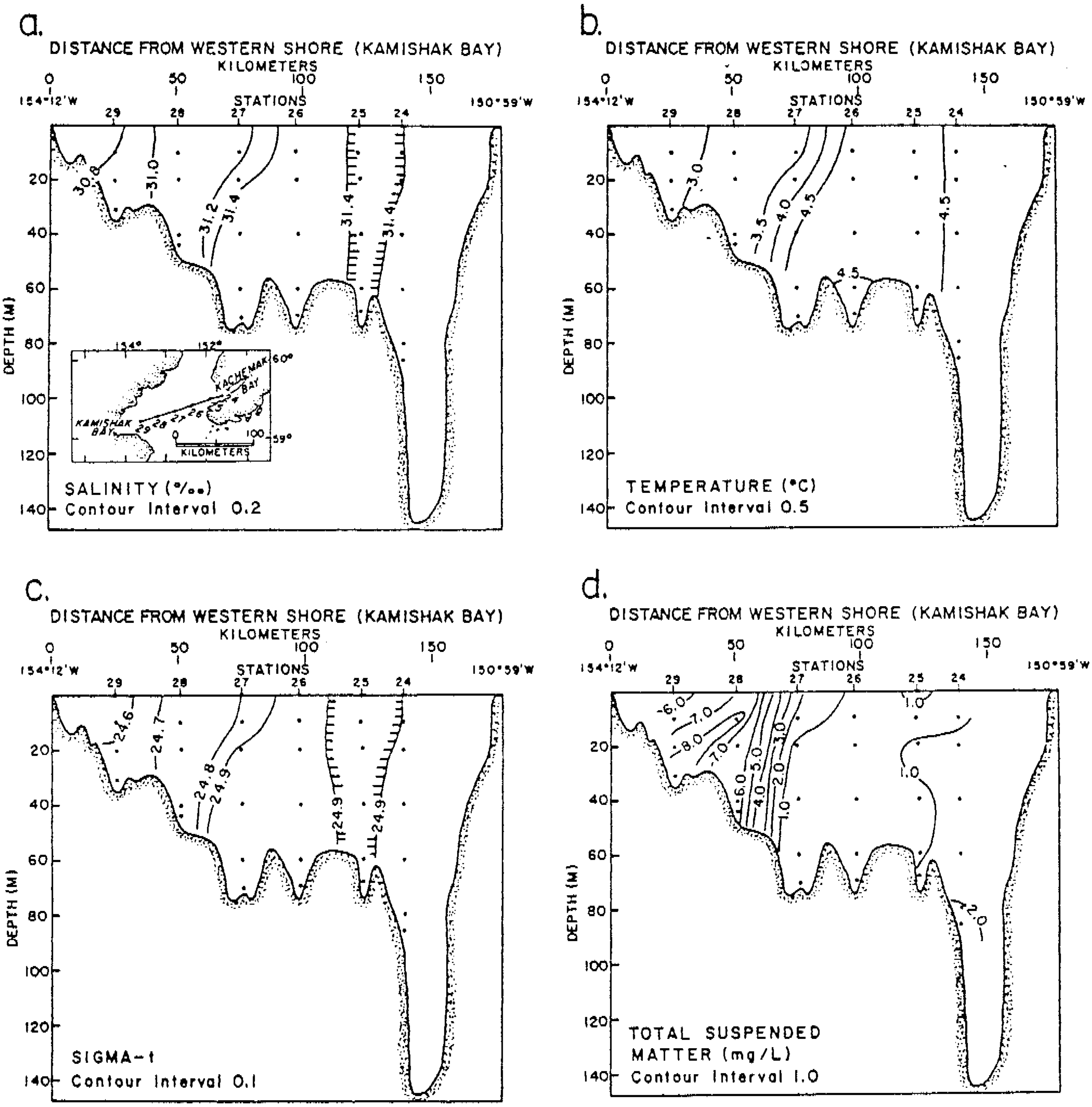

Figure 10. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations 24 thru 29 in lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

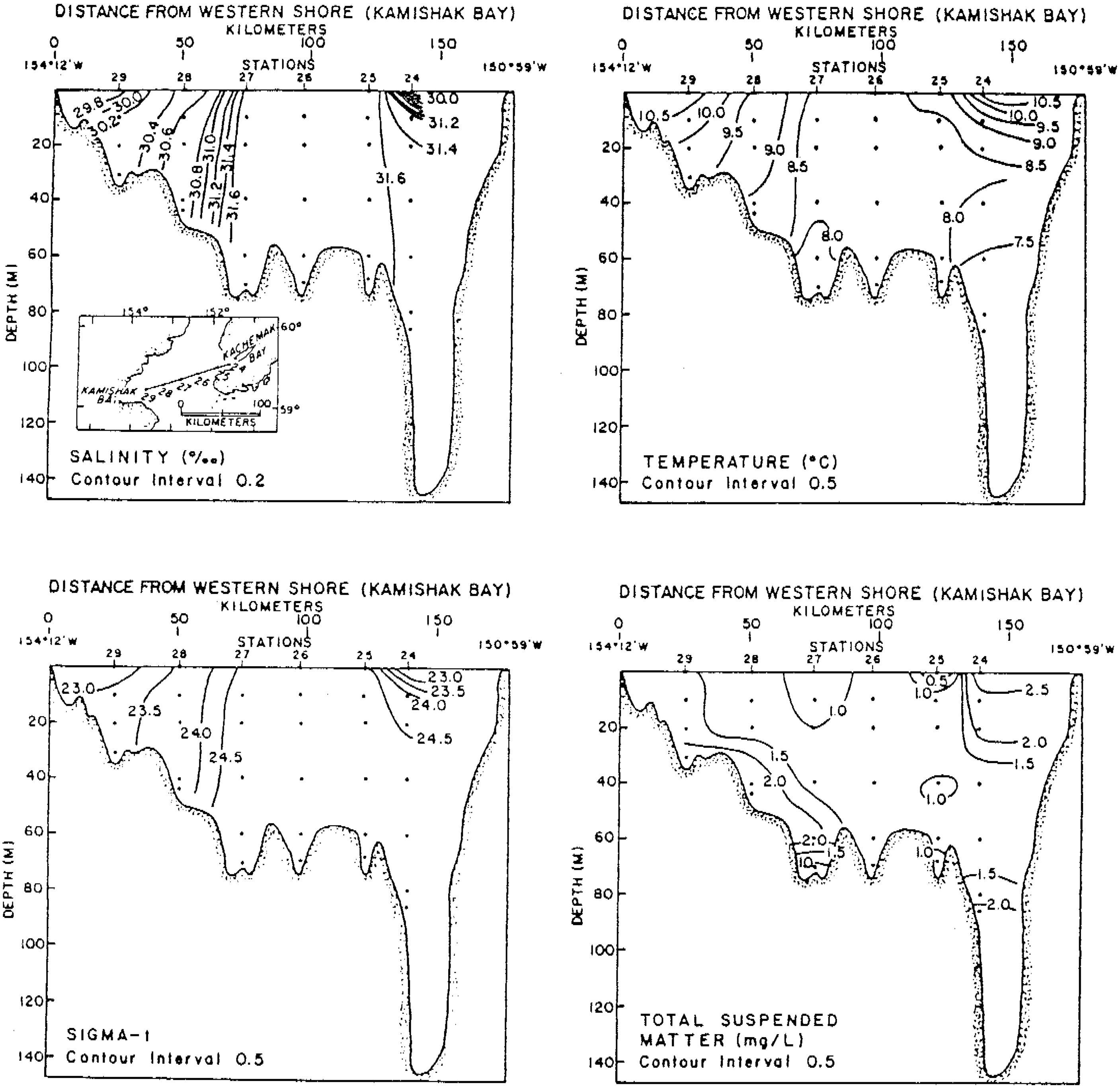

Figure 11. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations 24 thru 29 in lower Cook Inlet (Cruise Acona-245, 28 June-12 July 1977).

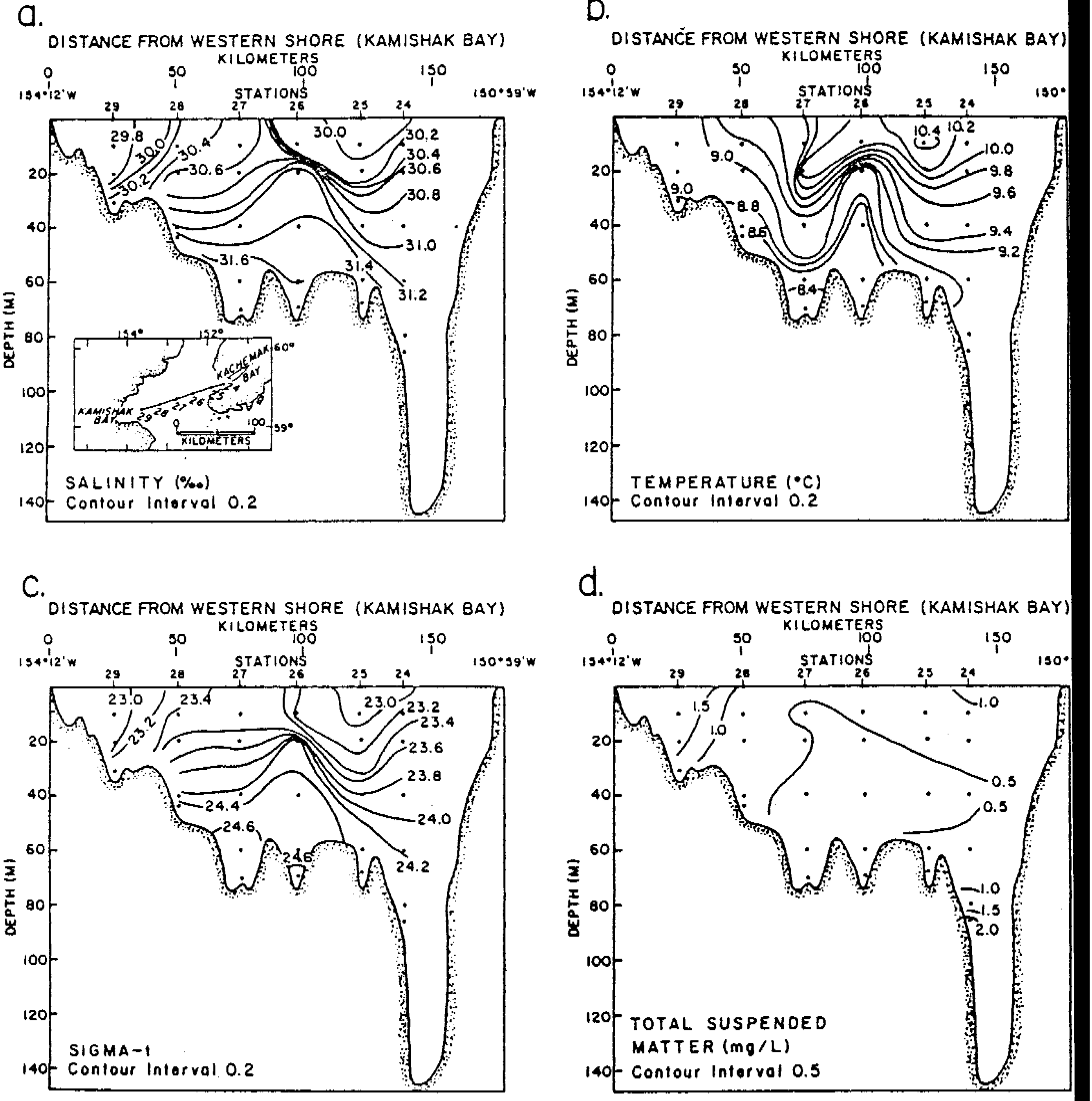

Figure 12. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations 24 thru 29 in lower Cook Inlet (Cruise RP-4-Di-77C-II, 3-12 October 1977).

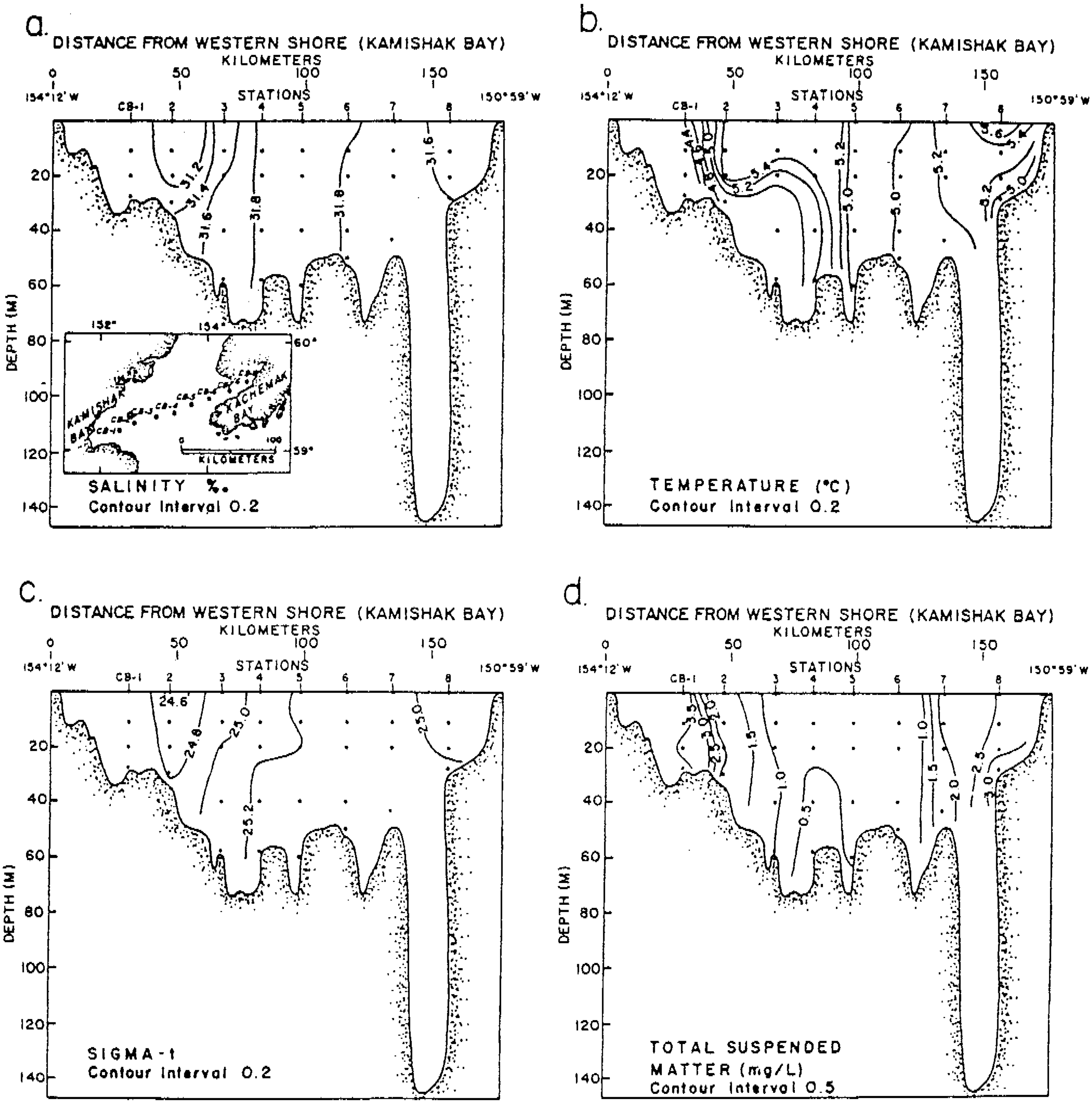

Figure 13. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations CB-1 thru CB-8 in lower Cook Inlet (Cruise RP-4-Di-78A-III, 4-17 May 1978).

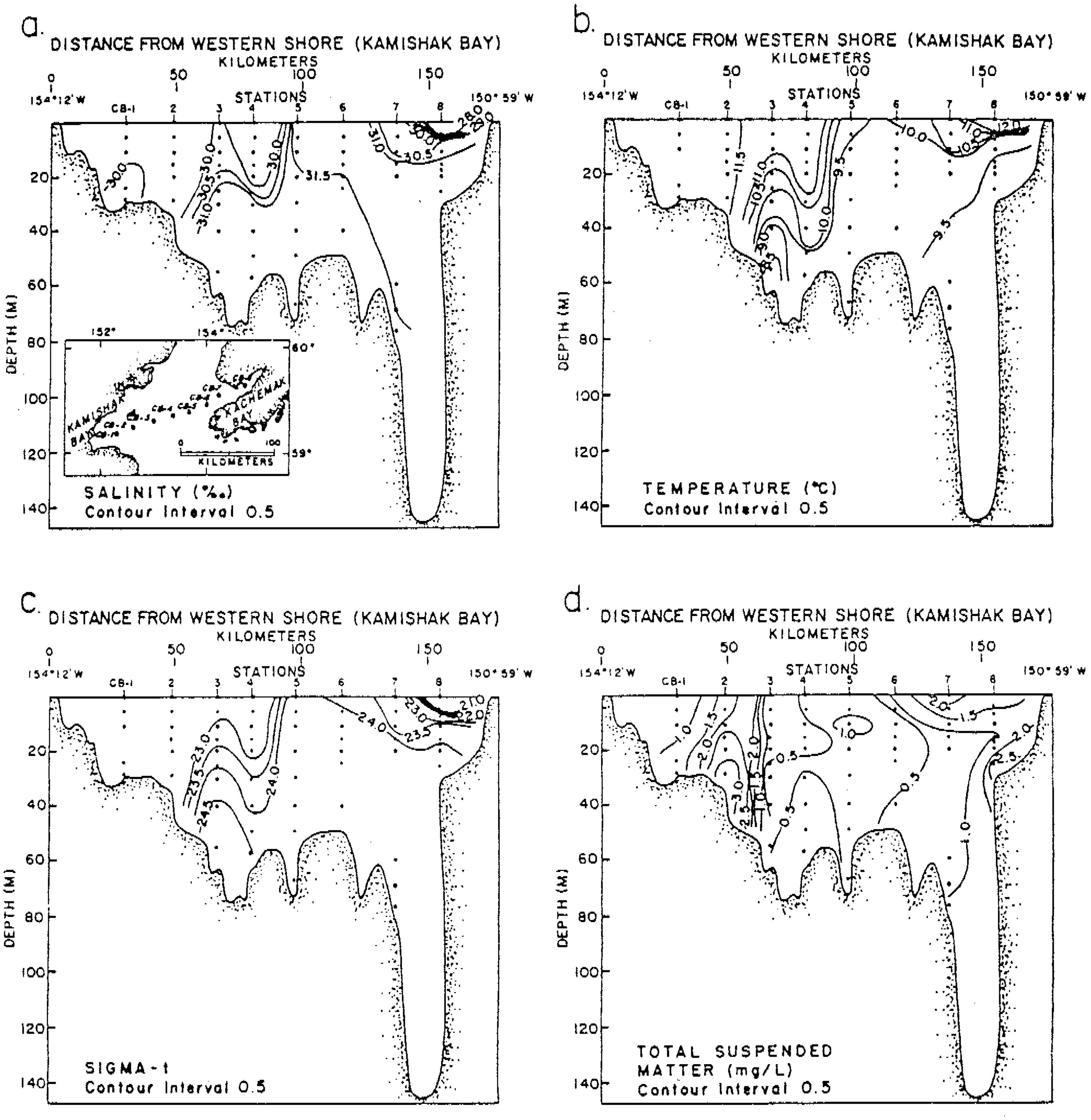

Figure 14. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations CB-1 thru CB-8 in lower Cook Inlet (Cruise RP-4-Di-78B-II, 22 August-6 September 1978).

The May and August-September 1978 data show some patterns which are consistent with the data from the previous year. First, the outward flowing brackish water on the western side is colder in May and warmer in August-September than the inward flowing Gulf of Alaska water. This feature is consistent with data obtained in April and July 1977 (Figs. 6 and 8) and appears to be related to the temperature of the inflowing river water and shows larger seasonal variations due to the larger fluctuations of temperature over the continental land masses. Furthermore, suspended matter concentrations in the Kamishak Bay region are higher in early spring than in late summer even though there is more freshwater input into Cook Inlet during late summer (Gatto, 1976). A possible explanation for this phenomenon is that early spring is usually the time when most of the ice breakup occurs in upper Cook Inlet. Resuspension and transport of previously deposited sediments may result from the ice movement. Another possibility is that if the currents are strong, there is less time for mixing and dilution of ambient suspended matter. This probably is true to some degree as the April 1977 data show higher suspended matter concentrations and lower salinities than the May 1978 data. However, this cannot be the only explanation because the July and October 1977 data show relatively low suspended matter concentrations (< 2.0 mg/L) in Kamishak Bay waters without extensive mixing with seawater (i.e., salinity < $30^{\circ}/_{oo}$). Nevertheless, the data suggest that more riverborne suspended matter is transported out of the inlet and into Shelikof Strait during early spring than during the summer.

Since suspended matter may play an important role in scavenging and transporting contaminants from the study region, the question of where the large amount of suspended materials that pass into lower Cook Inlet ultimately reside becomes important. The dramatic decrease in suspended loads from > 100 mg/L near The Forelands to < 1.0 mg/L near the inlet's mouth may be an indication of particulate settling. However, recent studies of major sediment types in lower Cook Inlet indicate that the sediments in the central part of the inlet consist primarily of unconsolidated coarse-grained sands deposited during the retreat of the Pleistocene glaciers (Bouma and Hampton, 1976). Another possibility is that the suspended matter gradients are the result of dilution of the brackish water by the less turbid oceanic water. Figure 15 shows a scatter plot of the relationship between total suspended matter and salinity for the surface samples from the central region of lower Cook Inlet, where the cross-channel gradients are highest. The data, which were from the April 1977 cruise, show that the suspended loads are linearly correlated with salinity, indicating that dilution is the major process controlling suspended matter concentrations in the central portion of the inlet. A scatter plot for the July 1977 data shows similar results. These results suggest that the central part of lower Cook Inlet acts like a conduit, allowing large amounts of suspended material to pass through the system with little net sedimentation. Sedimentation of suspended matter may be occurring in the numerous small embayments along the coast. Some information on the relative significance of this process is discussed in section VI-C of this report.

Figures 16 and 17 show vertical cross-sections of temperature, salinity, total suspended matter, and sigma-t for stations located in Shelikof Strait. The data were obtained on the August-September cruise. Stations SS2, SS5, SS6, SS8, SS9, SS10, and SS12 represent a longitudinal cross-section along the axis of the strait. Stations SS4 through SS6 and SS11 through SS13 represent transverse cross-sections at mid-channel and at the upper mouth, respectively. The data show cross-channel gradients of temperature, salinity, and suspended matter which are consistent with the cross-channel gradients in lower Cook Inlet. This is the strongest evidence to date which suggests that riverborne suspended

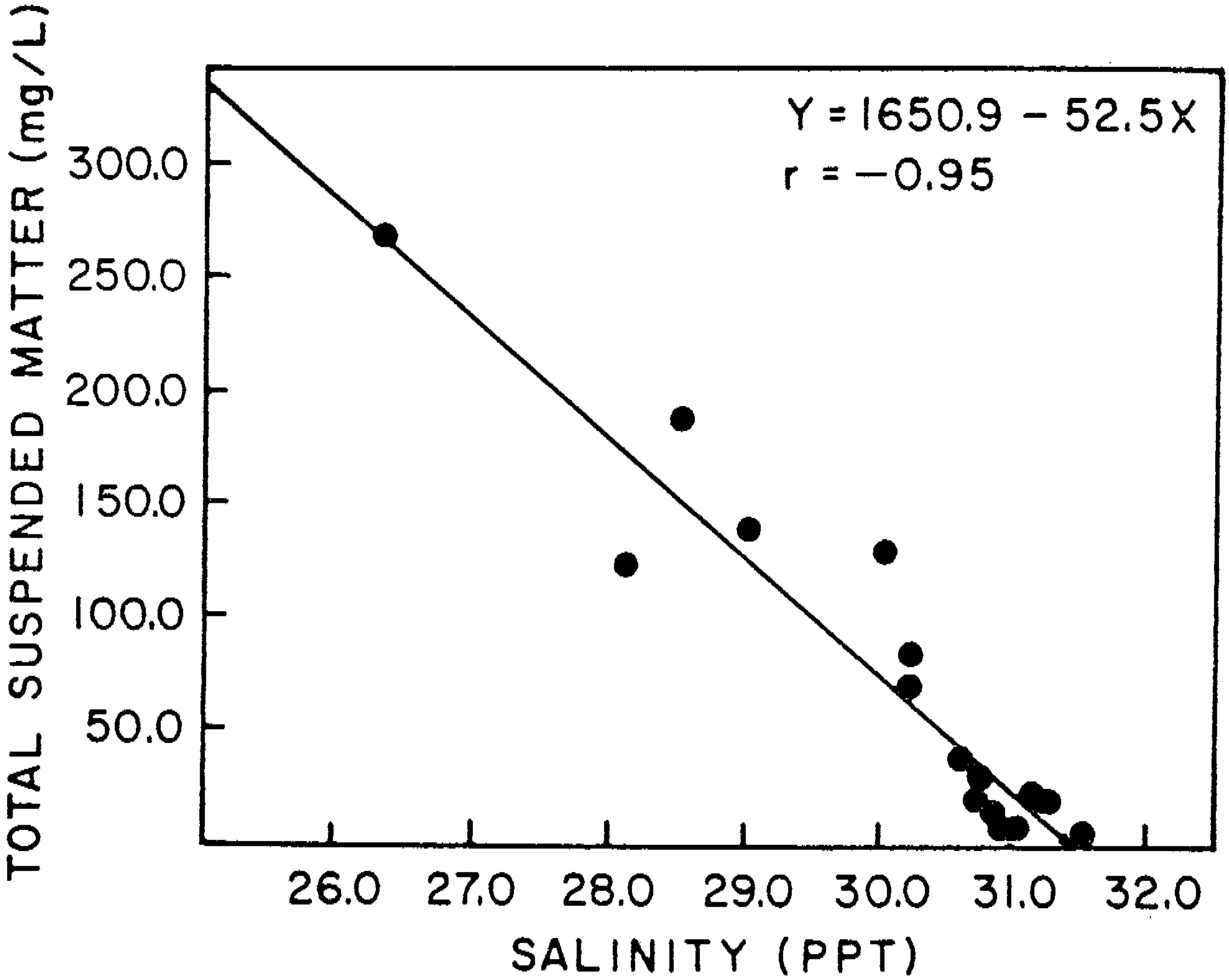

Figure 15. Scatter plot of the relationship between total suspended matter and salinity for surface samples from lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

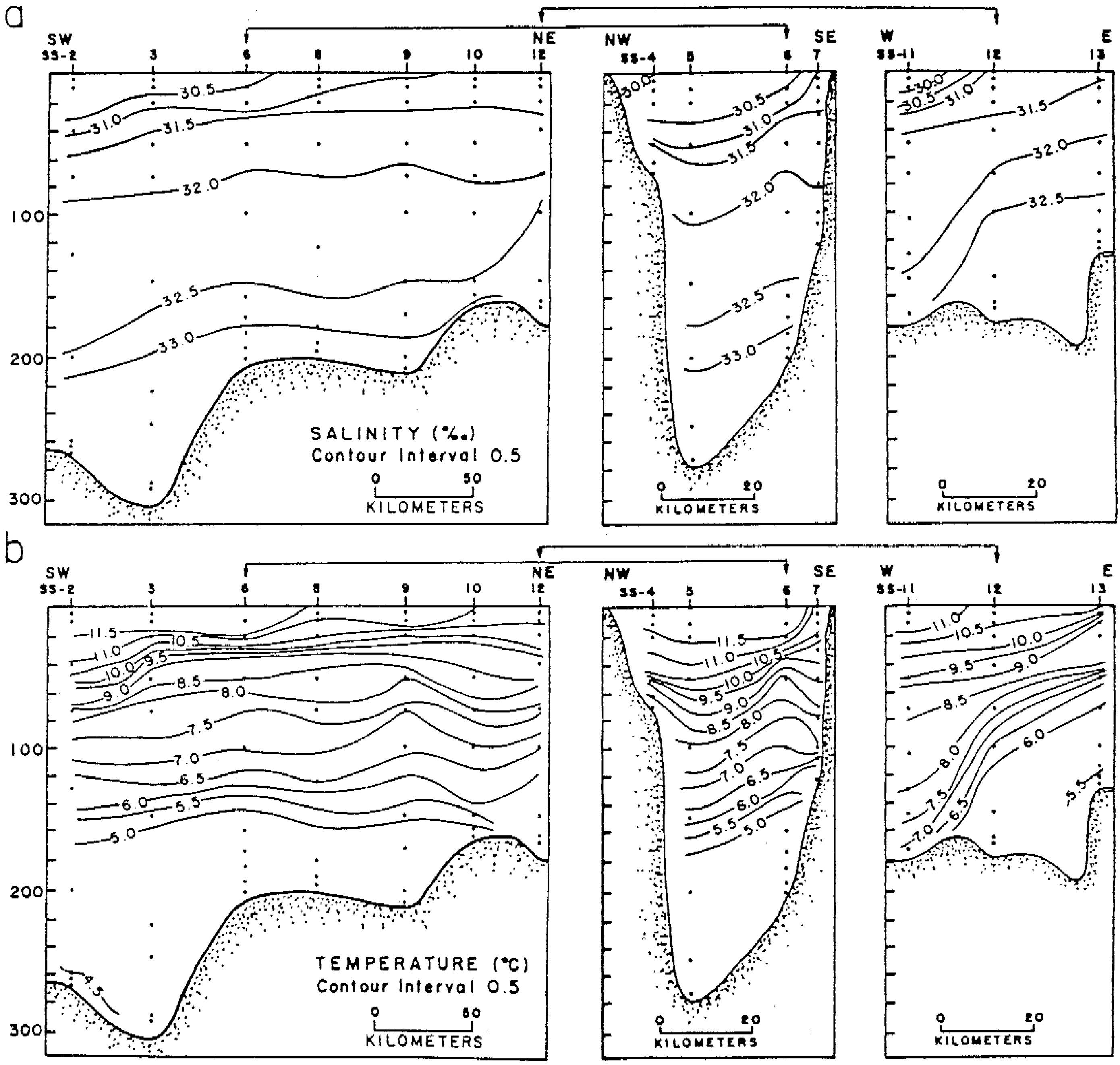

Figure 16. Vertical cross sections of the distributions of: a. salinity; and b. temperature for stations SS-2 thru SS-13 in Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August-6 September 1978).

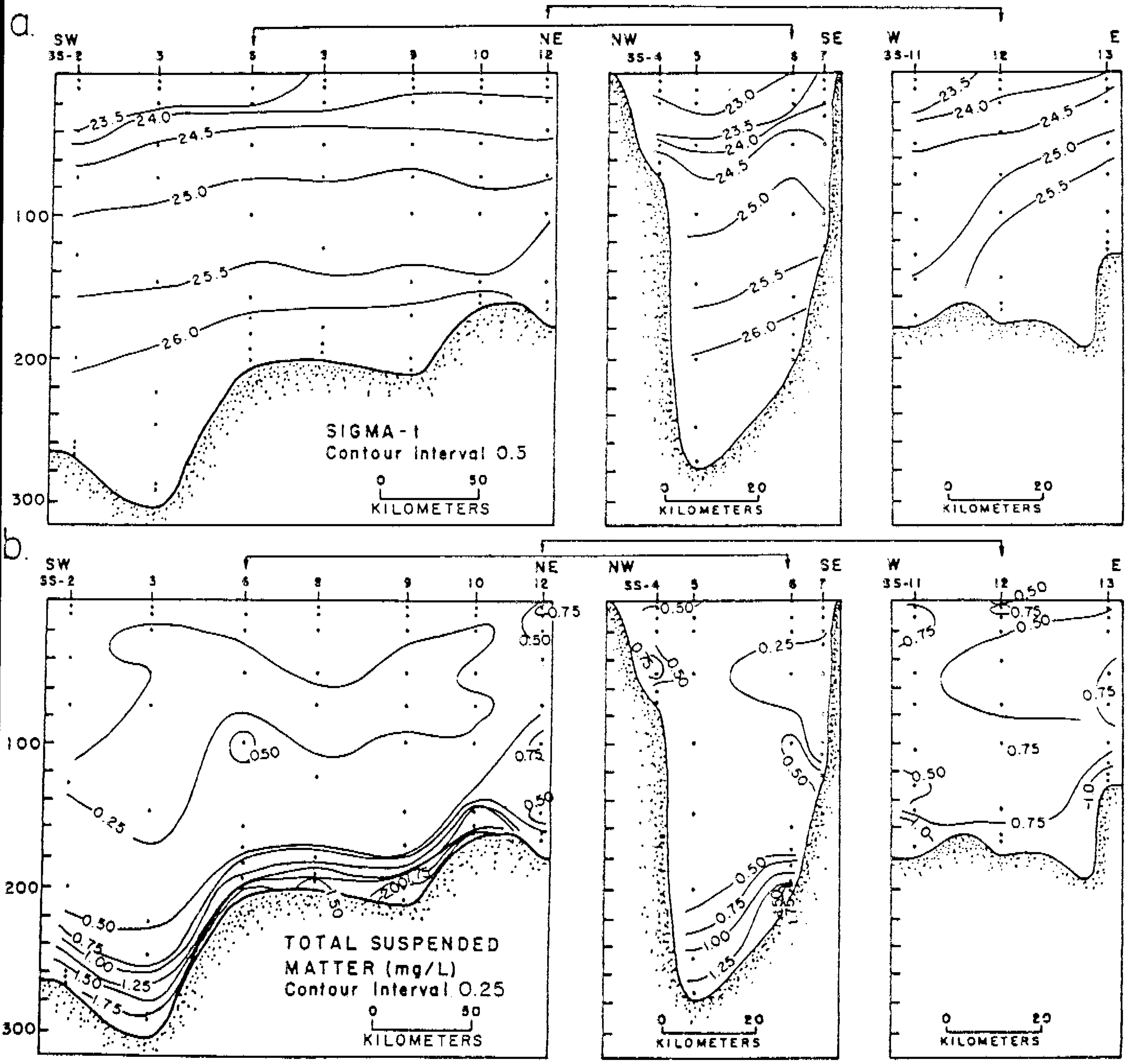

Figure 17. Vertical cross sections of the distributions of: a. sigma-t; and b. total suspended matter for stations SS-2 thru SS-13 in Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August-6 September 1978).

matter from Cook Inlet is transported into Shelikof Strait. There is also evidence for a near-bottom nepheloid layer in the strait which exists in the lower 50-60 m of the water column. Since there are no corresponding large changes in temperature and salinity which would tend to buoy up suspended material, the bottom nepheloid layer in this region is probably due to resuspension of bottom sediments. This suggests that sediments and/or contaminants probably get redistributed in the strait before final deposition occurs.

B. Temporal Variability of Suspended Matter

In order to obtain some information about high frequency (hourly) fluctuations of particulate concentrations in lower Cook Inlet, a number of time-series experiments were conducted at different locations during each of the five cruises. Figure 18 shows the times and locations of the individual experiments. As shown in the figure, time series experiments were conducted at stations 4 and 11 during the April and July 1977 cruises, respectively, at stations CB-7 and CB-9 during the May 1978 cruise, and at CB-10 on the August-September 1979 cruise. Water samples were collected and filtered every two hours from the surface and 5 m above the bottom. The results of these experiments are shown in Figure 19. The high and low tides are represented in the figures by arrows. The reference points for the tidal data are indicated in the figure caption. At the stations on either side of Kalgin Island, suspended matter loads are highly variable both at the surface and near the bottom. At the surface particulate concentrations range from 10 to 180 mg/L. The highest concentrations were obtained at CB-10 on the east side of Kalgin Island. The surface maxima at CB-10 have a 6-hour period and appear to reach their peak shortly after the tidal currents have reached maximum velocity. At this location, ebbing and flooding waters converge, current velocities are high and the water column is vertically mixed, causing complex circulation patterns (Gatto, 1976). On the west side of the

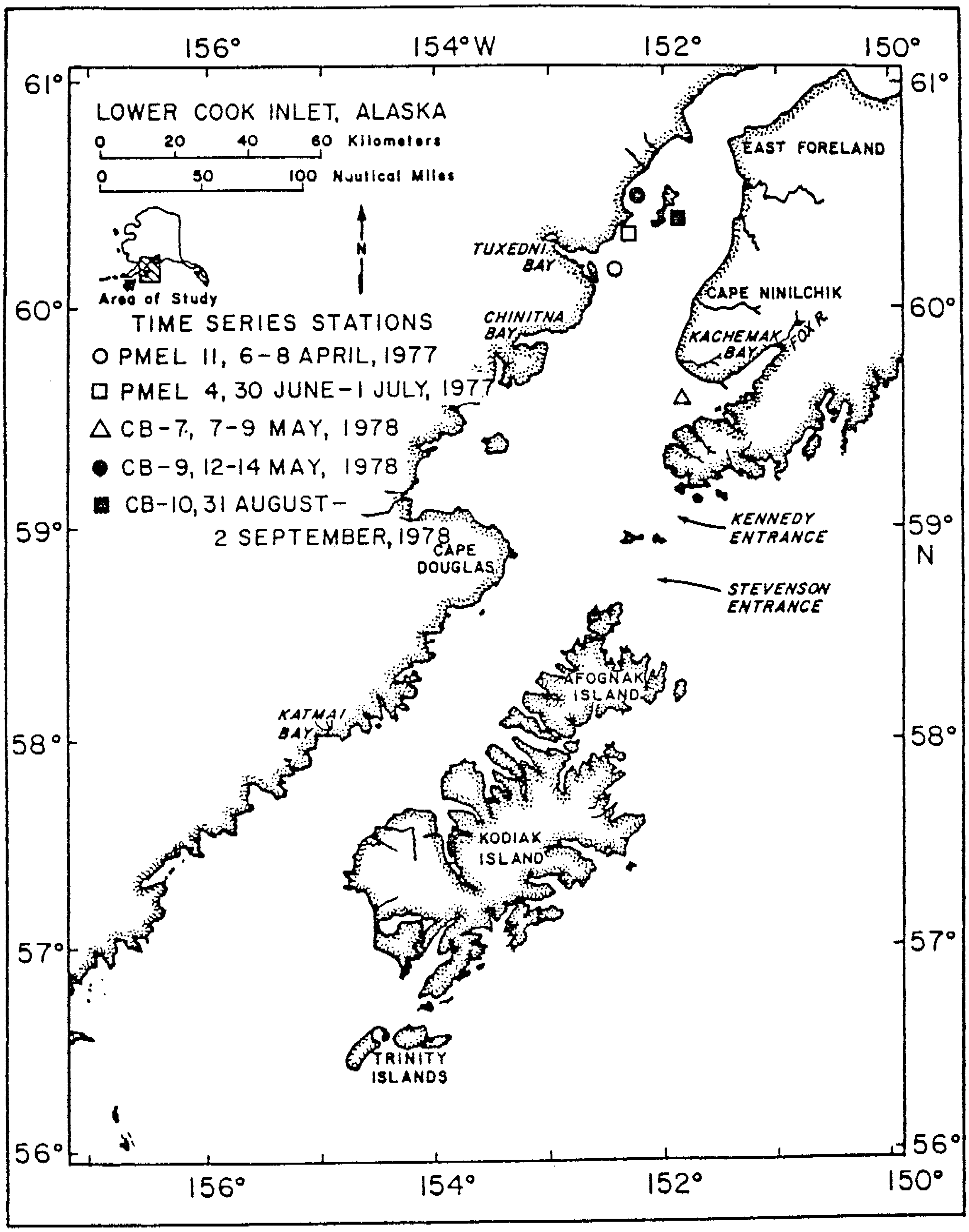

Figure 18. Locations and dates of time series experiments conducted in lower Cook Inlet.

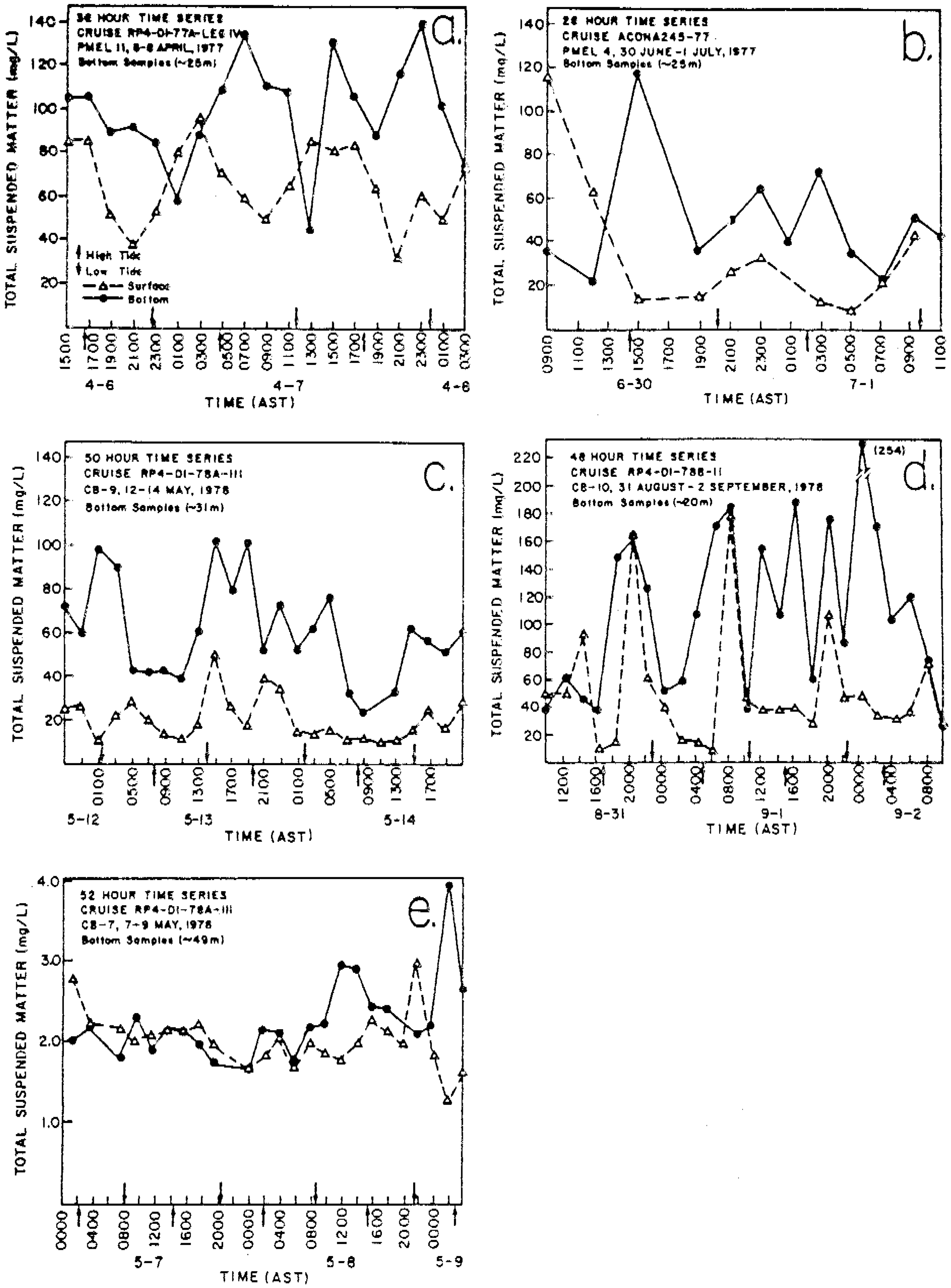

Figure 19. Temporal variability of total suspended matter at the surface and 5 m above the bottom at the time-series stations in lower Cook Inlet. The reference points for the tidal data are: a. Tuxedni Channel; b. Drift River Terminal Tide Station; c. Drift River Terminal Tide Statio d. Kenai City Pier; and e. Homer, Alaska.

island, flow patterns are dominated by tidal currents, with maximum suspended matter concentrations in surface waters usually occurring during flood tide. This is probably the result of lateral movement of suspended matter plumes from Drift and Big Rivers during flood tide (Gatto, 1976).

The near-bottom particulate maxima do not show a consistent periodicity pattern, but peaks associated with both the ebb and flood currents are evident. Furthermore, near-bottom suspended matter concentrations generally are higher than at the surface, indicating that when the tidal currents reach maximum velocity, the bottom sediments are being resuspended.

While the time series data for the Kachemak Bay station show evidence for greatly reduced concentration fluctuations, the general trend of particulate maxima in surface waters occurring shortly after the ebb current reaches maximum velocity still exists. These data suggest that throughout the inlet tidal currents are a major cause of high frequency fluctuations of suspended matter distributions. It appears that during ebb current, the turbid brackish water from the north moves southward, elevating the ambient suspended load. In near-bottom waters this process is augmented by local resuspension of bottom sediments, if the bottom currents reach some threshold velocity. These conclusions are consistent with the general conclusions of Gatto (1976), who stated that from observations of LANDSAT images of lower Cook Inlet, it appeared that turbid plumes were more prominent in the southern and central part of the lower inlet just after the ebb current.

C. Sediment Trap Studies

During cruise RP-4-MF-78A-11 (19 May-4 June 1978), three moorings, each supporting one set of tandem sediment traps located 10 m above the bottom, were deployed along a transect line extending from Kamishak Bay to Kachemak Bay in lower Cook Inlet (Fig. 4). The purpose of the traps was to obtain long-term averages of the vertical fluxes of suspended matter in selected regions of lower Cook Inlet. The sediment trap capture period was set for closure approximately 85 days after deployment, which occurred on 27 May 1978. Of the six sediment traps deployed, four were recovered. The two sediment traps from station ST-3 were accidentally dredged up by the fishing vessel, Columbian, and the samples were lost. In addition, one sample from the sediment traps at ST-2 was also lost due to breakage of the sodium azide diffusion cup during recovery. Table 3 summarizes the particulate matter fluxes obtained by gravimetric analysis of the material captured by the traps. Also included are the mean particulate fluxes obtained by Larrance (1978) for short-term sediment trap deployments at CB-1, CB-4, and CB-7. The long-term flux at ST-1 is about the same as the mean value obtained by Larrance for traps deployed at CB-1 (20.8 g m^{-2} day^{-1} vs. 22.0 g m^{-2} day). This suggests that the two locations are very similar in their sedimentation characteristics and the data from the two sets of traps can be intercompared. The long-term sediment flux at ST-2 was 2.4 times greater than the mean of the sediment fluxes at CB-4 (28.5 g m^{-2} day^{-1} vs. 12.0 g m^{-2} day). While these stations were less than 15 nautical miles apart (Fig. 4), these differences are probably real because station ST-2 is within the region dominated by the outflowing brackish water and station CB-4 is in the region influenced by the inward flowing Gulf of Alaska water. Presumably, a significant fraction of the suspended matter in the outward flowing brackish water settles out in Kamishak Bay. These data are consistent with the ^{210}Pb sediment accumulation rates for the underlying sediment cores (Table 3). The good agreement between the sedimention rate and the sediment accumulation rate for CB-1 in Kamishak Bay indicates that this region is a depositional environment for the fine-grained material that originates from upper Cook Inlet.

Table 3. Comparison of sedimentation rates of suspended materials collected by sediment traps deployed on moorings approximately 10 m above the bottom at selected locations in lower Cook Inlet with average accumulation rates of the underlying sediments as determined by ^{210}Pb geochronology.

Location	Station No.	Average Sedimentation Rate of Suspended Matter ($g\ m^{-2}\ day^{-1}$)	Average Accumulation Rate of Sediments ($g\ m^{-2}\ day^{-1}$)
Kamishak Bay	CB-1*	22.0 ± 25	27.1
	ST-1	20.8 ± 7	2.2
Central Inlet	ST-2	28.5	no data
	CB-4*	12.0 ± 8	no data
Kachemak Bay	CB-7*	18.8 ± 2	10.5

*After Larrance et al. (1979).

D. Elemental Composition of the Particulate Matter

The particulate matter collected during the five cruises in lower Cook Inlet have been analyzed using a variety of methods to determine how the elements are distributed in the particles. On all five cruises the total elemental composition of the particulate matter was determined by the x-ray fluorescence and atomic absorption techniques described in section V of this report. Trace elements associated with the easily oxidizable organic matter and iron and manganese oxyhydroxide coatings were determined on the selected samples from the 1978 time series stations at CB-7, CB-9 and CB-10. In addition the sediment trap samples were also analyzed for their elemental content. The results of these studies are described below.

1. Total Elemental Composition of the Particulate Matter

Tables 4 through 6 compare summaries of the data on the total elemental composition of suspended matter from the Susitna, Knik, and Matanuska Rivers

Table 4. Summary of the elemental composition of particulate matter samples from the major rivers discharging into Cook Inlet. (Surface samples were obtained with a precleaned 4-L polyethylene bottle extended from a bridge 26 June 1977.)

Element	Susitna River	Matanuska River	Knik River
C (Wt. %)	1.04	0.55	0.75
N (Wt. %)	0.06	0.03	0.05
Mg (Wt. %)	4.28	3.02	4.30
Al (Wt. %)	10.39	8.57	12.90
Si (Wt. %)	36.12	28.53	36.32
K (Wt. %)	2.62	1.54	2.73
Ca (Wt. %)	2.33	2.37	1.33
Ti (Wt. %)	0.63	0.55	0.67
Cr (ppm)	172	112	182
Mn (ppm)	1308	1157	1206
Fe (Wt. %)	6.45	6.07	6.90
Ni (ppm)	94	43	70
Cu (ppm)	71	49	61
Zn (ppm)	186	106	152
Pb (ppm)	56	25	51

with summaries of the surface and near-bottom data for the April and July 1977 cruises in lower Cook Inlet. Within the statistical limits of the measurements the samples from lower Cook Inlet have very nearly the same major element composition as the samples from the rivers. This is especially true for Al, K, Ti, and Fe which have been shown to be almost exclusively associated with aluminosilicate minerals of terrestrial origin (Price and Calvert, 1973). The high concentrations of these elements in the surface and near-bottom samples from

Table 5. Summary of the elemental composition of particulate matter samples from lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

Element	Average of 50 surface samples	Average of 50 samples from 5 m from the bottom
C (Wt. %)	4.01 ± 4.0	2.72 ± 2.5
N (Wt. %)	0.65 ± 0.5	0.41 ± 0.4
Mg (Wt. %)	3.54 ± 0.6	3.47 ± 0.9
Al (Wt. %)	3.64 ± 1.6	8.70 ± 1.6
Si (Wt. %)	31.04 ± 3.4	30.20 ± 4.3
K (Wt. %)	2.15 ± 0.4	2.24 ± 0.4
Ca (Wt. %)	2.20 ± 0.4	2.23 ± 0.3
Ti (Wt. %)	0.55 ± 0.1	0.58 ± .07
Cr (ppm)	95 ± 15	99 ± 16
Mn (ppm)	1313 ± 113	1326 ± 159
Fe (Wt. %)	6.22 ± 1.0	6.42 ± 0.8
Ni (ppm)	61 ± 10	63 ± 10
Cu (ppm)	71 ± 15	76 ± 17
Zn (ppm)	165 ± 32	176 ± 34
Pb (ppm)	56 ± 13	56 ± 12

lower Cook Inlet indicate that aluminosilicate minerals are the most dominant solid phase in the particulate matter. These data indicate that approximately 80-95% of the particulate matter is aluminosilicate minerals. These results are not surprising since the Susitna, Matanuska and Knik Rivers supply about 15-20x10^6 tons of sediment annually to the inlet (Rosenberg and Hood, 1967).

Tables 5 and 6 also summarize the elemental composition of 42 samples taken 5 m above the bottom. In general, the major element concentrations of

Table 6. Summary of the elemental composition of particulate matter from lower Cook Inlet and Shelikof Strait (Acona-245, 28 June-12 July 1977).

Element	Lower Cook Inlet		Shelikof Strait	
	Average of 50 Surface Samples	Average of 51 Samples from 5 m above the Bottom	Average of 17 Surface Samples	Average of 16 Samples from 5 m above the Bottom
C (Wt. %)	10.77 ± 11.0	6.18 ± 9.0	31.17 ± 11.2	8.40 ± 5.8
N (Wt. %)	1.98 ± 2.0	0.99 ± 1.4	4.89 ± 1.5	1.24 ± 0.8
Mg (Wt. %)	2.86 ± 1.41	3.59 ± 0.82	1.89 ± 0.91	4.01 ± 1.22
Al (Wt. %)	6.98 ± 4.24	8.88 ± 2.34	3.72 ± 2.46	9.49 ± 3.20
Si (Wt. %)	35.75 ± 5.56	38.09 ± 4.92	28.67 ± 10.10	44.71 ± 3.60
K (Wt. %)	1.86 ± 0.86	2.24 ± 0.45	0.89 ± 0.43	2.19 ± 0.63
Ca (Wt. %)	1.84 ± 0.63	2.33 ± 0.32	1.53 ± 0.35	2.08 ± 0.33
Ti (Wt. %)	0.46 ± 0.20	0.58 ± 0.10	0.27 ± .09	0.53 ± 0.12
Cr (ppm)	99 ± 30	115 ± 24	75 ± 36	116 ± 29
Mn (ppm)	1138 ± 574	1460 ± 362	981 ± 709	4174 ± 7642
Fe (Wt. %)	5.14 ± 2.11	6.50 ± 0.95	3.15 ± 1.14	6.39 ± 1.71
Ni (ppm)	70 ± 25	81 ± 16	59 ± 19	77 ± 13
Cu (ppm)	99 ± 33	100 ± 31	94 ± 27	112 ± 30
Zn (ppm)	352 ± 158	343 ± 194		
Pb (ppm)	65 ± 19	69 ± 13	60 ± 10	76 ± 22

the near-bottom samples are similar to the surface samples. This is especially true for the April 1977 cruise and in the northern part of the inlet where the water column is well mixed. However, during the July 1977 cruise and in the southern part of the inlet the water column was vertically stratified (Fig. 11) and the elemental composition of the suspended matter showed distinct differences between the surface and 5 m above the bottom. For example, Figure 20 shows vertical cross-sections of particulate carbon and carbon-nitrogen ratios for the May and August-September 1978 cruises. The August-September data show higher particulate carbon concentrations at the surface than at the bottom indicating a vertical stratification of the particulate organic matter. Similar vertical gradients are not easily discernible in the May 1978 or April 1977 data which suggests that in early spring the waters are extremely well-mixed with respect to water properties and suspended matter.

The vertical cross-sections of particulate carbon also show significant cross channel gradients in both spring and summer data, with the highest concentrations and vertical gradients occurring at stations located in Kachemak Bay. Larrance et al. (1977) state that phytoplankton productivity and standing stocks of chlorophyll a are highest in Kachemak Bay and decrease steadily to low values in the middle of the inlet. These data suggest that the observed variations of particulate carbon are directly related to production of marine organic matter in the inlet, with Kachemak Bay being the most productive. This is probably the result of a number of factors, including: (1) upwelling of nutrient-rich subsurface waters in the region northwest of the Chugach Islands (Burbank, 1977); (2) stratification and stabilization of the surface waters due to formation of two gyre systems (Burbank, 1977 and Larrance et al., 1977); and (3) deeper light penetration due to input of relatively nonturbid oceanic water from the Gulf of Alaska (this report).

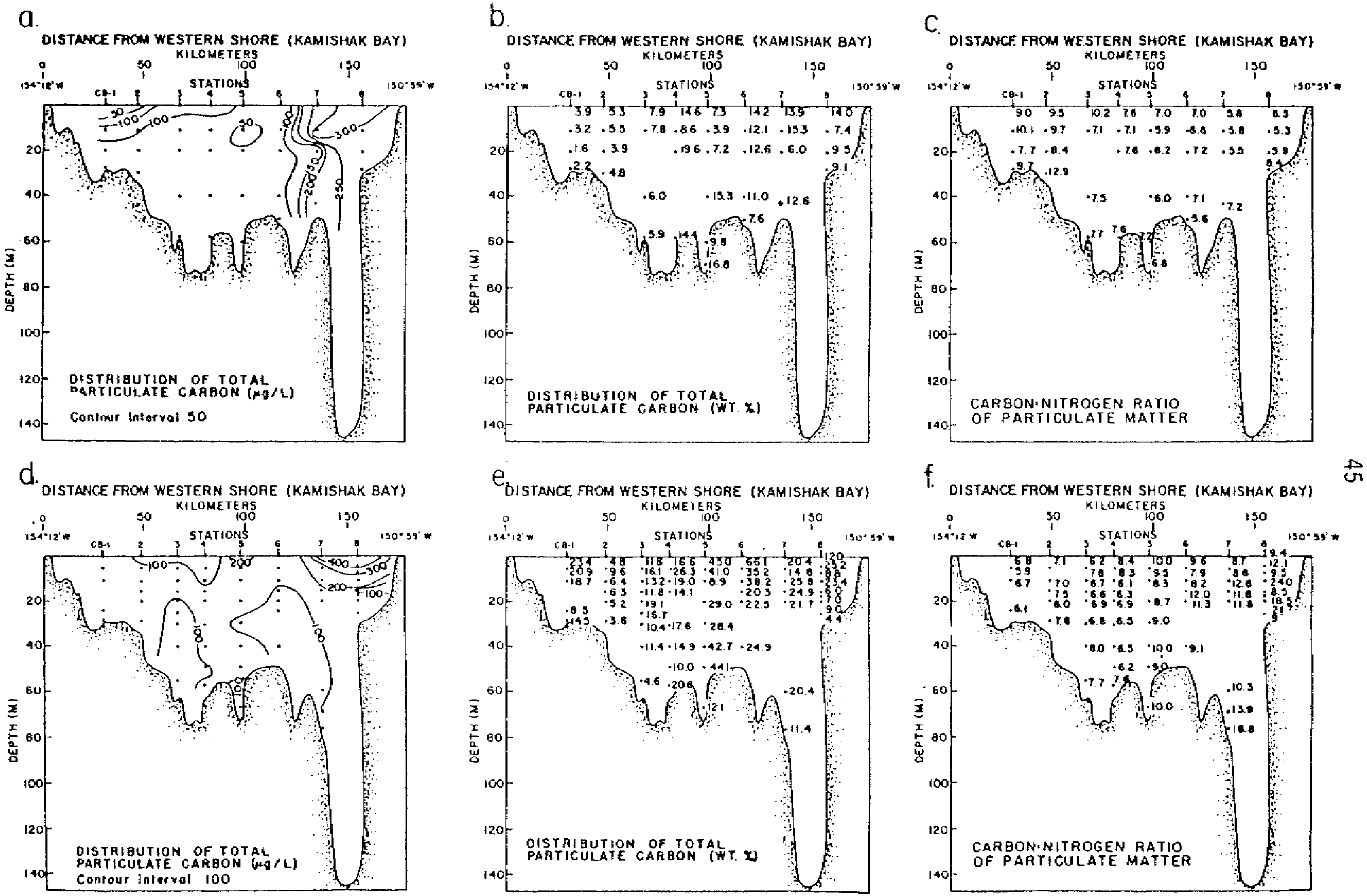

Figure 20. Vertical cross sections of the distributions of: a. particulate carbon in units of µg/L; b. particulate carbon in weight percent of the suspended matter; and c. carbon to nitrogen atom ratios for stations CB-1 thru CB-8 in lower Cook Inlet (Cruise RP-4-Di-78A-III, 4-17 May 1978). Figures 20d, 20e and 20f show the same type of data for Cruise RP-4-Di-78B-II (22 August - 6 September 1978).

Undoubtedly, some of the organic matter that is produced in the Kachemak Bay region settles to the bottom and gets buried within the sediments. However, since the net circulation is to the north and back again to the southwest into Shelikof Strait, a significant fraction of the organic matter produced in Kachemak Bay probably gets deposited in Shelikof Strait. This means that the two regions are linked by physical, chemical, and biological processes. While detailed information on chemical and biological processes in Shelikof Strait are unavailable at this time, some recent data from the August-September cruise are available which tend to support the hypothesis that the two regions are linked by chemical processes. Figure 21 shows the distributions of particulate C and particulate Mn in Shelikof Strait. The enrichment of particulate Mn in the near-bottom waters is probably due to release of reduced Mn from the sediments. This process occurs in regions of high productivity and high sedimentation (Graham et al., 1976). While data on regional productivity and sedimentation in Shelikof Strait are unavailable at this time, the data suggest that there is a positive correlation between particulate carbon and manganese in the near-bottom waters and that lower Cook Inlet is probably a major source for the organic matter. Although limited to a great extent, these data indicate that physical and chemical processes occurring in dynamic environments in lower Cook Inlet directly affect bottom water chemistry in the less dynamic environments of Shelikof Strait. If any of these processes are altered, either by natural or artificial means, the major effect might be observed in Shelikof Strait. If this is the case, then environmental parameters monitored in Shelikof Strait may be sensitive indicators of subtle changes occurring in the inlet.

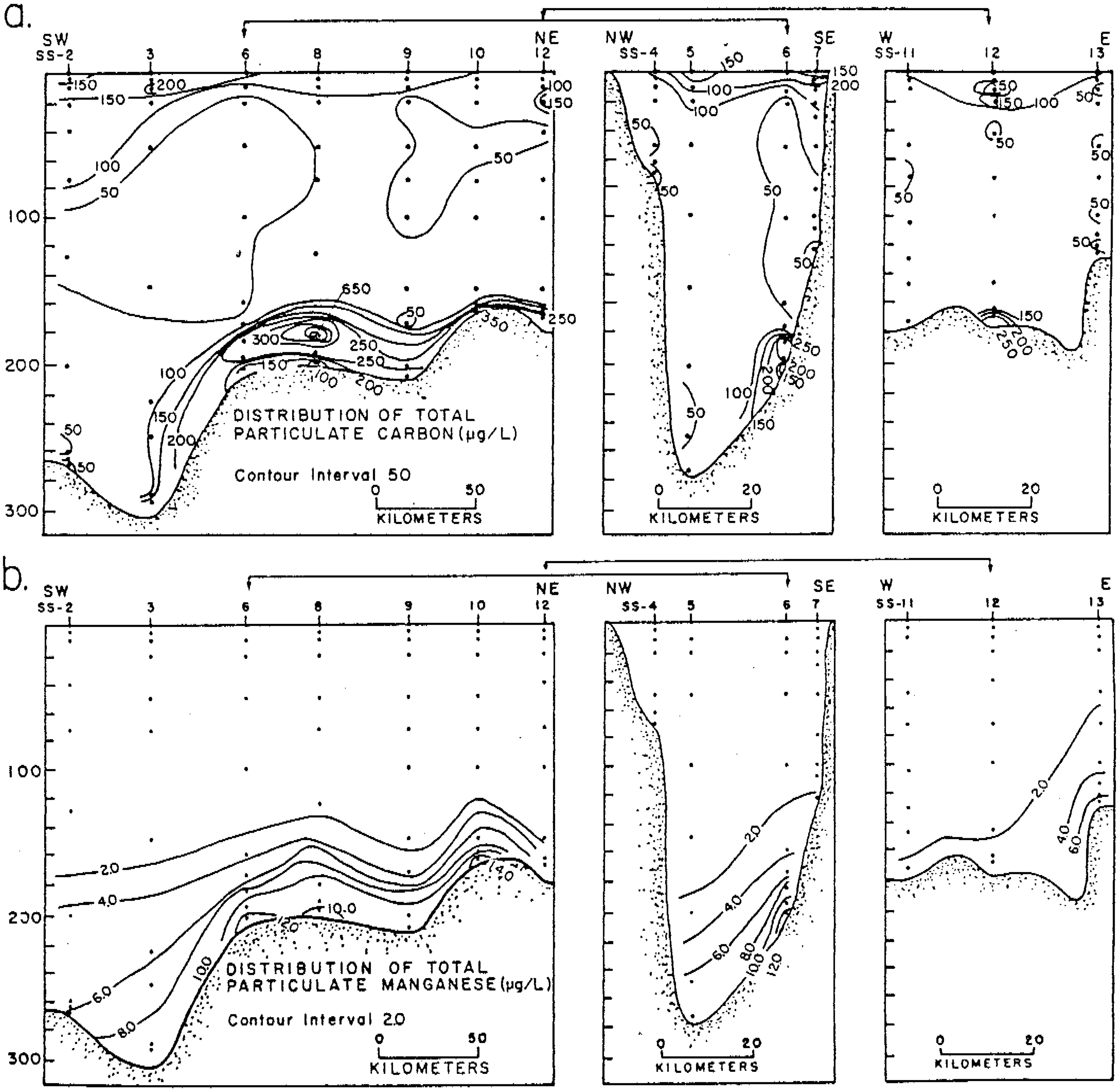

Figure 21. Vertical cross sections of the distributions of: a. total particulate carbon and b. total particulate manganese for stations SS-2 thru SS-13 in Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August-6 September 1978).

2. Elemental Composition of Particulate Matter Collected with the Sediment Traps

The results of the elemental analysis of the particulate materials collected with the sediment traps deployed at ST-1, ST-2, and CB-7 are shown in Table 7. The data are reported as the mean ± standard deviation as determined from replicate analyses. When the data are compared with the ambient suspended matter (as described in Feely et al., 1978 and shown in Fig. 20), some interesting relationships become apparent. For example, the trace element data of the trapped materials show regional differences which are significant. The Kamishak Bay samples (ST-1) are significantly enriched in Fe, Cr, and Ni relative to the Kachemak Bay samples (CB-7). This trend is very similar to what was found for ambient particulate matter (Feely et al., 1978) and appears to be related to differences in the composition of the source materials as described in the previous section of this report. Also, particulate carbon and nitrogen in the trapped samples from Kachemak Bay (CB-7) are more than three times more concentrated than corresponding samples from Kamishak Bay (ST-1 and ST-2). This represents nearly a threefold difference in the flux of organic matter to the sediments (0.95 g m^{-2} day at CB-7 as compared with 0.32 g m^{-2} day at ST-1). Similarly, ambient suspended matter from Kachemak Bay is about three times more concentrated in carbon than suspended matter from the Kamishak Bay region (Fig. 20). As stated earlier, the data of Larrance et al. (1977) indicates that primary production is highest in the Kachemak Bay region. Therefore, it seems apparent that there is a positive correlation between production of organic matter in the water column and organic matter fluxes to the sediments, with the highest production rates and sedimentation occurring in Kachemak Bay. Furthermore, the C:N ratio of trapped organic matter at CB-7 is 8.3, which is characteristic of marine organic matter (Loder and Hood, 1972). In contrast, organic matter from the sediment traps at ST-1 have a mean C:N ratio of 10.1 which is indicative of a mixture of terrestrial and marine organic matter. These results illustrate the differences of the composition and fluxes of organic matter that are reaching the sediments of lower Cook Inlet and are providing food resources to filter-feeding organisms.

Table 7. Summary of the elemental composition of sediment trap samples from stations ST-1, ST-2, and CB-7 in lower Cook Inlet. Precision was determined by replicate analysis (± 1 S.D.).

Element	ST-1 (32 m)	ST-2 (75 m)	CB-7 (60 m)
C (Wt. %)	0.87 ± .02	0.84 ± 0.38	2.80 ± 0.35
N (Wt. %)	.09 ± .01	.09 ± .04	0.35 ± .05
Al (Wt. %)	5.24 ± 0.28	4.79 ± 0.34	N.A.*
Si (Wt. %)	24.70 ± 1.10	30.0 ± 1.10	22.6 ± 3.20
Fe (Wt. %)	4.60 ± 0.20	3.40 ± 0.10	3.80 ± 0.93
Cr (ppm)	82 ± 12	55 ± 6	63 ± 8
Mn (ppm)	887 ± 77	662 ± 37	915 ± 170
Ni (ppm)	51 ± 14	30 ± 7	34 ± 2
Cu (ppm)	29 ± 2	18 ± 2	43 ± 3
Zn (ppm)	142 ± 6	106 ± 2	215 ± 120
Pb (ppm)	15 ± 2	10 ± 2	13 ± 6

*N.A. = Not available.

3. Extractable Elements in the Particulate Matter

During the May and August-September 1978 cruises, suspended matter was collected onto 142 mm Nuclepore filters at the time-series stations for the purpose of providing information on the potential availability of trace elements to organisms. At each of the time-series stations (Fig. 18), water samples were collected at the surface and 5 m above the bottom and filtered for particulate matter every twelve hours for a 48-hour period. The samples were subjected to: (1) a peroxide treatment to release organically bound trace elements; (2) a 0.3 N HCl treatment to release elements associated with Fe-Mn oxyhydroxide coatings on particles; and (3) a total element analysis of untreated samples. A full description of the procedures is provided in section 4. The results of these studies are illustrated in Figures 22 through 24 and summarized in Table 8. In general, the suspended matter from Kalgin Island (CB-9 and CB-10) do not show differences in the trace element composition or in the trace element associations with time or depth. In Kachemak Bay (CB-7), particulate Al, Fe, Mn, Cr, and Ni are enriched in the near-bottom samples relative to the surface samples. These enrichments are probably due to the increased amount of inorganic material associated with resuspended particulate matter.

The data in Table 8 also illustrate some rather striking differences in the elemental compositions of suspended matter from the Kalgin Island region as compared with suspended matter from Kachemak Bay. As was stated previously in this report, suspended matter in the vicinity of Kalgin Island has as its source inorganic and organic terrestrial material from the coastal rivers discharging into upper Cook Inlet, particularly the Susitna, Knik, and Matanuska Rivers. In contrast, the suspended matter in Kachemak Bay includes primarily biogenically produced marine organic matter (i.e., marine plankton) mixed with inorganic material from the Gulf of Alaska and from the Fox and Martin Rivers which discharge into the inner Kachemak Bay. These distinctly different sources of the suspended matter are undoubtedly responsible for the differences in trace element associations. For instance, Mn, Cu, and Zn are enriched in the organic phase of the suspended matter from the surface waters of Kachemak Bay (CB-7, Table 8). Between 32% and 108% of these metals are associated with the organic

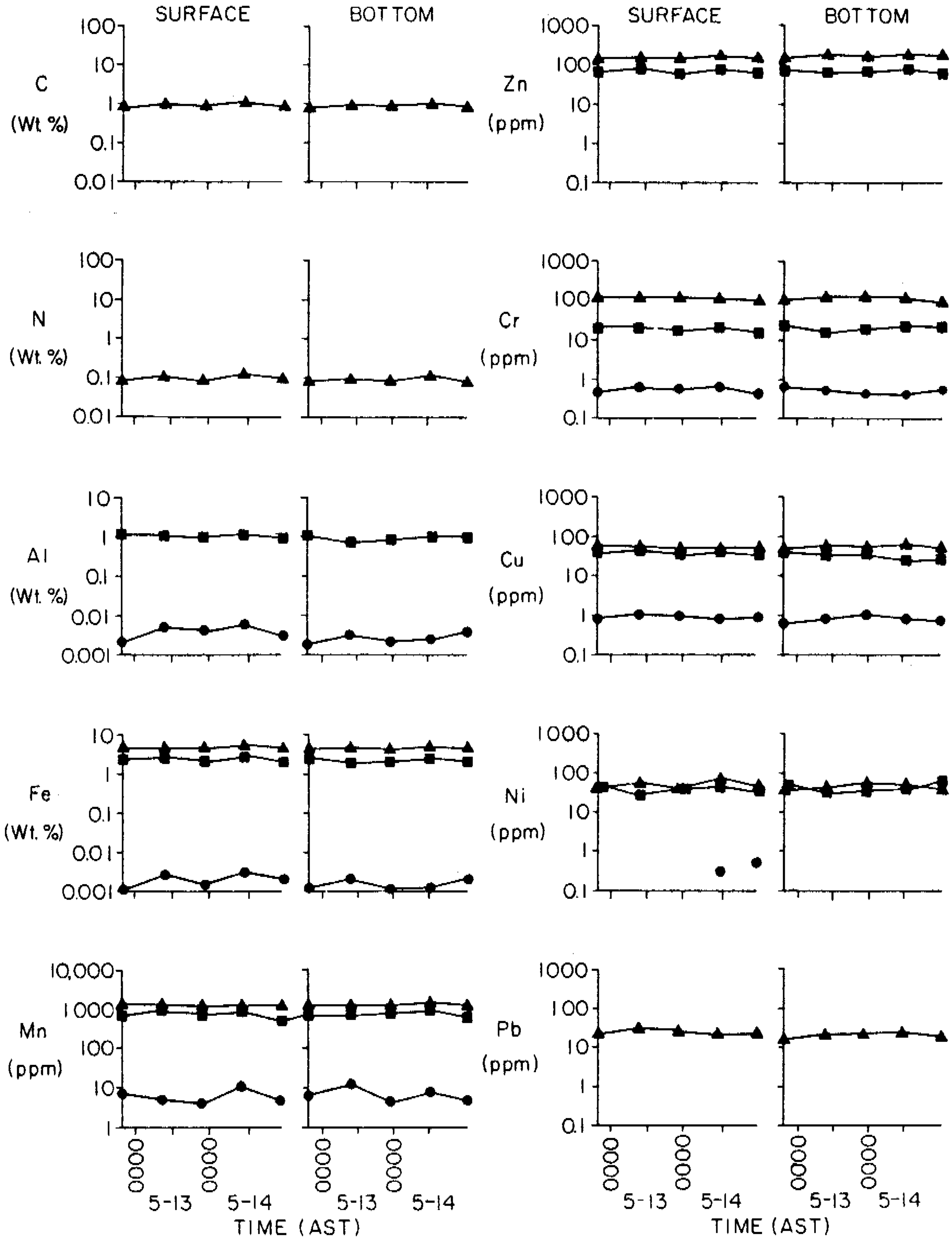

Figure 22. Temporal variations of major and trace elements in suspended matter (total concentration [▲], weak acid extractable [■], and peroxide extractable [●]) from station CB-9 in lower Cook Inlet. Samples were collected 13-14 May 1978.

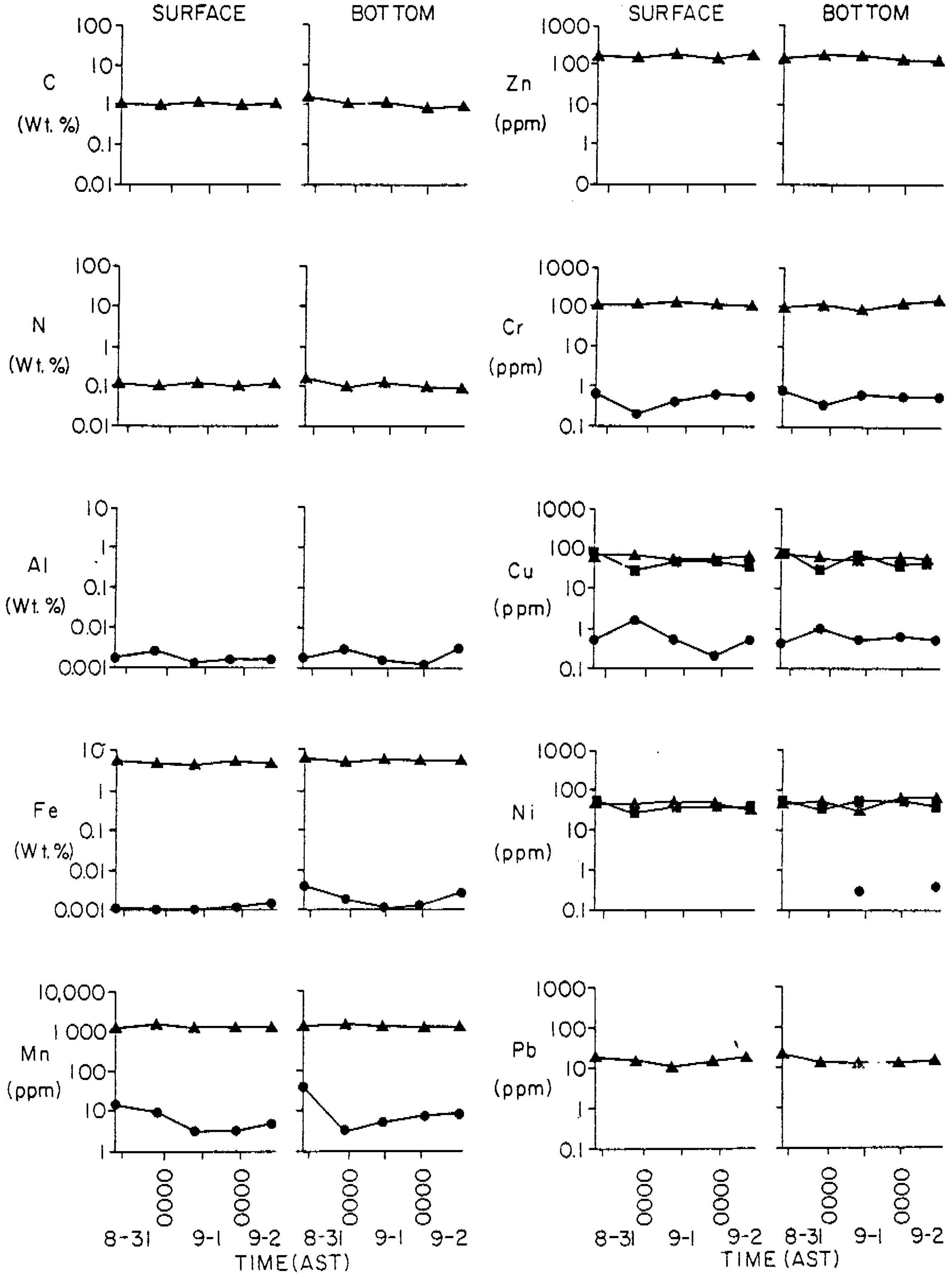

Figure 23. Temporal variations of major and trace elements in suspended matter (total concentration [▲], and peroxide extractable [●]) from station CB-10 in lower Cook Inlet. Samples were collected 31 August and 1-2 September 1978.

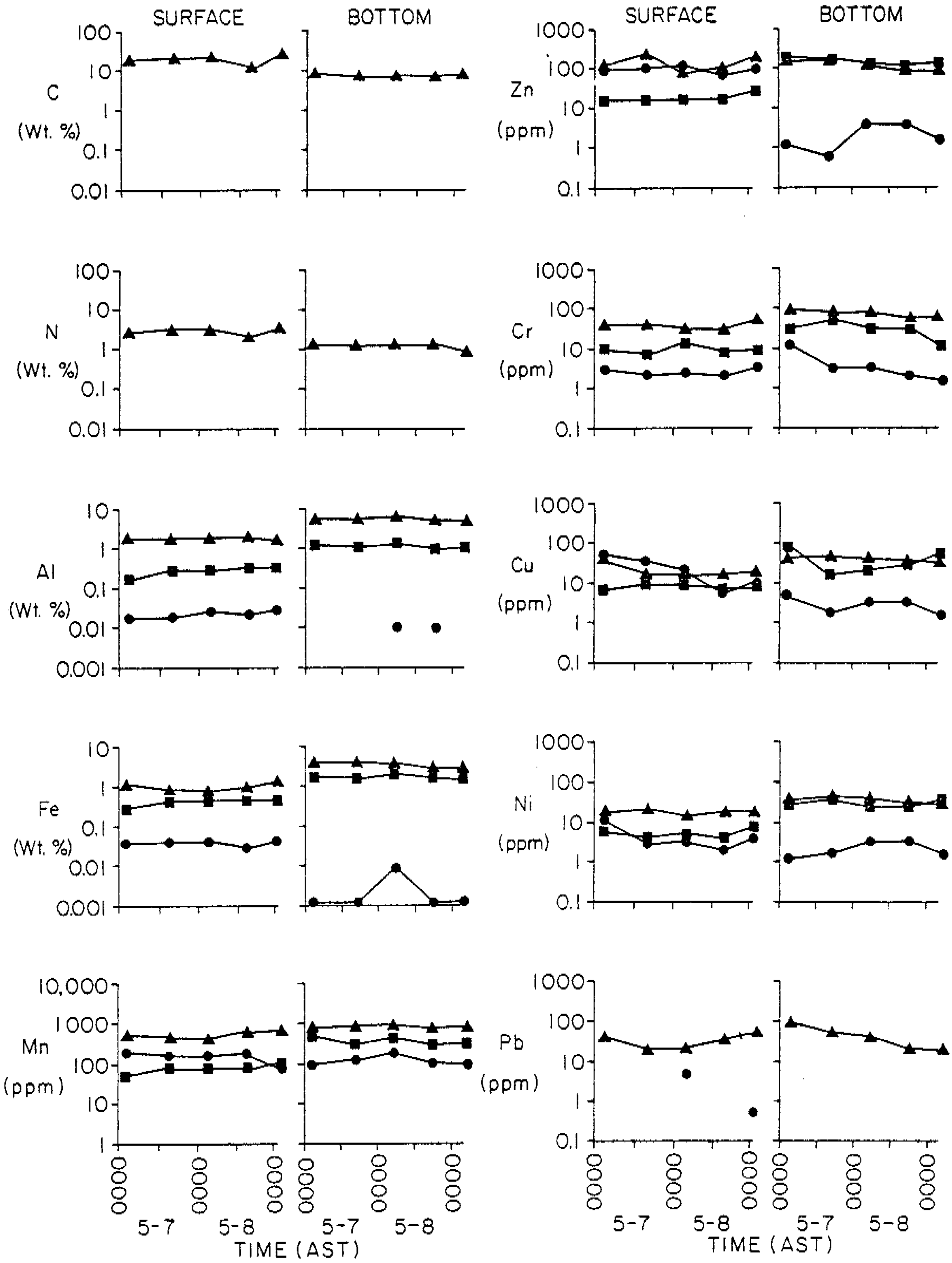

Figure 24. Temporal variations of major and trace elements in suspended matter (total concentration [▲], weak acid extractable [■], and peroxide extractable [●] from station CB-7 in lower Cook Inlet. Samples were collected 7-9 May 1978

Table 8. Trace metal associations for suspended particulate matter from Kachemak Bay and Kalgin Island region. Values are given as percent of total metal and are the average of time samples throughout the time series. Errors are ± 1 standard deviation.

	KACHEMAK BAY				KALGIN ISLAND REGION							
	CB-7 Surface		CB-7 Bottom		CB-9 Surface		CB-9 Bottom		CB-10 Surface		CB-10 Bottom	
	Peroxide Extractable	Weak Acid Extractable	Peroxide Extractable	Weak Acid Extractable	Peroxide Extractable	Weak Acid Extractable	Peroxide Extractable	Weak Acid Extractable	Peroxide Extractable	Weak Acid Extractable	Peroxide Extractable	Weak Acid Extractable
Al	1.0 ± 0.2	13 ± 12	.17* ± .04	22 ± 3	.07 ± .04	16 ± 2	.04 ± .01	15 ± 2	.02 ± .01	N.A.	.03 ± .02	N.A.
Fe	3.7 ± 1.0	42 ± 14	.08 ± .08	52 ± 9	.04 ± .02	47 ± 4	.04 ± .03	47 ± 7	.022 ± .004	N.A.	.05 ± .03	N.A.
Cr	6.4 ± 2.5	26 ± 9	6 ± 6	40 ± 18	0.46 ± .05	19 ± 2	0.5 ± 0.1	18 ± 4	0.51 ± 0.2	N.A.	0.6 ± 0.3	N.A.
Mn	32 ± 12	15 ± 3	14 ± 5	38 ± 11	0.5 ± 0.2	58 ± 14	0.5 ± 0.2	60 ± 6	0.7 ± 0.4	N.A.	1.0 ± 1.0	N.A.
Ni	29 ± 29	32 ± 10	6 ± 5	91 ± 24	1.0* ± 0.5	85 ± 20	N.D.	80 ± 6	N.D.	99 ± 22	0.9* ± 0.2	105 ± 37
Cu	108 ± 87	34 ± 9	8 ± 4	107 ± 69	1.7 ± 0.3	74 ± 7	1.4 ± 0.2	67 ± 18	1.1 ± 0.7	81 ± 24	1.0 ± 0.4	80 ± 24
Zn	66 ± 33	18 ± 9	2 ± 2	122 ± 45	N.D.	46 ± 6	N.D.	44 ± 6	N.D.	N.A.	N.D.	N.A.
Pb	5* ± 5	N.A.	N.D.	N.A.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.D. - Not detected (< .05% for Al, < 0.5% for Zn and Ni, and < 5% for Pb).
N.A. - Not available.
*Three of five samples had nondetectable values. The mean and error are for the two samples with detectable values.

phase in the Kachemak Bay samples, whereas organically bound trace elements comprise no more than 1.4% of the total metal content in suspended matter from the Kalgin Island region. Part of the explanation for this difference can be attributed to the enrichment of organic matter in the Kachemak Bay samples (i.e., 28-43% organic matter in suspended matter from Kachemak Bay versus 2% for suspended matter from the Kalgin Island region). This enrichment is due to the increased amount of organic productivity in Kachemak Bay (Larrance et al., 1977). However, this is not the only explanation as enrichment of trace elements in the marine organic matter relative to the terrestrial organic matter is also indicated.

In contrast to the enrichment of trace elements in organic phases in the Kachemak Bay samples, most trace elements in suspended matter from the Kalgin Island region are associated with the acid extractable fraction. This fraction contains from 46% to 99% of the total Cu, Ni, and Zn in the samples from CB-9 and CB-10. Since Fe and Mn are the major components in the acid extractant, these elements are probably associated with Fe-Mn oxyhydroxide coatings on the particles which are dissolved during the treatment process. This fraction of the suspended matter is less significant in the Kachemak Bay samples, as it contains only 18-34% of the total Cu, Ni, and Zn in the surface samples from Kachemak Bay (Table 8).

The significance of these results is evident when one considers recent studies on the availability of sediment bound trace elements to organisms. Luoma and Bryan (1978) studied the distribution of Pb and Fe in the soft tissues of the deposit feeding bivalve Scorbicularia plana and in the underlying sediments from 20 estuaries in southern and western England and northwest France. It was found that the Pb concentrations in the bivalves directly correlated with the Pb/Fe ratio in the sediment. The authors concluded that the iron concentration in the sediments was influencing the availability of Pb to the bivalves. To be more specific, they suggested that the availability of Pb to the bivalves may be a function of the partitioning of Pb between organically bound Pb and iron oxide-bound Pb in the sediments, with the organically bound Pb being more biologically available. Similarly, Eaganhouse and others (1976; 1978) found enrichments of Hg in tissues of the intertidal mussel *Mytilus californianus* in sediments that contained high concentrations of organically bound Hg. Here again, the implication is that organically bound trace elements are more available to organisms than trace elements that are bound to some other phase in the sediments. In lower Cook Inlet organically bound trace elements predominate only in Kachemak Bay where primary production is higher than any other region in the inlet. It is also the region where water circulation is the least dynamic. Therefore, it is possible to speculate that anthropogenic inputs of dissolved Cu, Ni, and Zn resulting from development activities would have a more profound impact on biological communities in Kachemak Bay than other regions in lower Cook Inlet because of their apparent incorporation into biologically available organic matter.

VIII. Conclusions

The most significant of the suspended matter programs in lower Cook Inlet are listed below.

1. The suspended matter distributions appear to follow the general pattern of circulation in lower Cook Inlet and Shelikof Strait. The inflowing relatively clear Gulf of Alaska water, which contains significant amounts of biogenic particles as well as aluminosilicate material from the Copper River, flows northward along the eastern coast until it reaches Cape Ninilchik, where it mixes with the outflowing turbid brackish water. The outflowing turbid water moves along the western side of the inlet past Augustine Island and Cape Douglas into

Shelikof Strait where it mixes with the oceanic water and is dispersed. Comparison of suspended matter and sediment characteristics as well as regional sedimentation rates indicates that net sedimentation of suspended matter in the central basin of lower Cook Inlet is minimal. However, net sedimentation is occurring in the embayments along the coast.

2. Chemical analyses of the suspended material from lower Cook Inlet reveal that aluminosilicate minerals from the coastal rivers comprise about 80-95% of the suspended matter, with biogenic matter making up the rest. Analysis of seasonal and regional variations of C:N ratios indicates that organic matter of marine origin predominates the eastern part of lower Cook Inlet throughout the year, whereas organic matter of terrestrial origin predominates the western part of the inlet during winter and early spring when primary production is at a minimum.

3. Comparisons of regional average concentrations of major and trace elements in the particulate matter indicate regional differences which can be related to differences in the average composition of source material and the relative amounts of biogenic and terrigenous components.

4. Studies of trace metal associations with particulate matter reveal that: (1) Mn, Cu, and Zn are enriched in the organic phase of suspended matter in surface waters of Kachemak Bay; and (2) the weak acid soluble phase contains about 46-99% of the total Cu, Ni, and Zn in the samples from the Kalgin Island region. These differences are attributed to differences in the sources for the particles, with primary production of biogenic particles predominant in Kachemak Bay and river discharge of terrestrial rock debris predominant in the Kalgin Island region.

IX. Suggested Future Studies

The results of the suspended matter distribution studies show that while concentration gradients for suspended matter in lower Cook Inlet are extremely high, little net sedimentation occurs in the central basin of lower Cook Inlet. Therefore, the embayments along the coasts of lower Cook Inlet and Shelikof Strait may be receiving most of the fine-grained particulate materials which are discharged from the coastal rivers. Since suspended particles from Cook Inlet have been shown to be efficient scavengers of crude oil (Feely et al., 1978) and because many of the living resources indigenous to lower Cook Inlet are suspension and detrital feeders, future studies should be devoted to determining the nature and extent of the sedimentation processes in the embayments along the coast.

X. Summary of Second Quarter Operations

A. Task Objectives

The primary objectives of the particulate matter program during the second quarter have been to complete the chemical analyses of the samples that were collected during the spring and fall cruises.

B. Laboratory Activities from 1 January to 1 April 1979

During the second quarter, most of our laboratory work has been concerned with chemical and gravimetric analyses of samples from the spring and summer cruises. We have completed all of the analyses and the data are presently being compiled according to the format designed by EDS and will be submitted to the project office by the end of the next quarter.

C. Laboratory Procedures

The laboratory methods are described in Section V of this report.

D. Sampling Protocol

The sampling methods are described in Section V of this report.

E. Data Analysis

The data from the summer cruises are being reduced and compiled according to the formats designed by EDS. These data will be submitted to the project office by the end of the next quarter.

F. Results

The results of our laboratory activities have been reported in Sections VI and VII of this report.

XI. Publications and Presentations

Following is a list of publications and presentations that have resulted from this research unit:

Feely, R. A., E. T. Baker, J. D. Schumacher, G. J. Massoth, and W. M. Landing (1979). Processes affecting the distribution and transport of suspended matter in the northeast Gulf of Alaska, Deep-Sea Res. (in press).

Feely, R. A., W. M. Landing, J. D. Schumacher, and J. S. Fisher (1978). Vertical transport of particulate matter in the coastal waters of the northeast Gulf of Alaska: A study using a newly designed self-closing sediment trap, submitted to Marine Geology.

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Annual Report

Distribution and Abundance of Low Molecular Weight Hydrocarbons and Suspended Hydrocarbons in Cook Inlet, Alaska

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1. GENERAL SUMMARY

1.1 Objectives

The low molecular weight hydrocarbon program was initiated on the OCS of Alaska in response to the environmental guidelines set forth in the Environmental Study Plan for the Gulf of Alaska, Southeastern Bering Sea, and the Beaufort Sea (January 1975). The purpose was to establish the spatial and temporal variations (seasonal and diurnal) in the dissolved hydrocarbon fraction composed of methane, ethane, ethene, propane, propene, isobutane, and n-butane. These data were collected in order to establish baseline levels of naturally occurring hydrocarbons in the lease areas prior to exploration, development, and production of fossil fuel reserves as these components have proven to be valuable indicators of petroleum input arising from drilling, production, and transportation of crude oil and refined products.

During the past two years, emphasis has shifted toward sources of LMW hydrocarbons in Cook Inlet, including both natural and anthropogenic sources. Special attention has been devoted to sources of LMW aromatics in upper Cook Inlet and the fate of these compounds. Specialized studies in Cook Inlet have continued on the air-sea exchange of LMWH and in-situ production of gases in both the water column and from the underlying sediments. These data provide necessary information for the identification and sources of petroleum-like hydrocarbons in the waters of Cook Inlet.

1.2 Implications to Oil and Gas Development

These studies were enacted to characterize the dissolved LMW natural hydrocarbons in Cook Inlet, Alaska. The purpose was to establish concentration levels and temporal and spatial variability of hydrocarbon components common to petroleum or natural gas resources prior to actual production. These measurements were felt to be an invaluable precursor to future monitoring efforts.

Examination of our data to date indicates that the LMWH will be excellent tracers of petroleum input in most of the OCS areas investigated. Although methane occurs ubiquitously over the shelf regions of Alaska in moderate concentrations, the concentrations of the C_2-C_4 hydrocarbons are everywhere low (except upper Cook Inlet), thereby increasing their effectiveness as tracers of crude oil. Of course, the value of these components as tracers will depend critically on the magnitude of the input, whether it is at depth or at the surface, and the prevailing hydrographic and meteorological conditions at the point of input. The extent to which microbial metabolism of the volatile hydrocarbon fractions is important is not clear.

Studies to date also have revealed useful compositional parameters for distinguishing hydrocarbon sources. The most valuable of these is the ethane: ethene and propane:propene ratio. The low abundance of the aliphatic unsaturates in crude oil coupled with low abundance of alkane associated with natural systems gives a clear unequivocal indicator of petrogenic input. These ratios have been effectively tested in both Cook Inlet and Norton Sound.

More recently our investigations in upper Cook Inlet have shown that LMW aromatics may be useful indicators of petroleum and refined products. These compounds are unique to crude oil and refined products, possess modest solubilities, and apparently are not produced by marine biological systems. Because of the low background levels found in pristine marine environments, these compounds should provide a sensitive and reliable measure of both chronic and massive spillage.

In view of the possible leakage of crude oil and refined products into the waters of Cook Inlet (source: MacArthur River oil field), we continue to investigate the associations between crude oil and suspended particles. The high concentrations of suspended matter in Cook Inlet provide an optimal setting in which to carry out such investigations. Using detailed chromatographic analyses of collected suspended matter, we hope to distinguish between natural and petroleum-like hydrocarbons, and to assess the significance of suspended particles in transporting adsorbed hydrocarbons. Field observations are being supplemented by simulated laboratory studies of the interactions between suspended particles and Cook Inlet crude oil.

2. INTRODUCTION

2.1 General Nature of Study

The development of petroleum resources in the Alaskan OCS may result in the release of toxic hydrocarbons to the marine environment with possible deleterious effects on the pelagic, benthic, and intertidal biota. Increases in the natural levels of petroleum-derived hydrocarbons are likely to occur from the normal activities associated with exploration, production, and transportation of crude and refined products within the region. Thus, it is of environmental significance that baseline levels of both naturally occurring and petroleum-derived hydrocarbons be established prior to the development of fossil fuel resources in the area, and that attention be focused in the sources and residence times of these components.

Petroleum contains three broad classes of hydrocarbons: paraffins, naphthenes, and aromatics, but few olefinic hydrocarbons. The proportions of each varies in petroleum, depending on the geologic and geographic sources, but on the average paraffins represent about 30% of the total (NAS, 1975). In contrast, many of the gas wells in Upper Cook Inlet are producing methane in excess of 98 mole percent (Kelly, 1968), the remainder being small quantities of ethane and propane.

It is presently believed that the most toxic fractions of crude oil are the low boiling point aliphatics and aromatics as well as the polynuclear aromatics (Blumer, 1971). Also associated with these complex fractions are the LMWH, in varying amounts. While these compounds are of lower toxicity than the aforementioned fractions (Sackett and Brooks, 1974), they are more soluble and, hence, are likely to be dispersed by normal mixing processes. Although the evaporation rates of the low molecular weight hydrocarbons appear to be quite rapid from a surface oil slick (McAuliffe, 1966), this does not preclude their incorporation in the water column from subsurface injection (e.g., ruptured pipeline) or from severe wave-induced turbulence.

The occurrence of light hydrocarbons in the water column may arise from both petroleum production activities and natural marine sources. Gaseous hydrocarbons may exchange across the sea surface in response to a concentration gradient (Broecker and Peng, 1974), diffuse from underlying sediments (Frank et al., 1970), escape in the form of bubbles from natural occurring gas and oil seeps (Link, 1952; Geyer and Sweet, 1973), or be produced by in situ biological processes (Lamontagne et al., 1973).

Methane (CH_4) is a significant component of natural gas and is also produced in anoxic sediments by bacterial CO_2 reduction and fermentation reactions (Claypool, 1974). Thus, the presence of excess methane in the water column overlying organic-rich sediments is not an unequivocal indicator of a petroleum source, unless viewed jointly with the distribution of the heavier fractions, C_2-C_4 (Brooks and Sackett, 1973).

Above saturation values of methane, ethylene, and propylene also have been observed in the surface layers of open ocean and are believed to be related to biological activity or photochemical reactions involving organic matter (Swinnerton and Lamontagne, 1974; Lamontagne et al., 1973).

2.2 Objectives

The objectives of this study are twofold. They include an expanded assessment of the validity of LMWH (aliphatics and aromatics) to detect low level input of petroleum-related hydrocarbons and the evaluation of the significance of suspended matter in the transport of petroleum through The Forelands.

2.2.1 Low Molecular Weight Hydrocarbons

During the last year, detailed hydrographic studies were conducted north of Kalgin Island into Trading Bay for the purpose of delineating the composition and concentration of dissolved LMW aliphatics and aromatics. These compositions will be related to the constituents of petroleum crude presently being produced from the region.

In a continuing effort to refine our knowledge concerning the utility of the LMWH as an early warning system for the introduction of petroleum hydrocarbons, a detailed study of the relationships between the occurrence of LMWH and primary production was initiated in Kachemak Bay. This study focuses on various alkane/alkene ratios and attempts to correlate our findings with primary production, incident light levels, chlorophyll, hydrographic parameters, and wind speed. This last factor is important because the hydrocarbons of interest are gaseous and readily transported across the air-sea boundary. This particular study will be supported by a systematic analysis of interstitial waters for the LMWH with the aim of identifying compositional relationships prevalent in the near surface sediments. In shallow, highly productive areas (e.g, Kachemak Bay), the production of hydrocarbons from the bottom may represent a significant local source.

2.2.2 Suspended Sediment - Oil Transport Studies

The objectives of this work element are to assess the significance of suspended sediments in the transport of oil through The Forelands and to evaluate the composition of agglutinated hydrocarbons. In an ancillary study, an effort is being made to identify the nature and amount of petroleum-related hydrocarbons transported vertically via suspended matter. These estimates will be constructed from a hydrocarbon analysis of suspended matter collected in sediment traps placed in an east-west array between Kachemak and Kamishak

Bays. An attempt will be made to correlate the composition of petroleum hydrocarbons retrieved from the sediment traps with the probable source area to the north.

2.3 Relevance to OCSEAP

The principal concern surrounding the distributions, sources, and sinks of LMWH is not their direct impact on biota, but rather their role as tracers of more toxic hydrocarbon fractions commonly found in crude oils. Of particular value is the use of LMWH to identify probable trajectories of the toxic dissolved fractions (e.g., PAH) during a spill, well blowout, or pipeline rupture. Because some of the hydrocarbons common to petroleum are also produced by marine organisms, it becomes necessary to evaluate the normal background levels of hydrocarbons before an accurate assessment of anthropogenic input can be made.

Accidental introduction of crude oil onto the surface of the ocean can be readily traced by a variety of visual techniques (e.g., remote sensing). However, the dispersion of soluble hydrocarbon fractions cannot be so easily traced, except with the expenditure of considerable time in sampling and laboratory analysis. In all likelihood, the results would not be available for days, or possibly weeks. The LMWH becomes valuable short-term tracers of the dissolved hydrocarbon fraction because of their relatively high concentration in crude oils, ease of analysis, and low natural background levels in marine waters.

The principal goal is to provide the criteria for an early warning detection of petroleum-derived hydrocarbons and to establish the feasibility of using light hydrocarbons as tracers, particularly in reference to near-bottom mixing and resuspension processes.

3. Current State of Knowledge

3.1 Low Molecular Weight Hydrocarbons - Cook Inlet

Observations into the distributions and abundances of the low molecular weight aliphatic hydrocarbons in numerous lease areas of Alaska have been carried out over the past three years. These studies have shown that, under certain constraints, the abundances of the higher homologs of methane, together with the alkane/alkene ratio, serve as an operational indicator of the presence of petroleum-derived hydrocarbons. This was shown to be the case in Norton Sound with the discovery of a submarine gas seep (Cline and Holmes, 1977) and more recently in Cook Inlet.

Recent surveys of LMWH in the region just north of The Forelands documented the occurrence of unusually high concentrations of ethane, propane, and butanes, not accompanied by a similar increase in the low molecular weight alkenes. The source of these hydrocarbons is in the MacArthur River oil field located in Trading Bay. In a survey of dissolved LMWH conducted in 1968, elevated concentrations of methane were observed in the region between The Forelands and just to the north in Trading Bay (Kinney et al., 1970). Unfortunately, analytical difficulties precluded the analysis of the higher homologs of methane.

The source of these gaseous hydrocarbons may include subsurface seepage from structural faults or leakage from production platforms. The earlier measurements of Kinney et al. (1970) and those of ours in May and September of this year suggest that the source is chronic in nature. Moreover, heavier fractions of petroleum may be associated with the gas, since the MacArthur field produces mostly petroleum (API 33) with the dry gas component being used to run machinery associated with the liquid extraction plant (Blasko, 1974).

The occurrence of the LMW alkanes was largely confined to the region between Trading Bay and Kalgin Island. It is assumed that strong tidallyinduced vertical and horizontal mixing results in rapid dilution and volatilization of these components. The lower inlet, in contrast to the area above The Forelands, reflects a strong seasonal biological component of LMWH (Cline, 1977). Lower Cook Inlet, in particular the region near Kamishak and Kachemak Bays, reveals elevated concentrations of ethene and propene during summer, which is presumably related to primary productivity, either directly or indirectly, or to possible photochemical effects (Wilson et al., 1970). Our work has shown that under normal conditions the ethane/ethene ratio rarely exceeds 0.5 in most shelf areas and is most nearly 0.1-0.2 for Cook Inlet during summer. There is a concomitant rise in the concentration of ethane that accompanies increases in ethene, but the $C_{2:0}/C_{2:1}$ ratio rarely exceeds 0.5. How these two C_2 aliphatics are related is not clearly understood, but that relationship has direct bearing on the utility of the LMW aliphatics for the detection and discrimination of petroleum-induced hydrocarbons, whether it be in Cook Inlet or elsewhere in Alaskan shelf waters.

This year's study focused on the occurrence of LMW aromatics (e.g., benzene, C_1-benzenes, etc.), since their occurrence above background would provide the highest order of distinguishability for the presence of petroleum hydrocarbons. Preliminary data taken in May of this year indicate a significant accumulation of LMW aromatics north of The Forelands, particularly on the western side of the Inlet, where excess concentrations of ethane and propane were also found. Although not quantifiable, the predominantly identified aromatic compounds were benzene, toluene, and xylenes. Compounds of lower boiling point than benzene were also apparent, presumably hexanes and cycloparaffins. By way of contrast, station CB-5, located just east of Kamishak Bay, was largely devoid of LMW aromatics, except a component with retention indices similar to that of toluene. This component was not present in the blanks, thus it appears to represent a natural background constituent.

3.2 Oil-Suspended Solid Agglutinization Studies

Oil spilled onto the surface of the ocean is acted upon by several physical processes, including evaporation, solution, emulsification, and injection into the atmosphere (Kreider, 1971; McAuliffe, 1966, 1969; Baier, 1970). With respect to the oceanic environment, only the solution and emulsification processes represent important mechanisms by which spilled oil becomes entrained in the water column, thus increasing its potential for impacting marine organisms.

Since crude oil is sparingly soluble in seawater, it tends to form emulsions when introduced into seawater, especially under intense wave action. The emulsions have a high affinity for particles and tend to be adsorbed rapidly. Recent studies of oil spills in coastal waters containing high suspended loads have indicated rapid dispersal and removal of the oil by adsorption onto suspended matter (Forrester, 1971; Farrington and Quinn, 1973).

There is very little published information about the processes by which oil is transported in association with suspended particles or the quantities of oil that can be adsorbed onto the particles. Early investigators have shown that flocculation of oil bears an inverse relationship to salinity (Chipman and Galtsoff, 1949; Hartung and Klinger, 1968). Later investigations suggest that sedimentation of oil may involve a two-step process (Bassin and Ichiye, 1977; Huang and Elliott, 1977). This process begins with the adsorption of oil onto the suspended particles and is followed by the flocculation of these oil-sediment emulsions by electrostatic interactions. The amount of oil that can be accommodated by a specific quantity of suspended matter appears to be dependent upon the physical and chemical nature of the suspended particles as well as the amount of naturally occurring organic matter that is associated with the particles (Poirier and Thiel, 1941; Meyers and Quinn, 1973).

Cook Inlet has a history of chronic exposure to crude oil arising from both production and transfer operations. Preliminary estimates place the input in the range of 9,500-17,500 bbl/yr (Kinney et al., 1970), mostly above The Forelands, where suspended matter concentrations generally exceed 100 mg/l (Feely and Cline, 1977). While our measurements in the laboratory suggest that these sediments have a modest capacity to retain oil, the measurements by Kinney et al. (1970) and Shaw (1977) show no significant increases in the levels of hydrocarbons in the water or associated with suspended sediments north of The Forelands. In the former case, the sample volumes were 4 l; in the latter, the volume was 1 l. While these results show no gross pollution of either the waters or the suspended matter, the sample volume may have been too small to detect incipient contamination of suspended matter with crude oil. More refined techniques are required to assess the importance of suspended matter in the transport of oil in Cook Inlet, particularly in view of the high transport rates of water and associated suspended matter.

During the past two years, our efforts (R.U. #152) have been directed toward defining the load capacity of Cook Inlet suspended solids for Cook Inlet crude oil as a function of sediment/oil ratios and temperature. These results show that Cook Inlet sediments have a modest affinity for crude oil (up to 20% of the sediment weight). Initial condition reaction studies reveal that the adsorption phenomenon is rapid, largely completed in less than one hour. No fractionation of the normal alkanes ($> C_{12}$) was apparent during the course of the reaction (i.e., 48 hrs).

4. Study Area

Cook Inlet is a relatively shallow, elongated embayment extending approximately 300 km in a north south direction. The lower inlet is delineated by The Forelands in the north and by Stevenson and Kennedy Entrances on the south. Mean depth of the lower inlet is approximately 60 m (Muench et al., 1978). Significant geographic features within the inlet include Kamishak Bay and Kachemak Bay, Augustine Island, an active volcano, and Kalgin Island located at the northern end.

Water from the Gulf of Alaska enters Cook Inlet primarily through Kennedy Entrance, traverses the lower inlet cyclonically, generally following the bathymetric contours, and returns to the Gulf via Shelikof Strait (Muench et al., 1978). Freshwater, introduced primarily during summer from the upper inlet, passes just to the east of Kalgin Island and moves down the western side of the inlet in general agreement with the conditions of estuarine flow. During the southward movement, salinity steadily increases in the outflowing water due to lateral entrainment and mixing (Muench et al., 1978). Because of intense tidal mixing, vertical stratification is limited to the lower inlet, primarily during the summer season. Additional information concerning hydrography and circulation processes can be found in the work of Muench et al. (1978).

During the past year, two cruises have been conducted in Cook Inlet. The first was in May 1978, the last in August-September 1978 (Cline and Feely, 1978). Sampling locations are shown in Figures 4-1 and 4-2. In May, all the stations shown in Figure 4-1 were occupied. Because of unavoidable delays, the cruise in August-September was shortened, resulting in time series stations CB-7 and CB-9 being dropped. The time series station at CB-10 was moved due west to a point along the 10 fathom isobath of Kalgin Island. The

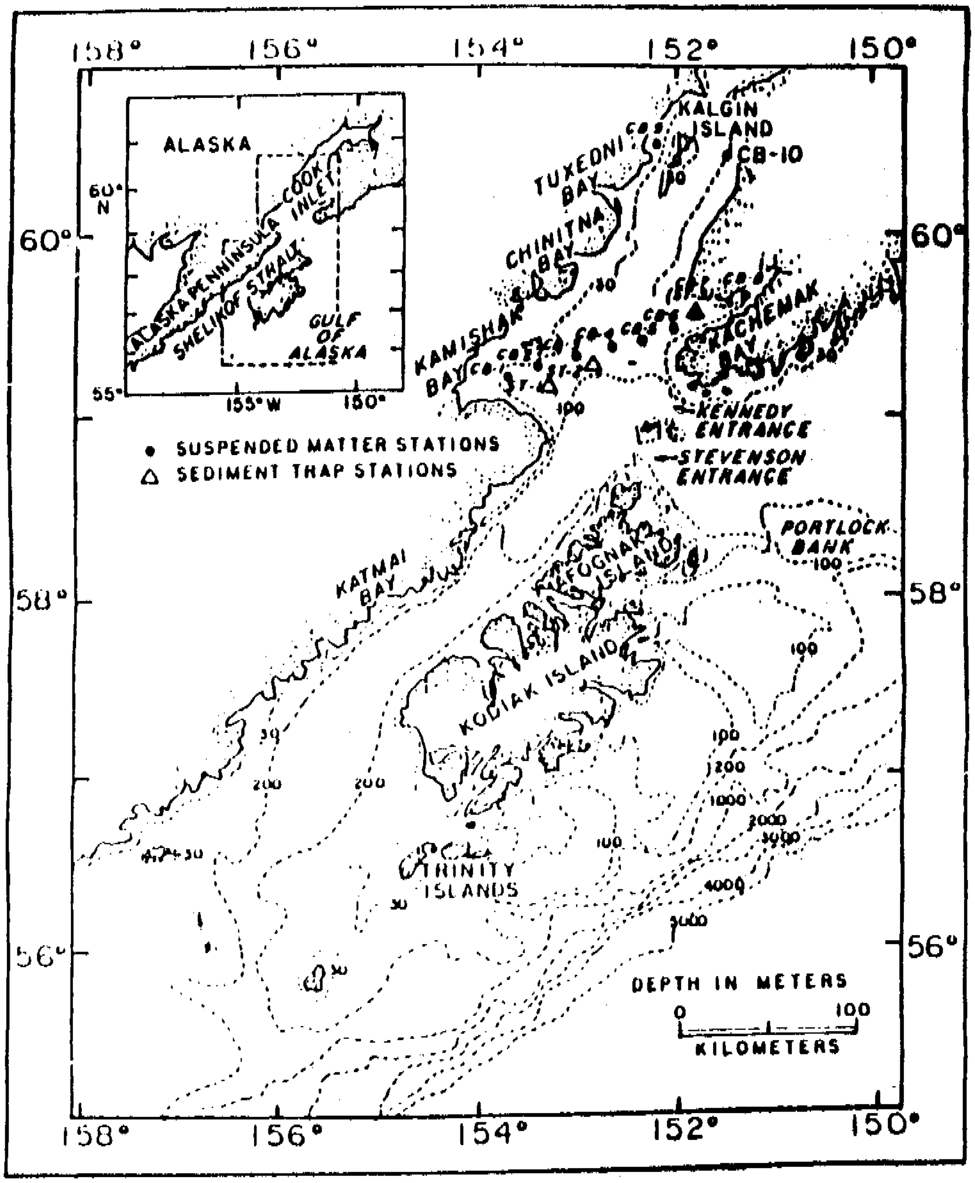

Figure 4-1. Location of stations occupied in Lower Cook Inlet during May and August-September 1978. Station CB-10 was moved due west to the 10 fathom isobath on Kalgin in August-September.

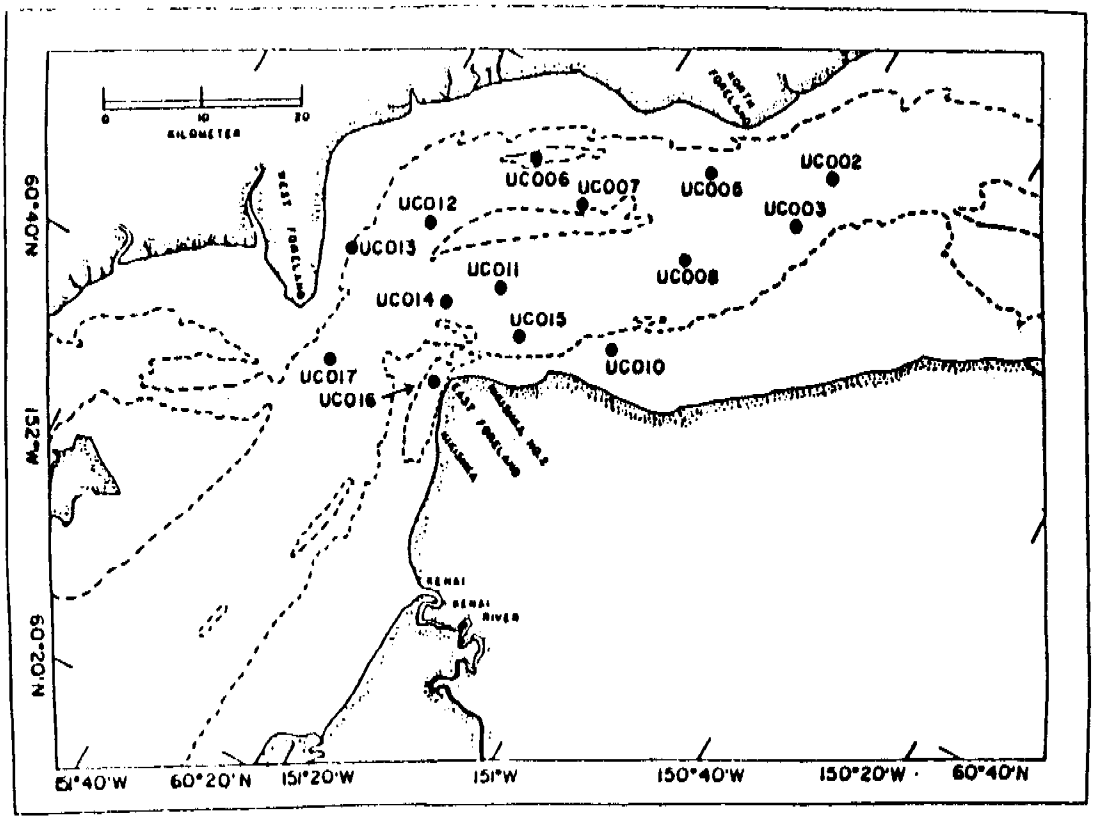

Figure 4-2. Location of stations occupied in May and August-September 1978 in upper Cook Inlet.

change in the location of CB-10 was necessary in order that the principle advective flow from the upper Cook Inlet could be representatively sampled.

The sampling protocol in the upper inlet (Figure 4-2) was nearly the same in August-September as it was in May, although the stations were moved slightly to provide better source and trajectory information. In the result section, the actual station locations for each cruise will be shown.

5. Methodology

5.1 Low Molecular Weight Aliphatics

LMWHs are stripped from a 1-l volume of seawater using a modified procedure recommended by Swinnerton and Linnenbom (1967). A schematic diagram of the method is shown in Figure 5.1.

Chromatography of the components is effected on a column of activated alumina (4' x 3/16"), 60-80 mesh, in series with a small column of activated alumina (3/16" x 2") impregnated with 1% silver nitrate by weight. This dual column configuration results in sharper peaks, better separation of olefins, and reduced component retention times. Chromatography of LMWH components through C_4 is accomplished in less than 6 minutes. Detection of the component hydrocarbons is performed with a flame ionization detector.

5.2 Low Molecular Weight Aromatics

Aromatics were stripped from solution in an analogous fashion (T = 40°C) and trapped on Tenax GC^R, which does not retain water. The adsorbed aromatics were backflushed off the Tenax column at 200°C and chromatographed on a column of Chromosorb 102 (6' x 1/8" i.d.). In May the separations of LMW aromatics was attempted on 5% SP-1200/1.75% Bentone 34 on 100/120 mesh Supelcoport. This particular support did not effectively separate the LMW aromatics from the heavier alkanes (C_6+), thus the Chromosorb 102 column was used this summer.

5.3 Analysis of Heavy Hydrocarbons Adsorbed to Suspended Matter

Suspended matter collected in sediment traps and by continuous flow centrifugation was analyzed according to the procedures established by MacLeod et al. (1976). Briefly, an appropriate weight of sediment (1-10 g) is dewatered with methanol, then extracted with a methylene chloride/methanol mixture for 18-24 hours in a ball mill tumbler. The extraction is repeated and the washings and extracts combined. Additional dewatering is accomplished and removal of

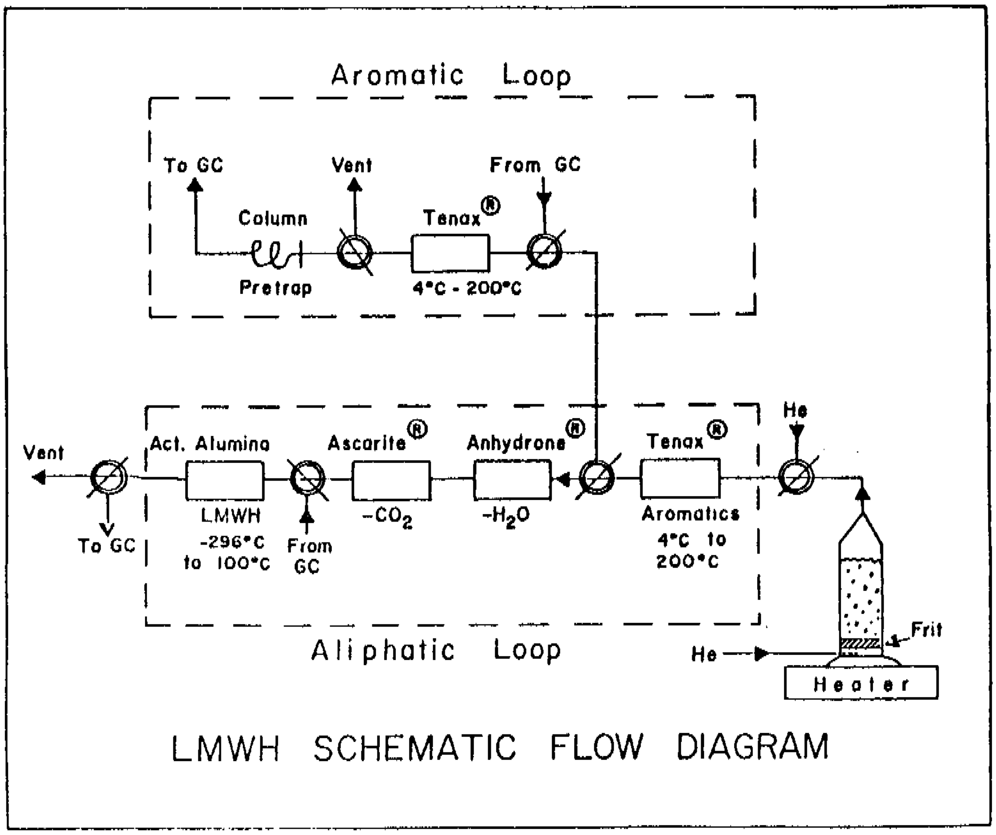

Figure 5.1. Flow diagram of the low molecular weight analyses. The procedure shown here was modified in that separate samples are taken for aliphatics and aromatics.

particulates and humic material is effected by passing the extracts through a small bed of silica gel and washing with methlene chloride. The eluate is concentrated to approximately 2 ml. At this point the sample is chromatographed on silica gel to separate the aliphatic and aromatic fractions; sulfur is removed from each fraction. After concentration of each fraction to approximately 0.2 ml, the two samples are ready for GC and/or GC-MS analyses.

6. Results

6.1 Kamishak-Kachemak Bay Transects

During the observational period covered by this report, the vertical distributions of dissolved LMW aliphatics were determined along the transect CB-1 through CB-8 (Figure 4-1). The purpose of these measurements was to provide zonal data for the computation of hydrocarbon fluxes. Several of the stations along the transect were also selected for reference purposes. Analysis of these waters for dissolved aromatics provides necessary comparative data for the results obtained in upper Cook Inlet.

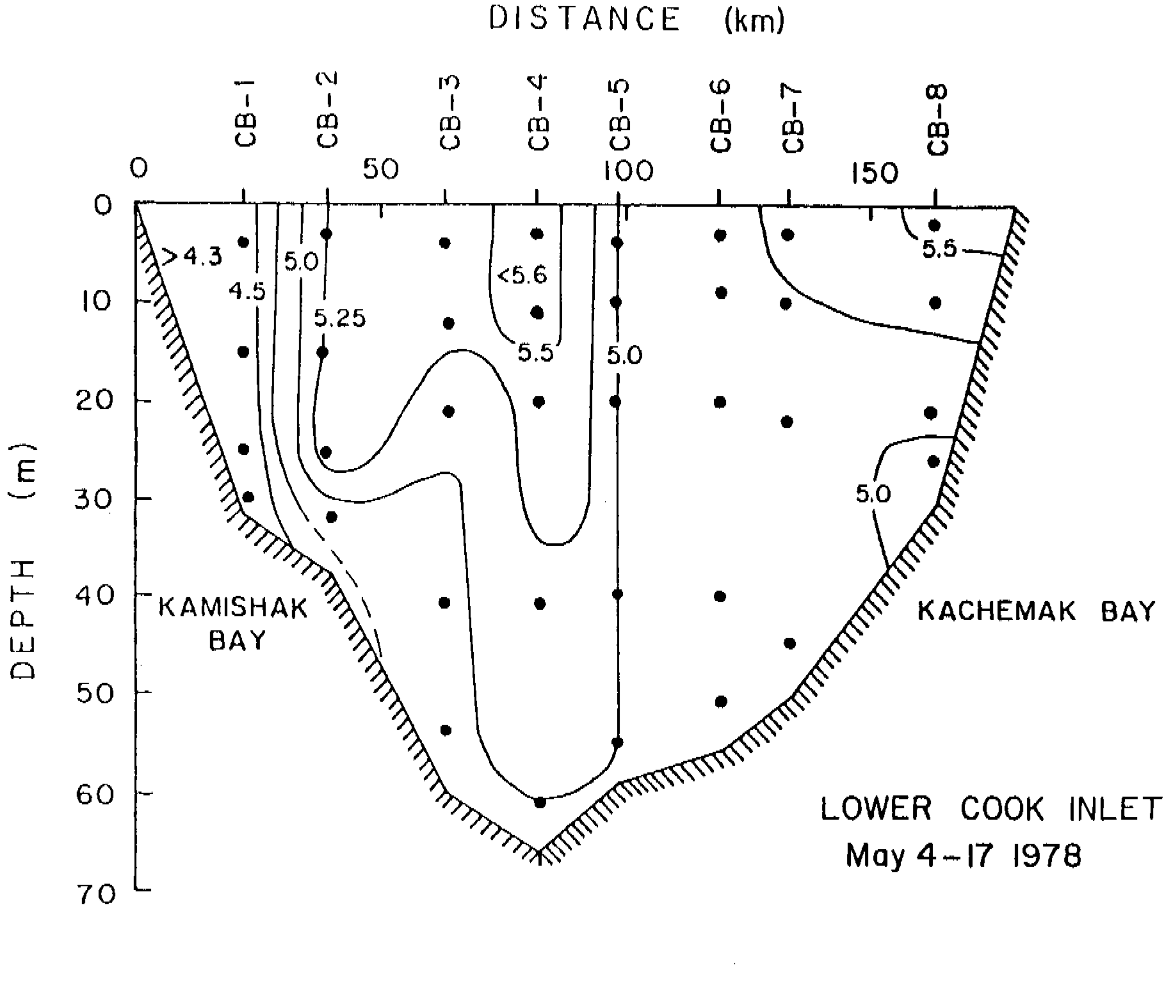

Figure 6-1. Vertical distribution of temperature along a transect between Kamishak and Kachemak Bays in May 1978.

6.1.1 Transect - May 1978

Cook Inlet is a partially mixed estuary, which during May was laterally inhomogeneous and vertically unstratified. These features, which are characteristic of a wide, tidally-mixed estuary, are reflected in Figures 6-1 and 6-2. The sectional temperature distribution shows relatively cold water in Kamishak Bay with some local warming of the surface waters in Kachemak Bay. The temperature of the incoming seawater was presumably near 5°C. Lateral

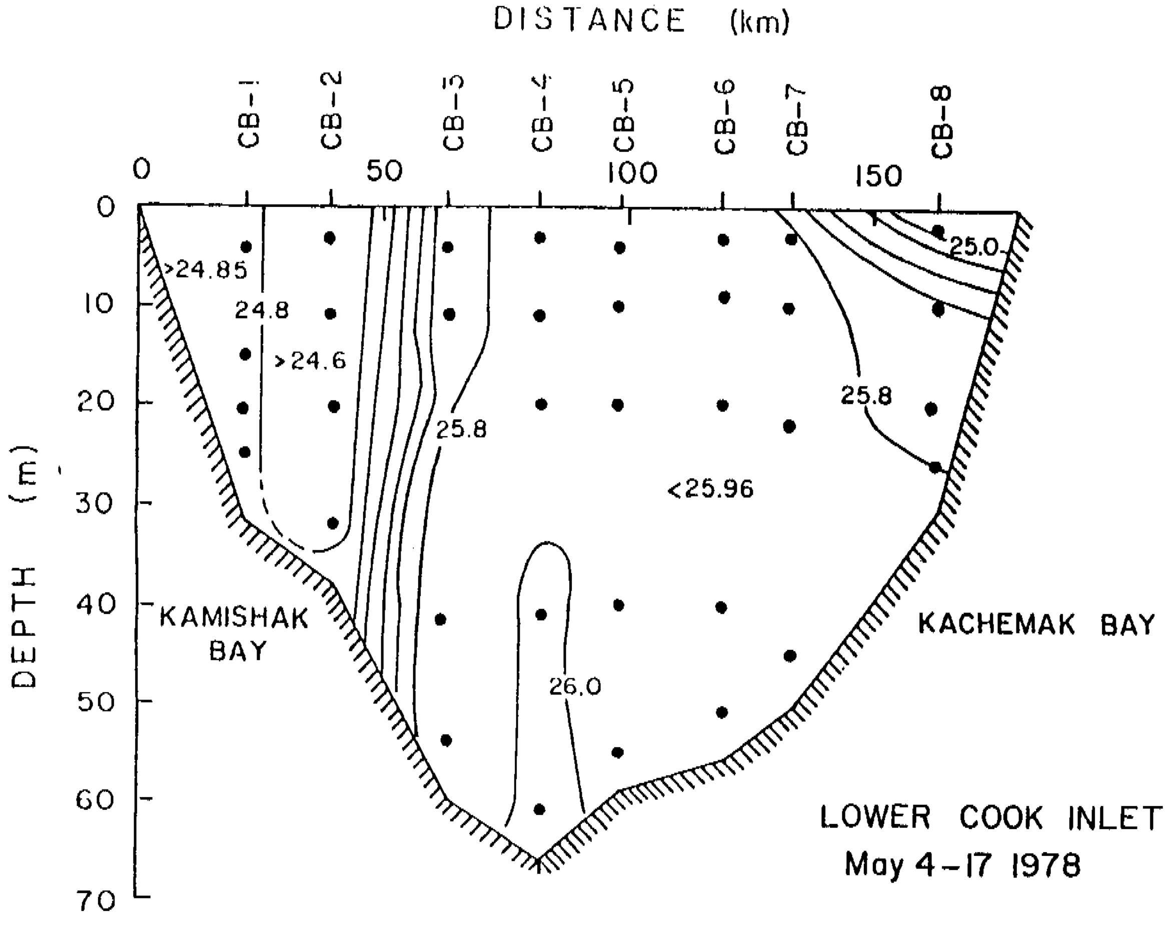

Figure 6-2. Vertical distribution of density (σ_t) along the transect between Kamishak and Kachemak Bays in May 1978.

inhomogeneity is evident in Figure 6-2, where, with the exception of Kachemak Bay, the isopycnals are vertical. At the time of the measurements, stratification was developing in Coal Bay (sta. CB-8) due to solar insolation and/or local runoff.

The distribution of dissolved methane is analogous to that of density (Figure 6-3), although input of methane is apparent in both Kamishak and Kachemak Bays. The largest concentration of methane observed was near the bottom at CB-8, where more than 1500 nl/l (STP) was present. Although significant production was obvious at CB-7, the major contribution of methane appears

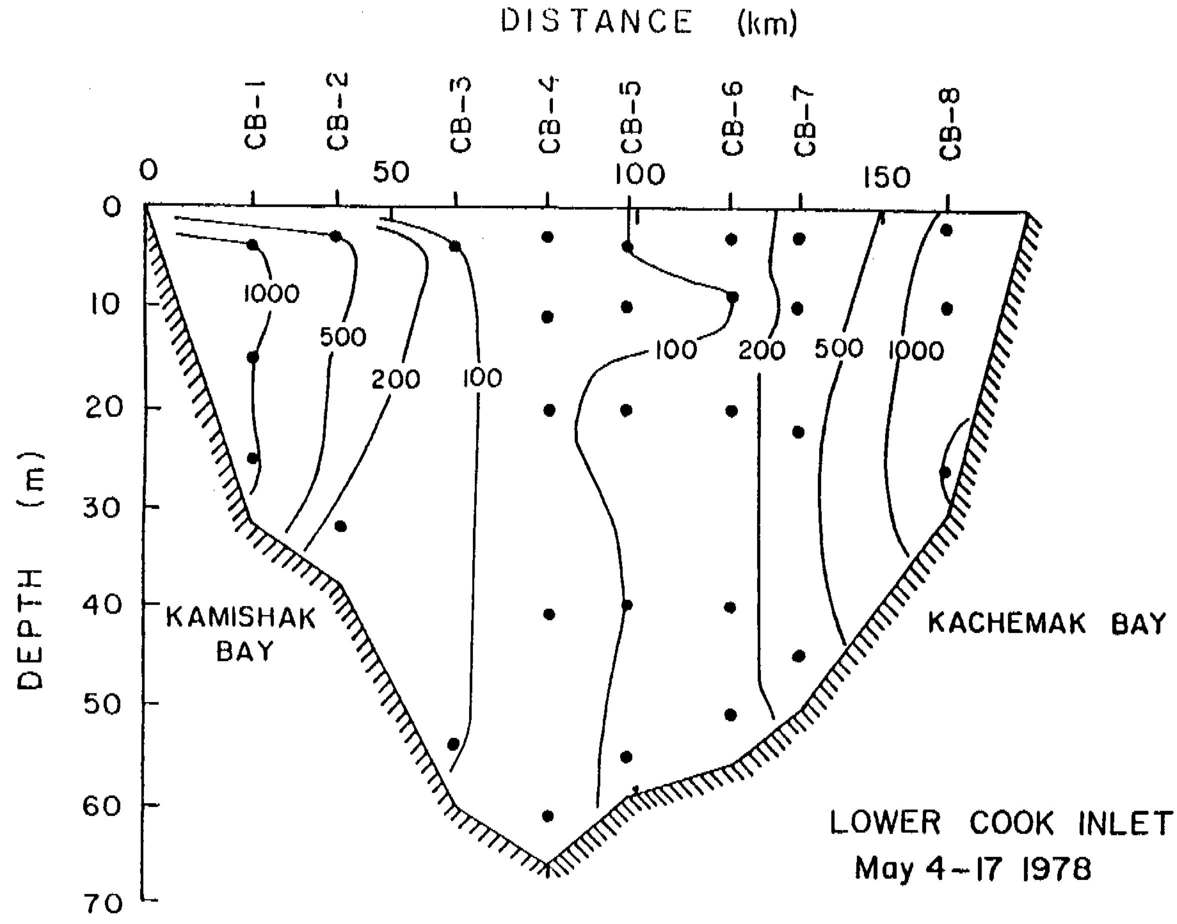

Figure 6-3. Vertical distribution of dissolved methane (nl/l, STP) along the transect between Kamishak and Kachemak Bays in May 1978.

to be from the organic-rich bottom sediments found in the area. A similar situation exists in Kamishak Bay, where concentrations of methane exceeding 1000 nl/l (STP) were encountered. Incoming seawater through Kennedy Entrance was characterized by concentrations of methane near 100 nl/l (Figure 6-3).

The vertical distribution of dissolved ethane is revealed in Figure 6.4. In general, the concentration of ethane was less than 1 nl/l, with the exception of a single sample in Kamishak Bay (C_2H_6 = 1.7 nl/l). Under normal circumstances little attention would be given to a single value, but this particular area has shown an anomalous hydrocarbon composition on a previous

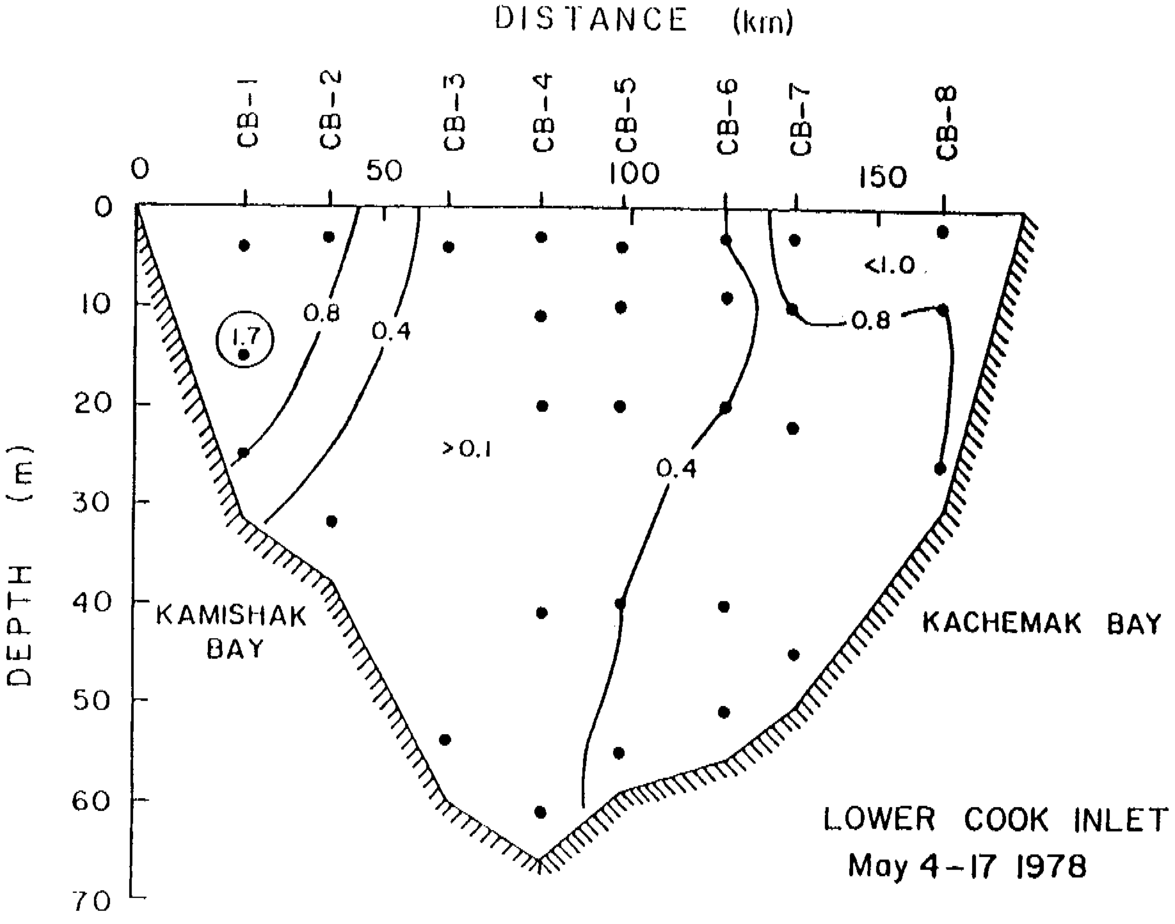

Figure 6-4. Vertical distribution of dissolved ethane (nl/l, STP) along a transect between Kamishak and Kachemak Bays in May 1978.

visit (Cline, 1977). The alleged petroleum seeps near Cape Douglas represent a possible source for ethane, but our measurements are inconclusive at this point. If there is a submarine seep in this area, its gas production is probably low. The high concentrations of ethane observed in Kachemak Bay are correlated with elevated levels of ethene (Cline and Feely, 1978). Both these gases are biogenic and/or photochemical in origin.

In Figure 6-5 is shown the biogenic C_2 index ratio ($C'_{2:0}/C_{2:1}$) for the transect. With the exception of the single sample in Kamishak Bay, the values

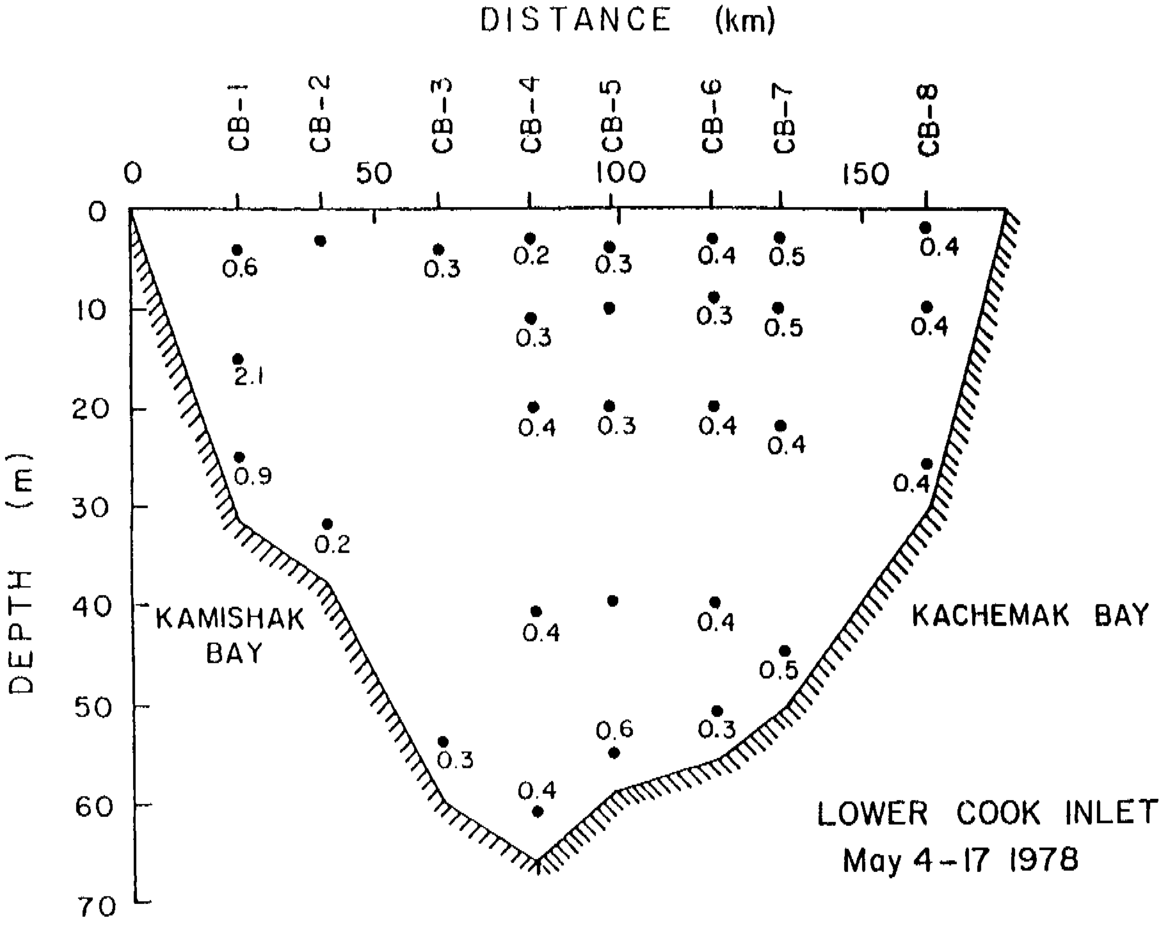

Figure 6-5. Biological index ratio ($C_{2:0}/C_{2:1}$) along the transect between Kamishak and Kachemak Bays in May 1978.

cluster around 0.4 ± 0.1, indicating that the proportions of ethene to ethane represent a biological source. Ratios greater than 1 for concentrations of ethane and ethene > 1 nl/l signify a thermogenic source or He gases originating from anoxic sediments. The above ratio presumably does not hold in anoxic waters (Hunt, 1972), where saturated hydrocarbons are more prevalent.

6.1.2 Transect - August-September 1978

In late summer, hydrographic conditions had changed substantially from that observed during the previous spring. Water was uniformally warmer with little lateral or vertical structure (Figure 6-6). Temperatures less than 10°C

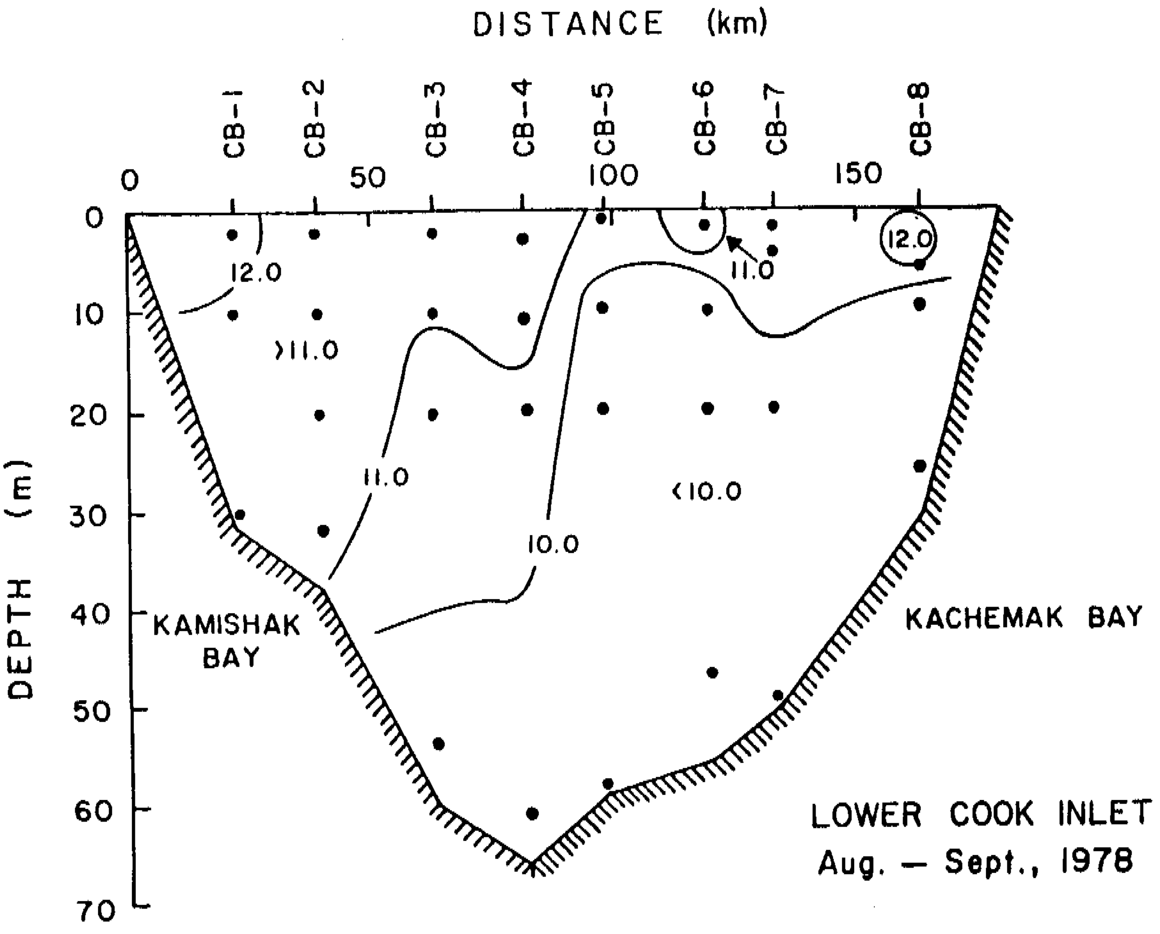

Figure 6-6. Vertical distribution of temperature along the transect between Kamishak and Kachemak Bays in Aug.-Sept. 1978.

were found along the eastern side of the inlet and correlated with salinities greater than 31 $^{o}/oo$. As observed earlier, the warmest temperatures were found in Kamishak and Kachemak Bays. Density surfaces are shown in Figure 6-7. As usual, little stratification was observed along the west side near Kamishak Bay with weak vertical stratification in Kachemak Bay.

The lateral distribution of methane is shown in Figure 6-8. The most obvious feature is the strong lateral gradient across the inlet between Kachemak Bay and Kamishak Bay. Concentrations in excess of 3,000 nl/l were observed in Kachemak Bay, decreasing to values less than 200 nl/l near CB-5.

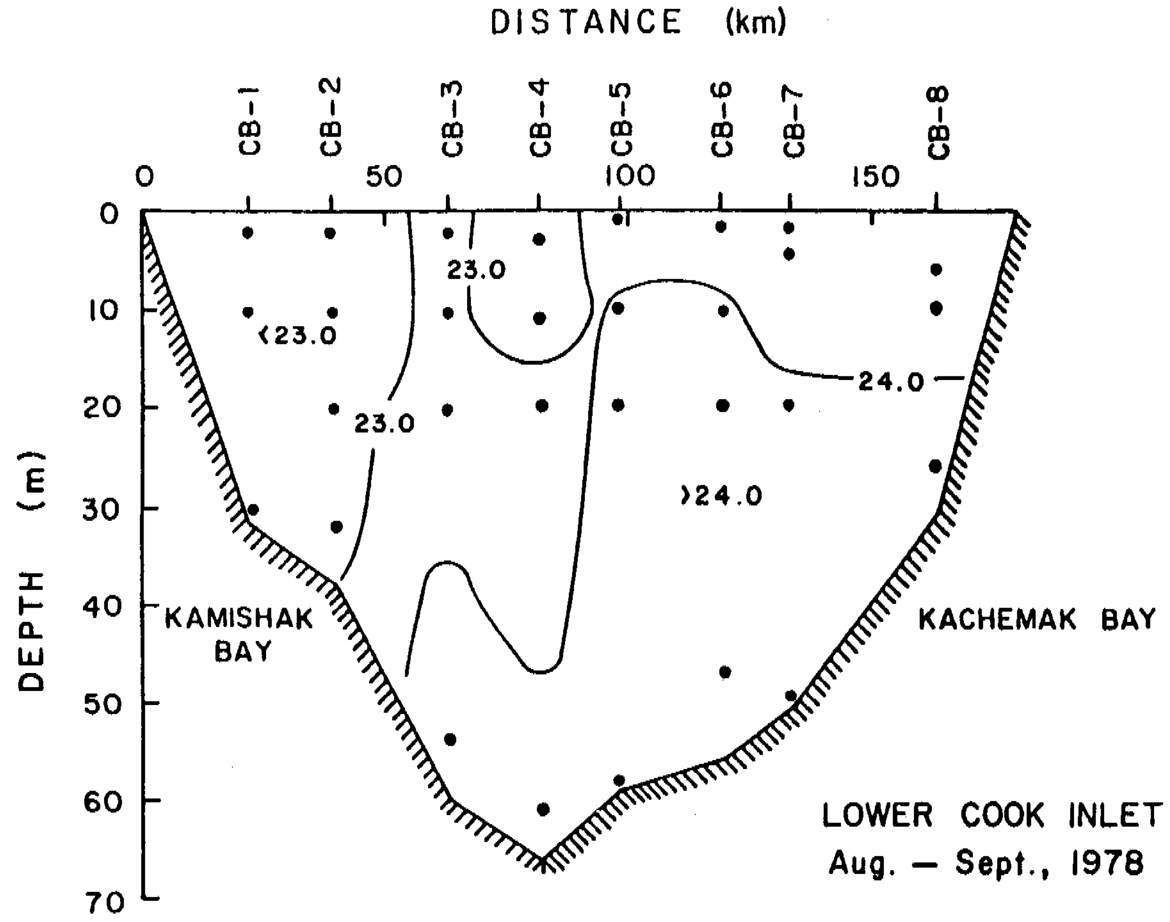

Figure 6-7. Vertical distribution of density (σ_t) along a transect between Kamishak and Kachemak Bays in August-September 1978.

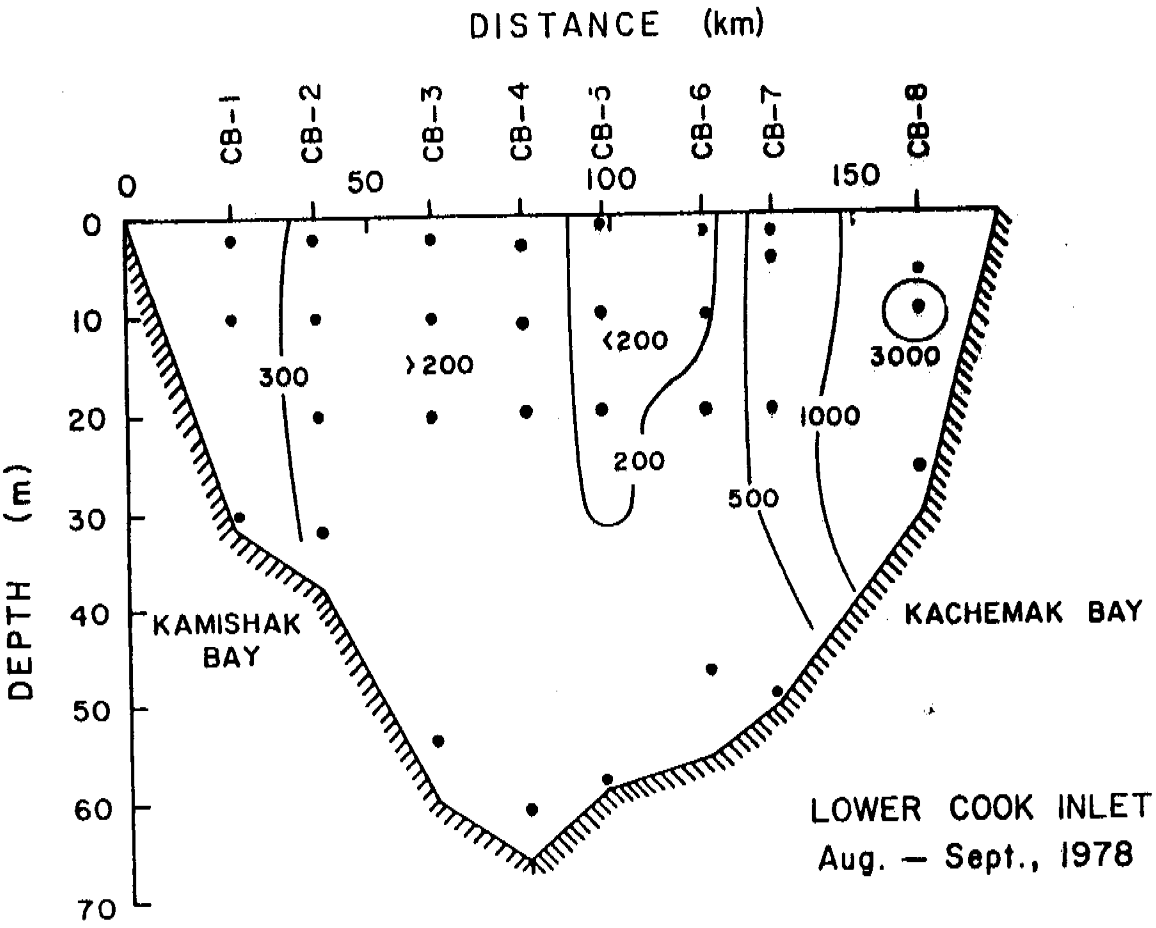

Figure 6-8. Vertical distribution of dissolved methane (nl/l, STP) along a transect between Kamishak and Kachemak Bays in August-September 1978.

The source of dissolved methane in Kachemak Bay is either the organic-rich sediments or water column production (Scranton and Farrington, 1977). In either case, it is most certainly of biological origin. The core of low methane water near CB-5 delineates the trajectory of incoming seawater, since we have already shown that Gulf of Alaska surface waters are generally characterized by concentrations of methane less than 200 nl/l (Cline and Feely, 1978). Interestingly enough, neither salinity nor temperature shows the trajectory of incoming water as clearly as does methane.

The distribution of ethene (nl/l, STP) is shown in Figure 6-9. Again, elevated concentrations are found in Kachemak Bay, the maximum values observed were in excess of 4 nl/l. Compared to observations taken in May 1978, these concentrations are approximately a factor of two higher and reflect either greater biological productivity or higher incident light levels. Since primary production was lower in August relative to May, we suspect that light may be the important factor.

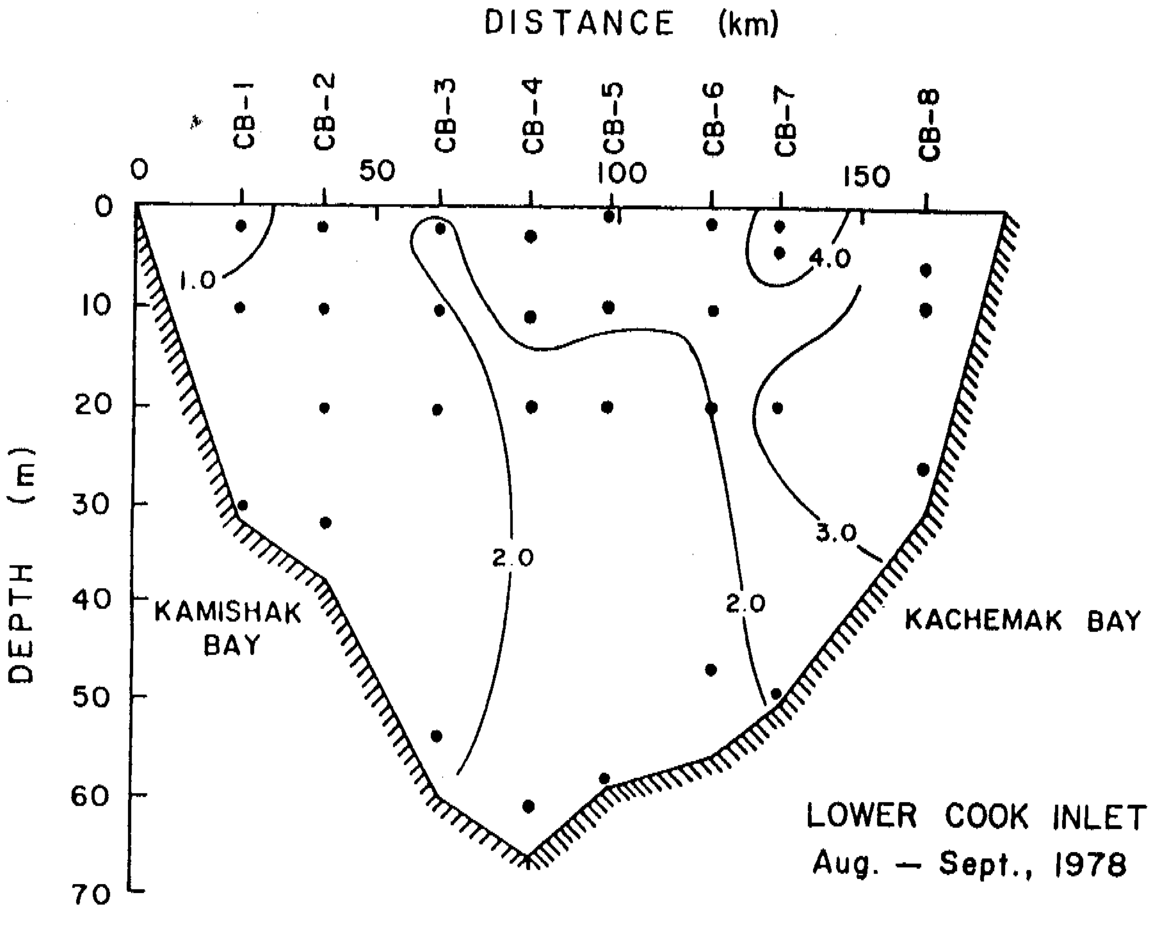

Figure 6-9. Vertical distribution of ethene (nl/l, STP) along the transect between Kamishak and Kachemak Bays in August-September 1978.

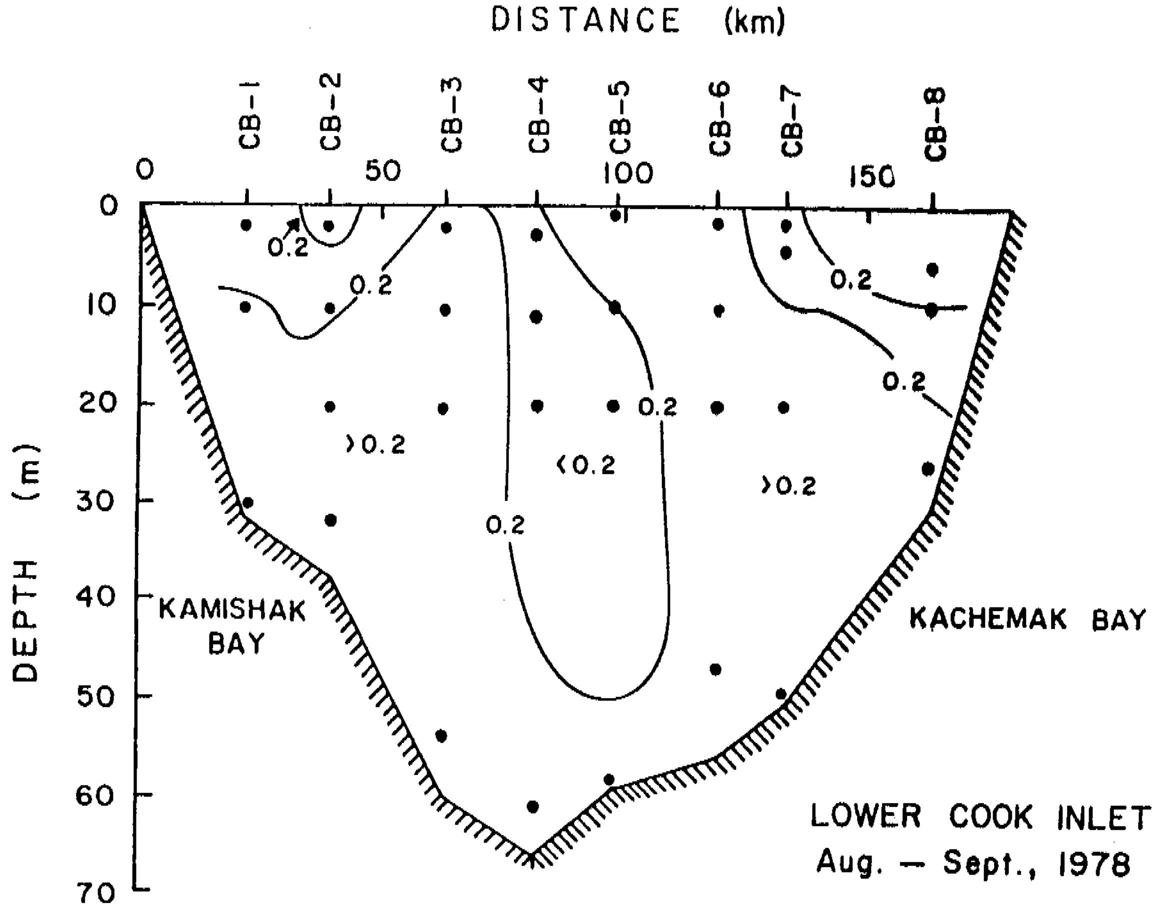

Figure 6-10. Biological index ratio ($C_{2:0}/C_{2:1}$) along a transect between Kamishak and Kachemak Bays in August-September 1978.

The biological index ratio ($C_{2:0}/C_{2:1}$) is reflected in Figure 6-10. The ratio was uniformally 0.2 ± 0.1, down from an average value of 0.4 ± 0.1 observed in May. The decrease is due to a relative increase in the amount of ethene produced (see Figure 6-5), which again is related to biological activity or photochemical effects.

6.2 LMWH - Upper Cook Inlet

In May and again in August-September 1978, observations on the distributions of LMWH north of The Forelands were conducted aboard a small charter vessel. In order to assess all possible sources of hydrocarbons, water samples were taken as far north as Fire Island, but emphasis was devoted to production platforms and the region known as the MacArthur River oil field in Trading Bay. After each day of sampling, samples were returned to the R/V DISCOVERER for analyses, usually within 5 days of collection. Water samples were preserved with approximately 200 mg of NaN_3 at the time of collection.

Because tidal mixing is intense north of The Forelands, samples were collected at two depths (i.e., surface and bottom-5m). Separate samples were collected for aliphatic and aromatic analyses.

6.2.1 LMWH - May 1978

The near surface distribution of dissolved methane is presented in Figure 6-11. The highest methane concentration (1560 nl/l) was observed in Trading Bay with a lateral decrease toward the east. Minimum values less than 200 nl/l were observed on the east side of the inlet. Because of large tidal mixing, no vertical stratification was apparent, resulting in an apparent uniform hydrocarbon distribution with depth. Surface concentrations of methane decreased uniformly in all directions away from the apparent locus in Trading Bay.

In Figure 6-12 is shown the surface distribution of ethane in nl/l. The highest surface concentration of ethane observed was 8.3 nl/l near the West Foreland. Concentrations of ethane were greater than 2 nl/l in all of Trading Bay. Not unlike that observed for dissolved methane, the lowest concentrations of ethane were observed north and east of Trading Bay. Background levels were 0.2 to 0.4 nl/l north of the apparent point source.

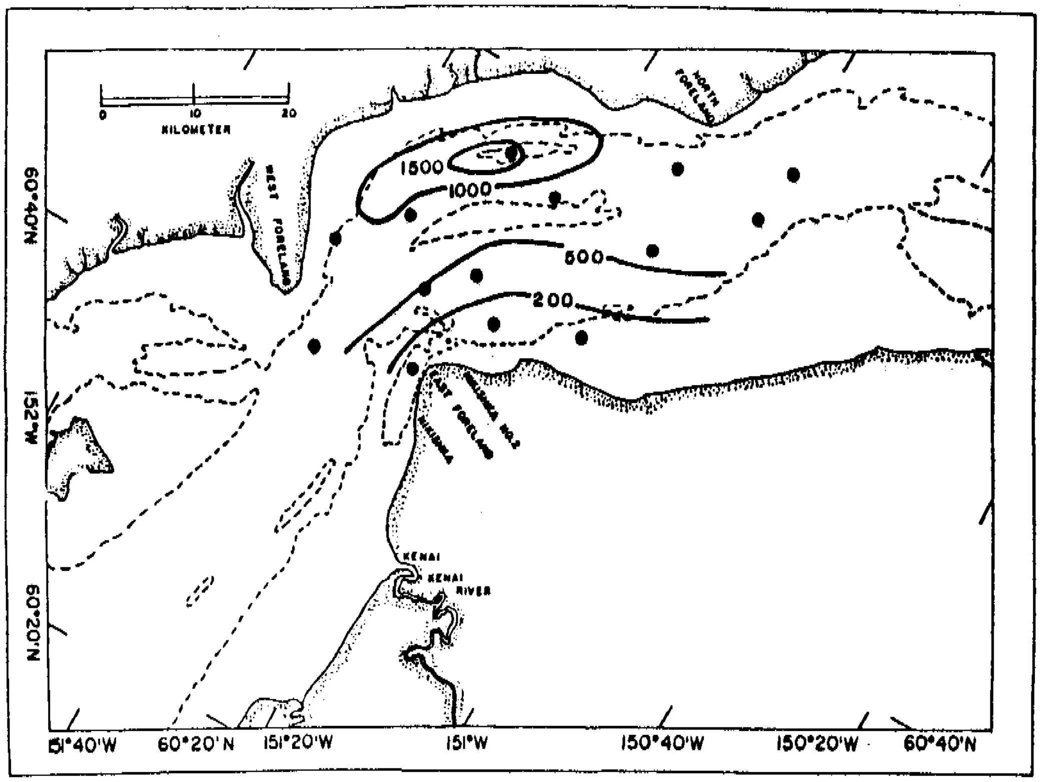

Figure 6-11. Surface distribution of dissolved methane (nl/l, STP) in upper Cook Inlet in May 1978.

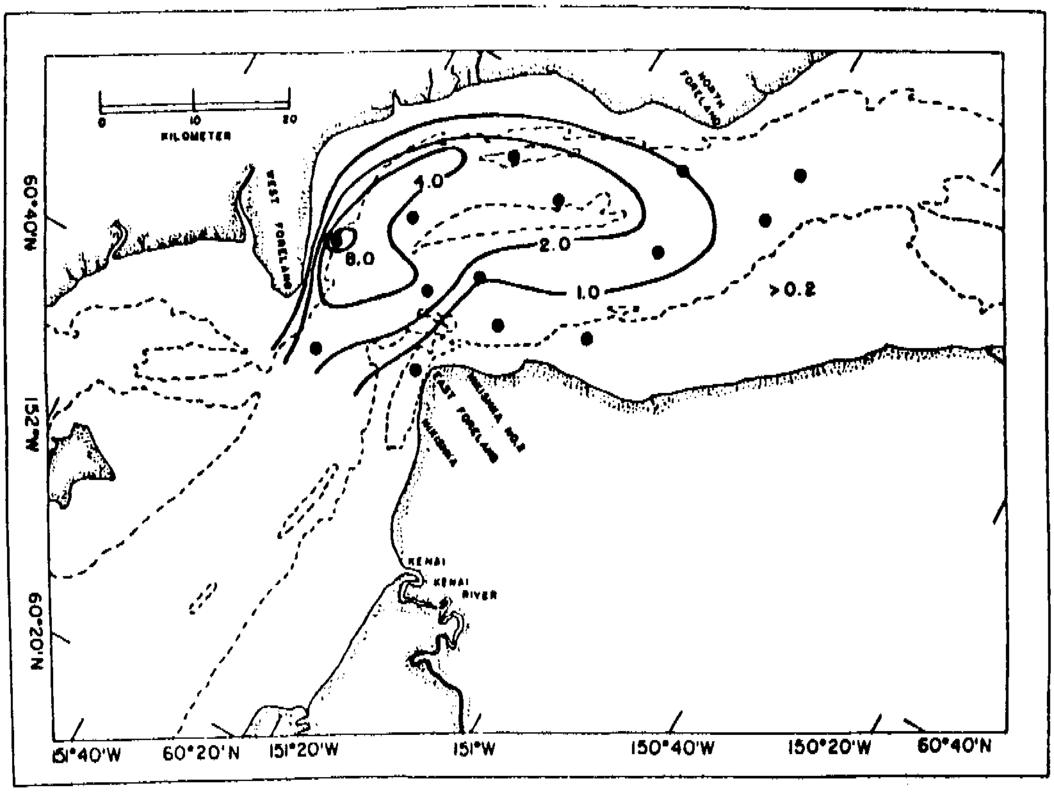

Figure 6-12. Surface distribution of dissolved ethane (nl/l, STP) in upper Cook Inlet in May 1978.

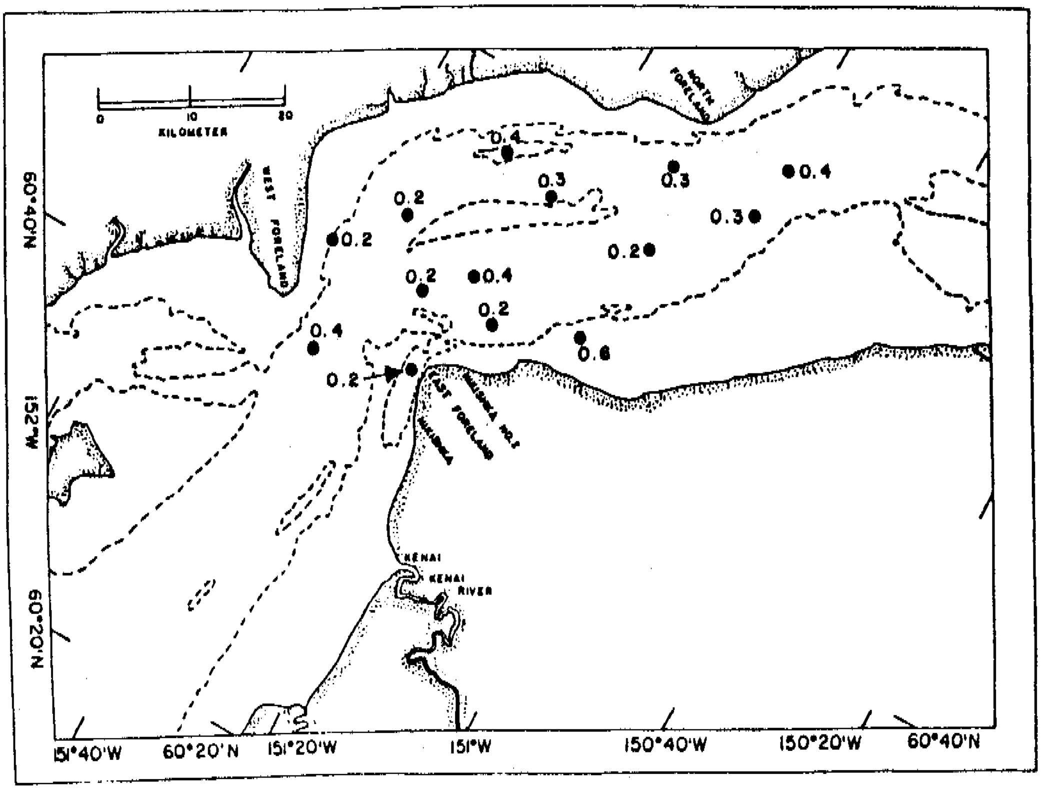

Figure 6-13. Surface distribution of dissolved ethene (nl/l, STP) in upper Cook Inlet in May 1978.

In contrast, the concentration of ethene was invariant throughout the entire region (Figure 6-13). The surface values ranged from 0.2 to 0.6 nl/l; the mean was 0.3 nl/l. The relatively low concentrations of ethene suggest minimal biological input or low light levels, or both. The abundance of suspended matter in this region of the inlet would further inhibit the penetration of light.

Not unlike that observed in the case of ethane, the surface concentration of a propene was higher in Trading Bay relative to surrounding areas (Figure 6-14). The highest concentration was 4.4 nl/l near the West Foreland. Concentrations diminished toward north, reaching minimum values of 0.2 nl/l. Again the strongest signature was at station UC013.

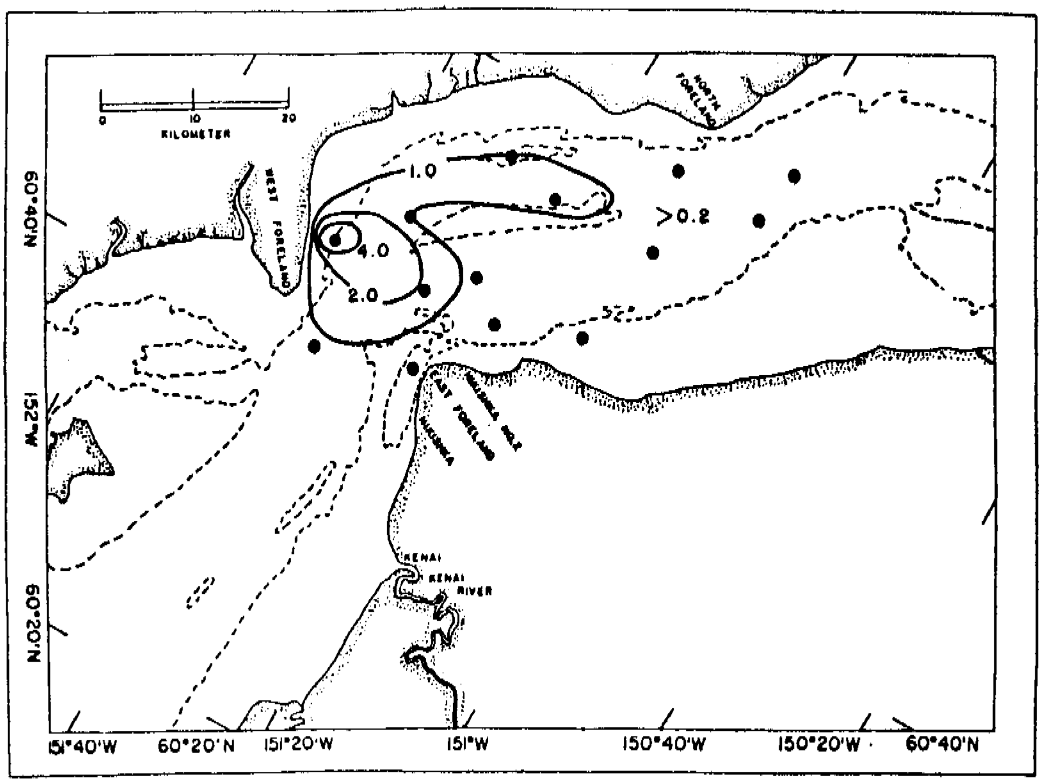

Figure 6-14. Surface distribution of dissolved propane (nl/l, STP) in upper Cook Inlet in May 1978.

During last year's investigation aboard the R/V ACONA, a source of LMW aliphatics was tentatively identified in Trading Bay (Cline et al., 1978). With greater sampling density, the source of aliphatics appears confined to Trading Bay as suspected.

A preliminary attempt was made to correlate the occurrence of LMW aliphatics and existing platforms and/or pipelines. These comparisons are shown in Figure 6-15. The locations of structures and pipelines are approximate and were taken from hydrographic chart 16660 dated October 18, 1975. Not shown, however, are numerous capped test wells, particularly in the region of Trading Bay. The highest concentration of ethane and propane were found approximately 5 km south of the southern-most platform. Two wells, apparently capped, are within 2 km of the locus of gaseous hydrocarbons. A close scrutiny

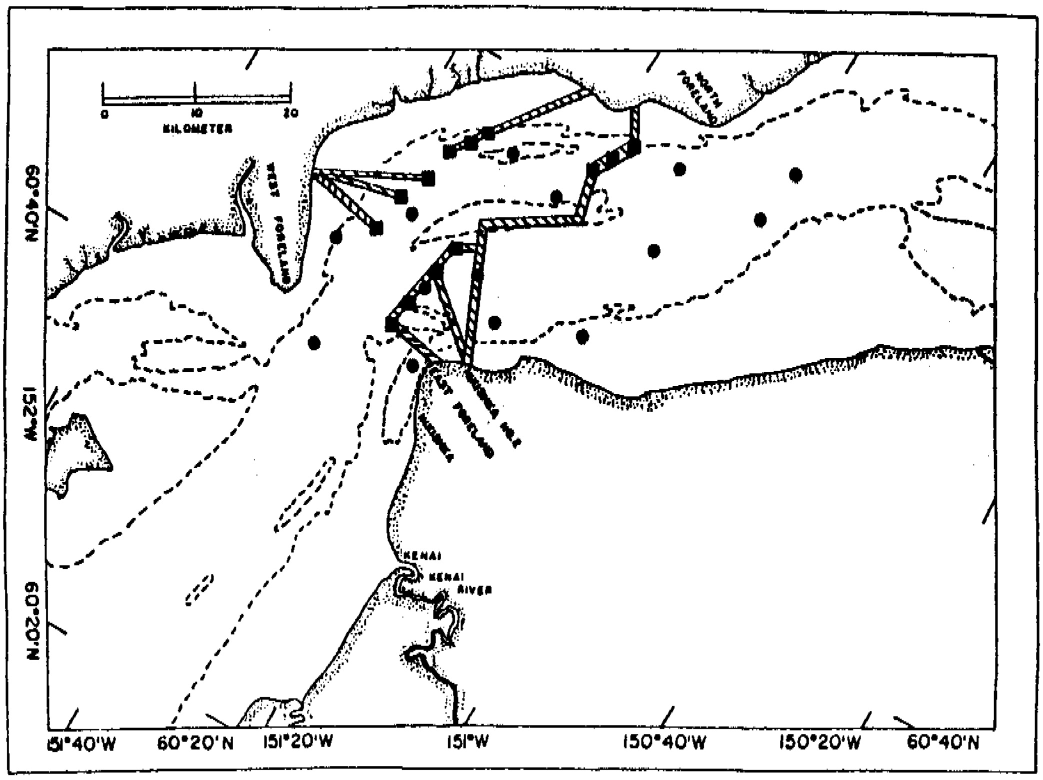

Figure 6-15. Location of stations (●), platforms (■), and pipelines (▥) in upper Cook Inlet. The locations are approximate and were taken from hydrographic chart 16660, dated Oct. 18, 1975.

of the chart reveals numerous wells near the 10 fathom curve in Trading Bay. If the mean drift of the current is clockwise, the actual source of LMW hydrocarbons could be west of the existing platforms. It is also conceivable that natural gas seeps in the area are the major source of gaseous hydrocarbons.

Selected water samples also were analyzed for low molecular weight aromatic compounds. Numerous analytical difficulties were encountered, consequently only a few samples were analytically credible. The major problems encountered included incomplete stripping of aromatics from solution, contamination, and a complex array of naturally-occurring low boiling point hydrocarbons. In the procedure adopted in May, the aromatics were sorbed on Tenax^R at about 4^{O}C, then eluted at 250^{O}C. Under the conditions of the purge and trap procedure pentane and heavier alkanes and cycloalkanes are also retained and would co-elute with benzene.

In August-September 1978, aromatic compounds were stripped as before, except the chromatography was performed on Chromosorb 102. Problems similar to those incurred on the previous cruise were again observed, namely contamination and poor resolution. Rather than attempt another major modification of the procedure, samples were collected and stored until an operational procedure could be adequately tested.

Since last September, emphasis has been given to sources of contamination and the use of high resolution glass capillary-gas chromatography. The stripping and trapping system has been redesigned to the point that we feel a workable system is now on hand. This system was designed and is being tested to interface with a HP 5992 g.c.-m.s. detector system. The stability of the aromatic samples collected last fall is not known, but some of these samples will be analyzed before the cruise this spring.

Examples of aromatic chromatograms obtained during May 1978 can be found in the June-October 1978 quarterly report (Cline and Feely, 1978). Comparison of samples obtained above The Forelands with those collected in the lower inlet show an unresolved complex mixture indicative of C_5 and C_6 hydrocarbons. It must be stressed that these results are provisional.

6.2.2 LMWH - August-September 1978

The surface distribution of salinity is shown in Figure 6-16. As expected, surface salinities decrease in a northerly direction in response to fresh water input. It should be noted that the high salinity water is found on the western side of the inlet in conflict with our general notion of estuarine dynamics. There appears to be a clockwise rotation of the mean circulation north of The Forelands.

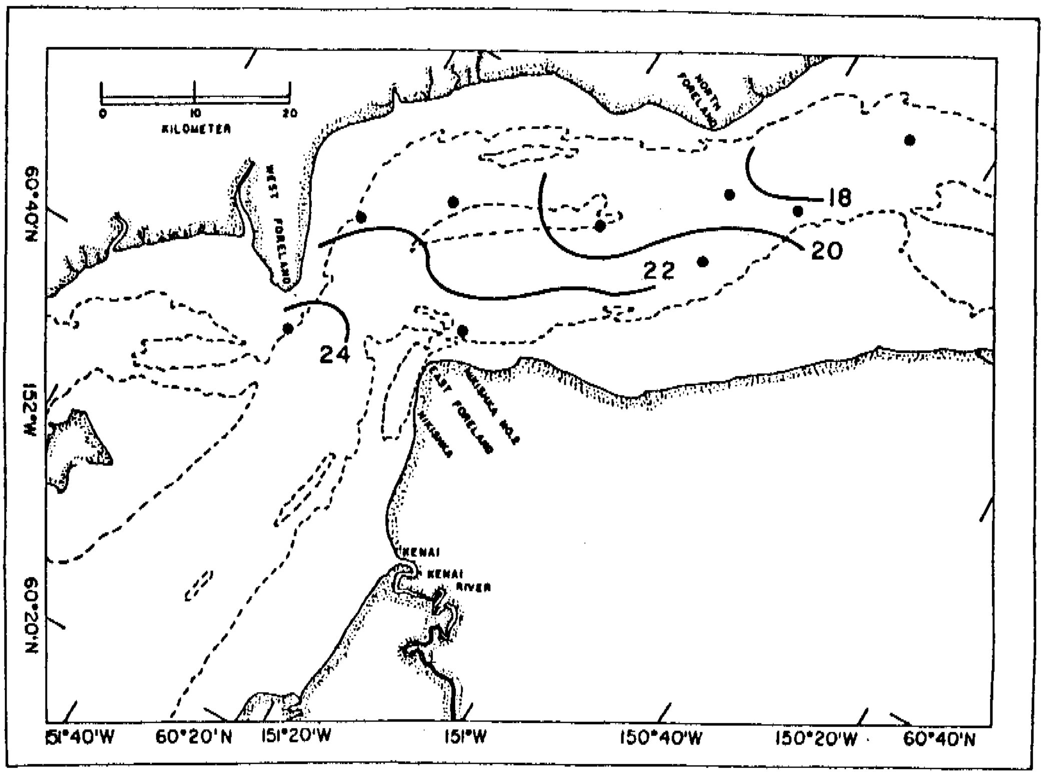

Figure 6-16. Surface distribution of salinity in upper Cook Inlet in August-September 1978.

The surface distribution of dissolved methane (nl/l, STP) is reflected in Figure 6-17. Concentration of methane was everywhere greater than 400 nl/l with the maximum concentration found in Trading Bay. This is in contrast to the situation observed in May (see Figure 6-11), where the greatest amounts of methane were found near a shoal area just north of the West Foreland. It is theorized that the high concentrations of methane observed in spring were the result of biogenic input as there were no similar increases in ethane or propane. The maximum concentration of methane observed in the fall occurs in the vicinity of the gas seep (see below).

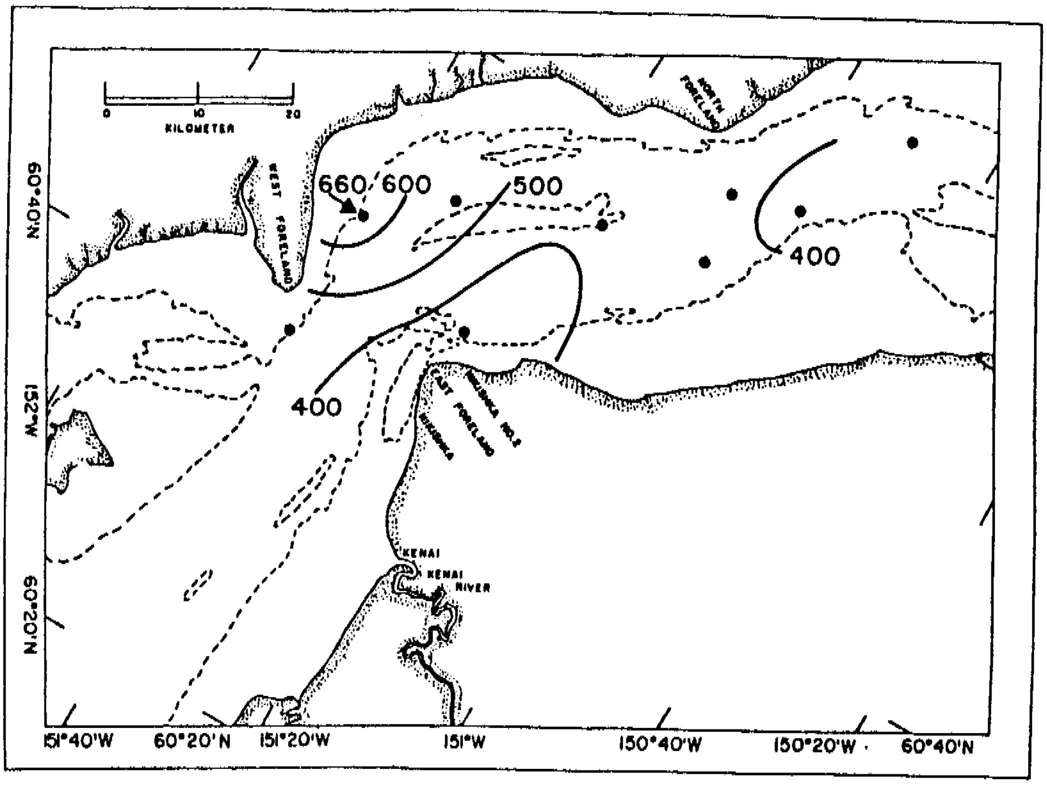

Figure 6-17. Surface distribution of dissolved methane (nl/l, STP) in upper Cook Inlet in August-September 1978.

Rather similar to the situation observed in May, the highest concentration of ethane was found in Trading Bay (Figure 6-18). Whereas the concentration of ethane was higher in May, 8 nl/l versus 5.2 nl/l, the location of the source appears to be the same. This fact suggests that the seep is continuous in time, since the occurrence has been documented over the last two years and inferred from the previous year's data.

The biological index ratio ($C_{2:0}/C_{2:1}$) also reflects the locus of the seep in Trading Bay (see Figure 6-19). The high degree of mixing and the low hydrocarbon sources adjacent to Trading Bay result in a ten-fold decrease in the ethane:ethene ratio. Again, the mean clockwise circulation is evident above The Forelands.

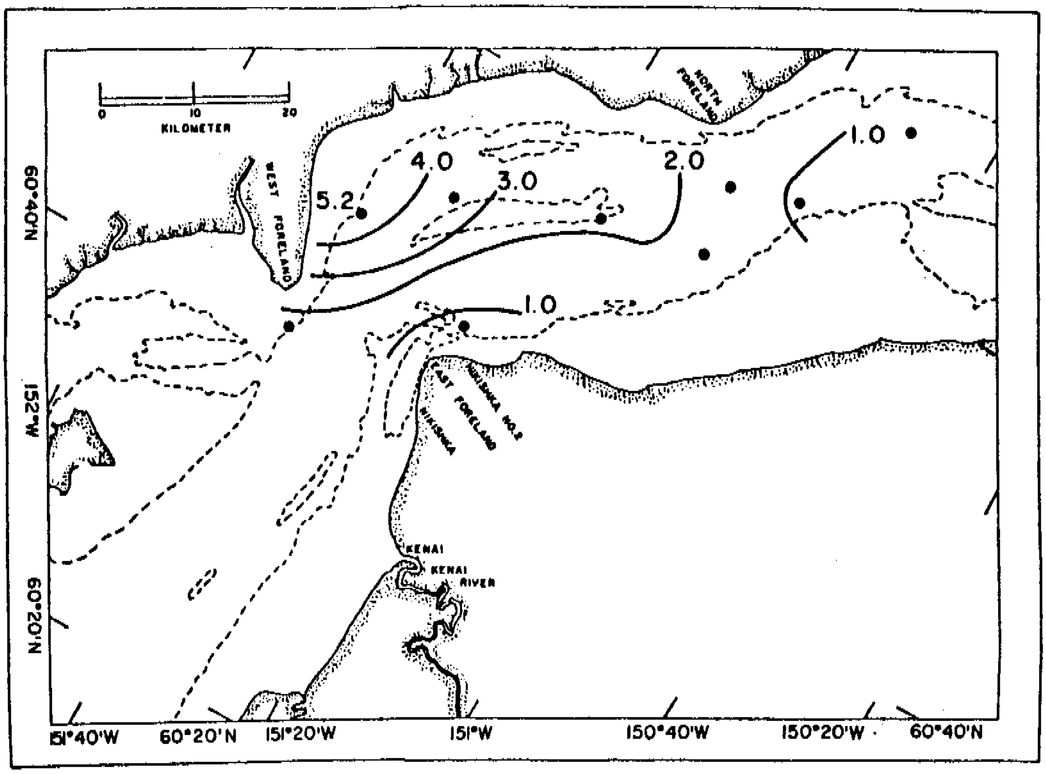

Figure 6-18. Surface distribution of dissolved ethane (nl/l, STP) in upper Cook Inlet in August-September 1978.

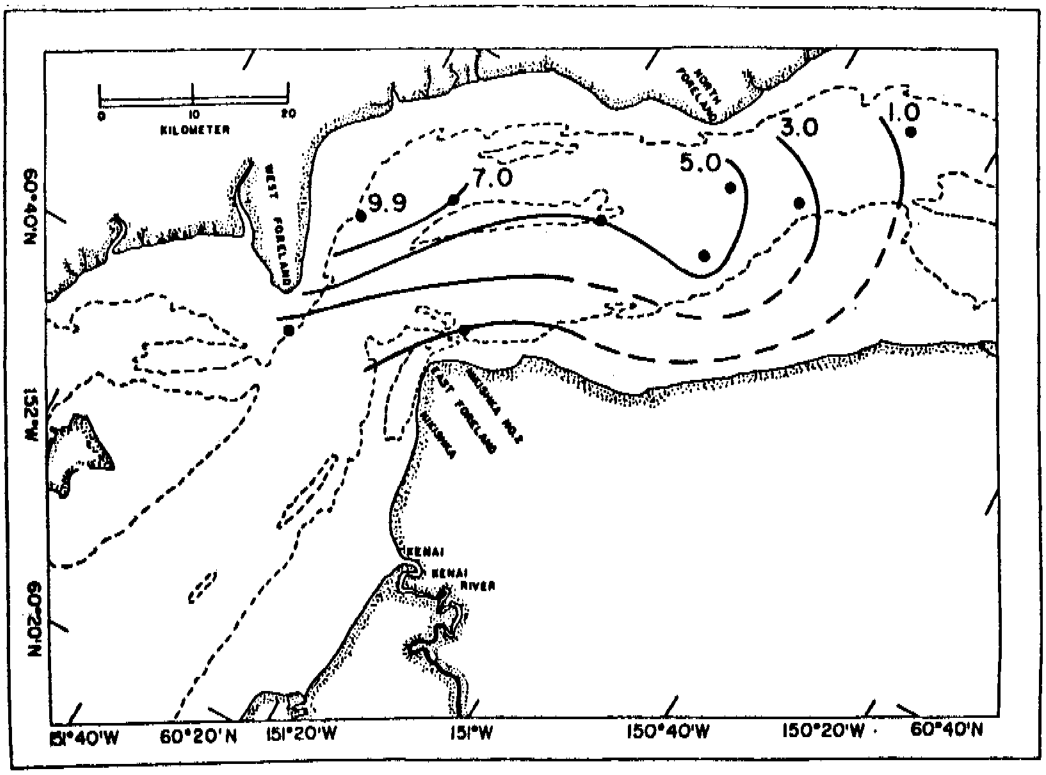

Figure 6-19. Surface distribution of the biological index ratio ($C_2:_0/C_2:_1$) in upper Cook Inlet in August-September 1978.

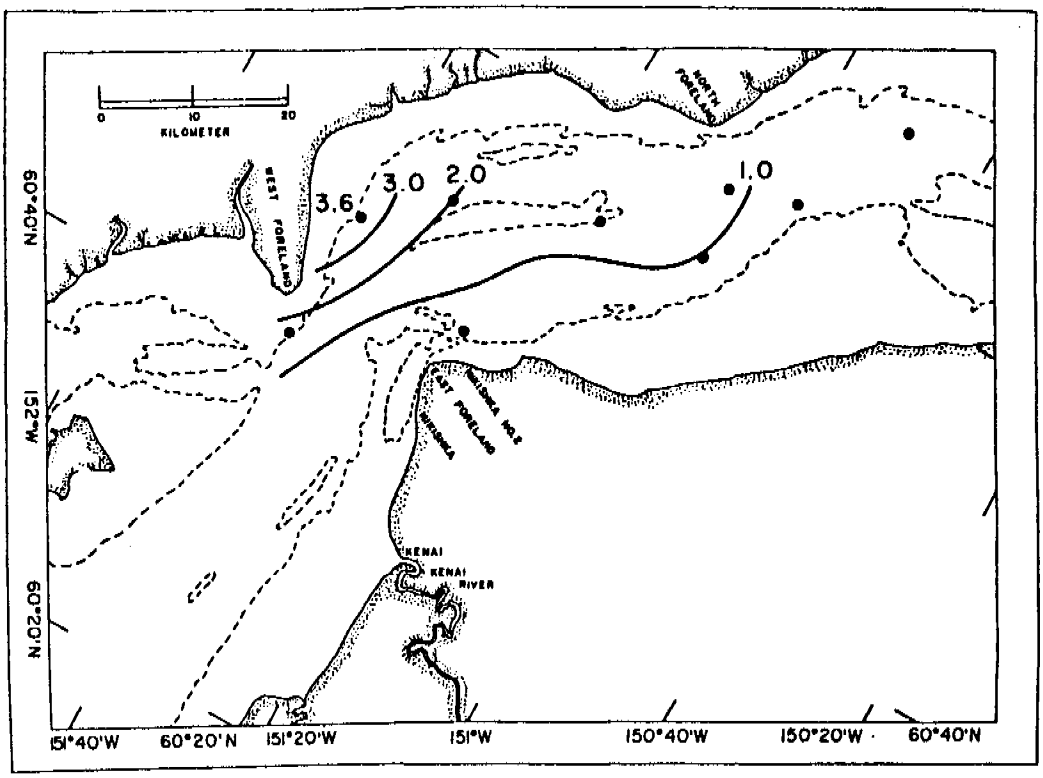

Figure 6-20. Surface distribution of dissolved propane (nl/l, STP) in upper Cook Inlet in August-September 1978.

The surface distribution of propane is given in Figure 6-20. As is the case with the other saturated hydrocarbons, the concentration decreases northward, away from the source in Trading Bay. The highest concentration of propane observed was 3.6 nl/l, decreasing to normal background levels of less than 0.5 nl/l at the northern end of the survey grid.

Surface distribution of ethene (nl/l, STP) is reflected in Figure 6-21. Concentrations were uniform over the upper inlet and averaged about 0.5 nl/l. By way of comparison, the concentrations of ethene in May averaged about 0.3 nl/l. This fact suggests that biological activity or the light levels were higher in September than in May. Either or both alternatives seem reasonable.

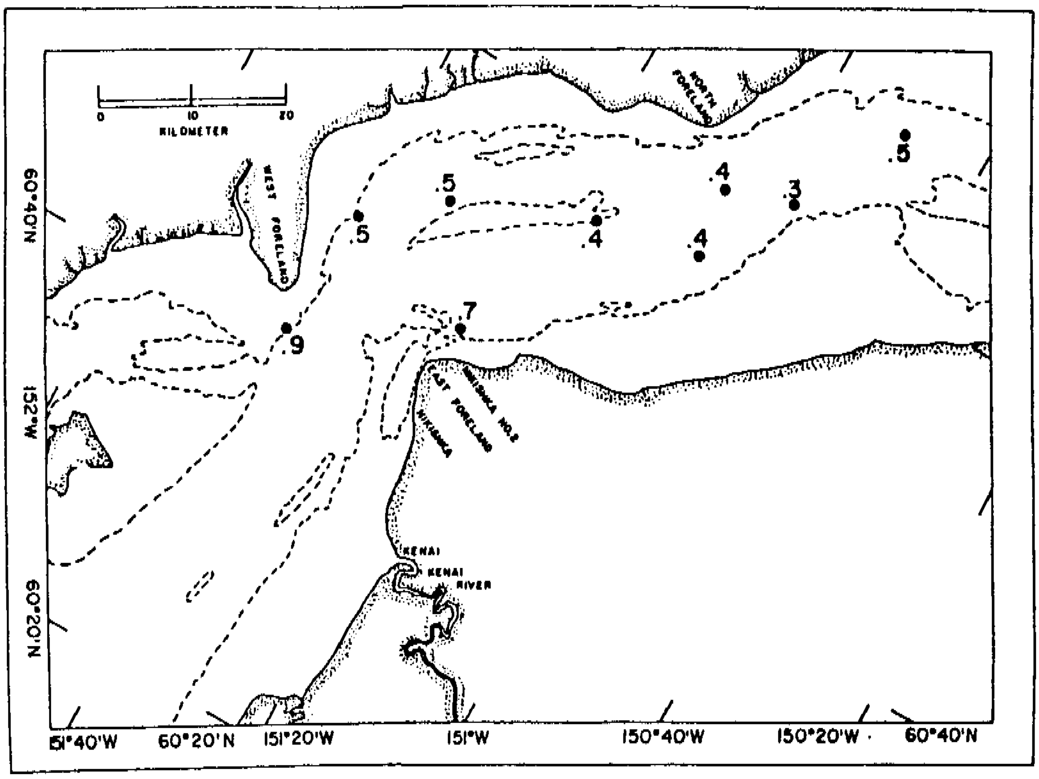

Figure 6-21. Surface distribution of dissolved ethene (nl/l, STP) in upper Cook Inlet in August-September 1978.

6.3 Suspended Hydrocarbons

In order to assess the significance of suspended matter in the transport of hydrocarbons, time series stations were occupied in lower Cook Inlet for the purpose of collecting significant quantities of suspended solids. Time series stations were sampled for periods of 24 to 36 hours, with subsamples being collected every 12 hours. Collection of suspended matter was effected with a well head pump and a Sorvall® continuous flow centrifuge. In addition to the pump stations, suspended matter was also collected in sediment traps deployed by Dr. Feely in the summer of 1978. Aliquots of collected material were obtained from stations ST-1 and ST-2, both stations located on the western side of lower Cook Inlet.

In May 1978, a total of 3 time series stations were occupied (see Figure 4-1). However, because of an abbreviated cruise schedule, only station CB-10 was occupied in September 1978. The station was moved from its previous location to a point just east of Kalgin Island on the 10 fathom isobath. All time series stations were conducted while the ship was anchored.

Vertically settling sediment was also collected at two sediment traps in lower Cook Inlet. Both sediment traps were located 10 m from the bottom at stations ST-1 and ST-2 (see Figure 4-1). The deployment time of the traps was 86 2/3 days.

6.3.1 Suspended Hydrocarbons - May 1978

As previously mentioned, station CB-7, CB-9, and CB-10 were occupied during this cruise. The aliphatic analysis has been completed and shown in Table 6.1, although chromatography of the aromatic fraction remains to be accomplished.

Station CB-7, located in Kachemak Bay, was sampled every 12 hours for a total of 36 hours. Material collected in the centrifuge was mostly of marine biogenic origin as evidenced by the low dry weight yields and large amounts of extractable chlorophyll (see Table 6-1). A typical chromatogram of the aliphatic fraction from station CB-7 is reflected in Figure 6-22.

The characteristic feature of the alkane hydrocarbons is the unresolved complex mixture centered near C_{28} and the lack of odd-even dominance in the heavier n-alkanes. This sample and the second subsample were obviously contaminated with petroleum hydrocarbons, presumably arising from the ship.
Dr. Griffiths of OSU also made note of bacterial contamination at this station and attributed it to ships pumping of the holding tanks and bilges. Even though the sample weights were extremely small (~0.7g), oil contamination of the collected suspended matter was obvious.

Table 6.1 Concentration of aliphatic hydrocarbons in ng/g dry weight of suspended matter. Suspended matter was collated by centrifugation (CB-7,9,10) and sediment traps (ST-1,2). Total extracted sample weights and a maximum limit of detection is also shown.

Carbon No.	CB-7-1 5/7/78	CB-7-2 5/7/78	CB-7-3 5/8/78	CB-9-1 5/13/78	CB-10-2 5/11/78	CB-10-2 9/1/78	ST-1 10/18/78	ST-2 10/18/78
12	<47	66	<42	15	12	17	18	32
13	<47	82	<42	17	16	17	22	39
14	<47	128	175	20	18	20	21	43
15	136	371	444	47	36	118	62	232
16	106	255	269	38	28	34	33	64
17	256	376	328	68	33	43	49	78
Pris	642	1471	1533	57	36	70[1]	1875[1]	365
18	103	290	270	40	28	39	63	56
Phy	<47	63	68	13	10	13	42	33
19	175	160	143	43	28	35	184	83
20	213	214	246	41	28	37	167	82
21	256	160	168	75	62	74	140	95
22	274	180	170	58	49	62	72	70
23	287	259	215	148	132	150	136	150
24	606	320	237	70	70	80	65	90
25	725	392	324	228	211	224	300	217
26	605	338	255	92	74	88	74	102
27	544	543	407	407	384	411	390	326
28	622	403	290	172	80	77	51	118
29	593	635	494	502	297	305	261	347
30	361	444	413	351	68	48	69	145
31	533	633	523	708	260	266	243	322
32	312	574	795	700	75	44	58	128
Sample Wght (g)	0.62	0.70	0.68	10.30	19.65	14.84	17.59	6.84
Detection Limit (ng)	47	41	42	2.8	1.4	1.9	1.6	4.2

[1] Peak doublet. Value represents concentration if both peaks were pristane.

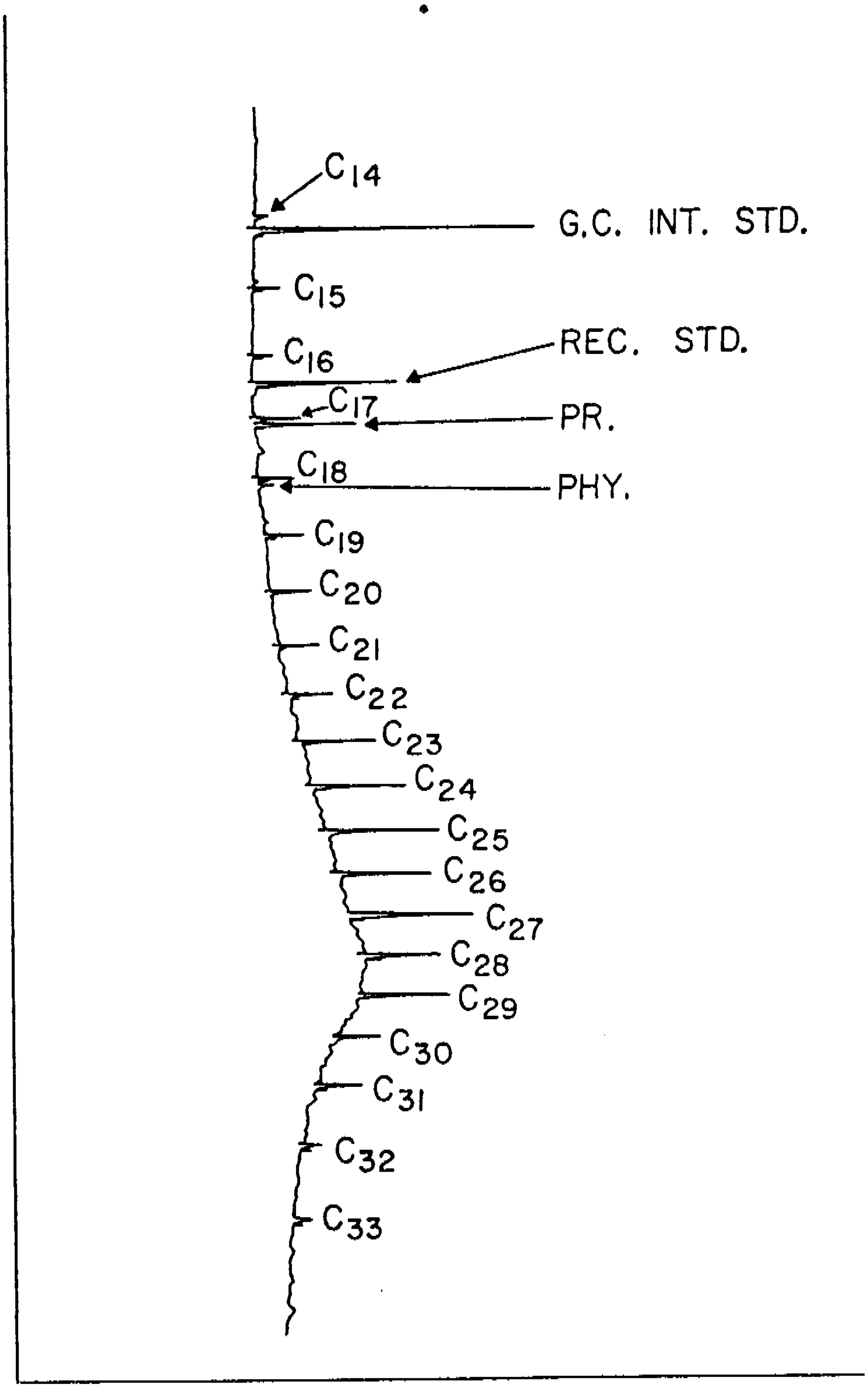

Figure 6-22. Chromatogram of the alkane fraction recovered from suspended matter collected at station CB-7. This is subsample 1 (see Table 6-1). Suspended matter was recovered from approximately 5 m depth.

Station CB-9, located west of Kalgin Island, was representative of suspended hydrocarbons effluxing from upper Cook Inlet (see discussion on CB-10 below). The chromatogram of the n-alkane fraction is shown in Figure 6-23. The component concentrations are presented in Table 6-1. Major features of the hydrocarbon pattern include: (1) no unresolved complex mixture, strong odd-even dominance in the plant wax hydrocarbons (C_{23}-C_{32}), and a low contribution from the normally associated phytoplankton hydrocarbons (C_{15}-C_{17}).

The location of station CB-10 was near the 10 fathom isobath on the east side of the inlet (see Figure 4-1) during this cruise. The alkane hydrocarbon pattern was identical to that observed in September, thus the chromatogram will not be shown. Not unlike that observed at CB-9, the n-alkane fraction was dominated by the odd carbon plant waxes (see Table 6-1). The dominant alkane was C_{27}; its concentration was 380 ng/g dry weight. Aside from the relatively large amounts of C_{23}, C_{25}, C_{27}, C_{29}, and C_{31}, all other alkanes were found in concentrations less than 75 ng/g.

6.3.2 Suspended Hydrocarbons - September 1978

Only station CB-10 was occupied in the fall. Its position was relocated to take advantage of the major water discharge from upper Cook Inlet. The characteristic n-alkane chromatogram is shown in Figure 6-24 with the concentrations of individual alkanes presented in Table 6-1. A total of three subsamples were taken at this station; the chromatogram is representative of all samples taken at this station.

The composition of n-alkanes in this sample is not unlike that found at CB-9. There is a strong dominance of odd-even alkanes in the carbon chain length C_{23}-C_{32}. The most abundant alkane was C_{27}; its concentration was 411 ng/g dry weight. The odd-even ratio of n-alkanes in the C_{23} to C_{32} range is 4 and represents a characteristic pattern of plant waxes originating from

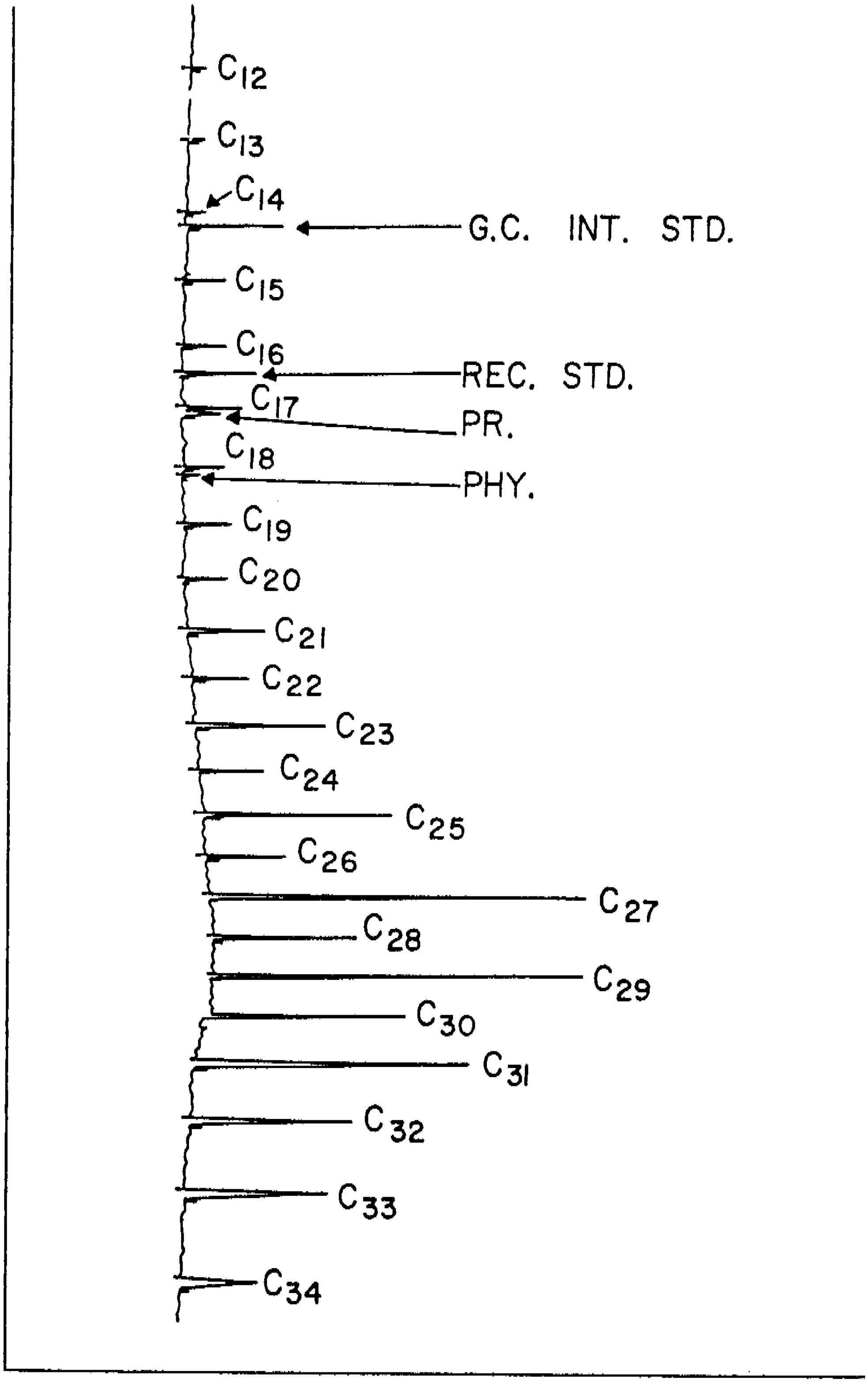

Figure 6-23. Chromatogram of the alkane fraction recovered from suspended matter collected at station CB-9 (see Table 6-1). Suspended matter was recovered from approximately 5 m depth.

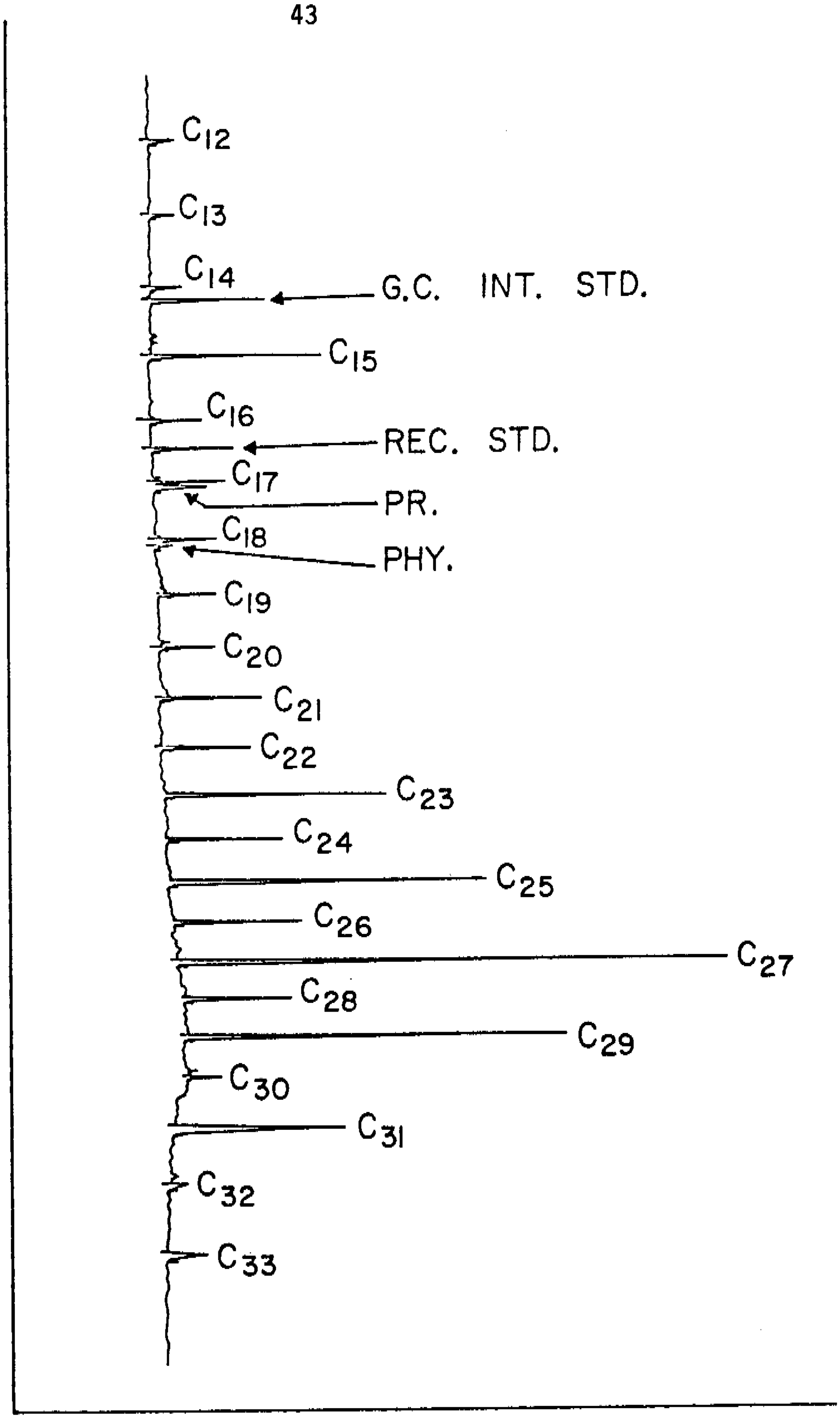

Figure 6-24. Chromatogram of the alkane fraction recovered from suspended matter collected at station CB-10 in September 1978 (see Table 6-1). Suspended matter was nominally recovered from approximately 5 m depth.

terrestrially derived organic detritus. It is also noteworthy that the concentrations of the individual n-alkanes were nearly the same in both samples collected in May and September (Table 6-1). There is no persuasive evidence of petroleum contamination of these sediments.

There is evidence of a slight increase in the phytoplankton hydrocarbons (C_{15} and C_{17}) between the two sampling periods (Table 6-1). Comparison between samples collected at CB-7 in Kachemak Bay and CB-10 near Kalgin Island show the marked influence of phytoplankton production on the composition of hydrocarbons. With respect to pentadecane and heptadecane, suspended matter at CB-7 contained approximately a ten-fold greater concentration of these hydrocarbons than did the samples taken at CB-10 (see Table 6-1).

6.3.3 Suspended Hydrocarbons - Sediment Traps

Sediment traps were deployed at stations ST-1 and ST-2 (see Figure 4-1) during the summer of 1978 for the purpose of collecting vertically settling particles. Specifically, these sediments were analyzed for the occurrence of petroleum-like hydrocarbons. A representative chromatogram of the n-alkane fraction is presented in Figure 6-25 (ST-2). Concentrations of the individual alkanes are reflected in Table 6-1. The principle features of the chromatogram include a broad unresolved complex mixture and a strong odd-even dominance of the higher molecular weight alkanes. Pentadecane, heptadecane, and pristane also were relatively abundant. With the exception of pristane, the composition of the saturated hydrocarbons from station ST-2 is quite similar to that observed at CB-10.

The broad UCM suggests that some contamination may have occurred, possibly during deployment and recovery or through microbial activity in the traps. Our experience with suspended matter collected in Puget Sound has shown that microbial metabolism results in a complex mixture of saturated and unsaturated

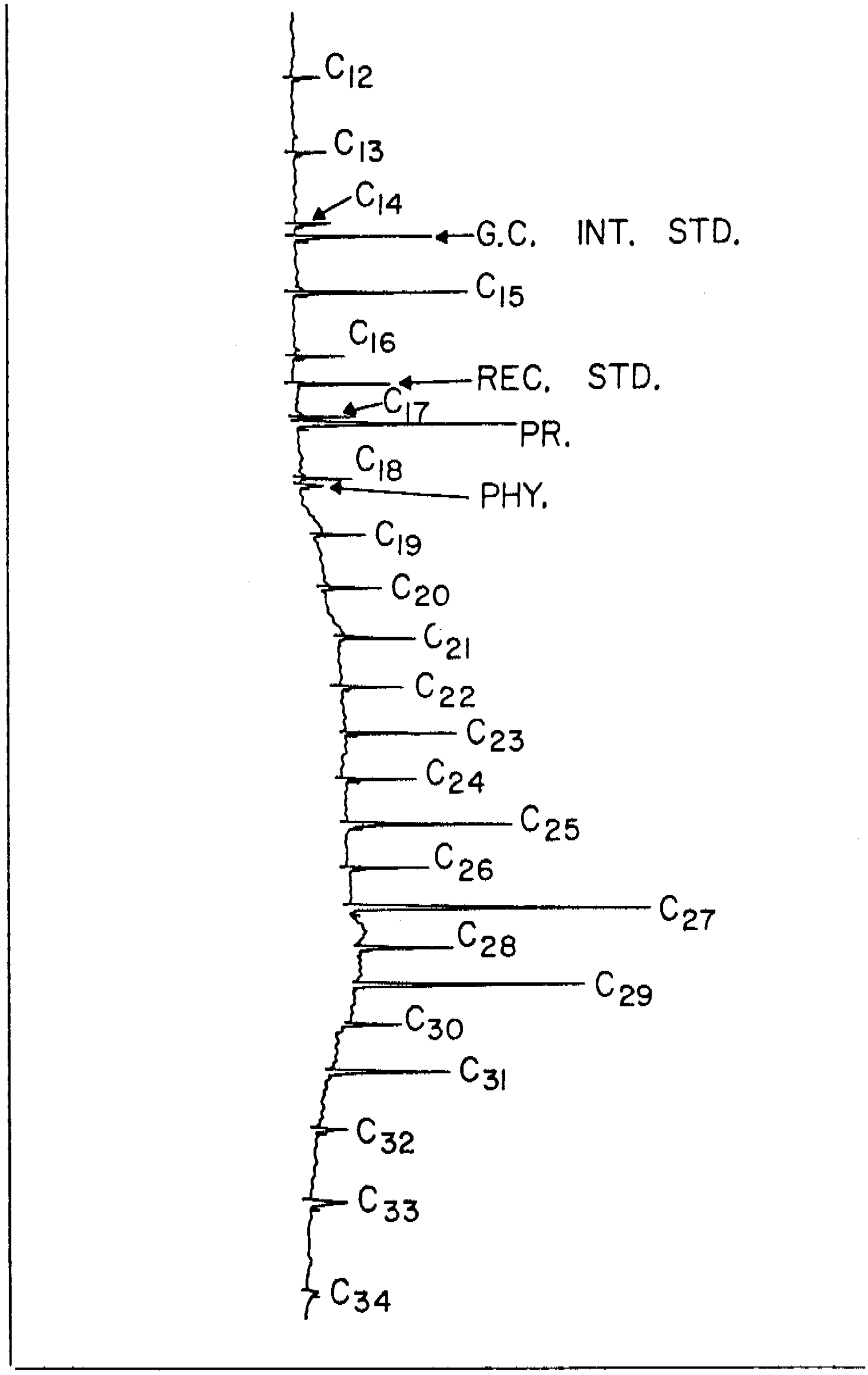

Figure 6-25. Chromatogram of the alkane hydrocarbon fraction recovered from suspended matter collected at station ST-1. Suspended matter was collected in a trap placed 10 m above the bottom in a total water depth of 43 m. Deployment of the trap was 86 days; approximately 40 g of material was collected.

hydrocarbons, whose median carbon chain length is 21. In order to reduce microbial activity, the sediment traps were armed with a compressed pellet of sodium azide (NaN_3) or mercuric chloride ($HgCl_2$). The biocidal effect of NaN_3 may not be sufficiently strong to inhibit hydrocarbon production or degradation. Neither trap contained NaN_3 or $HgCl_2$ upon recovery, suggesting that both salts may have dissolved and dispersed prior to the closing time. This would have allowed microbial activity to take place.

The sample taken from ST-1 revealed a significant UCM, with maxima at C_{21} and C_{27}. For the purpose of brevity, the chromatogram is not shown. However, the salient features are similar to that found at ST-2, with the exception of pristane (see Table 6-1). We show the pristane concentration to be greater than 1800 ng/g, although a close scrutiny of the chromatogram suggests that another component may be present. Our explanation for the UCM is the same as described above. One difference between this sample and that taken from ST-2 was that the former was poisoned with mercuric chloride rather than sodium azide. While the biocidal activity of $HgCl_2$ is greater than that of NaN_3, neither trap contained any retardent upon recovery. This suggests that chemical control of biological activity in both traps may have been ineffective, at least over the entire 86 day deployment time. Sediment traps represent an effective means of collecting vertical settling material, but contamination difficulties and bacterial inhibition must be resolved before this methodology is applicable to the collection of suspended hydrocarbon material.

7. Discussion

7.1 Sources of LMWH

During the past two years, four cruises were conducted to Cook Inlet for the purpose of identifying and characterizing the sources and fate of LMWH. Based on several surveys conducted above The Forelands, there appears to be a point source of hydrocarbons in Trading Bay, although the precise origin of these gases is not known. The most likely sources include natural seeps or possibly leaking test wells.

The identity of the gas seep was made on the basis of an unusual composition of LMW alkanes. Comparison of these data with similar HC data taken in LCI reveal that the waters in Trading Bay are relatively deficient in the alkenes. Near the locus of the seep, the ethane/ethene ratio is in excess of 10 compared to values less than 1 over the remainder of the inlet. This ratio, referred to here as the biological index ratio, usually decreases to values near 0.2 in LCI, particularly during periods of intense biological activity.

Another distinguishing parameter is the ratio of methane to the sum of ethane plus propane. In biogenic systems, the ratio is usually greater than 50 and may achieve values in excess of 1000. Petroleum and natural gas sources (deep seated) are usually characterized by a ratio less than 50. For example, in a study of several petrogenic gas vents located in the Gulf of Mexico, Bernard et al. (1976) characterized the vented HC on the basis of the $C_1/C_2 + C_3$ ratio and the $\delta^{13}C$ composition of the methane.

Significant contributions of petrogenic gas were identified on the basis of a $C_1/C_2 + C_3$ ratio of less than 50 and a $\delta^{13}C$ composition of >-50°/oo relative to PPB (Bernard et al., 1976). Unfortunately, no companion measurements of ethene and propene were made. In a detailed study of dissolved hydrocarbon gases in recent sediments associated with the Norton Sound gas seep

(Kvenvolden et al., 1979), the authors observed $C_1/C_2 + C_3$ ratios less than 10, ethane/ethene ratios greater than 2, and $\delta^{13}C$ values of dissolved methane greater than $-35^{o}/oo$. Interstitial pore water hydrocarbons extracted from sediments near the seep showed $C_1/C_2 + C_3$ ratios greater than 1000. The ethane (ethene ratio varied from approximately 0.4 in the surface layers of the sediments to a maximum value of 13 at depth (~2 m). It appears that in aerobic waters and sediments, the ethane/ethene ratio is less than 1, but increases to values greater than unity under anoxic conditions. This supposition is supported by the studies of Hunt (1972) in which the vertical distributions of LMW hydrocarbons in the Black Sea were investigated. Minimum values of the ratio were found in the aerobic surface waters (~0.2), increasing to a maximum value of 50 in the anoxic bottom waters. Obviously, the more oxidized olefinic hydrocarbons are either not produced or are more metabolically reactive than their saturated homologs. The average $C_1/C_2 + C_3$ ratio in the deeper waters (700 to 1900 m) of the Black Sea is approximately 400 (Hunt, 1972), further suggesting that these hydrocarbons are of biogenic origin.

Currently, several parameters are used to distinguish biogenic from petrogenic hydrocarbon sources. Of these, the $\delta^{13}C$ composition of associated methane appears to be most definitive, while the $C_{2:0}/C_{2:1}$ ratio appears to be less diagnostic, depending on the actual source of hydrocarbons. If the source is a bottom seep, care must be taken in the interpretation of the $C_{2:0}/C_{2:1}$ ratio to ensure that the gases are not of shallow biogenic origin. Such is the case at many sites in Norton Sound, where shallow, buried peat layers provide a suitable environment for the production of methane and its higher homologs. If anaerobic conditions prevail in the peat layers, it is likely that the concentrations of saturated alkanes are going to dominate over the olefinic homologs.

Norton Basin has been extensively surveyed for the presence of gas charged sedijments (see Kvenvolden et al., 1978, and the references contained therein). Most of the gas charged zones appear to be shallow in origin and presumably associated with buried peat beds. Hydrocarbon gases emanating from these beds are presumably biogenic, and would be relatively deficient in alkenes ($C_{2:0}/C_{2:1} > 1$). Although there appear to be hundreds of such sites throughout the inner basin, little HC compositional influence is observed in the water column. This would suggest that transport of biogenic hydrocarbons from depth is largely diffusive or by minor sporadic degassing. The latter mechanism would be likely under storm conditions (Nelson, 1977).

When strong point sources of hydrocarbons are observed, such as those seen in Cook Inlet and Norton Sound, it is very likely that the gases are emanating from a relatively large reservoir. This, of course, does not rule out deep-seated biological accumulations. By using appropriate geochemical tracer techniques, the likely source of the gas can be more firmly established. In the case of Cook Inlet, high $C_{2:0}/C_{2:1}$ ratios; low $C_1/C_2 + C_3$ ratios; presence of pentanes, hexanes, LMW aromatics; and the strength of the source suggest that the gases are of thermogenic origin. Not the least of these criteria is the fact that Trading Bay is the site of production gas and oil wells.

7.2 Residence Times and Transport of HC

As was shown earlier, anomalously high concentrations of ethane and propane were observed in upper Cook Inlet. The source of these hydrocarbons appears to be in Trading Bay, the location of the MacArthur River oil field. Moreover, the source of the gases is probably the bottom rather than a point source in the water column.

In response to freshwater input from the rivers in upper Cook Inlet and intense tidal mixing prevalent throughout most of Cook Inlet, the gaseous HC are dispersed into the water column. The combined effects of estuarine flow and tidal pumping result in a plume structure that appears to rotate clockwise, at least in the region above The Forelands. Previous data taken in the region around Kalgin Island show that the hydrocarbon-rich water follows a trajectory just to the east of Kalgin Island (Cline and Feely, 1977). Apparently, the brackish water leaving upper Cook Inlet moves down the western side of the inlet in response to estuarine circulation, with relatively high salinity water moving up the eastern side and crossing to the western side after passing through The Forelands on flood tide.

One of the objectives of this study was to identify the dispersion characteristics of the LMW alkanes and to establish their usefulness in tracing the trajectory of dissolved hydrocarbons. For this purpose, we will select ethane for discussion.

Ethane, along with other gaseous hydrocarbons, is lost from the system through the action of several physical, chemical, and biological processes. In upper Cook Inlet, the principle mechanisms include advective entrainment and air-sea exchange. Advective flow from upper Cook Inlet contains two components. The first is tidal pumping and the second is the mean southward flow induced by estuarine circulation. For the purpose of our calculations here, they are not readily separable.

To calculate the amount of dissolved ethane exchanged on each tidal cycle, we have calculated the cross sectional area between The Forelands and estimated a mean depth between the 10 fm isobaths. These values are, respectively, 6700 m and 46 m. Referring to the appropriate current tables (DOC, 1978), the mean current velocity during ebb tide is 2 m sec^{-1} at The Forelands. Choosing a mean ethane concentration of 2 nl/l in the outflowing water (see Figure 6.12), we calculate a transport rate of 1.6 g sec^{-1}, or 25 tonnes yr^{-1}.

The mean southward transport of dissolved hydrocarbons can be estimated by knowing the freshwater input rates. According to Muench et al. (1978), the maximum mean freshwater input into upper Cook Inlet is approximately 2.8 x 10^3 m^3 sec^{-1}. This represents only 0.4% of the instantaneous volume transported by tidal action. Maximum delivery of freshwater occurs between the months of April and November; the average rate estimated to be near 1000 m^3 sec^{-1}. Again, assuming a mean discharge concentration of ethane of 2 nl/l, the aforementioned mean flow rate would transport only 3 mg sec^{-1} or approximately .06 tonnes of ethane in an eight month period. Clearly, tidal exchange is the dominant transport process. These calculations assumed that no mixing occurred between "old water" in upper Cook Inlet and "new water" entering through The Forelands. We also assumed that the relatively high salinity water entering upper Cook Inlet contained negligible quantities of ethane.

The transfer of gaseous hydrocarbons across the air-sea interface depends on several chemical and physical processes. Among these are solubility, vapor pressure in the atmosphere, and the sea state. The simplest approach used in the calculation of air-sea exchange rates is the stagnant film boundary layer model (Broecker and Peng, 1974),

$$F_{C_2H_6} = - \frac{D}{h} (C_{C_2H_6} - C^*_{C_2H_6}) \qquad (1)$$

where D is the diffusion coefficient of ethane in the molecular film at the sea surface, h is the thickness of the layer in cm, and C* is the equilibrium concentration of ethane. Assuming average sea state conditions, the thickness of the molecular film would be approximately 50 μm. The diffusion coefficient of ethane at $4^\circ C$ is 0.7 x 10^{-5} cm^2 sec^{-1} (Witherspoon and Bonoli, 1969). In order to evaluate C*, the partial pressure of ethane in the atmosphere must be known together with an estimate of the Bunsen coefficient. Since neither of these is accurately known, we will assume that the equilibrium concentration is less than 0.2 nl/l (see Figure 6.12), although it is probably much less. Choosing a mean surface concentration of ethane of 2 nl/l, the flux of ethane across the air-sea interface is 3.4×10^{-6} ng cm^{-2} sec^{-1}. Estimating a plume area of 7.2×10^{12} cm^2, the integrated flux is computed to be .025 g sec^{-1}. This value is only 2% (.025/1.6) of the tidal flux. The transport estimates for methane and ethane are summarized below.

Table 7.1 Transport rates of methane and ethane from upper Cook Inlet

	Tidal	Mean Flow[1] g sec^{-1}	Air-Sea Exchange
Methane[2]	400	0.8	6.3
Ethane	1.6	.003	.025

[1] Derived by assuming that net transport of water is equal to freshwater input.

[2] Calculated on the basis of a 250-fold increase in concentration over that of ethane.

The summary reflected in Table 7.1 shows that tidal exchange through The Forelands is the dominant removal mechanism of dissolved hydrocarbons originating in upper Cook Inlet. If we assume that the transport of ethane southward through The Forelands is equal to the amount introduced at the point source in Trading Bay, then the seep is producing approximately 25 tonnes yr^{-1} of dissolved ethane. Because air-sea exchange and biological consumption appear to be inconsequential processes in the removal of ethane in upper Cook Inlet, hydrocarbons appear to be a quasi-conservative tracer of water movement. From an inspection of Figures 6.12 and 6.18, ethane can be traced in a highly turbulent mixing regime for distances up to 100 km (Cline and Feely, 1977).

On the basis of two detailed surveys, the locus of the seep appears to be in shallow water ($Z < 20$ m). At these depths, gas bubbles rising from the bottom will probably be large, thus inefficiently transferring hydrocarbons to the dissolved state. If the exchange is via bubbles, we do not know their size. However, Schink et al. (1971) have shown, on the basis of a simple stagnant film bubble model, that little gas is actually exchanged when the water depth is shallow. For example, a bubble of gas, 0.5 cm dia., will loose only about 0.2% of its weight per meter of water column traversed. Larger bubbles loose even less. Thus, we conclude that the seep in Trading Bay may be venting most of the gaseous hydrocarbons to the atmosphere.

The residence time of ethane and other hydrocarbons can be estimated on the basis of water exchange through The Forelands. We ignore freshwater input. In an above calculation, we estimated the flood tide transport at approximately 6×10^5 m^3 sec^{-1}. The volume of water contained between The Forelands on the south and the North Foreland is approximately 3.6×10^{10} m^3, assuming a mean depth of 18 m. Dividing the volume by the rate one obtains a residence time of only 17 hours, or three tidal cycles. We also did not take into account the increase in sea level at The Forelands due to tides, which has the effect of increasing the transport through The Forelands.

Clearly, hydrocarbons introduced into upper Cook Inlet are going to be rapidly dispersed and flushed from the system.

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DISTRIBUTION AND DYNAMICS OF HEAVY METALS IN ALASKAN SHELF ENVIRONMENTS SUBJECT TO OIL DEVELOPMENT

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March 31, 1979

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ACKNOWLEGMENTS

The work reported here is the result of the dedicated efforts of Tom Owens, Donna Weihs and Christine Cremo at the University of Alaska and of Dr. H. V. Weiss of the Naval Ocean Systems Center, San Diego.

I. SUMMARY

During the current 1978-79 contract period we have completed the remaining assigned baseline work in the Beaufort Sea and in Cook Inlet, and the principal objective of this year's work has been to pursue several process studies in selected estuarine areas adjacent to the shelf base areas. We have repeatedly emphasized the particular chemical sensitivity of the estuarine and nearshore areas and the consequent need for long-term research projects on the reaction and transport of heavy metals in these environments. As part of this latter program we have also continued our work on the uptake and transfer of heavy metals by natural marine sediment bacteria populations.

II. INTRODUCTION

A. General Nature and Scope of Study

The primary objective of this program is to research natural pathways of potentially toxic heavy metals to and through Alaskan Shelf and coastal marine biota (with emphasis on commercially important benthic species) and hence to determine and predict changes likely to result from oil industry activity in this marine zone. Ancillary components of this work include: (1) characterizing the heavy metal inventories of the water, sediment and indigenous biota in those geographical areas for which no background data exist; (2) determining non-biological pathways (rates and routes under both natural and stressed conditions) of the heavy metals as these affect the availability of metals to the organisms; (3) toxicity effects of selected heavy metals to animals which are of major commercial importance under Alaskan environmental conditions.

B. Specific Objectives

i. Continuation of baseline survey work in Lower Cook Inlet,

ii. Work on sediment-water exchange and reactions in NEGOA specific study sites,

iii. Continuation of baseline survey work in the Beaufort Sea,

iv. Laboratory studies on microbial remobilization of heavy metals at the sediment-water boundary.

C. Relevance to Problems of Petroleum Development

Apart from some continuing baseline survey work, this program addresses basic problems in heavy metal cycling in estuarine and nearshore areas. This work is an essential prerequisite to an understanding of the changes likely to be induced in the natural system by thorough large scale energy development impingements.

III. CURRENT STATE OF KNOWLEDGE

The general state of knowledge regarding heavy metal transport and reaction in the nearshore marine environment has been considered in previous Annual Reports and is also the subject of a review currently being prepared by the author (Burrell, 1979). More recent work specifically related to the objectives considered this year are referred to as appropriate in the body of this text.

IV. STUDY AREAS

A. Gulf of Alaska

The NEGOA specific study sites worked on during this year has been Yakutat Bay (Fig. 1).

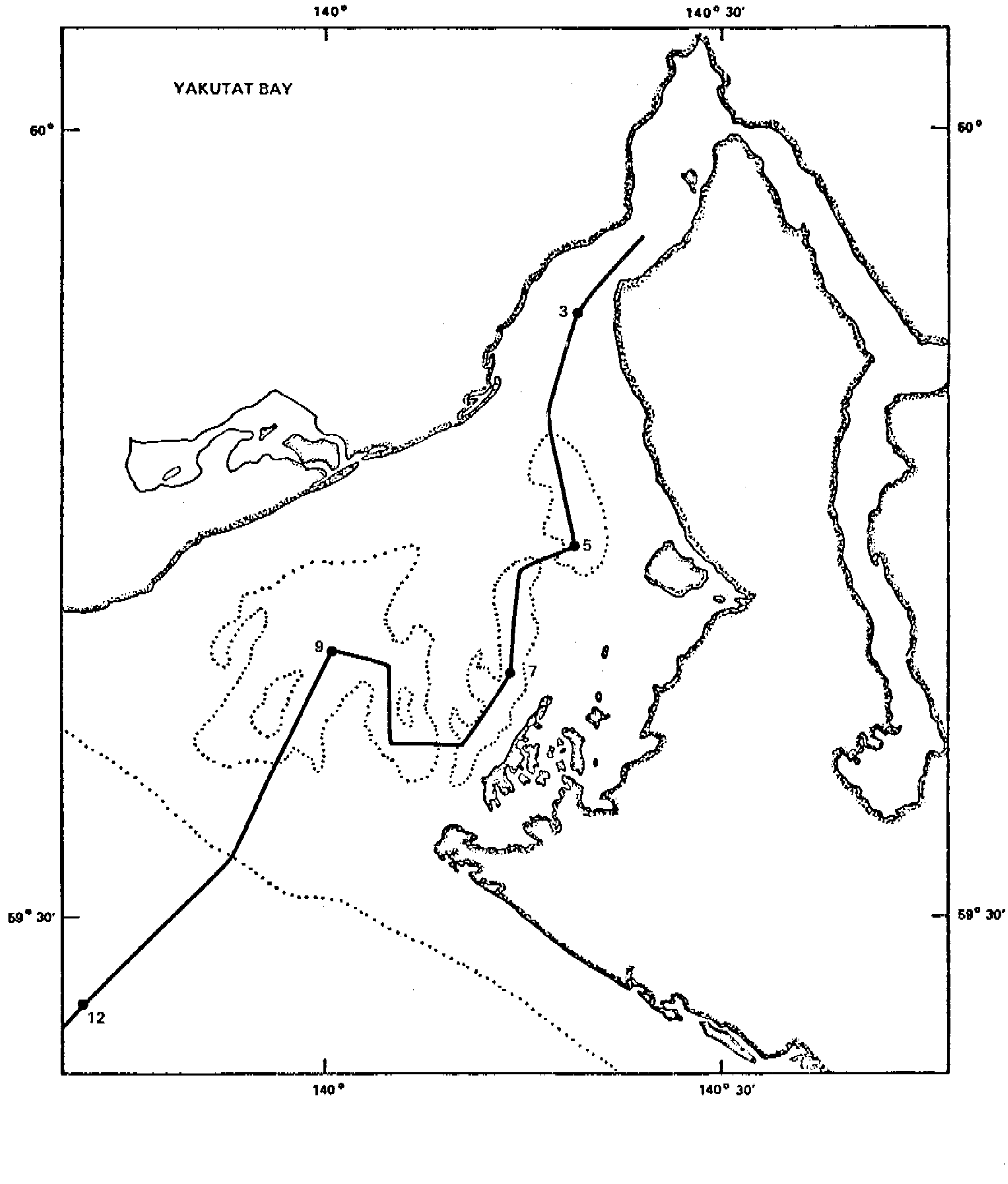


Figure 1. NEGOA specific study site: Yakutat Bay.

B. Lower Cook Inlet

No systematic grid has been established in this lease area. We have attempted wherever possible to tie in with changing benthic biology programs. Several tidal stations were specified for inter-laboratory occupation by OCSEAP Boulder. The specific study site for this lease area has been the adjacent Resurrection Bay (Fig. 2). *Macoma balthica* samples for some of the aquaria experiments have been collected from Katchemak Bay.

C. Bering and Chukchi Seas

The standard sampling grids in the S. Bering Sea and in Norton Sound were described in previous reports.

D. Beaufort Sea

Work on the Beaufort Sea lease area has been performed under subcontract and will be the subject of a later report.

V. FIELD AND LABORATORY ACTIVITIES

A. Field Work, 1978-79

1. Lower Cook Inlet
   OSS *Surveyor*, 27-31 March 1978
   Personnel: Donna Weihs

Further winter collection of subtidal benthic species. These samples were collected *via* trawl in cooperation with the benthic biology program. A few grab samples were also retained but those are, of course, not to be used for heavy metal analysis. Samples collected are listed in Table I. Additional five samples of the intertidal *Macoma balthica* were subsequently collected at the termination of the cruise for laboratory aquaria experiments.

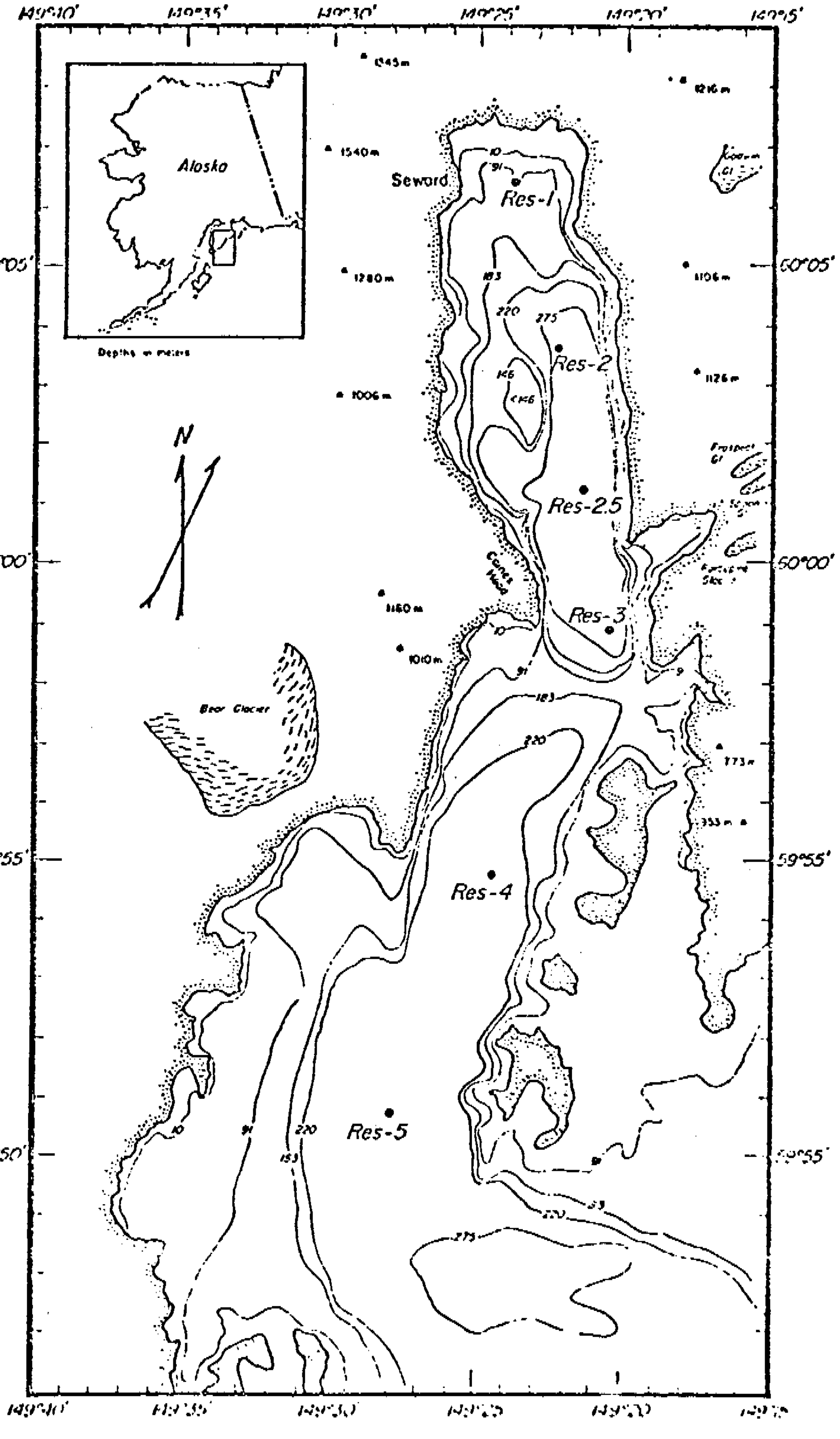


Figure 2. Resurrection Bay specific study site.

TABLE I

LOWER COOK INLET OSS *SURVEYOR*
27-31 March 1978
Biota Samples Collected for Heavy Metal Analysis

Station No.	Trawl	Sample No.	Species	Sex	Size (mm)	Wt (g)
5		a	tanner crab	F		
		b	tanner crab	F		
		c	*Neptunea*			
		d	Greenland cockles			
8		a	tanner crab	M		
		b	tanner crab w/eggs	F		
18		a	tanner crab	M		
		b	yellow finned sole			
23		a	tanner crab	F		
	radial trawl E	1	tanner crab	M		
		2	tanner crab	M		
		3	*Crangon*			
		4	*Pandalus* shrimp			
T3	radial trawl NE	a	King crab	F		
		b	tanner crab	M		
		c	rock sole			
56A		1	tanner crab	M		
		2	tanner crab	M		
		3	tanner crab	M		
		4	tanner crab	M		

TABLE I (CONT'D)

Station No.	Trawl	Sample No.	Species	Sex	Size (mm)	Wt (g)
		5	sponges			
		6	*Pandalus* shrimp			
		7	*Modiolus* mussel			
62A	2	1	*Pandalus* shrimp			
	7	a	*Pandalus* shrimp			
		b	*Crangon*			
	8	1	King crab	M		
	9	2	tanner crab	M	84	140
		3	tanner crab	M	105	350
		4	tanner crab	M	102	
		5	tanner crab	F	95	230
	10	6	tanner crab	M	109	
		7	tanner crab	M	102	
		8	tanner crab	M	93	260
	11	10	tanner crab	M	115	520
		11	tanner crab	M	106	390
		12	tanner crab	M	95	250
		13	tanner crab	M	97	290
	12	14	tanner crab	M	98	
		15	tanner crab	M	106	
	13	a	tanner crab	M	105	350
		b	tanner crab	M	112	454
		c	tanner crab	M	99	290

TABLE I (CONT'D)

Station No.	Trawl	Sample No.	Species	Sex	Size (mm)	Wt (g)
		d	tanner crab	M	109	
		e	tanner crab	F	86	140
		f	tanner crab	F	94	200
	14	a	tanner crab	F	90	200
		b	tanner crab	F	86	
		c	tanner crab	M	108	420
		d	tanner crab	M	118	538
56		1	*Pandalus* shrimp			
45A		1	rock sole			
43A		1	rock sole			
38A		1	*Pandalus* shrimp			
37		1	coon stripe shrimp			
		2	herring			
38		a	sole			
48		1	coon stripe shrimp			

Sample localities for benthos and sediment samples taken on this cruise are given in Table II and shown in Fig. 3.

2. Resurrection Bay
   R/V *Acona* No. 260, 23-24 April 1978
   Personnel: D. C. Burrell
   T. Owens
   D. Weihs

Spring survey of hydrography, nutrient distribution and other chemical parameters as shown in Table III. The primary objective of this cruise was to research the distribution and flux of metals across the sediment-water interface. Closely spaced water column and interstitial water samples were taken.

Fig. 4 gives the stations occupied on R/V *Acona* cruise No. 260.

3. Lower Cook Inlet
   OSS *Discoverer*, 4-16 May 1978
   Personnel: D. Weihs
   T. Owens

The primary purpose of this cruise was to collect the samples for heavy metal analysis on the two time series stations as requested by OCSEAP Boulder. Operations are given in Table IV.

The two time series stations occupied on the May 4-16 cruise are shown in Fig. 5.

4. Resurrection Bay (Lower Cook Inlet Project)
   R/V *Acona* No. 262, 10-11 July 1978
   Personnel: T. Owens
   M. Robb
   D. Weihs

TABLE II

LOWER COOK INLET OSS *SURVEYOR*
27-31 March 1978

Station No.	Location		Depth (m)	Sample type
5	59°00	152°42	172	Trawl
8	59°00	153°24	137	Trawl
18	59°10	153°49	50	Trawl, grab
23	59°16	152°50	91	Trawl, grab
25	59°16	153°09	58	
E	from St. Augustine			Trawl
T_3	NE of St. Augustine			Trawl
NS	N of St. Augustine			
56A	59°33	152°14	33	Trawl
62A	59°50	152°57	25	Trawl
56	59°37	153°02		Trawl
47A	59°27	152°45	66	Grab
45A	59°27	152°26	56	Trawl, grab
43A	59°17	152°06	78	Trawl, grab
42			47	Grab
41				Grab
38A			50	Trawl
37			53	Trawl
38			66	Trawl
48			33	Trawl
56B				Grab

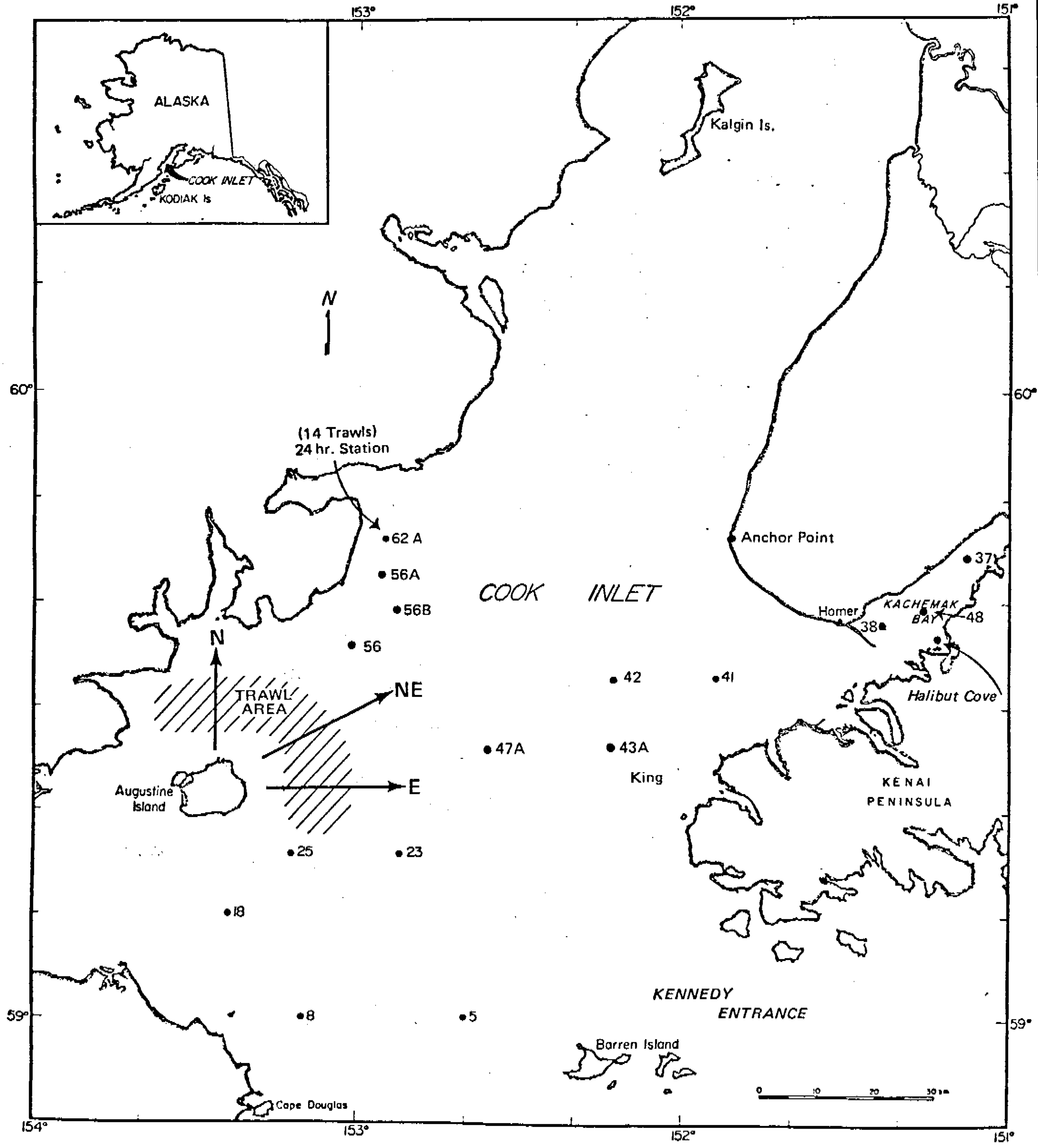


Figure 3. Stations occupied on OSS *Surveyor* cruise, Lower Cook Inlet, March 27-31.

TABLE III

RESURRECTION BAY
R/V *Acona* 260, 23-24 April 1978
Operations

Station	Depth (m)	Operations
Res 5	267	Hydro, SPD
Res 4	263	Hydro, STD
Res 3.5	195	STD
Res 3	292	Hydro, STD
Res 2.5 A	285	STD
Res 2.5 B	285	STD
Res 2	193	Hydro, STD
Res 2.5	288	Hydro, STD, T.M., vertical and horizontal tows, benthos cores
Res 1		STD
Res 4	260	STD
Res 2.5	289	STD

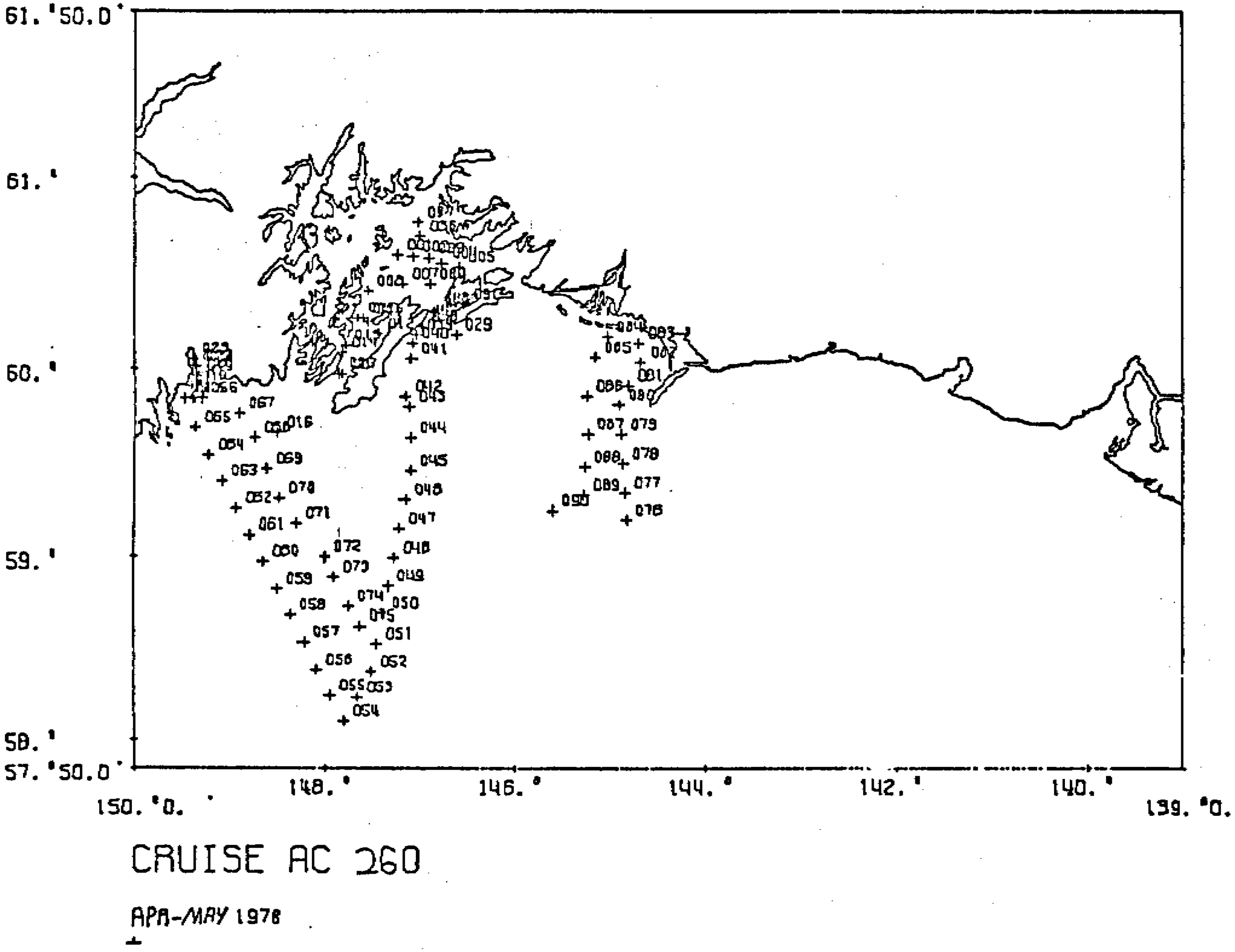


Figure 4. R/V *Acona* Cruise No. 260, April-May 1978.

TABLE IV

LOWER COOK INLET
OSS *Discoverer*, 4-16 May 1978
Operations

Date	Time	Cd Samples		Doc/Poc	Plankton	NAA water samples
		F	UF			
A. Station CB 7 59°33.3'N, 151°40.0'W 48 hour time series station Kachemak Bay (47 m)						
5-7	0	X	X	X	X	X
	6	X	X	X		X
	12	X	X	X	X	X
	18	X	X	X		X
5-8	24	X	X	X	X	X
	30	X	X			X
	36	X	X		X	X
	42	X	X			X
5-9	48	X	X		X	
B. Station CB 9 69°30.0'N, 152°10.0'W 48 hour time series station Redoubt Bay (50 m)						
5-12	0	X	X	X	X	X
	6	X	X	X		X
	12	X	X	X	X	X
	18	X	X	X		X
5-13	24	X	X	X	X	X
	30	X	X			X
	36	X	X		X	X
	42	X	X			X
5-14	48	X	X		X	

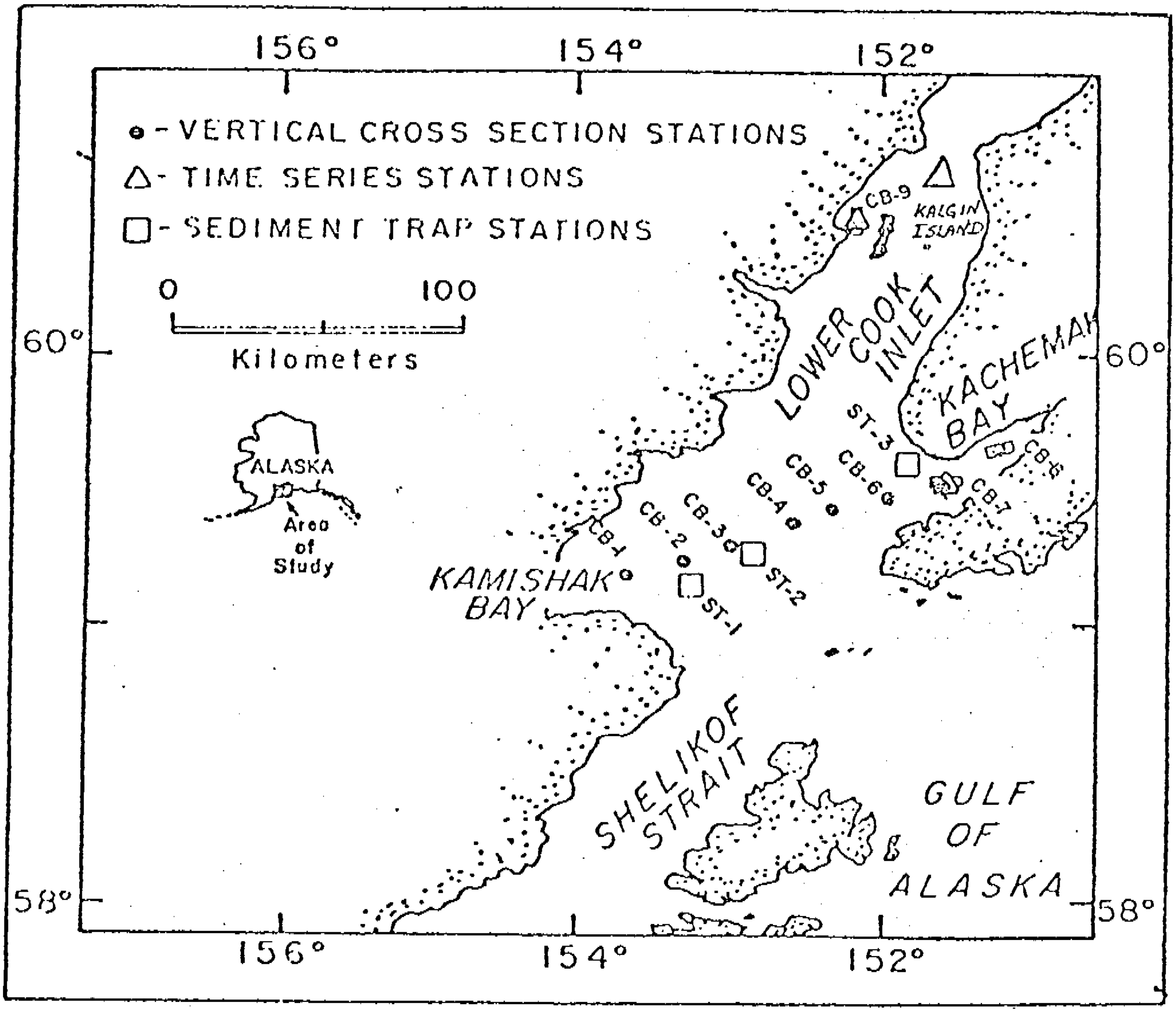


Figure 5. IMS-PMEL Sampling Grid

Summer survey of hydrography, nutrient distributions and other chemical parameters as shown in Table V. The primary object of this cruise was to research the distribution of heavy metals in the water column as related to suspended sediment load, nutrient distributions, dissolved and particulate organic carbon, etc. The overall aim, as for previous cruises, is to research the factors which determine the flux of heavy metals to and from the sediments and hence to predict the effects of anthropogenic perturbations of the natural system.

5. Lower Cook Inlet
OSS *Discoverer* 29 August-2 September 1978
Personnel: D. Weihs
M. Robb

The primary purpose of this cruise was to collect the samples for heavy metal analysis at the single time series station requested by OCSEAP Boulder. Operations as given in Table VI.

A second major objective of this sampling trip was to obtain fresh supplies of live *Macoma balthica* for use in the aquaria metal uptake experiments.

6. Resurrection Bay (Lower Cook Inlet Project)
R/V *Acona* No. 267, 9 October 1978
Personnel: D. C. Burrell
T. Owens
M. Robb
D. Weihs
C. Cremo

Full survey of hydrography, nutrient distributions, and other chemical parameters is shown in Table VII. Closed spaced water column

TABLE V

RESURRECTION BAY
R/V *Acona* No. 262, 10-11 July 1978
Operations

Station	Depth (m)	Operations
Res 2	223	Hydro, STD, Spectrex, nutrients
Res 5	264	Hydro, STD, Spectrex, nutrients
Res 4	257	Hydro, STD, Spectrex, nutrients
Res 3	289	Hydro, STD, Spectrex, nutrients
Res 2.5	287	Hydro, STD, Spectrex, Part. load, TM, POC, DOC, nutrients

TABLE VI

LOWER COOK INLET
OSS *Discoverer*, 29 August-2 September 1978
Operations

Station	Hours	Operations
CB 10	0	TM Poc Doc
	6	TM Poc Doc
	12	TM Poc Doc
	18	TM Poc Doc
	24	TM Poc Doc

TABLE VII

RESURRECTION BAY
R/V *Acona* 267, 9 October 1978
Operations

Station	Depth (m)	Operations
Res 2.5	287	Water column samples: T, S, O_2, nutrients, POC, DOC, SL, particulate sediment sizing, sampling for dissolved Ca, Cu, Mn and V and particulate Al, Mn and V. Benthos core: Interstitial H_2S, SO_4, TM, Cl, alk, DOC, Eh, pH, samples for dissolved Ca, Mn, Cu. Sediment samples retained for size analysis, POC, chemical extracts for TM.
Res 4	261	T, S, O_2.

and interstitial water samples were taken. The primary objective of this cruise was to research the distribution and flux of metals across the sediment-water interface.

7. Resurrection Bay (Lower Cook Inlet Project)
R/V *Acona* No. , March 1979
Personnel: T. Owens
M. Robb
D. Weihs
S. Sugai

Hydrography, nutrient distributions and other chemical parameters as previously. The principal objectives of this cruise were (1) to obtain close interval interstitial water samples to better define the gradients at the sediment-water boundary, (2) to obtain interstitial water samples for characterization of organo-metallic complexes, (3) to set a sediment trap at RES 2.5.

B. Field Collection Methods

No major changes from the methods given and discussed in detail in the 1977-78 Annual Report.

C. Laboratory Analysis Program

1. Hydrography

Hydrography was determined on all R/V *Acona* cruises *via* shipboard STD system with tape storage and discrete Nansen bottle calibrations. Two sets of measurements were taken. At all stations continuous profile STD data were obtained; at designated "chemistry stations" discrete values were obtained at standard depths.

The Institute of Marine Science employs a Plessey Environmental Systems 9040 STD system (S.N. 5341) for vertical profiling of temperature and salinity. During a cast, S, T and D are sampled five times per second and are recorded digitally on magnetic tape and on analog chart paper. The analog trace is for backup and field use; the magnetic tape is processed to yield high quality data.

The STD system is capable of high precision but relatively less accuracy unless field corrected using Nansen bottles for discrete samples. When thusly corrected, the accuracy is dependent on standard techniques for determining temperature and salinity. The generally accepted accuracy for temperature using deep sea reversing thermometer is within ± 0.02°C and that for salinity using a bench salinometer is within ± 0.02°/$_{oo}$.

The STD system is recalibrated every two years against standards traceable to NBS. Field corrections are determined separately for each cruise base on discrete samples. Thermometers are calibrated at least every two years and the bench salinometers are calibrated on an irregular basis. Records of field corrections are kept to monitor STD function.

StandardSTD data products are listings of S, T and Sigma-t at selected depths, vertical profiles for S, T and Sigma-t (one meter average), horizontal sections of S and T with respect to depth, and time series S and T with depth at a fixed location. Since the final data is retained in one meter averages, it is readily available for any other processing as is required.

2. Dissolved oxygen analysis

The dissolved oxygen contents of discrete water samples are determined using the Chesapeake Bay Institution microburet modification of the Winkler titration (Carpenter, 1965). Samples are drawn from the Nansen Bottles into calibrated BOD-type bottles in the usual fashion. One ml each of 3M $MnCl_2$ and the Na OH/Na I (8N and 4M respectively) are added to preserce the oxygen contents. Analysis consists of acidification with 10N H_2SO_4 and titration against 0.2M sodium thiosulfate using a Gilmont micropipet-buret. Standardization is against KIO_3. The precision of this method is about ± 0.05 ml O_2/ℓ (see discussion by Carritt and Carpenter, 1966).

3. Nutrient analysis

Nutrients are determined using Technicon Autoanalyzer procedures based on the manual methods of Murphy and Riley (/967) for reactive phosphorus and Armstrong, Sterns, and Strickland (1967) for dissolved silicon, nitrite. Ammonia is measured by the phenol-hypochlorite method of Koroluff (1970), as adapted by Shawyk and MacIssac (1972).

Ammonia: Ammonia is determined by the Berthelot reaction in which hypochlorous acid and phenol react with ammonia in aqueous alkaline solution to form indophenol blue, an intensely blue chromophore with an absorption maximum at 637 nm.

Orthosilic Acid: Orthosilic acid is determined by its reaction with molybolate in aqueous acidic solution to form silicomolybdic acid. In this procedure stannous chloride is used to reduce silicomolybdite acid to the heteropoly acid which has an absorption maximum at 820 nm.

Nitrate, Nitrite, Nitrite: Nitrite is determined by the Greiss reaction in which sulfanilamide and N-(1-naphthyl) ethylenidiamine dihydrochloride (NNED) reacts with nitrite in aqueous acidic solution to form an intensely pink diazo dye with an absorption maximum at 570 nm. Nitrate, after it is reduced to nitrite by passage through a column containing copperized cadmium filings, is determined in an identical manner. Thus, the sum of nitrate plus nitrite is determined in the nitrate procedure.

Orthophosphate: Phosphate is determined as phosphomolybdic acid which in its reduced form in the presence of antimony has an absorption maximum at $\simeq$ 880 nm.

4. Dissolved and particulate organic carbon

This procedure is a modification of the method of Strickland and Parsons (1968) as developed by Loder (1971) and outlined by the Oceanography International Corporation for use with their total carbon system. Two prepared glass fiber filters (Gelman AE, 42 mm, 0.45 μ, prebaked at 500°C for 4 hrs) are placed on a standard Millepore vacuum filter apparatus and approximately 1 ℓ of seawater is filtered. If samples are held for longer than one hour $HgCl_2$ is added (final concentration $\sim 10^{-5}$M Hg^{++}) to retard biological activity. The filters are placed in separate 10 ml ampules (prebaked at 500°C for 4 hrs) containing 0.2 gm $K_2S_2O_8$, 0.25 ml of 6% H_3PO_4 and 5 ml of deionized-triple distilled water are added to this. Two 5-ml aliquots of the filtrate are placed in 10 ml ampules containing 0.2 gm $K_2S_2O_8$ and 0.25 ml of 6% H_3PO_4 and all four ampules are flushed with purified oxygen to remove CO_2 and flame sealed for future analysis. On each cruise reagent blank ampules are prepared. These consist of an ampule with 0.2 gm $K_2S_2O_8$ and 0.25 ml of 6% H_3PO_4 with various volumes of water. Standards are prepared using the same reagents plus dextrose to give carbon concentrations over the range 0.0-3.2 mg C/ℓ for DOC and 0.0-2560 μg C/ampules for POC. The water used in this process is deionized-triple distilled which contains around 0.8 ng C/ℓ. The ampules are baked in a pressure bomb at 175°C for 24 hrs to oxidize the organic material to CO_2. After cooling to room temperature, the samples are analyzed using a Beckman IR (Model 1215) and recorded on a Sargent recorder equipped with a disc integrator. Standards are plotted as integration units *vs.* carbon concentration with the integration of 0.0 mgC taken as zero. The reagent blank is the value of a linear regression line through the points of integration units *vs.* volume for the reagent blank ampules. The DOC value is the carbon concentration corresponding to the value of the sample integration units minus the reagent blank on the DOC standards graph. The POC value in the carbon concentration corresponding to the integration units of the sample filter minus the integration units of the blank filter of the POC standards graph divided by the volume of the filtered water.

5. pH, alkalinity, Eh

Determination of pH in the core was accomplished by insertion of a semimicro combination pH electrode in the sediment. Eh was measured at the same time using a combination platinum electrode. Both measurements were made on freshly extruded core material under a N_2 atmosphere.

For determination of alkalinity, the second end point of the carbonic acid system is assumed to be a good measure of total alkalinity (Gieskes and Rogers, 1973). pH is measured after small increments of HCl are added to the interstitial water. The end point was determined from a plot of pH versus volume of acid added. The determination of alkalinity was performed on samples which were frozen after collection.

6. Copper and manganese in seawater *via* neutron activation analysis (H. V. Weiss)

Copper in seawater, collected as specified elsewhere, was determined according to the procedures given in Weiss *et al.*, (1979).

Manganese was also basically determined *via* this neutron activation method except that the radiochemical steps were less exhaustive. After irradiation the oxirate was treated with 10 ml of conc. HNO_3 and Mn carrier and then evaporated to dryness. The residue was dissolved in 50 ml of 20% HNO_3, the solution was warmed and MnO_2 was precipitated upon addition of potassium bromate. This single decontamination step yielded a product free of interfering radioisotopes.

7. Soluble vanadium *via* NAA (H. V. Weiss)

The procedure is given in detail in the 1977-78 Annual Report.

8. Biota analysis

Samples are prepared so as to reject any potentially contaminated surfaces then freeze dried. 0.5 I 0.02 g replicate portions of well ground tissue are weighed into watch glasses and ashed in a low temperature plasma ashing furnace (50w; 1.0 torr) for at least eight hours (as long as 48 hours may be required for some samples using these settings). The ash is washed into a teflon digestion bomb with 3 ml Ultrex HNO_3. The bombs are then wrapped in plastic to prevent contamination from the bath and held in a 90°C water bath for a further eight hours. At the end of this period the bomb contents are rinsed into a 40 ml glass stoppered centrifuge tube using approximatley 20 ml triple distilled water, 1 ml of 30% H_2O_2 is added and the sample is diluted to 25 ml. These solutions are then analyzed *via* carbon furnace or flame atomin absorption depending on the expected concentration range of the element.

All glassware used in soaked for 8 hours in Nochromix--a trace metal free cleaning agent--and then rinsed three times with 10% HCl and three times with triple distilled water. All pastic ware is soaked in 10% HCl for al least one week then rinsed three times with triple distilled water.

The standard curves run with each batch are prepared by adding standards to a matrix prepared in bulk for each type of tissue sample. No standards are made in such a way as to dilute the matrix. At least three separate standard concentrations are prepared and standard lines computed *via* a linear regression program with rejection of points clearly outside the linear range. NBS standard samples are carried through with each batch of samples to monitor accuracy.

9. Particulate load

Particulate load (suspended sediment) determination are determined using a modified Strickland and Parsons (1968) procedure. We incorporate a blank determination with every measurement.

Two preweighed 0.4 μm Nuclepore filters (47 mm), are placed on a standard Millepore vacuum filtering apparatus and approximately one liter of seawater is filtered shipboard, followed by 10 ml of distilled water to wash salt from the filters. The filters are then stored until they can be reweighed in the laboratory. The volume of the filtered seawater is recorded. The particulate load is the increase in the weight difference of the two filters divided by the volume of seawater filtered. The filters are dried to a constant weight of 60°C for 12 hrs prior to weighing. This procedure is carried through in duplicate for all samples.

10. Nephelometer profiling

The nephelometer functions through a fourth channel on the STD system but is processed in a different manner as no convenient standard or means of standardization is presently available. A range selector is located on the underwater unit which allows the user to alter sensitivity. Ideally the unit is set so that a definite background is obtained upon which is superimposed maxima and minima; at present, the final data is retained in percent of full scale. Discrete samples are obtained to assist in interpretation of netheloid porfiles. Nepheloid concentration may be listed and plotted in the same fashion as temperature, salinity and Sigma-t.

11. Al, Mn and V content of seawater particulates (H. V. Weiss)

The aluminum, manganese and vanadium content of particulates isolated from seawater are quantitatively determined by instrumental neutron activation analysis.

The nucleopore membrane filter containing the particulate deposit is folded and placed at the bottom of a snap-top polyethylene (PE) vial. Standards of these elements are prepared by placing a small volume of standard solution (50 to 100 ul) on a disc of absorbent filter paper similarly placed in a vial and the liquid is vaporized at room temperature. Samples and standards are compressed and maintained in position with a PE spacer. They are then irradiated sequentially in the pneumatic tube facility of the University of California, Iraine TRIGA Mark I reactor at 250 kW for 1 to 3 minutes. The thermal neutron flux at this power level in the reactor position is 3×10^{12} neutrons$\cdot$cm$^{-2}\cdot$sec^{-1}. Following the irradiation the sample is allowed to decay (usually 30 sec) and then counted (1 to 3 minutes) above a Ge(Li) detector coupled to a 4096-channel pulse height analyzer. The irradiation, decay and count times are adjusted according to the activity levels encountered. The dead time is recorded at the beginning as well as several seconds before the end of the counting interval.

After counting, the pulse height data are either transferred to magnetic tape for subsequent processing or the photopeaks of Al^{28} (1779 keV) Mn^{56} (847 keV) and V^{52} (1434 keV) are immediately printed out. The net area is quickly computed using the PDP-8 computer of the system. The counting rate of of the sample photopeak is compared with that of the standard after each is corrected for the average fractional dead time, where the irradiation time, delay time and counting period are the same for both. From these data and the value of the standard the quantity of element in the sample is computed.

12. Sediment size analysis

Two complementary techniques have been used for the sediment grain size analysis. The size fraction larger than 4 ϕ (62.5 μm) was dried and passed through a battery of sieves of decreasing 0.5 ϕ mesh using a Ro-tap shaker. After shaking the sediment on each screen was transferred to pre-weighed beakers for determination of the amount of material in each size class.

The less than 4 ϕ fraction was transferred to 1 ℓ volumetric cylinders in a 27°C water bath. Aliquots were extracted by pipette at different times and depths according to standard technique based on Stokes Law assuming a density of 2.65 in this case Calgon (2.5 g/ℓ) was used as a dispersant to present floculation. The above general analytical scheme was prefaced by a peroxide treatment to destroy organic matter.

Size class data were plotted in the normal way to give cumulative curves and the statistical parameters computed according to the methods of Folk (1968).

13. Revised procedure for obtaining standardized chemical extracts from sediments

At the beginning of the OCS program we utilized the method of Chester and Hughes (1967; 25% ,cetic acid + 1 M hydroxylamine hydrochloride) to obtain a single extract for heavy metal analysis. This procedure removes acid leachable and reducible metals and is widely utilized. Later in the program we received a BLM mandate to standardize with other BLM-OCS operations in the contiguous states and hence to use a 25% acetic acid extract only. This current contract period we have cooperated with PMEL to devise and utilize yet a third standardized scheme. This leaching procedure, details of which are given below, is based on that of Malo (1977) and involves a two-step procedure to (a) release metals organically bound and (b) weakly bound inorganic associates.

Details of the method used in our laboratory follow. The starting material is freeze dried sediment.

a. H_2O_2 extraction:

  i. Place triplicate 0.5 g sub-samples into 50 ml poly centrifuge tubes.

  ii. Add 5 ml 10% Ultrex H_2O_2 and heat in 50°C water bath for 48 hrs.

  iii. Centrifuge at 1500 rpm for 1 hr and decant supernatant into tared 50 ml capped plastic beakers.

  iv. Add 5 ml H_2O to pellet, repeat from step (iii) twice more combining supernatants.

  v. Approximating volume of supernatants, acidify with Ultrex HCl to 0.3 N.

  vi. Weight solution to determine dilution and filter through 0.45 µm Nuclepore membrane into small plastic vial.

  vii. Analyze solution *via* atomic absorption.

b. 0.3 N HCl extraction:

   i. Add 5 ml Ultrex 0.3 N HCl to above pellet and heat on 90°C water bath for 30 min.

   ii. Centrifuge for 1 hr at 1500 rpm and decant supernatant into tared 50 ml capped plastic beakers.

   iii. Add further 5 ml aliquot of 0.3 N Ultrex HCl to pellet and repeat extraction step twice more combining supernatants.

   iv. Filter solution through 0.o5 HA Millepore membrane into small plastic vial and analyze *via* atomic absorption spectrophotometry.

14. Total sediment analysis

Approximately 0.1 g of dried and well ground sediment sample is weighed into a graphite crucible 0.5 g of lithium metaborate is added and the powders well mixed. The crucible is held in a muffle furnace 1050°C for 15 minutes. The resulting fusion pellet is stirred with approximately 30 ml of 4% HNO_3 with 2-4% H_2O_2. The peroxide solution maintains an oxidizing environment and helps prevent flocculation of silica gel. The resulting solution is diluted to 50-100 mls depending on sample and analyzed *via* atomic absorption.

The graphite crucibles are cleaned by heating at 500°C for circa 30 minutes.

VI. RESULTS

A. Lower Cook Inlet

Additional data for epibenthic data for samples collected on the 3-17 November 1977 *Surveyor* cruise are given in Tables VIII-X. (Station locations shown in Fig. 6.) and Tables XI and XII.

TABLE VIII

LOWER COOK INLET
OSS *Surveyor*, 3-17 November 1977
Heavy Metal Contents of Tanner Crab
(μg/g dry weight; mean of triplicate determinations)

Station No.	Tissue	Cd	Ni	Cu	Zn
40 g	eggs	<0.13	0.5[a]	13.1[a]	125[a]
	muscle	<0.13	0.6	26.7	200[a]
	gut	32.5	0.8	59.0	166
40 e	muscle	<0.13	<0.25	54.0	98
40 f	muscle	0.31	0.50	45.2	110
62 d	muscle	<0.13	0.50	54.0	118
35 a	muscle			78[a]	
41 b	muscle			57.5	
41 c	muscle			59.6	
41 d	muscle			46.2	
41 e	muscle			45.0	
41 g	muscle			43.7	

a = Single determinations

TABLE IX

LOWER COOK INLET
OSS *Surveyor*, 3-17 November 1977
Heavy Metal Contents of Biota (μg/g dry weight)

Station No.	Organism	Cd	Ni	Cu	Zn
B	sole	2.80	<0.25	0.49	28
41 a	King crab	<0.13	<0.25	61.0	175
40	Cockles		0.81	2.5	63
	Cockles		1.0	<1.3	65
	Cockles		1.8	29	-

TABLE X

LOWER COOK INLET
OSS *Surveyor*, 3-17 November 1977
Heavy Metal Contents of Tanner Crab (μm/g dry weight)

Station No.	Sample	Cd	Cu	Ni	Zn
5		0.10 ± 0.08	57.4 ± 0.6	Contam.	58 ± 12
41	B	0.45 ± 0.03	57.3 ± 3.0	"	70[a]
	C	0.45 ± 0.08	48.8 ± 7.3	"	28 ± 17
	D	0.57 ± 0.4	45.9 ± 2.0	"	22 ± 2
	E	0.6[a]	110.7[a]	"	132[a]
35	A	0.36 ± 0.3	85.5 ± 2.3	"	109 ± 6
	B	0.18 ± 0.1	72.3 ± 4.6	"	27 ± 9
62	C	0.4[a]	33.9[a]	"	37[a]
	F	0.22 ± 0.06	67.4 ± 4.0	"	66 ± 2
53	C	0.25 ± 0.05	28.7 ± 4.0	"	19 ± 3

a = Single determinations

TABLE XI

LOWER COOK INLET
OSS *Surveyor*, 27-31 March 1978
Heavy Metal Contents of Shrimp Parts (μg/g dry weight)

Station	Sample	Ni	Cd
G2A1	Humpy muscle	n.d.	0.43 ± 0.06
G2A2	Humpy eyes	-	0.07 ± 0.05
48	Coon stripe eyes		0.74 ± 0.32

TABLE XII

LOWER COOK INLET
OSS *Surveyor*, 27-31 March 1978
Heavy Metal Contents of Crab Muscle
(Triplicate analyses; μg/g dry weight)

Station	Sample	Cu	Ni	Cd
40 I	Leg muscle	43.0 ± 3.7	0.36 ± 0.01	0.09 ± 0.04
40 C	Body muscle	45.8 ± 3.9	0.54 ± 0.01	0.47 ± 0.05
5		105.7 ± 8.7	0.71 ± 0.01	0.23 ± 0.17
53 B		128.0 ± 3.0	0.59 ± 0.08	0.40 ± 0.30
40 C	Leg muscle	71.8 ± 6.8	0.52 ± 0.14	0.37 ± 0.15
62 A	Tanner crab muscle	-	0.45 ± 0.14	0.52 ± 0.13
62 A	King crab muscle	-	0.77 ± 0.40	0.16 ± 0.01

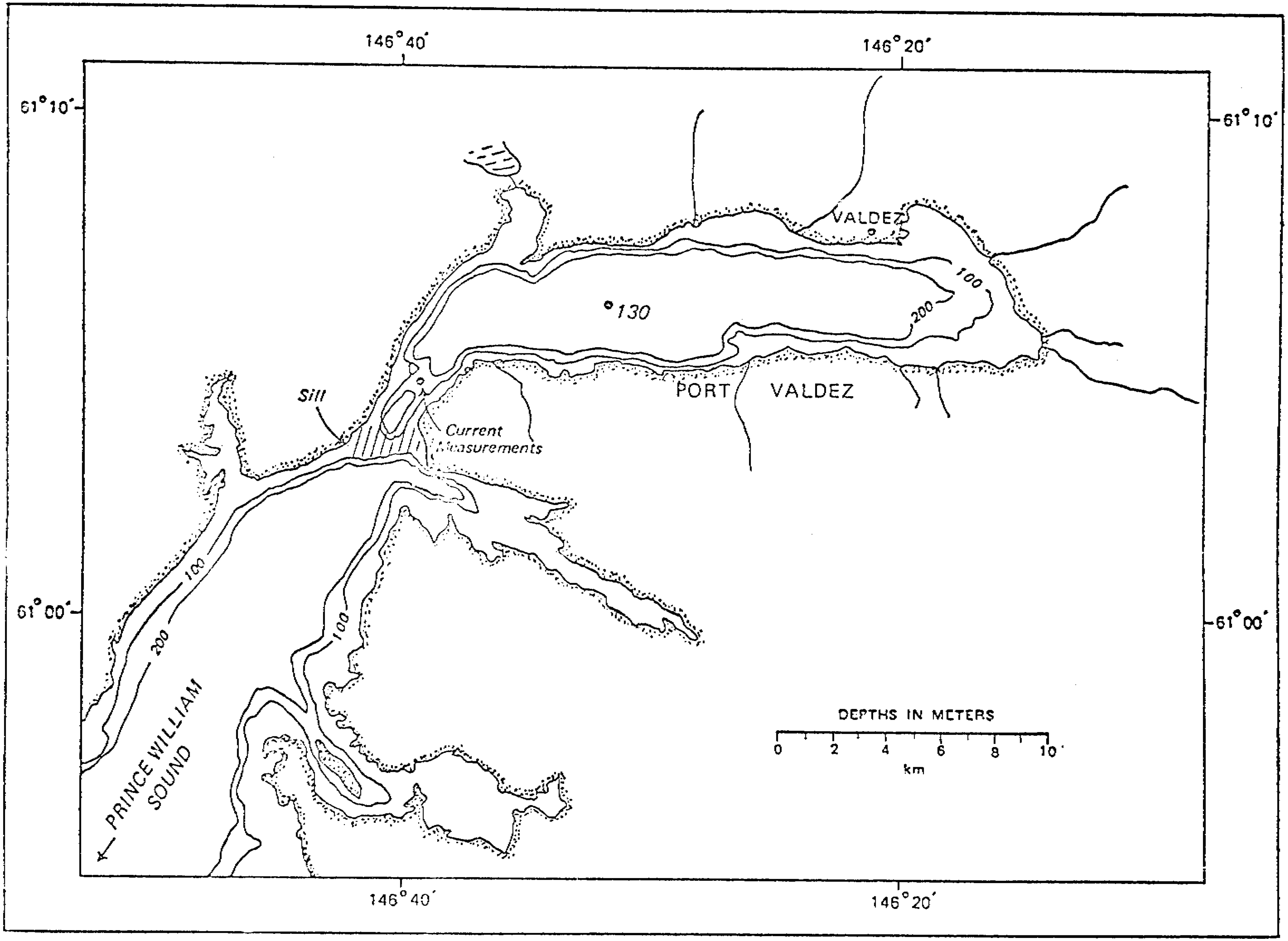


Table 6. Lower Cook Inlet, *Surveyor*, 3-17 November 1977.

Geochemical data for Stations CB-7 and CB-9 occupied on the 4-16 May 1978 *Discoverer* cruise are given in Tables XIII-XVI, and for the 29 August-2 September 1978 cruise in Tables XVII-XIX.

Sediment size data are given in Table XX and values for extractable metals in Tables XXI and XXII.

B. Yakutat Bay

Hydrographic data and vertical profiles for R/V *Acona* cruise No. 246 (July 1977) are given in Appendix I. Heavy metal distribution data additional to that reported in the previous Annual Report are discussed in the following section.

C. Beaufort Sea

[Data not available at time of preparation of report.]

D. Resurrection Bay

Hydrographic data and the corresponding vertical profiles for the period November 1977 through October 1978 are given in Appendix I. Dissolved oxygen and nutrient data for R/V *Acona* cruises 254 (December 1977), 260 (April 1978), 262 (July 1978) and 267 (October 1978) are given in Appendix II.

Seasonal suspended sediment load distributions at Station RES 2.5 are given in Table XXIV and corresponding data for dissolved and particulate organic carbon in Tables XXV-XXVII. The heavy metal contents of the particulate sediment at this station are shown in Tables XXVIII-XXIX

TABLE XIII

LOWER COOK INLET
OSS *Discoverer*, 4-16 May 1978
Particulate Sediment Geochemistry at Time Series
Station CB-7, Kachemak Bay

Hours	Depth	Particulate sediment (mg/l)	POC (µg/l)
0	surface		lost
0	deep		"
6	surface		"
6	deep		"
12	surface		"
12	deep		"
18	surface		"
18	deep		"
24	surface		"
24	deep		174
30	surface		
30	deep		
36	surface		
36	deep		
42	surface		
42	deep		

TABLE XIV

LOWER COOK INLET
OSS *Discoverer*, 4-16 May 1978
Particulate Sediment Geochemistry at Time Series
Station CB-9, Redoubt Bay

Hours	Depth	Particulate sediment (mg/l)	POC (μg/l)
0	surface		480
0	deep		>1320
6	surface		300
6	deep		1450
12	surface		310
12	deep		580
18	surface		520
18	deep		>1400
24	surface		670
24	deep		1270
30	surface		-
30	deep		-
36	surface		-
36	deep		-
42	surface		-
42	deep		-

TABLE XV

LOWER COOK INLET OSS *DISCOVERER*

4-16 May 1978

Water Column Chemistry at Time Series Station CB-7, Kachemak Bay

Heavy metal data by H. V. Weiss

Hour	Depth	Copper (μg/kg)	Mercury (ng/kg)	Manganese (μg/kg)	DOC (mg C/ℓ)
0	surface	0.52	29	0.58	> 3.80
0	deep	0.54	33	0.63	2.99 ± 0.04
6	surface	0.59	13	0.54	2.31 ± 0.31
6	deep	0.26	17	0.49	2.52 ± 0.36
12	surface	0.68	18	0.49	3.10 ± 0.09
12	deep	0.57	28	0.50	2.50 ± 0.18
18	surface	0.82	20	0.48	2.65 ± 0.26
18	deep	0.28	12	0.40	2.55 ± 0.10
24	surface	0.72	18	0.40	2.86 ± 0.10
24	deep	0.30	11	0.40	1.76 ± 0.02
30	surface	0.34	15	0.49	-
30	deep	0.28	11	0.46	-
36	surface	0.34	17	0.42	-
36	deep	0.35	15	0.41	-
42	surface	0.33	13	0.37	-
42	deep	0.42	13	0.39	-

TABLE XVI

LOWER COOK INLET OSS *DISCOVERER*
4-16 May 1978
Water Column Chemistry at Time Series Station CB-7, Redoubt Bay
Heavy metal data by H. V. Weiss

Hour	Depth	Copper (μg/kg)	Mercury (ng/kg)	Manganese (μg/kg)	DOC (mg C/ℓ)
0	surface	0.67	13	-	2.43 ± 0.26
0	deep	0.65	20	-	2.27 ± 0.42
6	surface	0.56	> 100		2.22 ± 0.55
6	deep	0.63	34	-	2.14 ± 0.13
12	surface	1.04	30	-	1.76 ± 0.17
12	deep	0.69	54	-	1.91 ± 0.10
18	surface	0.76	26	-	2.57 ± 0.84
18	deep	0.79	37	-	1.95 ± 0.34
24	surface	0.66	19	-	2.09 ± 0.07
24	deep	0.94	63	-	2.23 ± 0.36
30	surface	0.79	15	-	-
30	deep	0.72	9	-	-
36	surface	0.67	19	-	-
36	deep	0.65	14	-	-
42	surface	0.57	25	-	-
42	deep	0.81	25	-	-

TABLE XVII

LOWER COOK INLET OSS *DISCOVERER*
29 August-2 September 1978
Particulate Sediment Geochemistry at Time Series Station CB-10

Hour	Depth	POC (μg/ℓ)
0	surface	369[a]
0	deep	1500 ± 600
6	surface	303 ± 46
6	deep	>2700[a]
12	surface	867 ± 177
12	deep	>2700[a]
18	surface	153 ± 39
18	deep	2429 ± 8
24	surface	650 ± 43
24	deep	466 ± 32

TABLE XVIII

LOWER COOK INLET OSS *DISCOVERER*
29 August-2 September 1978
Water Column Chemistry at Time Series Station CB-10

Hour	Depth	DOC (mg C/ℓ)
0	surface	1.87 ± 0.23
0	deep	1.9
6	surface	1.73 ± 0.31
6	deep	1.3
12	surface	1.47 ± 0.07
12	deep	2.11 ± 1.08
18	surface	1.28 ± 0.29
18	deep	1.47 ± 0.42
24	surface	2.0
24	deep	1.20 ± 0.26

TABLE XIX

LOWER COOK INLET OSS *DISCOVERER*
29 August-2 September 1978
Soluble Heavy Metal Contents Station CB-10
H. V. Weiss, Analyst

Hour	Depth	Copper (μg/kg)	Mercury (ng/kg)
0	surface	1.02	29 ± 1
	deep	1.15	83 ± 1
6	surface	0.89	32 ± 1
	deep	1.01	42
12	surface	2.03	64 ± 2
	deep	2.68	85
18	surface	0.96	56 ± 9
	deep	2.00	65
24	surface	1.06	22 ± 1
	deep	0.81	40 ± 7

TABLE XX

LOWER COOK INLET OSS *SURVEYOR*
27-31 March 1978
Sediment Grain Size and Texture (< 1mm fraction)

Station	% Sand (weight)	% Mud (weight)	mean (ϕ)	Standard deviation (ϕ)	Sorting	Skewness	
43A	100	0	2.0	0.34	very well sorted	+0.13	fine skewed
45A	99.6	0.4	1.9	0.56	moderately well sorted	-0.12	fine skewed
47A	99.4	0.6	2.3	0.45	well sorted	-0.15	coarse skewed

TABLE XXI

LOWER COOK INLET R/V *ACONA*
21-26 June 1977
Heavy Metal Contents of Organic Matrix Extractions
of Surface Haps Core Samples (μg/g)

Station	Cu	Fe	Mn	Zn	Ni	Cd
CI- 6	6.0 ± 0.7	<1.5	1.1 ± 0.2	<0.6	<0.3	<0.3
CI-12	3.7 ± 0.6	<1.5	-	<0.6	<0.3	<0.3

TABLE XXII

LOWER COOK INLET R/V *ACONA*
21-26 June 1977
Heavy Metal Contents of Inorganic Matrix Extractions
of Surface Haps Core Samples (μg/g)

Station	Cu	Fe	Mn	Zn	Ni	Cd
CI- 5	15.2 ± 2.0	>6,000	239 ± 16	29 ± 8	5.1 ± 1.2	<0.08
CI- 6	31.9 ± 1.7	$> 10^4$	197 ± 57	48 ± 11	24.2 ± 4.8	<0.08
CI-12	-	>6,000	172 ± 50	15	-	<0.08

TABLE XXIII

LOWER COOK INLET
Biota Analysis-Accuracy Data

A. NBS standard # 1571 ordered leaves

Element	N	This study	Certified
Cd	2	0.09	0.11
Cu	2	8.9	12
Ni	2	1.5	1.3
Zn	2	33	25

B. NBS standard # 1577 Bovine liver

Element	N	This study	Certified
Cd	2	0.23	0.27
Cu	2	149	193
Zn	2	114	130

TABLE XXIV

RESURRECTION BAY (LOWER COOK INLET PROJECT)
Seasonal Suspended Sediment Load (mg/ℓ)
Station RES 2.5

Depth (m)	*Acona* 254 Dec. 77	*Acona* 260 April 78	*Acona* 262 July 78	*Acona* 267 Oct. 78
5	-	-	-	0.80
10	0.18 ± .01	1.32 ± .01	0.86 ± .02	-
25	-	-	-	0.30
30	0.18 ± .04	0.69 ± .02	0.85 ± .04	-
55	-	-	-	0.25
70	0.18 ± .03	0.43 ± .02	0.28 ± .005	-
110	0.16 ± .02	0.43 ± .02	0.78 ± .07	-
120	-	-	-	0.15
130	0.22 ± .02	-	-	-
150	0.45 ± .01	-	-	-
170	0.41 ± .04	0.52 ± .05	0.60 ±0.01	-
190	0.76 ± .07	0.49 ± .05	0.58 ± .01	0.30 ± .02
210	0.63 ± .03	0.60 ± .01	0.65 ± .05	-
220	-	-	-	0.02 ± .03
230	0.40 ± .01	0.66 ± .03	0.70 ± .04	-
250	0.61 ± .02	0.79 ± .07	0.60 ± .01	-
260	0.58 ± .05	0.76 ± .08	0.63 ± .06	0.52 ± .10
270	0.77 ± .07	0.59 ± .02	0.66 ± .14	-
280	0.78 ± .06	0.85 ± .01	1.07 ± .07	0.55 ± .17
285	1.37 ± .09	1.11 ± .04	-	0.72 ± .02

TABLE XXV

RESURRECTION BAY (LOWER COOK INLET PROJECT)
Seasonal Dissolved Organic Carbon Distributions (mg C/ℓ)
Station RES 2.5

Depth (m)	*Acona* 256 Dec. 77	*Acona* 260 April 78	*Acona* 262 July 78
10	0.52 ± 0.08	2.3	>4.0
30	0.70 ± 0.14	1.15 ± 0.12	1.04 ± 0.49
70	0.37 ± 0.04	1.68 ± 0.76	0.75 ± 0.13
110	0.57 ± 0.14	1.45 ± 0.33	1.17 ± 0.06
130	0.34 ± 0.15	-	-
150	0.36 ± 0.02	-	-
170	0.24 ± 0.02	0.89 ± 0.05	1.09 ± 0.30
190	0.40 ± 0.05	1.06 ± 0.08	0.78 ± 0.05
210	0.74 ± 0.15	1.45 ± 0.45	0.76 ± 0.22
230	0.42 ± 0.17	1.13 ± 0.03	0.52 ± 0.03
250	1.05 ± 0.63	1.08 ± 0.02	0.69 ± 0.06
260	4.87 ± 0.70	1.34 ± 0.02	0.58 ± 0.12
270	[7.9]	1.12 ± 0.09	0.79 ± 0.35
280	0.53 ± 0.25	0.98 ± 0.05	1.58 ± 0.23
285	1.40 ± 0.19	1.44 ± 0.45	-

TABLE XXVI

RESURRECTION BAY (LOWER COOK INLET PROJECT)
Seasonal Distribution of Particulate Organic Carbon
(I) mg C/g particulate sediment
Station RES 2.5

Depth (m)	*Acona* 256 Dec. 77	*Acona* 260 April 78	*Acona* 262 July 78
10	207 ± 1	318[a]	756[a]
30	193 ± 24	190[a]	363 ± 62
70	219 ±108	60.4 ± 9.4	211 ± 59
110	158 ± 12	60.8 ± 8.7	323 ± 59
130	133 ± 53	-	-
150	54 ± 24	-	-
170	38 ± 6	60.2 ± 6.5	162 ± 2
190	62 ± 9	49.8 ± 3.0	72 ± 17
210	63 ± 9	45.6 ± 0.5	168 ± 2
230	31[a]	23.7 ± 0.5	94 ± 23
250	53 ± 6	134 ±57	348 ± 58
260	200[a]	66 ±25	52 ± 1
270	193 ± 42	44 ± 5	88 ± 12
280	[444]	36.7 ± 0.5	56 ± 11
285	128 ± 87	83 ±49	-

TABLE XXVII

RESURRECTION BAY (LOWER COOK INLET PROJECT)
Seasonal Distribution of Particulate Organic Carbon
(II) μg C/ℓ Station RES 2.5

Depth (m)	*Acona* 256 Dec. 77	*Acona* 260 April 78	*Acona* 262 July 78
10	37 ± 0.2	418[a]	652[a]
30	35 ± 4	93[a]	309 ± 53
70	40 ± 19	26 ± 4	59 ± 17
110	25 ± 2	26 ± 4	251 ± 46
130	31 ± 12	-	-
150	24 ± 11	-	-
170	16 ± 2	32 ± 3	97 ± 1
190	47 ± 7	24.6± 1.5	42 ± 10
210	39 ± 6	27.5± 0.3	110 ± 1
230	13[a]	157 ± 0.3	65 ± 16
250	32 ± 4	106 ± 46	208 ± 35
260	116[a]	50 ± 20	33 ± 1
270	149 ± 33	26 ± 3	58 ± 8
280	[350 ±220]	31.1± 0.4	60 ± 12
285	176 ±119	92 ± 55	-

TABLE XXVIII

RESURRECTION BAY R/V *ACONA* 254
December 1977, Station RES 2.5
Heavy Metal Contents of Particulate Sediment: mg/g

Depth	Mn	V	Al
10	3.20 ± .08	0.25 ± .07	71.8 ± 2.6
30	3.64 ± .59	0.23 ± .03	93.6 ± 7.2
70	4.53 ± .10	0.27 ± .03	94.9 ± 14.2
110	5.23 ± .54	0.17 ± .05	78.4 ± 10.9
130	3.33[a]	0.18[a]	58.9[a]
150	2.51[a]	0.13[a]	56.2[a]
170	3.78 ± .39	0.21 ± .03	70.0 ± 9.0
190	1.97[a]	0.10[a]	51.8[a]
210	3.71 ± .24	0.19 ± .03	76.6 ± 4.3
230	4.36 ± .36	0.19 ± .01	72.2 ± 0.7
250	5.80 ± .33	0.21 ± .02	78.8 ± 0.9
260	6.78 ± .29	0.20 ± .01	77.3 ± 4.4
270	5.63 ± .24	0.17 ± .01	69.5 ± 3.2
280	6.12 ±1.14	0.20 ± .04	79.6 ± 18.8
285	3.93 ± .08	0.16 ± .01	67.6 ± 2.2

[a] single determinations

TABLE XXIX

RESURRECTION BAY R/V *ACONA* 254
December 1977, Station RES 2.5
Heavy Metal Contents of Particulate Sediment: µg/ℓ

Depth (m)	Al (µg/ℓ)	Mn (µg/ℓ)	V (µg/ℓ)
10	12.7 ± 0.7	0.57 ± .02	0.04 ± .01
30	16.3 ± 3.1	0.62 ± .07	0.04 ± .01
70	17.7 ± 5.2	0.83 ± .14	0.05 ± .01
110	12.1 ± 0.2	0.81 ± .01	0.03 ± .01
130	11.9[a]	0.67[a]	0.04[a]
150	25.6[a]	1.14[a]	0.06[a]
170	28.3 ± 1.2	1.54 ± .03	0.09 ± .01
190	43.0[a]	1.64[a]	0.09[a]
210	49.8 ± 1.1	2.33 ± .04	0.12 ± .01
230	35.6 ± 7.0	2.12 ± .27	0.10 ± .02
250	48.0 ± 2.2	3.76 ± .31	0.13 ± .02
260	44.4 ± 1.3	3.90 ± .17	0.12 ± .01
270	53.3 ± 2.7	4.33 ± .24	0.17 ± .01
280	60.7 ± 9.5	4.68 ± .51	0.15 ± .02
285	92.3 ± 2.8	5.37 ± .23	0.22 ± .01

[a] single determinations

(December 1977) and XXX-XXXI (April 1978). Corresponding Mn/Al and V/Al ratios are listed in Tables XXXII and XXXIII.

Heavy metal contents of extracts of cores collected in April and October 1978 are listed in Tables XXXIV-XXXVI. Redox and alkalinity data for the latter case are given in Table XXXVII. Additional geochemical data are given and discussed in the following section.

E. Aquaria Food Chain Heavy Metal Transfer Project

See following section.

VII. DISCUSSION

A. Bering Sea

A survey of the baseline data for the Bering-Chukchi project areas was given in last year's report. No further field work has been conducted in this region but we have continued to generate data especially as regards the sedimentology and geochemistry of the bottom sediments in the S. Bering Sea. At the same time ongoing NSF funded work continues to unravel the complex circulation patterns here. A further summary of the benthic data is being prepared for presentation at the upcoming Bering Sea symposium.

A revised version of the paper or the heavy metal contents of Bering Sea seals given at the 1978 Alaska Science Conference is included in this report as Appendix III.

B. Flux of Heavy Metals in the Alaskan Coastal Zone

The first part of this program, which has been largely concerned with the benthic cycling of manganese, is now being prepared for comprehensive

TABLE XXX

RESURRECTION BAY R/V *ACONA* 260
April 1978, Station RES 2.5
Heavy Metal Contents of Particulate Sediment: mg/g

Depth	Mn	V	Al
10	0.57 ± .01	0.05 ± .01	18.41 ± 0.57
230	1.44 ± .09	0.11 ± .01	44.08 ± 0.58
70	2.75 ± .29	0.41 ± .20	89.09 ± 1.66
110	2.92 ± .09	0.21 ± .01	86.90 ± 0.60
170	2.18 ± .09	0.17 ± .03	82.79 ± 6.75
190	1.80 ± .09	0.18 ± .01	76.39 ± 0.12
210	1.62 ± .06	0.19 ± .02	79.32 ± 0.32
230	1.90 ± .26	0.20 ± .01	79.00 ± 0.02
250	2.38 ± .26	0.19 ± .02	75.04 ± 7.86
260	2.74 ± .03	0.21 ± .01	76.68 ± 0.58
270	5.32 ± .30	0.22 ± .01	83.03 ± 2.20
280	6.06 ± .10	0.23 ± .01	81.65 ± 0.65
285	5.30 ± .21	0.19 ± .03	74.76 ± 2.46

TABLE XXXI

RESURRECTION BAY R/V *ACONA* 260
April 1978, Station RES 2.5
Heavy Metal Contents of Particulate Sediment: μg/ℓ

Depth (m)	Al (μg/ℓ)	Mn (μg/ℓ)	V (μg/ℓ)
10	24.23 ± 0.66	0.75 ± .01	0.07 ± .01
30	21.73 ± 1.26	0.71 ± .02	0.05 ± .01
70	38.51 ± 2.51	1.19 ± .18	0.18 ± .10
110	37.54 ± 2.24	1.26 ± .03	0.09 ± .01
170	42.36 ± 0.57	1.12 ± .07	0.09 ± .02
190	37.79 ± 4.05	0.89 ± .06	0.09 ± .01
210	47.71 ± 1.24	0.98 ± .06	0.12 ± .01
230	52.44 ± 2.33	1.26 ± .12	0.13 ± .01
250	58.84 ± 0.94	1.86 ± .04	0.14 ± .01
260	58.56 ± 5.44	2.10 ± .23	0.16 ± .01
270	48.61 ± 0.21	3.11 ± .08	0.13 ± .01
280	69.36 ± 1.05	5.15 ± .13	0.21 ± .01
285	82.86 ± 5.95	5.87 ± .36	0.22 ± .05

TABLE XXXII

RESURRECTION BAY R/V *ACONA* 254
December 1977
Particulate Sediment Metal/Al Ratios
Station RES 2.5

Depth (m)	Mn/Al x 10^3	V/Al x 10^4
10	44.5	34.6
30	38.6	24.4
70	48.6	28.6
110	67.1	20.9
130	56.6	31.1
150	44.7	23.7
170	42.4	29.7
190	38.1	19.8
210	46.8	23.1
230	60.3	26.7
250	73.6	26.0
260	87.7	25.2
270	81.1	24.8
280	77.4	25.1
285	58.2	23.9

TABLE XXXIII

RESURRECTION BAY R/V *ACONA* 260
April 1978
Particulate Sediment Metal/Al Ratios
Station RES 2.5

Depth (m)	Mn/Al x 10^3	V/Al x 10^4
10	30.9	25.5
30	32.6	24.1
70	30.7	45.5
110	33.5	24.3
170	26.4	20.7
190	23.5	23.6
210	20.4	24.3
230	24.0	25.4
250	31.6	24.5
260	35.7	27.0
270	64.0	25.8
280	74.2	28.4
285	70.8	25.3

TABLE XXXIV

NEGOA SPECIFIC STUDY SITE — RESURRECTION BAY
Organic Matrix Extractions from Sediments (µg/g)
Station RES 2.5 — *Acona* 260, April 1978

Depth (cm)	Cu	Mn	Fe	Zn	Ni	Cd
0 - 5.5	5.9 ± 1.8	18.4 ± 3.3	<1.5	<0.6	<0.3	<0.3
14.5 - 19.5	4.5 ± 0.6	7.8 ± 1.5	1.5	0.6	0.3	0.3
19.5 - 24.0	7.1 ± 1.1	5.0 ± 0.4	1.5	0.6	0.3	0.3
50.0 - 54.5	6.0 ± 1.3	2.6 ± 0.5	1.5	0.6	0.3	0.3

TABLE XXXV

NEGOA SPECIFIC STUDY SITE — RESURRECTION BAY
Inorganic Matrix Extractions from Sediments (μg/g)
Station RES 2.5 — *Acona* 260, April 1978

Depth (cm)	Cu	Mn	Fe	Zn	Ni	Cd
0 - 5.5	38.4 ± 11.0	440 ± 110	$>10^4$	71 ± 15	30 ± 6	<0.08
16.5 - 19.5	73.2 ± 6.7	233 ± 29	$>10^4$	69 ± 5	21 ± 7	<0.08
19.5 - 24.0	65.8 ± 7.2	223 ± 40	$>10^4$	62 ± 10	26 ± 5	<0.08
50.0 - 54.5	74.3 ± 7.0	278 ± 39	$>10^4$	80 ± 7	35 ± 6	<0.08

TABLE XXXVI

NEGOA SPECIFIC STUDY SITE — RESURRECTION BAY
Organic Matrix Extractions from Sediments (μg/g)
Station RES 2.5 — *Acona* 267, October 1978

Depth (cm)	Cu	Mn	Fe	Zn	Ni	Cd
0-10	1.66 ± 0.06	18.5 ± 2.7	<3	<1	5.4 ± 0.9	0.22 ± 0.05
10-20	1.26 ± 0.08	11.0 ± 0.3	<3	1.8 ± 1.3	5.5 ± 0.6	0.23 ± 0.04
20-30	1.02 ± 0.18	6.1 ± 0.3	<3	4.2 ± 0.9	4.0 ± 0.9	0.15 ± 0.03
30-40	1.04 ± 0.78	7.1 ± 1.4	<3	<1	3.8 ± 1.5	0.15 ± 0.02
50-60	0.92 ± 0.11	3.2 ± 0.6	<3	1.6 ± 0.8	4.5 ± 0.5	0.19 ± 0.02
60-85	0.96 ± 0.03	3.9 ± 0.5	<3	<1	5.0 ± 0.4	0.20 ± 0.03

TABLE XXXVII

RESURRECTION BAY
Sediment Eh, pH and Alkalinity Data
Acona 267, October 1978
Station RES 2.5

Depth (cm)	Cl (°/₀₀)	Eh (mv)	pH	Alk (m.eq)
0	-	71	7.33	-
2	8.89	53	7.31	3.17
4	-	51	7.39	-
6	-	-124	7.43	-
8	15.97	-180	7.40	3.77
10	-	-177	7.31	-
12	-	-163	7.28	-
14	-	-170	7.20	-
16	-	-176	7.15	-
18	16.07	-161	7.16	-
19	-	-159	7.15	8.23
20	-	-168	7.14	-
25	-	-178	7.12	-
30	-	-175	7.12	-
35	15.62	-161	7.12	15.28
40	-	-159	7.06	-
45	13.97	-157	7.07	11.02
50	-	-158	7.07	-
55	15.24	-149	7.10	-
62	-	-	-	16.08

publication, hence only a brief summary is included here. Together with a large amount of ancillary geochemical data which may not *per se* appear in the open literature.

The two field areas involved in this subproject are shown in Figure 7. Yakutat Bay has been the area assigned as the specific project site for NEGOA. Resurrection Bay serves as a paradigm for Cook Inlet; a project site having a manageable water circulation regime. Both estuarines have certain features in common. They are both silled fjords; Yakutat Bay contains multiple basins, Resurrection Bay one only. More importantly they are both subject to influence by seasonal patterns developed in the adjacent Gulf. These latter have been described in detail previously. Figure 8, for example illustrates seasonal density patterns off Resurrection Bay. Muench and Heggie (1978) have described the relationship between the shelf zone of minimum density variation, the height of the confining sill and the period of major basin flushing. Resurrection Bay — a deep silled fjord, for example — flushes in the oceanographic summer (Figure 9).

Yakutat Bay has a shallow entrance sill and basin water replacement appears to be complete before summer. We describe what limited seasonal hydrography was available to us in the 1977-1978 Annual Report. Under OCS we managed three cruises: in April, July and September. This coverage has been insuffient to determine water circulation characteristics in any detail and we have been unable to obtain further cruise time here. Figure 10 illustrates the July (1977) salinity distributions. Bottom water replacement appears to be complete in the outer two basins at this time, although the patterns within the inner basin are more complex as discussed previously.

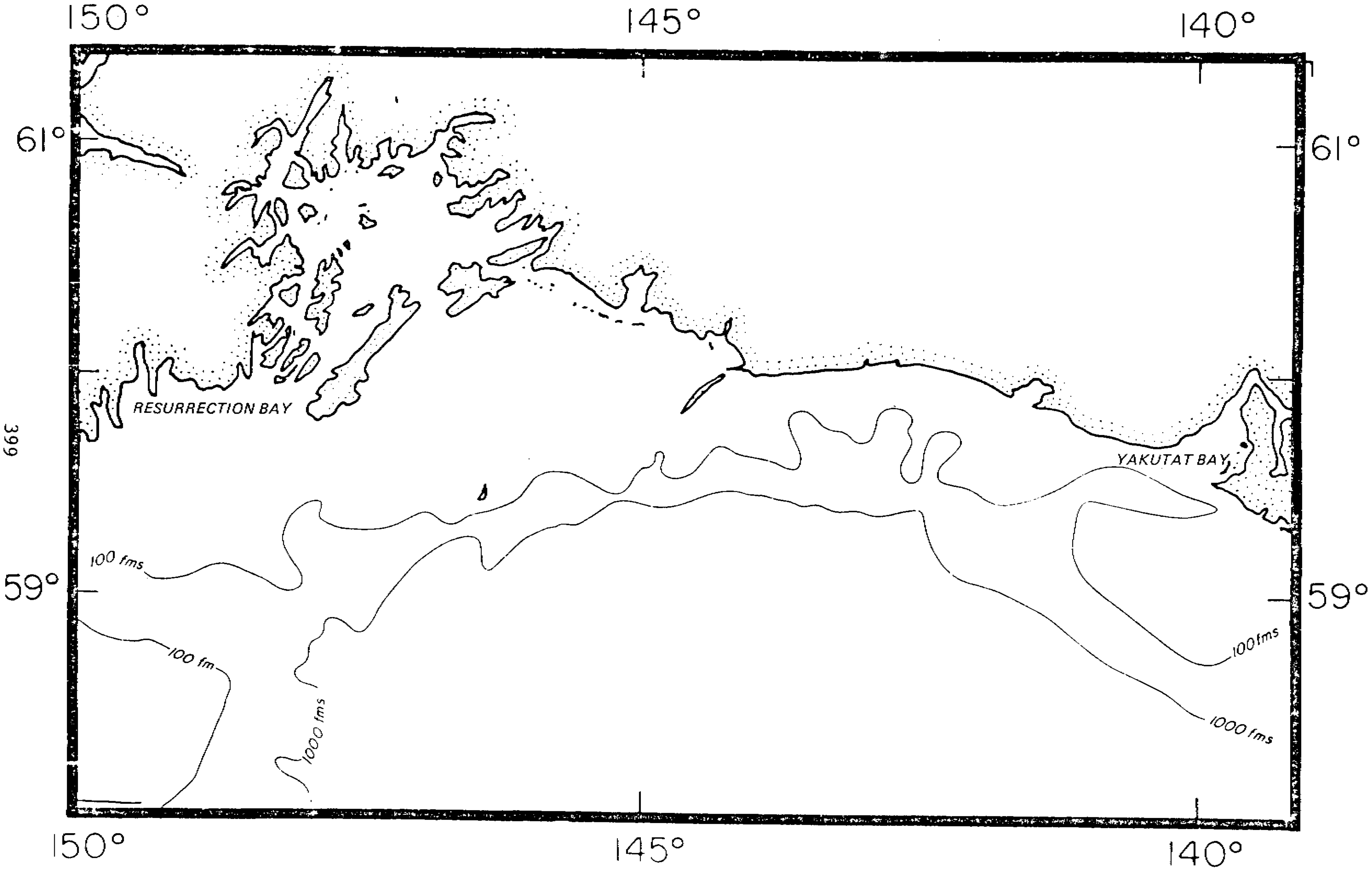


Figure 7. NEGOA and Cook Inlet specific study sites.

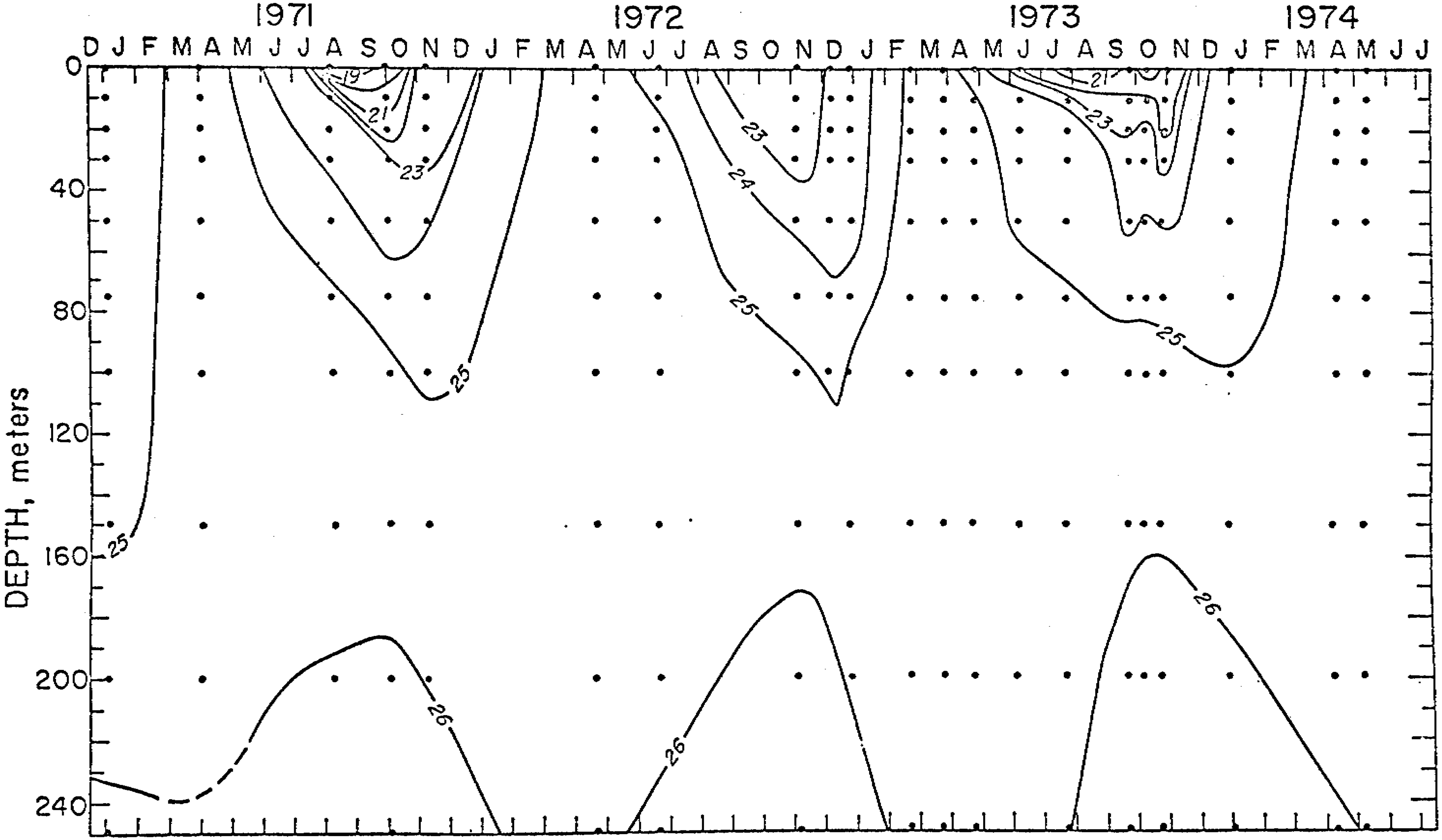


Figure 8. Time series NEGOA density.

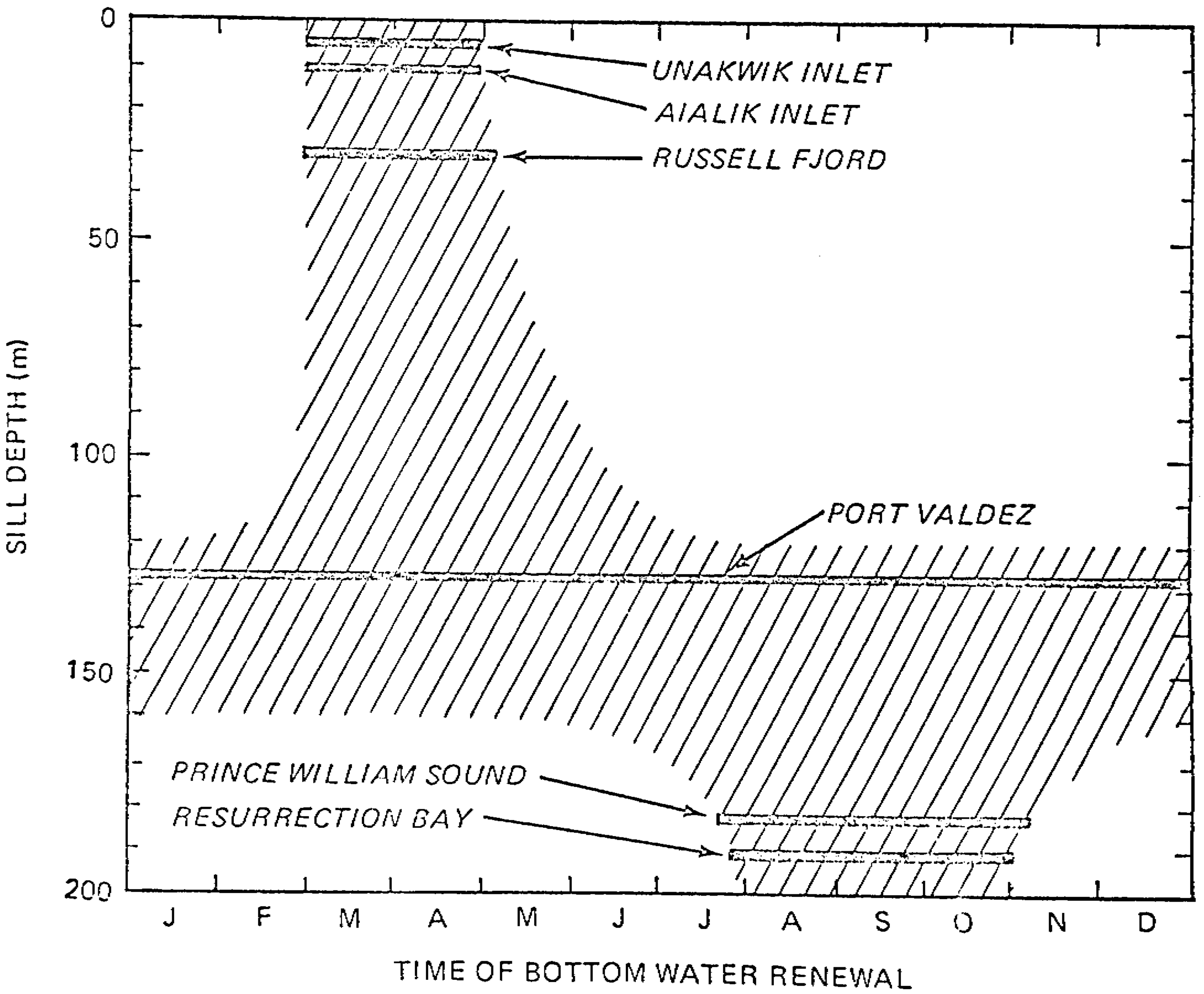


Figure 9. Seasonal flushing characteristics of NEGOA fjords (Muench and Heggie, 1978.

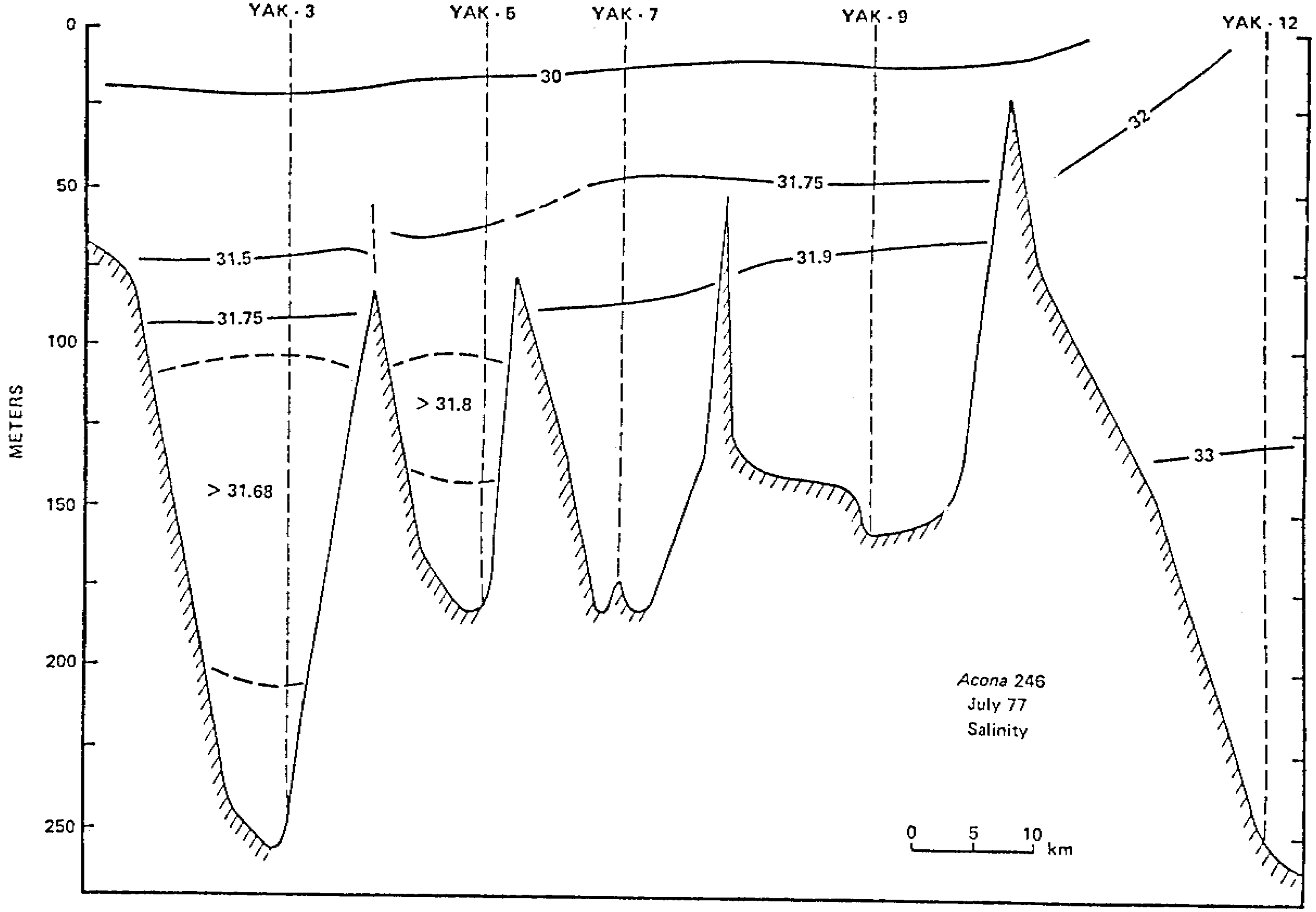


Figure 10. Salinity distribution in Yakutat Bay, July 1977 (*Acona* 246).

The soluble distribution of manganese in the other two stations at this time is shown in Figure 11. A flux of manganese emanating from the sediments penetrates almost to sill depth. We believe this represents mobile reduced manganese which oxidises and precipitates within the column. The oxidation of manganese in the marine environment is a complex kinetically controlled process. The theoretical reaction is well known, but the marine reaction rate is not understood in detail largely because of unknown catalytic agents. At the simplest level we believe that the distributions shown in Figure 11 may be fit by a simple vertical turbulent diffusion plus oxidation removal model without major error. Omiting advective terms, preliminary computations suggest relatively high vertical diffusion coefficients. Since we have been unable to obtain further data from this region we have preferred to transfer detailed study of this phenomenon to Resurrection Bay. Figure 12 shows the corresponding particulate manganese distributions and Figure 13 interstitial water concentrations for a coarsely spaced profile.

Resurrection Bay (Figure 14) is a single-silled fjord. In this estuary we have extensive background data which has enable us to compute a reasonable range for the basin vertical turbulent diffusion coefficient. (Heggie and Burrell, 1979). Since the time constant term for manganese oxidation is unknown this obviously represents a superior environment for studying this problem.

The hydrography and seasonal distribution patterns in this estuary over the period 1972-1975 have been summarized by Heggie and Burrell (1977). equivalent raw data for this OCS sponsored period (1977 to present) are

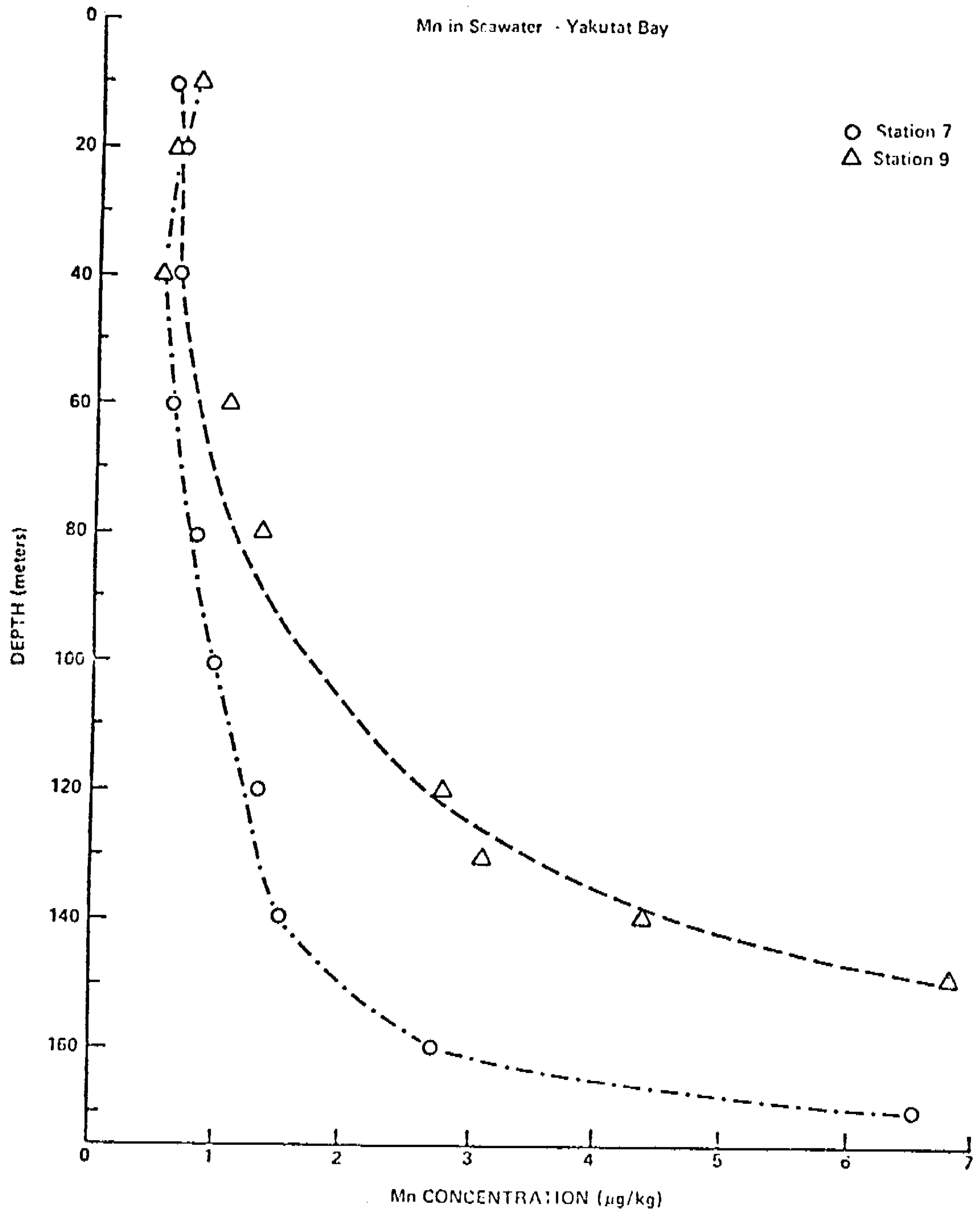


Figure 11. Soluble (0.4 µm) manganese at Stations YAK-7 and -9, Yakutat Bay, July 1977 (*Acona*).

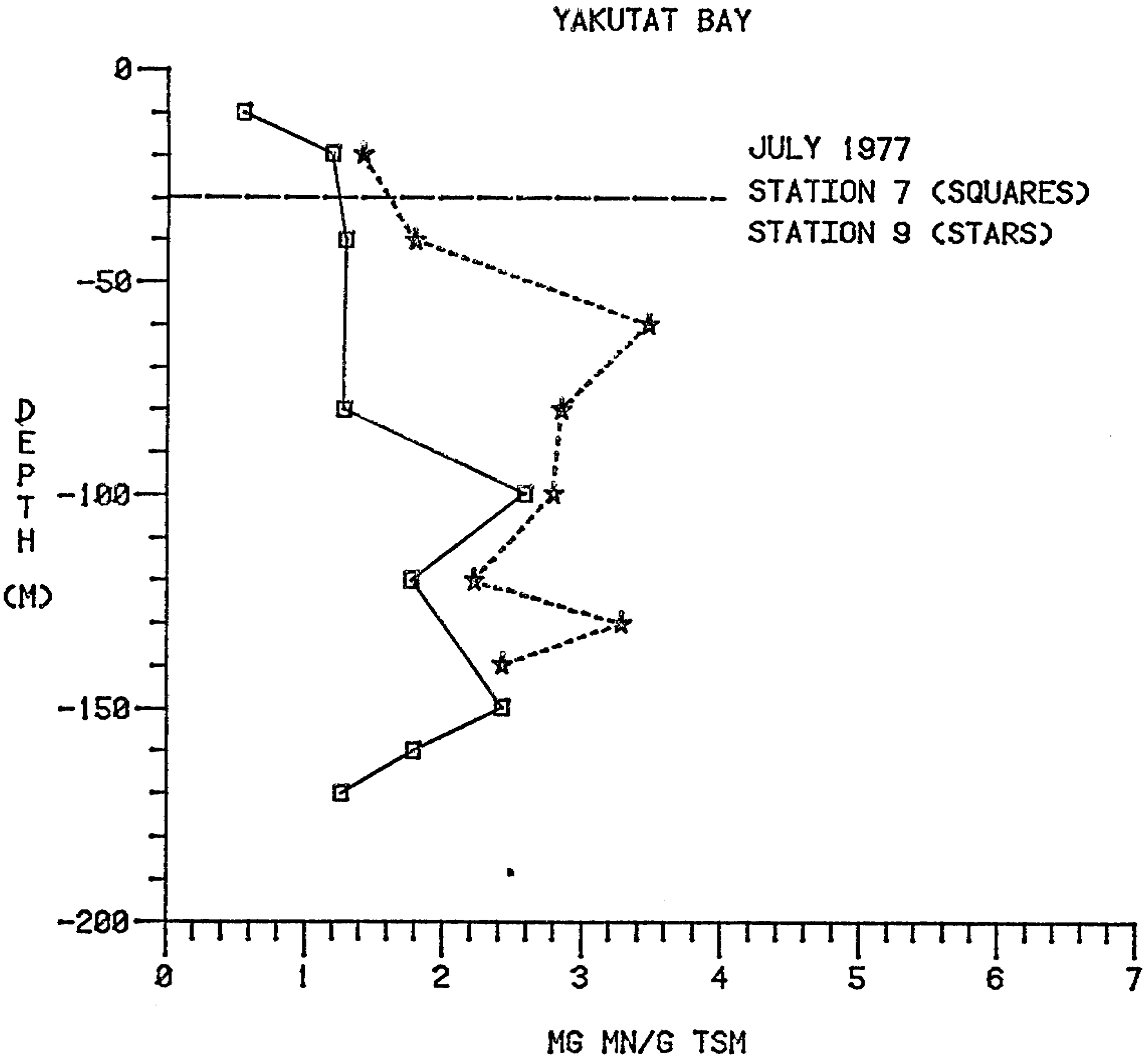
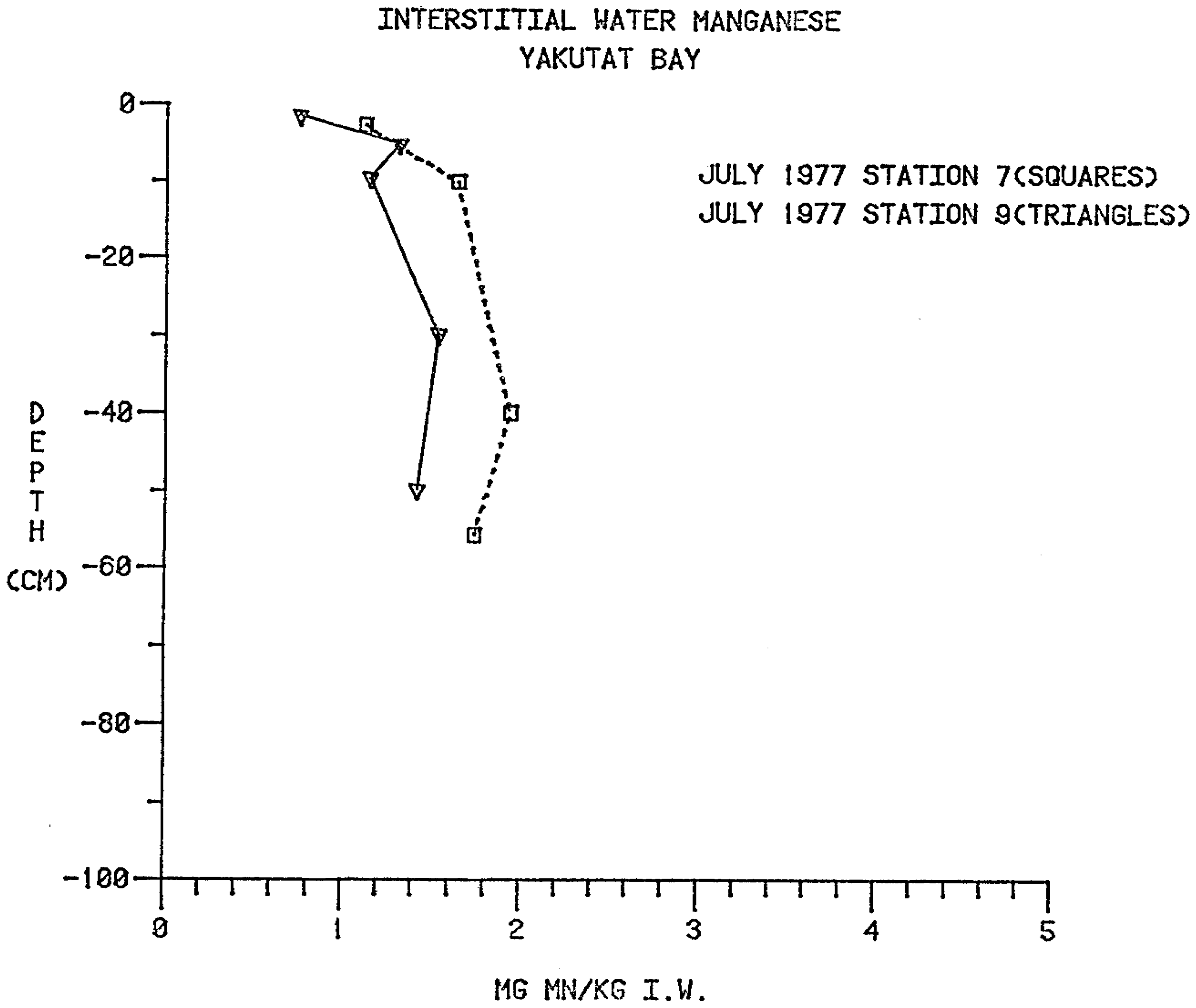


Figure 12. Suspended sediment manganese concentrations Yakutat Bay, July 1977.


INTERSTITIAL WATER MANGANESE
YAKUTAT BAY
JULY 1977 STATION 7(SQUARES)
JULY 1977 STATION 9(TRIANGLES)
DEPTH (CM)
0
-20
-40
-60
-80
-100
0
1
2
3
4
5
MG MN/KG I.W.

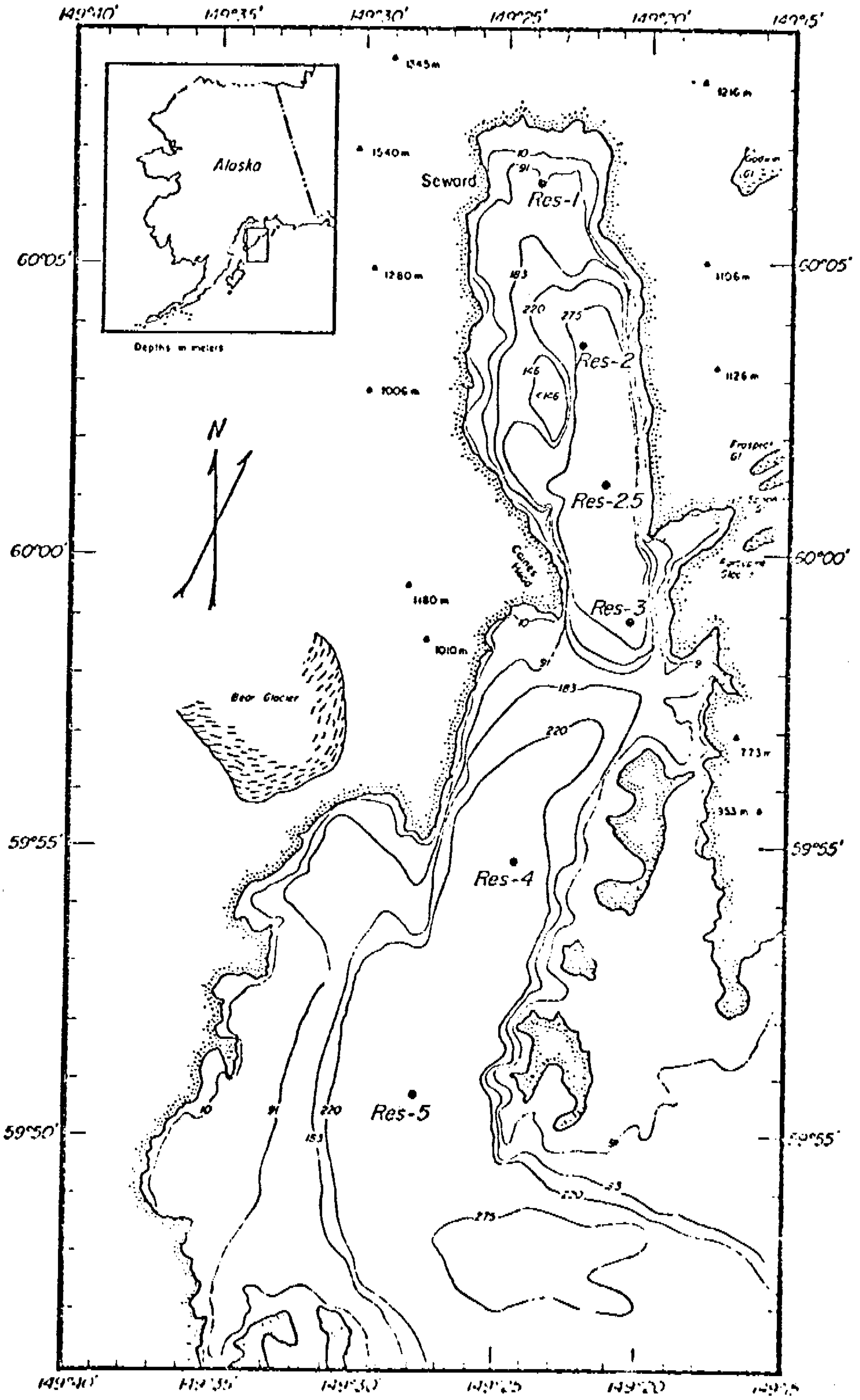


Figure 14. Resurrection Bay specific study site.

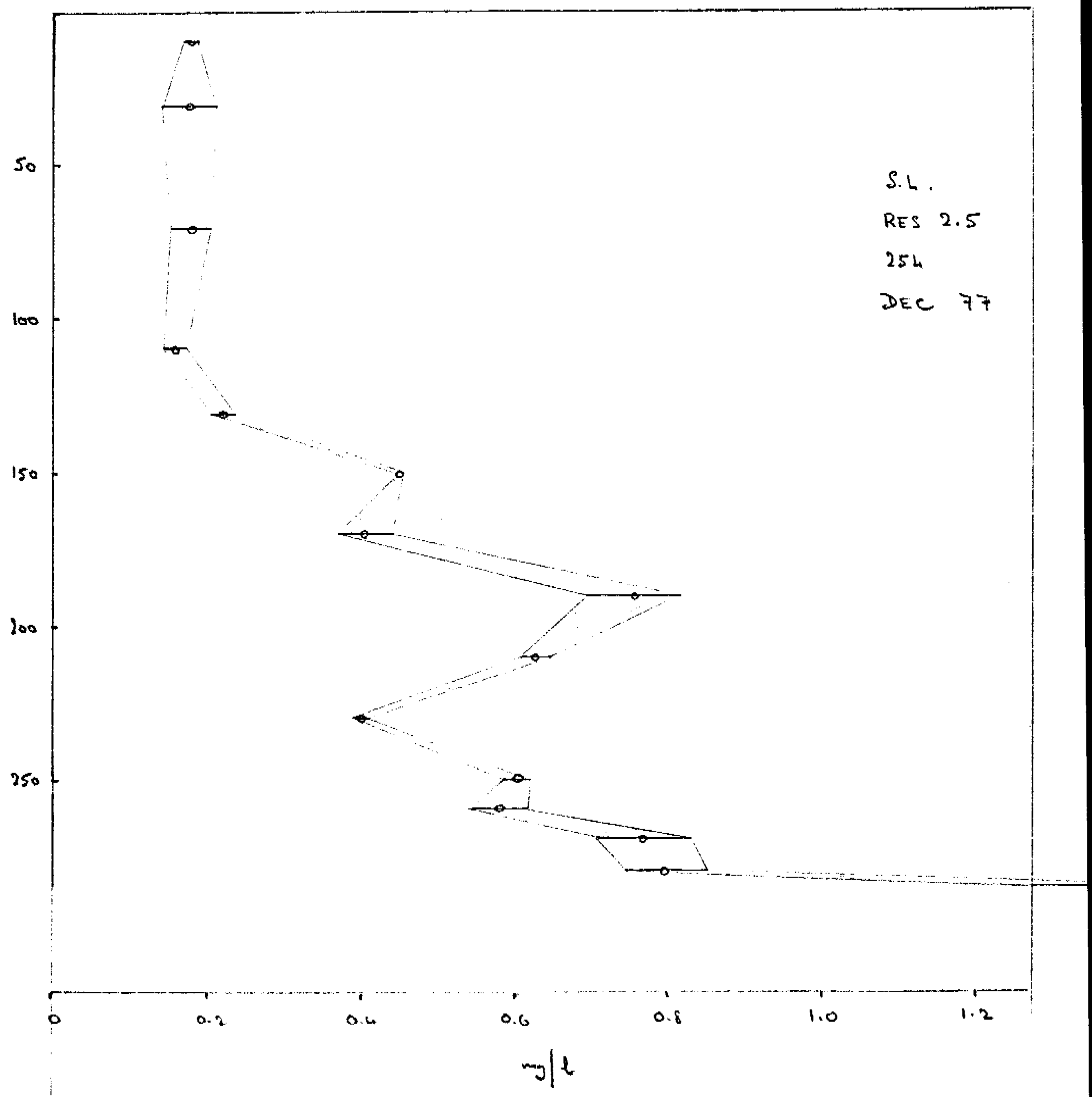


Figure 15. Suspended Sediment distributions at RES 2.5, December (1977; *Acona* 254).

S.L.

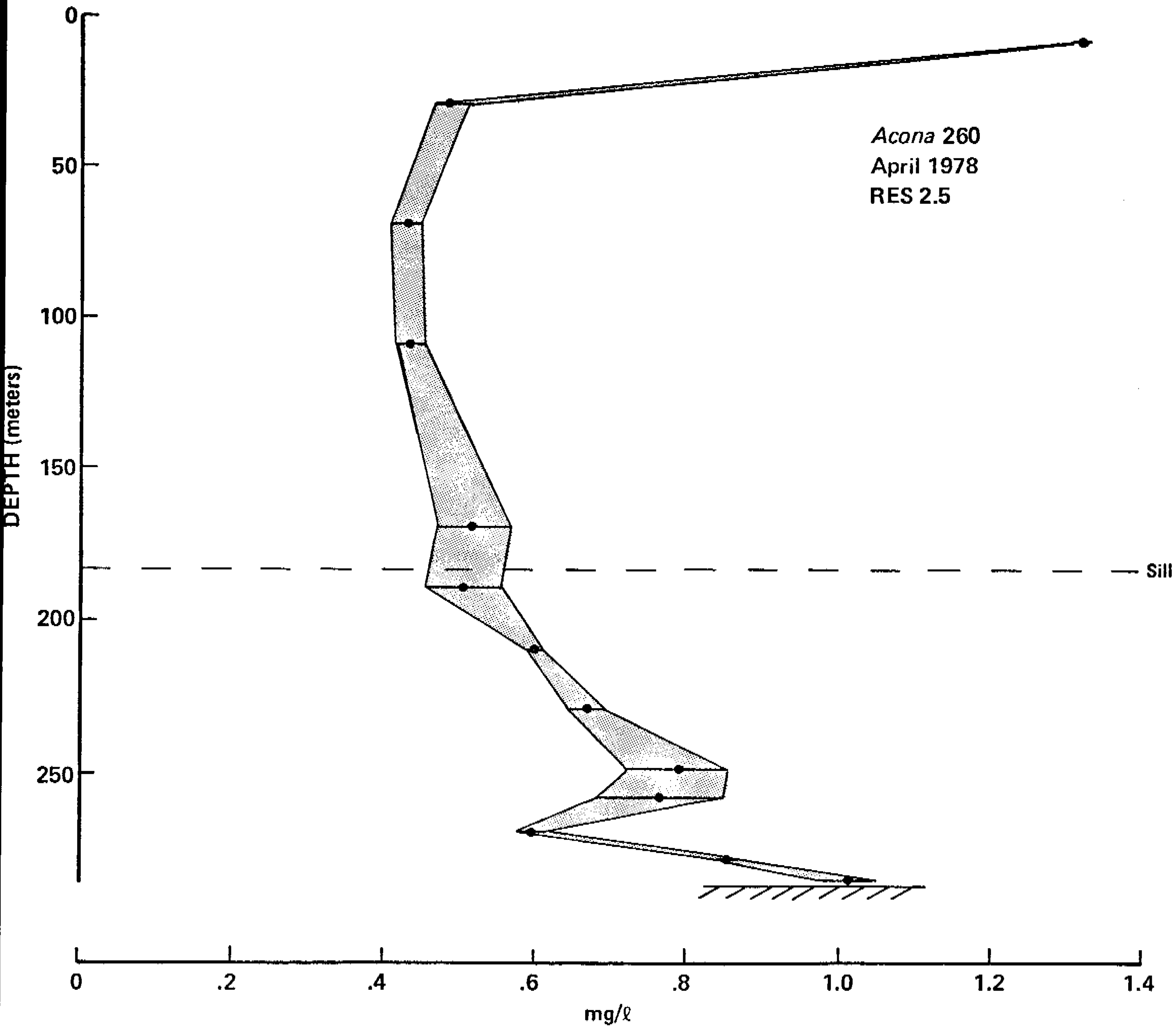


Figure 16. Suspended sediment distributions at RES 2.5, April (1978: *Acona* 260).

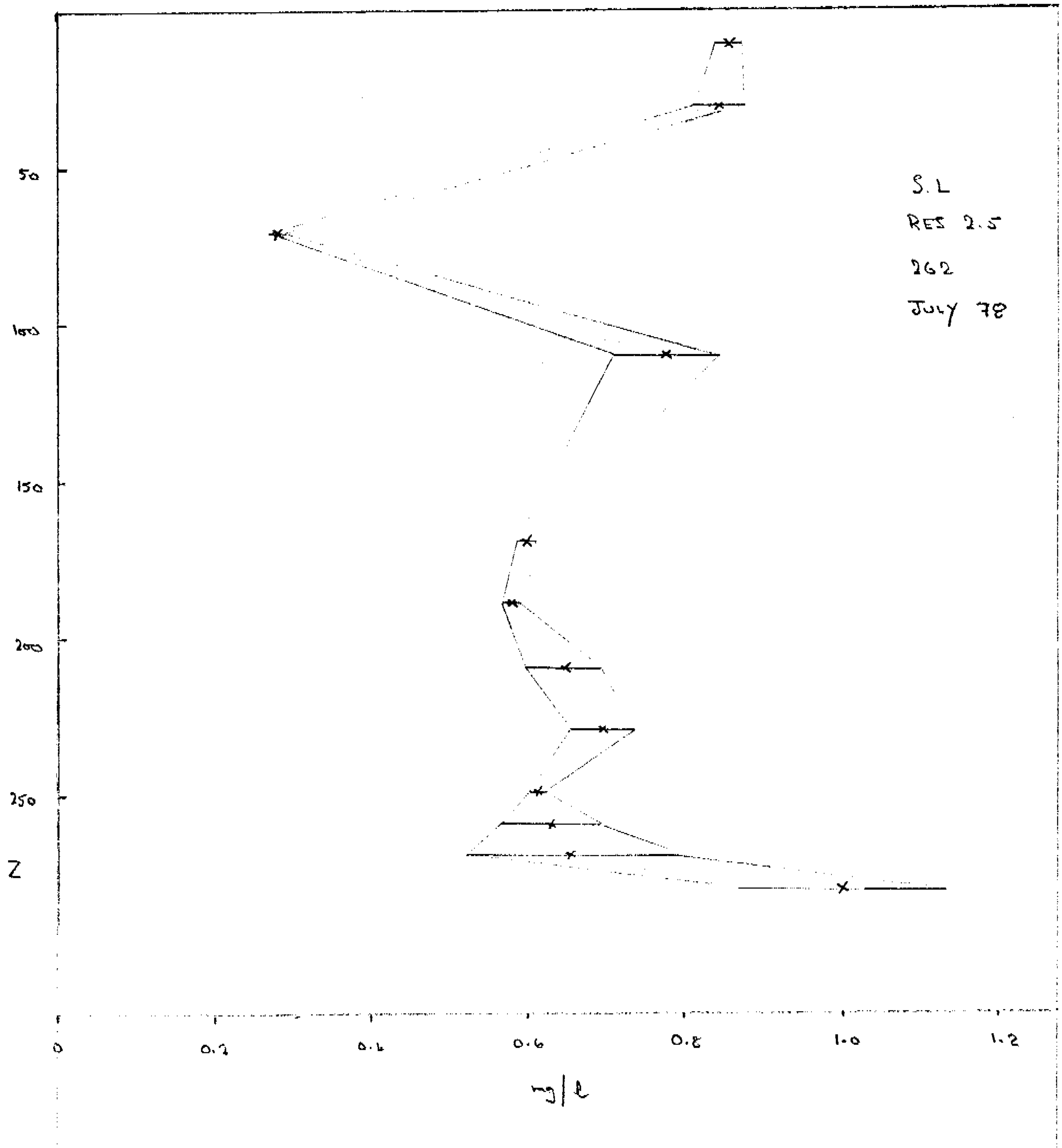


Figure 17. Suspended sediment distributions at RES 2.5, July (1978; *Acona* 262).

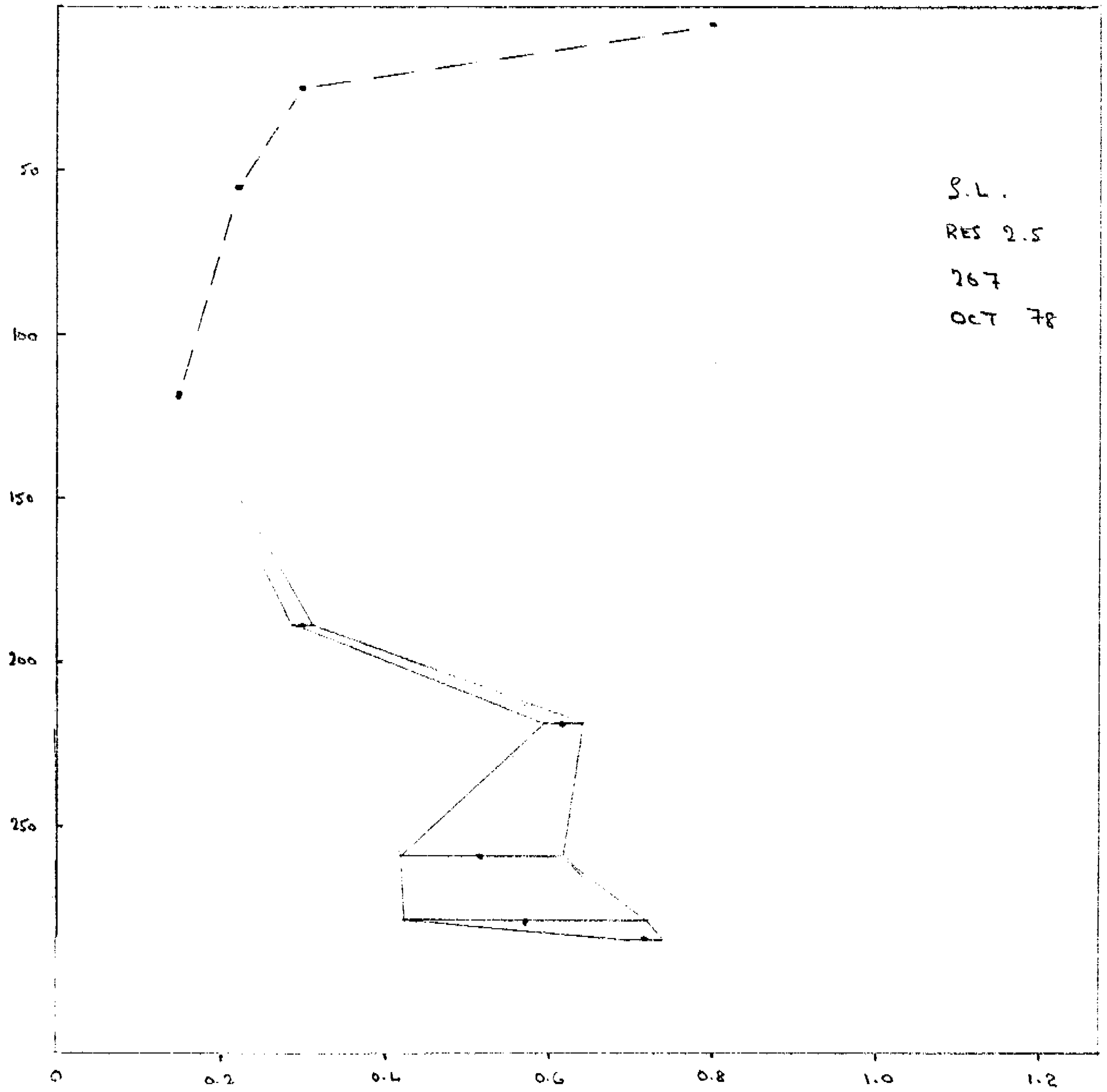


Figure 18. Suspended sediment load distributions. Station RES 2.5, October 1978 (*Acona* 267).

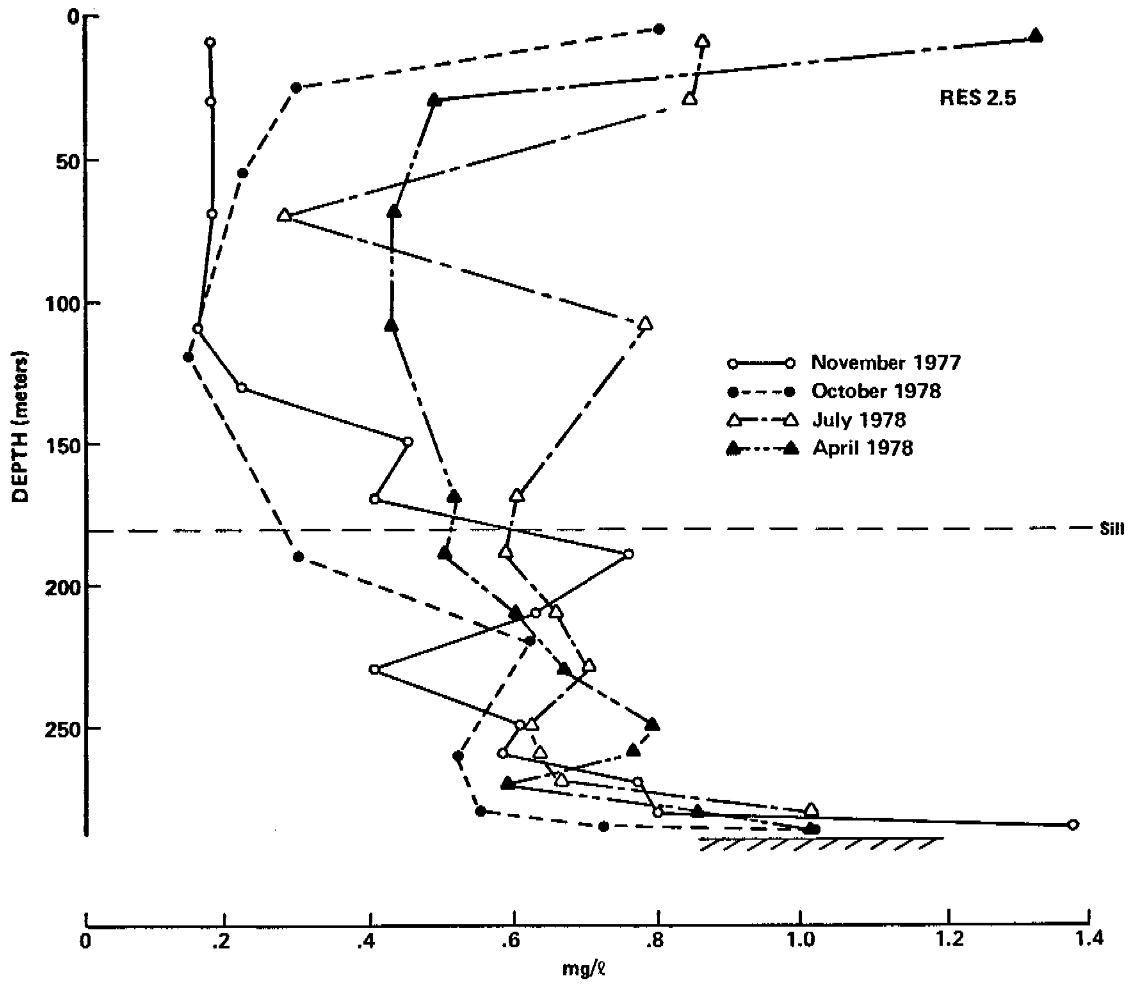


Figure 19. Seasonal suspended sediment load distributions at Station RES 2.5.

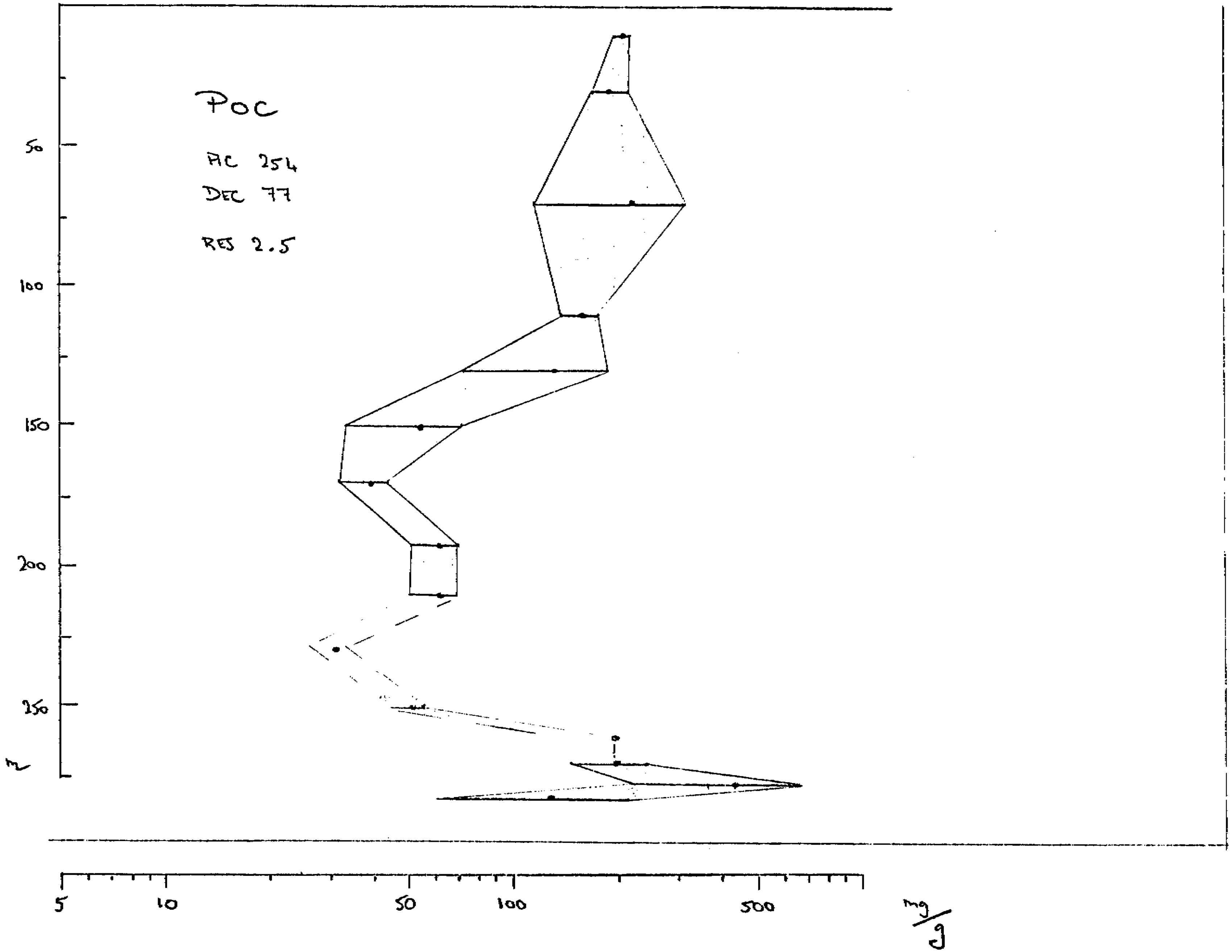


Figure 20. Particulate organic carbon, RES 2.5, December 1977.

Poc

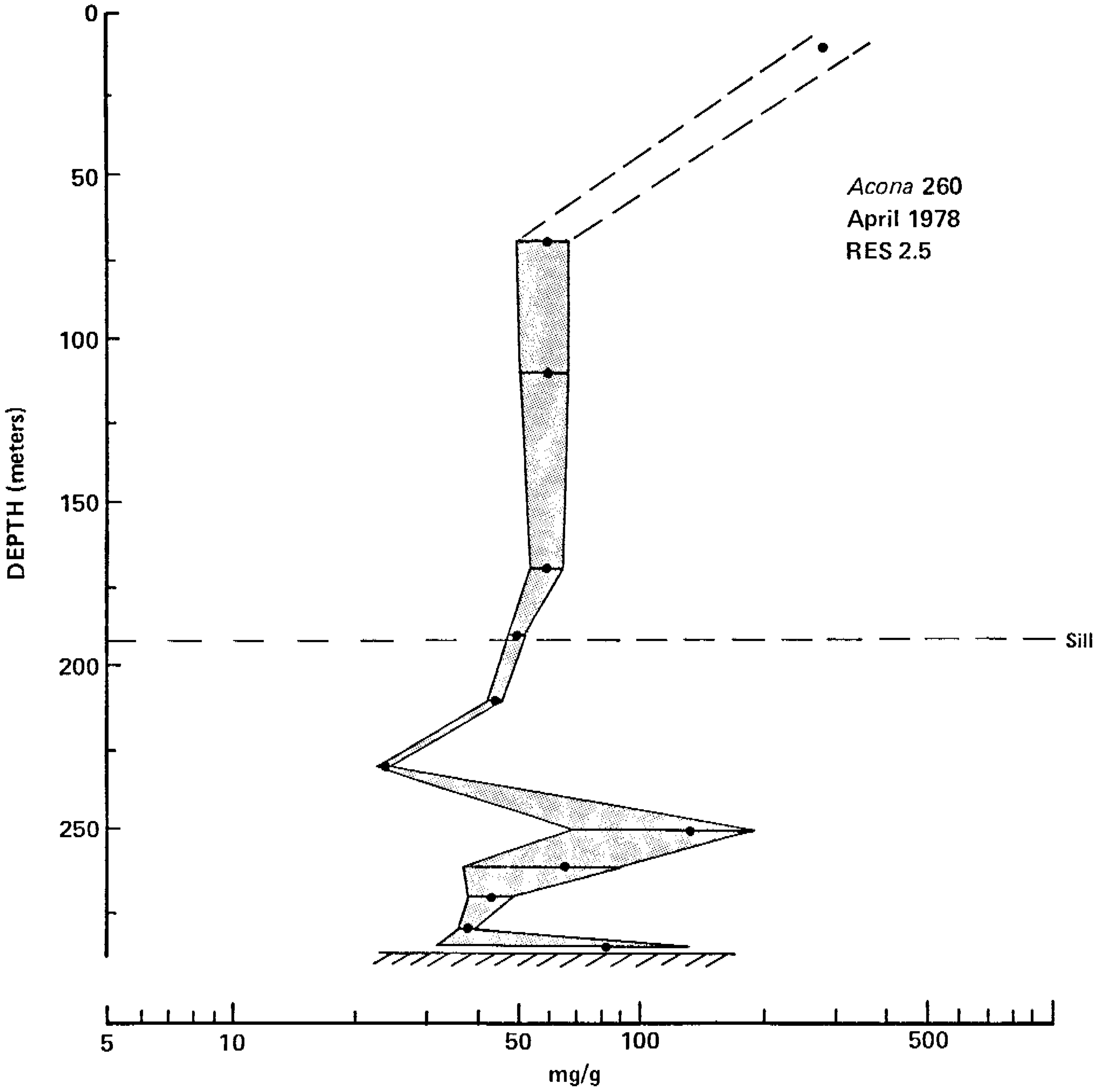


Figure 21. Particulate organic carbon, RES 2.5, April 1978.

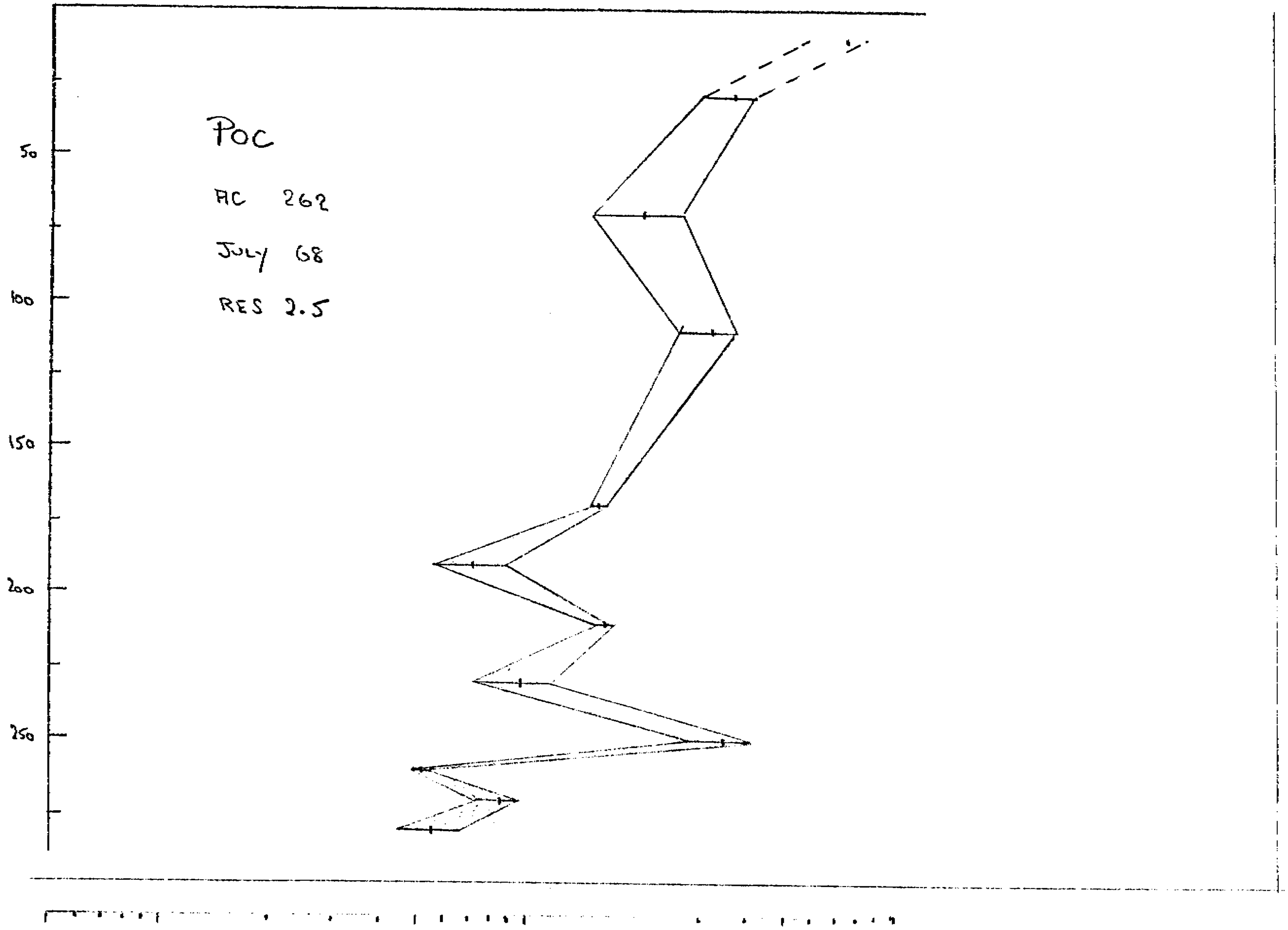


Figure 22. Particulate organic carbon, RES 2.5, July 1978.

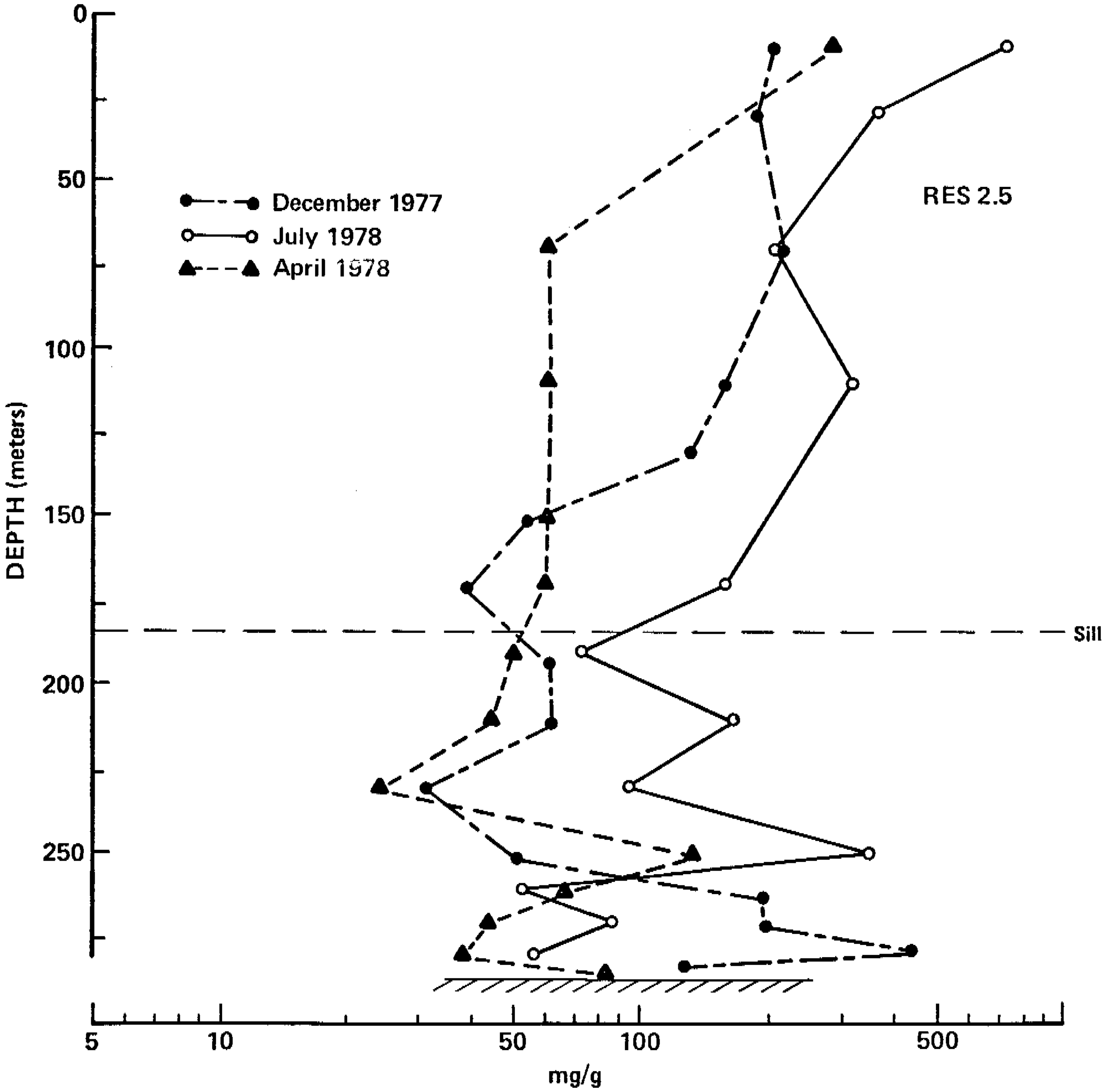


Figure 23. Seasonal particulate organic carbon distributions, RES 2.5.

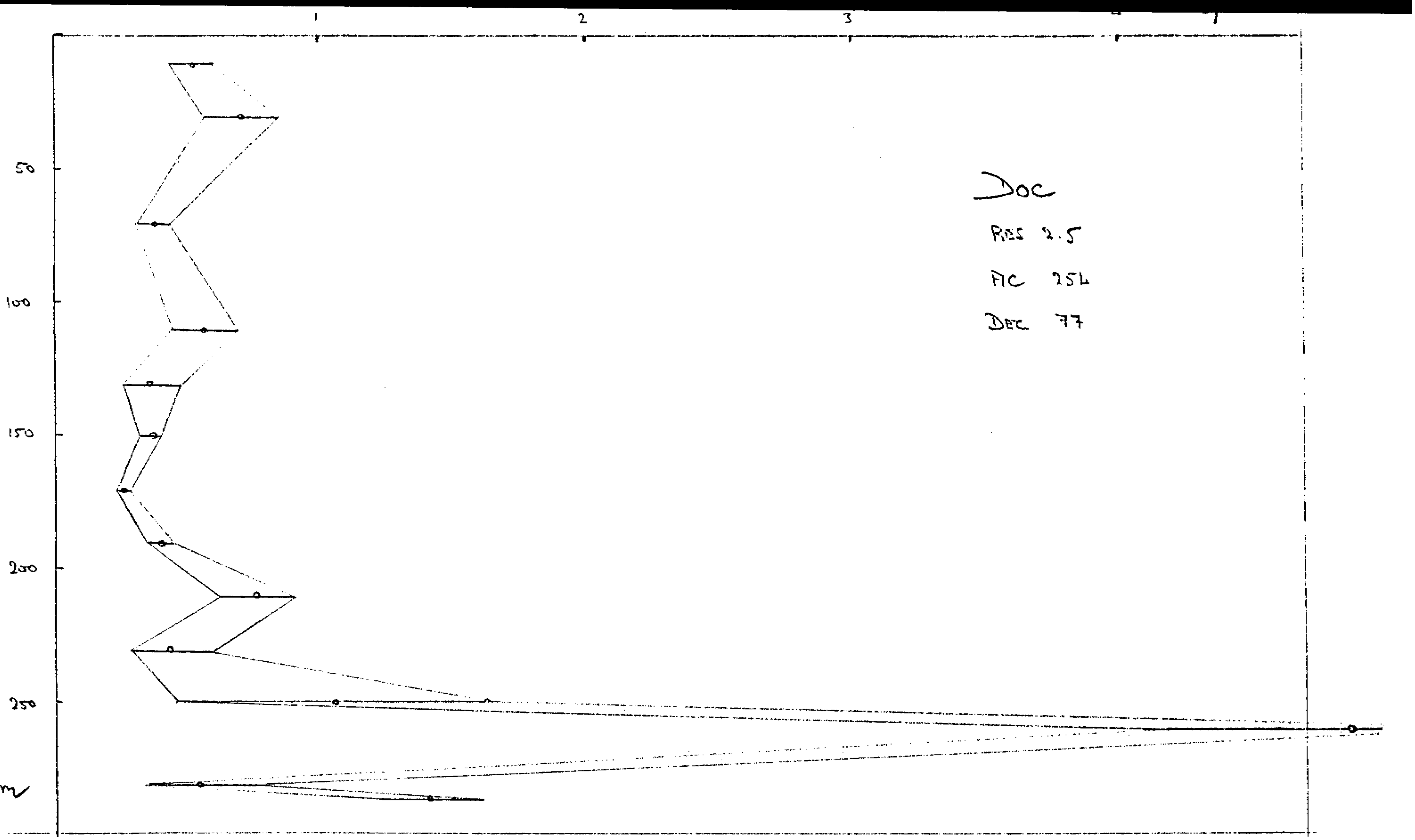


Figure 24. Soluble organic carbon concentrations, RES 2.5, December 1977.

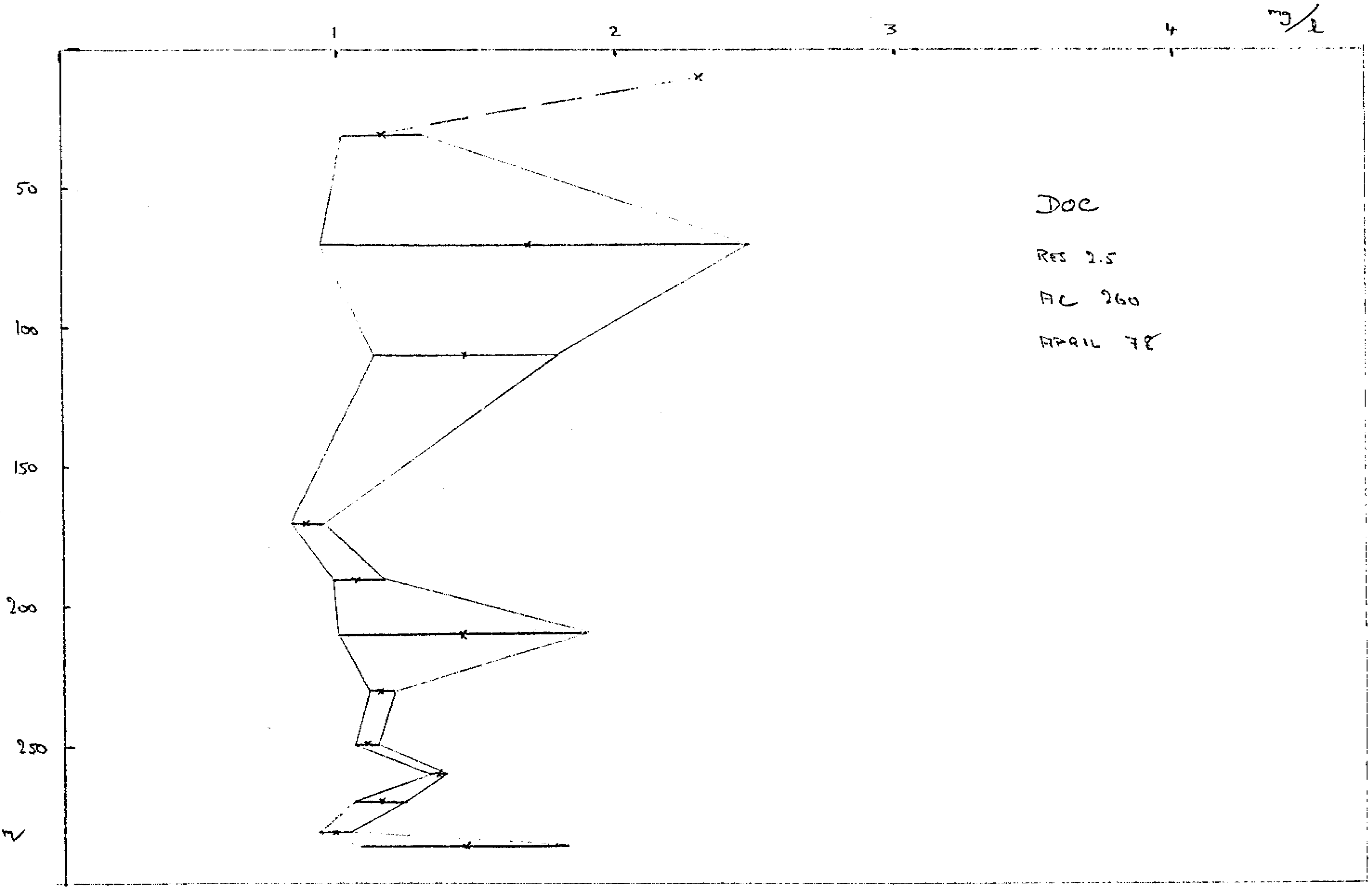


Figure 25. Soluble organic carbon concentrations, RES 2.5, April 1977.

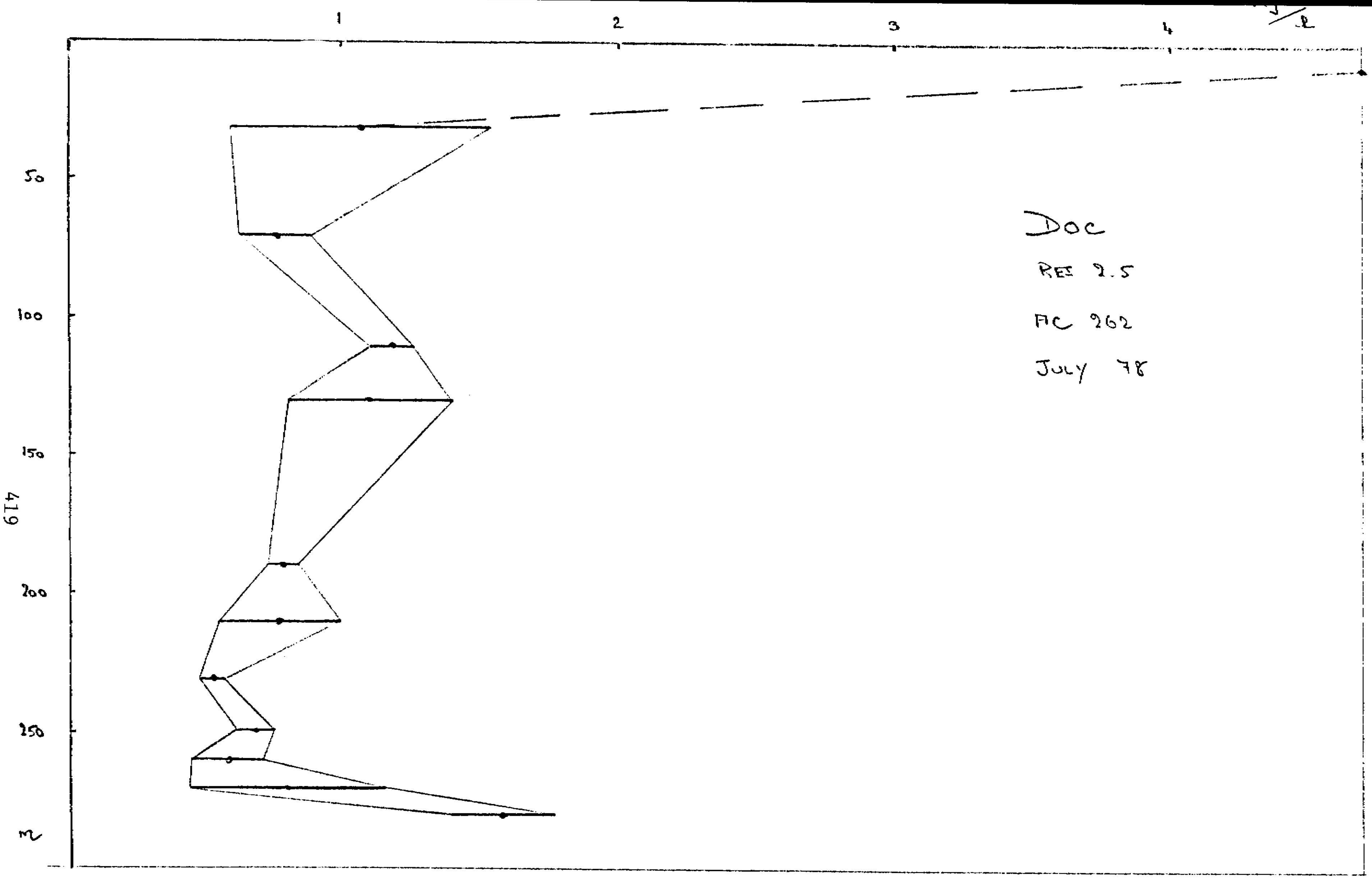


Figure 26. Soluble organic carbon concentrations, RES 2.5, July 1978.

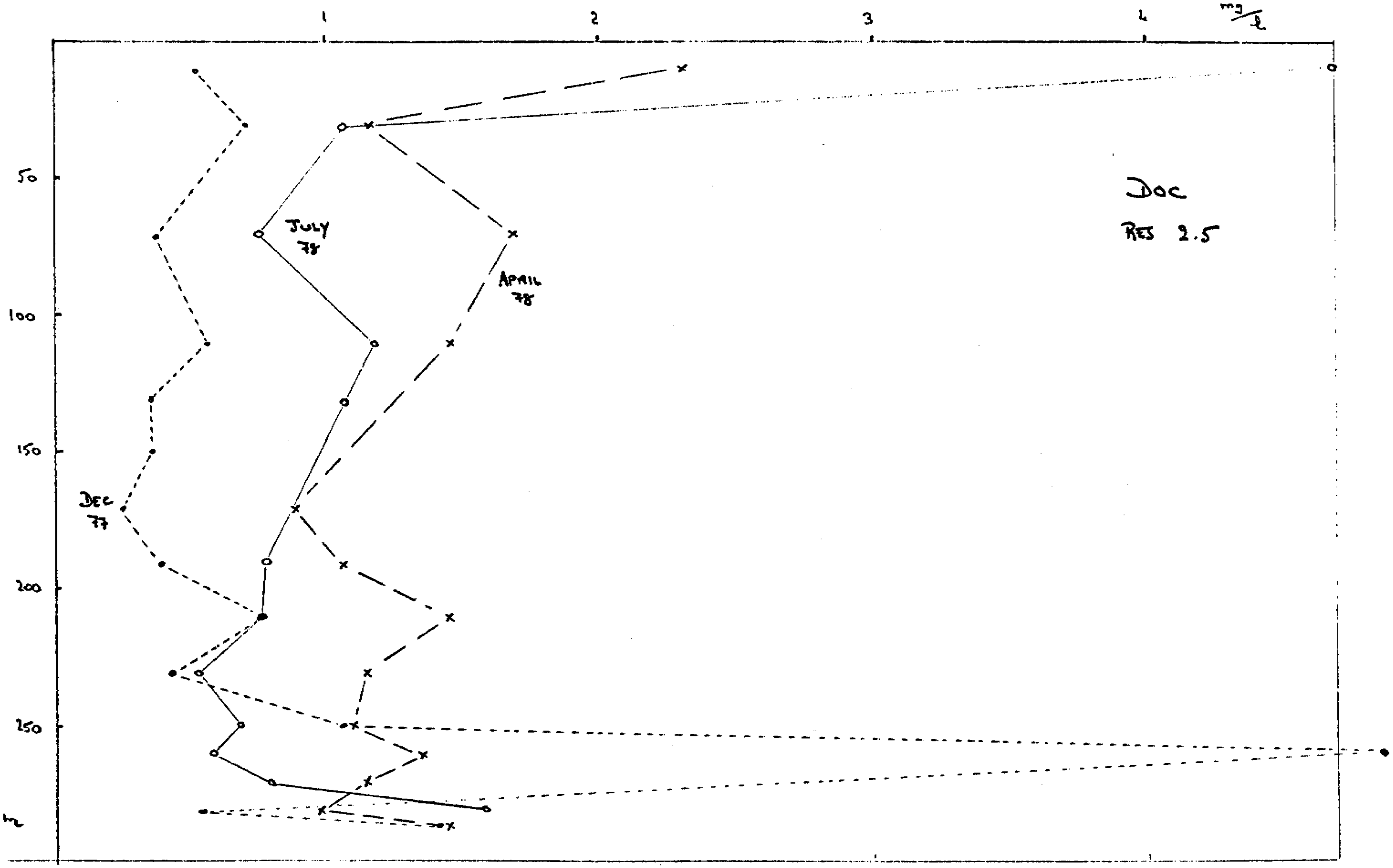


Figure 27. Seasonal total dissolved organic carbon concentrations, Station RES 2.5.

noted in Apprendices I and II. These data are currently being computer analyzed and will be given in later reports and publications.

Suspended sediment distributions in the column (Station RES 2.5) in the inner basin for December (1977), April, July and October (1978) are shown in Figures 15-18 respectively and summarized in Figure 19. Above sill depth, total particulate loads vary irregularly with depth. Highest contents appear at the surface in April with the spring bloom and are lowest there in November-December. Below sill depth year round contents vary between narrow limits. There is, however, a consistent nepheloid layer immediately adjacent to the boundary, presumably due to resuspension. It is clear that the modeling assumption of no (winter) advection is a simplication.

Particulate organic carbon contents for December, April and July are shown in Figures 20- 22 and together in Figure 23. Highest concentrations of organic material exist in the upper layers in July. Sub-sill contents are complex. We are attempting to fit an organic - aluminosilicate fractionation model to these data. This necessitates some rather large assumptions regarding the indigenous plankton compositions. As noted later, sediment regeneration ratios of the major elements suggest no significant change in e.g. C/N ratios with depth but these computations are very preliminary. Corresponding total dissolved organic carbon concentrations are given in Figures 24-27.

Sedimentation rates in these fjords are relatively high. This material is predominantly alumino-silicates and the organic loadings are considerably less than in more temperature estuaries. The oxygenated sediment zone is therefore somewhat larger than would be the norm in lower latitude estuarine — near shore environments. Figure 28 shows the redox boundary at between 5-8 cm. This environment is of considerable interest for studying sediment transformations — transportations of heavy metals since the usually compressed oxic zone can be studied with relative ease.

Heggie and Burrell (1979) have previously demostrated the regeneration and mobility of copper in the surface sediment layer (Figure 29). This metal then diffuses downward to a (anoxic) reaction zone and, more importantly, passes out into the base of the water column in large amounts. We have calculated that approximately 20% of copper removed to suspended sediment and deposited at the benthic boundary is recycled in this fashion. Clearly benthic reactions contribute measurably to the overall cycling of heavy metals in the environment and these reactions must be understood in order to predict the likely effects of oil, or any other type of pollution, at this interface. For the initial part of this current contract, therefore, we have been studying the behavior of manganese. Manganese exists in nature in two oxidation states of distinctly different behavior and the cycling of this metal is important to the behavior or many other heavy metals.

Figure 30 illustrates the distribution of soluble (< •4 μm) manganese in April. The positive gradient to the boundary is very marked at this time of year — late oceanographic winter — since this period falls near the end of the period when the basin water is largely advectively isolated. We may again assume a model of vertical turbulent diffusion of the reduced manganese with kinetically controlled oxidation and removal as a particulate phase.

How well does the distribution of particulate manganese (below sill depth) conform to this model? Vertical profiles for this parameter for

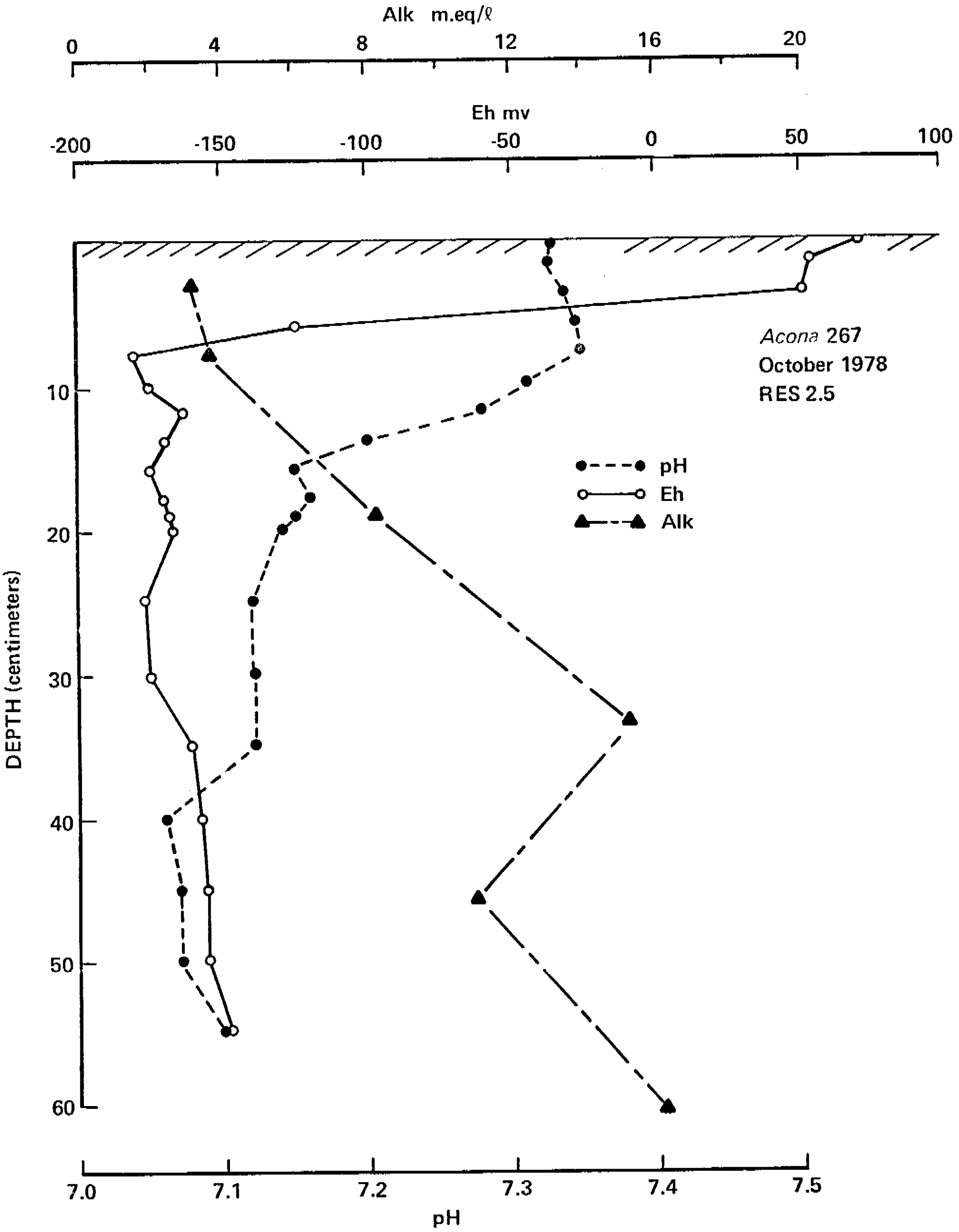


Figure 28. pH, redox, alkalinity environment of sediment at Station RES 2.5.

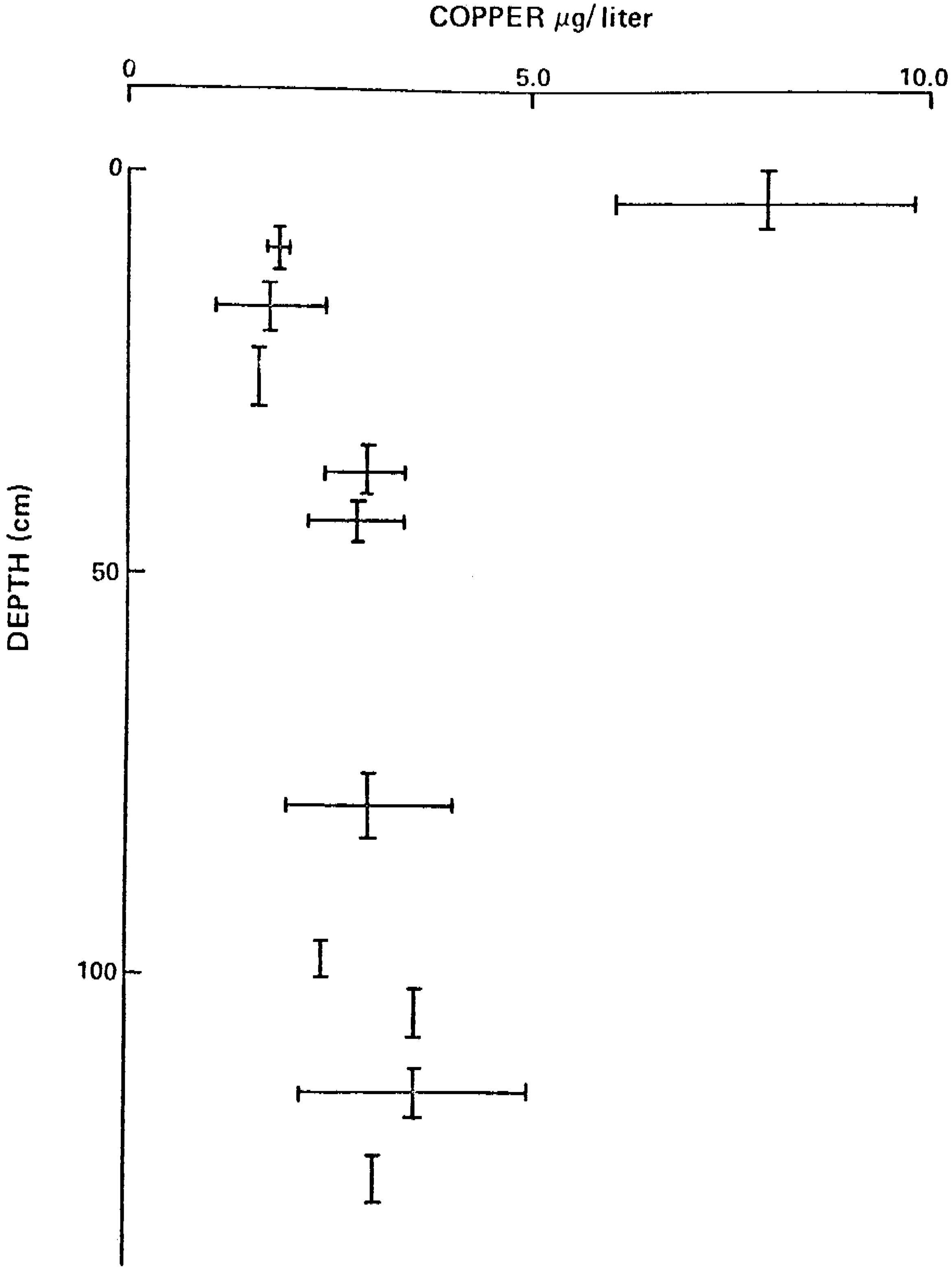


Figure 29. Concentrations of copper in sediment interstitial water at RES 2.5.

December (1977), and April, July and October (1978) are shown in Figures 31-34. Figure 35 gives the seasonal summary. Considering only distributions below sill depth, the April and possibly the December profiles appear to approach the expected distributions with a positive gradient to the boundary. The latter seasons fall within the "stagnant" winter period. In addition, during this season the particulate organic content at depth is minimal. For this argument we assume that the precipitated manganese is not specifically associated with the sedimentary biogenic material. To eliminate the latter, we may consider Mn/Al ratios through the column; assuming a reasonably constant relationship between Al and the alumino-silicate fraction of the particulate load. These data are shown by season in Figures 36-39 and in combination in Figure 40. The seasonal pattern is as for particulate manganese alone. Summer — July and October — patterns below sill depth show decreases with depth, winter patterns give positive gradients to the sediments. In both the latter cases there is, however, a reversal at the very bottom. Since resuspension of bottom sediment appear to occur thoughout the year (Figure 19), this latter feature may be due to preferential resuspension of alumino-silicate material. We have no immediate explanation of the sill-depth maxima, but horizontal advections are important at this time of year and these may be due in some fashion to precipitated river-bourne manganese. The rationale for plots such as given in Figures 36-40 is to differentiate between "primary" aluminosilicate manganese and forms not so bound: presumably predominantly the precipitated oxide. Figure 41 shows total particulate manganese per unit volume of water. The seasonal trends here appear to mirror that previously given for copper with well developed gradients towards the sediment in the winter.

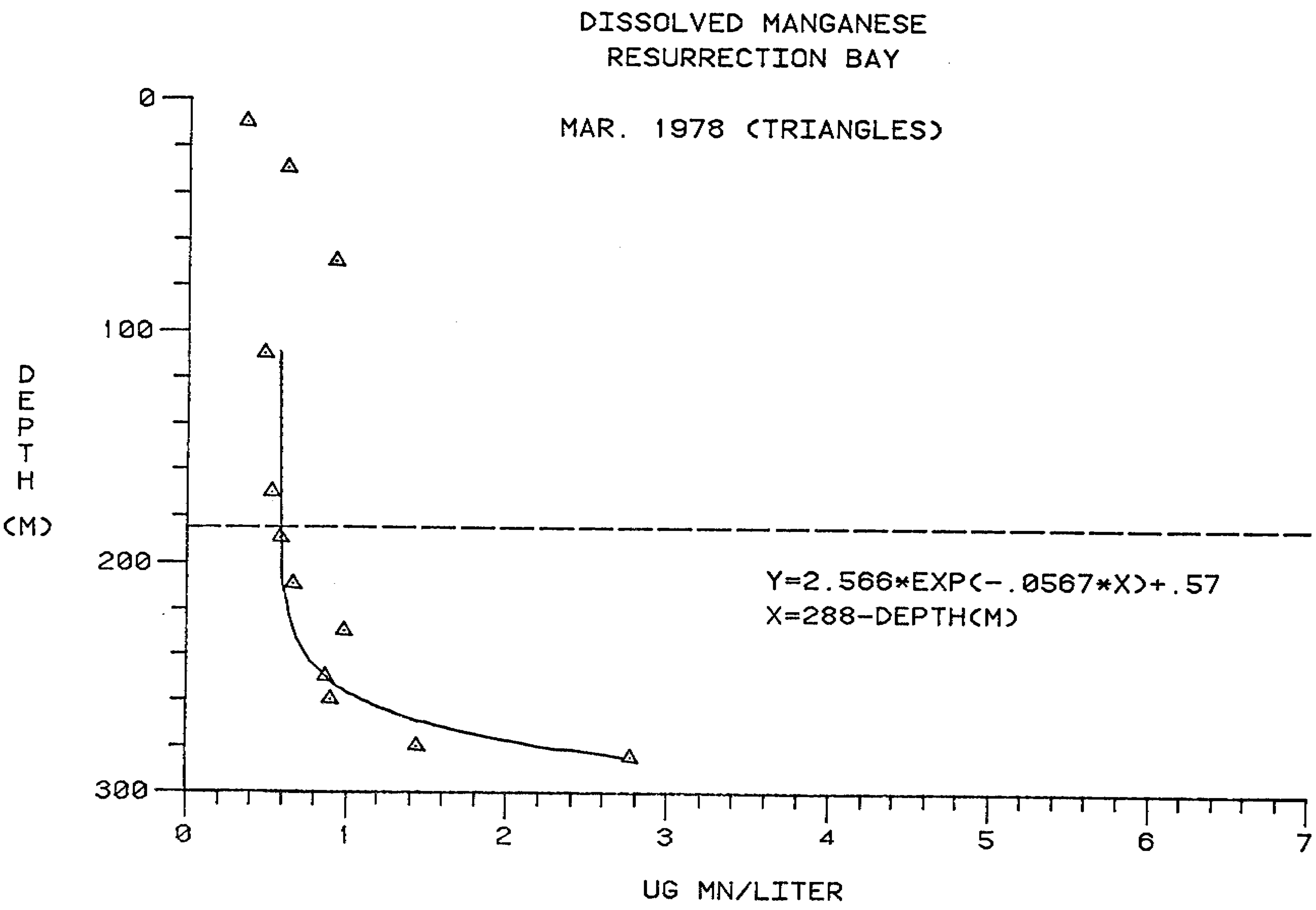


Figure 30. Dissolved Mn (II) at RES 2.5 in April (1978).

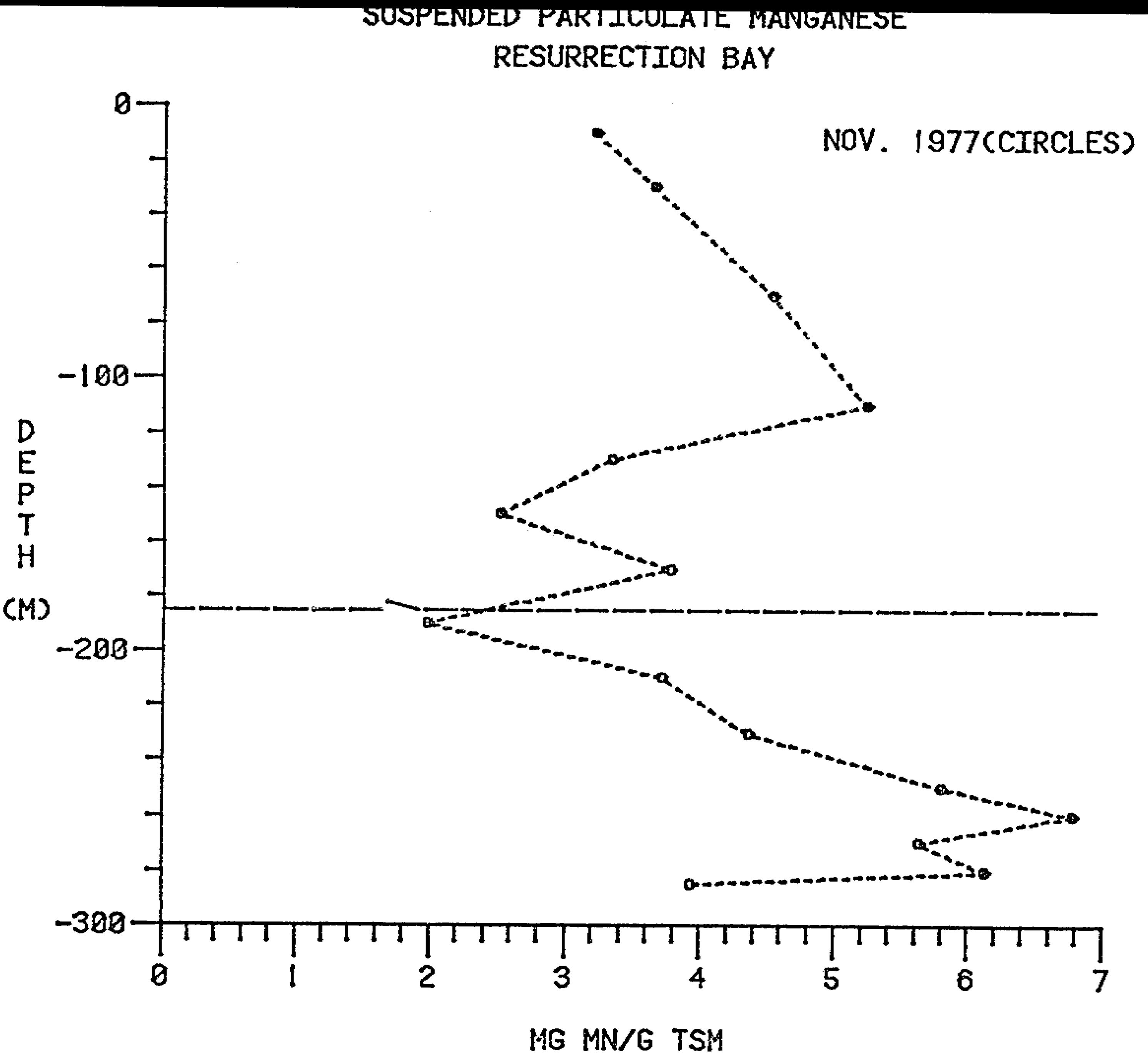


Figure 31. Particulate Mn at RES 2.5 in December (1977).

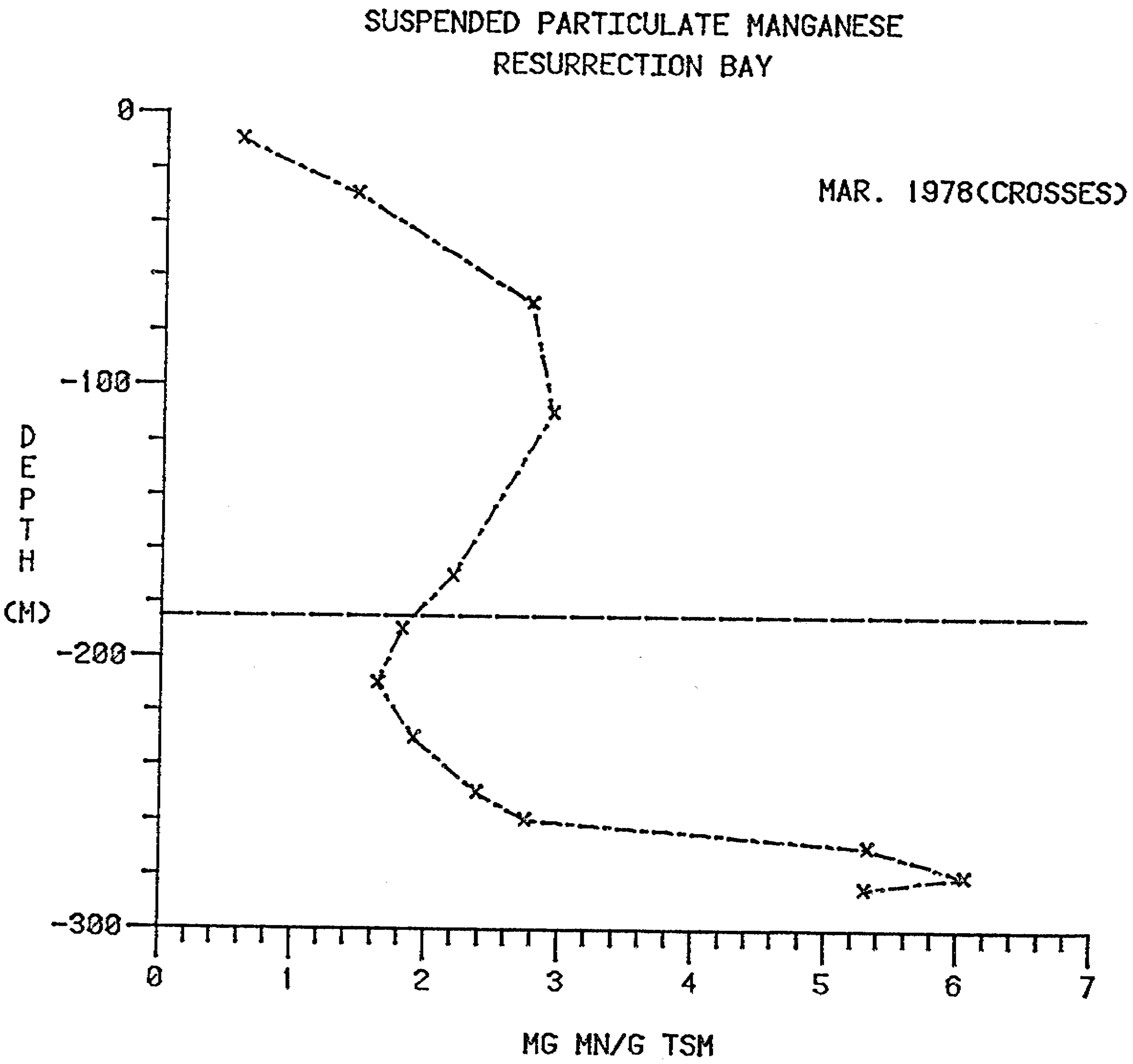


Figure 32. Particulate Mn at RES 2.5

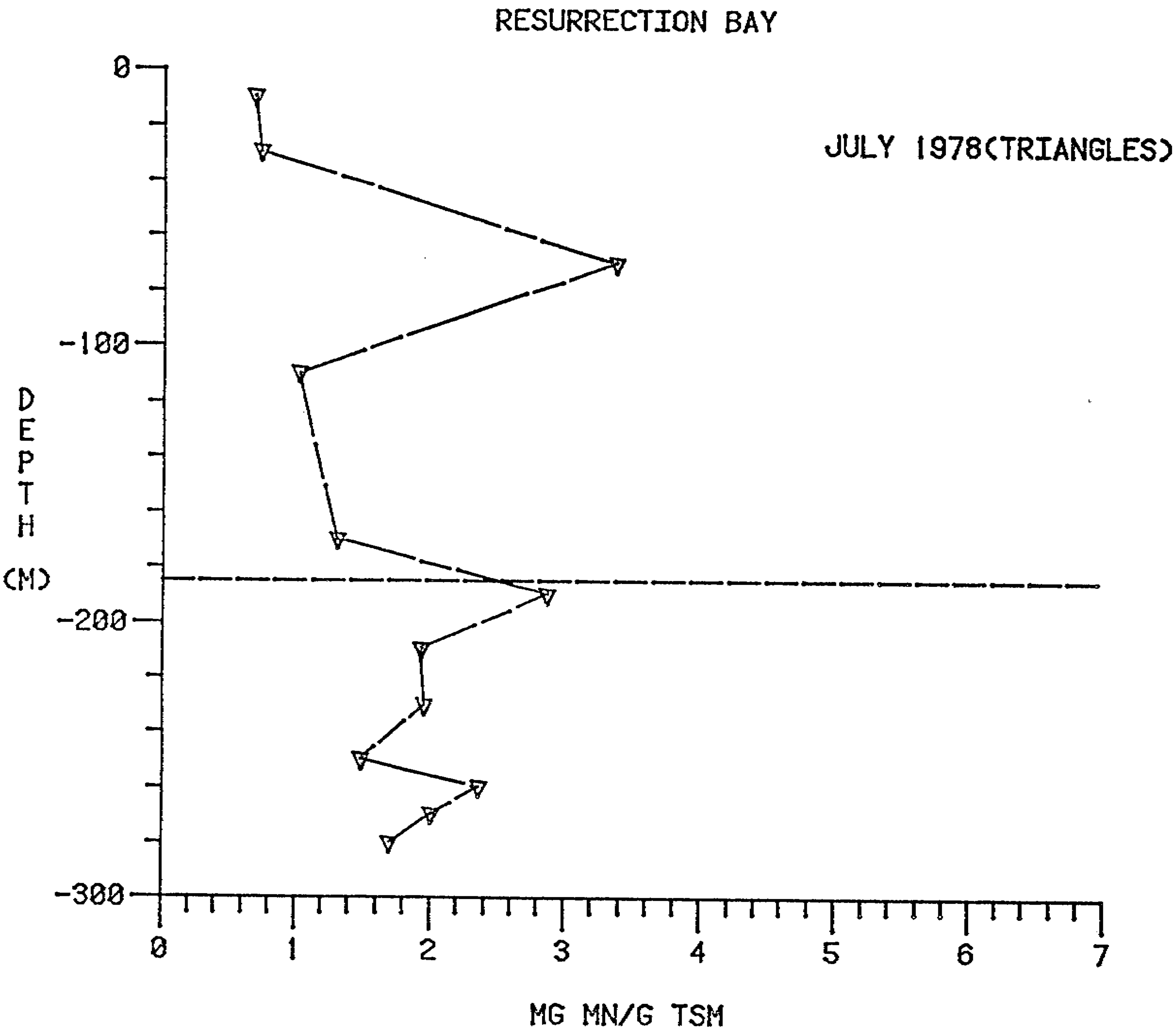
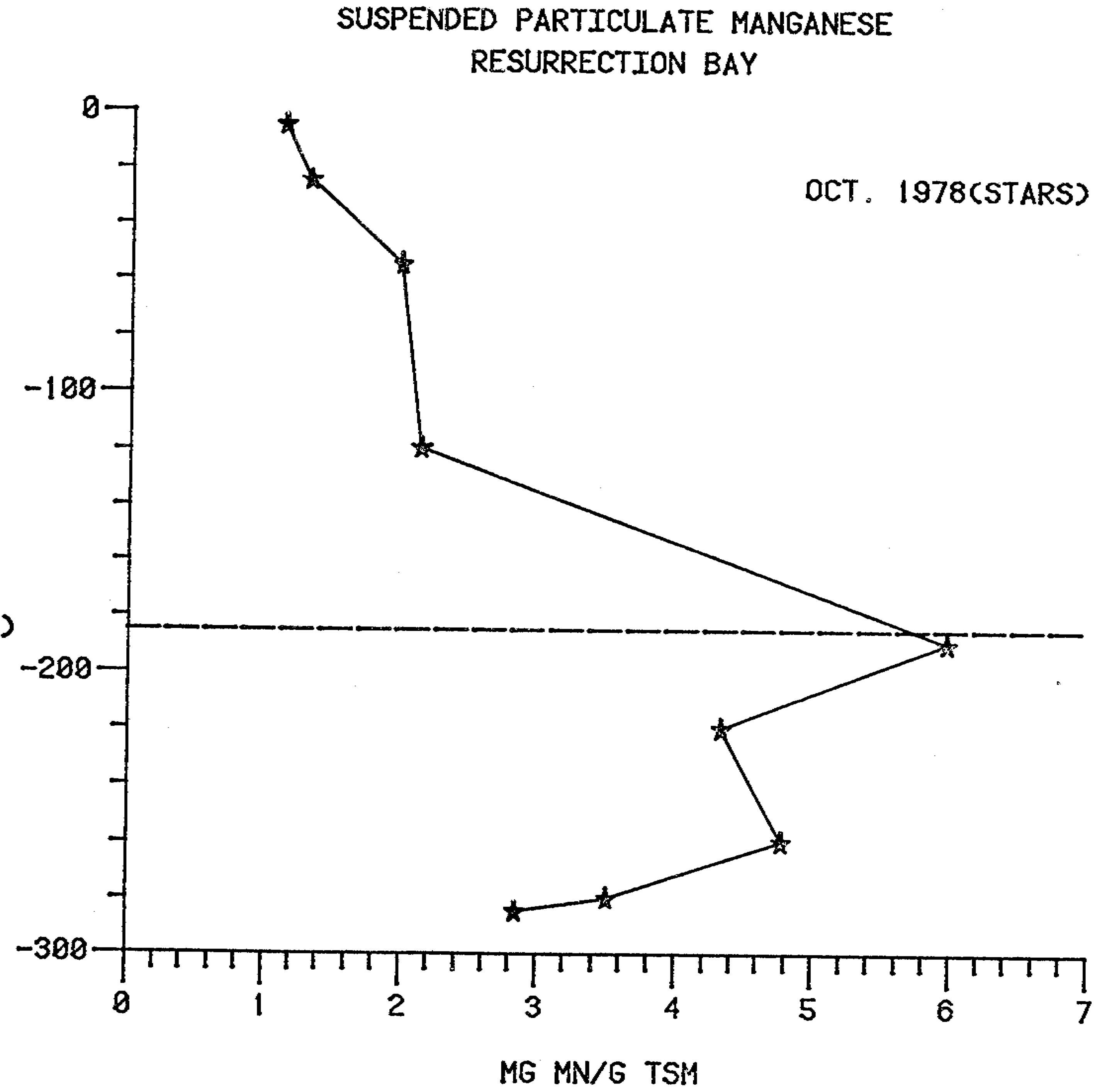


Figure 33. Particulate Mn at RES 2.5 in July (1978).


SUSPENDED PARTICULATE MANGANESE
RESURRECTION BAY
OCT. 1978(STARS)
0
-100
-200
-300
DEPTH (M)
0
1
2
3
4
5
6
7
MG MN/G TSM

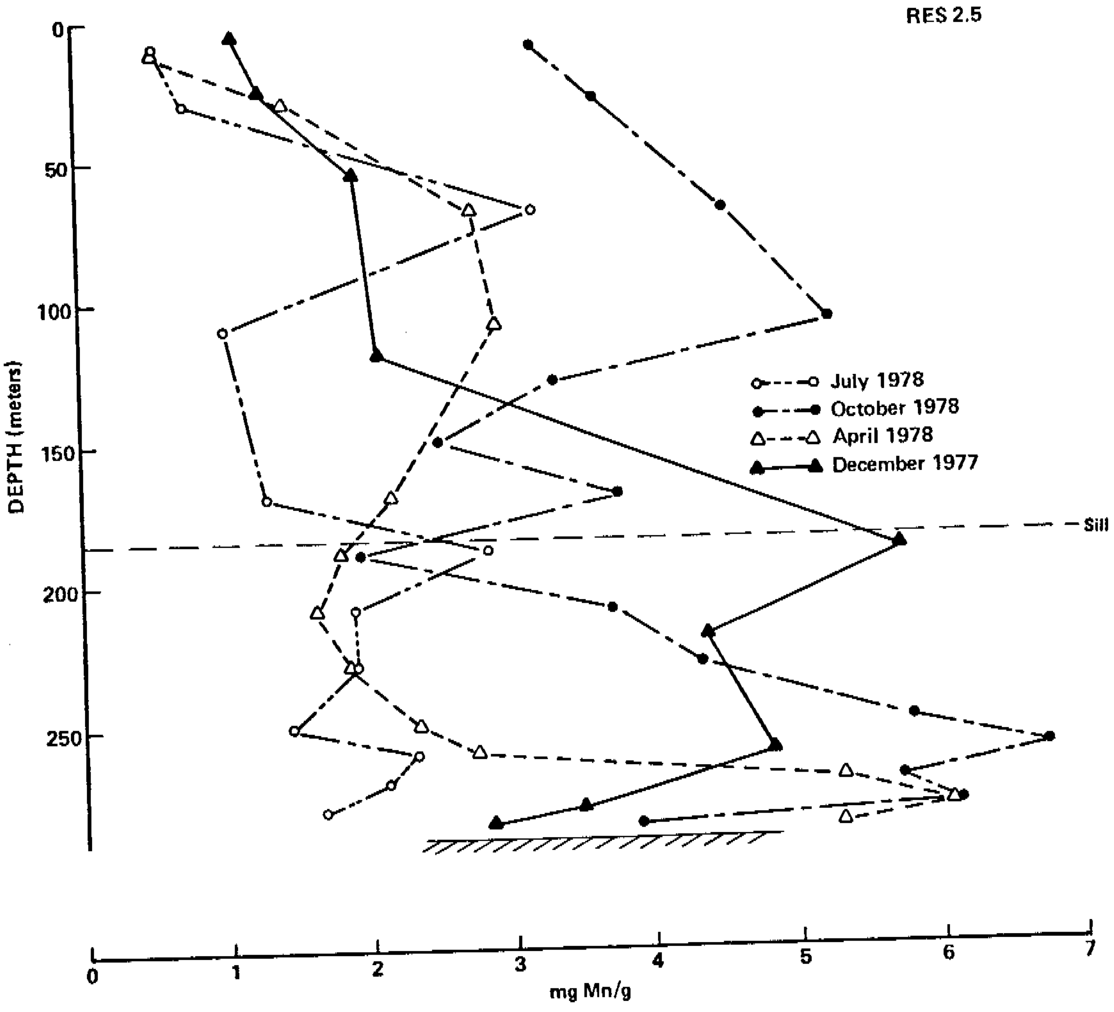


Figure 35. Seasonal distribution of particulate Mn at RES 2.5.

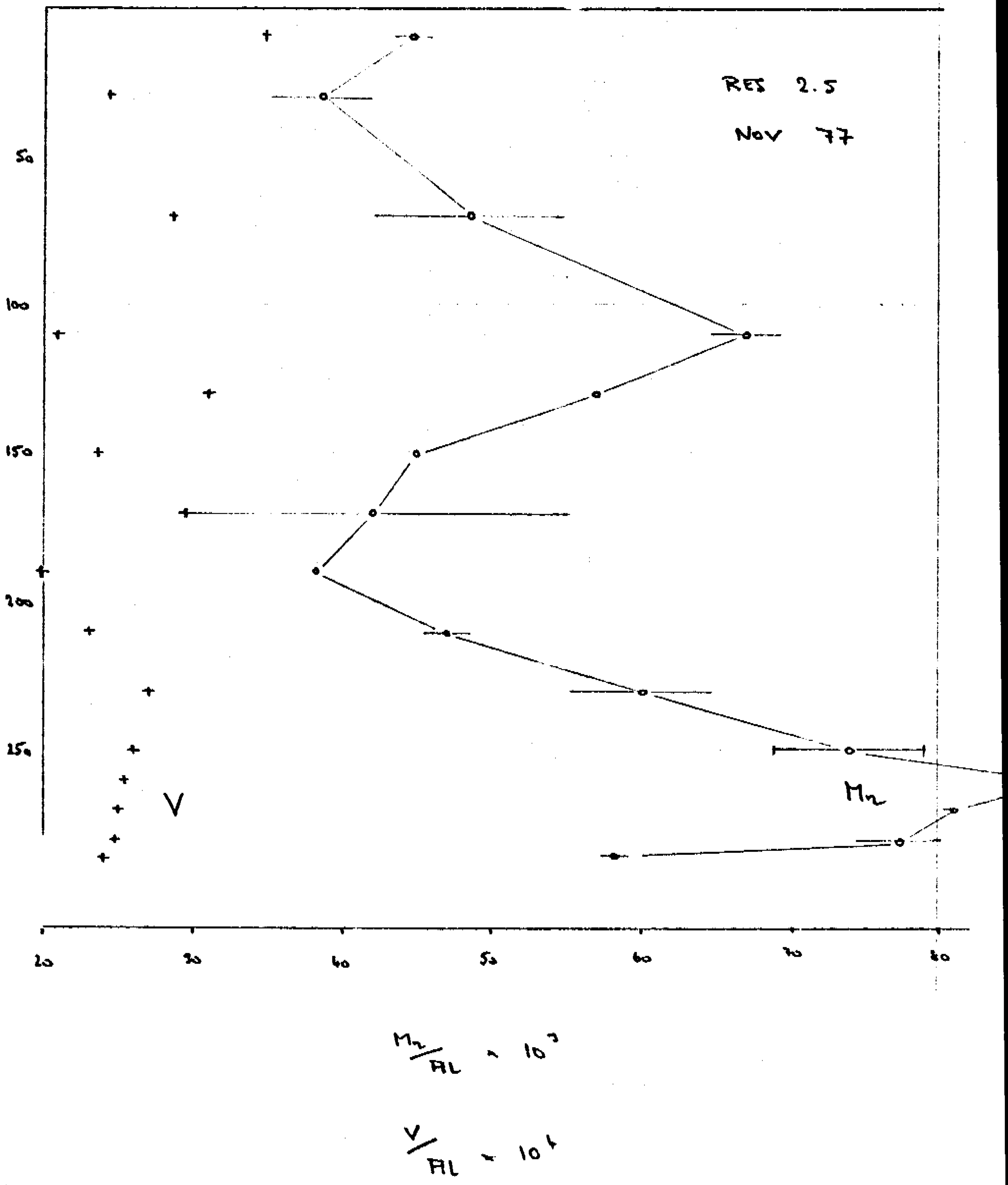


Figure 36. Mn/Al distribution at RES 2.5, December 1977.

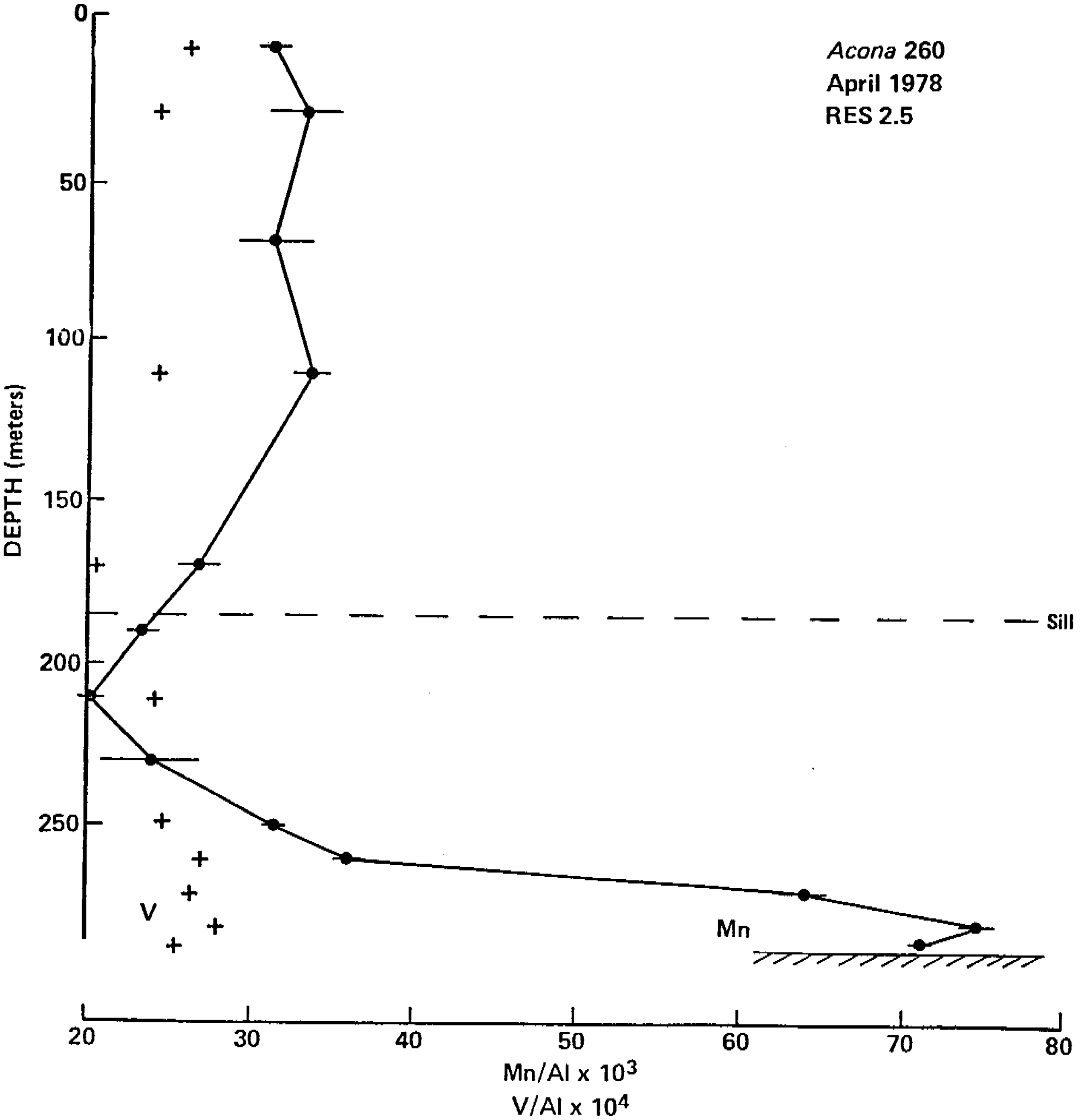


Figure 37. Mn/Al distribution at RES 2.5, April 1978.

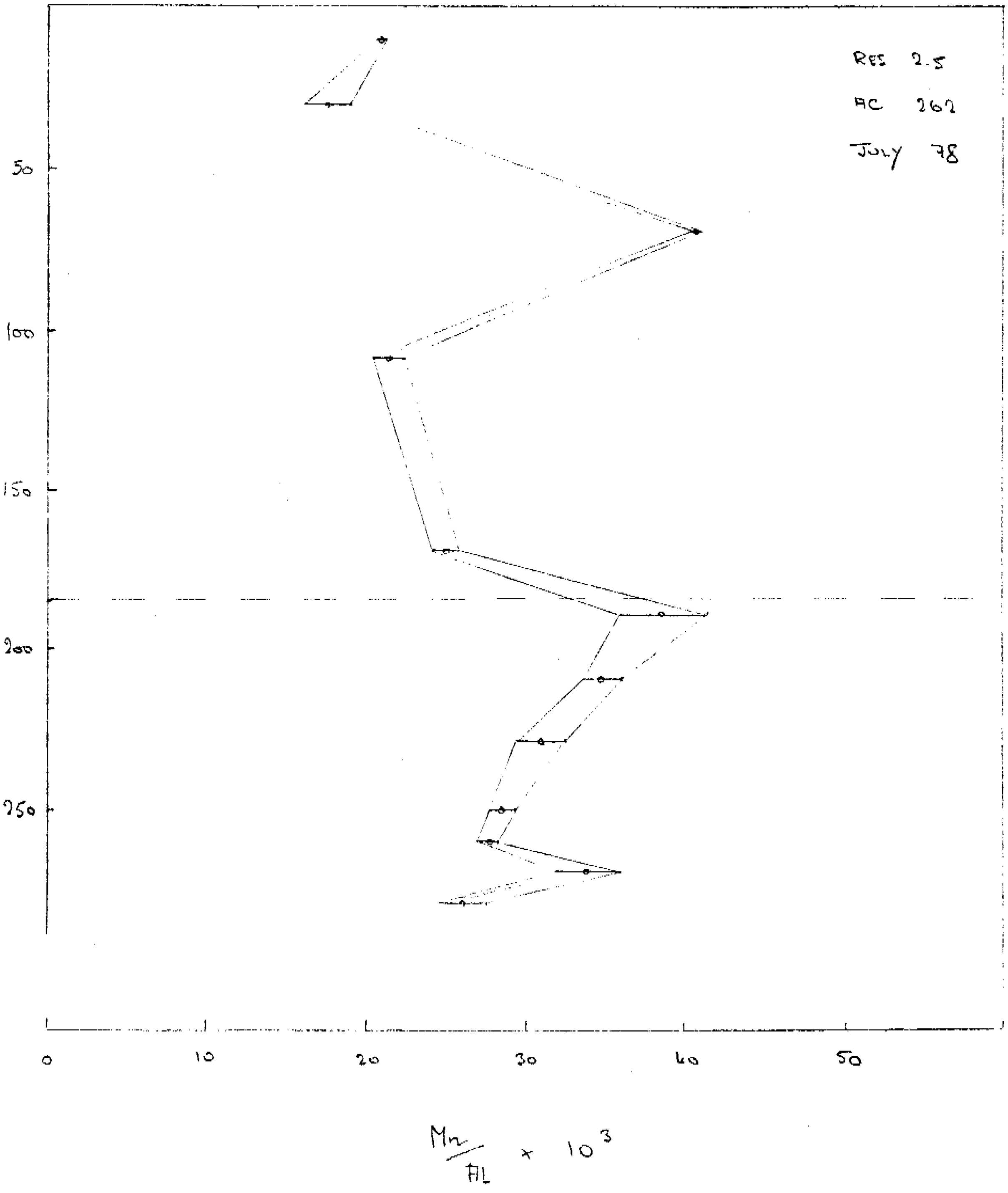


Figure 38. Mn/Al distribution at RES 2.5, July 1978.

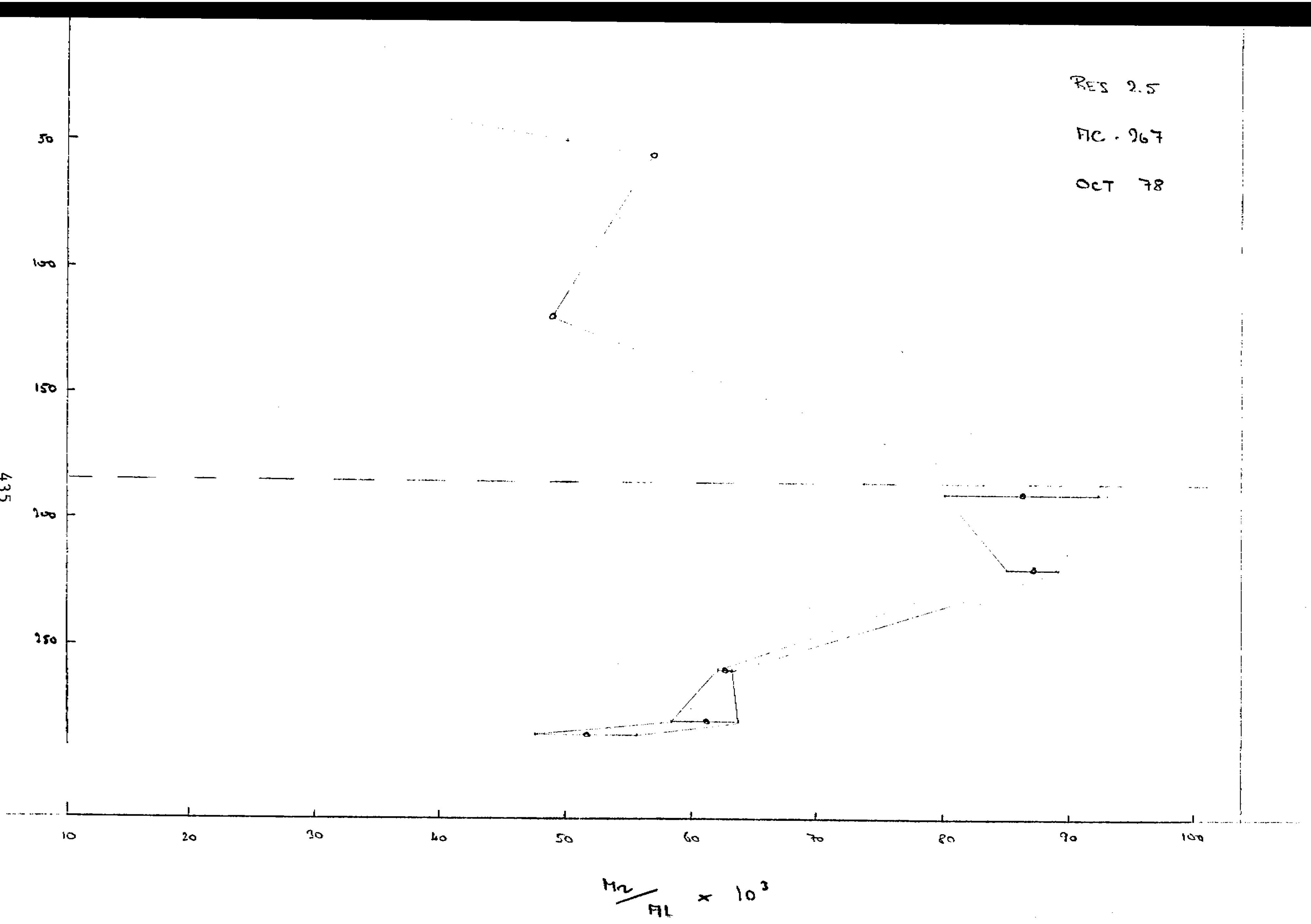


Figure 39. Mn/Al distributions at RES 2.5, October 1978.

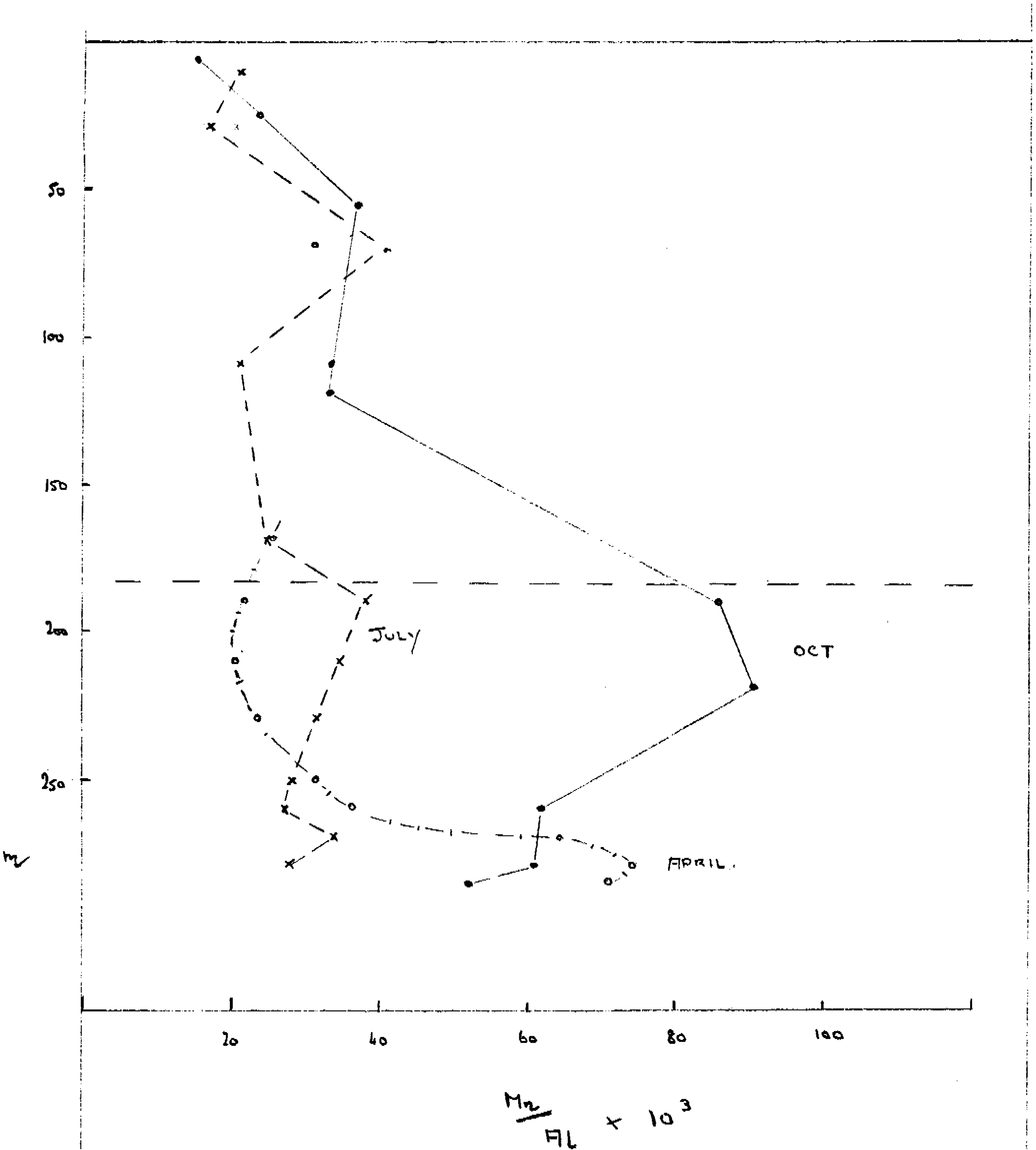


Figure 40. Seasonal distribution of Mn/Al at RES 2.5.

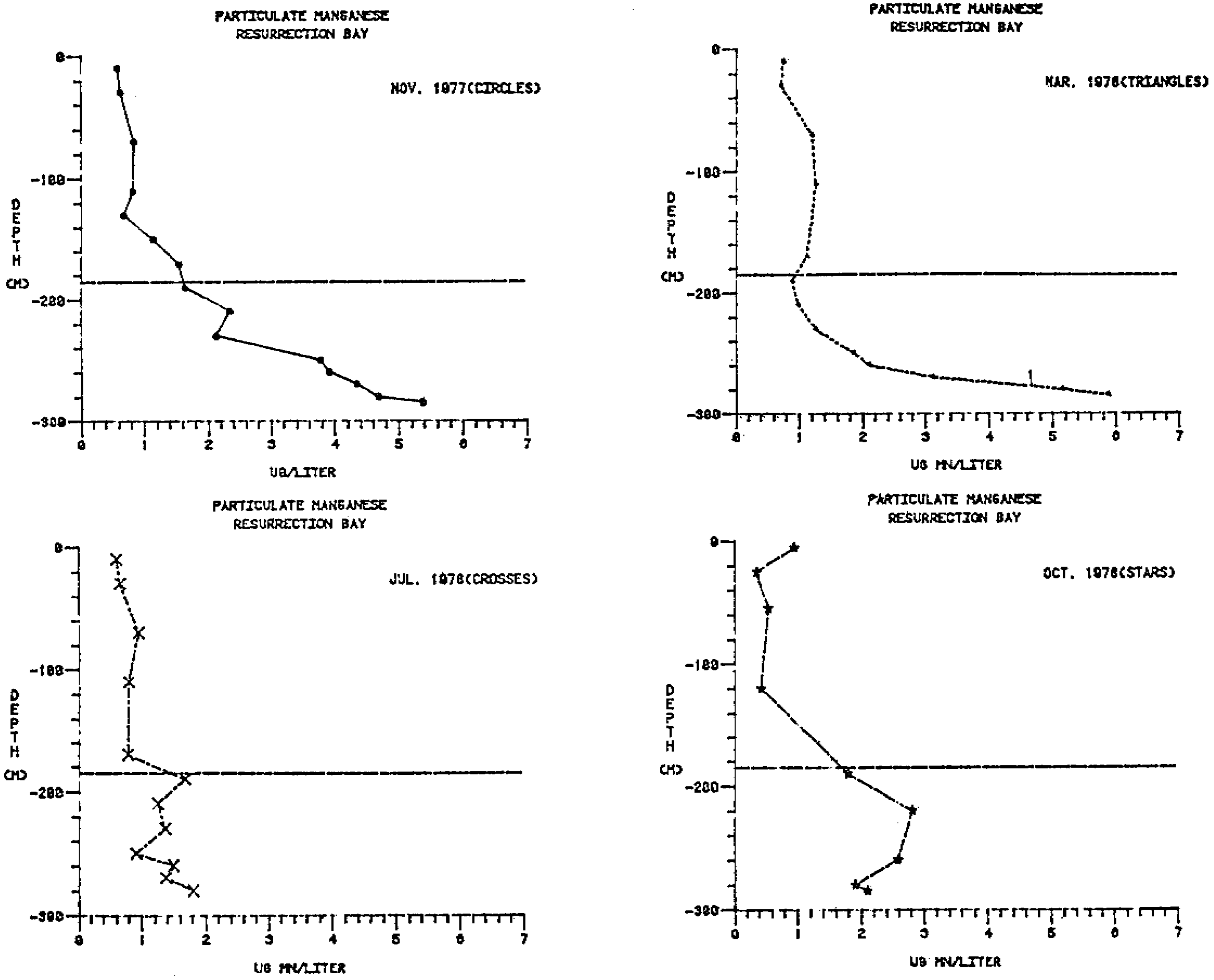


Figure 41. Seasonal distribution of particulate manganese per unit volume of water.

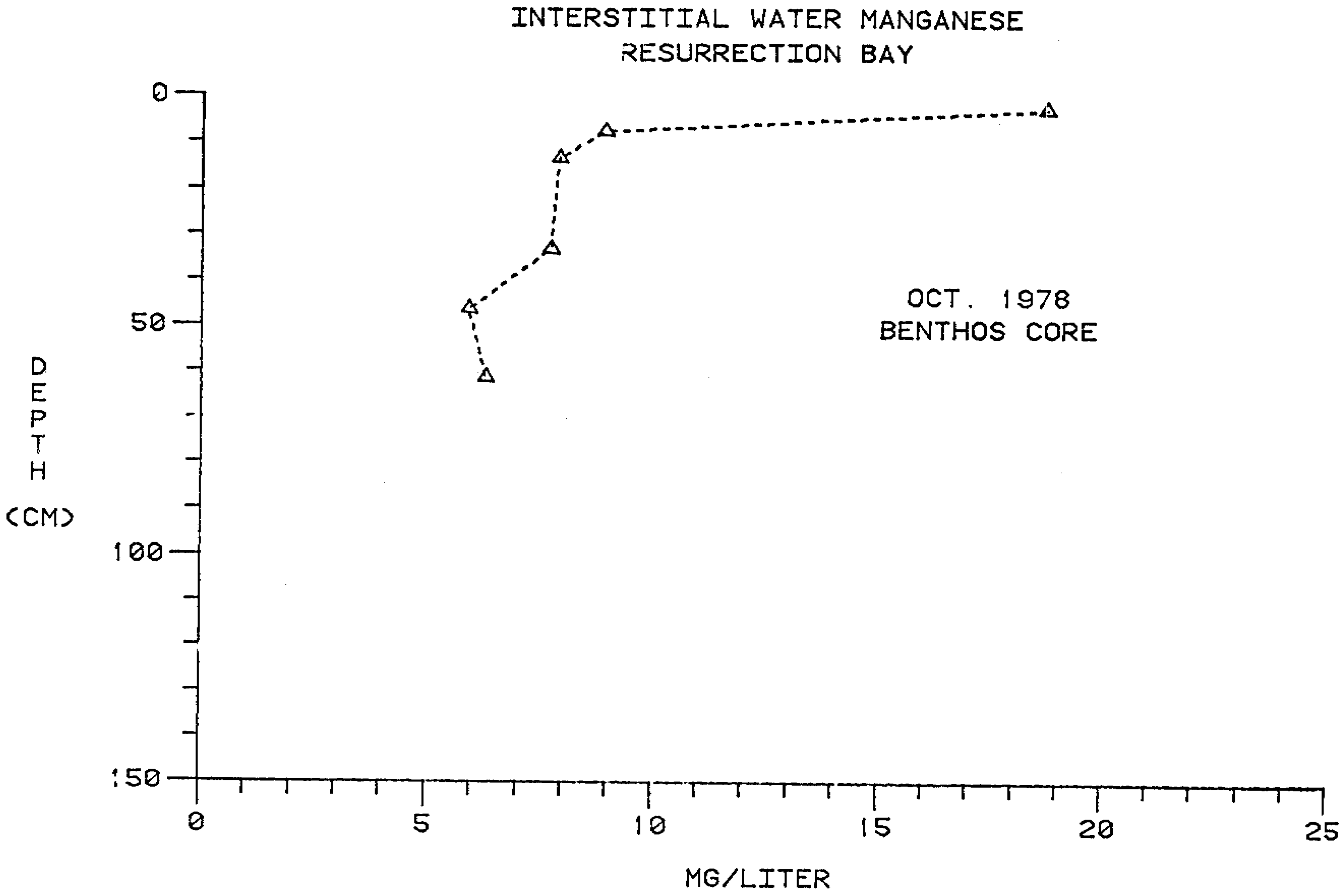


Figure 42. Interstitial water manganese concentrations, October 1978.

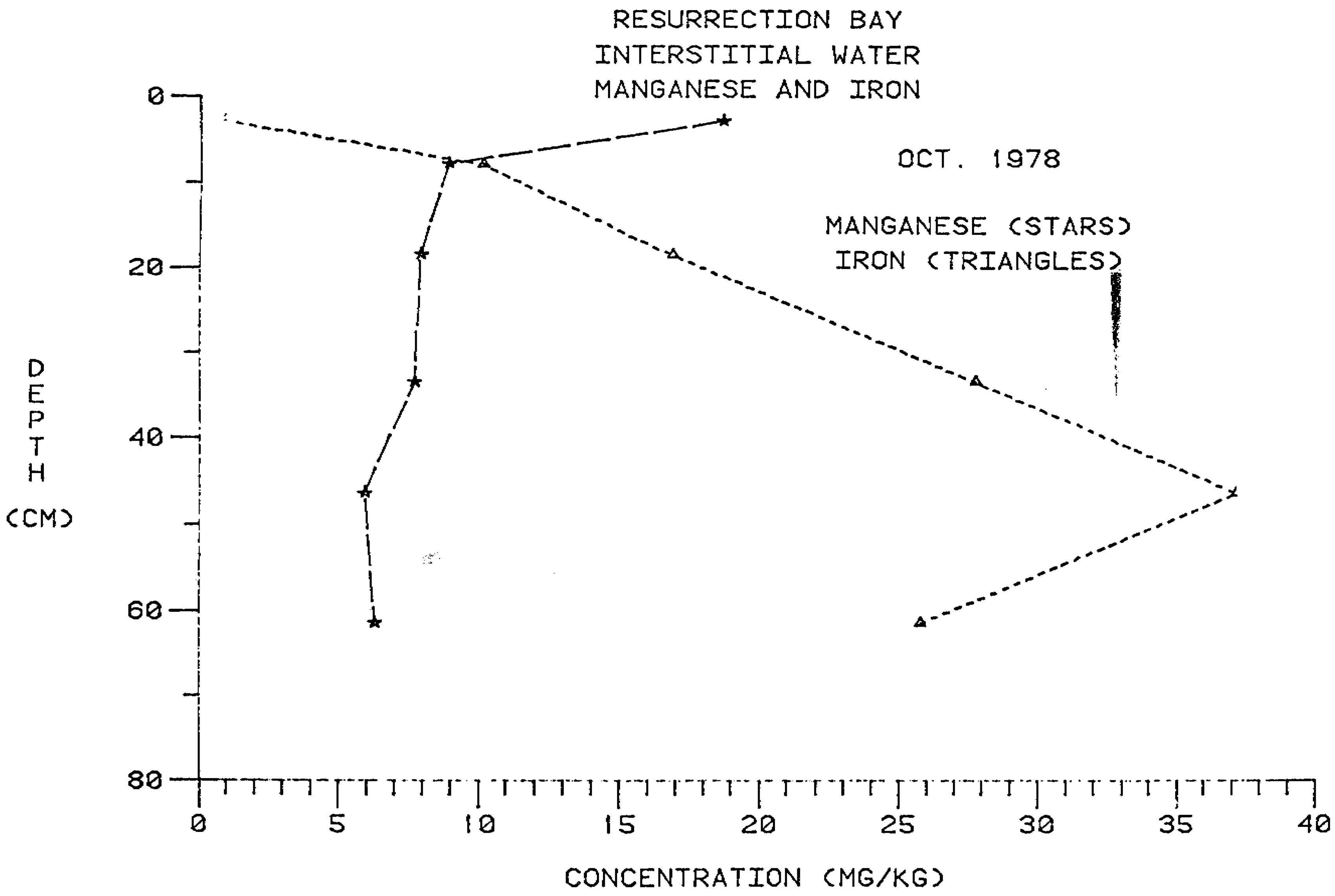


Figure 43. Interstitial water iron and manganese concentrations, October 1978.

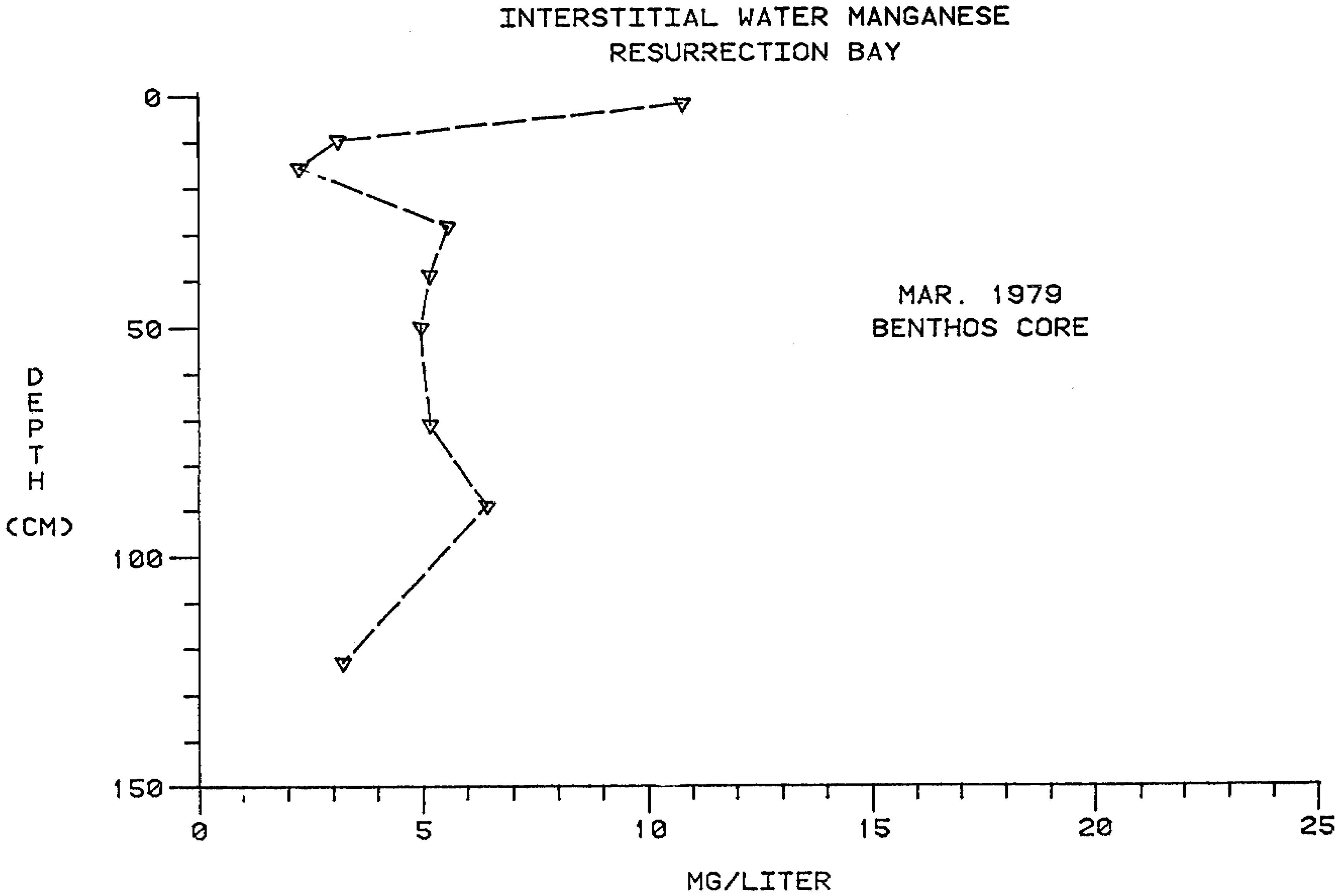


Figure 44. Interstitial water manganese concentrations, March 1979.

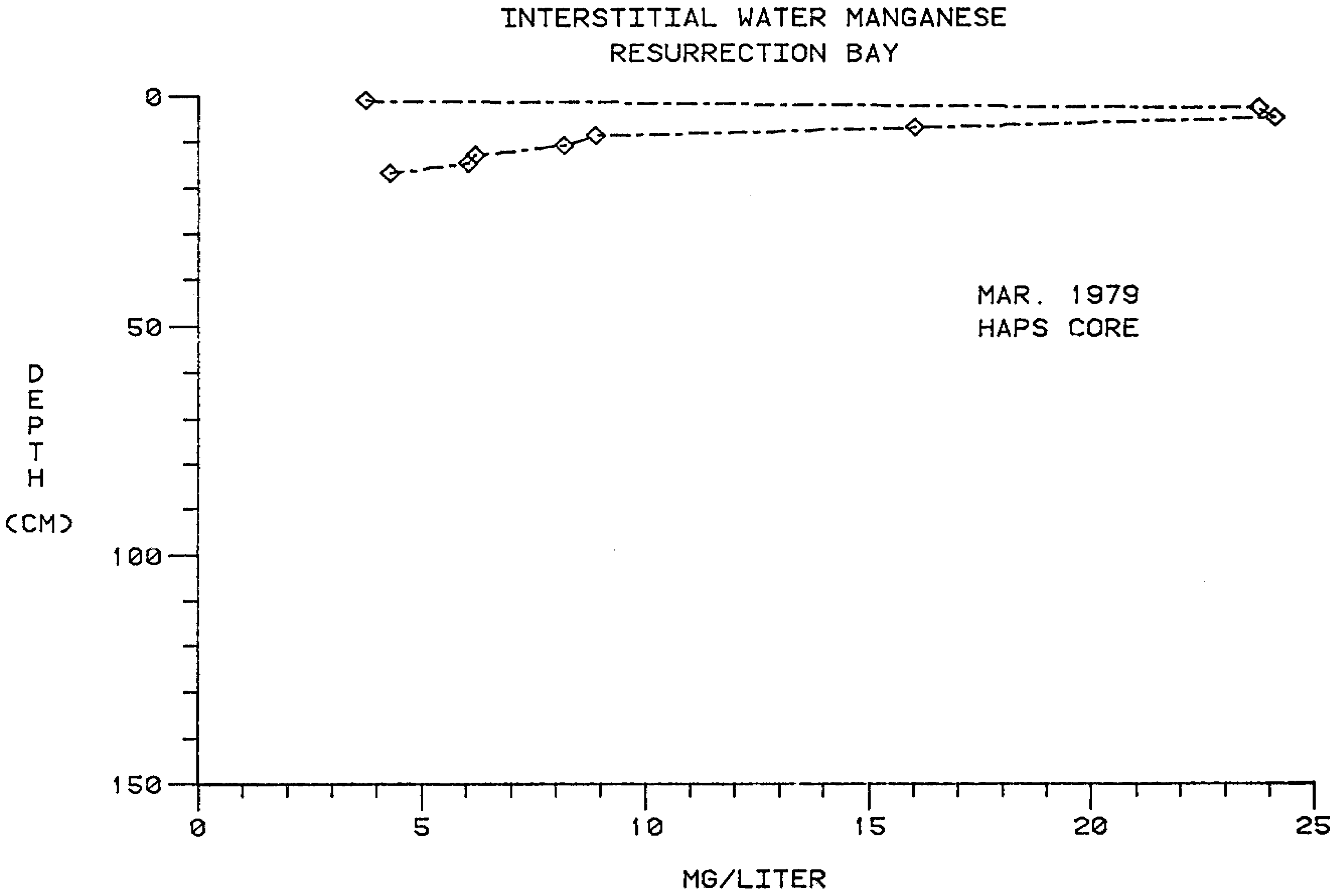
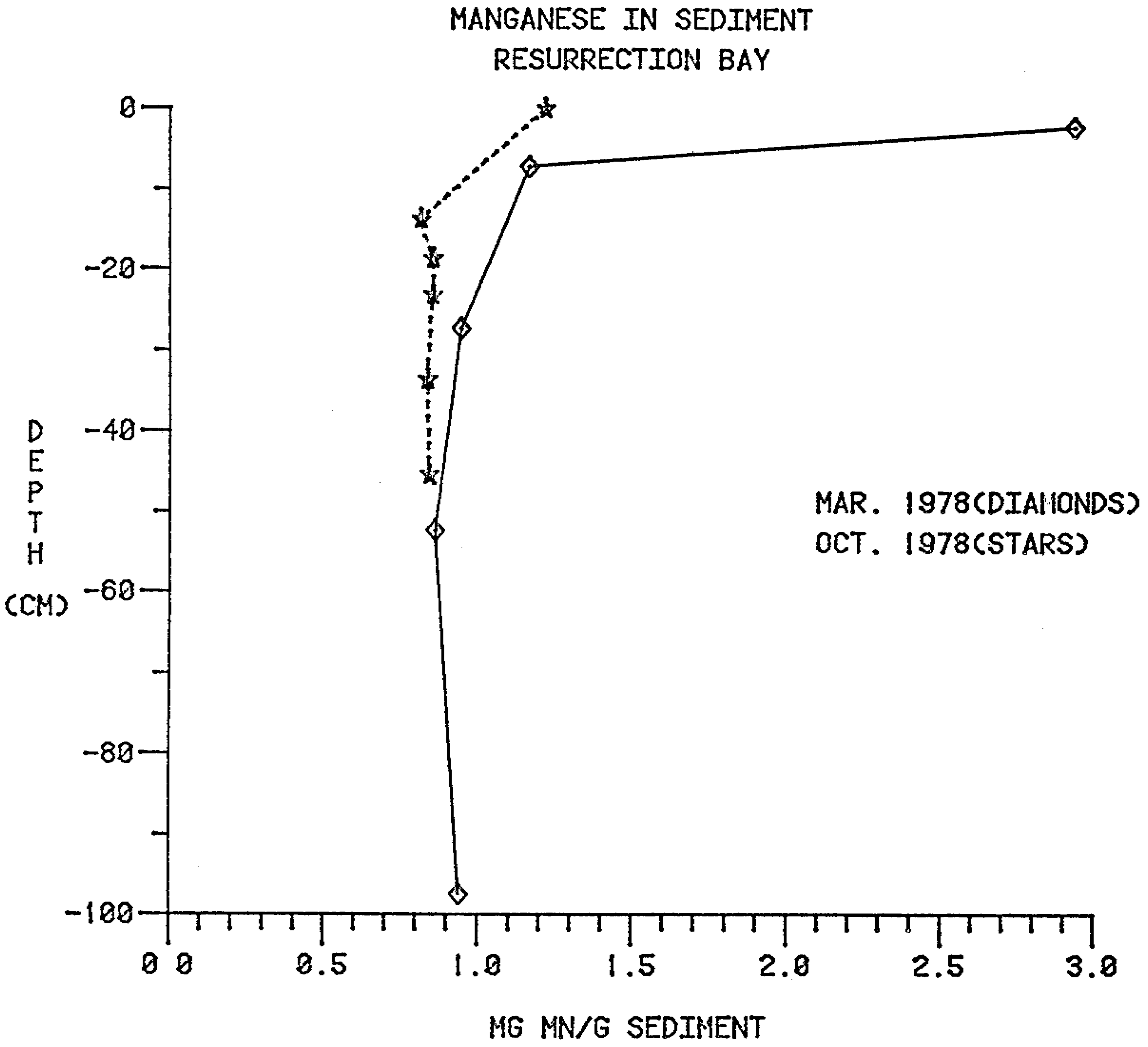


Figure 45. Interstitial water concentrations in surface sediment--close internal sampling.


MANGANESE IN SEDIMENT
RESURRECTION BAY
DEPTH (CM)
0
-20
-40
-60
-80
-100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
MG MN/G SEDIMENT
MAR. 1978(DIAMONDS)
OCT. 1978(STARS)

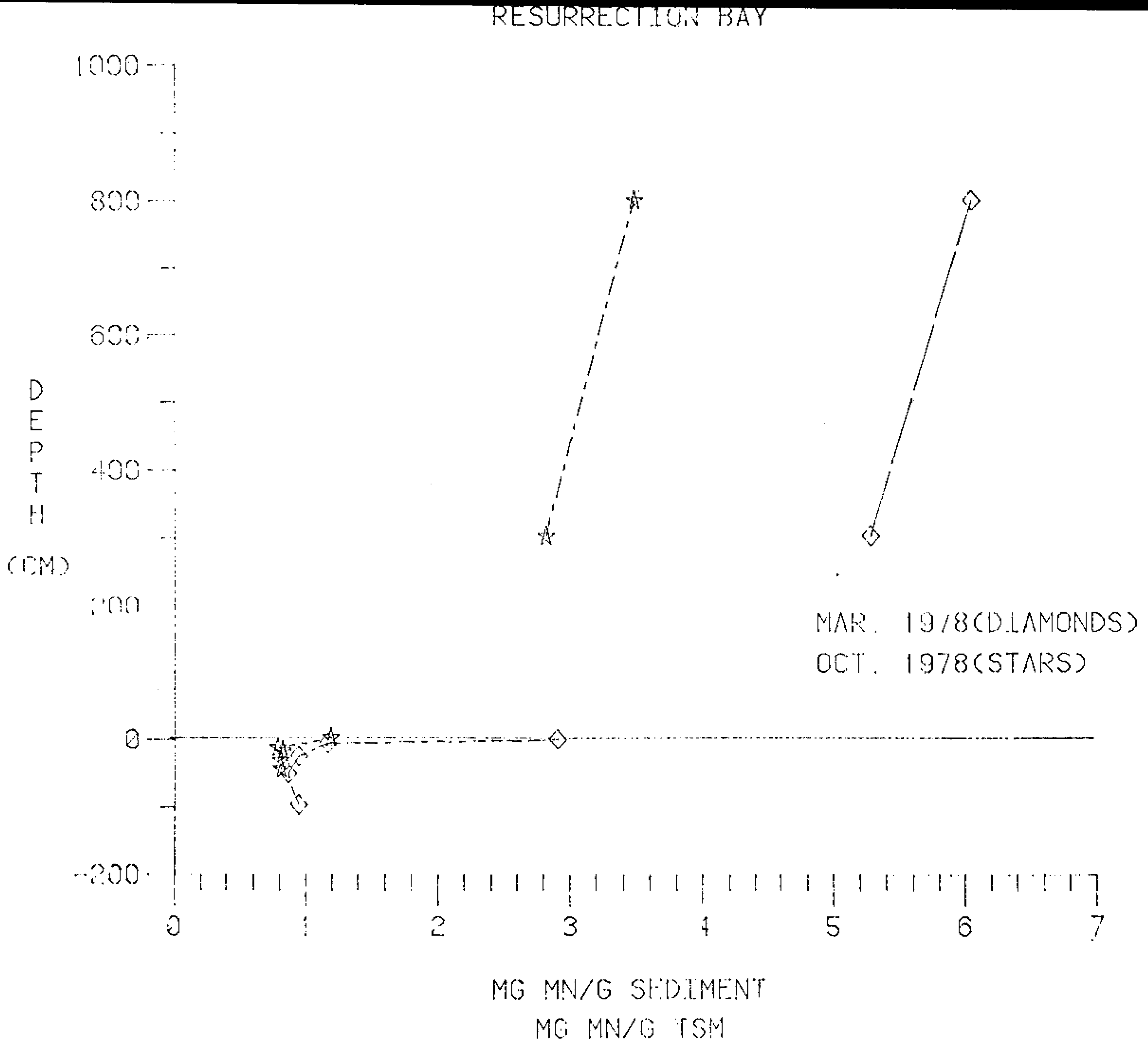


Figure 47. Particulate manganese contents of suspended and bottom sediments.

Obviously the indicated flux of manganese from the sediments should be apparent in the sediment interstitial water profiles. The simplest model of the behavior of manganese would involve mobilization below the redox boundary and diffusion upward in the sediment with partial oxidative removal within the oxic sediment zone but with a considerable flux into the base of the water column. This latter appears to be removed and re-sedimented below silt height so that these reactions represent a close sub-cycle. Figure 42 shows interstital water Mn from a core taken in October. This is a coarsely sampled profile so that a release is indicated in the upper part of the zone and high concentrations (∿ 15-20 ppm) are present in solution near the sediment surface. Figure 43 reproduces the same data but demonstrates that the soluble iron is removed within the upper zone. Data for a very recent core confirmes this trend (Fig. 44). However in the latter case we have performed very close interval sampling to better define the gradient in the new surface sediment. Figure 45 is preliminary data showing the form of the gradient in the surface layers. A flux of manganese into the water column may be thus determined if reasonable assumptions are made about the diffusion coefficient range to use here. At the sediment surface the concentration of soluble (reduced) manganese is around 2-3 mg/1. This is recuded about three orders of magnitude over a 3-5 meter vertical column.

Manganese mobilized below the redox boundary is partially re-precipitated in the oxic sediment zone. Figure 46 gives total sediment manganese profiles and Figure 47 shows the relative concentrations of this element in suspended and the deposited sediments. The approximately contant sediment content below around 20 cm represents the "equilibrium" content leaving the marine cycle.

As required by the OCSEAP Boulder Office, we have carried out a series of standarized extraction treatments on these sediments. Figure 48 shows both peroxide and acid extract contents of manganese for the April core, Figure 49 peroxide fraction data only for the October core. The peroxide treatment is intended to indicate organic associated methods but clearly will remove some oxidable fraction material also and dissolution of manganese oxide in to be expected. Figures 50 and 51 show peroxide and acid extraction concentrations of copper and zinc from the April core and Figures 51-54 copper, zinc and cadmium contents of the peroxide extract for the October core.

C. Aquaria Experiments on Food Chain Transfers of Heavy Metals

The purpose of this project was to define, in a quantitative way, the pathway of cadmium through a biological food web. The first set of experiments (see 1977-1988 OCS Annual Report) established important background information and observations on the overall, long term experimental design needed. The bacteria choosen for the food source dramatically accumulated cadmium from their liquid growth medium, concentrating the cadmium up to 10^3 times. Results of this experiment correspond closely with other published work dealing with marine bacteria and agal cell responses to heavy metals (Kerfoot and Jacobs, 1975; Patrick and Loutit, 1975). Experimental difficulties were encountered in the actual measuring of accumulated Cd from the bacteria food source to the test clam, *Macoma balthica*. In particular, the feeding characteristics of *Macoma* resulted in sediment contamination of the samples. Purging the digestive tracts of these organisms was not always succesful, so that cadmium levels in clam samples above control levels were a measurement of tissue plus

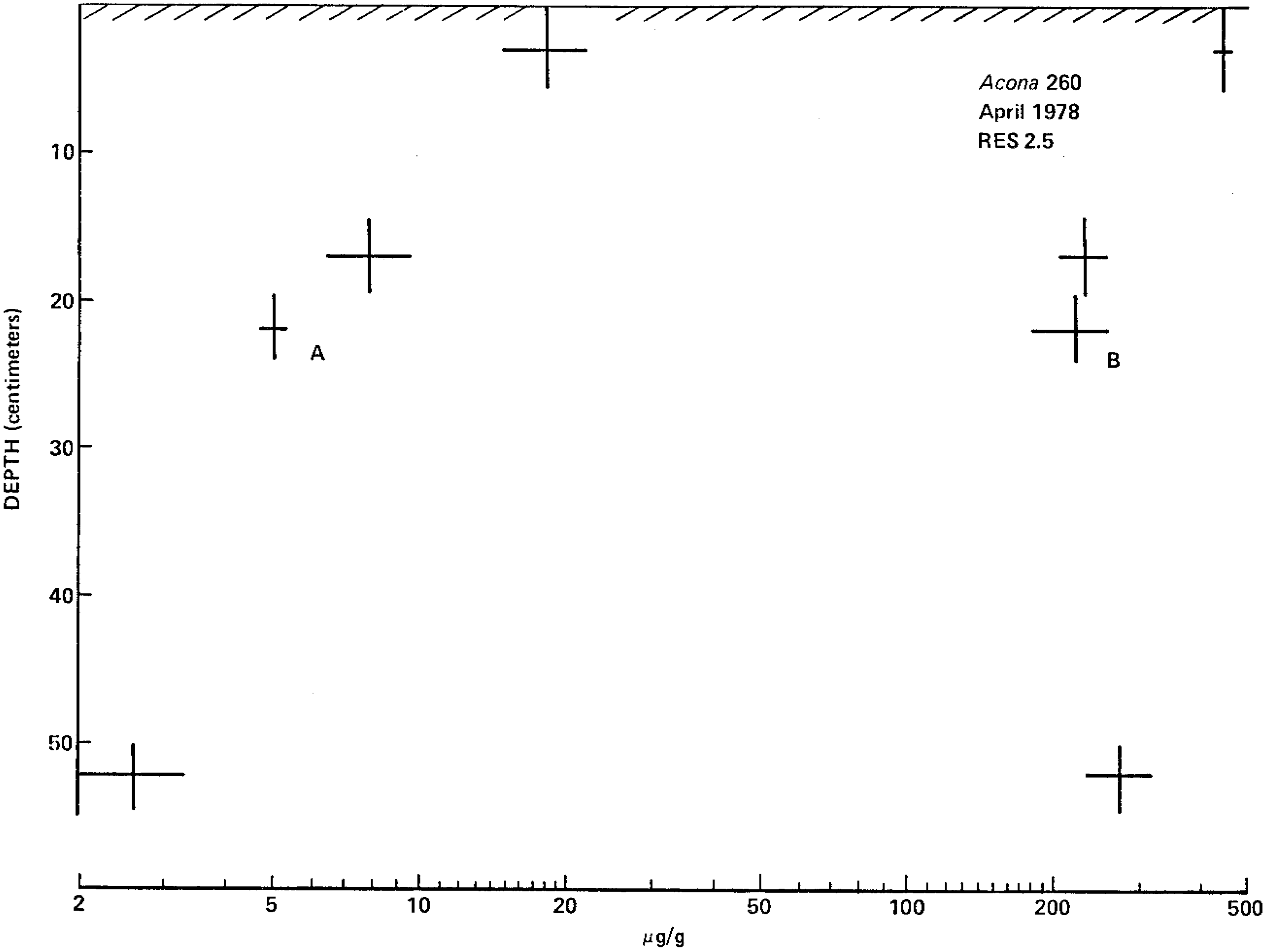


Figure 48. Manganese contents of peroxide and acid extracts of sediment, April 1978.

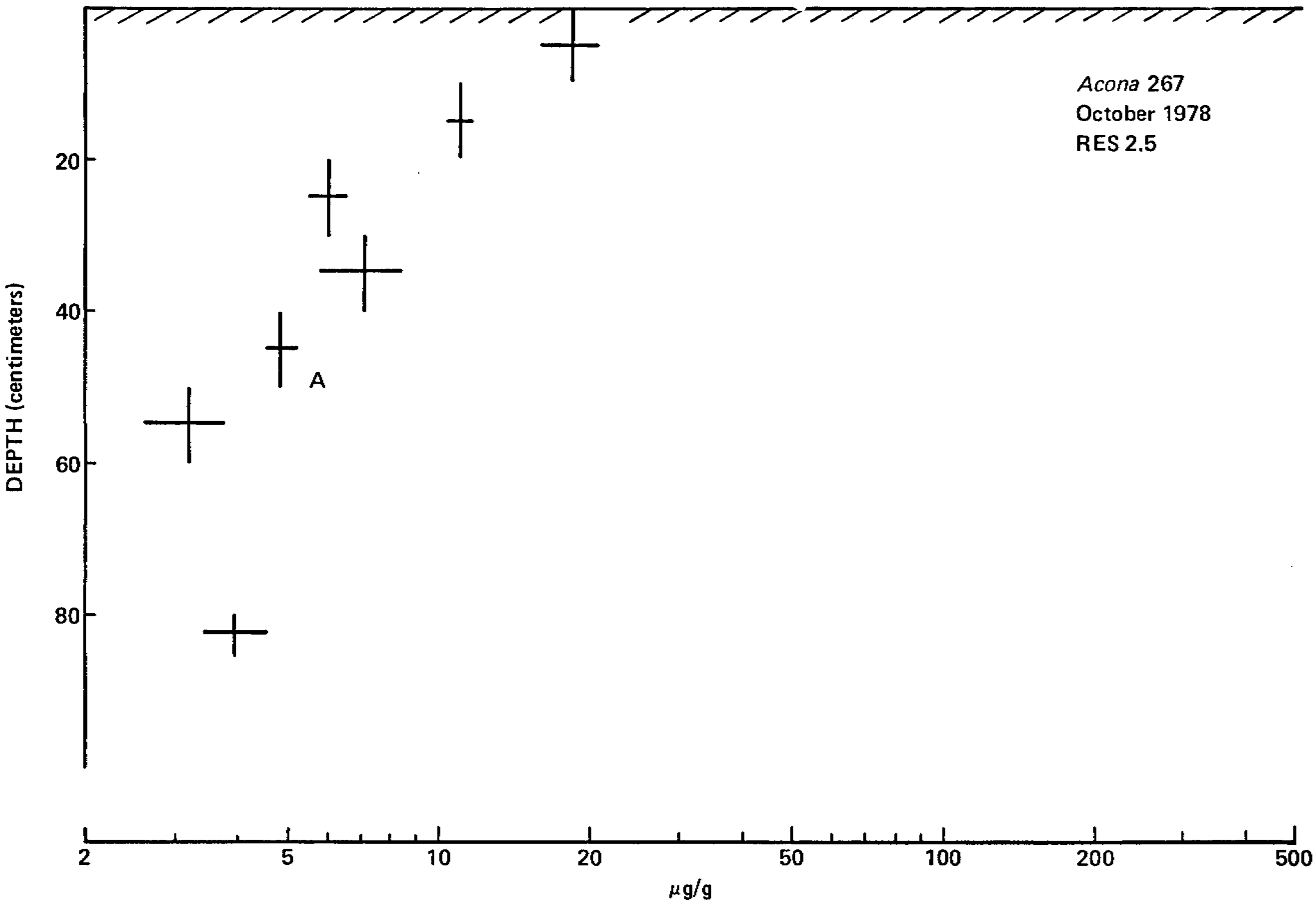
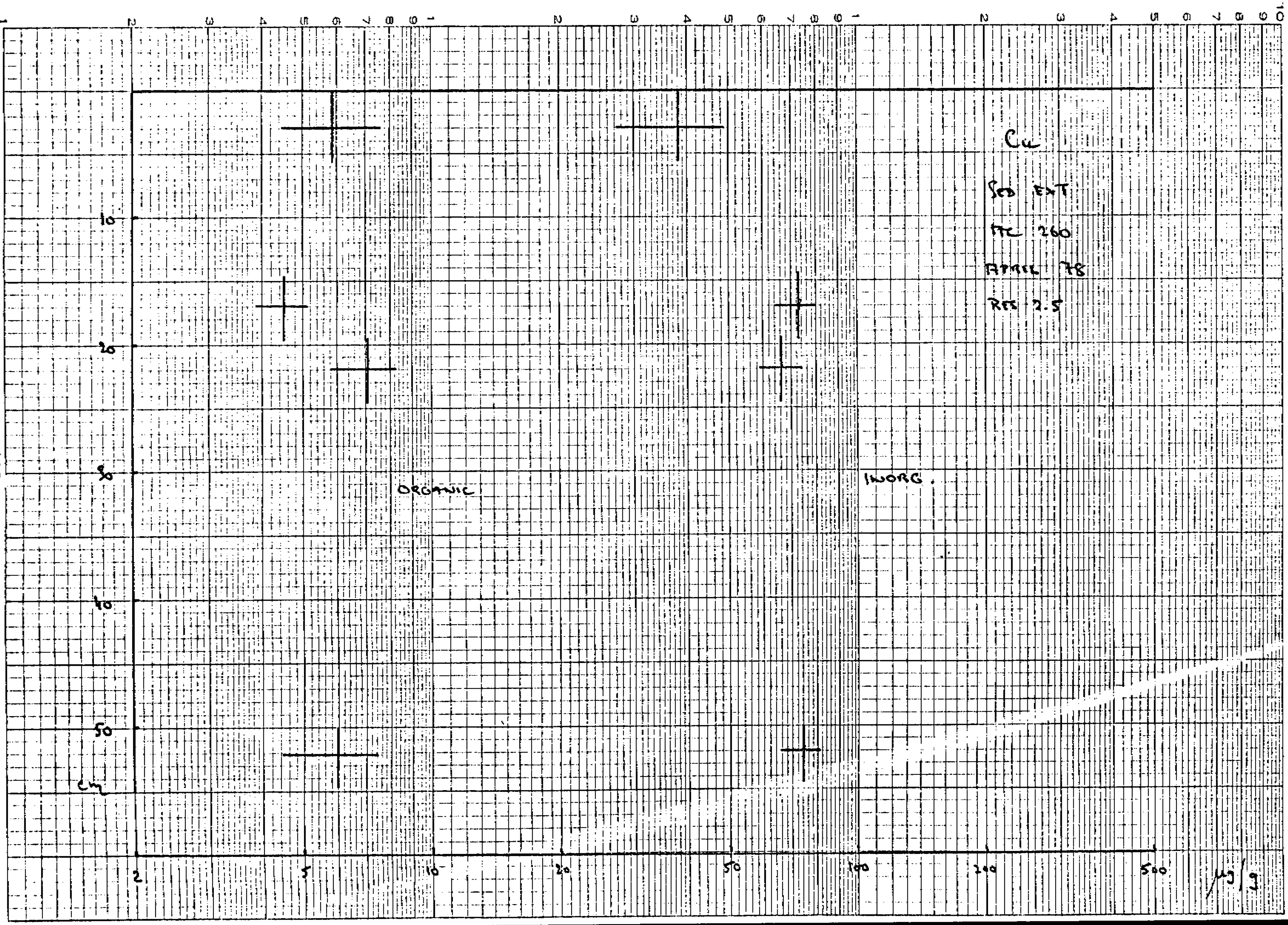


Figure 49. Manganese content of peroxide extracts of sediments, October 1978.


Cu
SED EXT
MC 260
APRIL 78
RES 2.5
ORGANIC
INORG.
10
20
30
40
50
cm
2
5
10
20
50
100
200
500
µg/g

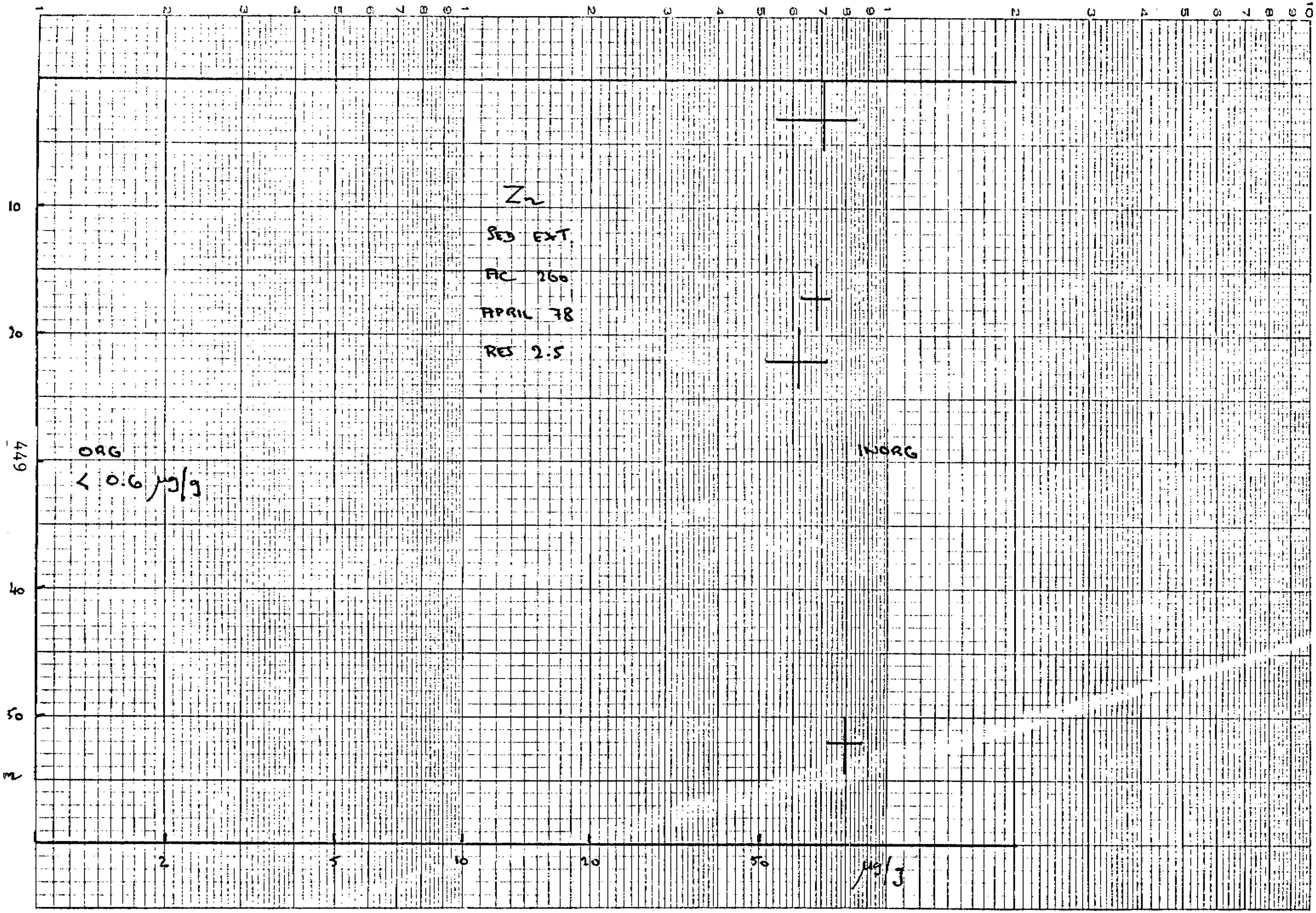
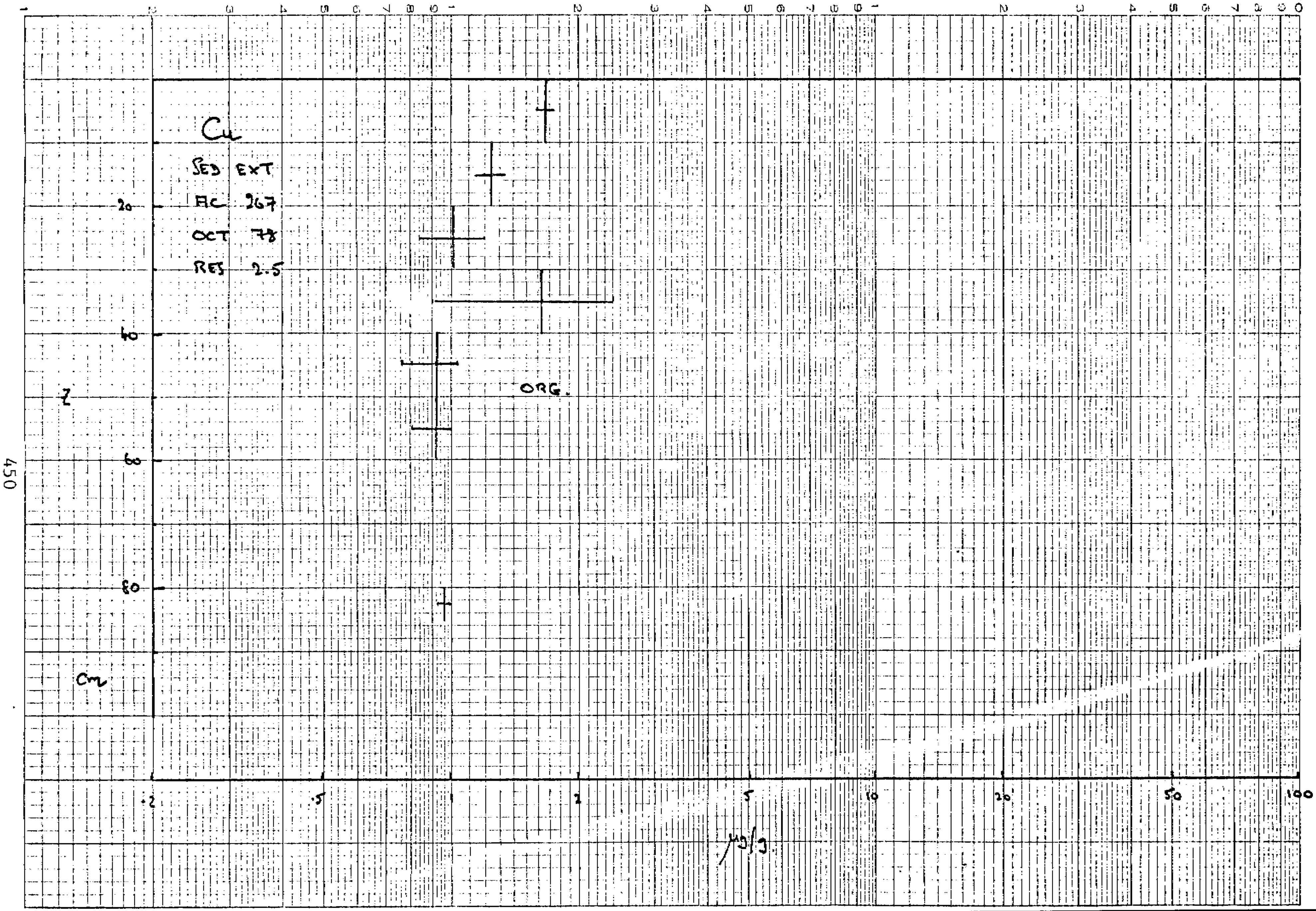


Figure 51. Concentration of zinc in peroxide and acid extracts, April 1979.


Cu
SED EXT
AC 267
OCT 78
RES 2.5
ORG.
z
cm
20
40
60
80
·2
·5
1
2
5
10
20
50
100
μg/g

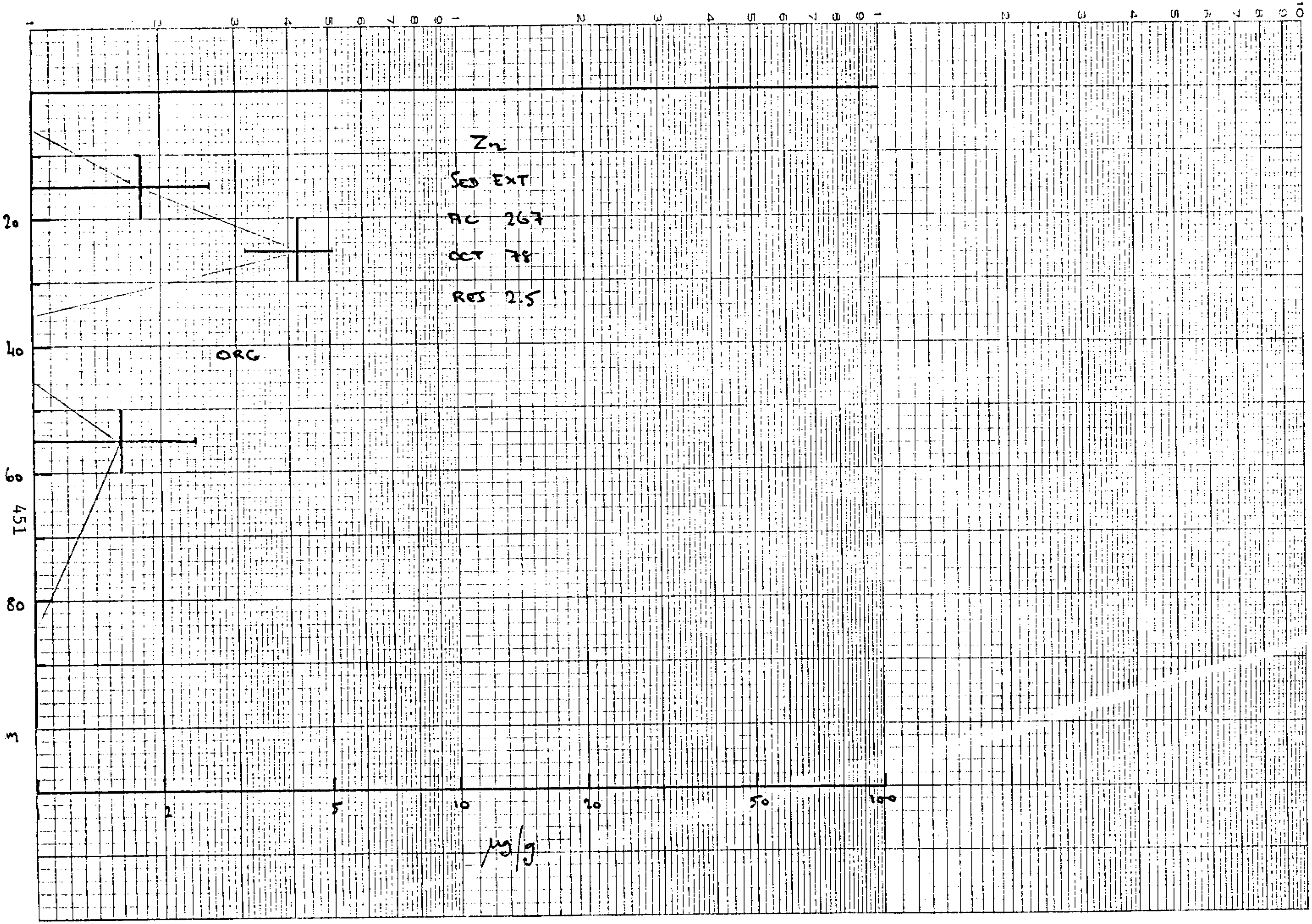
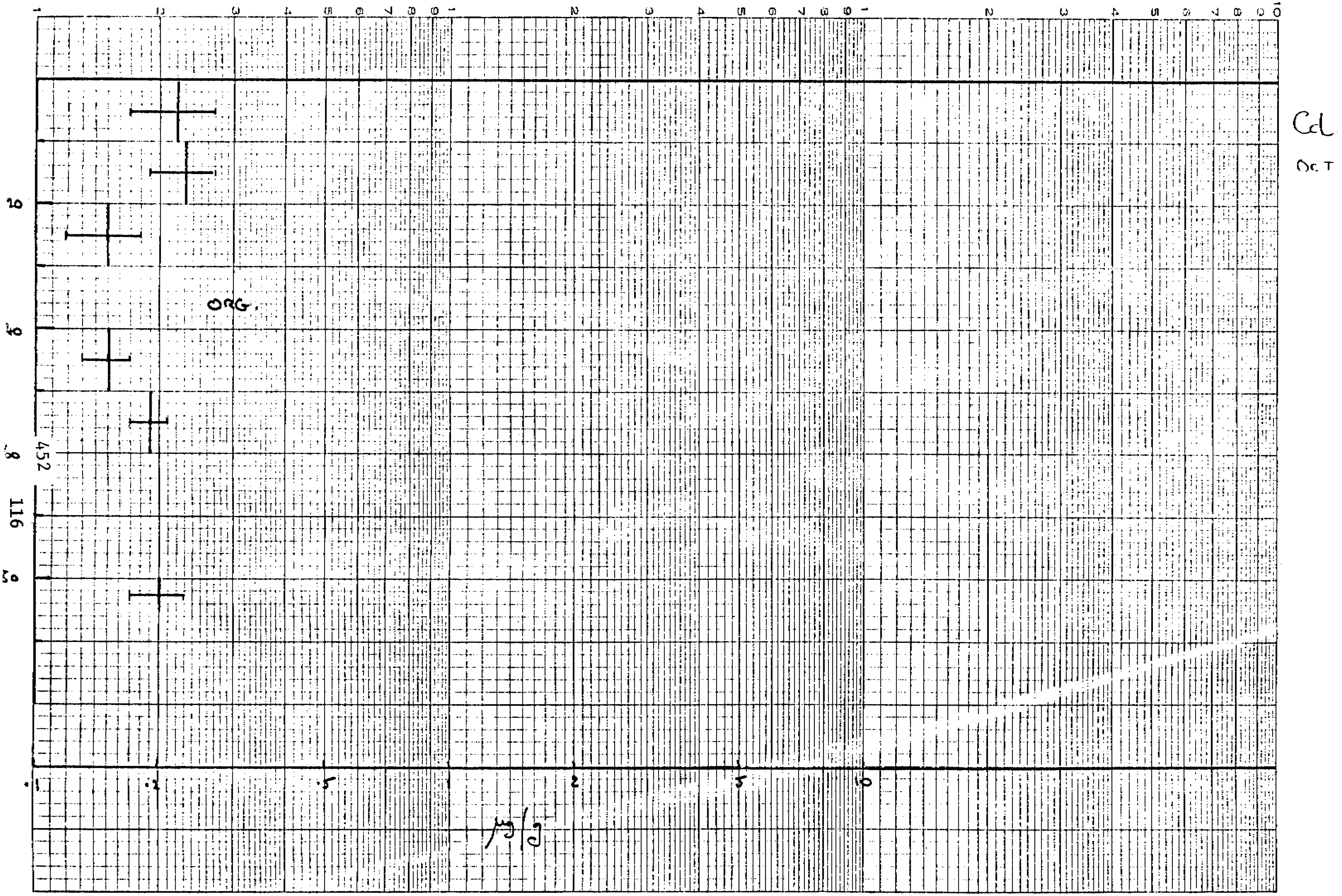


Figure 53. Concentration of zinc in peroxide extract of October core samples.


Cd
Oct
ORG.
20
40
60
80
452
116
.1
.2
.5
1
2
5
10
μg/g

sediment in tissue. From this experiment, it could not be determined whether the clams significantly accumulated Cd from their food source. A second improved experiment was therefore designed and tested, the results of which are described in this report.

In summary, the G-rod marine bacteria were again found to accumulate and concentrate, from their medium, the cadmium addition of .1 ppm. Along with the growth characteristics of the bacteria we were able to correlate the logarithmic growth stages with the greatest uptake of cadmium. Clams feeding on cells at this stage showed significantly higher cadmium levels in their tissues than controls in the first 2 weeks of exposure.

1. Microbiology-Growth:

G-rod bacteria were isolated from marine sediment of Lower Cook Inlet. The growth rate was studied for relationships between growth and cadmium uptake. A growth curve was tabulated according to standard microbiological methods. Two cultures were grown, a test culture spiked with .1 ppm cadmium and a control culture. Optical density was measured for each culture at specified time intervals.

Data are shown in the growth curve graph (Fig. 55). Little or no difference in growth rate occurred as a result of cadmium enrichment. There is a slight increase in the lag time of the cadmium enriched culture but reasons for this are not clear.

2. Microbiology-Cadmium Uptake:

Having described the growth stages, test and control cultures were grown and sampled for cadmium uptake at each growth stage. Optical density was also measured for each sample. Sample was treated as follows: Culture medium

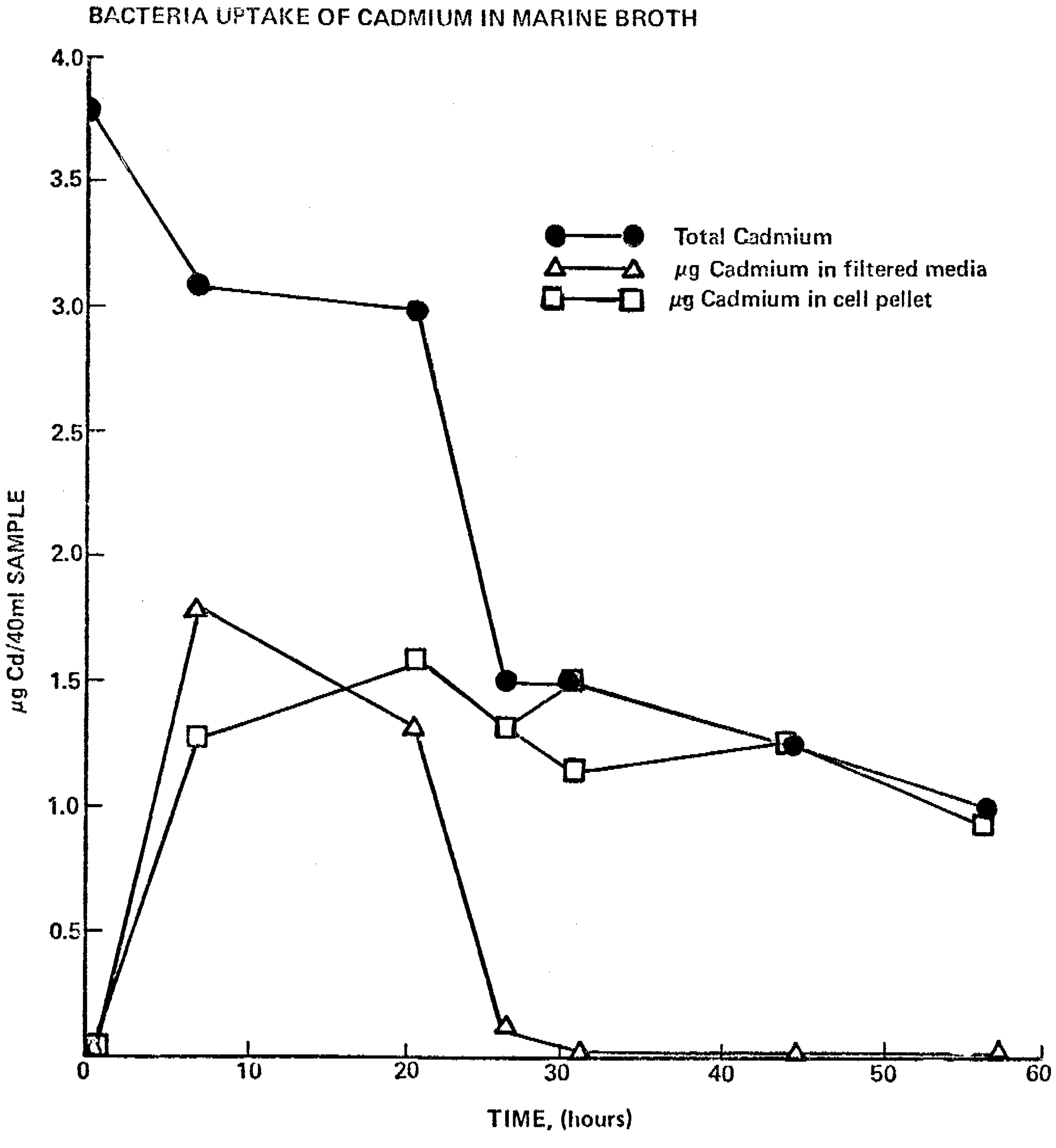


Figure 55. Bacteria uptake of cadmium in marine broth.

was centrifuged at 15 x g for 30 min, the supernatant (medium) poured off and filtered through a .45μ millipore filter. The cell pellet was resuspended in clean sea water centrifuged again and the supernatant (cell pellet wash) analyzed for cadmium. The pellet was then dissolved in 3 mls Ultrex HNO, 1 ml Ultrex H_2O_2 and diluted to 10 ml with distilled H_2O. Media samples were treated with 1 ml HNO_3, 1 ml H_2O_2, and diluted to 10 mls with distilled H_2O. All samples were run on the Perkin Elmer 360 graphite furnace using standards made in bacteria compatable matrix.

The results of this experiment are shown in Figure 56 and Table XXXVIII which is a graph of cell growth and cadmium concentration. It is clear that the most rapid accumulation of cadmium occurs during the logarithmic stage where cellular increase is most rapid. At the highest peak of this stage, the cadmium values in the medium are totally depleted. It is not evident from this work that dead cells in the medium released any cadmium back into solution.

Patrick and Loutist (1975) made the folowing observations: "Small amounts of metals in effluents can be concentrated by bacteria. Provided material is present in the effluent to cause increased number of bacteria the metal will be held and not dispersed. In this way, heavy metals can be passed up food chains".

The medium used in this experiment was a growth medium prepared for maximum cell growth and cell response were similar to observations made by these workers.

3. Bacteria-Sediment-Clam Uptake:

Control populations of *Macoma balthica* were kept in 30 gal. Instant Ocean Culture systems®. Individuals of this population were randomly chosen for control, test, and baseline information.

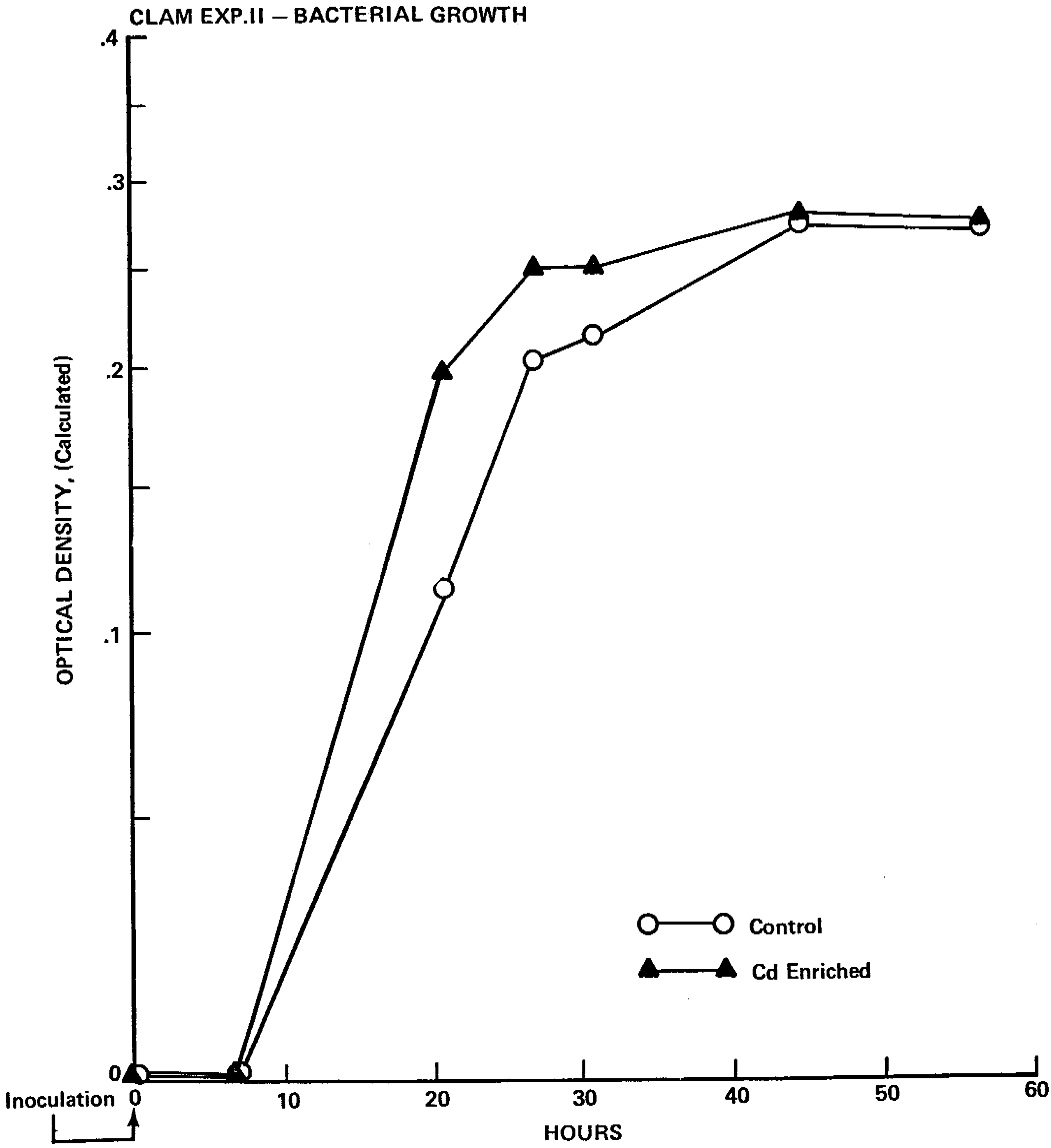


Figure 56. Clam experiment II: Bacterial growth.

TABLE XXXVIII

VALUES FOR BACTERIA MASS BALANCE
See Graphic Representation

		µg Cd in 40 mols					
Sample	Time	Pellet	Media µg	Wash	Total µg	±R	Pellet Mean
Initial Addition	ϕ	-	3.88*	-	3.88	-	-
2	6 hr 45 min.	1.28	1.84	-	3.12	-	1.28
3	20 hr 50 min.	1.83	1.36	.84	3.03	-	1.83
4a	26 hr 50 min.	.67	.16	.66	1.49	replicates	.85
4b	26 hr 50 min.	1.02	.00	.66	1.68	±.095	.85
5a	31 hr 5 min.	1.22	.00	0.30	1.52	replicates	-
5b	31 hr 5 min.	0.85	.00	0.30	1.15	±.185	1.05
6a	44 hr 25 min.	.96	.00	.32	1.28	replicates	-
6b	44 hr 25 min.	.91	.00	.32	1.23	±.025	.94
7a	56 hr 30 min.	.80	-	.23	1.03	replicates	-
7b	56 hr 30 min.	.70	-	.23	.93	±.050	.75

* Additional to clams, $\frac{.75 \mu g}{40\ ml} \times 200\ ml = 3.75\ \mu g$'s Cd/plate

Cell aliquots were taken from the cadmium enriched medium at the end of the logarithmic growth phase and spread on the autoclaved marine mud feeding plates. Ten clams were put on the plate and placed into a test aquarium culture system at 9°C. Half of the clams were sampled after two weeks and the final half sampled at four weeks. Control plates were run separately in another culture system under the same conditions, using bacteria from the control culture. When the clams were sampled, they were placed in fresh sea water daily for a period of seven days which succesfully removed excess detritus from the shell and purged the gut of ingested sediment. Clam samples were then frozen and freeze dried. Total body samples, shell, and internal tissue were separated out, weighed and placed in an oxygen plasma furnace for 24 hours. Ashed samples were dissolved in 3 mls ultrex HNO_3 and heated in a water bath at 90°C in teflon bombs for 10-12 hours. These samples were then diluted with triple distilled H_2O and 1 ml ultrex H_2O_2 was added to dissolve excess organics. Samples were analysed on the Perkin Elmer 360 graphite furnace, using standards made up in a matrix compatable with the sample soln.

The cell pellets added to each feeding plate end contained 3.75 μg cd. This value was determined as follows (Table XXXVIII):

i cell aliquot added to each feeding plate = 200 mls

ii measured conc of Cd in each 40 ml cell aliquot at sample = .75 μg Cd

iii total μg Cd added to each plate = $\frac{.75 \text{ μg Cd}}{40 \text{ ml}} \times 200 \text{ ml}$

The highest recorded value for test clams at day 10 of the experiment was 16.4 ± 1.4 μg Cd/gram dry wt. (Sample here = 6 clam inner tissues only).

Control and baseline values compare as follows (Tables XXXIX and XL).

control clams 10 day (total body) = .53 µg/g

test clams 10 day (total body) = .93 µg/g

*baseline clams (inner tissue only) = 2.43 µg/g

control clams 30 day (inner tissue only) = 1.94 µg/g

test clams (inner tissue only) 10 day = 16.4 µg/g

test clams 10 day (shell only) = .15 µg/g

Ten day test values are clearly higher than any control or baseline value. Baseline clam data show that naturally occurring Cd is most detectable in the soft inner tissue. Clam weight data reveal that the shell is approximately 8% of the total weight of the clam while the internal tissue is approximately 11% of the total clam weight. The shell accounted for little or no levels of cadmium in clams. Weight proportions of the total clam account for the low values obtained for the total organism relative to the higher values for the body only. Test values were compared to their analogs in control and baseline organisms--shell with shell, total body with total body, etc.

Results indicate that Cd levels in clam tissues, after 10 days of contaminated food ingestion, were significantly higher than those levels in control and baseline clams. Since these clams were sacrificed, it is hard to determine whether the increase is actually bioaccumulated from the

---

*Baseline clams: (Table XL) Before transfer experiment was run, clam aliquots composed of 10 clams each were taken from the clam population used during the experiment. This population was collected in Kachemak Bay, Homer, and kept in an instant ocean culture system using mud and sea water from the original habitat. Approximately 15 random aliquots were taken to establish natural levels of cadmium in the shell, soft internal tissues, and total organisms, for the population to be used. Values were used for comparison to those clams under both control and test situations.

TABLE XXXIX

CADMIUM LEVELS IN *MACOMA BALTHICA*
Experimental Values

Sample	Sample Weight g	Cadmium μg/g	$\bar{X}$ ±R
Test *Macoma* clam Day 10 Total	.356	.9	–
	–	.9	.93 ± .05
	–	1.0	–
Test *Macoma* Day 10 Shell	.350	.2	.15 ± .05
	–	.1	–
Test *Macoma* Day 10 inner tissues	.043	14.9	–
	–	16.6	16.4 ±.45
	–	17.8	–
Test *Macoma* Day 30 inner tissue	.093	1.15	1.24 ± .09
	–	1.33	–
Test *Macoma* Day 30 inner tissue	.031	2.13	2.21 ± .08
	–	2.29	–
30 Day Control inner tissue	.042	2.15	2.18 ± .03
	–	2.21	–
Experimental Controls			
30 Day Control inner tissue	.038	1.78	1.69 ± .09
10 Day Control Total Clam	.929	.3	.30
	–	.3	± ϕ
10 Day Control Total Clam	.514	.6	–
	–	.6	.63 ± .05
	–	.7	

1. replicates in μg/g are volume replicates for purposes of determining average peak height.
2. ±R values range of volume replicates on standard curve.

TABLE XL

PRE-EXPERIMENT CONTROLS
Baseline *Macoma balthica*

Sample	Weight g	µg/g Cd	$\bar{X}$ ±R	NB
Baseline 10 clams	.610	.4	.35	Analytical- Vol. replicates only. not sample replication.
	-	.3	±.05	
Baseline 10 clams	.580	.3	.30	
	-	.3	± 0	
Baseline 10 clams	.76	.4	.40	
	-	.4	± 0	
Baseline 10 Clams	.566	.1	-	
	-	.1	1.3	
	-	.2	±.05	
Baseline 10 Clams	.652	.1	.10 ± 0	
	.685	.2	.20	
	-	.2	± 0	
Baseline 10 clams	.460	.6	-	
	-	.5	.57	
	-	.6	±.05	
Baseline 10 clams	.675	.4	.4	
	-	.4	± 0	
Baseline 10 clams	.722	.4	-	
	-	.4	.40	
	-	.4	± 0	
Baseline 10 clams	.522	.6	.60	
	-	.6	± 0	
Baseline 10 clams	.506	.3	.30	
	-	.3	± 0	
	-	.3	-	
Baseline 10 clams	.505	.1	.15	
	-	.2	±.05	

TABLE XL

CONTINUED

Sample	Weight g	µg/g Cd	$\bar{X}$ ±R	NB
Baseline 4 clams	.220	.6	-	
	-	.6	.60	
	-	.6	± 0	
Shell only Baseline clam	.597	0	0 ± .03	
Body only baseline clam	.067	3.5	-	
	-	3.5	3.18	
	-	3.0	± .4	
	-	2.7	-	
Body only baseline clams	.241	1.6	-	
	-	1.7	1.67	
	-	1.7	± .05	

bacteria or a value which would change in time, relative to the naturally occurring levles by cellular excretion.

The bacteria population added to each plate was expected to change in the course of the 30 day experiment. The cell population naturally continued to go through a series of growth generations diluting the cadmium enriched cells. At day 10, the cadmium levels in the bacterial cells had caused a significant increase of this metal in the clam tissue. At day 30 tissue levels were comparable to control and baseline values:

Test clam inner body only 30 day = 1.73 μg/g

Control clams inner body only 30 day = 1.94 μg/g

Baseline clams inner body only = 2.43 μg/g

Certain observations seem relevant here:

1) The biology and behavior of these small clams are such that it would be unrealistic for the clams to ingest all the mud in the feeding plate (and therefore expose themselves to all the cadmium enriched cells in the mud). A feeding plate contains a total volume of 127.2 cm^3: The ten clams on each plate will only consume a fraction of this total.
2) Healthy clams cannot be forced to feed but may only be exposed to a food source which they will respond to naturally. Some organisms will feed while others will not; even when environmental conditions are the same.
3) Cadmium enriched cells by day 30 are not as available as those at 10 days, since the population under natural conditions dilutes itself by continual growth.

4) The experimental design assumed that the clams sampled at day 10 and 30 would feed simultaneously. This being so it must be concluded that tissue concentrations peaked and fell over the 30 day period. However, we have no direct evidence that the clams sacrificed at day 30 had, at day 10, cadmium concentrations similar to those actually analysed after that time period. It is possible that the two sets of test samples did not behave (i.e. basically fed) similarily.

The values at this stage give indications of how an initial contamination of the food chain manifests itself over a period of time if the addition of contamination is not continued. The initial addition of cadmium was first added to the bacteria at .1 ppm, which was then incorporated into the cells and fed to clams, a pellet addition containing 3.75 µg Cd.

Clams at day 10 of sampling indicate an increase by a factor of 2 for total body values over controls and a factor of 10 for inner tissues over control values. Shell values in all cases whether test, control, or baseline were on order of magnitude below control, baseline bodies. At day 30, clam tissue values show no increases. The detection of cadmium when using such small batch introductions to a relatively complex food chain becomes increasingly more difficult to detect as the metal is incorporated into more and more biological and chemical pools, as exemplified in the simplified chart on the following page.

The sampling of each pool becomes more complex with time and variation of initial cadmium concentrations. This experiment has been successful in determining the initial response of these clams to a cadmium enriched food source.

The Cd concentration increase is evident at 10 days. At 30 days, however, the cadmium has reached enough pools to make interpretation of values unclear in a quantitative way without further understanding the pathway cadmium takes in this system.

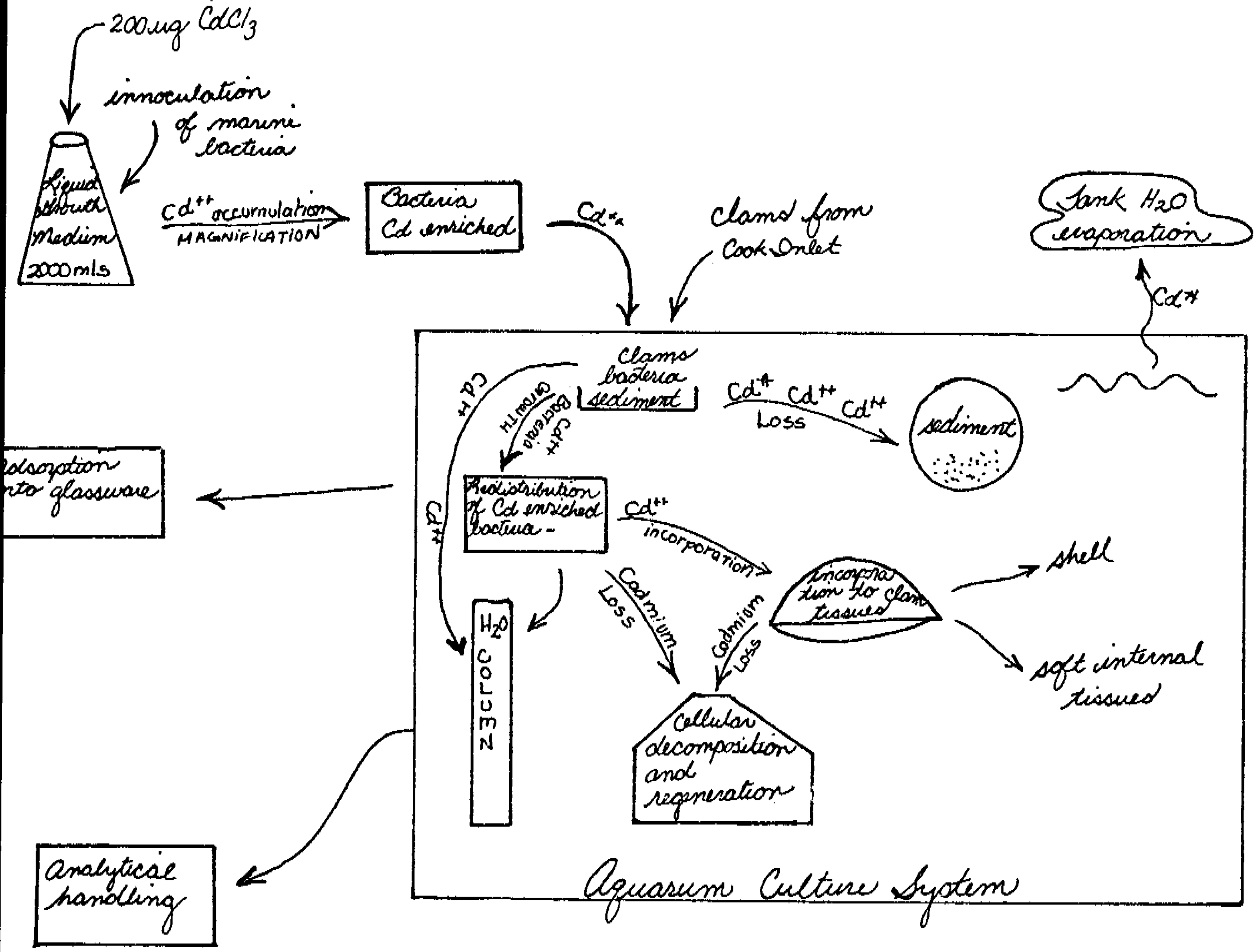


TABLE XLI

CONDITIONS GENERALLY USED FOR BIOTA ANALYSIS

Perkin Elmer, 360 A.A.

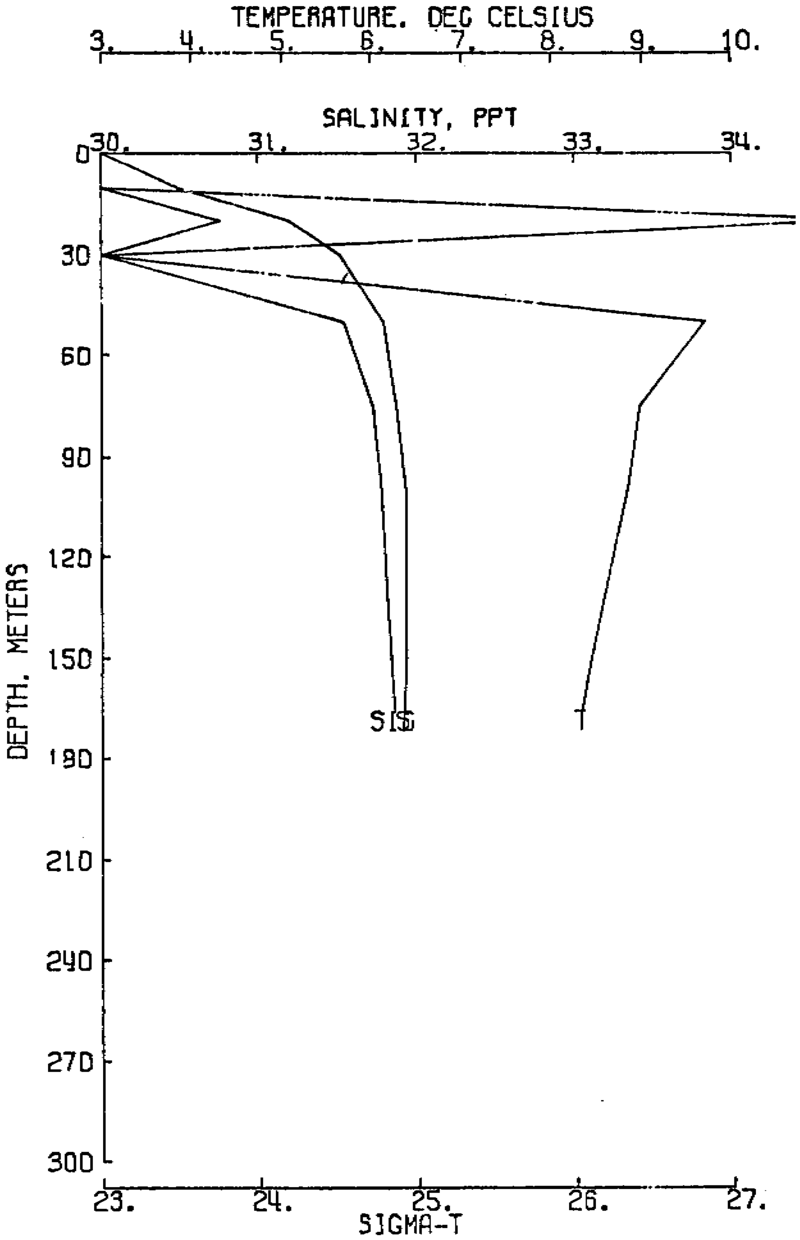
Element	nms	Gas Flow N=normal I=interupt	Current (mas)	Filter	Bgd. Core	Slit Width	Atom. Time (secs)	Atom. Temp.	Ash Time	Ash Temp.	Secs dry time	C dry temp.	ppm linearity To:	ppm min. detect. standard	Matrix Dilution	
Copper	324.7	60N	15	no	yes	0.7	7	2700	20	900	15	90	0.2	.005	1/4	crab and shrimp
	-	60N	15	no	yes	0.7	7	2700	20	900	15	-	-	-	-	*Macoma*
	-	60N	15	no	yes	0.7	7	2700	20	800	15	90	0.1	.005	1/4	orchard leaves
	-	60N	15	no	yes	0.7	7	2700	20	800	15	100	0.1	.005	1/100	bovine liver
Zinc	213.9	55N	10	no	no	0.7	7	2500	15	500	15	100	-	-	1/100	crab and shrimp
	-	55N	10	no	no	0.7	7	2500	15	500	15	100	-	-	-	*Macoma*
	-	55N	10	no	no	0.7	7	2500	15	400	15	100	.025	.005	1/100	orchard leaves
	slightly off 213.9	55N	10	no	no	0.7	7	2500	15	400	15	100	.025	.003	1/100	bovine liver
Cadmium	228.8	20N	6	yes	yes	0.7	8	2100	15	200	20	100	.03	.002	1	crab and shrimp
	-	20I	6	yes	yes	0.7	8	2100	15	200	20	90	-	-	1	*Macoma*
	-	20N	6	yes	yes	0.7	8	2100	15	200	20	100	.03	.002	1	orchard leaves
	-	20N	6	yes	yes	0.7	8	2100	15	200	20	100	.03	.002	1	bovine liver
Nickel	232.0	25I	25	no	yes	0.2	8	2800	30	1000	30	90	.1	.005	1	crab and shrimp
	-	25N	25	no	yes	0.2	8	2800	30	1000	30	-	-	-	1	*Macoma*
	-	25N	25	no	yes	0.2	8	2800	30	1000	30	100	.05	.005	1	orchard leaves
	-	25N	25	no	yes	0.2	8	2800	30	1000	30	100	.05	.005	1	bovine liver

APPENDIX I

Kakutat and Resurrection Bays
Hydrography and Vertical Profiles

```
AC   CRUISE 246 CONSECUTIVE STATION NO.   1.   YAK  7     27/ 7/77
--------------------------                                 20.5 HOURS GMT

  LATITUDE = 59  40.0N   LONGITUDE = 139  59.5W   SONIC DEPTH =  172 M


  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS
  CLOUD AMOUNT --- (4) ---4/8
  VISIBILITY.--- (6) ---4-10 KM
-----------------------------------------------------------------------
I          DIRECTION          SPEED                                   I
I WIND     245 - 254 DEGR      7 KNOTS                                I
-----------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                      I
I SEA      215 - 224 DEGR   1.0 M.          SECS                      I
I SWELL         -      DEGR      M.          SECS                      I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =          DEGR C.   BAROMETRIC PR. =1019.3 MB   I
I              -WET =          DEGR C.   TRANSPARENCY   =         M   I
-----------------------------------------------------------------------

STANDARD DEPTHS

        DEPTH    TEMP     SALIN       SIG-T      SPVOL      DEL-D
          0.      0.      24.634      0.          0.        0.
         10.      0.      30.485      0.          0.        0.
         20.     11.58    31.194     23.76      415.9       0.
         30.     10.33    31.521     24.14      379.3       0.
         50.      9.71    31.790     24.54      341.7       0.
         75.      8.99    31.860     24.72      324.4       0.
        100.      8.85    31.928     24.78      319.2       0.
        150.      8.45    31.928     24.84      314.1       0.

OBSERVED DEPTHS
          0.      0.      24.634      0.
         10.      0.      30.485      0.
         20.     11.58    31.194     23.76
         30.      0.      31.521      0.
         50.      9.71    31.790     24.54
         75.      8.99    31.860     24.72
        100.      8.85    31.926     24.78
        150.      8.45    31.928     24.84
        165.      8.34    31.926     24.86
```

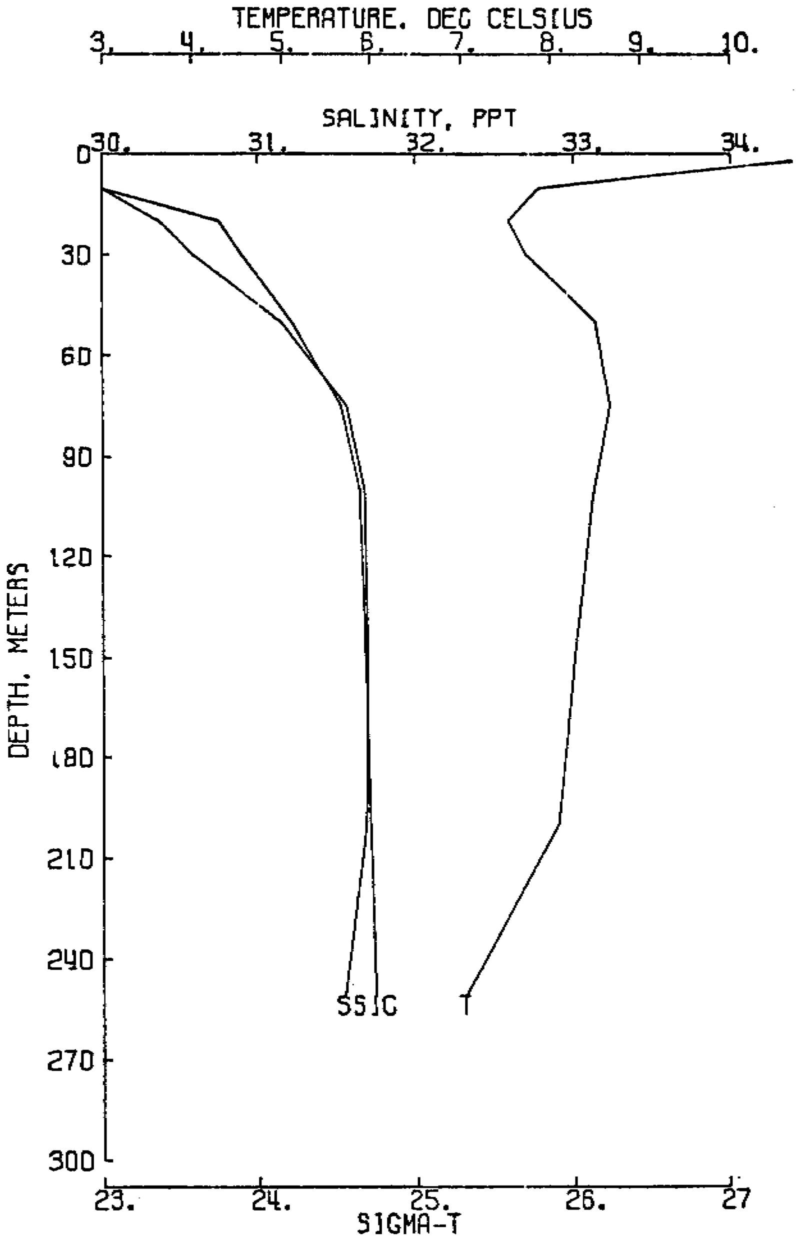
Yakutat Bay hydrographic data
July 1977 R/V *Acona* cruise No. 246.



CRUISE 246 STATION 1

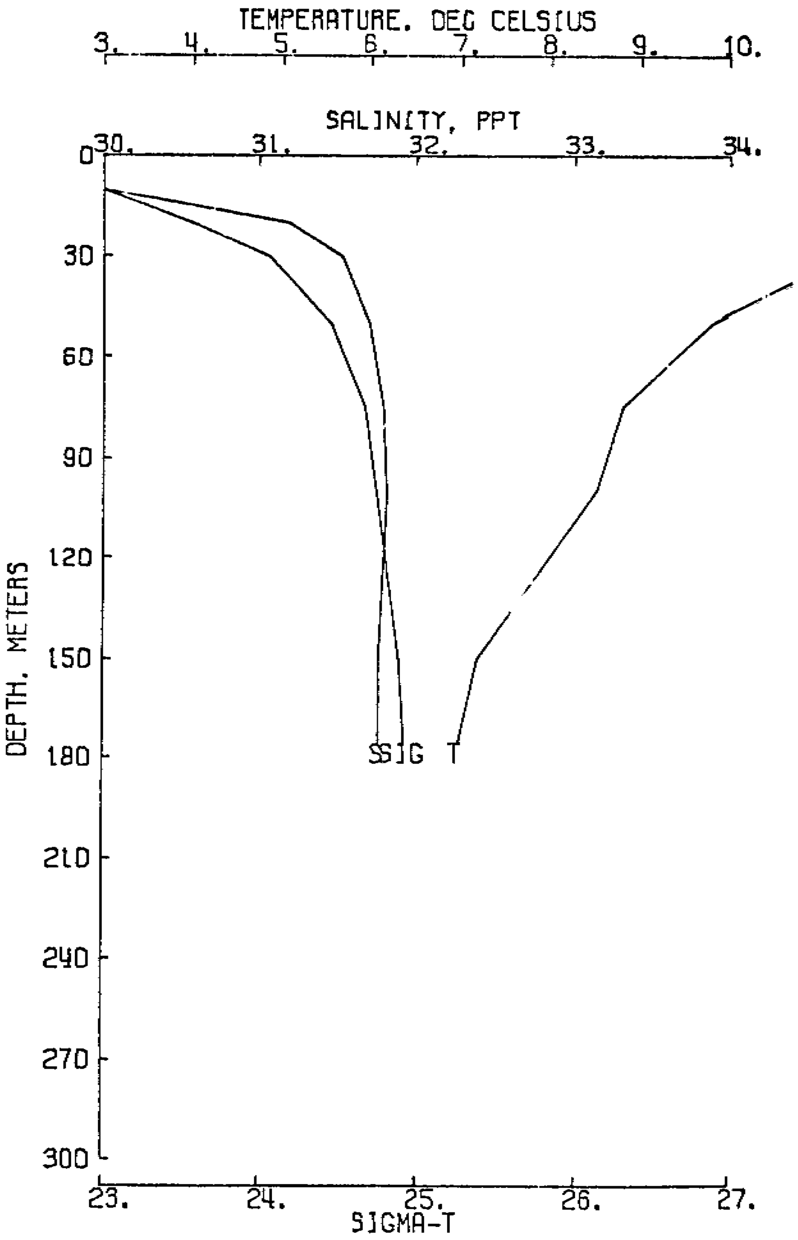
```
AC   CRUISE 246 CONSECUTIVE STATION NO.    2.    YAK   3     28/ 7/77
--------------------------                                  6.6 HOURS GMT

  LATITUDE = 59  52.5N   LONGITUDE = 139  40.0W   SONIC DEPTH =  256 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS
  CLOUD AMOUNT --- (2) ---2/8
  VISIBILITY --- (6) ---4-10 KM
----------------------------------------------------------------------
I          DIRECTION          SPEED                                  I
I WIND      15 -  24 DEGR       KNOTS                                I
----------------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                       I
I SEA      215 - 224 DEGR  1.0 M.          SECS                      I
I SWELL        - .    DEGR       M.          SECS                    I
----------------------------------------------------------------------
I TEMPERATURES -DRY =          DEGR C.   BAROMETRIC PR. =1015.4 MB  I
I              -WET =          DEGR C.   TRANSPARENCY   =        M  I
----------------------------------------------------------------------

STANDARD DEPTHS

        DEPTH    TEMP     SALIN         SIG-T       SPVOL       DEL-D
          0.    15.07    21.600         15.72      1188.8       0.
         10.     7.88    29.199         22.79       508.2       0.085
         20.     7.53    30.363         23.75       416.7       0.131
         30.     7.74    30.578         23.89       403.4       0.172
         50.     8.51    31.145         24.22       371.8       0.250
         75.     8.67    31.569         24.53       342.9       0.339
        100.     8.49    31.680         24.64       332.4       0.423
        150.     8.27    31.685         24.68       329.6       0.589
        200.     8.07    31.681         24.70       327.7       0.753
        250.     7.05    31.545         24.74       324.7       0.916

OBSERVED DEPTHS
          0.    15.07    21.600         15.72
         10.     7.88    29.199         22.79
         20.     7.53    30.363         23.75
         30.     7.74    30.578         23.89
         50.     8.51    31.145         24.22
         75.     8.67    31.569         24.53
        100.     8.49    31.680         24.64
        150.     8.27    31.685         24.68
        200.     8.07    31.681         24.70
        250.     7.05    31.545         24.74
```

Yakutat Bay hydrographic data
July 1977 R/V *Acona* cruise No. 246.



CRUISE 246 STATION 2

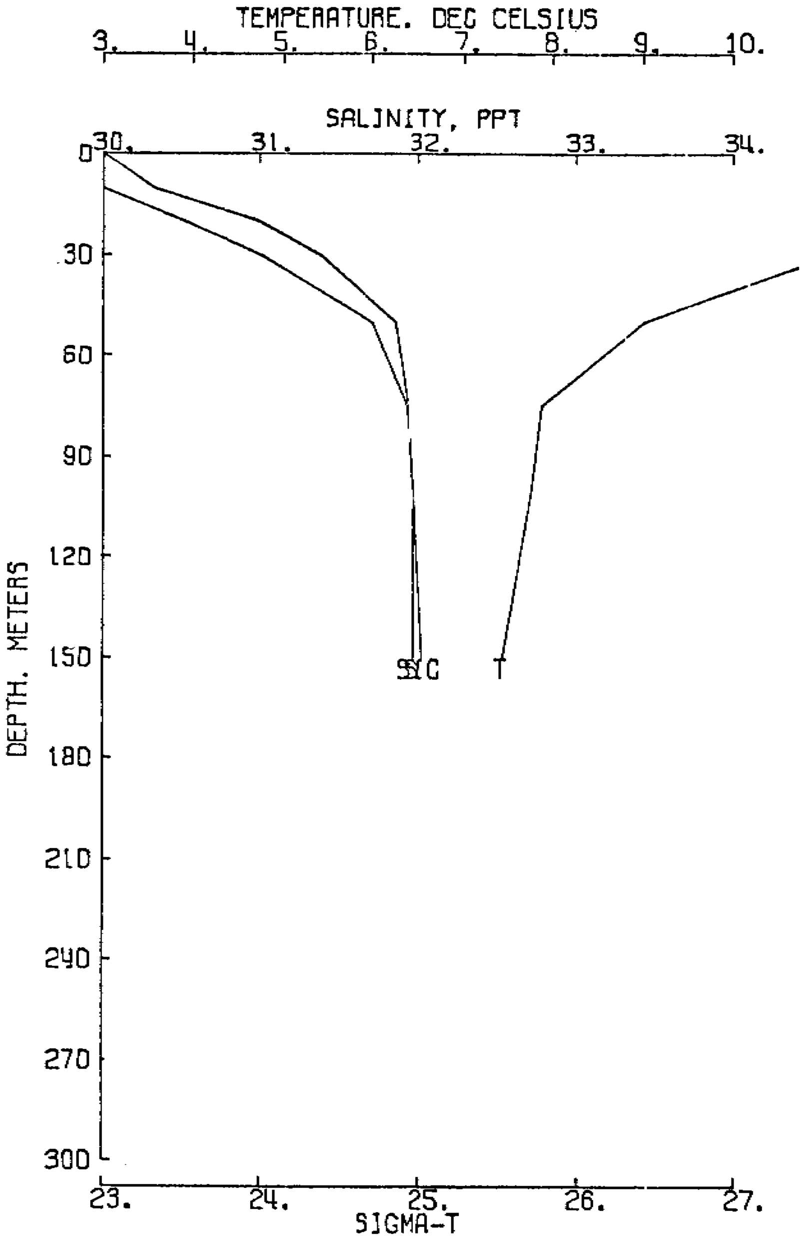
```
AC   CRUISE 246 CONSECUTIVE STATION NO.   3.   YAK 05     28/ 7/77
--------------------------                              8.3 HOURS GMT

 LATITUDE = 59  44.0N   LONGITUDE = 139  40.5W   SONIC DEPTH =  183 M


 1-DIGIT WEATHER CODE IS (   ) AND INDICATES NOT RECORDED
 CLOUD TYPE --- ( ) ---NOT RECORDED         .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
------------------------------------------------------------------------
I          DIRECTION         SPEED                                     I
I WIND         -      DEGR     KNOTS                                   I
------------------------------------------------------------------------
I          DIRECTION        HEIGHT     PERIOD                          I
I SEA      215 - 224 DEGR  0.5 M.        SECS                          I
I SWELL        -     DEGR      M.        SECS                          I
------------------------------------------------------------------------
I TEMPERATURES -DRY =         DEGR C.   BAROMETRIC PR. =1014.7 MB  I
I              -WET =         DEGR C.   TRANSPARENCY   =       M   I
------------------------------------------------------------------------

STANDARD DEPTHS

        DEPTH   TEMP    SALIN      SIG-T     SPVOL     DEL-D
          0.   13.53   24.039     17.88     979.6     0.
         10.   12.01   29.995     22.75     511.8     0.075
         20.   12.56   31.181     23.56     434.3     0.122
         30.   11.33   31.531     24.06     386.9     0.163
         50.    9.77   31.705     24.46     348.9     0.236
         75.    8.80   31.792     24.68     329.2     0.321
        100.    8.51   31.818     24.75     322.4     0.402
        150.    7.17   31.760     24.89     309.1     0.560

OBSERVED DEPTHS
          0.   13.53   24.039     17.88
         10.   12.01   29.995     22.75
         20.   12.56   31.181     23.56
         30.   11.33   31.531     24.06
         50.    9.77   31.705     24.46
         75.    8.80   31.792     24.68
        100.    8.51   31.818     24.75
        150.    7.17   31.760     24.89
        175.    6.96   31.763     24.92
```



CRUISE 246 STATION 3

Yakutat Bay hydrographic data
July 1977 R/V *Acona* cruise No. 246.

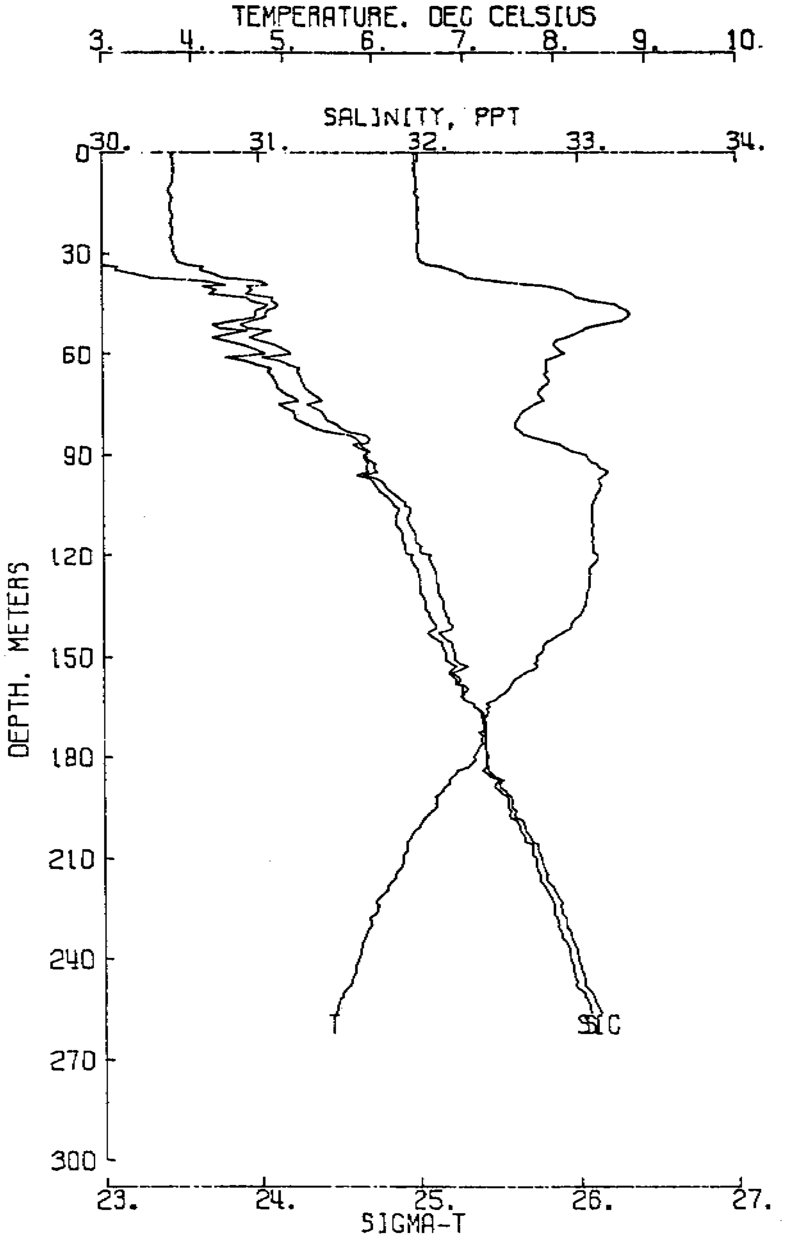
```
AC.  CRUISE 246 CONSECUTIVE STATION NO.    4.    YAK-9      28/ 7/77
-------------------------                                    18.5 HOURS GMT

  LATITUDE = 59  40.0N   LONGITUDE = 139  59.5W   SONIC DEPTH =  158 M

  1-DIGIT WEATHER CODE IS (  ) AND INDICATES NOT RECORDED
  CLOUD TYPE --- ( ) ---NOT RECORDED          ,
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------
I           DIRECTION        SPEED                              I
I WIND         -      DEGR     KNOTS                            I
-----------------------------------------------------------------
I           DIRECTION        HEIGHT     PERIOD                  I
I SEA       195 - 204 DEGR  0.5 M.         SECS                 I
I SWELL        -      DEGR      M.         SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =         DEGR C.  BAROMETRIC PR. =1013.3 MB  I
I              -WET =         DEGR C.  TRANSPARENCY    =       M  I
-----------------------------------------------------------------

STANDARD DEPTHS

         DEPTH    TEMP     SALIN       SIG-T      SPVOL      DEL-D
           0.    13.56    24.429      18.17      951.2      0.
          10.    14.06    30.324      22.61      525.5      0.074
          20.    12.09    30.990      23.50      439.9      0.122
          30.    11.06    31.396      24.00      392.3      0.164
          50.     9.00    31.861      24.71      325.7      0.235
          75.     7.38    31.939      24.93      304.3      0.314
         100.     7.76    31.966      24.97      300.9      0.390
         150.     7.44    31.972      25.02      296.8      0.539

OBSERVED DEPTHS
           0.    13.56    24.429      18.17
          10.    14.06    30.324      22.61
          20.    12.09    30.990      23.51
          30.    11.06    31.396      24.01
          50.     9.00    31.961      24.71
          75.     7.38    31.939      24.93
         100.     7.76    31.966      24.97
         150.     7.44    31.972      25.02
```



CRUISE 246 STATION 4

Yakutat Bay hydrographic data
July 1977 R/V *Acona* cruise No. 246.

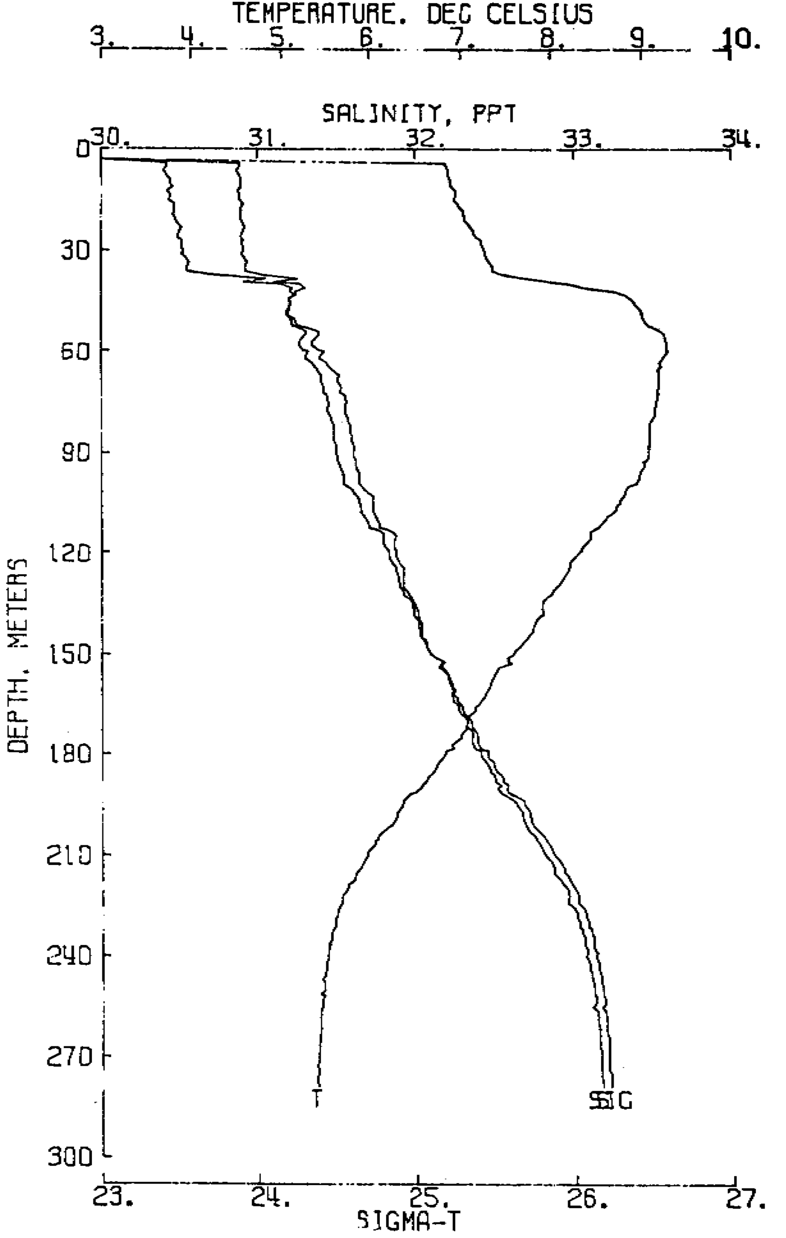
```
AC   CRUISE 253 CONSECUTIVE STATION NO.  32,   RES  5     17/11/77
--------------------------                                  17.5 HOURS GMT

  LATITUDE = 59  50.7N   LONGITUDE = 149  28.0W   SONIC DEPTH =  265 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (8) ---8/8 TOTAL    .
  VISIBILITY --- (7) ---10-20 KM
-------------------------------------------------------------------------
I           DIRECTION          SPEED                                    I
I WIND      335 - 344 DEGS     20 KNOTS                                 I
-------------------------------------------------------------------------
I           DIRECTION        HEIGHT      PERIOD                         I
I SEA       335 - 344 DEGR   1.0 M.         SECS                        I
I SWELL         -      DEGR      M.         SECS                        I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. =1031.1 MB   I
I              -WET =        DEGR C.   TRANSPARENCY    =        M   I
-------------------------------------------------------------------------


         DEPTH        TEMPERATURE     SALINITY        SIGMA-T        DELTA-D
         METERS          DEG C          PPT                           DYN M
           2.0            6.46         29.799          23.44          0.009
           1.0            6.46         29.729          23.44          0.004
           5.0            6.46         29.823          23.46          0.022
          10.0            6.49         29.793          23.43          0.045
          15.0            6.49         29.796          23.43          0.067
          20.0            6.49         29.803          23.44          0.039
          25.0            6.50         29.802          23.44          0.112
          30.0            6.50         29.833          23.46          0.134
          35.0            6.86         30.085          23.61          0.156
          40.0            7.89         30.641          23.91          0.176
          45.0            8.67         31.039          24.11          0.196
          50.0            8.74         30.826          23.94          0.215
          60.0            8.10         31.030          24.19          0.254
          70.0            7.85         31.104          24.28          0.292
          75.0            7.79         31.108          24.30          0.310
          80.0            7.57         31.238          24.43          0.327
          90.0            8.34         31.673          24.66          0.361
         100.0            8.50         31.794          24.73          0.394
         125.0            8.37         32.105          24.99          0.472
         150.0            7.72         32.219          25.17          0.545
         175.0            7.17         32.413          25.40          0.613
         200.0            6.50         32.613          25.65          0.676
         250.0            5.64         33.029          26.08          0.784
```



CRUISE 253 STATION 32

```
--------------------------                                   19.0 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (8) ---3/8 TOTAL    ,
  VISIBILITY --- (6) ---4-10 KM
---------------------------------------------------------------------
I          DIRECTION         SPEED                                  I
I WIND       0 -    0 DEGR   15 KNOTS                               I
---------------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                      I
I SEA        0 -    0 DEGR  0.3 M.         SECS                     I
I SWELL        -      DEGR      M.         SECS                     I
---------------------------------------------------------------------
I TEMPERATURES -DRY =    0.6 DEGR C.   BAROMETRIC PR. =1032.1 MB   I
I              -WET =        DEGR C.   TRANSPARENCY   =        M   I
---------------------------------------------------------------------
```

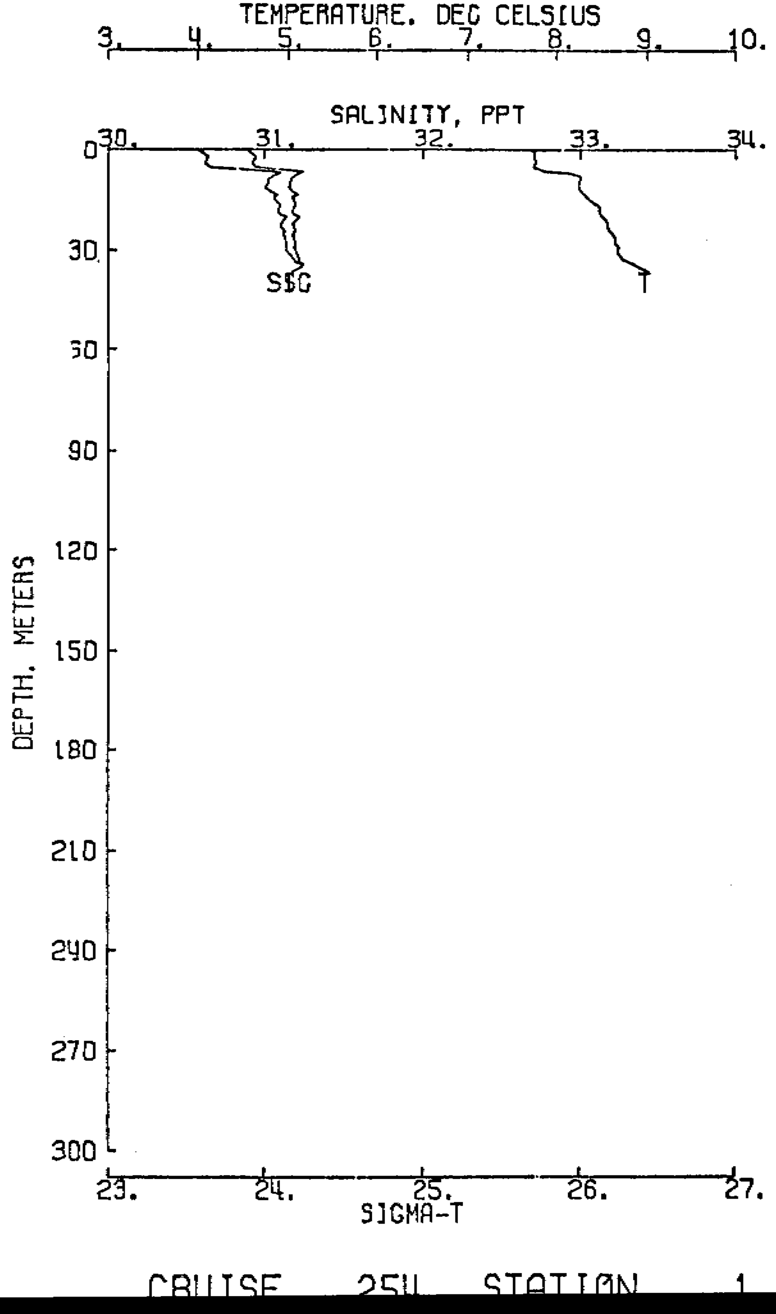
DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
2.0	-1.67	26.585	21.38	0.013
1.0	-1.66	26.585	21.38	0.006
5.0	6.84	30.419	23.88	0.027
10.0	6.88	30.447	23.90	0.047
15.0	6.94	30.432	23.88	0.068
20.0	7.04	30.469	23.89	0.088
25.0	7.16	30.494	23.90	0.108
30.0	7.27	30.528	23.91	0.128
35.0	7.36	30.551	23.92	0.148
40.0	8.18	31.140	24.26	0.167
45.0	8.92	31.210	24.21	0.186
50.0	9.02	31.230	24.21	0.205
60.0	9.30	31.421	24.32	0.241
70.0	9.26	31.531	24.42	0.277
75.0	9.17	31.559	24.44	0.295
80.0	9.12	31.571	24.46	0.312
90.0	9.09	31.612	24.50	0.347
100.0	8.86	31.644	24.56	0.382
125.0	8.19	31.917	24.87	0.463
150.0	7.57	32.092	25.10	0.538
175.0	6.98	32.354	25.38	0.607
200.0	6.25	32.680	25.73	0.668
250.0	5.47	33.122	26.17	0.769



CRUISE 253 STATION 33

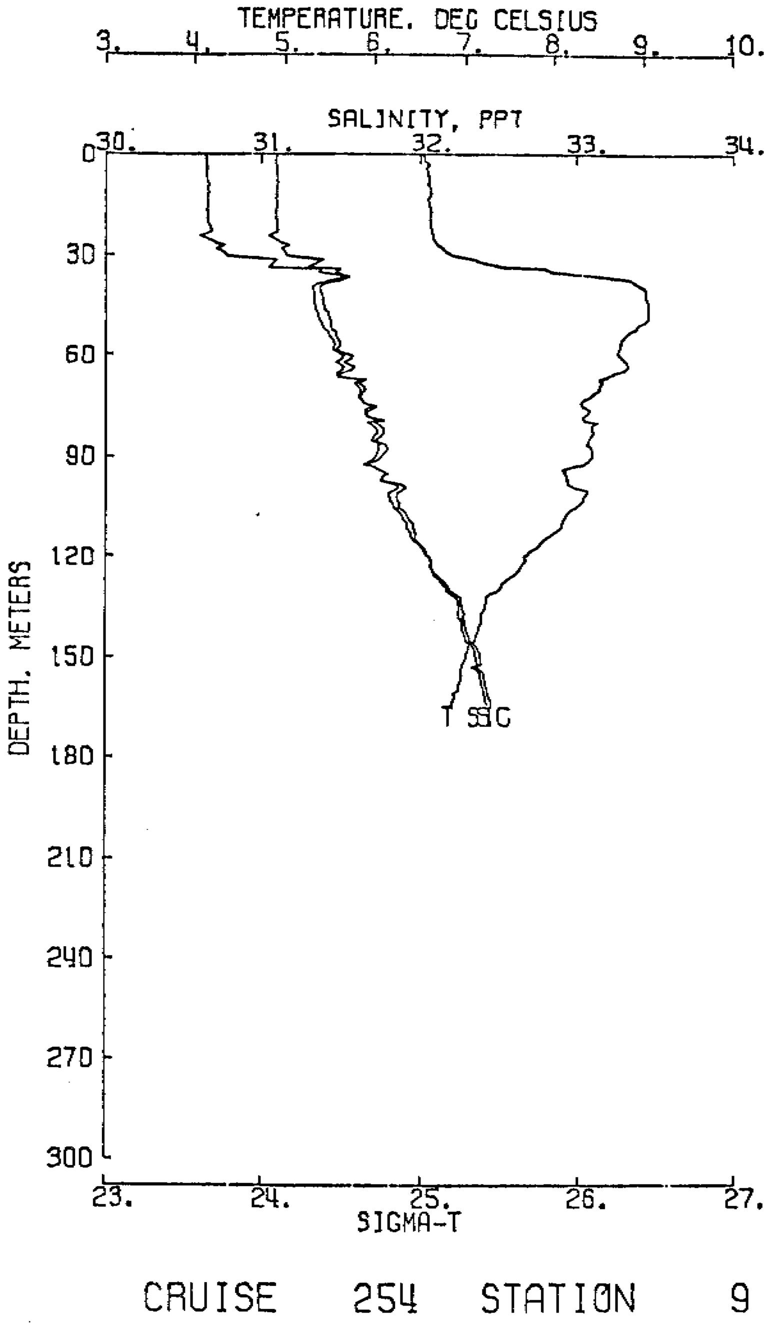
```
AC   CRUISE 254 CONSECUTIVE STATION NO.   1.   RES  1     28/11/77
---------------------------                                19.0 HOURS GMT

  LATITUDE = 60   6.5N   LONGITUDE = 149  23.8W   SONIC DEPTH =   38 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (3) ---3/8         .
  VISIBILITY --- (8) ---20-50 KM
--------------------------------------------------------------------
I           DIRECTION          SPEED                                I
I WIND        0 -    0 DEGR   20 KNOTS                              I
--------------------------------------------------------------------
I           DIRECTION         HEIGHT      PERIOD                    I
I SEA         0 -    0 DEGR  0.3 M.          SECS                   I
I SWELL         -      DEGR      M.          SECS                   I
--------------------------------------------------------------------
I TEMPERATURES -DRY =  -1.1 DEGR C.   BAROMETRIC PR. = 988.3 MB  I
I               -WET =       DEGR C.   TRANSPARENCY   =       M  I
--------------------------------------------------------------------


         DEPTH      TEMPERATURE   SALINITY       SIGMA-T       DELTA-D
         METERS        DEG C        PPT                         DYN M
            2.0        7.74       30.642         23.94          0.008
            1.0        7.75       30.606         23.91          0.004
            5.0        7.73       30.651         23.94          0.020
           10.0        8.25       31.019         24.16          0.039
           15.0        8.37       31.072         24.18          0.058
           20.0        8.59       31.135         24.22          0.076
           25.0        8.63       31.109         24.18          0.095
           30.0        8.67       31.140         24.19          0.114
           35.0        8.91       31.234         24.23          0.133
```

Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.

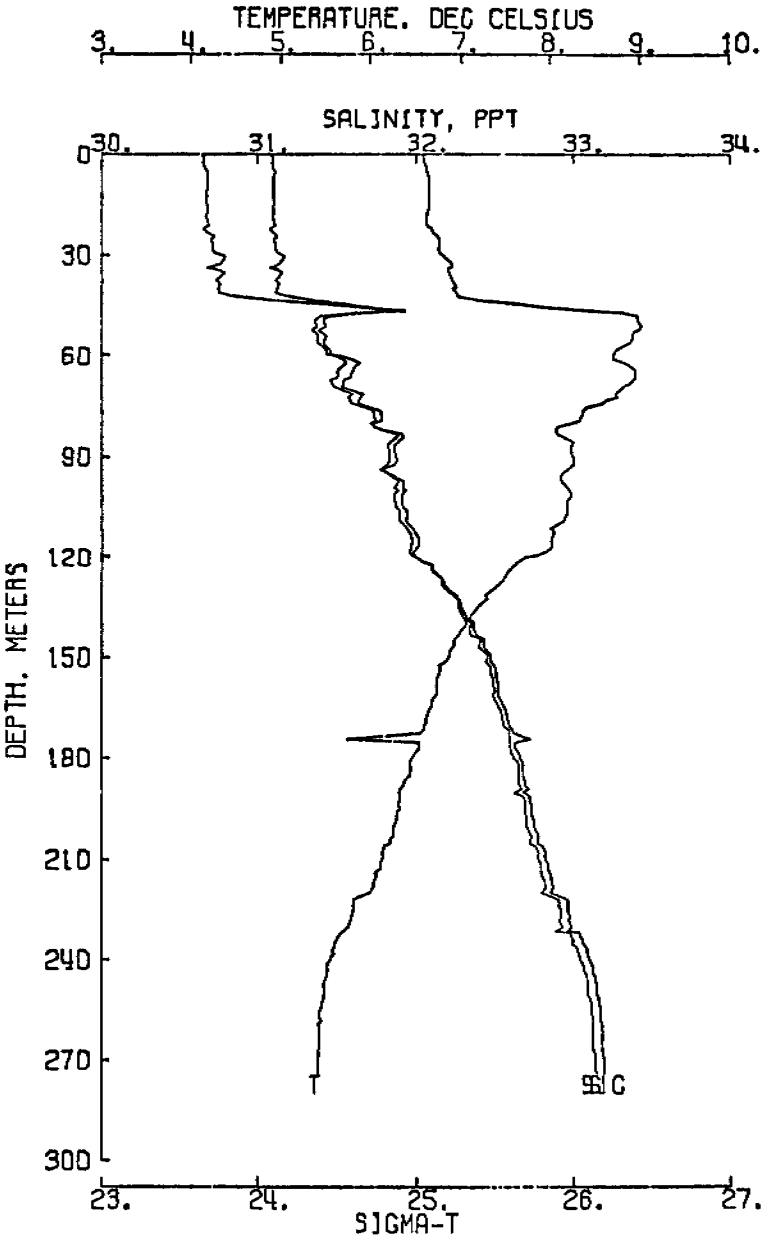


```
AC   CRUISE 254 CONSECUTIVE STATION NO.    9,   RES  2     29/11/77
--------------------------                                 11.1 HOURS GMT

  LATITUDE = 60   3.5N   LONGITUDE = 149  23.4W   SONIC DEPTH =  168 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I            DIRECTION          SPEED                           I
I WIND       345 - 354 DEGR     20 KNOTS                        I
-----------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD              I
I SEA        345 - 354 DEGR     1.0 M.        SECS              I
I SWELL          -       DEGR      M.         SECS              I
-----------------------------------------------------------------
I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. = 991.8 MB  I
I               -WET =        DEGR C.   TRANSPARENCY   =       M  I
-----------------------------------------------------------------


         DEPTH     TEMPERATURE   SALINITY     SIGMA-T      DELTA-D
         METERS       DEG C        PPT                      DYN M
           3.0        6.60       30.656       24.10        0.012
           1.0        6.54       30.644       24.09        0.004
           5.0        6.59       30.656       24.10        0.019
          10.0        6.62       30.655       24.09        0.038
          15.0        6.59       30.657       24.10        0.058
          20.0        6.60       30.652       24.09        0.077
          25.0        6.64       30.659       24.09        0.096
          30.0        6.86       30.773       24.16        0.115
          35.0        7.98       31.372       24.47        0.133
          40.0        9.01       31.352       24.31        0.151
          45.0        9.04       31.401       24.34        0.169
          50.0        9.01       31.440       24.38        0.187
          60.0        8.72       31.571       24.52        0.222
          70.0        8.50       31.660       24.62        0.256
          75.0        8.31       31.724       24.70        0.273
          80.0        8.47       31.714       24.67        0.289
          90.0        8.62       31.751       24.71        0.322
         100.0        8.37       31.915       24.84        0.354
         125.0        7.56       32.085       25.09        0.430
         150.0        7.01       32.361       25.38        0.499
```

Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.



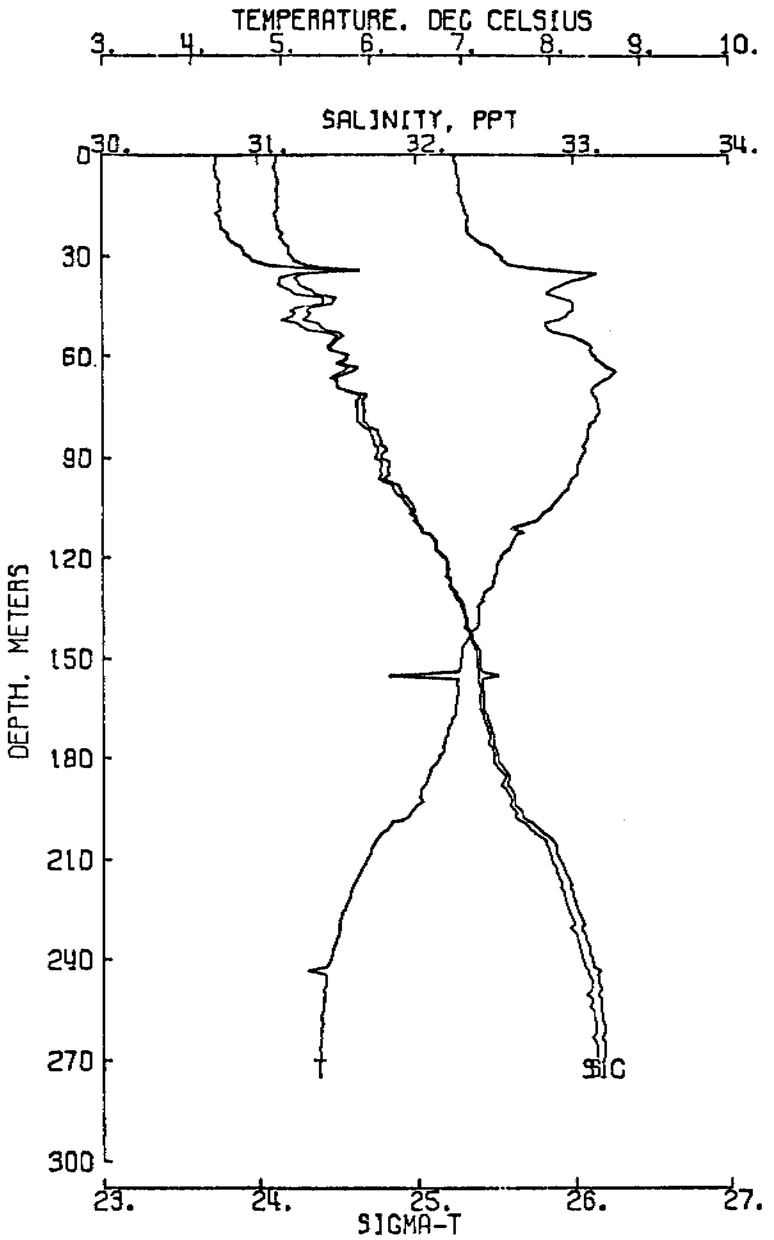
```
AC   CRUISE 254 CONSECUTIVE STATION NO.  10.    RES25A     29/11/77
--------------------------                                 13.3 HOURS GMT

 LATITUDE = 6     1.2N   LONGITUDE = 149  23.0W   SONIC DEPTH =  278 M


 1-DIGIT WEATHER CODE IS (XX) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I          DIRECTION          SPEED                                   I
I WIND       5 -  14 DEGR   18 KNOTS                                  I
-----------------------------------------------------------------------
I          DIRECTION        HEIGHT     PERIOD                         I
I SEA        5 -  14 DEGR  1.0 M.         SECS                        I
I SWELL      -       DEGR      M.         SECS                        I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =  -1.7 DEGR C.   BAROMETRIC PR. = 993.0 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =         M  I
-----------------------------------------------------------------------


         DEPTH     TEMPERATURE   SALINITY     SIGMA-T      DELTA-D
         METERS       DEG C        PPT                      DYN M
            2.0        6.59       30.652       24.09        0.008
            1.0        6.59       30.652       24.09        0.004
            5.0        6.62       30.677       24.11        0.019
           10.0        6.65       30.673       24.10        0.038
           15.0        6.64       30.674       24.10        0.057
           20.0        6.63       30.674       24.11        0.077
           25.0        6.77       30.697       24.11        0.096
           30.0        6.81       30.790       24.17        0.115
           35.0        6.87       30.785       24.16        0.134
           40.0        6.91       30.746       24.13        0.153
           45.0        7.93       31.658       24.71        0.171
           50.0        8.99       31.426       24.37        0.188
           60.0        8.71       31.531       24.49        0.224
           70.0        8.77       31.599       24.54        0.258
           75.0        8.49       31.694       24.67        0.275
           80.0        8.23       31.724       24.71        0.291
           90.0        8.27       31.871       24.82        0.323
          100.0        8.20       31.932       24.88        0.354
          125.0        7.49       32.140       25.15        0.430
          150.0        6.85       32.452       25.48        0.497
          175.0        6.55       32.596       25.63        0.559
          200.0        6.26       32.701       25.75        0.617
          250.0        5.47       33.104       26.16        0.721
```



Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  11,   RES25B     29/11/77
--------------------------                                  16.5 HOURS GMT

  LATITUDE = 60    1.2N   LONGITUDE = 149  20.6W   SONIC DEPTH =  275 M

  1-DIGIT WEATHER CODE IS (XX) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------
I          DIRECTION          SPEED                          I
I WIND  *  335 - 344 DEGS    25 KNOTS                        I
--------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD               I
I SEA        5 -  14 DEGS  1.0 M.          SECS              I
I SWELL        -      DEGR     M.          SECS              I
--------------------------------------------------------------
I TEMPERATURES -DRY =  -1.7 DEGR C.   BAROMETRIC PR. = 996.2 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M   I
--------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                       DYN M
           2.0        6.93         30.729        24.11        0.008
           1.0        6.93         30.729        24.11        0.004
           5.0        6.95         30.734        24.11        0.019
          10.0        6.98         30.746        24.12        0.038
          15.0        7.03         30.760        24.12        0.057
          20.0        7.07         30.766        24.12        0.076
          25.0        7.16         30.826        24.16        0.095
          30.0        7.46         30.956        24.22        0.114
          35.0        8.53         31.238        24.29        0.132
          40.0        8.02         31.206        24.34        0.150
          45.0        8.27         31.249        24.34        0.168
          50.0        7.93         31.256        24.39        0.186
          60.0        8.50         31.571        24.55        0.221
          70.0        8.44         31.574        24.56        0.255
          75.0        8.54         31.668        24.62        0.272
          80.0        8.43         31.666        24.64        0.288
          90.0        8.34         31.774        24.74        0.321
         100.0        8.19         31.903        24.86        0.353
         125.0        7.37         32.190        25.20        0.426
         150.0        7.00         32.384        25.40        0.493
         175.0        6.81         32.457        25.49        0.558
         200.0        6.19         32.702        25.76        0.618
         250.0        5.47         33.080        26.14        0.720
```

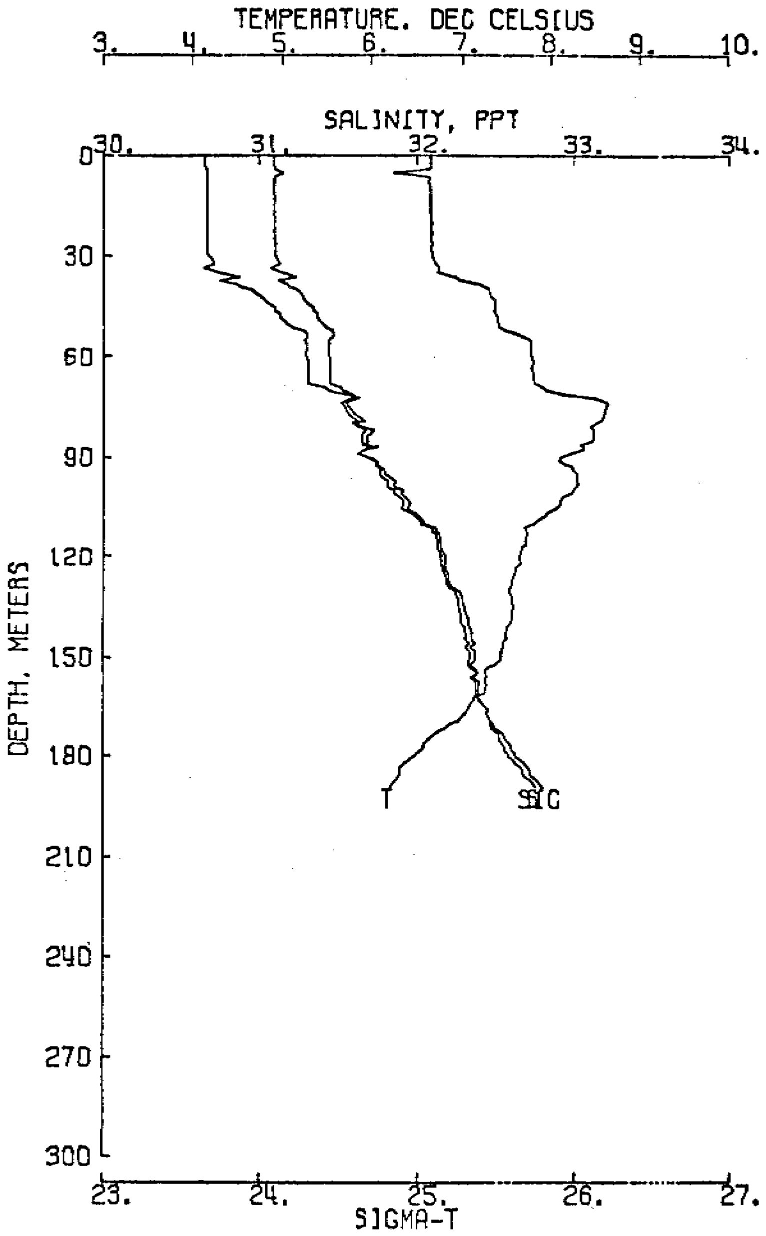
Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.



CRUISE 254 STATION 11

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  14,    RES 35     29/11/77
---------------------------                                 24.0 HOURS GMT

  LATITUDE = 59  57.9N   LONGITUDE = 149  20.7W   SONIC DEPTH =  193 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS
  CLOUD AMOUNT --- (6) ---6/8
  VISIBILITY --- (8) ---20-50 KM
------------------------------------------------------------------------
I            DIRECTION          SPEED                                  I
I WIND        0 -    0 DEGR    20 KNOTS                                I
------------------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD                     I
I SEA         0 -    0 DEGR   1.0 M.          SECS                     I
I SWELL         -      DEGR       M.          SECS                     I
------------------------------------------------------------------------
I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. =1002.1 MB       I
I              -WET =        DEGR C.   TRANSPARENCY   =        M       I
------------------------------------------------------------------------


          DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
          METERS       DEG C          PPT                       DYN M
            2.0        6.65         30.657        24.09        0.008
            1.0        6.65         30.657        24.09        0.004
            5.0        6.23         30.660        24.14        0.019
           10.0        6.65         30.663        24.10        0.038
           15.0        6.65         30.660        24.09        0.058
           20.0        6.66         30.660        24.09        0.077
           25.0        6.65         30.662        24.09        0.096
           30.0        6.66         30.672        24.10        0.115
           35.0        6.73         30.741        24.15        0.134
           40.0        7.31         30.941        24.23        0.153
           45.0        7.36         31.099        24.35        0.171
           50.0        7.40         31.177        24.40        0.189
           60.0        7.78         31.298        24.45        0.224
           70.0        7.95         31.432        24.53        0.259
           75.0        8.62         31.566        24.53        0.276
           80.0        8.54         31.614        24.58        0.293
           90.0        8.10         31.691        24.71        0.326
          100.0        8.25         31.908        24.86        0.358
          125.0        7.57         32.193        25.18        0.432
          150.0        7.43         32.369        25.33        0.500
          175.0        6.69         32.523        25.56        0.565
```

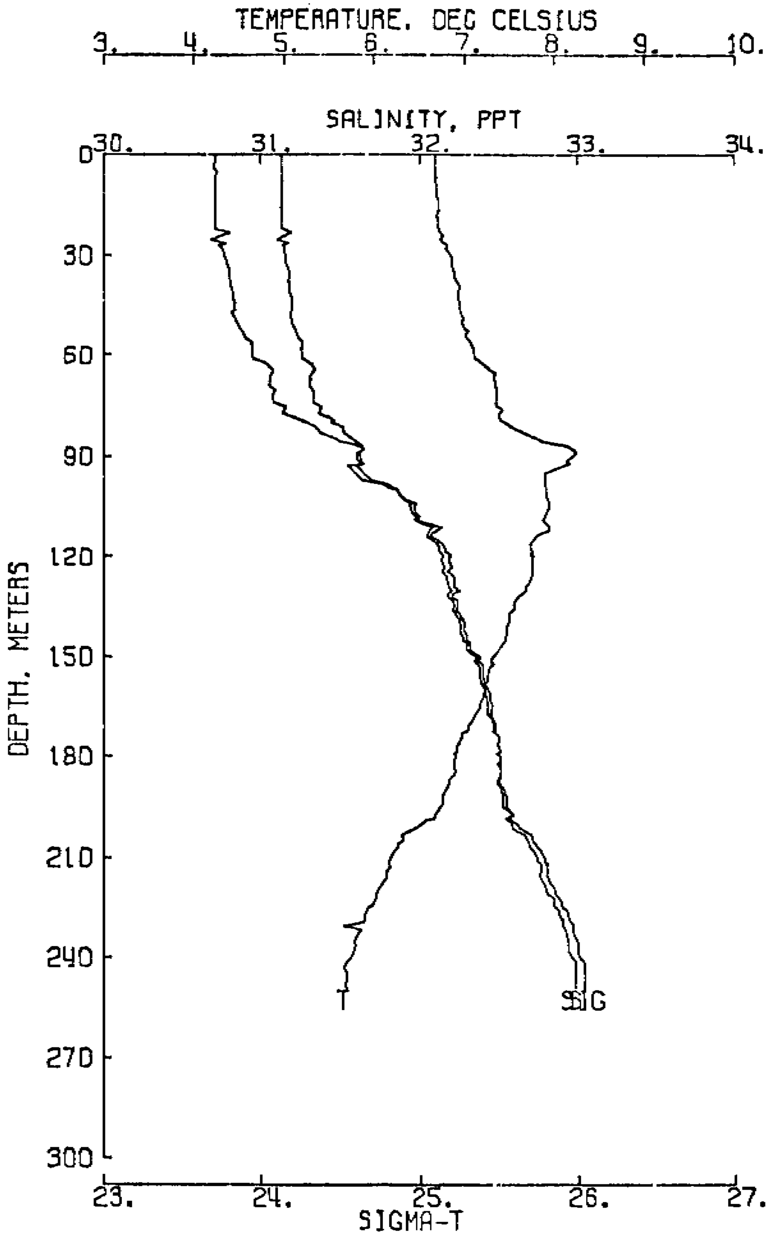
Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.



CRUISE 254 STATION 14

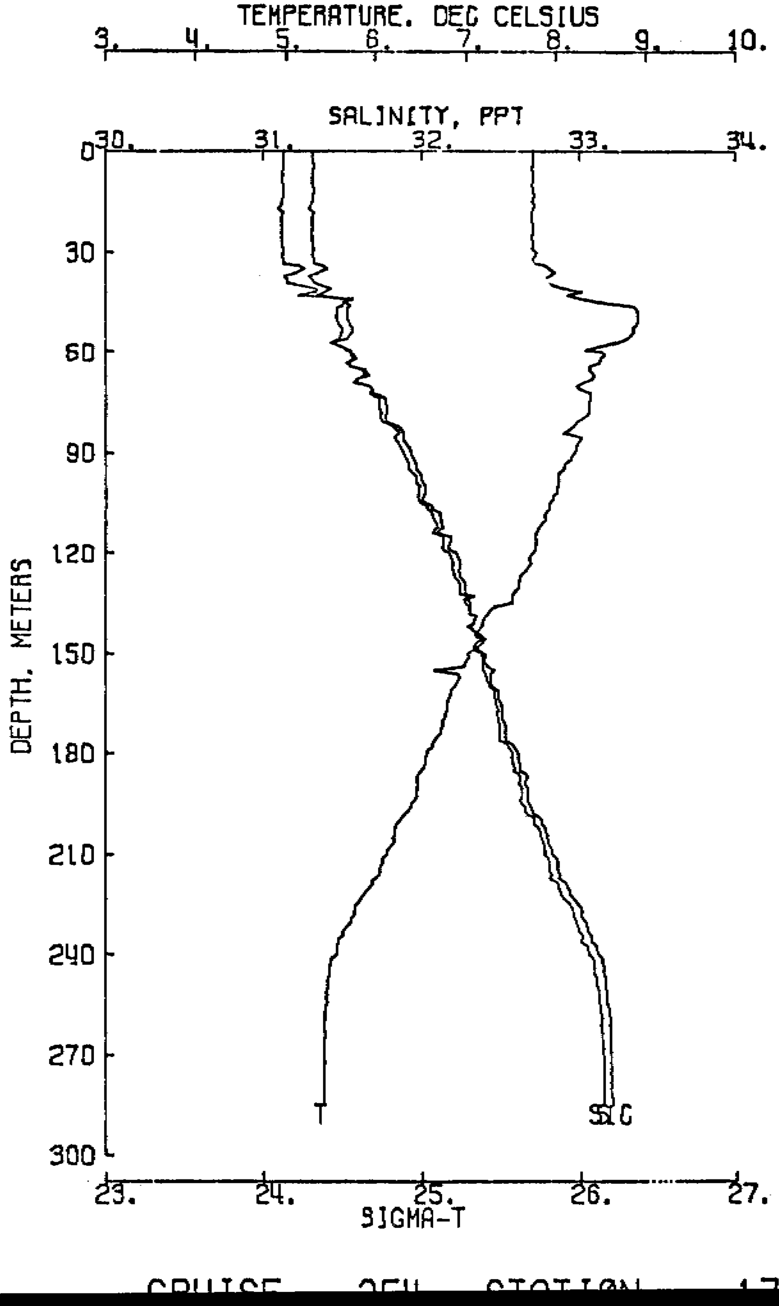
```
AC   CRUISE 254 CONSECUTIVE STATION NO.  15.    RES  4     30/11/77
---------------------------                                   1.4 HOURS GMT

  LATITUDE = 59  54.7N   LONGITUDE = 149  24.5W   SONIC DEPTH =  255 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (3) ---ALTOCUMULUS
  CLOUD AMOUNT --- (7) ---7/8
  VISIBILITY --- (7) ---10-20 KM
---------------------------------------------------------------------
I             DIRECTION          SPEED                              I
I WIND     355 -   4 DEGR    25 KNOTS                               I
---------------------------------------------------------------------
I             DIRECTION         HEIGHT       PERIOD                 I
I SEA      355 -   4 DEGR   1.0 M.           SECS                   I
I SWELL        -     DEGR       M.           SECS                   I
---------------------------------------------------------------------
I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. =1003.2 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =         M  I
---------------------------------------------------------------------


        DEPTH      TEMPERATURE     SALINITY       SIGMA-T       DELTA-D
        METERS       DEG C           PPT                         DYN M
          2.0         6.67          30.706         24.13         0.008
          1.0         6.67          30.706         24.13         0.004
          5.0         6.65          30.717         24.14         0.019
         10.0         6.69          30.708         24.13         0.038
         15.0         6.70          30.712         24.13         0.057
         20.0         6.71          30.711         24.13         0.076
         25.0         6.73          30.687         24.10         0.095
         30.0         6.84          30.772         24.16         0.114
         35.0         6.88          30.805         24.18         0.133
         40.0         6.93          30.818         24.18         0.152
         45.0         6.94          30.830         24.19         0.170
         50.0         6.99          30.848         24.20         0.189
         60.0         7.11          30.945         24.26         0.226
         70.0         7.36          31.085         24.33         0.263
         75.0         7.37          31.157         24.39         0.281
         80.0         7.45          31.248         24.45         0.298
         90.0         8.20          31.608         24.63         0.332
        100.0         7.92          31.565         24.87         0.365
        125.0         7.74          32.215         25.17         0.439
        150.0         7.31          32.391         25.37         0.508
        175.0         6.94          32.508         25.51         0.572
        200.0         6.52          32.591         25.63         0.635
```

Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.



CRUISE 254 STATION 15

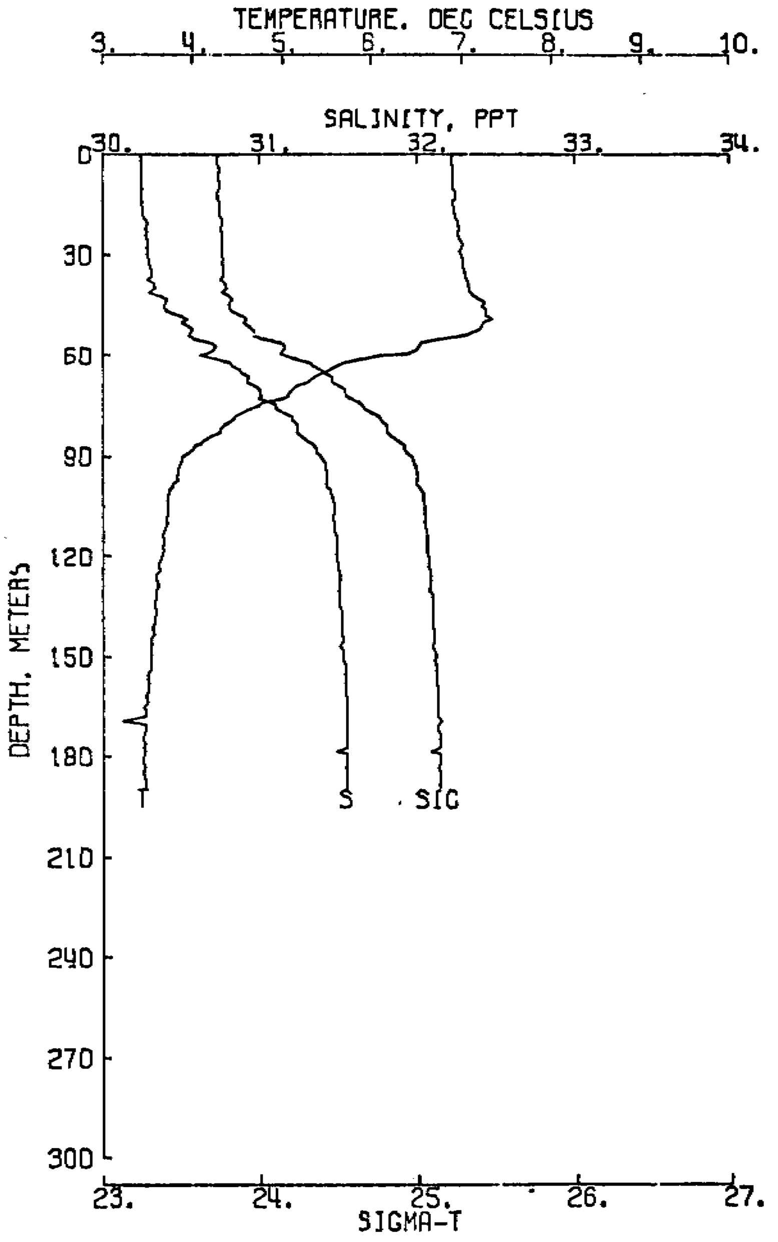
```
AC   CRUISE 254 CONSECUTIVE STATION NO.  17.   RES 25      1/12/77
---------------------------                                  7.6 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS
  CLOUD AMOUNT --- (1) ---1/8 OR LESS .
  VISIBILITY --- (8) ---20-50 KM
--------------------------------------------------------------------------------
I            DIRECTION          SPEED                                          I
I WIND     325 - 334 DEGS    35 KNOTS                                          I
--------------------------------------------------------------------------------
I            DIRECTION         HEIGHT      PERIOD                              I
I SEA      325 - 334 DEGS  2.0 M.          SECS                                I
I SWELL         -      DEGS      M.          SECS                              I
--------------------------------------------------------------------------------
I TEMPERATURES -DRY =  -3.3 DEGS C.   BAROMETRIC PR. =1014.8 MB   I
I               -WET =        DEGS C.   TRANSPARENCY  , =       M   I
--------------------------------------------------------------------------------


          DEPTH      TEMPERATURE     SALINITY       SIGMA-T       DELTA-D
          METERS       DEG C           PPT                         DYN M
            2.0         7.73         31.122         24.31         0.007
            1.0         7.73         31.122         24.31         0.004
            5.0         7.72         31.126         24.32         0.018
           10.0         7.71         31.120         24.31         0.036
           15.0         7.72         31.116         24.31         0.054
           20.0         7.71         31.115         24.31         0.073
           25.0         7.71         31.115         24.31         0.091
           30.0         7.77         31.126         24.31         0.109
           35.0         7.91         31.262         24.40         0.127
           40.0         7.85         31.132         24.31         0.145
           45.0         8.49         31.505         24.51         0.163
           50.0         8.91         31.528         24.46         0.180
           60.0         8.51         31.550         24.54         0.215
           70.0         8.22         31.677         24.68         0.249
           75.0         8.37         31.770         24.73         0.265
           80.0         8.30         31.754         24.73         0.281
           90.0         8.20         31.933         24.88         0.313
          100.0         8.00         32.028         24.99         0.343
          125.0         7.66         32.235         25.20         0.416
          150.0         7.01         32.383         25.40         0.483
          175.0         6.67         32.496         25.53         0.547
          200.0         6.27         32.717         25.76         0.606
          250.0         5.46         33.118         26.17         0.709
```



Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.

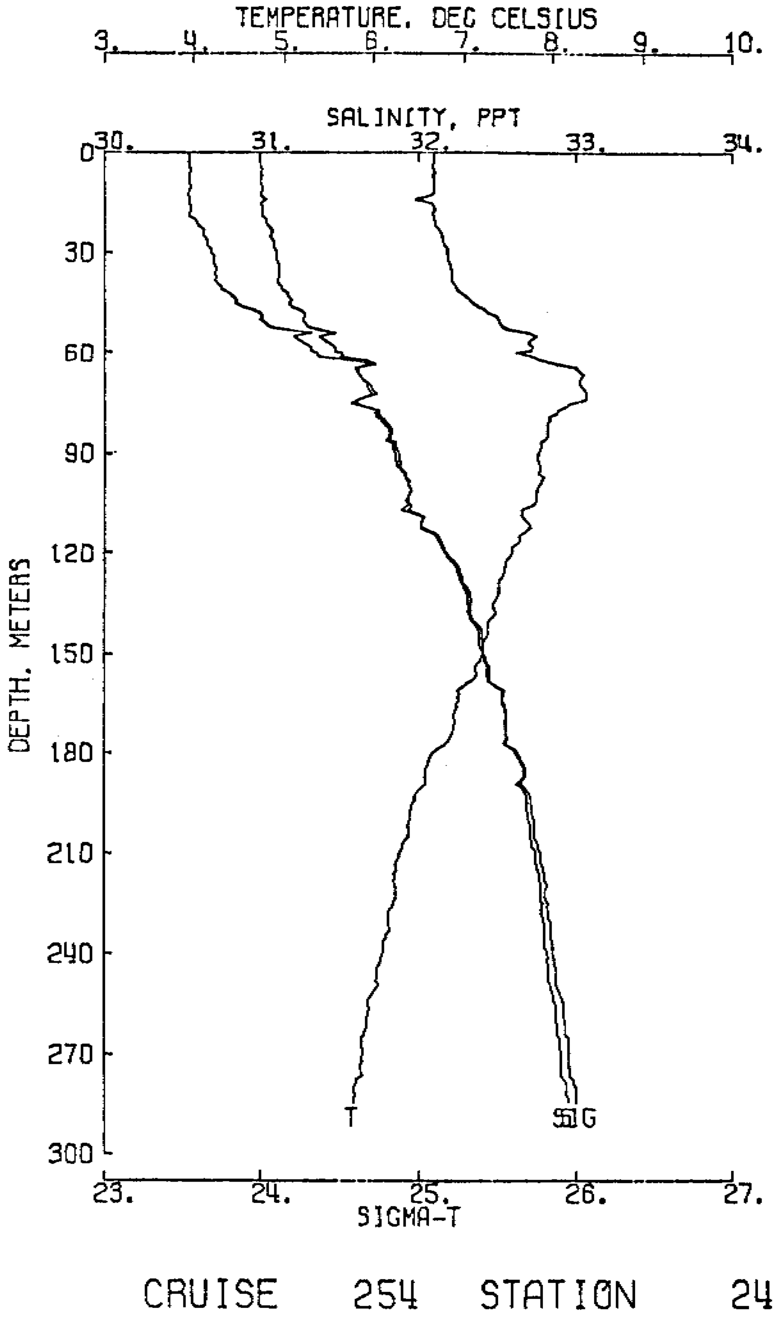
```
AC   CRUISE 254 CONSECUTIVE STATION NO.  20.     A  1       2/12/77
--------------------------                                1.3 HOURS GMT

 LATITUDE = 59  53.7N   LONGITUDE = 149  41.4W   SONIC DEPTH =  193 M


 1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- (2) ---20-50 KM
-------------------------------------------------------------------
I           DIRECTION          SPEED                               I
I WIND      335 - 344 DEGR     11 KNOTS                            I
-------------------------------------------------------------------
I           DIRECTION         HEIGHT      PERIOD                   I
I SEA       335 - 344 DEGR   0.4 M.          SECS                  I
I SWELL         -      DEGR      M.          SECS                  I
-------------------------------------------------------------------
I TEMPERATURES -DRY =    0.  DEGR C.   BAROMETRIC PR. =1010.5 MB   I
I              -WET =        DEGR C.   TRANSPARENCY  . =       M   I
-------------------------------------------------------------------


         DEPTH      TEMPERATURE   SALINITY      SIGMA-T      DELTA-D
         METERS       DEG C         PPT                       DYN M
           2.0         6.89       30.246        23.74        0.008
           1.0         6.89       30.246        23.74        0.004
           5.0         6.90       30.249        23.74        0.021
          10.0         6.90       30.254        23.74        0.042
          15.0         6.92       30.253        23.74        0.063
          20.0         6.94       30.277        23.76        0.084
          25.0         6.97       30.290        23.75        0.104
          30.0         6.99       30.296        23.76        0.125
          35.0         7.03       30.308        23.77        0.146
          40.0         7.07       30.338        23.79        0.167
          45.0         7.21       30.381        23.80        0.187
          50.0         7.23       30.503        23.90        0.208
          60.0         6.16       30.615        24.12        0.247
          70.0         5.19       30.999        24.54        0.282
          75.0         4.72       31.102        24.66        0.299
          80.0         4.39       31.220        24.78        0.315
          90.0         3.88       31.386        24.97        0.346
         100.0         3.73       31.447        25.03        0.376
         125.0         3.60       31.502        25.08        0.449
         150.0         3.53       31.534        25.11        0.522
         175.0         3.45       31.555        25.14        0.593
```

Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.



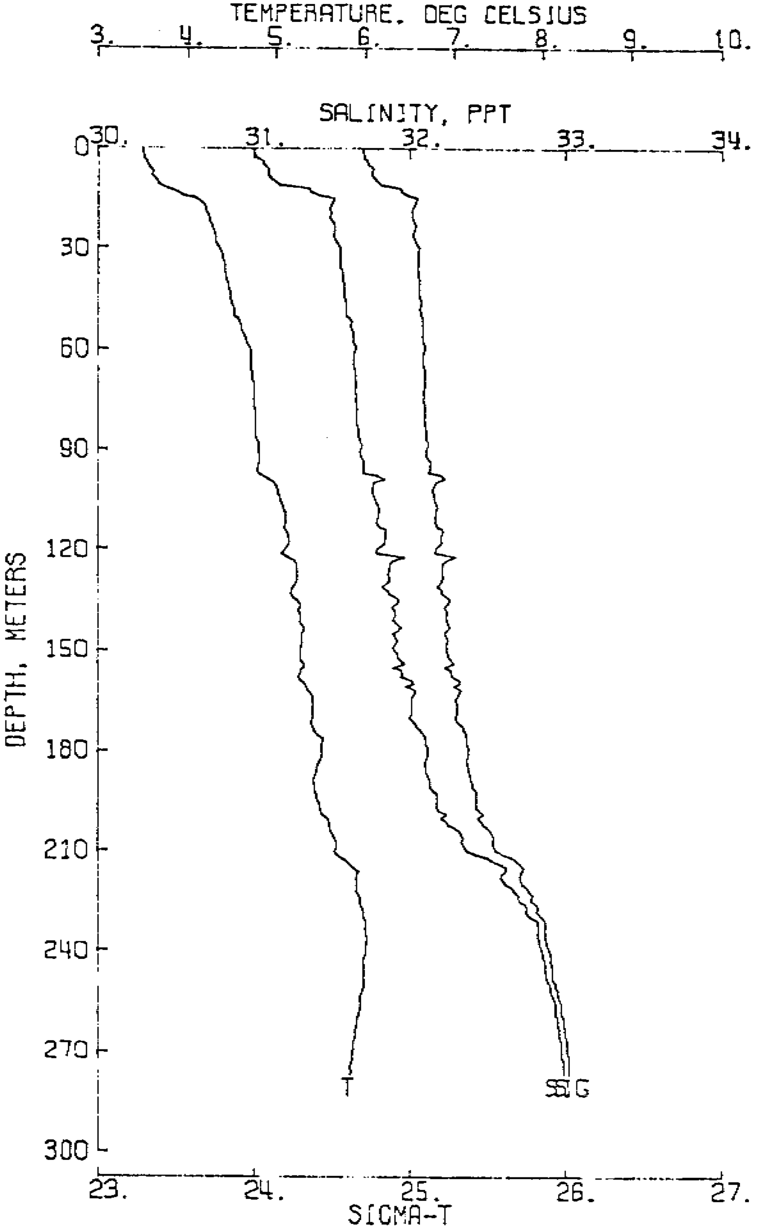
CRUISE 254 STATION 20

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  24.     A-3          2/12/77
------------------------------                                17.5 HOURS GMT

  LATITUDE = 59  45.7N   LONGITUDE = 149  41.3W   SONIC DEPTH =  289 M


  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED        ,
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- ( ) ---NOT RECORDED
----------------------------------------------------------------------------
I            DIRECTION          SPEED                                       I
I WIND        0 -    0 DEGR   40 KNOTS                                      I
----------------------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD                          I
I SEA         0 -    0 DEGR   2.0 M.        SECS                            I
I SWELL         -      DEGR       M.        SECS                            I
----------------------------------------------------------------------------
I TEMPERATURES -DRY =   -3.3 DEGR C.   BAROMETRIC PR. =1007.8 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =         M I
----------------------------------------------------------------------------


          DEPTH      TEMPERATURE   SALINITY      SIGMA-T       DELTA-D
          METERS       DEG C         PPT                        DYN M
            2.0         6.66       30.546        24.00         0.008
            1.0         6.66       30.546        24.00         0.004
            5.0         6.66       30.555        24.01         0.020
           10.0         6.67       30.557        24.01         0.039
           15.0         6.65       30.545        24.00         0.059
           20.0         6.65       30.579        24.03         0.078
           25.0         6.76       30.636        24.06         0.098
           30.0         6.91       30.690        24.10         0.117
           35.0         6.86       30.716        24.11         0.136
           40.0         6.91       30.745        24.13         0.155
           45.0         7.19       30.835        24.17         0.174
           50.0         7.40       31.001        24.26         0.193
           60.0         7.60       31.354        24.51         0.228
           70.0         8.33       31.700        24.68         0.262
           75.0         8.21       31.570        24.60         0.278
           80.0         7.98       31.761        24.78         0.294
           90.0         7.84       31.852        24.87         0.326
          100.0         7.86       31.940        24.94         0.357
          125.0         7.45       32.261        25.25         0.430
          150.0         7.20       32.423        25.41         0.496
          175.0         6.84       32.562        25.56         0.559
          200.0         6.39       32.710        25.74         0.618
          250.0         6.01       32.840        25.89         0.729
```



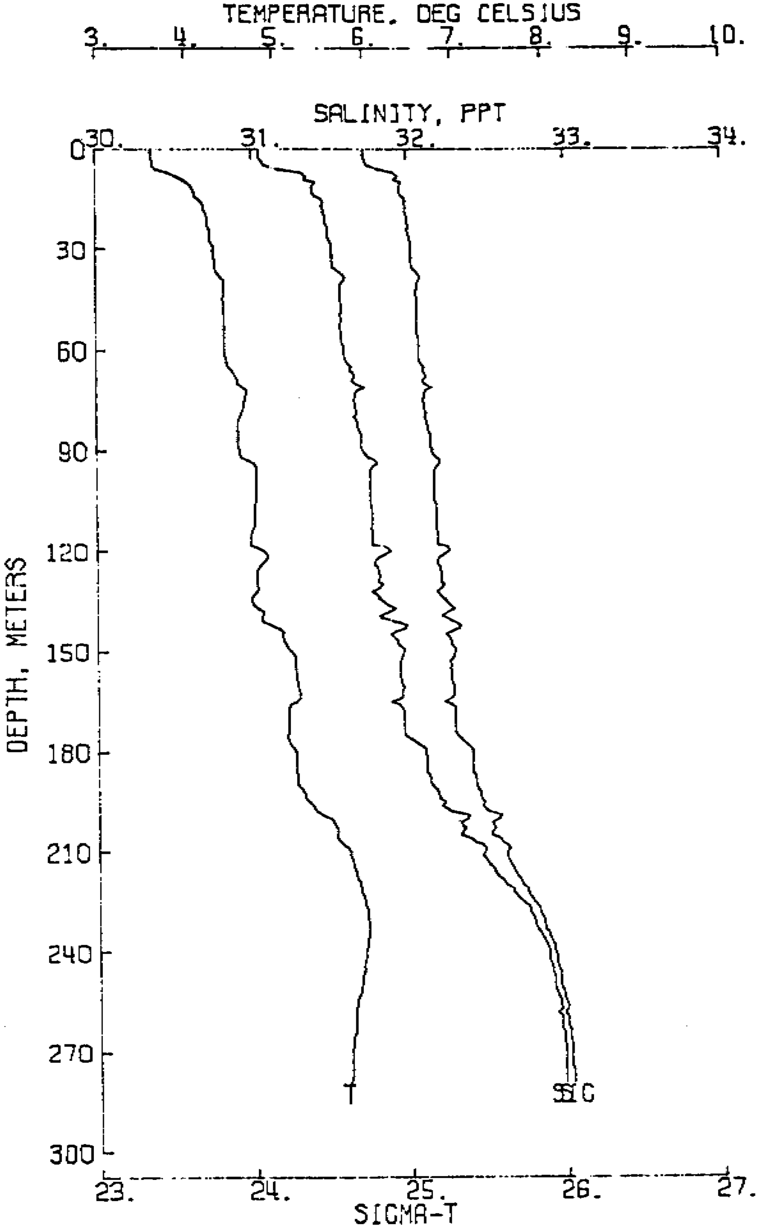
Resurrection Bay hydrographic data
November 1977 R/V *Acona* cruise No. 254.

```
AC   CRUISE 256 CONSECUTIVE STATION NO.   1.   RES2.5      16/ 2/78
---------------------------                                  20.1 HOURS GMT

  LATITUDE = 60   1.0N   LONGITUDE = 149  22.0W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (6) ---4-10 KM
-------------------------------------------------------------------------
I             DIRECTION          SPEED                                  I
I WIND         0 -   0 DEGR       KNOTS                                 I
-------------------------------------------------------------------------
I             DIRECTION        HEIGHT      PERIOD                       I
I SEA          0 -   0 DEGR  0.5 M.           SECS                      I
I SWELL          -     DEGR      M.           SECS                      I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =    4.4 DEGR C.   BAROMETRIC PR. =1003.5 MB        I
I              -WET =        DEGR C.   TRANSPARENCY   =        M        I
-------------------------------------------------------------------------


          DEPTH     TEMPERATURE    SALINITY      SIGMA-T       DELTA-D
          METERS       DEG C         PPT                        DYN M
            0.          3.49        30.995        24.69        0.
            1.0         3.49        30.995        24.69        0.003
            5.0         3.56        31.055        24.73        0.016
           10.0         3.65        31.112        24.77        0.032
           15.0         4.07        31.512        25.05        0.048
           20.0         4.23        31.498        25.01        0.062
           25.0         4.30        31.511        25.02        0.077
           30.0         4.34        31.555        25.05        0.092
           35.0         4.41        31.551        25.05        0.106
           40.0         4.45        31.573        25.06        0.121
           45.          4.49        31.590        25.07        0.136
           50.0         4.53        31.593        25.07        0.150
           60.0         4.70        31.650        25.09        0.179
           70.0         4.74        31.650        25.09        0.208
           75.0         4.75        31.646        25.09        0.223
           80.0         4.76        31.656        25.09        0.237
           90.0         4.82        31.694        25.11        0.266
          100.0         4.97        31.770        25.16        0.294
          125.0         5.23        31.862        25.21        0.365
          150.0         5.26        31.909        25.24        0.434
          175.0         5.44        32.095        25.36        0.501
          200.0         5.57        32.205        25.44        0.567
          250.0         5.99        32.902        25.94        0.681
```



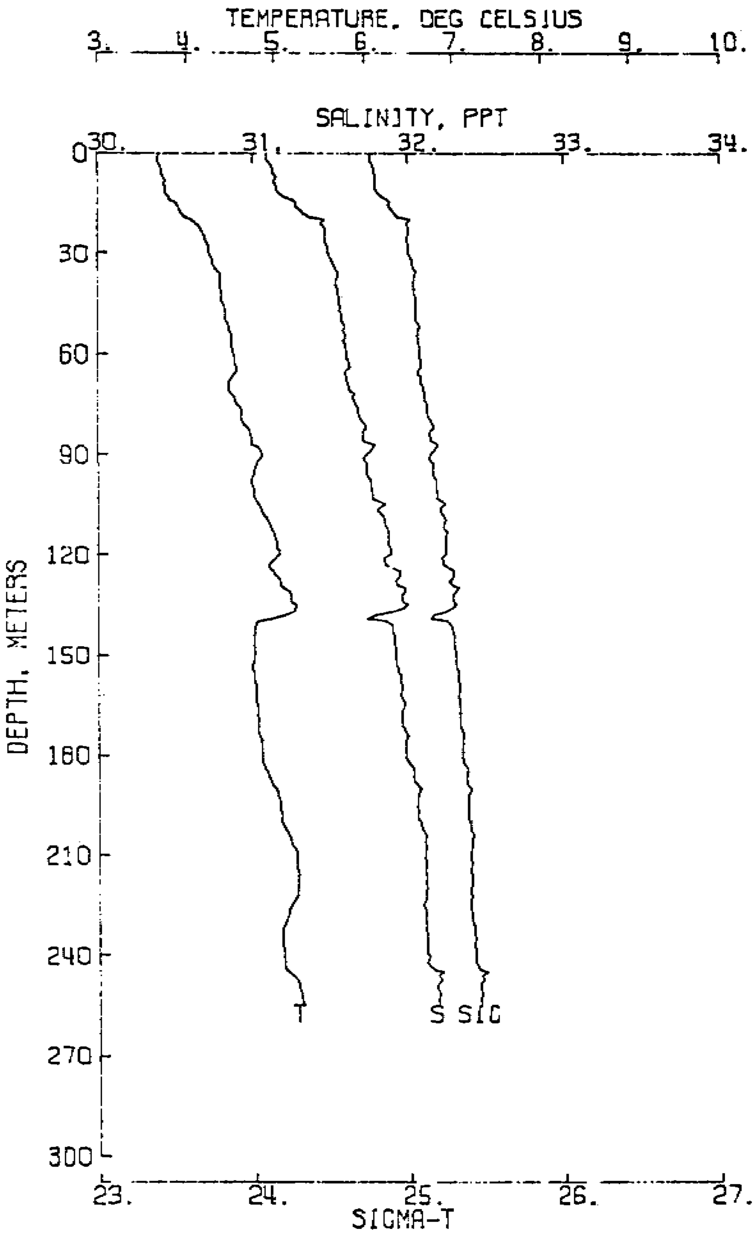
CRUISE 256 STATION 1

```
AC   CRUISE 256 CONSECUTIVE STATION NO.   2.   RE5003     16/ 2/78
--------------------------                                21.3 HOURS GMT

  LATITUDE = 6[illegible] 59.0N   LONGITUDE = 149  20.5W   SONIC DEPTH =  290 M

  1-DIGIT WEATHER CODE IS ([illegible]) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------------
I          DIRECTION        SPEED                                      I
I WIND     335 - 344 DEGR   [illegible] KNOTS                          I
-----------------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                         I
I SEA      335 - 344 DEGR   0.5 M.          SECS                       I
I SWELL        -      DEGR      M.          SECS                       I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    4.4 DEGR C.   BAROMETRIC PR. =1003.5 MB       I
I              -WET =        DEGR C.   TRANSPARENCY   =        M       I
-----------------------------------------------------------------------


         DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
         METERS       DEG C          PPT                      DYN M
           0.          3.61        31.040        24.71       0.
           1.0         3.62        31.044        24.72       0.003
           5.0         3.63        31.078        24.74       0.016
          10.0         4.03        31.407        24.97       0.032
          15.0         4.15        31.452        24.99       0.047
          20.0         4.24        31.470        25.00       0.062
          25.0         4.27        31.490        25.00       0.076
          30.0         4.31        31.511        25.02       0.091
          35.0         4.34        31.522        25.03       0.106
          40.0         4.44        31.568        25.06       0.121
          45.0         4.42        31.570        25.06       0.135
          50.0         4.43        31.568        25.06       0.150
          60.0         4.44        31.586        25.07       0.179
          70.0         4.54        31.656        25.11       0.208
          75.0         4.67        31.652        25.10       0.222
          80.0         4.6[illegible]        31.648        25.10       0.237
          90.0         4.59        31.705        25.15       0.265
         100.0         4.78        31.756        25.17       0.293
         125.0         4.81        31.800        25.20       0.363
         150.0         5.17        31.964        25.29       0.432
         175.0         5.12        31.976        25.31       0.500
         200.0         5.42        32.368        25.56       0.565
         250.0         5.94        32.918        25.96       0.678
```



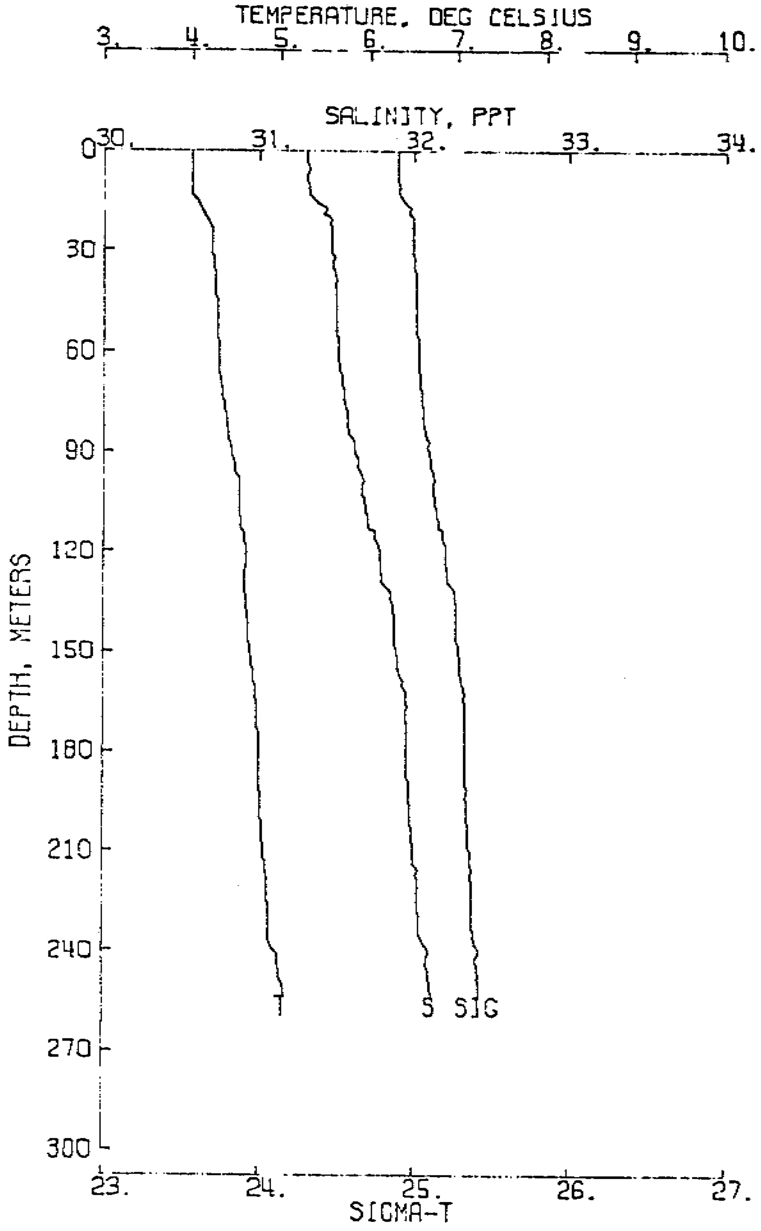
CRUISE 256 STATION 2

```
AC   CRUISE 256 CONSECUTIVE STATION NO.   3,   RES004     16/ 2/78
--------------------------                                 22.2 HOURS GMT

  LATITUDE = 59  54.6N   LONGITUDE = 149  24.5W   SONIC DEPTH =  260 M

  1-DIGIT WEATHER CODE IS (X) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (7) ---STRATU
  CLOUD AMOUNT --- (8) ---8/8 TOTAL
  VISIBILITY --- (7) ---10-20 KM
--------------------------------------------------------------------
I           DIRECTION          SPEED                               I
I WIND      335 - 344 DEGS     5 KNOTS                             I
--------------------------------------------------------------------
I           DIRECTION          HEIGHT      PERIOD                  I
I SEA         0 -    0 DEGS   2.0 M.          SECS                 I
I SWELL        -       DEGS       M.          SECS                 I
--------------------------------------------------------------------
I TEMPERATURES -DRY =     4.4 DEG C.   BAROMETRIC PR. =1003.5 MB   I
I              -WET =         DEG C.   TRANSPARENCY   =       M    I
--------------------------------------------------------------------


        DEPTH       TEMPERATURE    SALINITY       SIGMA-T      DELTA-D
        METERS        DEG C          PPT                        DYN M
          0.           3.69         31.093         24.75        0.
          1.0          3.69         31.096         24.75        0.003
          5.0          3.71         31.123         24.77        0.016
         10.0          3.75         31.148         24.79        0.032
         15.0          3.97         31.292         24.88        0.048
         20.0          4.05         31.459         25.01        0.063
         25.0          4.21         31.458         24.99        0.078
         30.0          4.26         31.492         25.01        0.093
         35.0          4.34         31.546         25.05        0.107
         40.0          4.38         31.538         25.04        0.122
         45.0          4.41         31.550         25.05        0.137
         50.0          4.44         31.564         25.05        0.151
         60.0          4.53         31.599         25.07        0.181
         70.0          4.49         31.617         25.09        0.210
         75.0          4.56         31.657         25.11        0.224
         80.0          4.62         31.699         25.14        0.238
         90.0          4.85         31.724         25.14        0.267
        100.0          4.74         31.759         25.18        0.295
        125.0          4.97         31.939         25.29        0.364
        150.0          4.74         31.920         25.30        0.432
        175.0          4.93         31.982         25.34        0.499
        200.0          5.07         32.069         25.39        0.565
        250.0          5.25         32.171         25.45        0.696
```



CRUISE 256 STATION 3

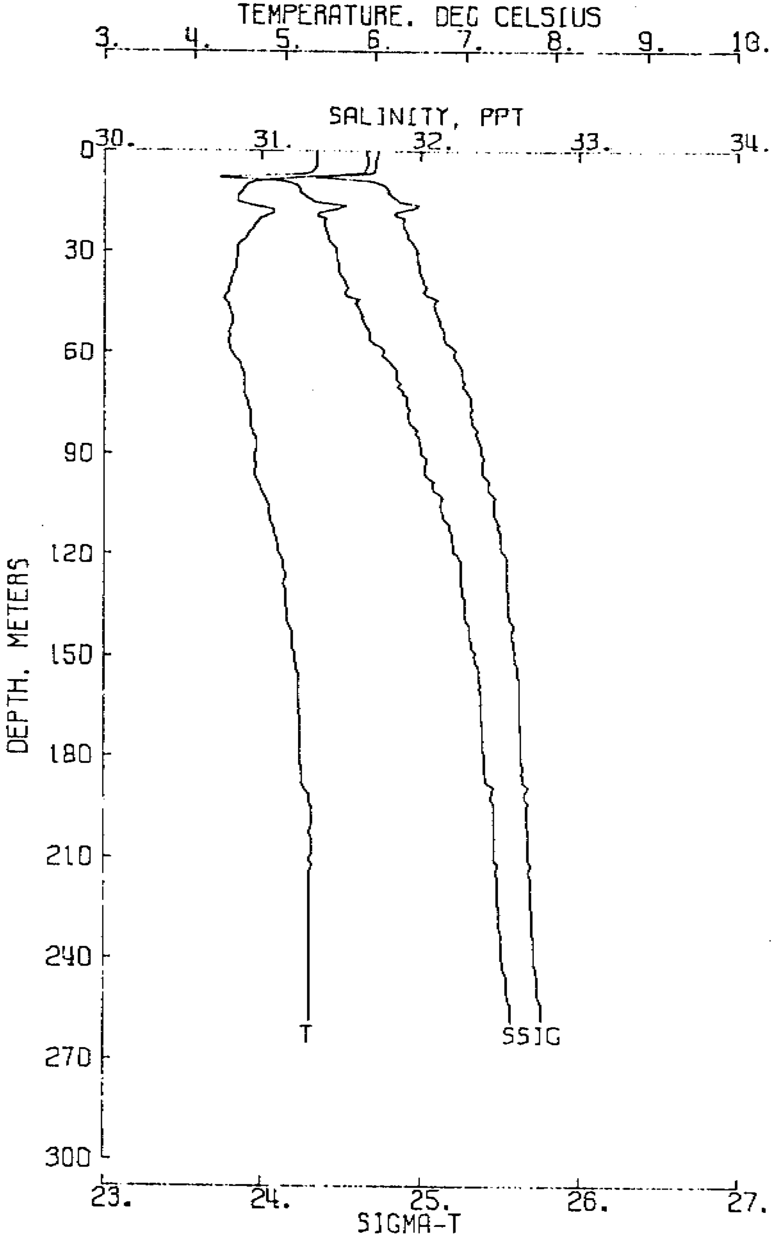
```
AC   CRUISE 256 CONSECUTIVE STATION NO.   4.   RES005     16/ 2/78
---------------------------                               23.5 HOURS GMT

 LATITUDE = 59  50.7N   LONGITUDE = 149  28.0W.   SONIC DEPTH =  263 M

 1-DIGIT WEATHER CODE IS (6) AND INDICATES RAIN
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- (6) ----4-10 KM
-----------------------------------------------------------------------
I           DIRECTION          SPEED                                  I
I WIND       45 -  54 DEGS   25 KNOTS                                 I
-----------------------------------------------------------------------
I           DIRECTION         HEIGHT     PERIOD                       I
I SEA       145 - 154 DEGS   2.5 M.        SECS                       I
I SWELL        -      DEGS       M.        SECS                       I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    4.4 DEGR C.   BAROMETRIC PR. =          MB   I
I              -WET =        DEGR C.   TRANSPARENCY   =          M    I
-----------------------------------------------------------------------

        DEPTH     TEMPERATURE   SALINITY      SIGMA-T      DELTA-D
        METERS      DEG C         PPT                       DYN M
          0.         3.94       31.304        24.89       0.
          1.0        3.94       31.304        24.89       0.003
          5.0        3.95       31.316        24.90       0.015
         10.         3.95       31.311        24.90       0.031
         15.0        4.04       31.345        24.92       0.046
         20.0        4.15       31.449        24.99       0.061
         25.0        4.21       31.453        24.99       0.076
         30.0        4.22       31.456        24.99       0.091
         35.0        4.24       31.475        25.00       0.106
         40.0        4.24       31.487        25.01       0.121
         45.0        4.27       31.490        25.01       0.136
         50.0        4.27       31.493        25.01       0.150
         60.0        4.29       31.507        25.02       0.180
         70.0        4.32       31.530        25.04       0.210
         75.0        4.35       31.543        25.05       0.224
         80.0        4.37       31.568        25.06       0.239
         90.0        4.44       31.614        25.09       0.268
        100.0        4.52       31.642        25.12       0.297
        125.0        4.55       31.776        25.21       0.367
        150.0        4.64       31.885        25.29       0.436
        175.0        4.74       31.949        25.33       0.503
        200.0        4.79       31.977        25.35       0.570
        250.0        5.02       32.107        25.42       0.701
```



CRUISE 256 STATION 4

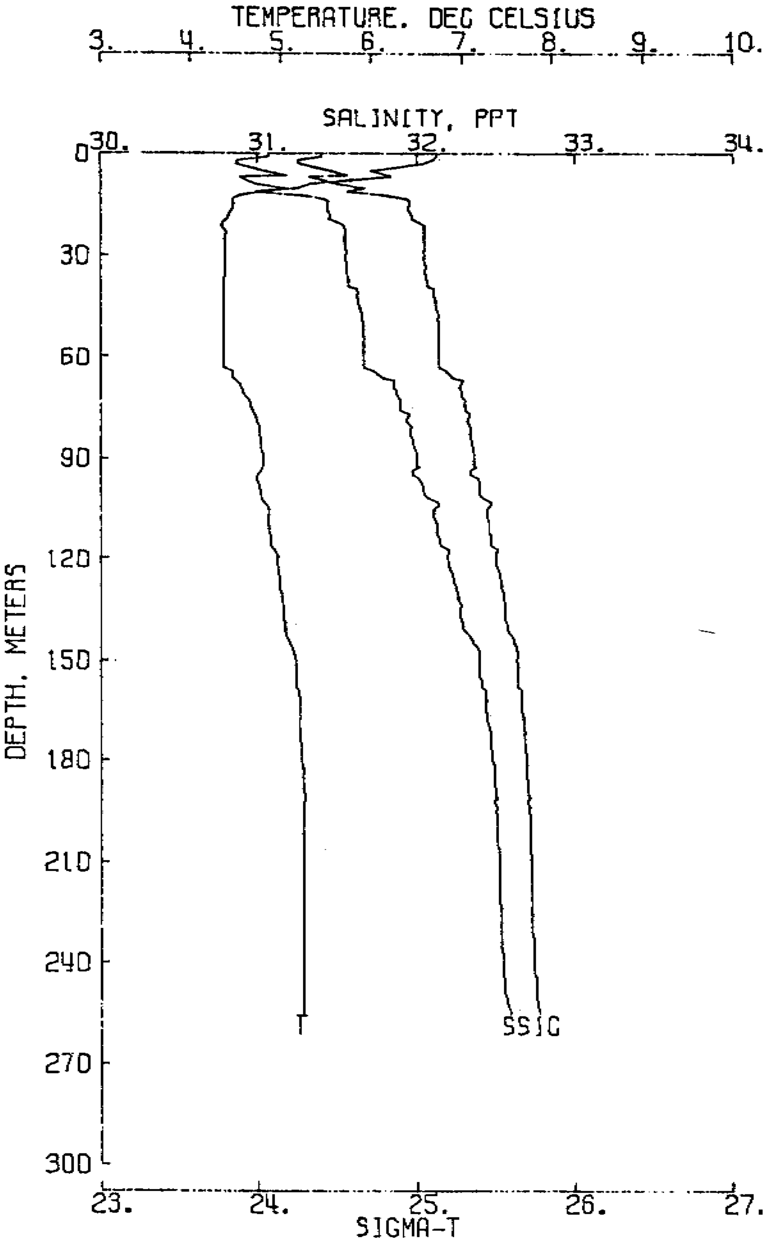
```
AC   CRUISE 260 CONSECUTIVE STATION NO.  17.   RES005     23/ 4/78
----------------------------                                9.1 HOURS GMT

 LATITUDE = 59  50.7N   LONGITUDE = 149  28.0W   SONIC DEPTH =  267 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- ( ) ---NOT RECORDED       .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------------------
I           DIRECTION          SPEED                                     I
I WIND      165 - 174 DEGR      5 KNOTS                                  I
--------------------------------------------------------------------------
I           DIRECTION         HEIGHT       PERIOD                        I
I SEA       165 - 174 DEGR   0.3 M.           SECS                       I
I SWELL           -      DEGR      M.         SECS                       I
--------------------------------------------------------------------------
I TEMPERATURES -DRY =    6.7 DEGR C.   BAROMETRIC PR. =1013.5 MB  I
I              -WET =        DEGR C.   TRANSPARENCY    =        M  I
--------------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	5.90	31.343	24.72	0.
1.0	5.90	31.343	24.72	0.003
5.0	5.91	31.332	24.71	0.016
10.0	4.59	31.216	24.76	0.033
15.0	4.49	31.330	24.86	0.049
20.0	4.72	31.398	24.89	0.064
25.0	4.58	31.413	24.92	0.079
30.0	4.48	31.471	24.98	0.095
35.0	4.46	31.482	24.99	0.109
40.0	4.40	31.528	25.03	0.124
45.0	4.38	31.589	25.08	0.139
50.0	4.42	31.636	25.11	0.153
60.0	4.43	31.774	25.22	0.182
70.0	4.56	31.855	25.27	0.209
75.0	4.60	31.909	25.31	0.222
80.0	4.62	31.926	25.32	0.236
90.0	4.67	32.004	25.38	0.262
100.0	4.73	32.075	25.43	0.288
125.0	5.00	32.254	25.54	0.351
150.0	5.12	32.336	25.59	0.412
175.0	5.17	32.393	25.63	0.472
200.0	5.29	32.463	25.67	0.531
250.0	5.27	32.548	25.74	0.647



CRUISE 260 STATION 17

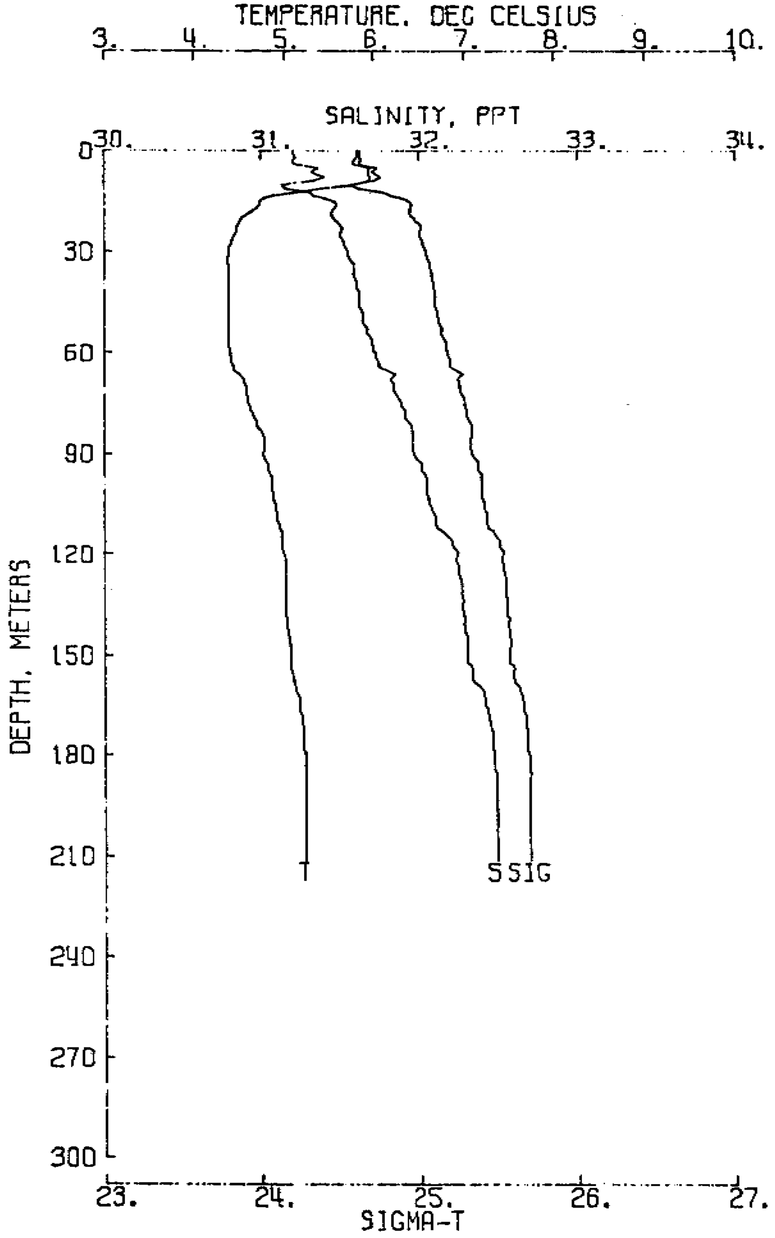
```
AC   CRUISE 260 CONSECUTIVE STATION NO.  18.    RES004     23/ 4/78
--------------------------                                  10.7 HOURS GMT

  LATITUDE = 59  54.7N   LONGITUDE = 149  24.5W   SONIC DEPTH =  263 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------------------------
I          DIRECTION        SPEED                                              I
I WIND     165 - 174 DEGR    5 KNOTS                                           I
--------------------------------------------------------------------------------
I          DIRECTION       HEIGHT     PERIOD                                   I
I SEA      165 - 174 DEGR  0.3 M.         SECS                                 I
I SWELL        -      DEGR     M.         SECS                                 I
--------------------------------------------------------------------------------
I TEMPERATURES -DRY =    6.1 DEGR C.   BAROMETRIC PR. =1013.8 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
--------------------------------------------------------------------------------

          DEPTH      TEMPERATURE   SALINITY      SIGMA-T       DELTA-D
          METERS        DEG C        PPT                        DYN M
            0.          6.72       31.063        24.40         0.
            1.0         6.72       31.063        24.40         0.004
            5.0         6.01       31.049        24.48         0.018
           10.0         5.20       31.182        24.67         0.035
           15.0         4.48       31.441        24.95         0.051
           20.0         4.36       31.495        25.01         0.066
           25.0         4.39       31.553        25.05         0.081
           30.0         4.39       31.556        25.05         0.095
           35.0         4.38       31.558        25.05         0.110
           40.0         4.36       31.619        25.11         0.125
           45.0         4.36       31.640        25.12         0.139
           50.0         4.37       31.662        25.14         0.153
           60.0         4.37       31.670        25.14         0.182
           70.0         4.58       31.873        25.28         0.209
           75.0         4.68       31.902        25.30         0.223
           80.0         4.74       31.938        25.32         0.236
           90.0         4.81       31.999        25.36         0.263
          100.0         4.77       32.042        25.40         0.289
          125.0         4.99       32.224        25.52         0.353
          150.0         5.16       32.389        25.63         0.414
          175.0         5.23       32.466        25.68         0.473
          200.0         5.25       32.509        25.72         0.531
          250.0         5.25       32.562        25.76         0.646
```



CRUISE 260 STATION 18

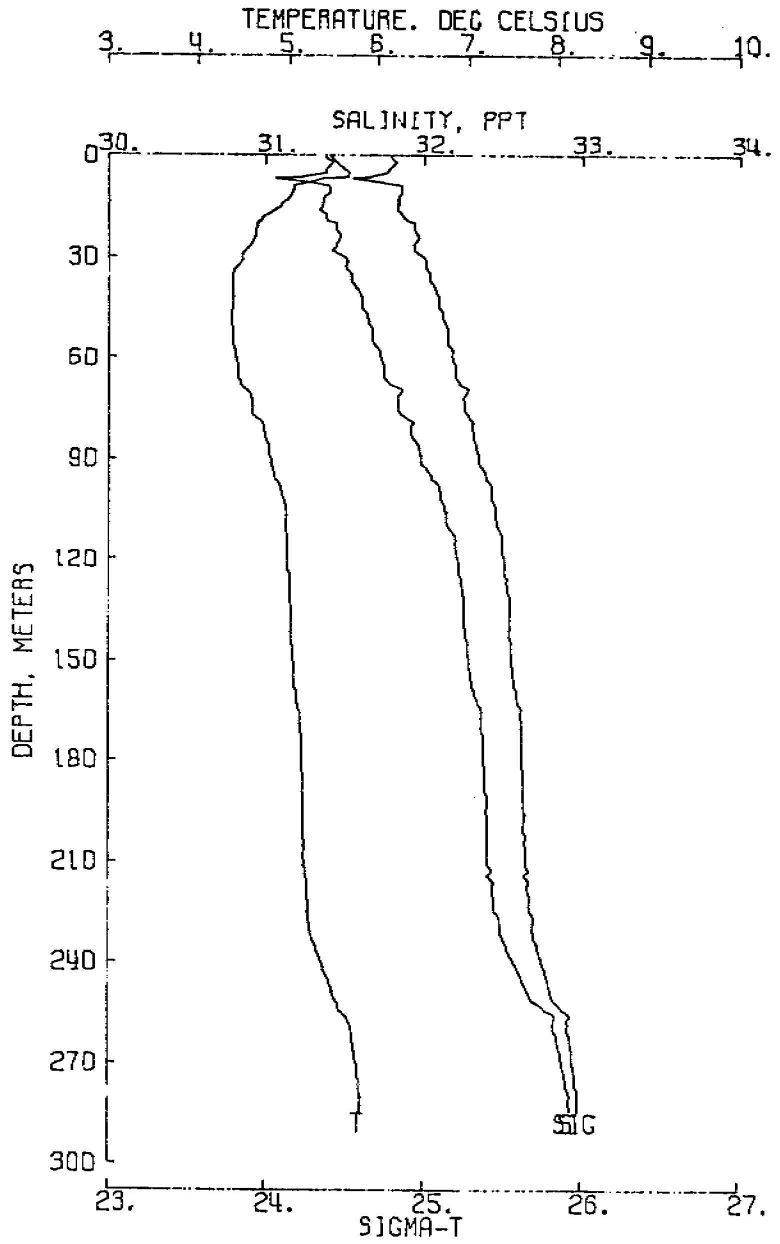
```
AC   CRUISE 260 CONSECUTIVE STATION NO.  19.   RES3.5    23/ 4/78
---------------------------                                  12.1 HOURS GMT

  LATITUDE = 59  57.9N   LONGITUDE = 149  20.7W   SONIC DEPTH =  195 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- ( ) ---NOT RECORDED
------------------------------------------------------------------
I           DIRECTION         SPEED                              I
I WIND          -       DEGR     KNOTS                           I
------------------------------------------------------------------
I           DIRECTION        HEIGHT     PERIOD                   I
I SEA        0 -   0 DEGR       M.        SECS                   I
I SWELL         -     DEGR       M.        SECS                   I
------------------------------------------------------------------
I TEMPERATURES -DRY =   5.6 DEGR C.  BAROMETRIC PR. =1014.0 MB   I
I              -WET =       DEGR C.  TRANSPARENCY   =       M    I
------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	5.81	31.206	24.62	0.
1.0	5.81	31.206	24.62	0.003
5.0	5.95	31.367	24.73	0.017
10.0	5.77	31.125	24.56	0.033
15.0	4.73	31.470	24.95	0.049
20.0	4.53	31.462	24.96	0.064
25.0	4.44	31.495	25.00	0.079
30.0	4.38	31.547	25.05	0.094
35.0	4.37	31.595	25.08	0.108
40.0	4.38	31.609	25.10	0.123
45.0	4.38	31.618	25.10	0.137
50.0	4.39	31.646	25.12	0.151
60.0	4.40	31.727	25.19	0.180
70.0	4.59	31.846	25.26	0.207
75.0	4.61	31.883	25.29	0.221
80.0	4.68	31.925	25.31	0.234
90.0	4.77	31.971	25.34	0.261
100.0	4.98	32.045	25.39	0.287
125.0	5.01	32.247	25.53	0.351
150.0	5.06	32.301	25.57	0.412
175.0	5.22	32.464	25.68	0.472
200.0	5.23	32.484	25.70	0.529



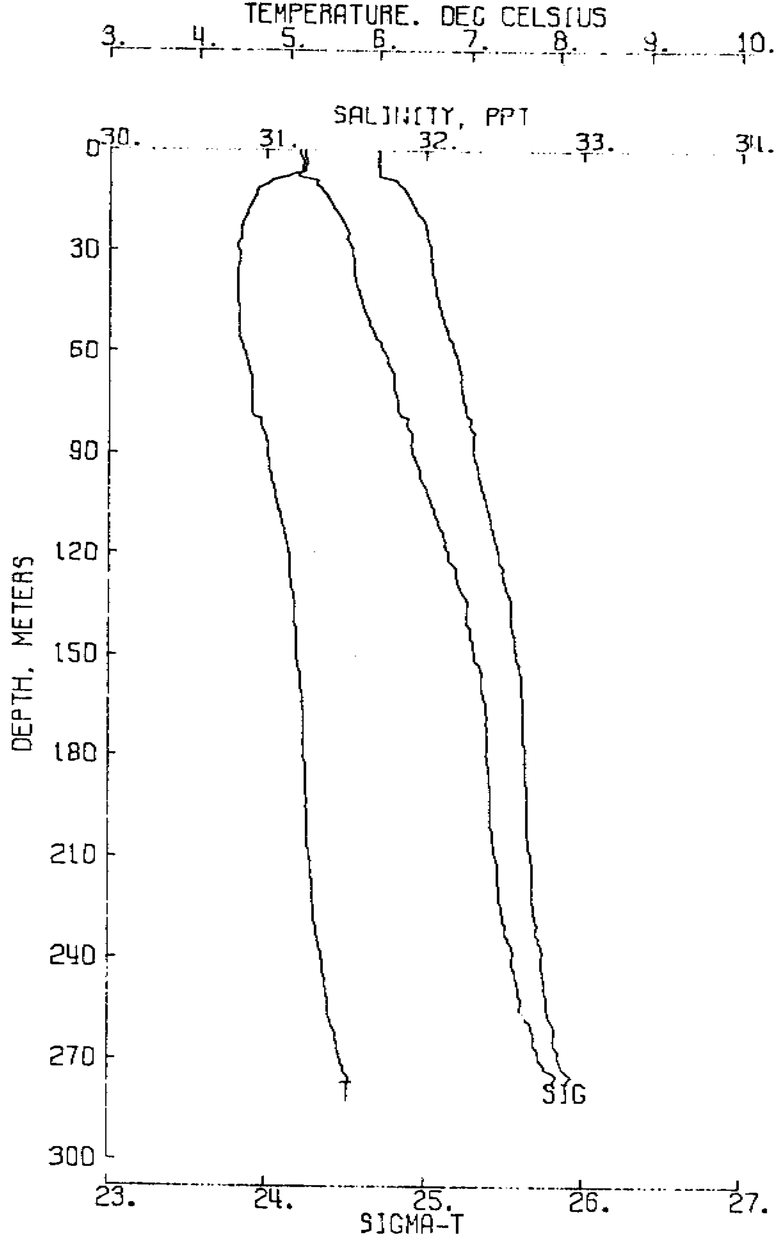
CRUISE 260 STATION 19

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  20.   RES003    23/ 4/78
--------------------------                               12.6 HOURS GMT

  LATITUDE = 59  59.0N   LONGITUDE = 149  20.5W   SONIC DEPTH =  292 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I           DIRECTION          SPEED                                  I
I WIND    175 - 184 DEGR     5 KNOTS                                  I
-----------------------------------------------------------------------
I           DIRECTION         HEIGHT      PERIOD                      I
I SEA         0 -    0 DEGR      M.          SECS                     I
I SWELL         -      DEGR      M.          SECS                     I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    5.6 DEGR C.   BAROMETRIC PR. =1014.0 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =       M   I
-----------------------------------------------------------------------


         DEPTH      TEMPERATURE   SALINITY      SIGMA-T       DELTA-D
         METERS       DEG C         PPT                        DYN M
           0.          5.48        31.376        24.79        0.
           1.0         5.48        31.376        24.79        0.003
           5.0         5.67        31.376        24.77        0.016
          10.0         5.04        31.404        24.86        0.032
          15.0         4.90        31.361        24.84        0.048
          20.0         4.64        31.449        24.94        0.063
          25.0         4.61        31.456        24.95        0.078
          30.0         4.48        31.504        25.00        0.093
          35.0         4.39        31.537        25.04        0.108
          40.0         4.38        31.583        25.07        0.123
          45.0         4.37        31.614        25.10        0.137
          50.0         4.37        31.661        25.14        0.152
          60.0         4.41        31.720        25.18        0.180
          70.0         4.56        31.869        25.28        0.207
          75.0         4.61        31.842        25.26        0.221
          80.0         4.72        31.923        25.31        0.235
          90.0         4.80        31.983        25.35        0.261
         100.0         4.93        32.100        25.43        0.288
         125.0         5.00        32.229        25.52        0.351
         150.0         5.06        32.287        25.56        0.412
         175.0         5.15        32.378        25.62        0.473
         200.0         5.17        32.403        25.64        0.532
         250.0         5.52        32.681        25.82        0.648
```



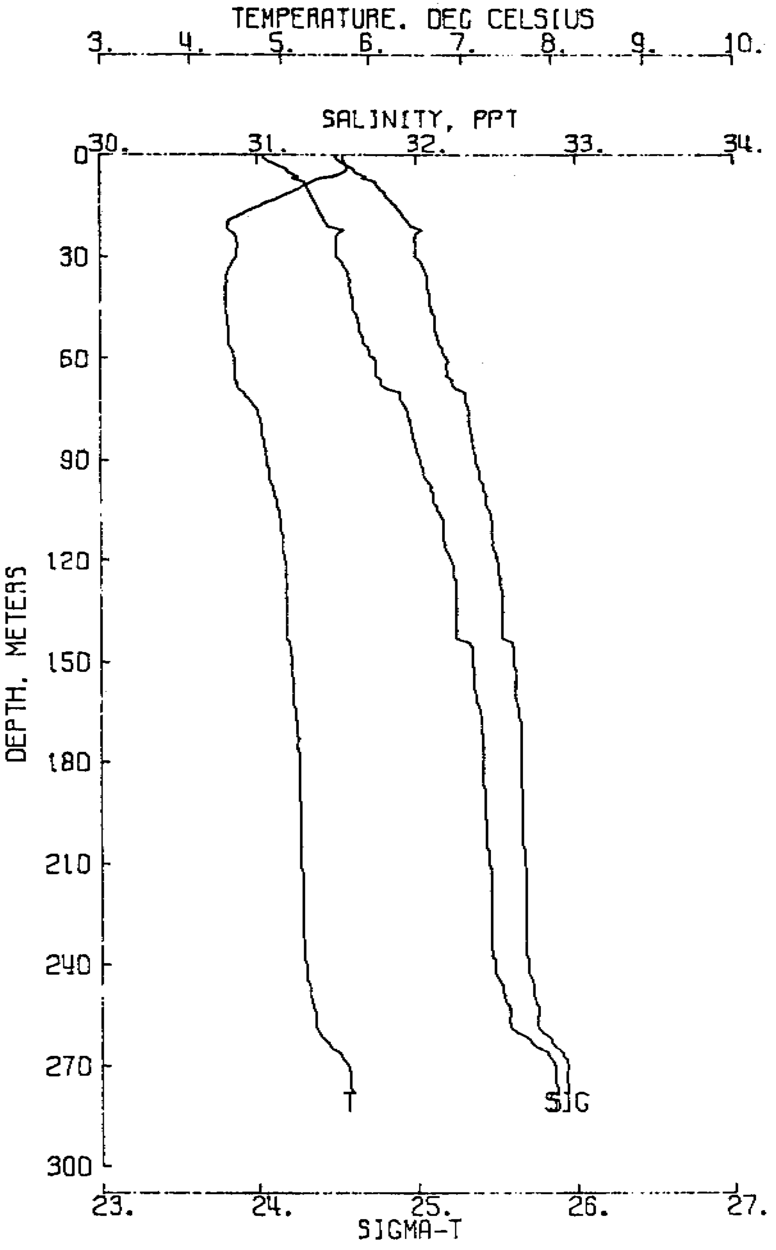
CRUISE 260 STATION 20

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  21.   RES25A    23/ 4/78
-------------------------                                13.8 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  23.0W   SONIC DEPTH =  285 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED       .
  CLOUD AMOUNT --- (6) ---6/8          .
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------
I          DIRECTION          SPEED                              I
I WIND     195 - 194 DEGR    7 KNOTS                             I
-----------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                   I
I SEA        0 -    0 DEGR      M.          SECS                 I
I SWELL        -      DEGR      M.          SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =     5.0 DEGR C.   BAROMETRIC PR. =1014.2 MB  I
I              -WET =         DEGR C.   TRANSPARENCY   =       M   I
-----------------------------------------------------------------


          DEPTH      TEMPERATURE    SALINITY       SIGMA-T      DELTA-D
          METERS        DEG C         PPT                        DYN M
            0.          5.17        31.210         24.70        0.
            1.0         5.17        31.210         24.70        0.003
            5.0         5.17        31.212         24.70        0.016
           10.0         4.74        31.315         24.83        0.032
           15.0         4.58        31.402         24.91        0.048
           20.0         4.50        31.472         24.97        0.063
           25.0         4.47        31.512         25.01        0.078
           30.0         4.44        31.543         25.04        0.093
           35.0         4.43        31.552         25.04        0.107
           40.0         4.42        31.568         25.06        0.122
           45.0         4.43        31.597         25.08        0.136
           50.0         4.44        31.642         25.11        0.151
           60.0         4.50        31.747         25.19        0.179
           70.0         4.58        31.807         25.23        0.207
           75.0         4.59        31.829         25.25        0.221
           80.0         4.68        31.896         25.29        0.234
           90.0         4.76        31.925         25.31        0.261
          100.0         4.83        32.000         25.36        0.288
          125.0         5.01        32.193         25.49        0.352
          150.0         5.10        32.311         25.58        0.414
          175.0         5.17        32.389         25.63        0.473
          200.0         5.21        32.422         25.65        0.533
          250.0         5.43        32.604         25.77        0.648
```



CRUISE 260 STATION 21

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  22.   RES25B     23/ 4/78
--------------------------                              14.2 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  20.6W   SONIC DEPTH =  285 M


  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (7) ---7/8              .
  VISIBILITY --- (6) ---4-10 KM
---------------------------------------------------------------------
I           DIRECTION        SPEED                                  I
I WIND    175 - 184 DEGR    9 KNOTS                                 I
---------------------------------------------------------------------
I           DIRECTION       HEIGHT      PERIOD                      I
I SEA     175 - 184 DEGR  0.2 M.          SECS                      I
I SWELL       -      DEGR     M.          SECS                      I
---------------------------------------------------------------------
I TEMPERATURES -DRY =     5.0 DEGR C.   BAROMETRIC PR. =1014.2 MB   I
I              -WET =         DEGR C.   TRANSPARENCY    =        M  I
---------------------------------------------------------------------


         DEPTH      TEMPERATURE   SALINITY      SIGMA-T      DELTA-D
         METERS        DEG C        PPT                       DYN M
           0.          5.70       31.032        24.50        0.
           1.0         5.70       31.032        24.50        0.003
           5.0         5.73       31.191        24.62        0.017
          10.0         5.19       31.320        24.78        0.033
          15.0         4.76       31.378        24.87        0.049
          20.0         4.41       31.428        24.95        0.064
          25.0         4.51       31.495        24.99        0.079
          30.0         4.50       31.496        24.99        0.094
          35.0         4.40       31.572        25.06        0.109
          40.0         4.39       31.586        25.08        0.123
          45.0         4.38       31.603        25.09        0.138
          50.0         4.41       31.639        25.12        0.152
          60.0         4.48       31.734        25.18        0.180
          70.0         4.58       31.894        25.30        0.208
          75.0         4.72       31.938        25.32        0.222
          80.0         4.78       31.955        25.33        0.235
          90.0         4.84       32.019        25.37        0.261
         100.0         4.92       32.107        25.43        0.287
         125.0         5.05       32.231        25.52        0.351
         150.0         5.11       32.347        25.60        0.412
         175.0         5.18       32.412        25.65        0.472
         200.0         5.20       32.437        25.66        0.531
         250.0         5.32       32.549        25.74        0.648
```



CRUISE 260 STATION 22

AC CRUISE 260 CONSECUTIVE STATION NO. 23. RES002 23/ 4/78
15.2 HOURS GMT

LATITUDE = 60 3.5N LONGITUDE = 149 23.4W SONIC DEPTH = 193 M

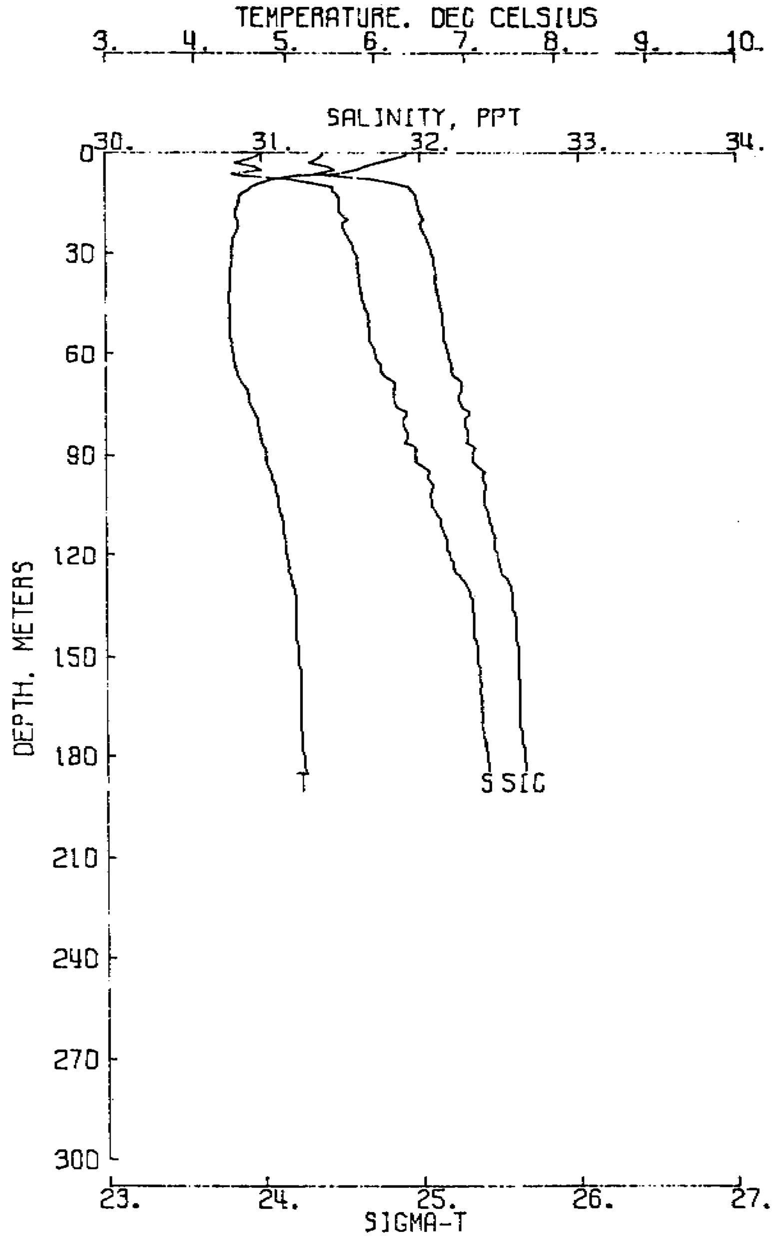
1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (6) ---STRATOCUMULUS .
CLOUD AMOUNT --- (6) ---6/8 .
VISIBILITY --- (7) ---10-20 KM

	DIRECTION	SPEED
WIND	175 - 184 DEGR	10 KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	175 - 184 DEGR	0.3 M.	SECS
SWELL	- DEGR	M.	SECS

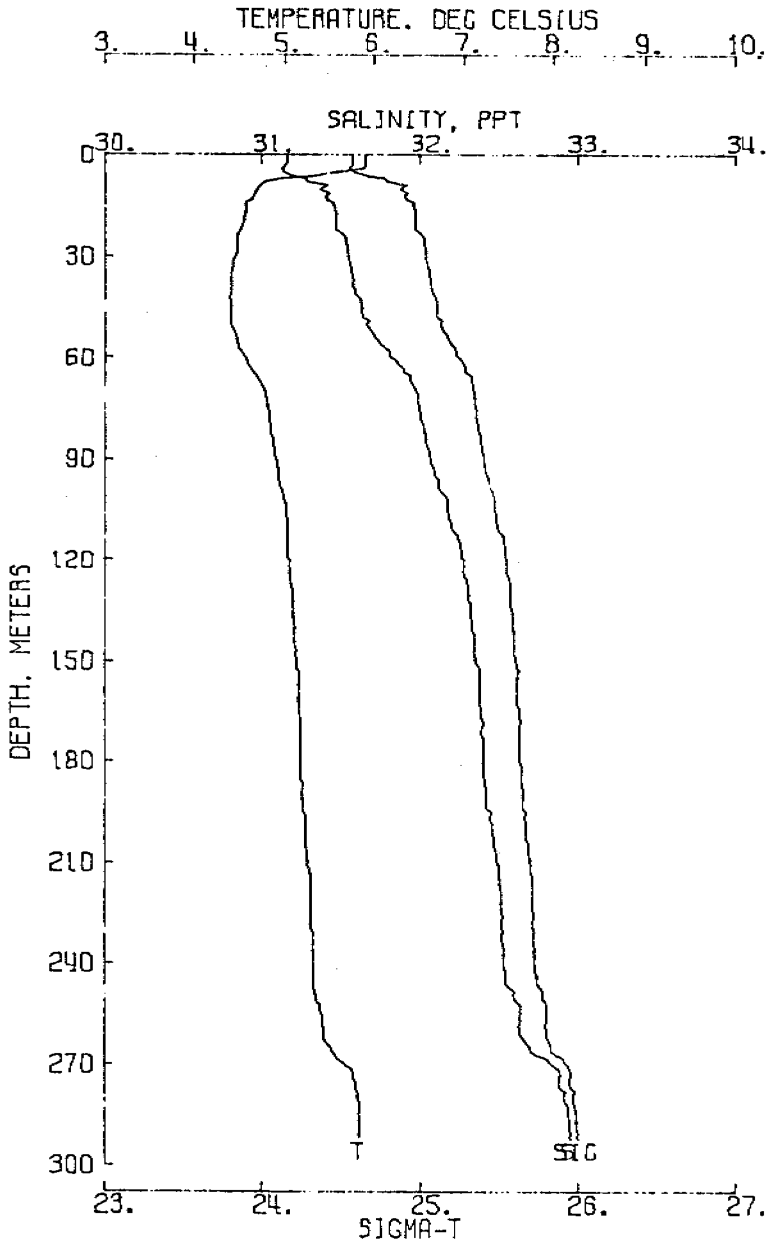
TEMPERATURES -DRY = 5.6 DEGR C. BAROMETRIC PR. =1014.5 MB
-WET = DEGR C. TRANSPARENCY = M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	6.33	30.979	24.38	0.
1.0	6.33	30.979	24.38	0.004
5.0	5.80	30.996	24.46	0.018
10.0	4.63	31.443	24.94	0.035
15.0	4.48	31.478	24.98	0.050
20.0	4.47	31.538	25.03	0.065
25.0	4.43	31.535	25.03	0.079
30.0	4.40	31.586	25.07	0.094
35.0	4.39	31.603	25.09	0.109
40.0	4.38	31.614	25.10	0.123
45.0	4.37	31.645	25.12	0.137
50.0	4.38	31.674	25.15	0.152
60.0	4.42	31.719	25.18	0.180
70.0	4.56	31.834	25.25	0.208
75.0	4.61	31.843	25.26	0.221
80.0	4.69	31.886	25.28	0.235
90.0	4.79	31.964	25.33	0.262
100.0	4.89	32.073	25.41	0.288
125.0	5.03	32.224	25.51	0.352
150.0	5.13	32.360	25.61	0.412
175.0	5.17	32.402	25.64	0.472



CRUISE 260 STATION 23

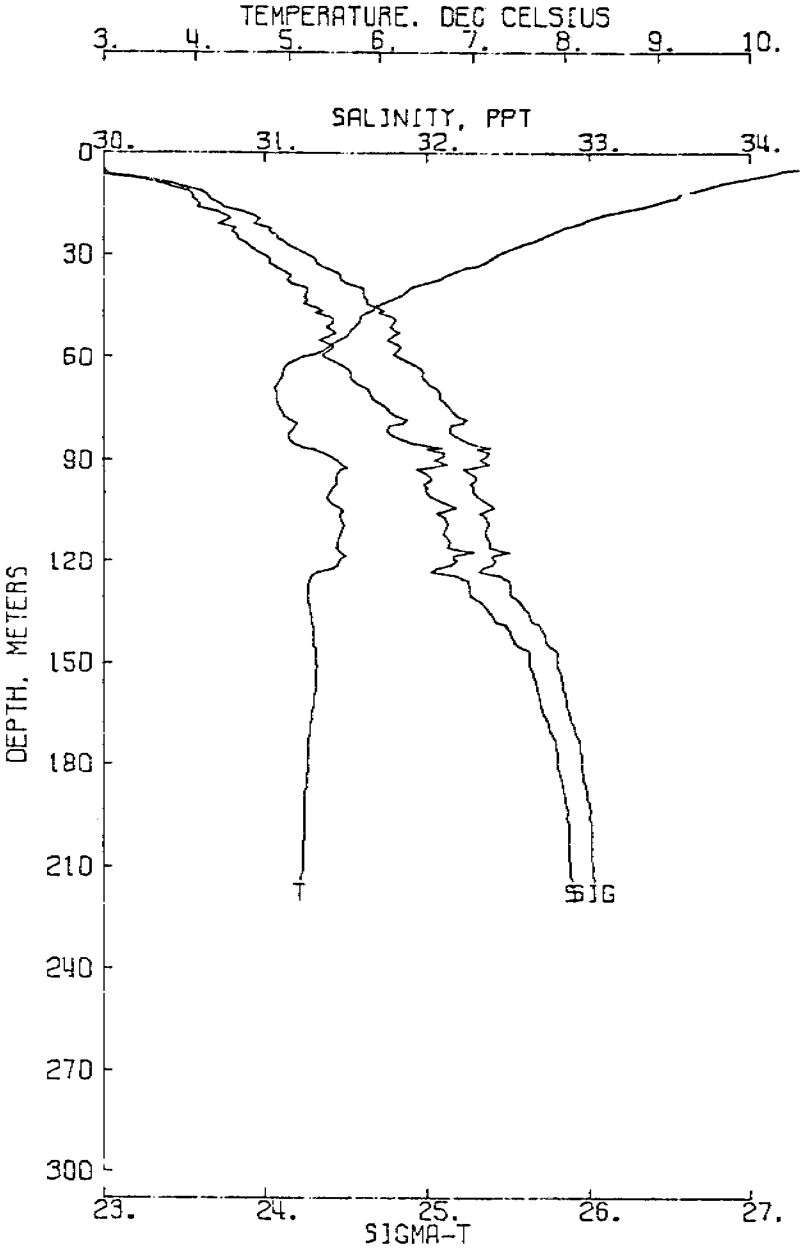
```
AC   CRUISE 260 CONSECUTIVE STATION NO.  24.    RES025     24/ 4/78
--------------------------                                 7.5 HOURS GMT

  LATITUDE = 61   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  291 M


  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (6) ---4-10 KM
------------------------------------------------------------------------
I            DIRECTION          SPEED                                   I
I WIND     175 - 184 DEGR     5 KNOTS                                   I
------------------------------------------------------------------------
I            DIRECTION         HEIGHT      PERIOD                       I
I SEA         0 -    0 DEGR       M.          SECS                      I
I SWELL.        -      DEGR       M.          SECS                      I
------------------------------------------------------------------------
I TEMPERATURES -DRY =      5.6 DEGR C.   BAROMETRIC PR. =1015.2 MB     I
I              -WET =          DEGR C.   TRANSPARENCY   =        M     I
------------------------------------------------------------------------


          DEPTH       TEMPERATURE    SALINITY      SIGMA-T       DELTA-D
          METERS        DEG C          PPT                        DYN M
            0.           5.90        31.164        24.58         0.
            1.0          5.90        31.164        24.58         0.003
            5.0          5.58        31.134        24.59         0.017
           10.0          4.70        31.367        24.87         0.033
           15.0          4.56        31.464        24.96         0.048
           20.0          4.52        31.472        24.97         0.063
           25.0          4.47        31.531        25.02         0.078
           30.0          4.43        31.544        25.04         0.093
           35.0          4.40        31.566        25.06         0.107
           40.0          4.40        31.586        25.07         0.122
           45.0          4.40        31.627        25.11         0.136
           50.0          4.41        31.661        25.13         0.151
           60.0          4.56        31.819        25.24         0.179
           70.0          4.78        31.979        25.35         0.206
           75.0          4.82        31.996        25.36         0.219
           80.0          4.84        32.015        25.37         0.232
           90.0          4.90        32.070        25.41         0.258
          100.0          4.97        32.146        25.46         0.284
          125.0          5.05        32.288        25.56         0.346
          150.0          5.13        32.365        25.61         0.407
          175.0          5.17        32.403        25.64         0.466
          200.0          5.23        32.464        25.68         0.525
          250.0          5.35        32.600        25.78         0.640
```



CRUISE 260 STATION 24

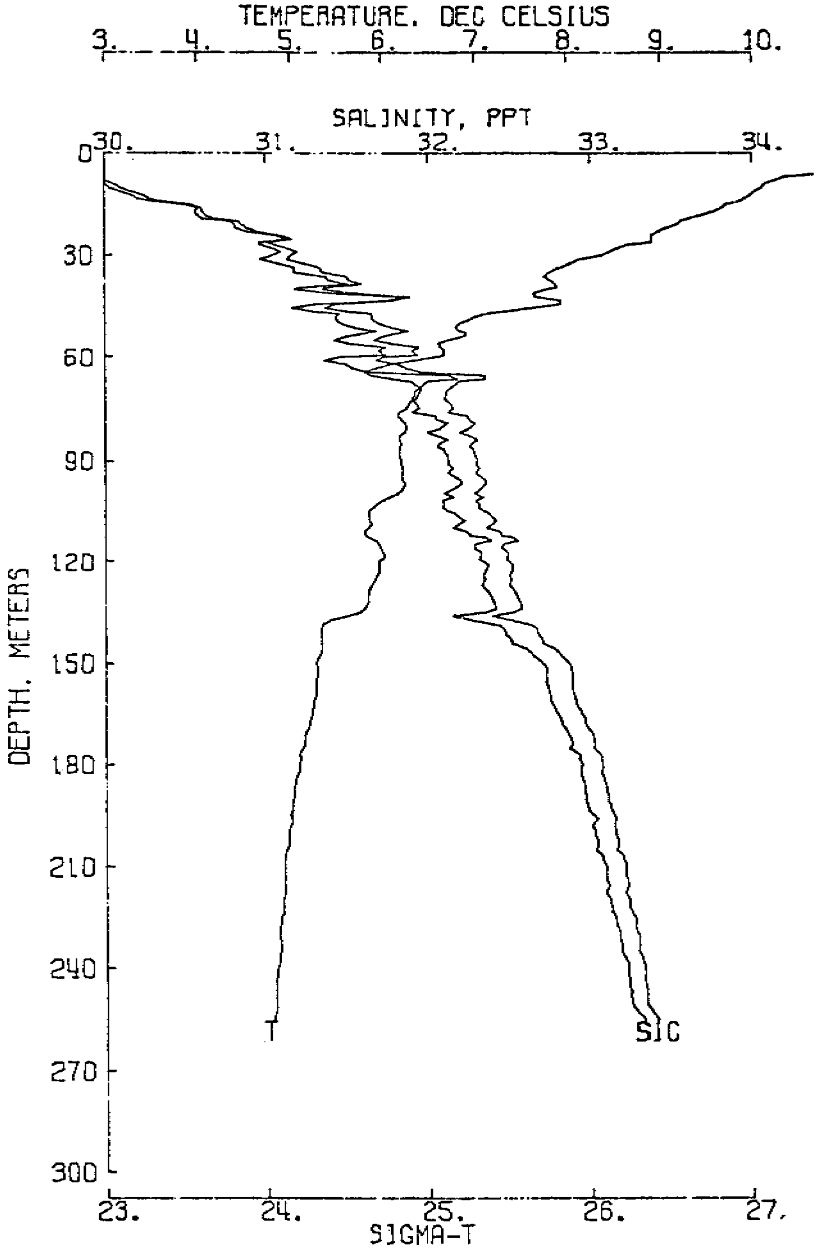
```
AC    CRUISE 262 CONSECUTIVE STATION NO.   2.   RES2.0      11/ 7/78
---------------------------                                  17.7 HOURS GMT

 LATITUDE = 60    3.5N   LONGITUDE = 149  23.4W   SONIC DEPTH =  223 M

 1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
 CLOUD TYPE --- ( ) ---NOT RECORDED        .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED,
 VISIBILITY --- (6) ---4-10 KM
----------------------------------------------------------------------
I           DIRECTION          SPEED                                 I
I WIND     175 - 184 DEGR    10 KNOTS                                I
----------------------------------------------------------------------
I           DIRECTION        HEIGHT      PERIOD                      I
I SEA      175 - 184 DEGR   0.2 M.          SECS                     I
I SWELL        -      DEGR      M.          SECS                     I
----------------------------------------------------------------------
I TEMPERATURES -DRY =  11.1 DEGR C.   BAROMETRIC PR. =1012.8 MB      I
I              -WET =       DEGR C.   TRANSPARENCY   =        M      I
----------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	11.42	28.379	21.60	0.
1.0	11.42	28.379	21.60	0.006
5.0	10.38	29.752	22.84	0.030
10.0	9.57	30.421	23.49	0.053
15.0	8.97	30.600	23.73	0.074
20.0	8.24	30.758	23.96	0.095
25.0	7.74	30.829	24.08	0.114
30.0	7.28	30.993	24.27	0.133
35.0	6.83	31.124	24.43	0.151
40.0	6.33	31.266	24.61	0.168
45.0	5.94	31.304	24.68	0.185
50.0	5.76	31.414	24.79	0.201
60.0	5.15	31.362	24.82	0.233
70.0	4.87	31.649	25.08	0.263
75.0	4.91	31.755	25.16	0.277
80.0	5.09	31.774	25.15	0.291
90.0	5.52	32.052	25.32	0.319
100.0	5.43	32.002	25.29	0.346
125.0	5.23	32.217	25.49	0.411
150.0	5.30	32.634	25.81	0.470
175.0	5.21	32.800	25.95	0.524
200.0	5.16	32.877	26.02	0.576



CRUISE 262 STATION 2

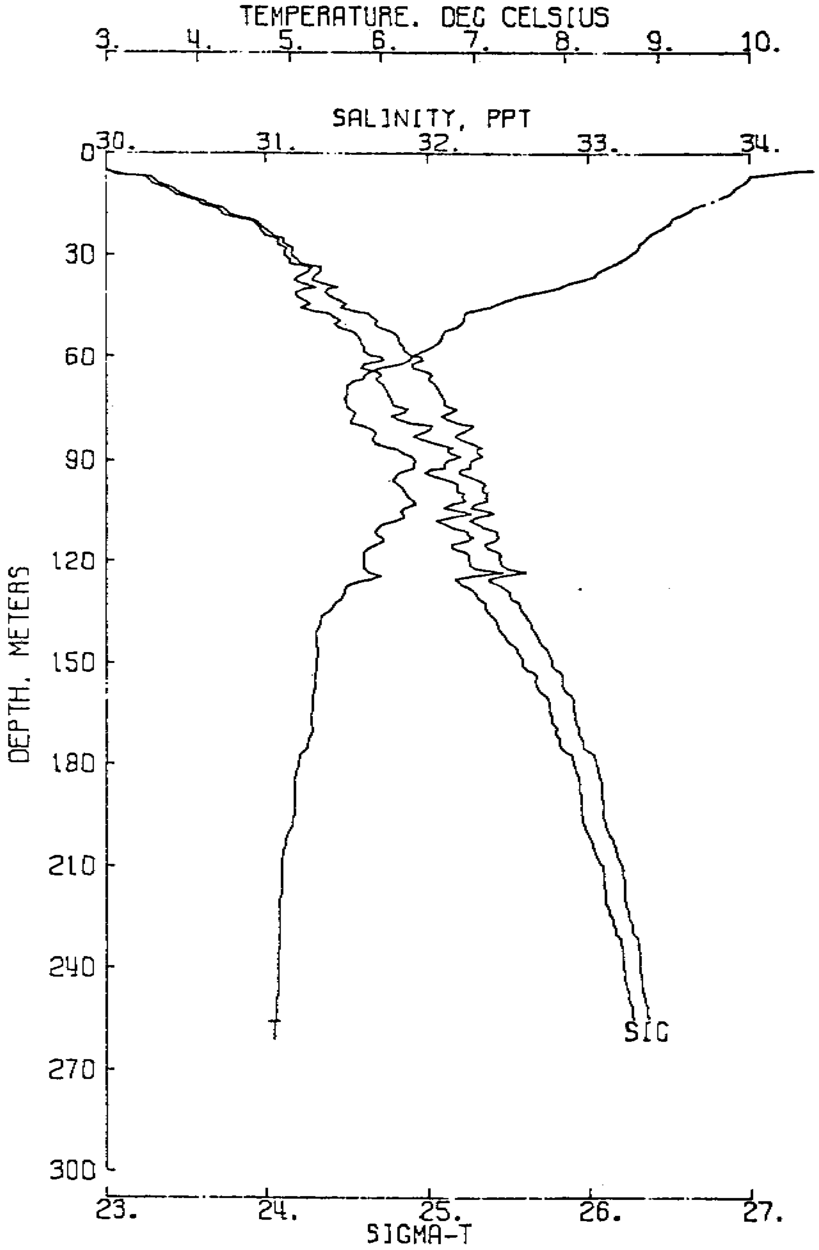
```
AC   CRUISE 262 CONSECUTIVE STATION NO.    4.     RES 5      11/ 7/78
---------------------------                                 20.5 HOURS GMT

 LATITUDE = 59  50.7N   LONGITUDE = 149  27.9W   SONIC DEPTH =  264 M


 1-DIGIT WEATHER CODE IS (X5) AND INDICATES DRIZZLE
 CLOUD TYPE --- ( ) ---NOT RECORDED        .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- (5) ---2-4 KM
------------------------------------------------------------------------
I          DIRECTION          SPEED                                    I
I WIND         -       DEGR      KNOTS                                 I
------------------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD                        I
I SEA      175 - 184 DEGR  1.0 M.           SECS                       I
I SWELL        -       DEGR      M.           SECS                       I
------------------------------------------------------------------------
I TEMPERATURES -DRY =   11.1 DEGR C.   BAROMETRIC PR. =1011.9 MB   I
I                -WET =        DEGR C.   TRANSPARENCY    =         M   I
------------------------------------------------------------------------


        DEPTH       TEMPERATURE    SALINITY      SIGMA-T       DELTA-D
        METERS        DEG C          PPT                        DYN M
          0.          12.05         25.955        19.62        0.
          1.0         12.05         25.955        19.62        0.008
          5.0         10.96         29.473        22.53        0.033
         10.0         10.11         30.039        23.11        0.058
         15.0          9.72         30.507        23.54        0.081
         20.0          9.22         30.782        23.83        0.102
         25.0          8.92         31.142        24.16        0.122
         30.0          8.38         31.028        24.15        0.141
         35.0          7.81         31.176        24.35        0.160
         40.0          7.79         31.176        24.35        0.177
         45.0          7.65         31.162        24.36        0.194
         50.0          6.82         31.468        24.71        0.211
         60.0          6.63         31.459        24.72        0.243
         70.0          6.41         31.904        25.10        0.272
         75.0          6.27         31.945        25.15        0.286
         80.0          6.27         32.105        25.28        0.300
         90.0          6.20         32.122        25.30        0.328
        100.0          6.16         32.097        25.28        0.354
        125.0          5.92         32.346        25.51        0.419
        150.0          5.28         32.707        25.87        0.479
        175.0          5.12         32.872        26.02        0.531
        200.0          4.97         33.024        26.15        0.580
        250.0          4.83         33.245        26.34        0.670
```



CRUISE 262 STATION 4

```
AC   CRUISE 262 CONSECUTIVE STATION NO.   5.    RES 4     11/ 7/78
---------------------------                                21.8 HOURS GMT

 LATITUDE = 59  54.7N   LONGITUDE = 149  24.0W   SONIC DEPTH =  257 M


 1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
 CLOUD TYPE --- ( ) ---NOT RECORDED       .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- (5) ---2-4 KM
-------------------------------------------------------------
I          DIRECTION          SPEED                         I
I WIND         -       DEGR      KNOTS                      I
-------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD              I
I SEA      175 - 184 DEGR  1.0 M.         SECS              I
I SWELL        -     DEGR      M.         SECS              I
-------------------------------------------------------------
I TEMPERATURES -DRY =  11.1 DEGR C.   BAROMETRIC PR. =1011.2 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------
```

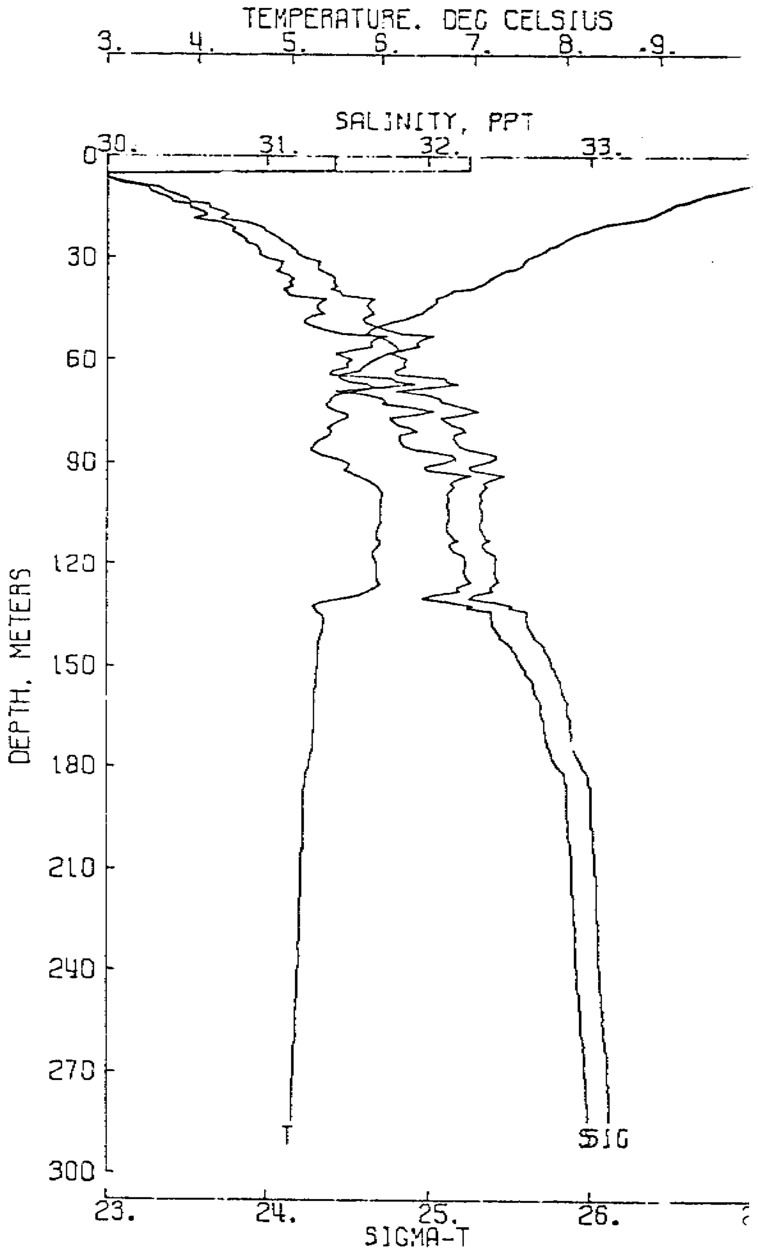
DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	11.85	26.536	20.11	0.
1.0	11.85	26.536	20.11	0.008
5.0	10.50	29.792	22.86	0.033
10.0	9.86	30.380	23.42	0.056
15.0	9.52	30.591	23.64	0.078
20.0	9.16	30.916	23.94	0.099
25.0	8.90	31.084	24.12	0.118
30.0	8.71	31.110	24.16	0.137
35.0	8.36	31.260	24.33	0.156
40.0	7.92	31.241	24.38	0.174
45.0	7.17	31.215	24.46	0.191
50.0	6.87	31.422	24.66	0.208
60.0	6.31	31.708	24.96	0.240
70.0	5.61	31.750	25.07	0.270
75.0	5.64	31.879	25.17	0.284
80.0	5.78	32.028	25.27	0.298
90.0	6.37	32.115	25.27	0.325
100.0	6.26	32.218	25.37	0.353
125.0	5.87	32.163	25.37	0.418
150.0	5.30	32.589	25.77	0.478
175.0	5.18	32.830	25.98	0.531
200.0	4.98	32.991	26.13	0.580
250.0	4.85	33.265	26.36	0.670



CRUISE 262 STATION 5

```
AC   CRUISE 262 CONSECUTIVE STATION NO.   6.    RES 3     11/ 7/78
---------------------------                                  23.0 HOURS GMT

 LATITUDE = 59  59.0N   LONGITUDE = 149  20.5W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (4) ---1-2 KM
-----------------------------------------------------------------
I           DIRECTION         SPEED                              I
I WIND      175 - 184 DEGR     7 KNOTS                           I
-----------------------------------------------------------------
I           DIRECTION        HEIGHT      PERIOD                  I
I SEA       175 - 184 DEGR  0.2 M.          SECS                 I
I SWELL          -     DEGR     M.          SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  11.1 DEGR C.   BAROMETRIC PR. =1010.0 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M   I
-----------------------------------------------------------------
```

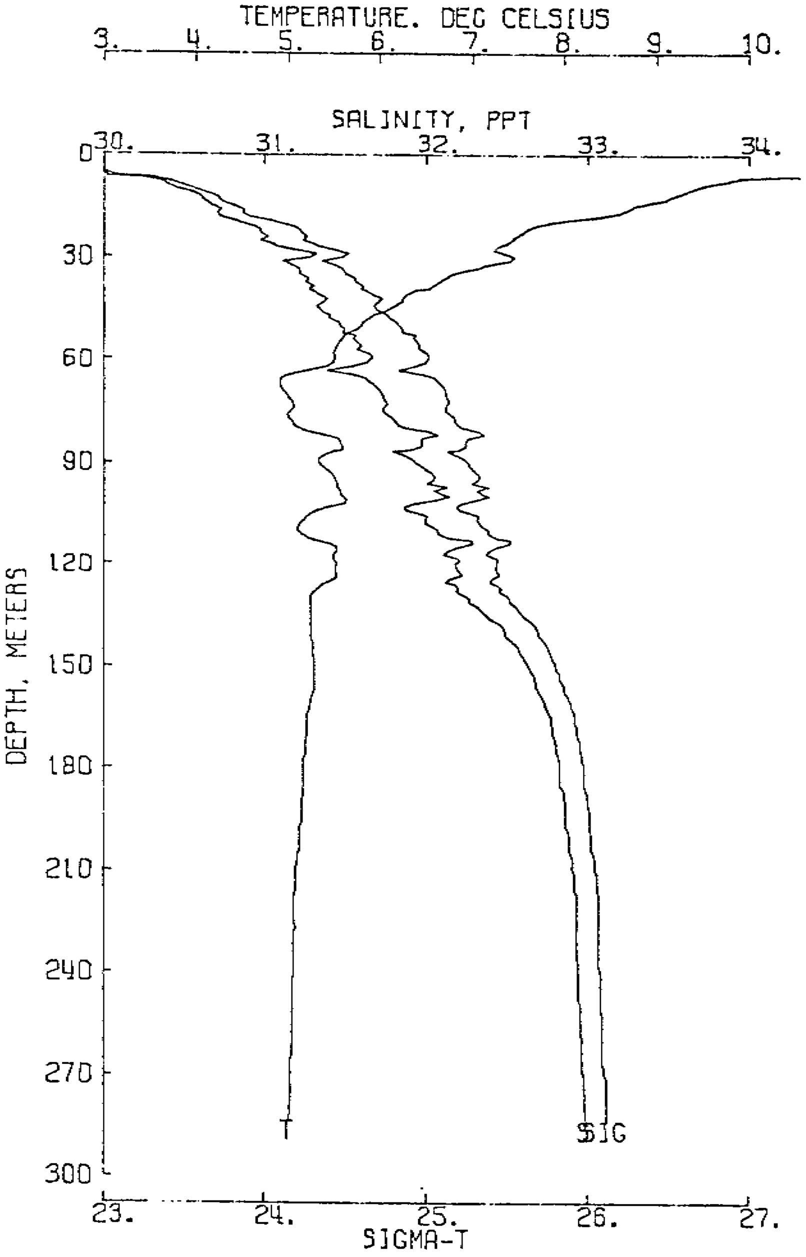
DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	12.50	32.261	24.41	0.
1.0	12.50	32.261	24.41	0.004
5.0	12.18	26.712	20.18	0.020
10.0	9.69	30.272	23.36	0.046
15.0	9.11	30.522	23.64	0.068
20.0	8.43	30.747	23.92	0.088
25.0	7.94	30.871	24.09	0.108
30.0	7.56	31.002	24.24	0.127
35.0	7.24	31.115	24.37	0.145
40.0	6.77	31.115	24.44	0.163
45.0	6.46	31.314	24.63	0.180
50.0	5.95	31.288	24.67	0.196
60.0	5.89	31.522	24.86	0.228
70.0	5.47	31.612	24.98	0.258
75.0	5.50	32.026	25.31	0.272
80.0	5.40	31.875	25.20	0.286
90.0	5.62	32.078	25.33	0.314
100.0	5.97	32.110	25.32	0.341
125.0	5.93	32.252	25.43	0.407
150.0	5.28	32.580	25.77	0.468
175.0	5.23	32.748	25.91	0.522
200.0	5.13	32.871	26.02	0.573
250.0	5.06	32.939	26.08	0.674



CRUISE 262 STATION

```
AC   CRUISE 262 CONSECUTIVE STATION NO.   7.   RES2.5     12/ 7/78
---------------------------                              0.2 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  287 M

  1-DIGIT WEATHER CODE IS (X() AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED          .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (5) ---2-4 KM
-------------------------------------------------------------------
I           DIRECTION           SPEED                               I
I WIND          -       DEGR      KNOTS                             I
-------------------------------------------------------------------
I           DIRECTION         HEIGHT     PERIOD                     I
I SEA          0 -   0 DEGR      M.         SECS                    I
I SWELL         -      DEGR      M.         SECS                    I
-------------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1009.7 MB   I
I              -WET =       DEGR C.   TRANSPARENCY   =         M   I
-------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	12.52	25.315	19.04	0.
1.0	12.52	25.315	19.04	0.009
5.0	11.52	28.545	21.72	0.040
10.0	9.36	30.472	23.57	0.064
15.0	8.76	30.672	23.81	0.085
20.0	7.88	30.847	24.08	0.105
25.0	7.44	30.971	24.23	0.124
30.0	7.45	31.288	24.48	0.141
35.0	6.79	31.214	24.51	0.159
40.0	6.38	31.295	24.63	0.176
45.0	6.09	31.338	24.69	0.192
50.0	5.80	31.471	24.83	0.208
60.0	5.51	31.654	25.01	0.239
70.0	4.99	31.721	25.12	0.268
75.0	5.02	31.723	25.12	0.282
80.0	5.11	31.864	25.22	0.297
90.0	5.34	31.937	25.25	0.324
100.0	5.60	32.140	25.38	0.351
125.0	5.44	32.123	25.39	0.417
150.0	5.30	32.639	25.81	0.476
175.0	5.19	32.815	25.96	0.529
200.0	5.13	32.890	26.03	0.581
250.0	5.05	32.956	26.09	0.680



CRUISE 262 STATION 7

APPENDIX II

Data List

Resurrection Bay

December 1977-October 1978

```
AC   CRUISE 254 CONSECUTIVE STATION NO.    9,   RES  2     29/11/77
--------------------------                                  11.1 HOURS GMT

   LATITUDE = 60   3.5N   LONGITUDE = 149  23.4W   SONIC DEPTH =  168 M

   1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
   CLOUD TYPE --- ( ) ---NOT RECORDED         ,
   CLOUD AMOUNT --- ( ) ---NOT RECORDED,
   VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I         DIRECTION         SPEED                                I
I WIND    345 - 354 DEGR    20 KNOTS                             I
-----------------------------------------------------------------
I         DIRECTION       HEIGHT      PERIOD                     I
I SEA     345 - 354 DEGR  1.0 M.         SECS                    I
I SWELL       -     DEGR     M.          SECS                    I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  -1.1 DEGR C.   BAROMETRIC PR. = 991.8 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M   I
-----------------------------------------------------------------

                                   OBSERVED

  TIME   DEP    TEMP    SAL     SIG-T     OXY   PO4    NH3   NO2   NO3    NO    SIO3   PH    T ALK
  11.2     0   6.52A  30.631   24.09     6.77  0.93   00.3  0.19  08.4  680.0   19     .      .
  11.2    10   6.56A    .        .       6.84  0.93   00.3  0.19  08.4  686.3   19     .      .
  11.2    20   6.62A  30.647   24.09     6.62  0.86   01.1  0.22  08.7  669.3   19     .      .
  11.2    30   7.13A  30.773   24.12     6.47  0.95   00.9  0.21  09.2  660.4   19     .      .
  11.2    50   8.99A  31.450   24.39     6.17  1.15   00.5  0.18  10.7  647.2   22     .      .
  11.2    75   8.403  31.681   24.66     5.82  1.33   00.6  0.17  14.9  653.7   32     .      .
  11.2   100   8.33C  31.861   24.80     5.67  1.28   00.4  0.11  13.9  631.3   27     .      .
  11.2   150   6.97A  32.371   25.40     5.17  1.65   00.5  0.10  19.9  640.7   36     .      .
  11.2   160   6.89A  32.421   25.45     5.40  1.68   00.5  0.11  20.8  669.3   37     .      .
                                   STANDARD

         DEP    TEMP    SAL     SIG-T     OXY       SP VOL    DEL D
           0   6.52   30.631   24.09     6.77      384.12     .000
          10   6.56   30.600   24.06     6.84      387.01     .039
          20   6.62   30.647   24.09     6.62      384.23     .077
          30   7.13   30.773   24.12     6.47      381.07     .115
          50   8.99   31.450   24.39     6.17      356.05     .189
          75   8.40   31.681   24.66     5.82      330.70     .275
         100   8.38   31.861   24.80     5.67      317.36     .356
         150   6.97   32.371   25.40     5.17      260.94     .500
```

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  11,   RES25B    29/11/7[illegible]
---------------------------                              16.5 HOURS GMT

   LATITUDE = 60   1.2N   LONGITUDE = 149  20.6W   SONIC DEPTH =  275 M

   1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
   CLOUD TYPE --- ( ) ---NOT RECORDED        .
   CLOUD AMOUNT --- ( ) ---NOT RECORDED,
   VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I          DIRECTION        SPEED                                     I
I WIND    335 - 344 DEGR   25 KNOTS                                   I
-----------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                      I
I SEA        5 -  14 DEGR   1.0 M.          SECS                      I
I SWELL        -     DEGR       M.          SECS                      I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =   -1.7 DEGR C.   BAROMETRIC PR. = 996.2 MB      I
I              -WET =        DEGR C.   TRANSPARENCY   =       M       I
-----------------------------------------------------------------------

                                  OBSERVED

 TIME   DEP     TEMP    SAL     SIG-T     OXY   PO4   NH3   NO2   NO3    NO   SIO3   PH   T ALK
 16.5     0    6.81A  30.678   24.09     6.53  0.93  00.5  0.13  08.4  658.6   19    .      .
 16.5    10    6.89A  30.682   24.08     6.77  0.95  00.5  0.13  08.7  682.7   19    .      .
 16.5    20    7.12A  30.730   24.09     6.48  0.96  00.5  0.13  08.7  656.8   19    .      .
 16.5    30    7.75B  30.946   24.17     6.32  1.02  00.5  0.14  09.2  647.0   20    .      .
 16.5    50    8.38B  31.384   24.43     6.05  1.20  00.6  0.12  11.0  639.1   23    .      .
 16.5    75    8.52A  31.662   24.62     6.31  1.19  00.7  0.11  12.7  677.7   25    .      .
 16.5   100    8.09B  31.951   24.91     5.62  1.34  00.4  0.09  15.6  642.2   28    .      .
 16.5   150    7.01A  32.370   25.39     5.27  1.65  00.3  0.10  19.8  648.7   36    .      .
 16.5   200    6.12A  32.779   25.83     4.76  1.90  00.4  0.08  24.0  641.0   45    .      .
 16.5   250    5.46C  33.114   26.17     3.96  2.19  00.4  0.09  29.5  619.0   53    .      .
 16.5   265    5.42D  33.130   26.19     1.30  2.23  00.4  0.09  29.7  383.4   57    .      .

                                  STANDARD

        DEP     TEMP    SAL     SIG-T     OXY        SP VOL    DEL D
          0     6.81  30.678   24.09     6.53       384.03     .000
         10     6.89  30.682   24.08     6.77       384.77     .038
         20     7.12  30.730   24.09     6.48       384.08     .077
         30     7.75  30.946   24.17     6.32       376.08     .115
         50     8.38  31.384   24.43     6.05       352.21     .188
         75     8.52  31.662   24.62     6.31       333.82     .273
        100     8.09  31.951   24.91     5.62       306.59     .353
        150     7.01  32.370   25.39     5.27       261.53     .495
        200     6.12  32.779   25.83     4.76       220.48     .616
        250     5.46  33.114   26.17     3.96       188.23     .718
```

```
LATITUDE = 60   1.2N   LONGITUDE = 149  23.0W   SONIC DEPTH =  278 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- ( ) ---NOT RECORDED        .
CLOUD AMOUNT --- ( ) ---NOT RECORDED,
VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------
I            DIRECTION          SPEED                        I
I WIND        5 -  14 DEGR    18 KNOTS                       I
--------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD           I
I SEA         5 -  14 DEGR    1.0 M.          SECS           I
I SWELL         -     DEGR        M.          SECS           I
--------------------------------------------------------------
I TEMPERATURES -DRY =   -1.7 DEGR C.   BAROMETRIC PR. = 993.0 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =       M   I
--------------------------------------------------------------

                                 OBSERVED

 TIME    DEP    TEMP    SAL     SIG-T    OXY   PO4    NH3   NO2   NO3    NO    SIO3   PH   T ALK
 13.3      0   6.62A  30.630   24.07   6.72  0.93   00.4  0.16  08.5  676.5   22     .      .
 13.3     10   6.66A  30.635   24.07   6.65  0.92   00.4  0.14  08.3  668.4   20     .      .
 13.3     20   6.67A  30.635   24.07   6.70  0.89   00.4  0.14  08.2  672.0   19     .      .
 13.3     30   6.80A  30.668   24.08   6.40  1.04   00.4  0.24  08.4  647.0   20     .      .
 13.3     50   8.94B  31.387   24.35   5.88  1.14   00.5  0.10  10.8  622.2   22     .      .
 13.3     75   8.42A  31.746   24.70   6.18  1.24   00.5  0.13  13.1  669.7   23     .      .
 13.3    100   8.22C  31.884   24.84   5.73  1.31   00.4  0.09  13.9  636.7   24     .      .
 13.3    150   6.88B  32.414   25.44   5.40  1.64   00.5  0.09  20.1  663.0   36     .      .
 13.3    200   6.25C  32.729   25.77   4.88  1.85   00.5  0.09  24.0  651.7   45     .      .
 13.3    250   5.46B  33.101   26.16   4.05  2.18   00.4  0.09  29.3  625.3   53     .      .
 13.3    270   5.41C  33.142   26.20   3.72  2.25   00.4  0.08  29.9  601.2   58     .      .

                                 STANDARD

         DEP    TEMP    SAL     SIG-T    OXY        SP VOL    DEL D
           0    6.62  30.630   24.07   6.72       385.37     .000
          10    6.66  30.635   24.07   6.65       385.54     .039
          20    6.67  30.635   24.07   6.70       385.72     .077
          30    6.80  30.668   24.08   6.40       384.88     .116
          50    8.94  31.387   24.35   5.88       360.00     .190
          75    8.42  31.746   24.70   6.18       326.15     .276
         100    8.22  31.884   24.84   5.73       313.39     .356
         150    6.88  32.414   25.44   5.40       256.58     .498
         200    6.25  32.729   25.77   4.88       225.80     .619
         250    5.46  33.101   26.16   4.05       189.20     .723
```

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  11,    RES25B      29/11/77
--------------------------                                    16.5 HOURS GMT

LATITUDE = 60   1.2N   LONGITUDE = 149  20.6W   SONIC DEPTH =  275 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- ( ) ---NOT RECORDED        .
CLOUD AMOUNT --- ( ) ---NOT RECORDED,
VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------
I            DIRECTION          SPEED                        I
I WIND      335 - 344 DEGR    25 KNOTS                       I
--------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD           I
I SEA         5 -  14 DEGR    1.0 M.          SECS           I
I SWELL         -     DEGR        M.          SECS           I
--------------------------------------------------------------
```

```
AC       SE 254 CONSECUTIVE STATION NO.  14,   RES 35     29/11/
-------------------------                                   24.0 HOURS GMT

  LATITUDE = 59  57.9N   LONGITUDE = 149  20.7W   SONIC DEPTH =  193 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS            ,
  CLOUD AMOUNT --- (6) ---6/8          .
  VISIBILITY --- (8) ---20-50 KM
---------------------------------------------------------------------
I           DIRECTION          SPEED                                I
I WIND        0 -    0 DEGR    20 KNOTS                             I
---------------------------------------------------------------------
I           DIRECTION          HEIGHT      PERIOD                   I
I SEA         0 -    0 DEGR   1.0 M.         SECS                   I
I SWELL         -      DEGR       M.         SECS                   I
---------------------------------------------------------------------
I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. =1002.1 MB   I
I              -WET =        DEGR C.   TRANSPARENCY   =        M   I
---------------------------------------------------------------------

                              OBSERVED

 TIME   DEP    TEMP    SAL     SIG-T    OXY   PO4    NH3   NO2   NO3    NO   SIO3   PH   T ALK
 24.0     0   6.64A  30.720   24.14    6.68  0.91   00.3  0.12  08.6  673.8   19    .      .
 24.0    10   6.65B  30.641   24.08    6.61  0.90   00.4  0.13  08.5  666.6   19    .      .
 24.0    20   6.66A  30.644   24.08    6.69  0.91   00.4  0.13  08.5  673.8   19    .      .
 24.0    30   6.73A  30.661   24.08    6.62  0.89   00.4  0.12  08.5  667.5   20    .      .
 24.0    50   7.38A  31.156   24.39    6.76  1.00   00.4  0.09  10.2  695.3   22    .      .
 24.0    75   8.62A  31.578   24.54    5.89  1.11   00.4  0.08  11.7  631.2   23    .      .
 24.0   100   8.23C  31.909   24.86    5.69  1.29   00.4  0.08  14.8  641.2   27    .      .
 24.0   150   7.44A  32.372   25.33    5.65  1.46   00.4  0.08  18.0  666.4   32    .      .
 24.0   185   6.27A  32.696   25.74    5.33  1.80   00.4  0.08  23.7  689.2   48    .      .
                              STANDARD

        DEP    TEMP    SAL     SIG-T    OXY        SP VOL     DEL D
          0    6.64  30.720   24.14    6.68       378.86      .000
         10    6.65  30.641   24.08    6.61       384.97      .038
         20    6.66  30.644   24.08    6.69       384.93      .077
         30    6.73  30.661   24.08    6.62       384.56      .115
         50    7.38  31.156   24.39    6.76       355.78      .189
         75    8.62  31.578   24.54    5.89       341.49      .276
        100    8.23  31.909   24.86    5.69       311.67      .358
        150    7.44  32.372   25.33    5.65       267.04      .503
```

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  15,   RES  4     30/11/77
-------------------------                                    1.4 HOURS GMT

  LATITUDE = 59  54.7N   LONGITUDE = 149  24.5W   SONIC DEPTH =  255 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (3) ---ALTOCUMULUS            ,
  CLOUD AMOUNT --- (7) ---7/8          .
  VISIBILITY --- (7) ---10-20 KM
---------------------------------------------------------------------
I           DIRECTION          SPEED                                I
I WIND      355 -    4 DEGR    25 KNOTS                             I
---------------------------------------------------------------------
```

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  15.   RES  4     30/11/77
-------------------------                                    1.4 HOURS GMT

   LATITUDE = 59  54.7N   LONGITUDE = 149  24.5W   SONIC DEPTH =  255 M

   1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
   CLOUD TYPE --- (3) ---ALTOCUMULUS
   CLOUD AMOUNT --- (7) ---7/8
   VISIBILITY --- (7) ---10-20 KM
 ----------------------------------------------------------------
 I          DIRECTION           SPEED                              I
 I WIND     355 -   4 DEGR     25 KNOTS                            I
 ----------------------------------------------------------------
 I          DIRECTION        HEIGHT       PERIOD                   I
 I SEA      355 -   4 DEGR   1.0 M.         SECS                   I
 I SWELL        -     DEGR      M.          SECS                   I
 ----------------------------------------------------------------
 I TEMPERATURES -DRY =   -1.1 DEGR C.   BAROMETRIC PR. =1003.2 MB  I
 I              -WET =        DEGR C.   TRANSPARENCY    =       M  I
 ----------------------------------------------------------------

                                      OBSERVED

   TIME    DEP     TEMP     SAL     SIG-T     OXY   PO4    NH3    NO2    NO3    NO     SIO3   PH    T ALK
   1.4       0    6.67A   30.679   24.10     6.64  0.89   00.5   0.12   08.7   671.1   19     .       .
   1.4      10    6.69B   30.701   24.12     6.61  0.90   00.4   0.11   08.5   666.6   19     .       .
   1.4      20    6.72A   30.722   24.13     6.67  0.91   00.5   0.11   08.6   672.9   19     .       .
   1.4      30    6.86A   30.792   24.17     6.68  0.88   00.5   0.11   08.7   674.7   19     .       .
   1.4      50    6.98A      .        .      6.44  0.91   00.4   0.11   08.9   655.1   19     .       .
   1.4      75    7.37B   31.104   24.35     6.39  1.11   00.4   0.12   10.1   661.4   23     .       .
   1.4     100    7.94C   31.850   24.85     5.96  1.29   00.4   0.09   14.1   659.0   35     .       .
   1.4     150    7.28A   32.406   25.38     5.60  1.57   00.4   0.09   18.9   670.1   39     .       .
   1.4     200    6.54A   32.615   25.64     5.12  1.80   00.5   0.10   22.5   659.6   44     .       .
   1.4     245    5.68B   32.998   26.05     4.23  2.12   00.4   0.11   28.0   629.7   58     .       .

                                      STANDARD

           DEP     TEMP     SAL     SIG-T     OXY         SP VOL     DEL D
             0    6.67    30.679   24.11     6.64        382.29      .000
            10    6.69    30.701   24.12     6.61        380.94      .038
            20    6.72    30.722   24.13     6.67        379.80      .076
            30    6.86    30.792   24.17     6.68        376.32      .114
            50    6.98    30.849   24.20     6.44        373.68      .189
            75    7.37    31.104   24.35     6.39        359.78      .281
           100    7.94    31.850   24.85     5.96        312.03      .365
           150    7.28    32.406   25.38     5.60        262.38      .508
           200    6.54    32.615   25.64     5.12        237.89      .633
           250    5.57    33.041   26.10     4.13        195.03      .741
```

```
AC   (  SE 254 CONSECUTIVE STATION NO.  17,   RES 25        1/12/
-------------------------                                    7.6 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (3) ---ALTOCUMULUS          ,
  CLOUD AMOUNT --- (1) ---1/8 OR LESS ,
  VISIBILITY --- (8) ---20-50 KM
--------------------------------------------------------------------
I          DIRECTION         SPEED                                  I
I WIND     325 - 334 DEGR    35 KNOTS                               I
--------------------------------------------------------------------
I          DIRECTION         HEIGHT        PERIOD                   I
I SEA      325 - 334 DEGR    2.0 M.          SECS                   I
I SWELL        -     DEGR       M.           SECS                   I
--------------------------------------------------------------------
I TEMPERATURES -DRY =   -3.3 DEGR C.   BAROMETRIC PR. =1014.8 MB    I
I              -WET =        DEGR C.   TRANSPARENCY   =        M    I
--------------------------------------------------------------------

                                   OBSERVED

 TIME   DEP     TEMP     SAL     SIG-T      OXY   PO4    NH3    NO2    NO3    NO    SIO3    PH   T ALK
  7.6    10    7.78A   31.100   24.29      6.34  1.01   00.5   0.11   10.3  658.7    24     .      .
  7.6    30    7.84A   31.119   24.30      6.47  1.00   00.5   0.10   10.4  671.2    24     .      .
  7.6    70    8.45A   31.641   24.62      5.81  1.19   00.5   0.09   12.8  633.9    27     .      .
  7.6   110    7.85B   32.126   25.08      5.73  1.31   00.5   0.09   15.8  653.8    31     .      .
  7.6   130    7.52B      .        .       5.85  1.50   00.4   0.08   18.2  686.1    33     .      .
  7.6   150    6.99A   32.379   25.40      5.17  1.63   00.6   0.08   20.5  646.1    37     .      .
  7.6   170    6.75C   32.489   25.52      5.14  1.69   00.6   0.09   21.7  654.2    39     .      .
  7.6   190    6.41A   32.636   25.68      4.92  1.78   00.6   0.08   23.2  648.1    43     .      .
  7.6   210    6.07A   32.807   25.85      4.85  1.92   00.5   0.09   25.2  659.8    47     .      .
  7.6   230    5.66C   32.986   26.04      4.26  2.17   00.7   0.10   28.0  632.3    52     .      .
  7.6   250    5.44A   33.121   26.18      3.97  2.19   00.5   0.09   29.5  619.9    56     .      .
  7.6   260    5.41B   33.147   26.20      3.86  2.26   00.3   0.08   29.9  613.7    58     .      .
  7.6   270T   5.41B   33.224   26.26      3.62  2.26   00.5   0.10   29.8  591.4    58     .      .
  7.6   280    5.41A   33.172   26.22      3.72  2.34   00.5   0.10   30.3  604.8    58     .      .
                                   STANDARD

        DEP     TEMP     SAL     SIG-T      OXY         SP VOL      DEL D
          0      .00       .  0      .         .             .          .
         10     7.78   31.100    24.29      6.34        364.78          .
         20     7.69   30.989    24.22      6.44        371.99          .
         30     7.94   31.119    24.30      6.47        364.36          .
         50     8.18   31.342    24.42      6.18        352.56          .
         75     8.41   31.709    24.68      5.77        328.76          .
        100     8.06   32.017    24.97      5.75        301.24          .
        150     6.99   32.379    25.40      5.17        260.60          .
        200     6.24   32.720    25.76      4.91        226.44          .
        250     5.44   33.121    26.18      3.97        187.48          .
```

```
AC   CRUISE 254 CONSECUTIVE STATION NO.  20,     A  I       2/12/77
-------------------------                                    1.3 HOURS GMT

  LATITUDE = 59  53.7N   LONGITUDE = 149  41.4W   SONIC DEPTH =  193 M

  1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
  CLOUD TYPE --- ( ) ---NOT RECORDED          ,
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (8) ---20-50 KM
--------------------------------------------------------------------
I          DIRECTION         SPEED                                  I
I WIND     335 - 344 DEGR    18 KNOTS                               I
--------------------------------------------------------------------
I          DIRECTION         HEIGHT        PERIOD                   I
I SEA      335 - 344 DEGR    0.6 M.          SECS                   I
```

```
AC     ISE 254 CONSECUTIVE STATION NO.  20.     A  I        2/12/
-----------------------------                              1.3 HOURS GMT

  LATITUDE = 59  53.7N   LONGITUDE = 149  41.4W   SONIC DEPTH =  193 M

  1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
  CLOUD TYPE --- ( ) ---NOT RECORDED        ,
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (8) ---20-50 KM
-----------------------------------------------------------------------
I             DIRECTION          SPEED                                I
I WIND        335 - 344 DEGR     18 KNOTS                             I
-----------------------------------------------------------------------
I             DIRECTION         HEIGHT       PERIOD                   I
I SEA         335 - 344 DEGR    0.6 M.            SECS                I
I SWELL           -     DEGR       M.             SECS                I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    0.  DEGR C.   BAROMETRIC PR. =1010.5 MB      I
I              -WET =        DEGR C.   TRANSPARENCY    =        M     I
-----------------------------------------------------------------------

                                    OBSERVED

   TIME   DEP    TEMP     SAL     SIG-T     OXY   PO4    NH3   NO2    NO3    NO    SIO3    PH    T ALK
    1.3     0   6.90C   30.233   23.73     6.77  0.94   00.5  0.13   09.0  685.4    20      .       .
    1.3    10   6.93A   30.233   23.72     6.38  0.92   00.4  0.12   09.1  651.5    20      .       .
    1.3    20   6.97A   30.261   23.74     6.58  0.92   00.5  0.12   09.1  669.4    20      .       .
    1.3    30   7.01B   30.283   23.75     6.30  0.93   00.4  0.12   09.1  644.4    20      .       .
    1.3    50   7.19A   30.499   23.90     6.30  1.01   00.4  0.12   10.1  653.4    20      .       .
    1.3    75   4.47A   31.177   24.74     4.75  1.68   00.5  0.11   22.0  622.1    30      .       .
    1.3   100   3.78C   31.419   25.00     4.18  1.85   00.5  0.11   25.2  600.0    39      .       .
    1.3   150   3.52A   31.506   25.09     3.98  2.02   01.0  0.13   27.2  600.1    46      .       .
    1.3   185   3.46A   31.539   25.12     3.61  1.97   00.5  0.12   26.4  559.9    46      .       .

                                    STANDARD

          DEP    TEMP     SAL     SIG-T     OXY        SP VOL     DEL D
            0    6.90   30.233   23.73     6.77       418.46      .000
           10    6.93   30.233   23.72     6.38       418.89      .042
           20    6.97   30.261   23.74     6.58       417.34      .084
           30    7.01   30.283   23.75     6.30       416.26      .125
           50    7.19   30.499   23.90     6.30       402.48      .207
           75    4.47   31.177   24.74     4.75       321.70      .298
          100    3.78   31.419   25.00     4.18       297.19      .375
          150    3.52   31.506   25.09     3.98       288.50      .521
```

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  17.   RES005     23/ 4/78
--------------------------                                   9.1 HOURS GMT

  LATITUDE = 59  50.7N   LONGITUDE = 149  28.0W   SONIC DEPTH =  267 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED           .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I            DIRECTION           SPEED                                 I
I WIND       165 - 174 DEGR       5 KNOTS                              I
-----------------------------------------------------------------------
I            DIRECTION         HEIGHT       PERIOD                     I
I SEA        165 - 174 DEGR    0.3 M.          SECS                    I
I SWELL          -     DEGR        M.          SECS                    I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =     6.7 DEGR C.   BAROMETRIC PR. =1013.5MB   I
I              -WET =         DEGR C.   TRANSPARENCY   =        M   I
-----------------------------------------------------------------------

                                  OBSERVED

 TIME    DEP      TEMP     SAL     SIG-T     OXY     PO4     NH3   NO2    NO3    NO        SIO3   PH    TALK
  9.1      0      5.76A  31.333   24.73    11.34    0.04      .   0.09   00.4  1016.0      2.     .       .
  9.1     10      4.48A  31.274   24.82     8.58    0.80      .   0.26   08.6   843.4     17.     .       .
  9.1     20      4.44Q  31.425   24.94     8.90    0.38      .   0.08   00.7   800.9      4.     .       .
  9.1     30      4.47A  31.476   24.98     8.03    1.01      .   0.28   10.2   808.7     18.     .       .
  9.1     50      4.42A  31.651   25.12     7.96    1.18      .   0.23   14.1   837.6     26.     .       .
  9.1     75      4.61A  31.901   25.30     7.14    1.42      .   0.25   17.3   793.2     30.     .       .
  9.1    100      4.73A  32.049   25.41     7.29    1.38      .   0.23   17.3   806.6     30.     .       .
  9.1    150      5.12B  32.346   25.60     7.09    1.33      .   0.23   17.1   786.9     29.     .       .
  9.1    200T     5.28A  32.456   25.67     7.41    1.34      .   0.23   16.9   813.7     28.     .       .
  9.1    250T     5.27B  32.542   25.74     7.14    1.33      .   0.23   17.2   792.3     29.     .       .

                                  STANDARD

         DEP      TEMP     SAL     SIG-T     OXY          SP VOL   DEL D
           0      5.76   31.333   24.73    11.34         322.84     .000
          10      4.48   31.274   24.82     8.58         314.27     .032
          20      4.44   31.425   24.94     8.90         302.53     .063
          30      4.47   31.476   24.98     8.03         299.01     .093
          50      4.42   31.651   25.12     7.96         285.42     .151
          75      4.61   31.901   25.30     7.14         268.57     .220
         100      4.73   32.049   25.41     7.29         258.78     .286
         150      5.12   32.346   25.60     7.09         240.93     .411
         200      5.28   32.456   25.67     7.41         234.87     .530
         250      5.27   32.542   25.74     7.14         228.81     .646
```

```
AC   CRUISE 260 CONSECUTIVF STATION NO.  18.   RES004     23/ 4/78
------------------------                                   10.7 HOURS GMT

  LATITUDE = 59  54.7N   LONGITUDE = 149  24.5W   SONIC DEPTH =  263 M

  1-DIGTT WEATHER CODE IS (X1) AND INDICATFS PARTLY CLOUDY
  CLOUD TYPF --- ( ) ---NOT PECORDED         .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I          DIRECTION          SPEED                              I
I WIND     165 - 174 DEGR      5 KNOTS                           I
-----------------------------------------------------------------
I          DIRECTION        HEIGHT       PERIOD                  I
I SEA      165 - 174 DEGR  0.3 M.           SECS                 I
I SWELL        -     DEGR      M.           SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =    6.1 DEGR C.   BAROMETRIC PR. =1013.8MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =       M  I
-----------------------------------------------------------------

                                    OBSERVED

TIME    DEP    TEMP    SAL    SIG-T    OXY   PO4    NH3  NO2   NO3   NO      SIO3  PH   TALK
10.7      0   5.43A  31.200  24.66   10.06  0.34    .   0.24  03.6  930.6   10.     .      .
10.7     10   4.48A  31.457  24.96    8.43  0.78    .   0.24  08.8  831.8   16.     .      .
10.7     20   4.39A  31.561  25.06    7.61  1.08    .   0.24  12.9  795.5   23.     .      .
10.7     30   4.38A  31.562  25.06    7.76  1.07    .   0.25  13.2  811.6   24.     .      .
10.7     50   4.38A  31.667  25.14    7.89  1.67    .   0.35  16.0  848.4   28.     .      .
10.7     75   4.71A  31.908  25.30    7.19  1.34    .   0.15  17.3  797.6   30.     .      .
10.7    100   4.87A  32.095  25.43    7.27  1.38    .   0.16  18.0  811.1   31.     .      .
10.7    150   5.16A  32.392  25.63    7.04  1.27    .   0.10  14.0  754.5   28.     .      .
10.7    200T  5.26B  32.508  25.71    7.21  1.31    .   0.14  17.0  796.7   29.     .      .
10.7    250T  5.24F  32.578  25.77    6.77  1.24    .   0.17  14.3  733.1   26.     .      .

                                    STANDARD

        DEP    TEMP    SAL    SIG-T    OXY        SP VOL   DEL D
          0    5.43  31.200  24.66   10.06       329.29    .000
         10    4.48  31.457  24.96    8.43       300.47    .031
         20    4.39  31.561  25.06    7.61       291.81    .061
         30    4.38  31.562  25.06    7.76       291.67    .090
         50    4.38  31.667  25.14    7.89       283.84    .148
         75    4.71  31.908  25.30    7.19       269.04    .217
        100    4.87  32.095  25.43    7.27       256.76    .283
        150    5.16  32.392  25.63    7.04       237.91    .406
        200    5.26  32.508  25.71    7.21       230.76    .523
        250    5.24  32.578  25.77    6.77       225.78    .638
```

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  20.   RES003     23/ 4/78
--------------------------                                  12.6 HOURS GMT

  LATITUDE = 59  59.0N   LONGITUDE = 149  20.5W   SONIC DEPTH =  292 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED          .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I            DIRECTION          SPEED                            I
I WIND       175 - 184 DEGR      5 KNOTS                         I
-----------------------------------------------------------------
I            DIRECTION        HEIGHT      PERIOD                 I
I SEA           0 -   0 DEGR      M.          SECS               I
I SWELL           -     DEGR      M.          SECS               I
-----------------------------------------------------------------
I TEMPERATURES -DRY =    5.6 DEGR C.   BAROMETRIC PR. =1014.0MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =       M  I
-----------------------------------------------------------------

                                   OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T    OXY    PO4    NH3  NO2   NO3    NO      SIO3  PH   TALK
 12.6      0    5.67A   31.355   24.76   11.41   0.00    .   0.08  05.0  1063.7     1.    .      .
 12.6     10    5.10B   31.394   24.85   10.66   0.09    .   0.06  02.0   969.7     1.    .      .
 12.6     20    4.65B   31.451   24.94    8.70   0.70    .   0.19  75.0  1451.7    17.    .      .
 12.6     30    4.42A   31.502   25.01    8.02   0.75    .   0.12  92.0  1544.0    21.    .      .
 12.6     50    4.39A   31.647   25.12    7.60   1.25    .   0.25  15.7   819.8    28.    .      .
 12.6     75    4.60A   31.831   25.25    7.32   1.35    .   0.16  17.0   806.5    30.    .      .
 12.6    100    4.85A   32.049   25.39    7.10   1.46    .   0.13  17.7   793.2    32.    .      .
 12.6    150    5.300   32.277   25.53    6.96   1.57    .   0.16  18.6   788.8    33.    .      .
 12.6    200T   5.17A   32.381   25.62    6.83   1.46    .   0.09  18.6   777.2    32.    .      .
 12.6    250T   5.59B   32.701   25.83    5.01   2.04    .   0.09  25.0   672.3    43.    .      .
 12.6    280T   5.79A   32.916   25.97    3.45   2.50    .   0.08  28.0   560.0    52.    .      .

                                   STANDARD

         DEP     TEMP     SAL     SIG-T    OXY        SP VOL   DEL D
           0    5.67    31.355   24.76   11.41      320.21     .000
          10    5.10    31.394   24.85   10.66      311.32     .032
          20    4.65    31.451   24.94    8.70      302.59     .062
          30    4.42    31.502   25.01    8.02      296.57     .092
          50    4.39    31.647   25.12    7.60      285.44     .150
          75    4.60    31.831   25.25    7.32      273.74     .220
         100    4.85    32.049   25.39    7.10      260.01     .287
         150    5.30    32.277   25.53    6.96      248.05     .414
         200    5.17    32.381   25.62    6.83      239.27     .536
         250    5.59    32.701   25.83    5.01      220.58     .651
```

```
AC   CRUISE 260 CONSECUTIVE STATION NO.  23.   RES002     23/ 4/78
--------------------------                                  15.2 HOURS GMT

  LATITUDE = 60   3.5N   LONGITUDE = 149  23.4W   SONIC DEPTH =  193 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (6) ---6/8            .
  VISIBILITY --- (7) ---10-20 KM
------------------------------------------------------------------
I          DIRECTION          SPEED                              I
I WIND     175 - 184 DEGR    10 KNOTS                            I
------------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                   I
I SEA      175 - 184 DEGR  0.3 M.          SECS                  I
I SWELL        -     DEGR      M.          SECS                  I
------------------------------------------------------------------
I TEMPERATURES -DRY =    5.6 DEGR C.   BAROMETRIC PR. =1014.5MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M I
------------------------------------------------------------------

                                  OBSERVED

 TIME    DEP      TEMP     SAL     SIG-T     OXY    PO4     NH3  NO2     NO3     NO          SIO3   PH     TALK
 15.2      0      5.08Q  30.971   24.52    11.57   0.00     .   0.07    00.3  1035.7         1.     .         .
 15.2     10      4.50A  31.464   24.97     8.25   0.98     .   0.20    10.9   834.7        23.     .         .
 15.2     20      4.49A  31.487   24.99     8.07   1.09     .   0.20    12.2   830.3        24.     .         .
 15.2     30      4.39B  31.567   25.06     7.68   1.27     .   0.22    14.7   818.0        27.     .         .
 15.2     50      4.39A  31.649   25.13     7.52   1.41     .   0.29    14.8   804.6        31.     .         .
 15.2     75      4.64B  31.835   25.25     7.28   1.45     .   0.17    17.0   803.0        30.     .         .
 15.2    100      4.93Q  32.037   25.38     7.08   1.57     .   0.11    17.4   788.7        30.     .         .
 15.2    150      5.14A      .        .     6.76   1.62     .   0.10    19.3   777.2        33.     .         .
 15.2    180T     5.20B  32.343   25.59     6.65   1.62     .   0.11    19.2   766.5        33.     .         .

                                  STANDARD

         DEP      TEMP     SAL     SIG-T     OXY          SP VOL   DEL D
           0      5.08   30.971   24.52    11.57          342.92     .000
          10      4.50   31.464   24.97     8.25          300.13     .032
          20      4.49   31.487   24.99     8.07          298.34     .062
          30      4.39   31.567   25.06     7.68          291.39     .092
          50      4.39   31.649   25.13     7.52          285.29     .149
          75      4.64   31.835   25.25     7.28          273.83     .219
         100      4.93   32.037   25.38     7.08          261.74     .286
         150      5.14   32.289   25.55     6.76          245.41     .413
```

```
AC   CRUISE 260 CONSECUTIVF STATION NO.  24.   RES025     24/ 4/78
--------------------------                                   7.5 HOURS GMT

  LATITUDE = 60    1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  291 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATFS RAIN
  CLOUD TYPF --- ( ) ---NOT RECORDED       .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------------
I           DIRECTION          SPEED                                  I
I WIND      175 - 184 DEGR      5 KNOTS                               I
-----------------------------------------------------------------------
I           DIRECTION          HEIGHT        PERIOD                   I
I SEA          0 -    0 DEGR      M.            SECS                  I
I SWELL          -      DEGR      M.            SECS                  I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =     5.6 DEGR C.   BAROMETRIC PR. =1015.2MB   I
I              -WET =         DEGR C.   TRANSPARENCY    =        M   I
-----------------------------------------------------------------------

                                 OBSERVED

 TIME    DEP      TEMP     SAL     SIG-T     OXY    PO4      NH3   NO2    NO3    NO        SIO3  PH     TALK
   .0      0     5.67B   31.128   24.58    12.32   0.00       .   0.19   04.6 1141.3    14.      .        .
   .0     10     4.68A   31.412   24.91     9.05   0.52       .   0.19   13.8  932.2    26.      .        .
   .0     30     4.42A   31.524   25.02     7.79   1.12       .   0.18   17.6  853.9    31.      .        .
   .0     70     4.80A   31.953   25.32     7.05   1.37       .   0.18   18.0  791.4    32.      .        .
   .0    110     5.03A   32.231   25.52     6.92   1.44       .   0.21   18.7  786.1    32.      .        .
   .0    170     5.17A   32.419   25.65     6.88   1.51       .   0.22   18.6  781.6    32.      .        .
   .0    190     5.19A   32.443   25.67     6.82   1.46       .   0.13   11.4  711.5    23.      .        .
   .0    210     4.30Q   31.475   25.00     8.21   0.95       .   0.24   14.5  863.5    27.      .        .
   .0    230     4.59A   31.571   25.04     7.69   1.17       .   0.33   15.9  829.7    28.      .        .
   .0    250     5.01Q   31.653   25.06     7.59   1.40       .   0.24   16.4  825.2    29.      .        .
   .0    260     4.84B   31.697   25.12     7.28   1.32       .   0.22   17.2  804.8    30.      .        .
   .0    270     4.87A   31.857   25.24     7.13   1.37       .   0.25   17.7  795.9    31.      .        .
   .0    280     4.91A   31.935   25.30     7.43   1.40       .   0.19   17.8  823.6    31.      .        .
   .0    285     4.93C   32.034   25.37     7.00   1.39       .   0.30   16.8  776.2    28.      .        .

                                 STANDARD

         DEP      TEMP     SAL     SIG-T     OXY          SP VOL   DEL D
           0      5.67   31.128   24.58    12.32         337.27     .000
          10      4.68   31.412   24.91     9.05         305.78     .032
          20      4.55   31.502   24.99     7.94         297.80     .062
          30      4.42   31.524   25.02     7.79         294.92     .092
          50      4.54   31.731   25.17     7.23         280.61     .149
          75      4.84   31.995   25.35     7.01         263.76     .218
         100      4.98   32.174   25.48     6.92         252.00     .282
         150      5.14   32.381   25.63     6.89         238.54     .405
         200      4.73   31.955   25.33     7.54         266.53     .531
         250      5.01   31.653   25.06     7.59         292.48     .671
```

```
AC   CRUISE 262 CONSECUTIVE STATION NO.    4,     RES 5      11/ 7/78
-----------------------------                                   20.5 HOURS GMT

  LATITUDE = 59  50.7N   LONGITUDE = 149  27.9W   SONIC DEPTH =  264 M

  1-DIGIT WEATHER CODE IS (X5) AND INDICATES DRIZZLE
  CLOUD TYPE --- ( ) ---NOT RECORDED         .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (5) ---2-4 KM
-------------------------------------------------------------------
I          DIRECTION        SPEED                                 I
I WIND         -      DEGR      KNOTS                             I
-------------------------------------------------------------------
I          DIRECTION       HEIGHT      PERIOD                     I
I SEA      175 - 184 DEGR  1.0 M.         SECS                    I
I SWELL        -     DEGR      M.         SECS                    I
-------------------------------------------------------------------
I TEMPERATURES -DRY =  11.1 DEGR C.   BAROMETRIC PR. =1011.9MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =         M  I
-------------------------------------------------------------------

                                  OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T     OXY   PO4     NH3   NO2    NO3    NO       SIO3  PH    TALK
 17.7     0    11.38F   21.891   16.59     7.82  0.33   06.0  0.13   02.6   721.6    17.     .      .
 17.7    10     9.96F   30.178   23.24     7.24  0.53   02.9  0.11   00.7   652.7     9.     .      .
 17.7    20     9.73H   30.872   23.82     6.99  0.62   03.8  0.22   02.5   646.6    10.     .      .
 17.7    30     8.73D   31.224   24.25     7.08  0.77   03.7  0.31   04.3   670.8    12.     .      .
 17.7    50     7.20I   31.567   24.73     7.29  1.02   04.0  0.73   08.4   726.5    17.     .      .
 17.7    75     6.29B   32.005   25.20     6.33  1.13   03.5  0.35   10.9   663.2    19.     .      .
 17.7   100     5.90B   32.078   25.30     6.48  1.34   01.6  0.30   16.5   727.0    28.     .      .
 17.7   150     5.32A   32.746   25.90     5.80  1.74   01.3  0.11   22.5   720.3    36.     .      .
 17.7   200T    4.96A   33.058   26.18     5.73  1.95   01.1  0.13   26.6   751.0    36.     .      .
 17.7   250     4.82B   33.300   26.39     4.75  2.08   01.0  0.18   30.5   698.6    45.     .      .

                                  STANDARD

         DEP     TEMP     SAL     SIG-T     OXY       SP VOL   DEL D
          0     11.38   21.891   16.59     7.82      1103.69    .000
         10      9.96   30.178   23.24     7.24       464.62    .078
         20      9.73   30.872   23.82     6.99       409.67    .122
         30      8.73   31.224   24.25     7.08       368.83    .161
         50      7.20   31.567   24.73     7.29       322.78    .230
         75      6.29   32.005   25.20     6.33       279.07    .305
        100      5.90   32.078   25.30     6.48       269.27    .374
        150      5.32   32.746   25.89     5.80       213.15    .495
        200      4.96   33.058   26.18     5.73       186.29    .594
        250     10.66   22.515   17.19     7.68      1047.58    .903
```

```
AC   CRUISE 262 CONSECUTIVF STATION NO.   5.    RES 4     11/ 7/78
---------------------------------                           21.8 HOURS GMT

  LATITUDE = 59  54.7N   LONGITUDE = 149  24.0W   SONIC DEPTH =  257 M

  1-DIGIT WEATHER CODE IS (\6) AND INDICATFS RAIN
  CLOUD TYPF --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (5) ---2-4 KM
-----------------------------------------------------------------------
I            DIRECTION          SPEED                                 I
I WIND           -       DEGR      KNOTS                              I
-----------------------------------------------------------------------
I            DIRECTION        HEIGHT        PERIOD                    I
I SEA        175 - 184 DEGR  1.0 M.            SECS                   I
I SWELL          -     DEGR      M.            SECS                   I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =   11.1 DEGR C.   BAROMETRIC PR. =1011.2MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
-----------------------------------------------------------------------

                                   OBSERVED

TIME    DEP     TEMP    SAL     SIG-T    OXY   PO4    NH3   NO2   NO3    NO       SIO3  PH   TALK
20.5     0    11.82D  26.915   20.40    8.07  0.00   02.6  0.06  00.6   725.9     8.    .      .
20.5    10     9.69C  30.532   23.56    7.49  0.36   02.5  0.19  01.2   679.5     9.    .      .
20.5    20     9.02B  31.083   24.10    6.80  0.64   03.5  0.25  03.7   640.4    14.    .      .
20.5    30     8.48A  31.272   24.32    7.16  0.71   04.0  0.28  04.3   677.9    14.    .      .
20.5    50     6.65A  31.593   24.83    7.35  1.17   05.5  0.77  15.2   793.0    36.    .      .
20.5    75     5.66C  31.870   25.16    6.71  1.25   01.9  0.38  16.2   744.9    25.    .      .
20.5   100     6.38A  32.208   25.34    6.81  1.29     .   0.40  15.4   746.6    26.    .      .
20.5   150T    5.28A  32.651   25.82    5.81  1.66     .   0.10  21.9   715.8    36.    .      .
20.5   200     4.95A  33.041   26.17    5.74  1.80     .   0.09  26.2   748.3    41.    .      .
20.5   250     4.86E  33.279   26.37    4.58  2.00     .   0.15  29.7   676.2    48.    .      .

                                   STANDARD

        DEP     TEMP    SAL     SIG-T    OXY      SP VOL   DEL D
         0     11.82  26.915   20.40    8.07     736.60    .000
        10      9.69  30.532   23.56    7.49     434.19    .059
        20      9.02  31.083   24.10    6.80     383.39    .099
        30      8.48  31.272   24.32    7.16     361.72    .137
        50      6.65  31.593   24.83    7.35     314.00    .204
        75      5.66  31.870   25.16    6.71     281.94    .279
       100      6.38  32.208   25.34    6.81     265.21    .347
       150      5.28  32.651   25.82    5.81     219.82    .468
       200      4.95  33.041   26.17    5.74     187.46    .570
       250      4.86  33.279   26.37    4.58     169.16    .659
```

```
AC   CRUISE 262 CONSECUTIVE STATION NO.   6,    RES 3    11/ 7/78
---------------------------                                23.0 HOURS GMT

  LATITUDE = 59  59.0N   LONGITUDE = 149  20.5W   SONIC DEPTH =  289 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED        ,
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (4) ---1-2 KM
------------------------------------------------------------------
I           DIRECTION          SPEED                             I
I WIND      175 - 184 DEGR      7 KNOTS                          I
------------------------------------------------------------------
I           DIRECTION        HEIGHT       PERIOD                 I
I SEA       175 - 184 DEGR   0.2 M.          SECS                I
I SWELL         -     DEGR       M.          SECS                I
------------------------------------------------------------------
I TEMPERATURES -DRY =   11.1 DEGR C.    BAROMETRIC PR. =1010.0MB I
I              -WET =        DEGR C.    TRANSPARENCY   =       M I
------------------------------------------------------------------

                                  OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T    OXY    PO4     NH3   NO2    NO3    NO      SIO3   PH    TALK
 21.8     0    12.60C   23.984   18.00    7.49   0.00     .    0.04   00.3   671.4   12.     .       .
 21.8    10     9.53B   30.453   23.53    8.52   0.27     .    0.09   00.7   767.0    6.     .       .
 21.8    20     8.19Q   30.932   24.10    7.71   0.53     .    0.21   02.7   712.6    9.     .       .
 21.8    30     7.49A   31.110   24.34    7.55   0.67     .    0.32   04.0   710.1   11.     .       .
 21.8    50     5.87B   31.444   24.80     .     1.04     .    1.14   08.2           15.     .       .
 21.8    75     5.50B   31.862   25.18    5.78   1.43     .    0.35   13.9   641.1   26.     .       .
 21.8   100     5.94A   32.072   25.29    6.67   1.57     .    0.41   13.9   720.6   27.     .       .
 21.8   150T    5.27A   32.624   25.80    5.90   1.92     .    0.15   19.6   703.2   38.     .       .
 21.8   200T    5.12A   32.897   26.04    4.73   1.84     .    0.16   22.2   622.1   43.     .       .
 21.8   250     5.07D   32.964   26.10    5.57   1.49     .    0.35   20.5   681.8   35.     .       .

                                  STANDARD

         DEP     TEMP     SAL     SIG-T    OXY       SP VOL   DEL D
          0    12.60    23.984   18.00    7.49      967.41    .000
         10     9.53    30.453   23.53    8.52      437.65    .070
         20     8.19    30.932   24.10    7.71      382.93    .111
         30     7.49    31.110   24.34    7.55      360.44    .148
         50     5.87    31.444   24.80    7.01      316.05    .216
         75     5.50    31.862   25.18    5.78      280.78    .291
        100     5.94    32.072   25.29    6.67      270.18    .360
        150     5.27    32.624   25.80    5.90      221.73    .482
        200     5.12    32.897   26.04    4.73      200.10    .588
        250     5.07    32.964   26.09    5.15      195.02    .687
```

```
AC   CRUISE 262 CONSECUTIVE STATION NO.    7,   RES2.5     12/ 7/78
-----------------------------                                  0.2 HOURS GMT

  LATITUDE = 60   1.2N   LONGITUDE = 149  21.5W   SONIC DEPTH =  287 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED          .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED,
  VISIBILITY --- (5) ---2-4 KM
-------------------------------------------------------------------
I              DIRECTION           SPEED                          I
I WIND             -       DEGR       KNOTS                       I
-------------------------------------------------------------------
I              DIRECTION          HEIGHT        PERIOD            I
I SEA            0 -     0 DEGR      M.            SECS           I
I SWELL            -       DEGR      M.            SECS           I
-------------------------------------------------------------------
I TEMPERATURES -DRY =   12.2 DEGR C.   BAROMETRIC PR. =1009.7MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------------

                                       OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T     OXY    PO4     NH3    NO2     NO3     :O        SIO3   PH     TALK
 21.8     10    9.53B   30.453   23.53     8.52   0.27     .     0.00    00.7   767.0        6.    .       .
 23.0     10    9.14D   30.617   23.71     8.13   0.39     .     0.38    00.8   733.0        8.    .       .
 23.0     30    7.06B   31.281   24.53     7.53   0.80     .     0.12    05.4   720.9       13.    .       .
 23.0     70    5.05D   31.718   25.11     6.91   1.41     .     0.12    16.9   769.0       25.    .       .
 23.0    130    5.16I   32.076   25.38     6.78   1.51     .     0.12    18.1   768.2       29.    .       .
 23.0    170    5.20A   32.801   25.95     5.72   1.77     .     0.13    22.8   715.9       39.    .       .
 23.0    190    5.15C   32.871   26.01     5.66   1.82     .     0.46    23.4   715.9       40.    .       .
 23.0    210    5.09A   32.874   26.02     5.53   1.87     .     0.10    24.8   716.9       43.    .       .
 23.0    230    5.07A   32.948   26.08     5.56   1.92     .     0.10    25.6   726.8       44.    .       .
 23.0    250    5.06A   32.964   26.10     5.54   1.88     .     0.10    25.6   725.0       43.    .       .
 23.0    260T   5.04A   32.976   26.11     5.52   1.86     .     0.10    25.4   721.4       43.    .       .
 23.0    270    5.03A   32.995   26.12     5.46   1.91     .     0.10    26.1   722.4       42.    .       .

                                       STANDARD

          DEP     TEMP      SAL     SIG-T     OXY       SP VOL   DEL D
          280    5.02A   32.995    26.13     5.52     77   . 0    1.025
            0     .00        . 0     .         .           .
           10    9.14    30.617    23.71     8.13     419.69      .
           20    7.56    31.172    24.38     7.68     356.67      .
           30    7.06    31.281    24.53     7.53     342.20      .
           50    6.06    31.500    24.83     6.93     313.99      .
           75    5.06    31.748    25.13     6.90     284.65      .
          100    5.11    31.897    25.25     6.85     274.08      .
          150    5.18    32.439    25.67     6.25     234.64      .
          200    5.12    32.873    26.02     5.60     201.93      .
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.   5,   BQ. 15      17/10/78
-----------------------------                              16.7 HOURS GMT

   LATITUDE = 55   3.3N   LONGITUDE = 131   7.0W   SONIC DEPTH =  362 M

   1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
   CLOUD TYPE --- ( ) ---NOT RECORDED        .
   CLOUD AMOUNT --- ( ) ---NOT RECORDED,
   VISIBILITY --- (7) ---10-20 KM
--------------------------------------------------------------------
I         DIRECTION          SPEED                                 I
I WIND        -       DEGR      KNOTS                              I
--------------------------------------------------------------------
I         DIRECTION        HEIGHT      PERIOD                      I
I SEA     165 - 174 DEGR  0.7 M.          SECS                     I
I SWELL       -     DEGR      M.          SECS                     I
--------------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1018.5MB   I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
--------------------------------------------------------------------

                                   OBSERVED

 TIME   DEP    TEMP     SAL     SIG-T     OXY   PO4    NH3   NO2   NO3    NO       SIO3  PH   TALK
 11.5     0   10.190   26.103   20.04     6.39  0.84   00.8  0.58  08.8   649.7    20.    .     .
 11.5    10   10.50B   28.972   22.22     5.76  0.69   01.8  0.71  07.3   580.0    16.    .     .
 11.5    20   10.43B   29.592   22.71     5.74  0.94   01.3  0.74  09.7   599.8    20.    .     .
 11.5    30   10.73A   30.228   23.16     5.86  0.86   01.4  0.47  08.9   603.3    18.    .     .
 11.5    50   10.30A   31.474   24.20     4.97  0.71   01.0  0.00  09.8   531.9    15.    .     .
 11.5    75    9.49B   31.830   24.60     4.03  1.40   00.7  0.00  17.7   519.1    24.    .     .
 11.5   100    7.73A   32.360   25.28     3.42  1.76   00.5  0.00  22.8   510.5    31.    .     .
 11.5   150    6.38D   33.026   25.99     2.82  1.69   00.5  0.24  24.9   475.9    36.    .     .
 11.5   200T   6.32A   33.065   26.03     2.75  2.17   00.5  0.00  29.1   507.4    41.    .     .
 11.5   250T   6.29A   33.082   26.04     2.72  2.12   00.1  0.00  29.2   505.6    41.    .     .
 11.5   300T   6.26A   33.090   26.05     2.66  2.07   00.4  0.00  29.5   503.0    41.    .     .

                                   STANDARD

        DEP    TEMP     SAL     SIG-T     OXY          SP VOL   DEL D
          0   10.19    26.103   20.04     6.39         771.35    .000
         10   10.50    28.972   22.22     5.76         562.60    .067
         20   10.43    29.592   22.71     5.74         515.59    .121
         30   10.73    30.228   23.16     5.86         473.35    .170
         50   10.30    31.474   24.20     4.97         374.40    .255
         75    9.49    31.830   24.61     4.03         335.69    .344
        100    7.73    32.360   25.28     3.42         271.20    .419
        150    6.38    33.026   25.99     2.82         204.65    .538
        200    6.32    33.065   26.03     2.75         201.60    .640
        250    6.29    33.082   26.04     2.72         200.59    .740
        300    6.26    33.090   26.05     2.66         200.29    .841
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.   6,   BO   3     17/10/78
--------------------------                                 22.1 HOURS GMT

  LATITUDE = 55  18.3N   LONGITUDE = 130  30.8W   SONIC DEPTH =  155 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED         .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------------
I              DIRECTION          SPEED                                I
I WIND             -      DEGR       KNOTS                             I
-----------------------------------------------------------------------
I              DIRECTION        HEIGHT       PERIOD                    I
I SEA            0 -    0 DEGR       M.           SECS                 I
I SWELL            -      DEGR       M.           SECS                 I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =   11.1 DEGR C.   BAROMETRIC PR. =1017.9MB   I
:              -WET =        DEGR C.   TRANSPARENCY   =        M   I
-----------------------------------------------------------------------

                                OBSERVED

 TIME    DEP    TEMP     SAL     SIG-T    OXY   PO4    NH3   NO2   NO3    NO      SIO3  PH   TALK
 16.7      0    9.83I  20.725   15.92    6.65  0.53   00.5  0.00  07.6   662.1   17.    .     .
 16.7     10   10.45B  28.940   22.20    5.21  0.89   00.5  0.00  14.8   598.3   26.    .     .
 16.7     20   10.03B  29.432   22.65    5.69  0.94   00.5  0.00  11.5   611.5   17.    .     .
 16.7     30    9.34A  29.913   23.14    5.30  1.09   00.8  0.00  12.3   583.9   18.    .     .
 16.7     50    7.38C     .        .     5.08  1.36   00.5  0.00  17.8   613.7   25.    .     .
 16.7     75    6.80A  31.562   24.78    4.15  1.35   00.6  0.00  18.7   538.8   28.    .     .
 16.7    100    6.65A  31.962   25.12    3.79  1.76   00.5  0.24  19.3   512.1   34.    .     .
 16.7    145    6.49A  32.160   25.29    3.36  1.93   00.2  0.51  25.5   529.5   36.    .     .

                                STANDARD

         DEP    TEMP     SAL     SIG-T    OXY      SP VOL   DEL D
           0    9.83   20.725   15.92    6.65    1168.89     .000
          10   10.45   28.940   22.20    5.21     564.20     .087
          20   10.03   29.432   22.65    5.69     521.25     .141
          30    9.34   29.913   23.13    5.30     475.24     .191
          50    7.38   22.168   17.31    5.08    1034.78     .342
          75    6.80   31.562   24.78    4.15     318.38     .511
         100    6.65   31.962   25.12    3.79     286.88     .587
         150    9.65   20.943   16.11    6.17    1150.23     .946
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.   9,   BO   5     18/10/78
---------------------------                                  4.9 HOURS GMT

  LATITUDE = 55  12.0N   LONGITUDE = 130  37.0W   SONIC DEPTH =  274 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED          .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I           DIRECTION        SPEED                               I
I WIND          -      DEGR     KNOTS                            I
-----------------------------------------------------------------
I           DIRECTION       HEIGHT     PERIOD                    I
I SEA         0 -   0 DEGR     M.         SECS                   I
I SWELL         -     DEGR     M.         SECS                   I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  11.7 DEGR C.   BAROMETRIC PR. =1018.4MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
-----------------------------------------------------------------

                                  OBSERVED

 TIME    DEP      TEMP     SAL     SIG-T     OXY   PO4    NH3   NO2    NO3    NO      SIO3  PH    TALK
 22.1     0       9.44A  13.066   10.04     7.08  0.27   00.4  0.00     .             19.     .      .
 22.1    10      10.54A  29.199   22.39     5.90  0.56   00.3  0.00   07.4   593.4   26.     .      .
 22.1    20      10.08A  29.952   23.05     4.89  0.53   00.1  0.00   06.5   495.1   11.     .      .
 22.1    30       9.31A  30.397   23.52     4.78  0.66   00.4  0.00   09.1   508.7   14.     .      .
 22.1    50       8.09A     .        .      4.42  0.41   00.0  0.00   02.4   416.2    5.     .      .
 22.1    75       7.80A  31.559   24.65     4.04  0.87   00.2  0.00   12.5   473.2   20.     .      .
 22.1   100       7.02A  31.966   25.07     3.81  1.36     .   0.00   18.8   509.4   35.     .      .
 22.1   150       6.31A  32.507   25.59     3.45  0.85     .   0.00   17.5   465.5   34.     .      .
 22.1   200T      6.26A  32.598   25.67     3.47  1.12     .   0.00   17.6   468.2   33.     .      .
 22.1   250T      6.26A  32.615   25.68     3.42  1.33     .   0.00   17.8   465.5   33.     .      .

                                  STANDARD

         DEP      TEMP     SAL     SIG-T     OXY        SP VOL   DEL D
          0       9.44   13.066   10.04     7.08      1742.30     .000
         10      10.54   29.199   22.39     5.90       546.37     .114
         20      10.09   29.952   23.05     4.89       483.39     .166
         30       9.31   30.397   23.52     4.78       438.79     .212
         50       8.09   30.913   24.10     4.42       383.27     .294
         75       7.80   31.559   24.65     4.04       331.51     .384
        100       7.02   31.966   25.07     3.81       291.22     .461
        150       6.31   32.507   25.59     3.45       242.53     .595
        200       6.26   32.598   25.67     3.47       235.69     .714
        250       6.26   32.615   25.68     3.42       235.02     .832
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.  12.   BQ   9    18/10/78
-------------------------------                          7.5 HOURS GMT

   LATITUDE = 55   6.8N   LONGITUDE = 130  43.5W   SONIC DEPTH =  355 M

   1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
   CLOUD TYPE --- ( ) ---NOT RECORDED          .
   CLOUD AMOUNT --- ( ) ---NOT RECORDED.
   VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------------------
I          DIRECTION           SPEED                                     I
I WIND      35 -  44 DEGR        KNOTS                                   I
--------------------------------------------------------------------------
I          DIRECTION         HEIGHT     PERIOD                           I
I SEA         0 -   0 DEGR       M.         SECS                         I
I SWELL         -     DEGR       M.         SECS                         I
--------------------------------------------------------------------------
I TEMPERATURES -DRY =          DEGR C.   BAROMETRIC PR. =1016.9MB    I
I              -WET =          DEGR C.   TRANSPARENCY    =        M    I
--------------------------------------------------------------------------

                                   OBSERVED

 TIME    DEP     TEMP      SAL     SIG-T     OXY   PO4     NH3   NO2   NO3    NO       SIO3  PH    TALK
  5.0      0     9.65B   11.862     9.08     7.29  0.27     .    0.24  00.2   652.7    24.    .       .
  5.0     10    10.53A   28.880    22.14     5.35  0.20     .    0.24  04.5   518.1    10.    .       .
  5.0     20    10.39A   29.230    22.44     5.72  0.52     .    0.41  07.8   580.9    17.    .       .
  5.0     30    10.17A   29.912    23.00     5.10  0.47     .    0.28  07.7   524.6    16.    .       .
  5.0     50     9.11A   31.017    24.03     4.40  0.17     .    0.00  04.0   428.8     7.    .       .
  5.0     75     8.21A   31.563    24.59     4.15  0.91   00.1   0.00  11.0   469.5    34.    .       .
  5.0    100     7.42A   31.953    25.01     3.81  0.65   00.0   0.00  11.5   443.7    21.    .       .
  5.0    150     6.41B   32.487    25.56     3.52  0.64   00.0   0.00  12.0   422.3    22.    .       .
  5.0    200T    6.28A   32.599    25.66     3.47  0.61   00.0    .      .              23.    .       .
  5.0    250T    6.27A   32.614    25.68     3.44  0.47   00.0    .      .              20.    .       .
  5.0    300     6.27A   32.618    25.68     3.51  0.60   00.0   0.00    .              24.    .       .
  5.0    345     6.27A   32.640    25.70     3.42  1.11   01.4   0.00  16.7   455.6    24.    .       .

                                   STANDARD

         DEP     TEMP      SAL     SIG-T     OXY        SP VOL   DEL D
           0     9.65    11.862     9.08     7.29      1836.02    .000
          10    10.53    28.880    22.14     5.35       569.91    .120
          20    10.39    29.230    22.44     5.72       541.84    .176
          30    10.17    29.912    23.00     5.10       487.88    .227
          50     9.11    31.017    24.03     4.40       390.00    .315
          75     8.21    31.563    24.59     4.15       336.82    .406
         100     7.42    31.953    25.01     3.81       297.37    .485
         150     6.41    32.487    25.56     3.52       245.25    .621
         200     6.28    32.599    25.66     3.47       235.86    .741
         250     6.27    32.614    25.68     3.44       235.22    .859
         300     6.27    32.618    25.68     3.51       235.55    .977
```

```
 AC   CRUISE 267 CONSECUTIVE STATION NO.  15.   BQ  11     18/10/78
 --------------------------                                 12.1 HOURS GMT

   LATITUDE = 55   6.2N   LONGITUDE = 130  53.0W   SONIC DEPTH =  358 M

   1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
   CLOUD TYPE --- ( ) ---NOT RECORDED          .
   CLOUD AMOUNT --- ( ) ---NOT RECORDED.
   VISIBILITY --- ( ) ---NOT RECORDED
 ------------------------------------------------------------------------
 I          DIRECTION          SPEED                                    I
 I WIND     125 - 134 DEGR       KNOTS                                  I
 ------------------------------------------------------------------------
 I          DIRECTION         HEIGHT     PERIOD                         I
 I SEA        0 -   0 DEGR       M.          SECS                       I
 I SWELL        -     DEGR       M.          SECS                       I
 ------------------------------------------------------------------------
 I TEMPERATURES -DRY =  13.3 DEGR C.   BAROMETRIC PR. =1015.2MB  I
 I              -WET =       DEGR C.   TRANSPARENCY    =        M   I
 ------------------------------------------------------------------------

                                 OBSERVED

 TIME    DEP     TEMP     SAL    SIG-T     OXY   PO4    NH3  NO2    NO3    NO      SIO3  PH   TALK
  7.5      0   10.17A  14.308   10.91     7.11  0.16  01.4  0.00   01.4  647.4     6.    .      .
  7.5     10   10.47C  28.733   22.04     5.88  0.53  00.5  0.45   07.6  593.4    14.    .      .
  7.5     20   10.39A  29.326   22.51     5.64  1.00  01.5  0.68   11.4  606.1    20.    .      .
  7.5     30   10.27A  30.106   23.14     5.43  0.16  00.7  0.00   01.8  501.0     4.    .      .
  7.5     50    9.96A  31.062   23.93     4.87  0.17  00.0  0.00   03.1  462.7     5.    .      .
  7.5     75    8.56A  31.587   24.56     4.17  0.18  00.0  0.00   05.0  417.3     8.    .      .
  7.5    100    8.22A  31.809   24.78     3.99  0.73  00.4  0.00   12.4  467.8    18.    .      .
  7.5    150    7.62A  32.196   25.17     3.69  0.93  00.1  0.00   15.3  467.1    21.    .      .
  7.5    200T   7.33A  32.275   25.27     3.78  1.08  00.1  0.00   17.0  490.5    24.    .      .
  7.5    250T   7.29C  32.284   25.29     3.51  1.04  00.5  0.00   16.4  461.0    24.    .      .
  7.5    300    7.20B  32.310   25.32     3.51  0.77  00.2  0.00   16.2  459.2    20.    .      .
  7.5    350    7.05A  32.338   25.36     3.70  0.74  00.4  0.00   13.6  452.7    20.    .      .

                                 STANDARD

         DEP     TEMP     SAL    SIG-T     OXY        SP VOL   DEL D
           0    10.17  14.308   10.91     7.11       1656.84    .000
          10    10.47  28.733   22.04     5.88        579.89    .112
          20    10.39  29.326   22.51     5.64        534.71    .168
          30    10.27  30.106   23.14     5.43        475.05    .218
          50     9.96  31.062   23.93     4.87        399.55    .305
          75     8.56  31.587   24.56     4.17        339.96    .398
         100     8.22  31.809   24.78     3.99        318.97    .480
         150     7.62  32.196   25.17     3.69        282.56    .631
         200     7.33  32.275   25.27     3.78        273.44    .770
         250     7.29  32.264   25.29     3.51        272.91    .906
         300     7.20  32.310   25.32     3.51        270.48   1.042
```

```
AC   CRUISE 267 CONSFCUTIVF STATION NO.  18,   BQ  3A      18/10/78
---------------------------                                 20.3 HOURS GMT

  LATIT IDE = 55  19.0N   LONGITUDE = 130  29.8W   SONIC DEPTH =  155 M

  1-DIGIT WEATHEP CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPF --- ( ) ---NOT PECORDED          .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- (5) ---2-4 KM
-------------------------------------------------------------
I          DIRECTION         SPEED                           I
I WIND         -       DEGR      KNOTS                       I
-------------------------------------------------------------
I          DIRECTION        HEIGHT     PERIOD                I
I SEA        0 -    0 DEGR     M.         SECS               I
I SWELL        -      DEGR     M.         SECS               I
-------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1013.2MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M  I
-------------------------------------------------------------

                                 OBSERVED

TIME   DEP     TEMP    SAL     SIG-T    OXY   PO4    NH3   NO2   NO3    NO      SIO3  PH   TALK
12.1     0    9.17B  10.580    8.14    7.14  0.04   00.4  0.00  02.8  662.7    13.    .     .
12.1    10   10.40A  29.009   22.26    5.36  0.33   00.6  0.00  05.9  531.6     9.    .     .
12.1    20    9.94B  29.462   22.69    5.28  0.69   00.4  0.00  09.1  553.3    12.    .     .
12.1    30    9.74B  29.808   22.99    5.33  1.04   00.1  0.00  13.2  594.7    16.    .     .
12.1    50    8.39Q  30.630   23.84    5.51  0.69   00.1  0.00  11.3  593.6    17.    .     .
12.1    75    7.13C  31.518   24.71    4.20  1.24   00.1  0.00  17.9  536.1    23.    .     .
12.1   100    6.57A  31.909   25.09    3.68  2.07   00.1  0.00  25.4  557.2    33.    .     .
12.1   150    6.50A  32.159   25.29    3.54  2.33   00.3  0.00  34.6  627.5    47.    .     .

                                 STANDARD

       DEP     TEMP    SAL     SIG-T    OXY        SP VOL   DEL D
         0     9.17  10.580    8.14    7.14       1928.33    .000
        10    10.40  29.009   22.26    5.36        558.29    .124
        20     9.94  29.462   22.69    5.28        517.65    .178
        30     9.74  29.808   22.99    5.33        489.01    .228
        50     8.39  30.630   23.84    5.51        408.51    .318
        75     7.13  31.518   24.71    4.20        325.80    .410
       100     6.57  31.909   25.08    3.68        289.86    .487
       150     6.50  32.159   25.29    3.54        270.84    .627
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.  19.    BQ  3B     18/10/78
                                                              23.0 HOURS GMT

  LATITUDE = 55  19.1N   LONGITUDE = 130  31.8W   SONIC DEPTH =  140 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I          DIRECTION         SPEED                              I
I WIND     215 - 224 DEGR     7 KNOTS                           I
-----------------------------------------------------------------
I          DIRECTION        HEIGHT     PERIOD                   I
I SEA      215 - 224 DEGR  0.3 M.         SECS                  I
I SWELL        -     DEGR      M.         SECS                  I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1009.4MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M I
-----------------------------------------------------------------

                                OBSERVED

 TIME   DEP    TEMP    SAL    SIG-T   OXY   PO4    NH3   NO2   NO3   NO     SIO3  PH   TALK
 20.3     0   9.70C  15.300  11.74   6.80  0.32   00.2  0.00  06.3  663.8  19.    .     .
 20.3    10  10.42A  29.092  22.33   5.26  1.01   00.0  0.00  11.7  574.9  16.    .     .
 20.3    30   9.28C  30.100  23.29   5.66  1.15   00.3  0.00  14.8  638.5  18.    .     .
 20.3    50   7.64B  30.955  24.20   4.77  1.17   00.1  0.00  15.5  565.4  20.    .     .
 20.3    75   7.14A  31.545  24.72   4.15  1.23   00.1  0.00  17.5  528.0  23.    .     .
 20.3   100   6.87B  31.830  24.98   4.13  1.37   00.1  0.00  18.4  534.3  23.    .     .
 20.3   135   6.54A  32.132  25.26   3.53  1.61   00.3  0.00  21.6  509.6  30.    .     .

                                STANDARD

        DEP    TEMP    SAL    SIG-T   OXY      SP VOL  DEL D
          0    9.70  15.300  11.74   6.80    1576.12   .000
         10   10.42  29.092  22.32   5.26     552.44   .106
         20    9.85  29.596  22.81   5.46     506.32   .159
         30    9.28  30.100  23.29   5.66     460.45   .208
         50    7.64  30.955  24.20   4.77     374.16   .291
         75    7.14  31.545  24.73   4.15     323.91   .378
        100    6.87  31.830  24.98   4.13     299.48   .456
```

```
AC   CRUISE 267 CONSECUTIVE STATION NO.  20.   BQ   5    19/10/78
                                                          5.2 HOURS GMT
  LATITUDE = 55  12.0N   LONGITUDE = 130  37.0W   SONIC DEPTH =  278 M

  1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I            DIRECTION          SPEED                                 I
I WIND       215 - 224 DEGR      5 KNOTS                              I
-----------------------------------------------------------------------
I            DIRECTION          HEIGHT      PERIOD                    I
I SEA          0 -    0 DEGR      M.           SECS                   I
I SWELL          -      DEGR      M.           SECS                   I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1010.5MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M I
-----------------------------------------------------------------------

                                 OBSERVED

 TIME   DEP    TEMP    SAL     SIG-T    OXY   PO4   NH3   NO2   NO3   NO     SIO3 PH   TALK
 23.0     0   10.13A  13.287   10.13   6.97  0.19  00.2  0.00  03.6  654.7  14.
 23.0    10   10.52A  29.118   22.33   5.30  0.96  00.4  0.00  11.3  574.9  18.   .     .
 23.0    20   10.24A  29.769   22.88   4.88  1.04  00.3  0.00  13.6  558.1  18.   .     .
 23.0    30    9.78B  30.163   23.26   4.80  1.09  00.3  0.00  14.1  555.4  20.   .     .
 23.0    50    8.44A  30.863   24.01   4.79  1.66  00.5  0.00  19.0  598.7  26.   .     .
 23.0    75    7.77A  31.603   24.69   4.00  1.56  00.3  0.00  20.2  538.9  27.   .     .
 23.0   100    7.07A  31.883   25.00   3.85  1.92  00.4  0.00  22.2  543.5  30.   .     .
 23.0   150    6.30A  32.524   25.60   3.48  1.97  00.4  0.00  27.2  555.5  37.   .     .
 23.0   200T   6.26A  32.596   25.66   3.45  1.89  00.8  0.00  29.9  577.1  42.   .     .
 23.0   250    6.26A  32.615   25.68   3.39  1.88  00.2  0.00  24.6  524.1  35.   .     .

                                 STANDARD

        DEP    TEMP    SAL     SIG-T    OXY       SP VOL  DEL D
          0   10.13   13.287   10.13   6.97     1733.58    .000
         10   10.52   29.118   22.33   5.30      552.07    .114
         20   10.24   29.769   22.88   4.88      499.46    .167
         30    9.78   30.163   23.26   4.80      463.23    .215
         50    8.44   30.863   24.01   4.79      391.85    .300
         75    7.77   31.603   24.69   4.00      327.82    .390
        100    7.07   31.883   25.00   3.85      298.05    .469
        150    6.30   32.524   25.60   3.48      241.14    .603
        200    6.26   32.596   25.66   3.45      235.84    .723
        250    6.26   32.615   25.68   3.39      235.02    .840
```

APPENDIX III

HEAVY METAL CONTENTS OF BERING SEA SEALS

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INTRODUCTION

This communication is based on base-line studies performed as part of the BLM/NOAA Outer Continental Shelf Environmental Assessment Program for Alaska and hence unfortunately consists of unintegrated survey work lacking the direction and cohesiveness generally associated with scientific projects. Nevertheless, we have obtained a number of precisely analysed heavy metal data for an area — the central Bering Sea — which is of considerable economic importance and current oceanographic interest, and for which very little chemical characterization exists.

The major portion of this work concerns heavy metal contents of various seal tissue samples. These distributions are considered within the context of the environmental base-lines determined for water and sediments within coincident and adjacent portions of the Bering Sea.

ANALYSIS TECHNIQUES

All biota and sediment samples considered here have been analysed for selected heavy metals spectrophotometrically. The major limitations on analytical precision for both classes of sample is connected with the dissolution step and inter-element matrix effects. The problem of oxidation of the tissue samples without loss of volatile metals was addressed here by low temperature ashing in an oxygen plasma furnace. The residues from this step were then treated with Ultrex nitric acid in a teflon digestion bomb prior to graphite furnace atomic spectrometric analysis. Standard curves run with each batch were prepared by adding standards to a matrix prepared in bulk for each type of tissue sample. NBS standards were carried through with each batch to monitor accuracy.

Only chemical extracts of sediments have been determined in this study as a very rough measure of bioavailability. The extractant used — 25 percent v/v acetic acid — was mandated by the contracting agency. Metal concentrations thus determined were lower than would have been given by the more conventional mixed acid-reducing treatment but the latter has only the virtue of more universal use since several studies (Luoma and Jenne, 1976, for example) have shown little correlation between "bioavailability", as evidenced by measured uptake, and various chemical leaching treatments.

Soluble seawater trace metal data constitutes only a very minor component of this particular report. The very stringent sampling strategy needed has been discussed in detail by Burrell (1978). Final analysis was by differential pulse anodic stripping voltammetry.

ENVIRONMENTAL DATA

Using the very careful sampling procedures referenced above, a number of water samples were collected from the U.S.S.R. Hydromet Vessel *Volna* on the stations shown in Figure 1 in July-August 1977. Coincidently, many of these localities cover that portion of the Alaskan Shelf west of Nunivak Island from which the seal specimens discussed below has been collected the previous spring.

To date, soluble copper and lead values have been determined and Figure 2 shows the mean ranges for over 100 samples collected through the water column. These closely conform with distributions given previously for the Gulf of Alaska and elsewhere. Since mean soluble concentrations

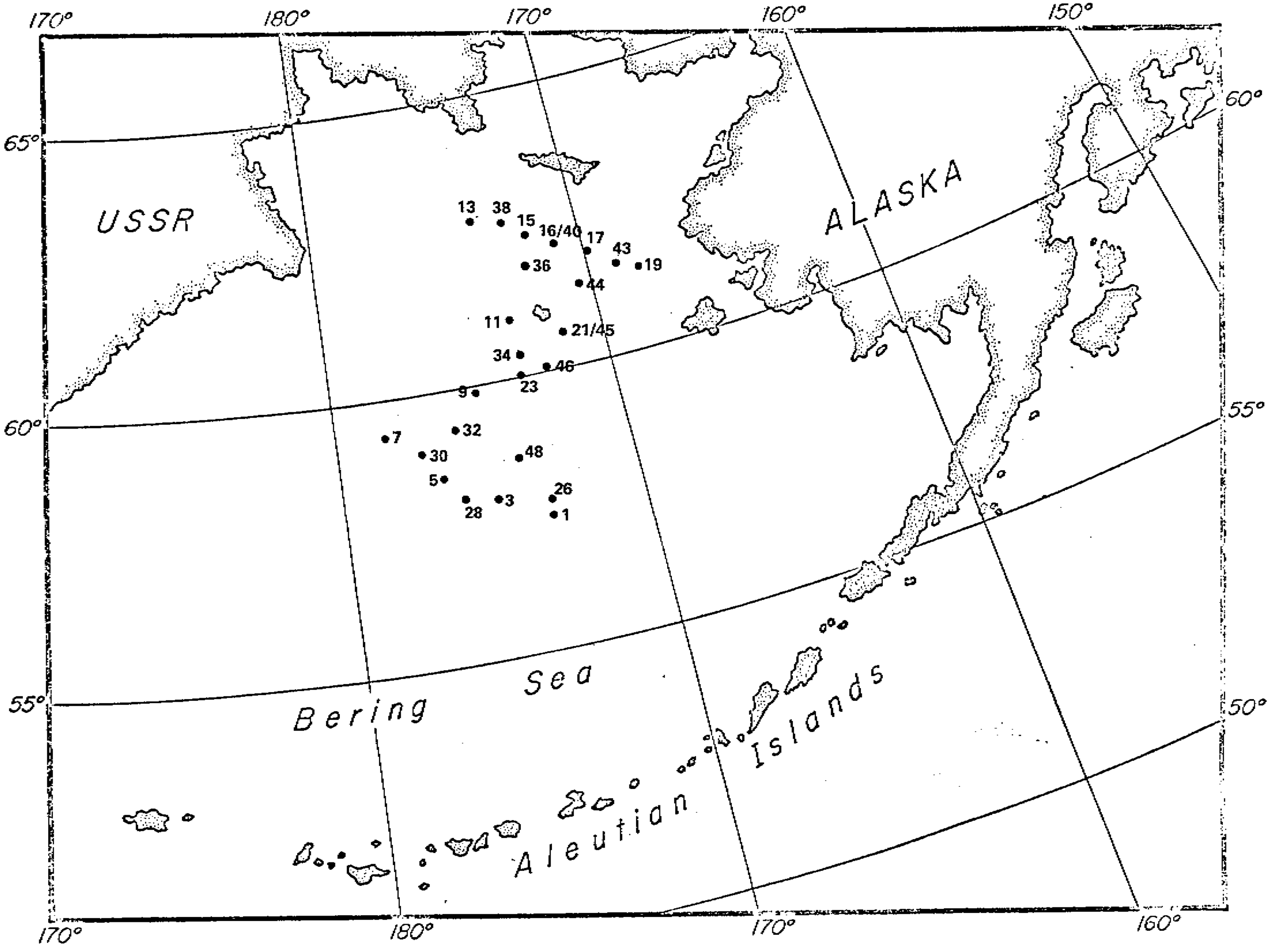

Figure 1. Stations occupied by U.S.S.R. hydromet vessel *Volna* July-August 1977.

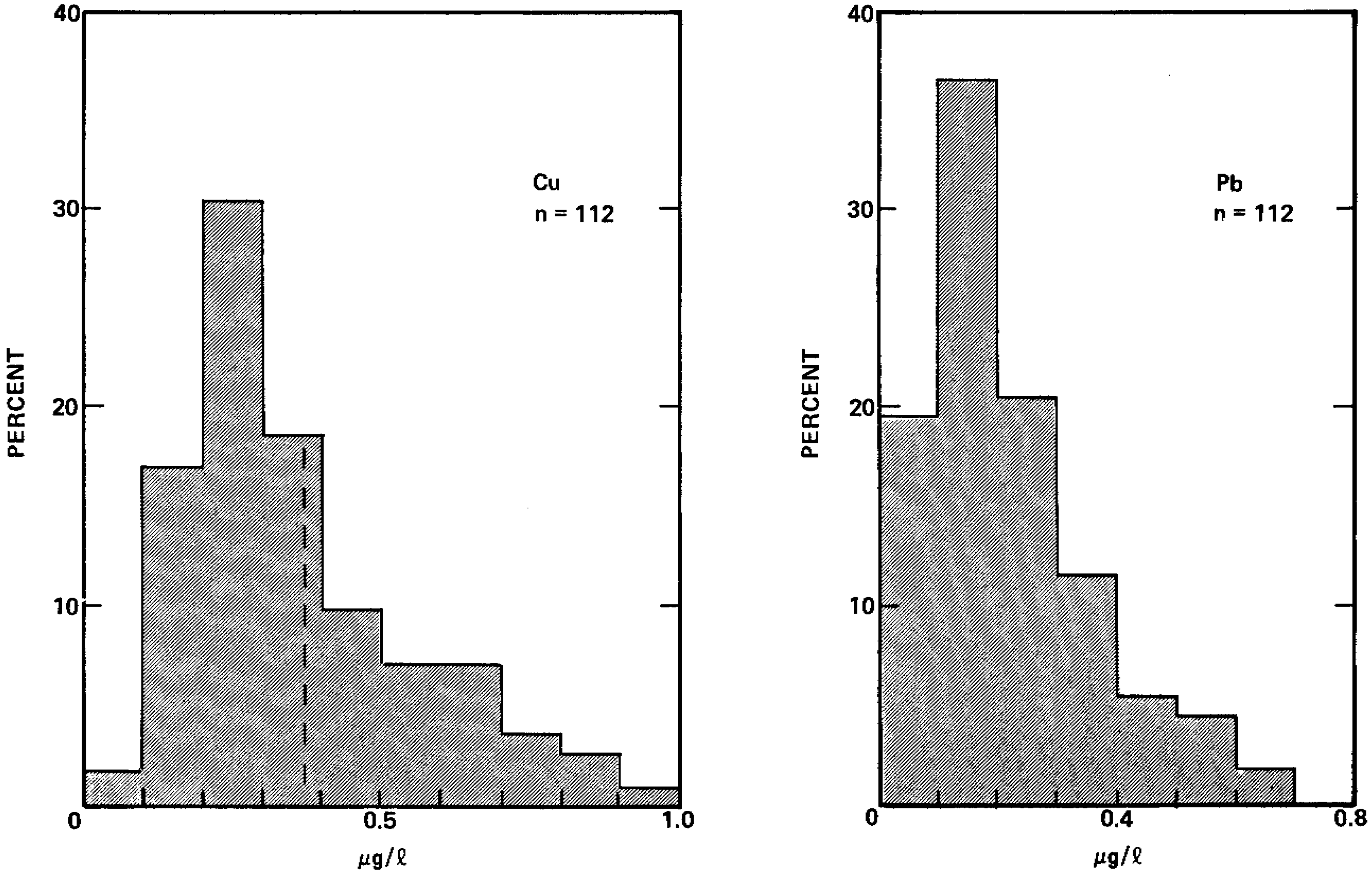

Figure 2. Mean ranges for soluble copper and lead concentrations for samples collected from the surface and adjacent to the bottom at the stations given in Figure 1. (D. T. Heggie, analyst)

should only vary between narrow limits in the open ocean, this would be expected. However, it is only recently that nanogram ranges have been suggested for these metals: our data supports such levels for unpolluted open ocean water and at the same time add confidence to their accuracy. Although we have good soluble data for these two metals only, there is no evidence for any anomolous trends and it is expected that the concentrations of other trace metals in solution will show the same low ranges given in earlier publications for the Gulf of Alaska (e.g., Burrell, 1978).

With regard to the "available" metal contents of Bering Sea surficial sediments, we have data for coarsely spaced grids of stations in Norton Sound and in the southern portion of the Bering Sea, which includes most of the geographic area from which the seals analysed in this study were harvested. Figures 3 and 4 illustrate the distribution of mud-sized material over this region and Table I lists acid-extractable contents of a number of metals from the Norton Sound samples. It is immediately apparent that these sediments are relatively coarse grained; considerably more so than the areas south of the Aleutian Chain. And, since extractable metal contents are a function of the grain size, these latter contents are similarly depressed and, for the most part below the analytical detection limits. Table II for example, shows correlations between concentrations of extracted metals and the content of mud-sized sediment for Norton Sound.

HEAVY METAL CONTENTS OF MARINE MAMMALS

Figure 5 shows the localities of sacrificed seal samples collected on two separate cruises in March-April and May-June of 1977.

The original objective of this project was to look for statistical differences between the heavy metal contents of four species of seal which

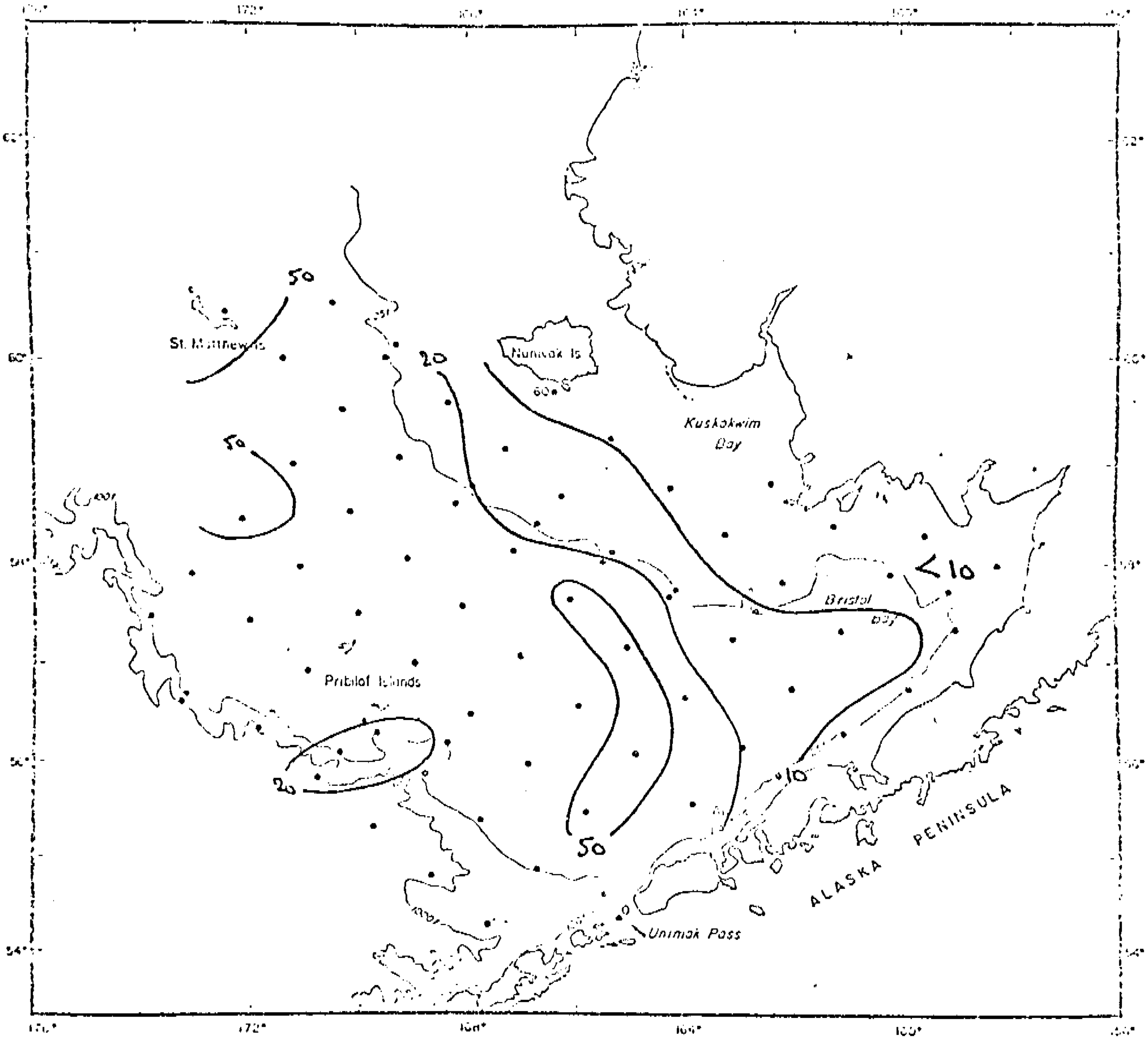

Figure 3. South Bering Sea weight percent of mud-sized fraction of superficial sediment. (C. Tommas, analyst)

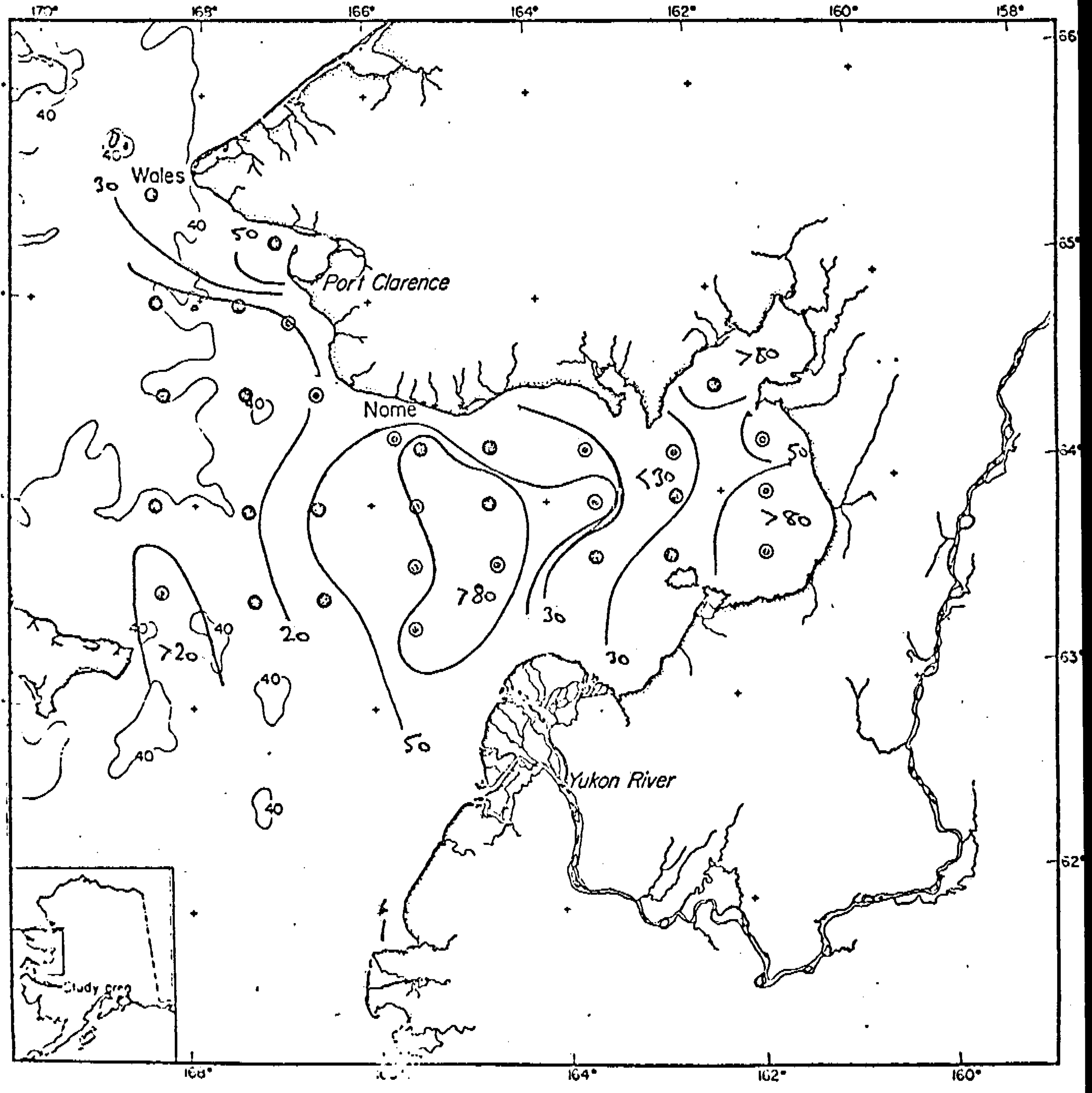

Figure 4. Northern Bering Sea: Norton Sound. Weight percent of mud-sized fraction of superficial sediment. (C. Tommos, analyst)

TABLE I

NORTON SOUND

OSS *Discoverer* - September 1976

Heavy metal contents of sediment extracts (μg/g) and clay + silt %

#	Clay/silt (%)	Cd	Cu	Ni	Zn	Fe	Mn
1	22.1	<0.1	<0.3	<1.3	6.2	746	8
4	87.0	<0.1	0.5	2.5	5.0	3050	48
5	64.3	<0.1	0.5	2.9	5.0	2843	86
6	86.4	<0.1	2.0	3.3	5.7	3084	121
9	89.0	<0.1	1.1	4.3	8.0	4250	79
12D	59.5	<0.1	0.6	1.4	5.1	1609	230
13	81.9	<0.1	0.5	1.8	6.0	2086	283
15	81.9	<0.1	<0.3	<1.3	5.1	1779	75
17	85.6	0.1	2.2	4.2	9.1	2961	193
20	35.2	<0.1	<0.3	<1.3	3.5	966	58
21	21.5	<0.1	0.3	<1.3	3.5	1219	52
23	43.8	<0.1	0.6	1.8	6.6	2066	70
26	17.6	<0.1	<0.3	<1.3	2.5	565	60
28A	14.8	<0.1	<0.3	<1.3	2.5	745	20

TABLE II

NORTON SOUND

Discoverer - September 1976

Heavy metal extract data and grain size correlation coefficients

	S + C	Fe	Mn	Zn	Ni	Cu
Silt and Clay		0.86	0.53	0.67	0.73	0.62
Fe			0.27	0.71	0.98	0.84
Zn					0.76	0.84
Ni						0.85

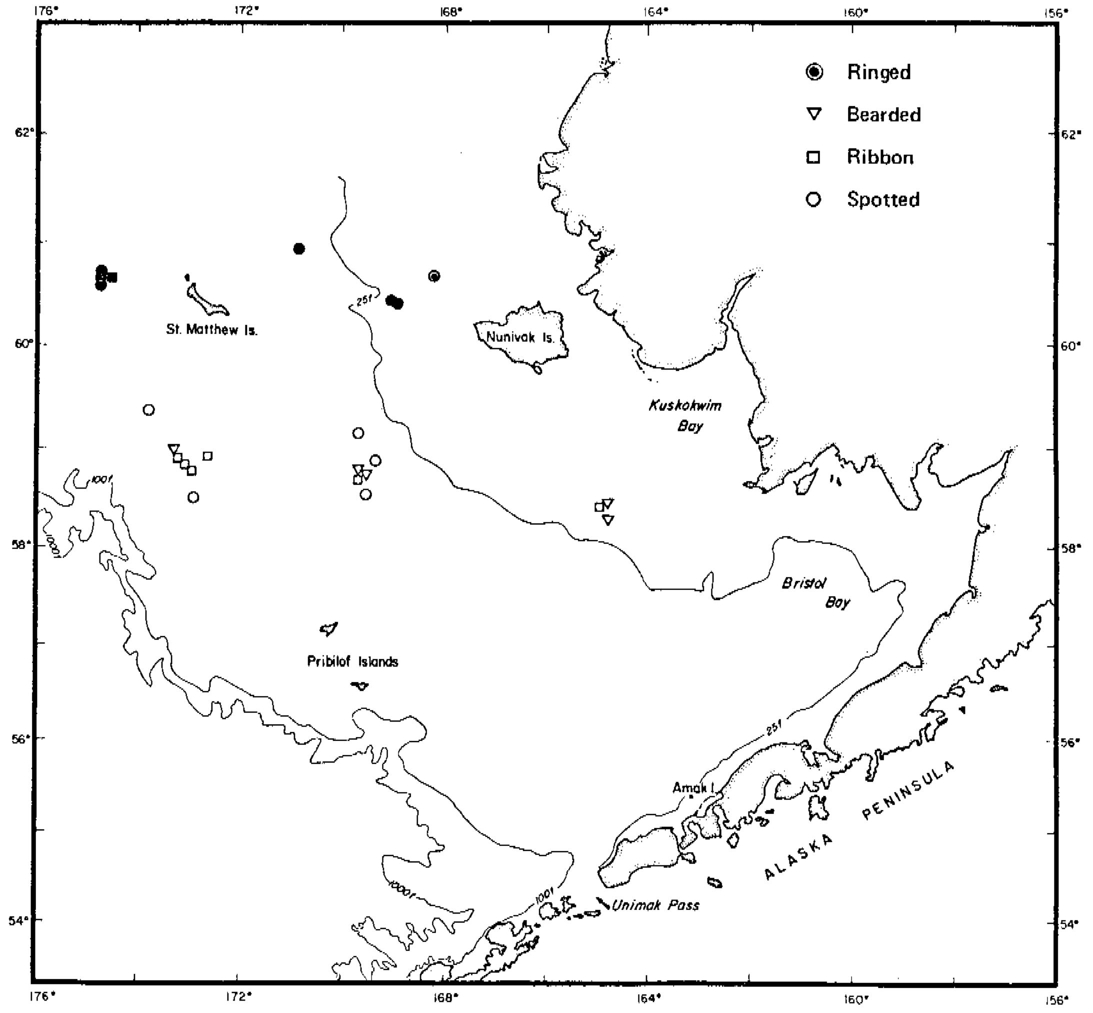

Figure 5. Localities of seal samples collected on *Surveyor* cruise March-April 1977 and *Discoverer* cruise May-June 1977.

were thought to have distinctive feeding habits. Our data are largely for ribbon, spotted and bearded seal samples (Tables III and IV) which were believed to feed predominantly on fish and benthos, pelagic fish, and invertebrate benthos respectively. Unfortunately it was not found feasible to obtain representative food species at the time of collection of the mammals. Nor were stomach contents suitable for either identification for analysis: in many cases it was found that the animals had starved for a number of days. The biological investigators also found the seals to be largely opportunistic feeders who would eat what was available, so that diet differentiation by species, where it occurred, was only noted where there was adequate choice.

For most of the individuals collected we have analysed for cadmium, nickel, copper, and zinc in muscle, liver and kidney tissue and these data, as means of duplicate determinations, are given in Tables V and VI. Table VII gives accuracy and precision information relating to this batch of numbers.

As noted above, marked differences in heavy metal contents as a reflection of transfer from a particular type of food would not be expected. Nevertheless, Table VIII lists some possible trends based on this very limited sample batch.

It appears likely that the spotted seals have the lowest overall metal contents and, yet more tentatively, bearded the highest. The former are considered to be largely consumers of fin fish, whereas the bearded seals consume large quantities of benthic invertebrates. Since the benthos concentrates metal more than pelagic communities this possible trend is of interest. Clearly more positive correlation would require not only a considerably larger number of specimens of one specific species but also concurrent food species or, preferably, fresh stomach contents.

TABLE III

BERING SEA

O.S.S. *Surveyor* 31 March - 27 April 1977

Seal samples collected for heavy metal analysis

Sample #	Latitude (N)	Longitude (W)	Species	Sex	Weight (kg)	Age (yrs)
1	58°51.0	173°08.0	Ribbon	F	39.5	1
2	58°51.0	173°08.0	Ribbon	M	102.0	-
3	58°56.0	172°40.0	Ribbon	M	81.8	4
4	58°45.6	172°55.4	Spotted	M	35.0	1
5	59°00.6	173°15.0	Bearded	F	181	6+
6	58°53.0	173°07.0	Ribbon	M	107.3	15
7	58°43.9	169°32.9	Bearded	M	232	12
8	58°48.5	169°41.0	Bearded	F	227	12+
10	59°06.3	169°41.3	Spotted	F	41.8	1
11	58°24.7	164°52.3	Ribbon	F	98.6	3
16	58°21.3	164°49.7	Bearded	F	204.5	2
17			Walrus	F		
28	58°54.2	169°13.6	Spotted	M	89.9	6
29	58°40.1	169°40.3	Ribbon	M	59.9	3
30	58°34.8	169°28.8	Spotted	M	84.0	7
32	59°22.5	173°43.0	Spotted	M	118.0	17

TABLE IV

BERING SEA

O.S.S. *Discoverer* 25 May - 5 June 1977

Seal samples collected for heavy metal analysis

Sample #	Latitude (N)	Longitude (W)	Species	Sex	Weight (kg)	Age (yrs)
1	60°37.7	174°27.2	Ribbon	M	80.0	10
2	60°36.3	174°37.5	Spotted	F	57.7	10
3	60°36.3	174°37.5	Spotted	M	45.5	0.3
5	60°36.3	174°37.5	Spotted	M	49.1	2
7			Ribbon	M	73.6	7
8	60°26.5	168°55.8	Spotted	F	55.0	4
10	60°24.2	169°49.8	Spotted	M	68.6	5
13	60°35.9	168°10.1	Ringed	M	8.7	1
15	60°56.6	170°48.3	Spotted	F	37.7	<1

TABLE V

BERING SEA

O.S.S. *Surveyor* 31 March - 27 April 1977

Heavy metal contents of seal tissue (μg/g dry weight)

Sample	Species	Tissue	Cd[a]	Ni[a]	Cu[a]	Zn[a]
01	Rib	muscle	0.13 ± 0.01	2.5 ± 0.4	6.7 ± 0.5	37 ± 12
		liver	6.4 ± 0.1	2.6 ± 0.9	16.5 ± 0.2	169 ± 7
		kidney	53.0 ± 0.3	2.8 ± 0.2	19.4 ± 0.1	149 ± 1
02	Rib	muscle	0.3 (c)	1.3 (c)	4.4 ± 0.6	50 ± 0
		liver	8.7 ± 1.2	1.3 (c)	16.5 ± 3.5	8 ± 2
		kidney	20.1 ± 4.5	0.5 ± 0	16.5 ± 3.5	102 ± 22
03	Rib	muscle	0.25 ± 0	8.3 ± 1.0	5.5 ± 0	54 ± 2
		liver	6.4 ± 0.1	2.2 ± 0.4	26.9 ± 1.3	140 ± 15
		kidney	34.5 (c)	3.0 (c)	16.0 (c)	98 (c)
04	S	muscle	0.14 ± 0.01	3.0 ± 0.2	6.7 ± 1.3	51 ± 9
		liver	0.4 ± 0.1	2.5 ± 0.2	25.0 ± 2.5	116 ± 51
		kidney	16.7 ± 0.2	2.4 ± 0.4	44 ±13	113 ± 23
05	B	muscle	0.8 ± 0.1	2.8 ± 0.3	7 ± 2	175 ± 25
		liver	21.0 ± 0.5	1.3 ± 0.1	36.5 (c)	182 ± 2
		kidney	16.0 ± 2.0	2.0 ± 0.1	28.5 ± 0	163 ± 3
06	Rib	muscle	0.47 ± 0.01	5.8 ± 0	6.8 ± 0.8	18 ± 6
		liver	11.4 ± 0.1	0.9 ± 0.2	29.0 ± 2.5	100 ± 10
		kidney	33.4 ± 0	1.2 ± 0.2	17.5 ± 0.3	48 ± 0
07	B	muscle	0.57 ± 0.04	2.8 ± 0.2	<5 (b)	147 ± 20
		liver	22.2 ± 1.3	0.8 ±	22.8 ± 0.2	170 ± 17
		kidney	22.5 ± 2.0	1.3 ± 0.3	40 ± 6	160 ± 15
08	B	muscle	1.26 ± 0	1.2 ± 0.1	7.6 ± 0	40 ± 1
		liver	41.1 ± 0.9	0.5 ± 0	44.1 ± 2.4	87 ± 3
		kidney	17.4 ± 0.1	1.5 ± 0.1	28.1 ± 0.6	110 ± 1
10	S	muscle	1.5 ± 1.0	2.4 ± 0.2	11 ± 3	52.5± 0
		liver	0.6 ± 0.1	8.1 ± 1.6	18 ± 4	213 ± 7
		kidney	44.3 ± 0.7	<1.0 (b)	24.5 (c)	183 (c)
11	Rib	muscle	0.24 ± 0.02	<0.5 (b)	16.5 ± 3.5	140 ± 5
		liver	35 ±15	<0.5 (b)	13.8 ± 1.2	15 ± 10
		kidney	16 (c)	<0.5 (b)	19 ± 6	8 ± 3

TABLE V (Continued)

Sample	Species	Tissue	Cd[a]	Ni[a]	Cu[a]	Zn[a]
16	B	muscle	1.13 ± 0.07	4.8 ± 0.2	6.9 ± 0.6	60 ± 10
		liver	5.3 ± 0.6	5.4 ± 1.1	37.6 ± 1.6	228 ± 3
		kidney	108.7 ± 0.5	6.2 ± 0.2	34.7 ± 0.2	110 ± 20
17	Walrus	muscle	1.50 ± 0.25	2.4 ± 0.5	6.3 ± 1.3	43 ± 8
		liver	26.0 ± 1.0	1.6 ± 0.3	41.6 ± 0.4	99 ± 1
		kidney	26.5 ± 1.0	<1.0 (b)	27.7 ± 0	96 ± 1
28	S	muscle	0.11 ± 0.01	<0.5 (b)	6.4 ± 0.05	68 ± 1
		liver	4.5 ± 0.05	<0.5 (b)	16.4 ± 0.1	136 ± 1
		kidney	- -	- -	- -	- -
29	Rib	muscle	0.70 ± 0.03	<0.5 (b)	1.7 ± 0	74 ± 2
		liver	17.0 ± 0.3	<0.5 (b)	5.2 ± 1.4	130 ± 3
		kidney	37 ± 5	<0.5 (b)	5.2 ± 1.3	92 ± 14
30	S	muscle	0.16 ± 0.04	<0.5 (b)	4.0 ± 0.1	133 ± 0
		liver	7.3 ± 0.2	<0.5 (b)	18.5 ± 0.2	160 ± 0
		kidney	34 ± 5	<0.5 (b)	15 ± 2.5	120 ± 17
32	S	muscle	0.17 ± 0.01	<0.5 (b)	1.1 ± 0.1	62 ± 9
		liver	15.9 ± 0.8	<0.5 (b)	17.1 ± 0.9	125 ± 23
		kidney	49 ± 7	<0.5 (b)	4 ± 2.5	110 ± 32

a = mean of duplicate determinations
b = duplicate determinations
c = single determinations

TABLE VI

BERING SEA

O.S.S. *Discoverer* 25 May - 5 June 1977

Heavy metal contents of seal tissue (μg/g dry weight)

Sample	Species	Tissue	Cd[a]	Ni[a]	Cu[a]	Zn[a]
01	Rib	muscle	0.29 ± 0.04	0.5 ± 0.1	4.6 ± 0.1	96 ± 5
		liver	3.2 ± 0.9	<0.5 (b)	6 ± 3	185 ± 15
		kidney	<0.3 (b)	1.3 ± 0.5	10 ± 1	197 ± 6
02	S	muscle	1.3 (c)	<0.5 (b)	3.9 ± 0.5	18.2 ± 1.1
		liver	2.48 ± 0.02	<0.5 (b)	11 ± 3	23.3 ± 0.2
		kidney	<0.5 (c)	<0.5 (b)	25.5 ± 0	22 ± 2
03	S	muscle	0.29 ± 0.07	2 ± 1	7.6 ± 0.8	87 ± 7
		liver	1.85 ± 0.15	2.5 ± 0	16.5 ± 0.1	114 ± 1
		kidney	11.0 (c)	1.4 (c)	24.0 (c)	93 ± 25
05	S	muscle	0.6 (c)	<0.5 (b)	2.2 ± 0.7	7.5 ± 1
		liver	0.99 ± 0.01	<0.5 (b)	2.3 ± 0.1	10 ± 1
		kidney	<0.5 (c)	<0.5 (b)	23 ± 3	13 ± 1
08	S	muscle	0.08 ± 0	<0.5 (b)	6.5 ± 0.5	62 ± 3
		liver	1.9 ± 0.4	<0.5 (b)	44.3 ± 0.3	101 ± 15
		kidney	1.52 ± 0.02	<0.5 (b)	29 ± 3	83 ± 3
10	S	muscle	0.24 ± 0	2.4 ± 0	7.1 ± 0.9	123 ± 2
		liver	2.6 ± 0.4	1.8 ± 0.2	20.3 ± 0	109 ± 5
		kidney	11 ± 4	0.9 ± 0.1	12 ± 3	103 ± 9
11	Ring	muscle	0.19 ± 0.01	0.6 ± 0.1	9.5 ± 0	135 ± 0
		liver	5.0 (c)	<0.5 (b)	25 (c)	72 ± 2
		kidney	2.52 ± 0.04	0.7 ± 0.1	10 (c)	227 ± 13
15	S	muscle	0.17 ± 0.05	1.4 ± 0.8	6.9 ± 0.1	80 ± 1
		liver	3.1 ± 0.4	2.1 ± 0.2	18.5 ± 1.5	134 ± 9
		kidney	13.1 ± 0.1	3.8 ± 0.3	16.1 ± 0.1	123 ± 1
07	Rib	muscle	0.27 ± 0.01	<0.5 (b)	3.3 ± 0.7	116 ± 7
		liver	3.0 ± 0.2	17.5 ± 0	2.5 (c)	115 ± 5
		kidney	5.5 ± 0	<0.5 (b)	10 ± 1	138 ± 3

a = mean of duplicate determinations
b = duplicate determinations
c = single determinations

TABLE VII

BERING SEA

Marine mammal analysis program - precision and accuracy
(μg/g dry weight ± one standard deviation)

a. NBS Standard # 1571 orchard leaves.

Element	n	This Study	NBS Certified
Cd	3	0.15 ± 0.06	0.11 ± 0.02
Ni	4	1.4 ± 0.03	1.3 ± 0.2
Cu	7	10.5 ± 3	12 ± 1
Zn	7	25 ± 5	25 ± 3

b. NBS Standard # 1577 bovine liver.

Element	n	This Study	NBS Certified
Cd	3	0.31 ± 0.07	0.27 ± 0.04
Ni	4	0.9 ± 0.08	--
Cu	3	150 ± 30	193 ± 10
Zn	8	120 ± 20	130 ± 10

TABLE VIII

HEAVY METAL DISTRIBUTIONS IN SEAL TISSUE

FROM BERING SEA - SPRING 1977

Cadmium

1. Concentrations in the kidneys of ribbon seals greater than in spotted or bearded
2. Higher cadmium contents in the muscle tissue of bearded seals than in ribbon or spotted
3. Liver contents of spotted seals relatively low
4. Liver contents of bearded seals relatively high

Nickel

Muscle contents generally higher than liver or kidneys

Copper

Spotted seal kidneys generally higher than liver, but reverse trend for ribbon and bearded seals

Zinc

1. Muscle contents of bearded (and possibly spotted) seals higher than ribbon
2. Concentration of zinc higher in livers than in kidneys of all species

Liver and kidney contents shown generally elevated contents of these metals, as would be expected. Enhancements of cadmium in these organs are notably high, but the general lack of comparable reference data does not permit comment as to whether these are unusually so. Olafson and Thompson (1974) have reported on the isolation of metallothiomeins from seal livers, and have suggested that the biosynthesis of such cadmium-binding protein acts primarily as a detoxification mechanism in these, as in terrestrial mammals. Assuming that these complexes serve no other metabolic function then the presence of such hepatic complexes implies toxic ambient marine levels of these metals (notably cadmium, but also mercury and zinc).

The mean kidney content of cadmium for all the analysed samples is around 24 ppm dry weight: a "critical" liver concentration in man has been estimated at around 200 ppm. Kerfoot and Jacobs (1976) have echoed earlier models in which a daily intake of some 50 μg Cd/day will produce the observed mean body burden of around 30 mg, which would vary approximately correspond to a "critical organ" concentration of around 50 ppm. Estimates such as these assume a long residenc time for cadmium in the mammalian tissue: this is one of the chief health hazards of this metal. There appears to be no correlation of liver and kidney contents of metals with the age of the animals given in this report, however. For the muscle tissue there is a suspicion of increasing contents, especially of zinc, with age but, in general, assumption of relatively short residence times with varying organ contents reflecting recent eating habits is attractive. (Note also that liver cadmium contents, for example, of the May samples are generally lower than those taken in April). We have here, however, for too few individuals of any one species or age group to permit anything approaching a vigorous statistical analysis.

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ACKNOWLEDGEMENTS

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HYDROCARBONS: NATURAL DISTRIBUTION AND DYNAMICS ON THE ALASKAN OUTER CONTINENTAL SHELF

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SECTION I. GENERAL SUMMARY

This is the fourth annual report in a continuing study of the distribution and dynamics of hydrocarbons on Alaska's outer continental shelves and coastal waters. This work has had two interrelated goals: to describe the ambient kinds and amounts of hydrocarbons in Alaskan marine environments which may be affected by potential petroleum development and to better understand the processes by which petroleum is dispersed and degraded in the marine environment regimes found around Alaska.

The primary emphasis of the year's work reported here has been directed toward addressing these general topics in one particular geographic region: Cook Inlet. We have measured hydrocarbons in pelagic and benthic environments of Cook Inlet in order to improve our knowledge of ambient concentrations and to understand more about transfer and dispersion processes.

Our results indicate that in the pelagic environment of Cook Inlet hydrocarbon concentrations are generally low and that in the upper Inlet any discharged petroleum is rapidly dispersed. Uptake of fossil hydrocarbons by benthic animals in lower Cook Inlet has been shown to occur in some quite specific ways.

SECTION II. HYDROCARBONS IN COOK INLET PELAGIC ENVIRONMENTS

Introduction

The work described in this section was part of a multi-investigator OCSEAP effort to determine chemical and microbiological characteristics of the water column in upper and lower Cook Inlet. The basic strategy of this effort was to repeatedly sample the water column at the same phase of the tidal cycle. It was hoped that in this way it would be possible to distinguish tidal and non-tidal variabilities in the observed parameters and thus produce a characterization that highlighted other short term variables.

This project has investigated non-volatile hydrocarbons in particulate matter and water. (This project also obtained plankton samples using a 100 μm net. However, the results of these analyses are incomplete and will be reported at a later date.) Materials for analysis were collected at time series stations in outer Kachemak Bay (lower Cook Inlet) and near Kalgin Island (central Cook Inlet) in May 1978. Another central Cook Inlet station was occupied in August 1978. Additional stations were taken in upper Cook Inlet in the vicinity of ongoing offshore petroleum production on each cruise.

The information about the hydrocarbon contents of pelagic environments of Cook Inlet produced by this project are relevant to future petroleum development activities for two reasons. First the information from lower Cook Inlet represents background data about the kinds and amounts of hydrocarbons in that area before petroleum development there. Second the information from central and upper Cook Inlet provides insights about the hydrocarbon loadings which have resulted from the only offshore petroleum production currently in operation in Alaska. This will obviously be useful in assessing the probable impact of contemplated future production activities.

Methods

At the time series stations in lower and central Cook Inlet water samples were collected on high slack water (approximately every 12 hours) from 1 m below surface and 10 m above bottom using 30 ℓ niskin bottles. Aboard ship a measured volume of water was filtered through Gelman type A glass filters which had been previously cleaned at 500° for 24 hours. The filters from each sample were frozen for laboratory analysis. The filtered water was extracted in 4 ℓ batches twice with 50 ml of methylene chloride for 3 minutes. Extracts of each sample were pooled and returned to the laboratory for analysis. Surface water samples were collected in upper Cook Inlet from the bow of a small boat using weighted 1 gallon bottles. These samples were processed in the same way as water collected in lower and central Cook Inlet.

In the laboratory water extracts were dried over sodium sulfate and concentrated to 1 ml. The samples collected in May were fractionated using silica gel column chromatography (see section V for conditions). For August samples the fractionation step was omitted. Extracts were concentrated to 0.2 ml and analysed by gas chromatography and mass spectrometry as described in section V.

Filters of suspended sediment and phytoplankton from Cook Inlet water samples were thawed, counted, and cut into 1 mm strips. The cut filters were placed in clean 50 ml centrifuge tubes, with samples of over 12 filters divided between 2 tubes. Twenty ml of aqueous 4N NaOH and 10 ml hexane were added to each tube. Six of the 21 samples were internally spiked with 1 ml each of chrysene and docosane standards, and four blanks of clean filters, NaOH solution, and hexane were constructed. The tubes were topped with teflon-lined caps and refluxed 2 hours in a 90°C H_2O bath.

After cooling, the samples were 3 x 15 ml hexane extracted following 3 x 15 minute centrifugations at 20,000 rpm. The extracts were dried over Na_2SO_4 overnight, and then were concentrated to 1 ml. Column chromatography on silica gel and gas chromatographic analysis were carried out as described in section V.

Results

The locations of water sampling stations are shown in Table II-I. Table II-II presents the observed concentrations of hydrocarbons in filtered seawater. Table II-III gives the hydrocarbon concentrations in suspended matter.

Discussion

Only nine of the 29 samples of filtered seawater showed detectable concentrations of hydrocarbons (Table II-II). That is, more than two thirds of

TABLE II-I

SAMPLING LOCATIONS FOR WATER COLUMN INVESTIGATIONS

Station Locations, Cook Inlet - May, 1978

Upper Cook	Latitude (°N)	Longitude (°W)
UC-6	60°56.0'	151°29.0'
UC-7	60°55.2'	151°22.0'
UC-8' Oil Rig	60°46.7'	151°31.6'
Lower Cook		
CB-7	59°39.4'	151°45.9'
CB-9	60°28.2'	152°12.2'

Station Locations, Cook Inlet - August, 1978

Upper Cook		
VC-1	61°08.4'	150°47.3'
VC-8	60°46.4'	151°23.0'
VC-9	60°48.2'	151°40.0'
Lower Cook		
CB-10	60°22.8'	151°51.5'

TABLE II-II

HYDROCARBONS IN COOK INLET FILTERED SEAWATER (μg/ℓ)

Station	Date	Volume Extracted	Depth	Hydrocarbons Saturated	Hydrocarbons Unsaturated	Total
CB7-0	May 78	16	Surface	20.6	ND	
		16	47 M	41.0	ND	
CB7-12	May 78	16	Surface	6.9	ND	
		16	47 M	t	ND	
CB7-24	May 78	16	Surface	ND	ND	
		16	47 M	ND	ND	
CB7-36	May 78	16	Surface	ND	ND	
		16	47 M	ND	ND	
CB9-0	May 78	16	Surface	ND	ND	
		16	32 M	ND	ND	
CB9-12	May 78	16	Surface	ND	ND	
		16	32 M	ND	ND	
CB9-24	May 78	12	Surface	ND	ND	
		12	32 M	ND	ND	
CB9-36	May 78	12	Surface	ND	ND	
		12	32 M	ND	ND	
CB10-0	Aug 78	12	Surface			ND
		12	8 M			ND
CB10-12	Aug 78	12	Surface			ND
		12	15 M			ND
CB10-24	Aug 78	12	Surface			ND
		8	11 M			1.0
UC1	Aug 78	4	Surface			ND
UC2	Aug 78	4	Surface			ND
UC6	May 78	8	Surface	0.16	ND	
UC7	May 78	8	Surface	0.07	ND	
UC8	Aug 78	4	Surface			ND
UC8'	May 78	8	Surface	0.18	ND	
UC9	Aug 78	4	Surface			0.23

ND = none detected

TABLE II-III

HYDROCARBONS IN SUSPENDED MATTER FROM COOK INLET IN $\mu g\ Kg^{-1}$ (WATER WEIGHT BASIS)

Station	CB7	CB7	CB7	CB7	CB9	CB9	CB9
Time Series	24	24	36	36	0	0	12
Date	8 May 78	8 May 78	8 May 78	8 May 78	12 May 78	12 May 78	24 May 78
Depth	surface	47 m	surface	47 m	surface	32 m	surface
Total Saturates	.211	62.5	N.D	.182	N.D.	t	1.26
Total Unsaturates	N.D.	21.8	.062	N.D.	N.D.	N.D.	.232
C_{17}	.024	–	–	.033	–	t	–
Pris.	–	t	–	–	–	–	t
C_{18}	t	–	–	t	–	–	–
Phyt.	–	t	–	–	–	–	t
C_{19}	t	–	–	t	–	–	–
C_{20}	.019	.662	–	.026	–	–	.015
C_{21}	t	1.43	–	t	–	–	.035
C_{22}	.014	2.47	–	–	–	t	.084
C_{23}	.019	3.09	–	.024	–	t	.137
C_{24}	.045	3.32	–	.028	–	t	.197
C_{25}	.040	3.17	–	.038	–	–	.225
C_{26}	.050	2.83	–	.035	–	–	.209
C_{27}	t	2.24	–	t	–	–	.147
C_{28}	t	1.72	–	t	–	–	.105
C_{29}	t	1.40	–	t	–	–	.059
C_{30}	t	1.04	–	t	–	–	.032
C_{31}	t	.748	–	t	–	–	.017
C_{32}	–	.643	–	–	–	–	–
Sq.	–	–	–	–	–	–	–
MW 234	–	t	–	–	–	–	t

TABLE II-III

CONTINUED

Station	CB9	CB9	CB9	CB9	CB9	CB10	CB10
Time Series	12	24	24	36	36	0	0
Date	13 May 78	13 May 78	13 May 78	14 May 78	14 May 78	31 Aug 78	31 Aug 78
Depth	32 m	surface	32 m	surface	37 m	surface	8 m
Total Saturates	.014	.136	.019	.032	.165	N.D.	.355
Total Unsaturates	N.D	.422	N.D.	N.D.	N.D.	N.D.	N.D.
C_{17}	–	–	t	–	–	–	t
Pris.	–	–	–	–	–	–	–
C_{18}	–	–	–	–	–	–	–
Phyt.	–	–	–	–	–	–	–
C_{19}	–	–	–	–	–	–	–
C_{20}	–	–	–	–	–	–	–
C_{21}	–	–	–	–	–	–	–
C_{22}	–	–	–	–	–	–	t
C_{23}	–	–	t	–	.026	–	.045
C_{24}	–	–	t	–	–	–	.078
C_{25}	–	–	.019	.012	.040	–	.144
C_{26}	–	–	–	.011	.033	–	.087
C_{27}	–	–	–	.007	.023	–	t
C_{28}	–	–	–	–	.013	–	t
C_{29}	–	–	–	–	.012	–	–
C_{30}	–	–	–	–	.050	–	–
C_{31}	–	–	–	–	–	–	–
C_{32}	–	–	–	–	–	–	–
Sq.	–	–	–	–	–	–	–
MW 234	–	–	–	–	–	–	–

TABLE II-III

CONTINUED

Station	CB10	CB10	CB10	CB10	UC6	UC7	UC Oil Rig
Time Series	12	12	24	24	-	-	-
Date	31 Aug 78	31 Aug 78	1 Sep 78	1 Sep 78	12 May 78	12 May 78	12 May 78
Depth	surface	15 m	surface	11 m	surface	surface	surface
Total Saturates	.166	.146	.170	N.D.	.050	.212	N.D.
Total Unsaturates	N.D.	N.D.	N.D.	N.D.	t	t	N.D.
C_{17}	.043	t	t	-	-	-	-
Pris.	-	-	-	-	-	-	-
C_{18}	t	-	-	-	-	-	-
Phyt.	-	-	-	-	-	-	-
C_{19}	t	-	-	-	-	-	-
C_{20}	t	-	-	-	-	-	-
C_{21}	t	t	t	-	-	-	-
C_{22}	-	.038	t	-	-	-	-
C_{23}	.029	t	t	-	-	.031	-
C_{24}	.035	.032	.051	-	-	.051	-
C_{25}	.026	.032	.057	-	-	.064	-
C_{26}	.032	.043	.062	-	-	.066	-
C_{27}	t	t	t	-	-	t	-
C_{28}	t	t	t	-	-	t	-
C_{29}	t	t	-	-	-	t	-
C_{30}	-	-	-	-	-	-	-
C_{31}	-	-	-	-	-	-	-
C_{32}	-	-	-	-	-	-	-
Sq.	-	-	-	-	t	-	t
MW 234	-	-	-	-	-	-	-

the samples contained no detectable hydrocarbons. The hydrocarbon pattern was similar in each case where hydrocarbons were detected: an array of normal alkanes with chain lengths ranging from the low twenties to the low thirties and no odd carbon predominance. When the water extract was fractionated by column chromatography it was observed that no unsaturated hydrocarbons accompanied this array of n-alkanes. Furthermore there was no obvious temporal or geographical order to the occurrence of the normal alkanes. The absence of an aromatic fraction and of an unresolved complex mixture indicates that petroleum is not the source of these hydrocarbons. A more likely explanation is that they are bacterial in origin since similar arrays of normal alkanes have been shown to be produced by bacteria (Han and Calvin, 1969). The Gelman type A filters used in this work are fairly coarse, making it possible that whole bacteria would be present in the filtered water.

The results for suspended matter (Table II-III) are similar to those for water. Several samples showed no detectable hydrocarbons. Most of the others showed arrays of hydrocarbons dominated by C-20 to C-32 normal alkanes with no odd carbon predominance. The only sample with a substantial concentration of unsaturates was the near bottom sample collected at 24 hours at CB-7, the Kachemak Bay time series station. Mass spectral analysis of this sample indicated that several of the unsaturates were terpenoid, possibly suggesting a contribution from Homer coal (see section III). But in the main the hydrocarbons associated with suspended matter in Cook Inlet appear to be bacterial and planktonic in origin. Observation of the normal array of hydrocarbons attributed to bacteria on suspended matter did not correlate with observation of that array in the filtered water. This may indicate the presence of more than one species of bacteria with different filtration characteristics.

Our inability to detect petroleum hydrocarbons in the vicinity of production platforms in upper Cook Inlet must be at least in part a reflection of the high degree of turbulent mixing that Cook Inlet's tidal currents produce. In a dye dispersion study carried out near Kenai in central Cook Inlet a dilution of 10^4 was observed within 25 m (Rosenberg *et al.*, 1969). When this dilution factor is extrapolated to the equivalent 10^{16} in 100 m it becomes obvious that hydrocarbons added to upper Cook Inlet's water column will be diluted below detectable levels in very short distances. However, this effect will be significantly attenuated in lower Cook Inlet where the tidal mixing is not nearly so intense.

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SECTION III. HYDROCARBONS IN LOWER COOK INLET BENTHIC ENVIRONMENTS

Introduction

We have continued our investigation of the kinds and amounts of hydrocarbons in intertidal and subtidal benthic organisms and sediment of Lower Cook Inlet. Analyses of subtidal animals and intertidal plants from this area were presented in the 1978 Annual Report of RU 275. Here we report additional plant analyses, intertidal and subtidal animal analyses and sediment analyses. From the results of the two years work we are able to make some inferences about the extent of movement of hydrocarbons in the food web of this region.

This work is related to petroleum development in two ways. First, it provides a body of data indicative of the ambient hydrocarbons present in the Lower Cook Inlet marine environment before petroleum exploration. This will be of use for comparisons during and after petroleum exploration and development. Second, it improves our understanding of the nature and extent of hydrocarbon transfer through some of the marine food webs of this region. This will allow qualitative prediction of transfer pathways which pollutant petroleum can be expected to take through Lower Cook Inlet food webs.

Methods

Sample Collection

The collection procedures and sites for all materials whose analyses are reported here have been tabulated in the 1978 annual report of RU 275. In this report only collection dates and descriptive names of collection sites are included.

Analytical Methods

Biota samples were thawed and diced into 1 cm^2 pieces, after appropriate shell/test removal. Aliquots were air dried for percent water determinations. All samples were spiked with an internal chrysene standard and most with a docosane standard, and blanks were run for all sample groups. Samples refluxed 24 hours in 150 ml aqueous 4N KOH or NaOH (limpets with 2N) and

100 ml hexane. After cooling, the samples were 3 x 100 ml hexane extracted, washed with saturated aqueous NaCl, and dried overnight in Na_2SO_4. Hexane extracts were subjected to column chromatography, gas chromatography and gas chromatography-mass spectrometry as described in section V.

Sediment samples were thawed and spiked with docosane and chrysene standards. The samples, with a blank, were 48-hour Soxhlet extracted with 150 ml each methanol and hexane, stirring the samples after the first 24 hours. The sediment was air dried for dry weights, and the solvents were 3 x 100 ml hexane extracted, washed with saturated aqueous NaCl, and dried in Na_2SO_4. The extracts were concentrated for column chromatography and elemental sulfur was removed with clean copper wire. Column chromatography with 10 g partially deactivated silica gel columns and subsequent GC-MS analyses followed the procedures for biota.

Diamond Gulch coal was ground with mortar and pestel and placed in a 50 ml centrifuge tube. To the sample and a blank, 20 ml each of aqueous 4N NaOH and hexane were added. The tubes were topped with telfon-lined caps and refluxed 2 hours in a 90°C water bath. After cooling, 3 x 15 minute centrifugations at 20,000 rpm were followed by 2 x 20 ml hexane extractions. Extracts dried over Na_2SO_4 overnight and were then concentrated for column chromatography using 10 g partially deactivated silica gel. Column chromatography and GC-MS analyses followed biota/sediment procedures.

Results

The kinds and amounts of saturated and unsaturated hydrocarbons in Lower Cook Inlet plants are shown in Tables III-I and III-II respectively. Tables III-III and III-IV give concentrations of saturated and unsaturated hydrocarbons in animals, while Tables III-V and III-VI show the results for sediments.

Discussion

Interpretation of the plant data of Tables III-I and III-II is best done together with results of determinations of hydrocarbons in algae of Lower Cook Inlet reported in the 1978 annual report of RU 275. Therefore, those results are reproduced here for comparison as Table III-VII.

TABLE III-I

SATURATED HYDROCARBONS IN LOWER COOK INLET PLANTS (μg g^{-1} DRY WEIGHT BASIS)

Species	*Agarum cribosun*	*Alaria* sp.	*Cymathere triplicata*	*Constantinea subulifera**	*Enteromorpha linea*	*Fucus distichus**	*Fucus distichus*	*Fucus distichus**
Date	11-11-77	05-05-77	06-22-77	05-05-77	05-04-77	05-06-77	05-02-78	05-02-78
Location	Station 41	Anchor Point	Dogfish Bay	Anchor Point	IBM	Homer Spit	Homer Spit	Homer Spit
Total saturates	2.08	40.1	30.1	36.4	15.1	7.9	16.7	10.8
14	.17	-	.79	-	.82	-	.10	-
15	.09	18.9	29.6	.10	10.2	3.88	12.7	9.49
16	-	-	-	.04	-	.08	.36	-
17	.26	.56	-	35.4	t	.29	.67	-
Pris.	-	-	-	-	-	.21	.35	-
18	.03	-	-	.05	-	.56	.37	-
Phyt.	-	-	-	-	-	.21	.18	-
19	-	-	-	.39	-	.90	.48	-
20	-	-	-	.04	-	.93	.36	-
21	.05	-	-	.05	.73	.64	.34	-
22	-	-	-	-	-	-	-	-
23	.05	-	-	.04	.73	-	.13	-
24	-	-	-	-	-	-	.07	-
25	-	-	-	-	1.63	-	.08	-
26	-	-	-	-	-	-	.05	-
27	-	-	-	-	.63	-	.08	-
28	-	-	-	-	-	-	.03	-
29	-	-	-	-	.33	-	.05	-
30	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	.06	-
32	-	-	-	-	-	-	-	-

TABLE III-I

CONTINUED

Species	*Halosaccion* sp.	*Lamiraria saccharina*	*Lamiraria saccharina*	*Zostera marina*	*Zostera marina*	*Zostera marina*
Date	06-26-77	05-07-77	05-06-77	05-04-77	06-25-77	06-23-77
Location	Douglas River	Diamond Gulch	NW-Spit	IBM	Iniskin Bay	Kasitsna Bay
Total Saturates	92.7	18.9	36.6	278.	887.	1800.
14	.24	-	-	.30	5.87	15.8
15	14.7	18.5	36.6	163.	723.	1610.
16	.42	-	-	2.61	5.15	6.82
17	75.0	-	-	66.3	111.	144.
Pris.	-	-	-	-	-	-
18	-	-	-	.97	1.48	1.10
Phyt.	-	-	-	-	-	-
19	-	-	-	31.9	37.0	29.3
20	-	-	-	-	-	-
21	-	-	-	4.03	3.60	5.87
22	-	-	-	-	-	-
23	.07	-	-	.96	.79	.84
24	-	-	-	.16	.57	.40
25	.14	-	-	-	-	-
26	-	-	-	-	-	-
27	.53	-	-	-	-	-
28	-	-	-	-	-	-
29	-	-	-	-	-	-
30	-	-	-	-	-	-
31	-	-	-	-	-	-
32	-	-	-	-	-	-

TABLE III-II

UNSATURATED HYDROCARBONS IN LOWER COOK INLET PLANTS (μg g^{-1} DRY WEIGHT BASIS)

Species	*Agarum cribosun*	*Alaria* sp.	*Cymathere triplicata*	*Constantinea subulifera**	*Enteromorpha linea*	*Fucus distichus**	*Fucus distichus*	*Fucus distichus**
Date	11-11-77	05-05-77	06-22-77	05-05-77	05-04-77	05-06-77	05-02-78	05-02-78
Location	Station 41	Anchor point	Dogfish Bay	Anchor Point	IBM	Homer Spit	Homer Spit	Homer Spit
Total Unsaturates	49.7	50.3	16.9	3.05	120.	69.8	157.	63.7
14:1	.10	-	-	-	-	-	-	-
16:1	-	-	-	-	-	-	-	-
16:3	-	-	.30	-	-	-	-	-
17:1	-	-	-	.16	10%	-	-	-
17:2	-	-	-	-	5.20	-	-	-
17:3	-	-	.06	-	-	-	-	-
19:5	-	-	-	-	-	-	-	-
19:6	-	-	-	-	-	-	-	-
21:5	19.1	47.7	9.81	-	-	-	-	-
21:6	25.2	19.9	5.40	-	2.80	30.6	116.	51.7
Sq.	3.69	1.81	1.33	2.40	4.42	19.0	40.2	12.0
Iosene	-	-	-	-	.52	-	-	-
Simonellite	-	-	-	-	.35	-	-	-
% H_2O	81.3%	88.6%	77.8%	93.3%	79.8%	93.6%	79.3%	86.6%

TABLE III-II

CONTINUED

Species	*Halosaccion* sp.	*Laminaria saccharia*	*Laminaria saccharia*	*Zostera marina*	*Zostera marina*	*Zostera marina*
Date	05-26-77	05-07-77	05-06-77	05-04-77	06-25-77	06-23-77
Location	Douglas River	Diamond Gulch	NW-Spit	IBM	Iniskin Bay	Kasitsna Bay
Total Unsaturates	9.64	33.9	26.9	7.70	8.59	33.3
14:1	-	-	-	-	-	-
16:1	.07	-	-	-	-	-
16:3	-	-	-	-	-	-
17:1	-	-	-	1.35	2.11	5.34
17:2	-	-	-		1.18	5.28
17:3	-	-	-	-	-	-
19:5	.43	-	-	-	-	-
19:6		-	-	-	-	-
21:5	-	-	-	4.16	1.86	16.7
21:6	3.97	32.1	25.1	-	-	-
Sq.	3.96	1.81	1.74	2.21	2.34	5.98
Iosene	-	-	-	-	-	-
Simonellite	-	-	-	-	-	-
% H_2O	82.4%	82.7%	86.9%	87.6%	86.3%	88.3%

TABLE III-III

SATURATED HYDROCARBONS IN LOWER COOK INLET ANIMALS (μg g^{-1} DRY WEIGHT BASIS)

Species	*Clinocardium nutalli*	*Collisella fenestrata*	*Collisella pelta*	*Collisella pelta*	*Collisella pelta**	*Collisella pelta*
Date	11-11-77	05-05-77	05-05--77	05-02-78	05-02-78	05-04-77
Location	Station 40	Anchor Point	Anchor Point	Homer Spit	Homer Spit	IBM
Total saturates	1.30	7.36	3.55	1550.	1510.	8.87
14	-	-	-	-	-	-
15	-	.72	-	2.54	3.11	.11
16	-	-	-	1.23	2.30	-
17	t	.14	-	2.71	t	.29
Pris.	.12	-	-	16.3	21.5	-
18	-	-	-	2.24	6.86	-
Phyt.	-	-	-	7.35	10.9	-
19	-	-	-	6.02	9.34	-
20	-	-	-	3.29	4.56	-
21	.22	-	-	10.3	124.	-
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	-	-	-	-	-	-
25	.03	-	-	-	-	-
26	-	-	-	-	-	-
27	.08	-	-	-	-	-
28	.14	-	-	-	-	-
29	.06	-	-	-	-	-
30	-	-	-	-	-	-
31	.05	-	-	-	-	-
32	-	-	-	-	-	-
F1 UCM	-	-	-	1420.	1390.	-

TABLE III-III

CONTINUED

Species	*Collisella scutum*	*Collisella scutum*	*Flustrella gigantea*	*Macoma balthica*	*Macoma balthica*	*Macoma nusuta*
Date	05-05-77	05-07-77	05-05-77	05-04-77	06-23-77	11-15-77
Location	Anchor Point	Diamond Gulch	Anchor Point	IBM	Kasitsua	Station 37
Total saturates	4.40	.78	1.55	42.6	18.9	134.
14	-	-	.52	-	-	-
15	1.89	t	.93	-	.17	t
16	-	-	-	.14	-	.07
17	.26	-	-	.24	.23	.06
Pris.	-	-	-	.28	.73	6.63
18	-	-	-	.14	-	.07
Phyt.	-	-	-	-	-	-
19	-	-	-	.27	-	.15
20	-	-	-	.29	-	-
21	-	-	-	.12	-	-
22	-	-	-	-	-	-
23	-	-	-	.79	-	-
24	-	-	-	.36	-	-
25	-	-	-	.96	-	-
26	-	-	-	.34	-	-
27	-	-	-	1.71	-	-
28	-	-	-	.21	-	-
29	-	-	-	1.40	-	-
30	-	-	-	-	-	-
31	-	-	-	.92	-	-
32	-	-	-	-	-	-
F1 UCM	-	-	-	33.0	-	-

TABLE III-III

CONTINUED

Species	*Modiolus modiolus*	*Mytilus edulis*	*Mytilus edulis*	*Mytilus edulis*	*Neptunea lyrata*	*Nucella lima*
Date	05-05-77	05-05-77	05-04-77	06-23-77	11-16-77	05-05-77
Location	Anchor Point	Anchor Point	IBM	Kasitsna	Bluff Station	Anchor Point
Total saturates	4.02	.67	11.6	1.34	.89	.55
14	-	-	-	-	-	-
15	-	.07	t	.47	-	-
16	-	-	t	-	-	-
17	-	.08	.25	.30	t	-
Pris.	.08	.18	.18	t	.17	.55
18	-	-	.78	-	-	-
Phyt.	-	-	.32	-	-	-
19	-	-	.77	-	-	-
20	-	-	.33	-	-	-
21	-	-	.23	-	-	-
22	-	-	-	-	-	-
23	-	-	-	-	.03	-
24	-	-	-	-	.04	-
25	-	-	-	-	.05	-
26	.04	-	-	-	.04	-
27	.25	-	-	-	.07	-
28	.52	-	-	-	.04	-
29	.71	-	-	-	.03	-
30	.87	-	-	-	-	-
31	.88	-	-	-	-	-
32	.63	-	-	-	-	-
F1 UCM	-	-	7.84	-	-	-

TABLE III-III

CONTINUED

Species	*Nucella lima*	*Strongylocentrotus droebachiensis*	*Strongylocentrotus droebachiensis*	*Strongylocetrotus droebachiensis*
Date	05-04-77	05-05-77	11-16-77	05-07-77
Location	IBM	Anchor Point	Bluff Station	Diamond Gulch
Total saturates	N.D.	3.06	20.7	27.6
14	-	-	-	-
15	-	.48	-	1.51
16	-	-	-	-
17	-	t	-	1.28
Pris.	-	.67	1.28	.97
18	-	-	-	-
Phyt.	-	-	-	-
19	-	-	-	-
20	-	-	-	-
21	-	-	-	-
22	-	-	-	-
23	-	.05	.96	.42
24	-	.09	.40	.23
25	-	.06	1.73	1.18
26	-	.14	.57	.40
27	-	.77	1.58	7.28
28	-	-	t	-
29	-	.33	1.01	5.24
30	-	-	-	-
31	-	.12	.41	.98
32	-	-	-	-
F1 UCM	-	-	-	-

TABLE III-IV

UNSATURATED HYDROCARBONS IN LOWER COOK INLET ANIMALS ($\mu g\ g^{-1}$ DRY WEIGHT BASIS)

Species	*Clinocardium nutalli*	*Collisella fenestrata*	*Collisella pelta*	*Collisella pelta*	*Collisella pelta**	*Collisella pelta*
Date	11-11-77	05-05-77	05-05-77	05-02-78	05-02-78	05-04-77
Location	Station 40	Anchor Point	Anchor Point	Homer Spit	Homer Spit	IBM
Total unsaturates	1.24	156.	160.	251.	591.	33.2
14:1	-	-	-	-	-	-
15:1	-	-	-	-	-	1.90
17:1	-	-	-	-	-	.12
18:1	-	-	-	-	-	-
19:1	-	-	-	-	-	-
20:2	-	-	-	-	-	.90
21:5	-	-	-	-	-	-
21:6	.17	.62	33.3	5.84	27.2	.66
27:6	-	2.00	5.27	-	-	.45
Sq.	-	20.6	18.3	21.2	20.5	1.03
Iosene	-	-	-	-	-	-
Simonellite	-	-	-	-	-	-
F2 UCM	-	-	-	220.	309.	-
% H_2O	80.9%	75.6%	75.1%	76.6%	72.2%	75.1%

TABLE III-IV

CONTINUED

Species	*Collisella scutum*	*Collisella scutum*	*Flustrella gigantea*	*Macoma balthica*	*Macoma balthica*	*Macoma nusuta*
Date	05-05-77	05-07-77	05-05-77	05-04-77	06-23-77	06-23-77
Location	Anchor Point	Diamond Gulch	Anchor Point	IBM	Kasitsna	Station 37
Total unsaturates	65.9	39.2	1.63	50.4	20.3	221.
14:1	-	-	-	-	-	-
15:1	t	t	-	-	.20	2.04
17:1	.32	-	-	-	.31	-
18:1	13.22	7.02	-	-	-	-
19:1	-	-	-	-	.86	1.13
20:2	-	.05	-	-	-	-
21:5	-	-	.49	-	-	-
21:6	3.67	1.11	-	7.48	1.76	40.4
27:6	.67	.11	-	-	-	-
Sq.	15.4	4.13	-	-	-	-
Iosene	-	-	-	-	-	-
Simonellite	-	-	-	4.22	-	-
F2 UCM	-	-	-	-	-	-
% H_2O	74.6%	77.0%	85.3%	79.7%	79.3%	84.4%

TABLE III-IV

CONTINUED

Species	*Modiolus modiolus*	*Mytilus edulis*	*Mytilus edulis*	*Mytilus edulis*	*Neptunea lyrata*	*Nucella lima*
Date	05-05-77	05-05-77	05-04-77	06-23-77	11-16-77	05-05-77
Location	Anchor Point	Anchor Point	IBM	Kasitsna	Bluff Station	Anchor Point
Total unsaturates	19.5	6.89	16.0	12.3	4.12	4.40
14:1	-	-	-	-	-	-
15:1	-	-	-	.15	-	-
17:1	-	-	-	.08	-	-
18:1	-	-	-	-	-	-
19:1	-	-	-	.15	-	-
20:2	-	-	-	-	-	-
21:5	-	-	-	-	-	-
21:6	-	4.13	6.91	1.28	-	.49
27:6	-	-	-	-	-	-
Sq.	1.36	-	-	-	.97	3.14
Iosene	-	-	t	-	-	-
Simonellite	-	-	.17	-	-	-
F2 UCM	-	-	-	-	-	-
% H_2O	75.3%	86.8%	84.7%	82.1%	68.9%	81.7%

TABLE III-IV

CONTINUED

Species	*Nucella lima*	*Strongylocentrotus droebachiensis*	*Strongylocentrotus droebachiensis*	*Strongylocetrotus droebachiensis*
Date	05-04-77	05-05-77	11-16-77	05-07-77
Location	IBM	Anchor Point	Bluff Station	Diamond Gulch
Total unsaturates	19.7	86.6	39.5	578.
14:1	-	-	-	-
15:1	-	-	-	-
17:1	-	-	-	-
18:1	-	-	-	-
19:1	-	-	-	-
20:2	-	-	-	-
21:5	-	-	-	-
21:6	8.39	-	-	-
27:6	-	-	-	-
Sq.	8.62	66.9	13.8	487.
Iosene	-	.11	.37	1.50
Simonellite	-	-	t	-
F2 UCM	-	-	-	-
% H_2O	79.4%	79.2%	68.9%	79.2%

TABLE III-V

SATURATED HYDROCARBONS IN LOWER COOK INLET SEDIMENTS AND COAL

Sample	Intertidal sediment	Intertidal sediment	Supralittoral sediment	Coal
Date	05-04-77	06-23-77	05-04-77	11-16-77
Location	IBM	Kasitsna	IBM	Diamond Gulch
Total saturates	31.7	.60	570.	443.
Fl UCM	-	-	105.	-
14	-	t	-	-
15	-	.01	-	-
16	-	.01	-	-
17	-	.01	-	-
Pr.	-	.02	-	-
18	-	.01	-	-
Ph.	-	-	-	-
19	-	.02	-	-
20	.12	-	4.64	-
21	.52	.10	53.0	4.60
22	.20	-	13.8	5.92
23	-	.02	63.3	16.7
24	.42	.01	10.6	7.33
25	1.17	.07	52.0	19.1
26	.42	-	10.2	10.4
27	2.57	.04	42.9	28.0
28	-	-	11.7	-
29	-	.04	50.8	63.0
30	-	-	-	-
31	-	.04	20.2	67.2
32	-	-	-	7.68

TABLE III-VI

UNSATURATED HYDROCARBONS IN LOWER COOK INLET SEDIMENTS AND COAL

Sample	Intertidal sediment	Intertidal sediment	Supralittoral sediment	Coal
Date	05-04-77	06-23-77	05-04-77	11-16-77
Location	IBM	Kasitsna	IBM	Diamond Gulch
Total unsaturates	103.	3.33	261.	512.
19:3	-	.01	-	-
20:2	-	.20	-	-
21:4	-	.03	-	-
21:5	-	1.05	-	-
21:6	-		-	-
24:4	.22	-	-	-
24:5	.21	-	-	-
Sq.	-	.54	-	-
C_1 Phenanthere	-	.40	-	-
Cadalene MW 198	3.80	t	-	28.1
Retene MW 234	3.17	-	.76	20.1
Tetrahydroretene MW 238	-	-	10.3	-
Simonelite MW 252	38.2	.10	-	43.4
Dehydrobietin MW 256	2.54	-	-	-
Fichtelite MW 262	-	-	1.37	10.4
Dehydrobietane MW 270	3.19	-	-	18.9
Iosene MW 274	5.11	.05	9.44	59.2
F2 UCM	-	-	39.6	-
% H_2O	31.1%	25.2%	80.3%	16.9%

TABLE III-VII

HYDROCARBONS OF COOK INLET BIOTA (μg/g)

Species	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*
Location	Cottonwood Bay	Diamond Gulch (1)	Diamond Gulch (2)	Dogfish Bay	Douglas River	IBM (1)
Total Saturates	22.5	594.	308.	78.3	36.4	296.
Total Unsaturates	165.	3420.	1860.	229.	109.	1206.
C_{15}	22.5	594.	308.	78.3	36.4	296.
C_{16}	-	-	-	-	-	-
C_{17}	-	-	-	-	-	-
Prist.	-	-	-	-	-	-
C_{18}	-	-	-	-	-	-
Phyt.	-	-	-	-	-	-
C_{19}	-	-	-	-	-	-
C_{20}	-	-	-	-	-	-
C_{21}	-	-	-	-	-	-
C_{22}	-	-	-	-	-	-
C_{23}	-	-	-	-	-	-
C_{24}	-	-	-	-	-	-
C_{25}	-	-	-	-	-	-
C_{26}	-	-	-	-	-	-
C_{27}	-	-	-	-	-	-
C_{28}	-	-	-	-	-	-
C_{29}	-	-	-	-	-	-
C_{30}	-	-	-	-	-	-
C_{31}	-	-	-	-	-	-
C_{32}	-	-	-	-	-	-
$C_{19:4}$	1.0	-	-	2.0	1.6	17.2
$C_{19:5}$	-	-	-	-	-	-
$C_{21:6}$	109.	2800.	1520.	155.	90.6	1504.
Sq.	54.1	585.	335.	70.1	8.2	127.

TABLE III-VII

CONTINUED

Species	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*	*Fucus distichus*
Location	IBM (2)	Iniskin Bay	Kasitsna Bay	N.W. Spit (1)	N.W. Spit (2)	Oil Bay
Total Saturates	32.5	28.5	22.7	18.6	36.0	29.2
Total Unsaturates	219.	97.9	122.7	33.7	46.9	17.1
C_{15}	32.5	28.5	22.7	18.6	23.3	29.2
C_{16}	-	-	-	-	-	-
C_{17}	-	-	-	-	-	-
Prist.	-	-	-	-	-	-
C_{18}	-	-	-	-	-	-
Phyt.	-	-	-	-	-	-
C_{19}	-	-	-	-	-	-
C_{20}	-	-	-	-	-	-
C_{21}	-	-	-	-	-	-
C_{22}	-	-	-	-	.12	-
C_{23}	-	-	-	-	.38	-
C_{24}	-	-	-	-	.65	-
C_{25}	-	-	-	-	.98	-
C_{26}	-	-	-	-	1.22	-
C_{27}	-	-	-	-	1.65	-
C_{28}	-	-	-	-	1.51	-
C_{29}	-	-	-	-	2.23	-
C_{30}	-	-	-	-	1.33	-
C_{31}	-	-	-	-	1.78	-
C_{32}	-	-	-	-	.72	-
$C_{19:4}$	-	1.6	0.7	-	-	1.1
$C_{19:5}$	-	-	-	-	-	-
$C_{21:6}$	199.	85.2	49.2	21.0	27.4	9.3
Sq.	19.0	10.4	50.3	12.5	19.0	6.6

TABLE III-VII

CONTINUED

Species	*Fucus distichus*	*Desmarestia aculeata*	*Desmarestia aculeata*	*Halosaccion glandiforme*	*Palmeria palmata*	*Constantinea subulifera*
Location	Homer Spit	Diamond Gulch	N.W. Spit	Douglas River	Anchor Point	Anchor Point
Total Saturates	153.	1.42	.21	2.2	26.8	27.1
Total Unsaturates	276.	68.6	39.1	.85	.29	40.0
C_{15}	22.7	.85	.05	–	.06	–
C_{16}	.42	–	–	–	.07	–
C_{17}	1.06	.57	.16	1.8	26.7	13.1
Prist.	.79	–	–	–	–	–
C_{18}	1.66	–	–	–	–	–
Phyt.	.80	–	–	–	–	–
C_{19}	3.44	–	–	–	–	.38
C_{20}	5.70	–	–	–	–	–
C_{21}	4.06	–	–	.28	–	.26
C_{22}	3.08	–	–	–	–	.17
C_{23}	1.74	–	–	–	–	.48
C_{24}	1.15	–	–	–	–	.19
C_{25}	.97	–	–	–	–	.48
C_{26}	.85	–	–	–	–	.21
C_{27}	.99	–	–	.16	–	.97
C_{28}	.80	–	–	–	–	.26
C_{29}	–	–	–	–	–	1.57
C_{30}	–	–	–	–	–	–
C_{31}	–	–	–	–	–	1.67
C_{32}	–	–	–	–	–	.27
$C_{19:4}$	–	–	–	–	–	–
$C_{19:5}$	3.00	3.2	5.3	.03	.05	–
$C_{21:6}$	112.	51.3	31.2	.44	–	–
Sq.	99.0	14.1	2.6	.38	.24	1.08

Enteromorpha linza was the only Chlorophyta (green alga) examined. The hydrocarbons of *E. linza* were dominated by heptadecene (17:1) which the 79% of the total. Heptadecene was not detected in any of the other algae analyzed in this study. In other studies (Youngblood *et al.* 1971, Youngblood and Blumer 1973) heptadecene has been found to be dominant only in *Enteromorpha* and *Ulva*, two genera of the order Ulotrichales. Among the normal hydrocarbons of *E. linza*, pentadecane (15) was the most abundant being 8% of the total hydrocarbons.

Four species from Rhodophyta (red algae) have been examined during the last two years: *Constantinea subulifera, Halosaccion* sp., *Halosaccion glandiforme,* and *Palmeria palmata.* In each of these algae the most abundant single compound was heptadecane (17) which ranged from 20% to 99% of the total hydrocarbons in the five samples analyzed. The sample of *C. subulifera* which contained only 20% heptadecane, contained a substantial amount of exogenous hydrocarbons (see below). Among the other samples of red algae the heptadecane range was 59% to 99%.

Six species of brown algae (Phaeophyta) have been analyzed: *Agarum cribosum, Alaria* sp., *Cymathere triplicata, Desmarestia aculeata, Fucus distichus,* and *Laminaria saccharina.* The chief saturated hydrocarbon of these brown algae was pentadecane which was present in all specimens exmined and was the only saturated hydrocarbon present in several samples of *F. distichus.* The only exception to this was *D. aculeata* in which pentadecane and heptadecane were present in comparable amounts. Heneicosahexaene (21:6) was also present in all of the brown algae analyzed, often as the most abundant single hydrocarbon. This compound was present in minor amounts if at all in the green and red algae. Heneicosapentaene (21:5) was also present in *A. cribosum, Alaria* sp., and *C. triplicata.* These two polyolefins have previously been reported in numerous marine algae (Youngblood *et al.* 1971, Youngblood and Blumer 1973, Rossi *et al.* 1978, Blumer *et al.* 1970).

The angiosperm *Zostera marina* has also been examined. Pentadecane (15) was the most abundant hydrocarbon. Heptadecane (17), nonadecane (19) and other normal alkanes were also present in substantial concentrations.

Samples of *D. aculeata, F. distichus, L. saccharina* and *Z. marina* were each collected at more than one location. The results for these samples show a considerable degree of intraspecific qualitative similarity but substantial quantitative variation. Some of this variability may be related to the collection sites, however, the primary cause is probably differences in plant age or vigor since rapidly growing plants and tissues have been shown to have higher hydrocarbon concentrations than mature ones (Youngblood and Blumer, 1973). Thus replicate analyses of *F. distichus* from Diamond Gulch, Homer's inner bay Mudflat (IBM) and the northwest spit at Homer each show levels of variation similar to that between *F. distichus* samples from different locations.

Squalene was identified in every specimen examined in this study. This compound was reported among the hydrocarbons of *Macrocystis pyrifera* (Rossi *et al.*, 1978) but not in any of the Atlantic algae examined by Blumer and his co-workers (Clark and Blumer, 1967; Youngblood *et al.*, 1971, Youngblood and Blumer, 1973). However, this apparent difference is probably attributable to a difference in the column chromatography step of the sample preparation procedure. In Blumer's laboratory, collection of the eluate from column chromatography was halted shortly before the breakthrough of the first pigmented band (Youngblood *et al.*, 1971). This probably left squalene (a C_{30} hexaene) on the column. However, the column chromatography procedure used in this study (which has been designed to elute five ring aromatics) eluted a considerable amount of pigment and, obviously, squalene.

It seems quite clear that the hydrocarbons discussed so far are products of endogenous biosynthesis of the algae. Now hydrocarbons which appear to be exogenous in origin will be considered. An *F. distichus* specimen [N. W. Spit (2) of Table III-VII] contains minor amounts of all normal alkanes from docosane through dotriacontane with a predominance of odd carbon chain lengths. While similar arrays have been observed in *Fucus* and other algae (Clark and Blumer, 1967; Youngblood *et al.*, 1971). in the present study only this one sample from sixteen *F. distichus* specimens analyzed showed these hydrocarbons. Other materials from the marine environment have been found to contain similar arrays: water collected from the surface microlayer (Marty and Saliot, 1976) and mixed zooplankton (Calder, 1976). Based on this apparently sporadic occurrence in various algal and other marine materials we suspect that the source of this array of normal hydrocarbons may be bacterial. This suspicion is reinforced by the finding of quite similar arrays of hydrocarbons in some bacterial cultures (Han and Calvin, 1969).

Three samples, *C. subulifera* (Table III-VII) and the two *F. distichus* collected at the end of Homer Spit in 1977 and 1978 (Table III-I and III-VII), showed saturated hydrocarbons that might have been associated with exogenous coatings of the plant materials. To examine this possibility additional plant material from those collections was rinsed copiously with distilled water and reanalyzed (samples noted with asterix). In each case several components were reduced or removed. The unwashed specimen of *Constantinea subulifera* showed normal hydrocarbons from nonadecane (19) through dotiacontane (32) with a marked dominance of odd carbon chain lengths. Also present in the unwashed *C. subulifera* two terpenoid hydrocarbons: retene, 9.9 μg g^{-1} and simonellite, 6.7 μg g^{-1}. Both of these compounds as well as the odd chain length normal alkanes are associated with terrigenous plant materials (Simoneit, 1977). These compounds are characteristic of detrital coal and intertidal muds of the Anchor Point - Homer area (Table III-VI). Their reduction or removal in the corresponding washed specimen (Table III-I) indicates that most of this material was easily removed and therefore probably external. The apparent 3-fold increase in heptadecane concentration in *C. subulifera* can be attributed to variation between plants or among the tissues of a single plant discussed above. Both unwashed specimens of *Fucus distichus* collected at the end of Homer Spit (Tables III-I and III-VII) near a boat harbor, contained a suite of normal hydrocarbons from hexadecane (16) through at least octacosane (28), the acyclic isoprenoids pristane (Pr) and phytane (Ph) and substantial complex unresolved mixtures. Together these characteristics strongly suggest petroleum pollution, probably as fuel lost at the adjacent boat harbor. Rinsing of these *F. distichus* with distilled water removed most of the petroleum hydrocarbons (Table III-I) indicating that little if any of this material was actually incorporated into the plants.

The hydrocarbons of animals of Lower Cook Inlet show considerable variety (Tables III-III and III-IV). Three species of limpet, *Collisella fenestrata*, *C. pelta* and *C. scutam* were analyzed. All species (although not every specimen) contained pentadecane (15), heptadecane (17), heneicosahexaene (21:6) and squalene, compounds prevalent in benthic algae. This is not surprising in view of the fact that *Collisella* are herbivorous, grazing algae from intertidal rocks. All of these hydrocarbons are commonly found in benthic algae of the area (Tables III-I, III-II and III-VII). The *C. pelta* collected at Homer Spit contained all of the normal alkanes pentadecane (15) through heneicosane (21), pristane (pr.), phytane (ph) and unresolved complex mixtures (UCM) in both fractions. This array of hydrocarbons is indicative of fuel oil; a very similar array was found in *Fucus distichus* collected at the same location. Washing of the shucked *C. pelta* prior to analysis did not markedly change the concentrations of these compounds. This suggests that petroleum hydrocarbons were not associated with the foot and mantle margin but that saturated and unsaturated hydrocarbons foreign to the species were either adhering tightly to the outer membranes or had passed through them. This incorporation of petroleum hydrocarbons into an animal is in marked contrast to the situation in plants discussed above in which petroleum hydrocarbons appear to be predominantly on the outer surface.

Flustrella gigantea a bryozoan fed upon by juvenile crabs, contains only tetradecane (14) pentadecane (15) and heneicosapentaene (21:5) all of which are probably algal in origin.

Two species of the deposit feeding bivalve genus *Macoma* have been examined. The *M. balthica* from the inner bay mudflat (IBM) at Homer (Tables III-III and III-IV) contain an array of hydrocarbons which closely reflects the sediment in which those animals live (Tables III-V and III-VI). These include pentadecane (15), hexadecane (16), heptadecane (17), octadecane and pristane (pr) whose probable origins are algae and zooplankton detritus (Avigan and Blumer, 1968). Also present in both the sediment and *M. balthica* of the inner bay mudflat are odd carbon chain length normal alkanes with 21-31 carbon atoms and the diterperoid simonellite. These compounds are all related to terrigenous plants (Simoneit, 1977) and are also found in abundance in coal of the Homer area (Table III-V and III-VI).

Two species of filter feeding mussels, *Modiolus modiolus* and *Mytilus edulis* were also examined. All specimens contained pristane, suggesting that planktonic material was being taken as food. All three samples of *M. edulis* also contained pentadecane (15) heptadecane (17) heneicosahexaene (21:6) indicating that this species was feeding on algae. The single specimen of *M. modiolus* showed a group of normal alkanes ranging from hexacosane (26) through dotriacontane (32) suggesting possible bacteria contamination. The *M. edulis* collected at Homer's inner bay mudflat contained all normal alkanes pentadecane (15) through heneicosane (21), pristane, phytane, and unresolved complex mixture (UCM); an array of hydrocarbons indicative of the presence of fuel oil perhaps as the result of pollution from the nearby town and boat harbor. The finding of petroleum contamination in the filter feeding *M. edulis* is of particular note in light of the fact that the deposit feeder *Macoma balthica* collected at the same location contained little or no petroleum as judged by the absence of a detectable amount of phytane.

Figure III-1 presents portions of the gas chromatogrous of *M. edulis* (above) and *M. balthica* (below) which show the different hydrocarbon arrays. *M. edulis* clearly contains the normal alkanes, pristane and phytane. These compounds are reduced or absent in *M. balthica's* chromatogram which instead contains diterperoids with retention indicies 1910, 1940, 1960 and 1980. The most abundant of these, 1980 is simonellite which was discussed above. It appears that petroleum pollution in the inner bay mudflat primarily occurs as hydrocarbons disolved or dispersed in the water column since they are taken up by a filter feeder but not a deposit feeder. In contrast, fossil hydrocarbons from coal are associated only with the deposit feeder and hence appear to enter the system as detrital sediments. It should also be noted that both *M. edulis* and *M. balthica* collected at Kasitsna Bay, an area of less human activity and no known coal outcrops, contain biogenic hydrocarbons only.

Gastropod mollusks of the species *Neptunea lyrata* and *Nucella lima* were assayed for hydrocarbons. These predators contained only low levels of biogenic hydrocarbons. This was true even of a sample of *N. lima* obtained in Homer's inner bay mudflat.

Three samples of the urchin *Strongylocentrotus droebachiensis* were also examined. On shucking, most of the individuals analyzed revealed the presence of black mineral material believed to be coal within the test. However, the hydrocarbon contents of these animals gave only equivical evidence of coal.

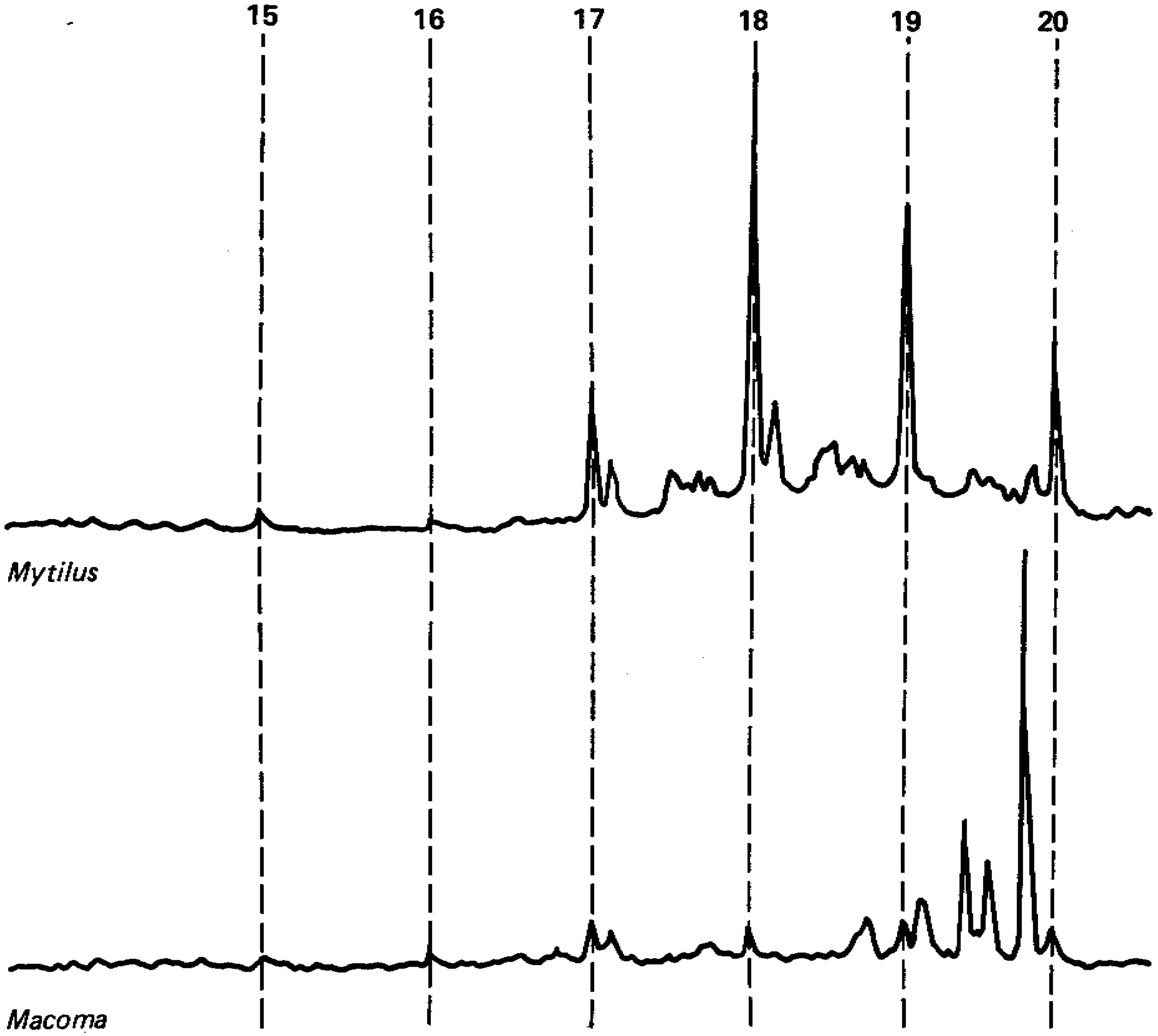

Figure III-1. Comparison of portions of gas chromatograms of *Mytilus edulis* and *Macoma balthica* from Homer's inner bay mudflat.

The normal hydrocarbon arrays were in keeping with coal (Tables III-III and III-V), but only a trace of simonellite, an abundant hydrocarbon in the coal (Table III-VII was detected in one of the *S. droebachiensis*).

These analyses provide clear examples of the uptake of fossil hydrocarbons by marine animals of the Lower Cook Inlet area. There are also examples of the transfer of biogenic hydrocarbons from one trophic level to another. Although this work has not provided an example of food chain transfer of fossil hydrocarbons, it seems probable that this also occurs.

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SECTION IV. HYDROCARBONS IN BEAUFORT SEA BIOTA

Introduction

In the summer of 1977 a suite of sediment samples from the nearshore Beaufort Sea was collected for hydrocarbon analysis. We found that in addition to aliphatic hydrocarbons of biogenic origin these sediments contained aromatic hydrocarbons of both fossil and combustion origin (1978 Annual Report of RU 275, Shaw *et al.*, 1979). Given the presence of aromatic hydrocarbons in Beaufort Sea sediments it is of importance to determine whether these compounds are being transferred to the biota of the area.

In the summer of 1978 a suite of biota samples was collected from the nearshore Beaufort Sea to be analyzed with special attention given to the aromatic fraction. Information from this effort will be relevant to petroleum development since it will document the levels of aromatic and aliphatic hydrocarbons in Beaufort Sea biota and make possible comparison of levels in organisms collected in areas where offshore oil exploration has and has not already taken place. This work should also provide information about the extent of hydrocarbon uptake and food web transfer at low temperature conditions.

Methods

Biological samples for this work were collected at 20 locations in the coastal Beaufort Sea between Barrow and Flaxman Island in August 1978. The primary collection tool was the otter trawl. Traps, graps and dredges were also used. Samples were frozen aboard ship and returned to Fairbanks for analysis.

Results

Analysis of these materials is just beginning; results will be reported at a later time.

TABLE IV-I

BIOTA COLLECTED IN THE NEARSHORE BEAUFORT SEA, AUGUST 1978

Station	Species	Amount
Elson Lagoon	*Portlandia* sp., *Psephidia lordi*	4 oz
71° 17.5'N	*Astarte montagui, Astarte borealis*	4 oz
156° 20.8'W	Polychaetes	8 oz
Dease Inlet		
71° 07.0'N	*Mysis littoralis*	1 oz
155° 22.3'W	*Astarte montagui, Portlandia* sp.	1 gm
Smith Bay		
70° 58.6'N	*Astarte borealis, Portlandia* sp.	1 oz
154° 30.1'W	*Pontoporeia affinis, Onisimus glacialis*	1 gm
	Boeckosimus glacialis, Pontoporeia femorata	1 gm
Pitt Point	*Astarte borealis, Astarte montagui*	1.5 oz
70° 56.5'N	Polychaetes	2 gm
153° 15.3'W	*Saduria entomon*	1.5 oz
	Monoculodes sp., *Acanthostepheia behringiensis*	1 gm
	Onisimus glacialis, Boeckosimus affinis	1 gm
Atigaru Pt.	*Saduria entomon*	2 oz
70° 36.7'N	*Mysis littoralis*	1.5 oz
151° 33.5'W	*Astarte borealis, Portlandia* sp., *Psephidia lordi*	1 gm
Harrison Bay	*Saduria entomon*	2 oz
70° 31.5'N 151° 08.7'W	*Acanthostepheia behringiensis, Onisimus glacialis, Pontoporeia femorata, Boeckosimus affinis*	2 gm

TABLE IV-I

CONTINUED

Station	Species	Amount
Colville Delta		
70°35.5'N	*Astarte montagui, Astarte borealis,*	
150°25.0'W	*Portlandia* sp.	
Thetis Island		
70°32.7'N	*Acanthogammarus loricatus*	2 gm
150°09.7'W		
Oliktok Point	*Mysis littoralis*	1 oz
70°32.0'N	*Psephidia lordi, Astarte borealis,*	
149°55.5'W	*Astarte montagui*	2 gm
Pingok Point	*Saduria entomon*	12 oz
70°33.8'N	*Pontoporeia affinis, Onisimus glacialis,*	
149°30.0'W	*Boeckosimus affinis, Monoculodes* sp.	1 oz
Egg Island		
70°27.1'N	*Mysis littoralis*	1 gm
148°43.7'W	*Saduria entomon*	1.5 oz
Stump Island		
70°24.1'N	*Mysis littoralis*	1 gm
148°32.6'W	*Saduria entomon*	8 oz
Cross Island	*Saduria entomon*	32 oz
70°30.0'N	*Mysis littoralis*	2 g
148°04.0'W	*Melaenis lordi, Priapulus caudatus*	1 oz

TABLE IV-I

CONTINUED

Station	Species	Amount
McLune Island		
70°21.2'N	*Saduria entomon*	8 oz
147°22.5'W		
Tigvaviak Island	*Astarte borealis, Astarte montagui*	2 gm
70°16.1'N	*Priapulus caudatus, Melaenis lordi*	3 gm
147°38.0'W	*Saduria entomon*	4 oz
Stockton Island		
70°18.1'N	*Saduria entomon*	16 oz
147°02.0'W		
Mickelson Bay	*Mysis littoralis*	2 gm
70°10.6'N	Polychaetes	1 gm
147°00.0'W	*Saduria entomon*	8 oz
	Asteria borealis, Portlandia sp.	1 gm
Challenge Entrance	*Mysis littoralis*	4 gm
70°12.2'N	*Saduria entomon*	16 oz
146°41.4'W	*Astarte borealis, Astarte montagui, Portlandia* sp.	3 gm
	Acanthogammarus borealis, Monoculodes sp.	1 gm
Point Hobson		
70°11.8'N	*Mysis littoralis*	3 gm
146°27.2'W	*Saduria entomon*	20 oz
Flaxman Island		8 oz
70°11.2'N	*Saduria entomon*	3 gm
146°05.8'W	*Mysis littoralis*	

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SECTION V. ANALYTICAL QUALITY CONTROL PROCEDURES

Introduction

In all scientific measurements it is necessary to establish the level of analytical precision and to compare measurements made in different laboratories. This need is especially great in the OCSEAP hydrocarbon measurements in which several laboratories are using non-standard and non-routine techniques to measure trace concentration of hydrocarbons in the marine environment.

In addition to routinely running "blank" analyses and internal and external calibration standards we have used the "draft BLM performance criteria" proposed by the Hydrocarbon Methodology Review Group to assess the recovery and precision of our column chromatography and gas chromatography procedures. We have also participated in round robin sediment analysis coordinated by the NMFS National Analytical Facility.

Methods

Column chromatography is performed using silica gel deactivated with 5-8% water. Two column configurations are used. For environmental samples which have yielded less than 15 mg extractable lipids 5 g of silica is packed in a 9 mm column. For larger extracts 10 gm of silica is packed in an 11 mm column. Two fractions are eluted. For the smaller column, the first fraction is 10 ml of hexane and the second 15 ml of 20% dichloromethane in hexane for the second fraction. Elution volumes are doubled for the larger column system. These elution volumes are approximate; each batch of silica gel is calibrated by elution of an aliphatic and aromatic standard. Elution volumes and/or percent water used to deactivate the silica are then adjusted.

Gas chromatography is performed on a Hewlett Packard 5710A instrument using 50 m x 0.7 mm support coated open tubular columns coated with OV-101. Carrier gas is helium flowing at 10 ml/minute with an addition 30 ml/minute of helium as makeup gas at the flame ionization detector. The column is temperature programmed from 70° to 270° at 8°/minute while the injector and detector are held at 300°.

Quantification was accomplished with Hewlett Packard 3380 or 3385 digital integrators using internal and external quantative standards and adjusting reported results for percent recovery. Quantification of unresolved complex mixtures was by planimetry. Results were reported as μg/g on a dry weight basis. Peak identifications are based on the use of external standards and gas chromatography-mass spectrometry.

Results:

Table V-I shows the results of column chromatography performance checks. Table V-II shows the concentrations of hydrocarbons in three analyses of an intercalibration sediment.

TABLE V-I

RECOVERY OF HYDROCARBONS IN INTRALABORATORY COLUMN CHROMATOGRAPHY CHECKS

	Percent Recovery		
Compound	Replicate 1	Replicate 2	Replicate 3
Check Number 1			
tridecane	100	90	70
heptadecane	100	91	73
octadecane	108	98	79
docosane	114	108	86
octacosane	115	99	79
dotriacontane	130	110	83
naphthalene	77	90	81
biphenyl	80	94	86
phenanthrene	91	107	94
fluoranthene	99	114	99
Check Number 2			
tetradecane	89	95	92
heptadecane	94	100	98
octadecane	95	106	105
docosane	98	100	97
octacosane	95	98	91
dotriacontane	82	91	86
anthracene	63	61	58

TABLE V-II

HYDROCRABONS IN REFERENCE SEDIMENT

(Extract prepared as describes in Section III)

Compound	Triplicate		
	No. 1	No. 2	No. 3
C_{15}	.068	.027	.021
C_{16}	.065	.049	.034
C_{17}	.068	.060	.051
Pristane	.084	.080	.075
C_{18}	.084	.071	.068
Phytane	.065	.057	.056
C_{19}	.124	.102	.104
C_{20}	.094	.076	.072
C_{21}	.063	.060	.061
C_{22}	.073	.064	.073
C_{23}	.060	.048	.055
C_{24}	.063	.065	.074
C_{25}	.078	.085	.092
C_{26}	.096	.100	.070
C_{27}	.103	.112	.125
Total Resolvable peaks	1.188 ppm	1.056 ppm	1.031 ppm
Total envelope	51.08 ppm	54.48 ppm	55.58 ppm
Dry sediment	42.9 g	43.7 g	41.5 g
Wet sediment	59.8 g	60.7 g	60.9 g

TABLE V-II

CONTINUED

Compound	Triplicate		
	No. 1	No. 2	No. 3
Phenanthrene	0.59	1.51	0.43
C_1-phenanthrene	0.21	0.10	0.07
4-5 methylenephenanthrene	-	0.19	0.09
Fluoranthene	0.48	1.84	0.79
Pyrene	0.46	1.74	0.75
C_1 fluoranthrene/pyrene	-	0.29	0.09
$C_{16}H_{10}S$ MW234	-	0.16	0.09
Chrysene	0.54	1.66	0.68
Chrysene and isomers	-	-	-
Perylene and isomers	0.79	2.61	1.66
Anthanthrene and isomers	-	0.55	0.54
Total	3.07	10.76	8.59

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CHARACTERIZATION OF ORGANIC MATTER IN SEDIMENTS FROM GULF OF ALASKA, BERING AND BEAUFORT SEAS

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I. Summary

Sediments were collected from the proposed lease areas of Beaufort Sea, Norton Sound, Kodiak Shelf and Cook Inlet during 1976-1978 and analyzed for total carbon, organic carbon, aliphatic and aromatic hydrocarbon contents. The objectives of the investigation are: 1) to establish the baseline hydrocarbon levels of sediment samples in the area, 2) to characterize the distribution and nature of these hydrocarbons, 3) to assess the possible source of the hydrocarbons in surface sediments, whether biogenic or anthropogenic, and 4) to understand the probable pathways of hydrocarbon transport in each of the areas in case of an oil spill. The baseline studies indicate that the sediment in the study areas is generally unpolluted. The characteristics of _n_-alkane hydrocarbons are typical of a mixture of marine and terrestrial components; with Norton Sound sediments containing the highest and Kodiak Shelf sediments, the lowest levels of terrigenous input. The distribution of polycyclic aromatic hydrocarbons is complex and shows a pyrolysic source in all the study areas. In addition, the presence of fossil arenes is indicated in Beaufort Sea sediments.

II. Introduction

A. General nature and scope of study

This study covers investigations of the baseline hydrocarbon concentrations and their distributions in the surface sediments of Beaufort Sea, Norton Sound, Kodiak Shelf and Cook Inlet. It is important to establish the existing background levels of classes of hydrocarbons and specific hydrocarbon pollution indicators, in order to assess any environmental impact of hydrocarbon pollution resulting from offshore oil drilling in the future. It is impossible to answer all the questions on the hydrocarbon levels in the Alaskan Seas from a two-year study, but the investigations should provide a preliminary understanding of the distribution of hydrocarbons in the sedimentary environment.

B. Specific objectives

The objectives of this investigation were to achieve the following results:

1. To establish the baseline hydrocarbon levels in the Southwestern Beaufort Sea, Norton Sound, Kodiak Shelf and Cook Inlet lease areas by measuring aliphatic and aromatic hydrocarbons.

2. To characterize the distribution and nature of these hydrocarbons.

3. To assess the possible source of the hydrocarbons, in surface sediment; whether biogenic or anthropogenic.

4. To understand the probable pathways of hydrocarbon transport in the event of oil spill in the areas.

C. Relevance to problems of petroleum development

Samples were taken in and around proposed lease areas of Beaufort Sea, Norton Sound and Kodiak Shelf. Oil production and transport has been going on for quite some time in Upper Cook Inlet. Exploration in Lower Cook Inlet may soon begin, therefore, baseline levels were also determined in the Lower Cook Inlet region. Information on the present level of hydrocarbons in these areas is required to assess, in the future, any chronic pollution arising from offshore drilling for oil and gas, or any residual affect resulting from an accidental spill or blowout. The baseline data should therefore be helpful in monitoring the cleanliness of the future Alaskan marine environment.

III. Current state of knowledge

Studies on the Alaskan Seas are relatively scant to date. Hydrocarbons and their possible precursors were investigated in the few samples in Beaufort Sea by Peake _et al_. (1972). Aliphatic and aromatic hydrocarbons, have been analyzed by Shaw _et al_. (1978) in Beaufort Sea nearshore sediments. Aromatic hydrocarbons in fish and sediment in Prince William Sound, northeast Gulf of Alaska, have also been reported (Chester _et al_., 1976). An extensive and informative study on hydrocarbon in sediments, water, organisms and fish in Beaufort Sea, along the Canadian border, was published by Wong et al. (1976). Data from analyses of sediments from Eastern Bering Sea, Gulf of Alaska, and Lower Cook Inlet indicate that these areas are generally unpolluted (Kaplan et al., 1977; Brenner et al., 1978) except in a few sample stations. Studies undertaken by our group on organic constituents of sediments from different parts of the Alaskan Seas are probably the most extensive investigations of hydrocarbons in this area as far as we know.

IV. Study area and cruises

The cruise of the USCGS GLACIER in the Beaufort Sea began off Prudhoe Bay on August 22, 1976 and terminated September 4, 1976 at Point Barrow. Only eleven samples could be collected, because ice conditions prevented the collection of a more complete set. Due to the difficulty in transporting the sampling device, a frame-supported Van Veem grab sampler could not be used on board this ship, and instead, a large volume (0.9 m^3) aluminum Van Veem grab sampler having teflon hinges and top-opening doors was used. Surface, 0-2 and subsurface, 2-4 cm samples were collected. A detailed description of the sampler and sample collection can be found in the September 1976 Quarterly Report.

Samples from Norton Sound were collected by Mark Sandstrom during Leg 2 of the R/V SEA SOUNDER cruise in October, 1976. The sample grid was extended to the western part of Norton Sound in July, 1977 to sample the sediments south of Nome, Alaska, in an area identified as a potential petrogenic seep. In addition, a few samples were collected by K. Kvenvolden (USGS) from vibracores and box cores in stations located near the potential seep area, to be analyzed by our group.

About 20 samples were collected in Kodiak shelf in July 1976 during the R/V SEA SOUNDER cruise. In the spring and summer of 1978, about 35 samples were collected in the western part of Lower Cook Inlet by David Winter and David Meredith in the cruises of the R/V DISCOVERER, to determine whether the organic material originating in the Upper Cook Inlet is being deposited near Kamishak Bay or transported and dispersed beyond Shelikof Strait. Results of the analyses of samples from the eastern portion of Lower Cook Inlet can be found in the Annual Report by Brenner et al., 1978. The station locations and the cruise area are shown in Figures 1-4.

V. Methods

Sediment samples were kept frozen from the time of collection until the beginning of the analysis. Details of methodology used for elemental and hydrocarbon analyses are the same as presented in our Annual Report 1978 (RU #480). Instead of a Varian, a Hewlett-Packard 5840A gas chromatograph equipped with a 30m x 0.25mm glass capillary column wall-coated with OV-101 and programmed from 35°C to 260°C at 4°C/min. was used. A Grob injector and a flame ionization detector were used. The flow rate of the helium carrier gas was 3.6 ml/min.

GC-MS analyses were carried out on a Finnigan model 4000 Quadrupole mass spectrometer directly interfaced with a Finnigan model 9610 gas chromatograph. The GC was equipped with a similar column as described above for the analyses of aliphatic fractions. The aromatic fractions were analyzed using a SE 54 (J&W) column. The mass spectrometric data was acquired and processed using a Finnigan INCOS Model 2300 data system.

VI. Results

Total and organic carbon, the lipid contents and typical gas chromatograms of aliphatic and aromatic fractions of Beaufort Sea sediments are represented in Figures 5 to 7. The same data for sediments from Norton Sound, Kodiak Shelf and Cook Inlet are shown in Figures 8-10, 11-13 and 14-16.

Total hydrocarbon content from gravimetric data, the alkane distributions from gas chromatography and the characteristic parameters from the above two analyses are given in Tables 1-3, 4-6, 7-9, 10-12, 13-15 and 16-18 for Beaufort Sea, Norton Sound 1976, 1977, Kodiak Shelf, Cook Inlet 1978 spring and summer samples, respectively.

The levels of major PAH compounds from all the study areas are presented in Table 19.

VII. Discussion

1. Beaufort Sea

1.1 Organic Carbon

The organic carbon content ranges from 0.4 to 1.01% (Table 1, Figure 5) and is comparable to values reported (Naidu, 1978) for the continental slope sediments from the Beaufort Sea collected in 1977. No clear trend in regional distribution is seen for the organic carbon contents. The Beaufort Sea samples have total organic carbon content comparable to many other geographical locations, such as Gulf of Mexico (Palacas *et al.*, 1976), but lower in organic carbon content than areas which have highly reducing conditions, such as Saanich Inlet and the Black Sea (Nissenbaum, *et al.*, 1971; Degens, 1971).

1.2 Hydrocarbons

1.2.1 Alkanes

The contents of the various resolved hydrocarbons are given in Table 2. The concentration range of the n-alkanes is 1.0-5 μg/g with an average of 3.0 μg/g. The *n*-alkanes analyzed in Beaufort Sea sediments collected to the east of the present study area (Wong *et al.*, 1976) were three times the concentration of these values (mean values 11.0 and 3.0 μg/g). The nearshore sediments from the same area (Shaw *et al.*, 1978) contain slightly more *n*-alkane than the sediments investigated here. Without specifying locations, Peake and co-workers (1972) have reported comparable *n*-alkane concentrations in other Beaufort Sea sediments. Odd chain length normal alkanes from 23 to 31 carbon atoms dominate (Fig. 7) with nonacosane and occasionally heptacosane being the most abundant compounds. The odd/even ratio is between 3 and 5 (Table 3). The data indicate substantial input of terrigenous detritus in these nearshore sediments (Eglinton and Hamilton, 1963; Kolattakudy and Walton, 1973). This is not surprising in view of the number of rivers along the shores of the study area, such as the Meade, Ikpikpuk and Colville Rivers. Stations from 1 to 4 in particular receive the terrigenous input from Colville River, since clay mineral assemblages in the Barter Island are thought to originate in the Colville River (Naidu, 1978). Significant amounts of fine-grained sediments discharged from the Colville River could be carried in the strong water currents moving eastward, during summer, and finally deposited in the Barter Island shelf area. At the same time, sediment eroded by the MacKenzie River may move westward--by bottom currents during other seasons (Pelletier, 1975).

However, a marine biogenic origin for some of the organic matter is also indicated by the presence of pristane and heptadecane, which are derived from marine plankton. Phytane is also present in detectable quantities and Pr/Ph is generally between 1.5 to 2.5 (Table 3). The presence of phytane and Pr/Ph ratio around 1.0 in marine sediments are often inferred as indicating petrol pollution (Speers and Whitehead, 1969; Zafiriou, et al., (1972). However, several unpolluted sediment samples from the estuarine environment of the English Channel were found to have Pr/Ph ratio of almost unity and this was attributed to bacteria (Tissier and Oudin, 1973). Bacterial production could therefore account for the presence of phytane in Beaufort Sea sediments. In short, the absence of unresolved complex mixture signal and the distribution pattern of major alkanes in the Beaufort Sea sediments can be attributed to recent biogenic-rich source with little or no anthropogenic input.

1.2.2. Alkenes

Alkenes from C_{15} to C_{23} with one or two degrees of unsaturation have been detected by GC/MS analyses in sample 6 and they are not abundant. These olefins could be of biogenic origin. Pristene and phytene have also been detected.

1.2.3 Di- and triterpenoids

A major peak eluting at Kovat Index 2085 was found in all the Beaufort Sea samples. This peak has been identified by GC/MS analyses for sample 6 to be a polycyclic alkane with a molecular formula $C_{25}H_{48}$ (base peak 57 and molecular ion 348 a.m.u.). Several steranes, diterpanes and triterpanoids such as adiantane, hopane, 22,29,30-trisnorhopane and a C_{31} methyltriterpane have been detected in sample 6. These triterpenoids and their extended homologs have probably been derived from recent biogenic activity (Simoneit, 1977) and not from petroleum (Dastillung and Albrecht, 1976). The absence of one of the two diastereomers at position 22 of the extended triterpanes could also suggest that absence of petroleum input (Dastillung and Albrecht, 1976). These diastereomers are commonly found as 1:1 mixture in petroleum polluted sediments as in Southern California (Kaplan et al., 1978; Simoneit and Kaplan, 1979).

1.2.4 Aromatic hydrocarbons

The concentration of the resolved aromatic hydrocarbons is approximately 1-3 μg/g for all the sediments, and is generally comparable to the data reported by Shaw et al. (1978) for the nearshore sediments and Wong and co-workers (1976) for sediments collected to the east of the present study area. These results are an upper boundary on the total aromatic compounds, as the analytical method employed did not yield pure aromatic compounds, and the "aromatic fraction" resolved included several olefins which are often abundant in the hexane:benzene fraction.

The distribution of aromatic compounds in these sediments is much more complex than the simple distribution of n-alkanes, which are characteristically of biogenic origin. The olefins which often coelute with aromatic compounds off the silica column may be confused with aromatic hydrocarbons because of similar retention indices, and their true identity must be confirmed by GC/MS analysis. Even in the absence of olefins, the identification of an aromatic component in a particular sediment by GC/MS cannot be extrapolated to a peak with the same Kovat index in another sample. For the above reasons, the concentrations of only the components analyzed by GC/MS which are reported on the coding sheets are considered reliable. Compounds identified by peak retention time from comparison with an aromatic standard, may or may not be a known compound. The discussion here on aromatic compounds is therefore restricted to the samples analyzed by GC/MS only.

In the two samples, 1 and 7, analyzed by GC/MS, several PAH compounds have been detected in significant amounts. Relatively large amounts of naphthalene, phenanthrene, pyrene, chrysene, etc. and their mono- and di-substituted alkyl homologs have been identified and the relative abundance decreases rapidly with further alkyl substitution (Figure 7, Table 19). This type of PAH distribution was previously found to result from mixed input from fossil fuel and pyrolytic sources (Youngblood and Blumer, 1975). Similar observation on the nearshore sediment from Maguire Islands close to station 1 has been reported by Shaw et al. (1978). Wong et al. (1976) have calculated the PAH budget from their study on Beaufort Sea sediments on the Canadian border and indicate that boreal forest fires are an insignificant source of arenes for the area. Lower latitude natural fires cannot be an important source of sedimentary arenes at those latitudes and hence such remote forest fires are also unlikely source in the distant Beaufort Sea environment. (Laflamme and Hites, 1978). Long distance transport from anthropogenic sources through atmospheric fallout could be an important source of the pyrolytic arenes in Beaufort Sea sediments (Shaw et al., 1978; Laflamme and Hites, 1978; Lunde and Bjorseth, 1977; Rahn et al., 1977). The other potential sources of fossil arenes may be coal outcrops on the Mead River and the oil seep area near Smith Bay. Oil shale fragments have also been reported in the Mead River (Smith and Mertie, 1930). The longshore current flowing westward (Pelletier, 1975) could carry materials discharged by the MacKenzie River into the area studied. MacKenzie River flows through regions with known fossil fuel deposits such as the Athabasca tar sands and Norman well oil seepage area. It is quite possible that unidentified offshore or onshore oil seeps also exist in the area.

A significant quantity of perylene has been detected in both the samples (Station 1-10 ppb; Station 7 - 40 ppb). Much lower values ($\leq$ 7 ppb) have been reported for Southeastern Beaufort Sea sediments by Wong et al. (1978). Peat material derived from land plants could be one of the major sources of perylene (Bergmann et al., 1964). Coronene and 1,12 benzperylene have also been detected by GC/MS analyses in these two samples and the latter compound is yet to be confirmed by coinjection. Perylene may be derived from perylene quinone pigments in marine organisms, though no such quinones have been isolated from any marine organism so far. It is also possible that the pigment skeletons could have been formed during sedimentation via oxidative coupling of two hydroxynaphthaquinone skeletons (Watts et al., 1977) which are widespread in plants, certain species of sea urchins and microorganisms (Thomson, 1971), since such reactions are known to occur readily in aqueous solutions (Cameron et al., 1966). Perylene could be subsequently formed in reducing micropaleoenvironmentary conditions as described by Welte and Ebhardt (1968), even though the overall sediment is oxidizing. The presence of moderate amounts of phytane (11-30 ppb) in these samples also would indicate such microreducing conditions. Aizenshtat (1973) suggests that perylene is formed from quinones transported from soils and originating from plants. Obviously, a more extensive investigation into the proposed formation mechanism is required to determine the origin of perylene in marine sediments.

The presence of cadalene, retene and simonellite in these samples indicate terrigenous input as also evident from the n-alkanes distribution discussed earlier. Cadalene is thought to be derived from the diagenetic alteration of cadinene and other sesquiterpenes from higher plants. Simonellite (traces) and retene (the most abundant of the three) found in these sediments are the products of diagenesis of the diterpane, abietic acid occurring in higher plants, especially conifers. The anomalously high levels of retene have also been reported by Laflamme and Hites (1978). These compounds have been identified in the nearshore Beaufort Sea sediments (Shaw et al., 1978) and the abundance of retene was attributed to the peat material which has not undergone sufficient diagenetic alteration to provide a full suite of fossil arenes.

2. Norton Sound (1976 Cruise)

2.1 Organic carbon

Total organic carbon content (Table 4, Figure 8) varies from 0.3 to 1.30%, and is similar to Beaufort Sea and other unpolluted, relatively coarse marine sediments.

2.2 Hydrocarbons

2.2.1 Alkanes

A representative gas chromatogram from the area is given in Fig. 10. The n-alkanes range from 0.1 to 9 $\mu g/g$ with a maximum at C_{27} for all the stations (Table 5). The odd/even ratio varies from 2 to 11, indicating land plants as major contributors to the organic matter (Table 6). Stations 49, 131 and 137 which are in the Sound and closer to shore, have the highest lipid contents and n-alkanes (Figure 9, Table 4). The lipid and n-alkane contents gradually decrease along the northeast to southwest transect, from station 131 through 125, 121 to 147. The southwest stations 154 and 156, which are near the mouth of the Yukon River, are richer in organic content and n-alkanes. These are derived from the terrigenous silt resuspended from the Yukon prodelta which extends across the mouth of the Sound. Hydrocarbons from marine planktonic input in this region is much less. Further south, around stations 162 to 168, the terrigenous detritus is diluted, by open ocean sedimentation. In general, terrigenous contribution is much more in Norton Sound than in Beaufort Sea stations analyzed. Sample analyses further offshore in this transect should indicate how far in the ocean the terrigenous input and also anthropogenic contamination could affect the ecosystem.

Samples collected closer to the suspected seep areas(47, 174, 172) are apparently not polluted with any petroleum hydrocarbons as evident at least from the n-alkane data. Their simple distribution of n-alkane is typical of mixed marine and predominantly terrigenous input.

The northern region of Norton Sound seems to be poorer in lipid content and also n-alkanes (stations 88, 105), possibly because: 1) there are no major rivers around the area, and 2) the longshore current movement and sediment transport is directed north toward Bering Strait.

Pristane and phytane are found in trace amounts in a few stations. The very low quantities detected indicate that zooplankton species like Calanus copepods which contribute substantial pristane to a few sediments north of Pribilof Islands in Eastern Bering Sea (Kaplan et al., 1977; Motoda and Minoda, 1974) may be impoverished in this area.

2.2.2 Alkenes

Several alkenes and cycloalkenes are detected from GC/MS analyses of the two samples 131 and 169, the former within and the latter outside the Norton Bay. In general, station 131 contains fewer olefins than station 169. The predominant olefin in station 169 is a $C_{17}H_{34}$ olefin eluting between n-C_{16} and n-C_{17}. Pristene is present in significant amounts. A $C_{25}H_{46}$ cycloolefin is present in both samples. These olefins could be of biogenic origin and are not uncommon in Recent marine sediments.

2.2.3 Di- and Triterpenoids

Several diterpanes have been detected in station 131 by GC/MS, while numerous triterpenoids such as adiantane, 30-normoretane, hop-22(29)ene (Diploptene), hopane, hop-17(21)ene and 22,29,30-trisnorhopane have been detected in samples from Station 131 and 169. Diploptene, hopane and hop-17(21)ene could have been derived from bacteria or blue-green algae (Bird et al., 1971; De Rosa, et al., 1971). These triterpenoids and other C_{30} and C_{31} triterpanes have been found in a number of Recent marine sediments such as Black Sea (Simoneit, 1977) and algal mat from Laguna Mormona (Cardoso et al., 1976). The major input into the latter region as evident from the lipid distribution was from algae and bacteria.

Further, only one of the diastereomers (R or S) of the triterpanes and their extended homologs ($>C_{30}$) was detected in these samples, suggesting the absence of petroleum input.

A $C_{30}H_{50}$ triterpene with base peak 69 and a molecular ion 410 a.m.u., (not a hopene) is found at both stations and is as abundant as n-C_{30}. The reason for its occurrence is not quite clear.

2.2.4 Aromatic Hydrocarbons

The resolved PAH compounds are $\leq$ 1.0μg/g and much less than those found in Beaufort Sea sediments. A sample taken from nearshore (131), and another from outside the basin (166) were analyzed by GC/MS. Both samples contain biphenyl, naphthalene, phenanthrene, fluorene, fluoranthene pyrene, chrysene and their alkyl substituted homologs in traces (Table 19). Benzo(E)pyrene has also been detected in both the samples. In general, the relative abundance of parent PAH compounds and their methylated homologs is in contrast to the PAH content of crude oil and oil shales (Coleman et al., 1973; Youngblood and Blumer, 1975). Though the distribution of these compounds indicate pyrolytic source, more detailed study is required before any positive conclusions can be reached.

Station 131 contains perylene at the level of about 10 ppb whereas station 166 has only traces. Coronene and 1,12 benzoperylene have also been detected in these samples.

Both samples contain olefins with 2-6 degrees of unsaturation. Olefins are more abundant in station 166 than in station 131, possibly derived from the relatively higher marine productivity outside the basin where this station is located. This is consistent with the data obtained from GC/MS analyses of aliphatic fractions from stations 131 and 169 (see Section 2.2.2).

3. Norton Sound (1977 Cruise)

3.1 Organic Carbon

The total organic carbon content (Table 7, Figure 8) varies from 0.12 to 0.86% except in one sample (48) where it is 4.23. At this station, the total carbon content is also unusually high (9%). However, a sample very close to this station (160), collected in 1976, had the carbon content 0.7%, within the range observed for the rest of the samples. These values are generally lower than those collected in the previous year. This could be due to the increased distance of the 1977 stations from a terrigenous source. In summary, the data are generally characteristic of a clean marine sediment.

3.2 Hydrocarbons

3.2.1 Alkanes

The range of n-alkanes (Table 8) is from C_{17} to C_{34} with amounts totaling 0.09 to 2 μg/g and averaging 0.8 μg/g. These values are lower than those from 1976 samples as expected from the increased distance of these stations from the shore. The gas chromatograms (Fig. 10) show the predominance of 23, 25, 27, 29 and 31 carbon n-alkanes with n-C_{27} being the maximum. The odd/even ratios range from 3 to 6, indicating terrigenous input (Table 9). Pristane was detected in amounts up to 5 ng/g only in some samples, and phytane if present, is below the detection limits of analysis.

Four samples (14-17) collected near the location where seepage was suspected based on low molecular weight hydrocarbon analysis(Kvenvolden, USGS, personal communication) show alkane distribution patterns (Figure 10) which are not characteristic of petroleum. However, these four samples have the highest resolved n-alkane contents of the 12 samples analyzed. Further information will be obtained by the analysis of additional samples from the same area in the future.

One other station (48) which has higher than normal n-alkane content, is that near the Yukon River delta and shows a typical terrestrial wax plant distribution pattern like that of station 49 taken in the previous year. Station 49, located closer to Pastol Bay, was richer in lipid content and had nearly 4 times the n-alkane content of station 48, even though both of these stations are located equidistant from the shore. This may be due to the fact that station 48 is in a higher energy region than station 49, and dispersion of organic matter into the open ocean may occur more readily. Two other stations closer to each other (70,34), one collected in October 1976 and the other in July, 1977, show comparable n-alkane distributions, indicating that there is no apparent seasonal variation despite the fact that terrigenous sediment supply is negligible in the winter. Strong tides in winter (Cacchione and Drake, 1978) may result in resuspension and homogenization of bottom sediments under the ice cover.

In general, the analyses of samples collected in two consecutive years lead us to conclude that the region is relatively clean, free of petroleum pollution, with organic input decreasing gradually from nearshore to offshore areas.

3.2.2. Alkenes

Several alkenes such as $C_{18}H_{36}$ and cyclic alkene $C_{25}H_{46}$ similar to those found in the previous year stations have been detected by GC/MS analyses at lower concentrations.

3.2.3 Di- and Triterpenoids

Many of the di- and triterpanes identified in station 43 are the same as those detected in stations 131 and 169. The absence of one of the diastereomers at position 22 of extended di- and triterpanes, again indicates the absence of detectable petroleum pollution in these sediments. The triterpene with the molecular formula $C_{30}H_{50}$ is also present in sample 43.

3.2.4 Aromatic Hydrocarbons

Sediment samples collected in 1977 have lower aromatic hydrocarbon content than those of 1976, similar to the trend observed with aliphatic hydrocarbons. The total resolved PAH compounds are ≤ 1.0 μg/g. The hydrocarbons in samples 35 and 43, have been analyzed by GC/MS. Naphthalene, biphenyl, fluorene, phenanthrene, pyrene, fluoranthene, chrysene and traces of their methylated homologs have been detected in both the samples similar to the samples collected in 1976. The PAH level is much lower than found in Beaufort Sea. In general, parent PAH compounds are relatively more abundant than their alkylated homologs (Table 19), indicating pyrolytic source. However, it is difficult to arrive at definite conclusions with the limited data available at present. Perylene is present at the level of about 1.5 ppb in station 43 and is found in traces in station 35. Coronene has also been detected in both the samples.

Station 43 contains predominantly olefins. Olefins with 4-6 degrees of unsaturation like $C_{21}H_{36}$, $C_{21}H_{34}$ and $C_{21}H_{32}$ are found in high concentrations, similar to station 166, sampled in the previous year. Simonellite and retene are present at levels below 3 ppb, the former being less than the latter at both stations. These compounds suggest terrigenous input consistent with the _n_-alkane distribution.

4. Kodiak Shelf

4.1 Organic carbon

Organic carbon content (Table 10, Figure 11) is within the range 0.2 - 2.5% and comparable to values typical of unpolluted marine sediments. The values are similar to those reported for Gulf of Alaska sediments (Kaplan _et al._, 1977).

4.2 Hydrocarbons

4.2.1 Alkanes

The total n-alkanes range from 0.01 to 0.86 μg/g with an average of 0.23 μg/g. These values fall within the range expected for unpolluted sediments from Beaufort Sea or Norton Sound. Three of the samples which had relatively higher organic carbon content (92, 97, 98) also have relatively higher aliphatic, aromatic fractions and resolved n-alkanes compared to the rest of the samples (Table 10). These stations are located southeast of Kodiak shelf where the other stations are farther north. In general, sediments from this area have the least lipid contents and total n-alkanes of all the sites investigated here. The n-alkanes are less by an order of mangitude compared to those of Beaufort Sea sediments.

A representative gas chromatogram is given in Figure 13. Most of them have a maximum at n-C_{27}, except a few which maximize at n-C_{29} (Table 11). The odd/even ratios are between 0.8 and 2.6 and are conspicuously lower than in the other sites, indicating that terrigenous input is substantially reduced in this area (Table 12). Unlike the other regions which may receive allochthonous material from rivers and intertidal marshes, transport of allochthonous material to the area around Kodiak Shelf is expected to be minimal because of the steep rugged topography of the Alaskan Peninsula which borders the shelf on one side and the Pacific water and the Gulf of Alaska on the other side. This region lacks large rivers and barrier island marshes. However, allochthonous organic material may be transported to this area from Cook Inlet, through Shelikof Strait.

A very narrow unresolved complex mixture signal localized around n-C_{21} to n-C_{23} could be attributed to the bacterial decomposition (Johnson and Calder, 1973; Cranwell, 1976) of algal material rather than a petroleum source. It is more likely that sediments in the West and South, rather than east of Kodiak Shelf would be contaminated with petroleum where hydrocarbons from natural seeps in Cape Douglas or from the oil and gas production in Upper Cook Inlet would be expected to be transported by surface currents and deposited. Atlas (1976) has reported the absence of oil-utilizing microorganisms in sediments from the Western Gulf of Alaska. Such microorganisms are generally present in sediments of chronically polluted areas, but have not been detected in sediments from non-polluted areas.

Pristane and phytane are present at levels in between those found for Beaufort Sea and Norton Sound sediments. Pristane/n-C_{17} and pristane/phytane ratios are higher in Kodiak Shelf sediments (Table 12) compared to all the other areas studied here. Pristane could be derived from zooplankton, in addition to that produced from reductive diagenesis of phytol.

4.2.2. Alkenes

A cluster of polyolefinic hydrocarbons with Kovat indices (2050 and 2090) elute between n-C_{20} and n-C_{21} and are major components in most of the samples. Their molecular formula have been determined to be ($C_{25}H_{46}$) from GC/MS analysis. These polyolefins indicate input from phytoplankton or zooplankton and similar polyolefins have been detected in continental shelf sediments from the Gulf of Mexico (Gearing et al., 1976) and the Atlantic Coast (Farrington et al., 1977). Kodiak area is known for high biological productivity and is important for commercial and sport fisheries. It is therefore not surprising to see relatively more input of marine organic matter into sediments around this area.

4.2.3 Di- and Triterpenoids

Several diterpanes, diterpenes, triterpanes and their extended homologs have been detected in the two samples (staions 92 and 130) analyzed by GC/MS, similar to the other areas studied. Surprisingly the two diastereomers (S and R) at position 22 of the C_{31} and C_{32} triterpanes have been detected in both the samples. The diastereomer eluting earlier is present only in trace amounts mixed with a C_{30} triterpene. Though the presence of both the isomers could indicate petroleum pollution (Dastillung and Albrecht, 1976), other data do not suggest any oil pollution in the area.

4.2.4 Aromatic Hydrocarbons

The concentrations of resolved aromatic hydrocarbons are less than 1.0 µg/g except in station 98 (1.5 µg/g) which has the highest aromatic content of all the stations in the area (Table 10). Station 98, represented in Figure 13 shows typical distribution pattern of aromatic compounds in the area, though the relative amounts of resolved PAH compounds are much higher than for all the other stations. Aromatic fractions of samples from station 98 and station 80, having three large peaks in addition to the usual gas chromatographic distributions, were analyzed for GC/MS. Both samples contain substantial amounts of phenanthrene and methylphenanthrenes (Table 19). Naphthalene, fluoranthene, pyrene, chrysene and their methylated homologs were also detected. Benzo(E)pyrene, perylene and coronene were detected in both the samples while benzo(A)pyrene is present in only station 98. Unlike samples from other areas, these two stations contain very few olefins, and the only major olefin in station 98 is a C_{26} compound with two degrees of unsaturation. In station 80, the three major peaks are 2-butoxy-2-oxoethylbutylphthalate, bis(2-hexyl-ethyladipate) and dioctylphthalate, respectively, the sources for which are unknown. No other station in this area appears to contain these compounds at these concentrations, as evident from the gas chromatographic profiles. Procedure blank did not contain these compounds.

Traces of simonellite, cadalene and retene are present but are usually less abundant than those found in Norton Sound.

5. Cook Inlet (1978 - Spring and Summer Cruises)

5.1 Organic Carbon

The total organic carbon contents (Tables 13 and 16, Figure 14) vary from 0.15 to 1.16% and are similar to those found for the central and eastern parts of Cook Inlet sediments collected in 1976 and 1977 (Annual Report 1978, RU #480).

5.2 Hydrocarbons

5.2.1 Alkanes

The total n-alkanes of the spring samples range generally from 0.1 to 0.7 µg/g with an average of 0.36 µg/g, which is three times lower than the average of 1977 samples collected in and around Kachemak Bay. Station 370 has the highest n-alkane content of 1.47 µg/g and also a relatively higher organic carbon content (0.71 %) compared to other samples (Table 14). One of the two other samples, 394, which has a high n-alkane content also has the highest organic carbon content (0.72%). of all samples collected in spring. Station 265, despite its lowest organic carbon content (0.15%), has the highest n-alkane content (0.54 µg/g) of all the stations in the north and central portions of the study area. The homogeneity of the samples and the reliability of the analytical technique are indicated by the similarity in data of the replicate samples at station 233 (Tables 13-15).

The summer samples have comparable lipid and *n*-alkane contents to those of spring samples (Tables 16 and 17). The *n*-alkane contents range from 0.10 to 1.66 μg/g, with the two replicates from Coal Bay in Kachemak Bay containing the most lipids and *n*-alkanes. The data on Coal Bay are consistent with those for the sediment samples analyzed in 1977 from the same area (Annual Report, 1978, RU #480). The analysis of samples from stations 204, 212, 234 and 390 in both spring and summer gave similar gravimetric and gas chromatographic results, indicating there might be no apparent seasonal trend in the hydrocarbon input to the sediments. Yet, the concentration of suspended matter was [illegible] to be higher in spring (Feely *et al.*, 1978) than in summer of 1977.

The representative gas chromatograms are depicted in Figure 16. The *n*-alkanes range from 15 to 34 with a maximum at *n*-C_{27} for all the spring and most of the summer samples. A few of the summer samples maximize at *n*-C_{29}. Station 265 contains an *n*-alkane suite with an odd/even ratio close to unity (1.06), whereas in the remaining samples, it ranges from 1.50 to 5.66 (Tables 15 and 18). Generally, the stations along Kamishak Bay have odd/even ratios greater than 3, indicating larger terrigenous input compared to those in the central part of the inlet. The terrigenous input could get diluted with the inflowing Gulf of Alaska water in the central part. Terrigeneous silt and anthropogenic contaminants, if any, are transported southwest along the Kamishak Bay from Upper Cook Inlet under the influence of tidal currents and Coriolis forces (Feely *et al.*, 1978).

In general, stations south of Kamishak Bay (370, 388, 390, 394) are as rich as, or richer than, those in the Bay, whereas stations in the north, especially 245 and 247 (with the exception of station, 265) are fairly depleted in hydrocarbons. This distribution could be a result of the net circulation pattern of the water, which is to the north along the eastern side of the inlet, and back again to the southwest into Shelikof Strait. This could lead to the deposition of considerable organic matter produced in Kachemak and Kamishak Bays in Shelikof Strait, which is consistent with our observations. Presumably, a significant fraction of the suspended matter containing hydrocarbons are buried in the sediments of the Bays where they cannot be resuspended, which may explain why the bay sediments, especially in the Kachemak region, are relatively rich in organic matter in spite of the strong tidal currents.

Pristane and phytane range from 0.1 to 37 μg/g (Tables 14 and 17) with pristane/phytane ratios from 1.1 to 12. The only sample which has a ratio lower than unity (0.77) is at station 265. In two of the stations, 388 and 398, around the Afognak Island, the alkane of highest concentration is pristane. This was also observed in station 24 sampled in 1976, however the nearby station, UC200, west of Barren Island does not show anomalously high levels of pristane. This may be due to a localized benthic community, a potential source of pristane.

A moderate level of unresolved complex mixture in the region between *n*-C_{19} and *n*-C_{25} is observed in stations UC 100, 200, 300, 378 and 394, as shown for station 398 in Figure 16, the reason for which is not clear at present. Correspondingly, their odd/even ratios are also in the lower range (1.5-3.5) of all the stations in the study area. A likely source could be a low-level leakage of petroleum underlying the reservoir rocks through the surface faults around Barren Islands and off Cape Douglas. GC/MS analysis of some of these samples should be able to confirm the possibility of petroleum pollution.

Station 265 just north of Kalgin Island, is unique in that it shows typical weathered petroleum distribution (Fig. 16) with Pr/Ph ratio of 0.77 and odd/even ratio of 1.06. This material originates from petroleum production and transport in Upper Cook Inlet. Yet, station 255 southeast of Kalgin Island, does not show any petrogenic input. This may indicate a localized source of hydrocarbon generation. Continuous monitoring of sediment samples around this area would be helpful in following the tranport of pollutants from the drilling activities in the north.

5.2.2 Alkenes

A cluster of olefins elute between $\underline{n}$-C_{20} and $\underline{n}$-C_{21}, and most likely have a composition similar to those found in Norton Sound and Cook Inlet (1976) sediment samples. They are most likely the same biogenic olefins reported from many other marine environments (Farrington and Tripp, 1977). The identification of these olefins and di- and triterpenoids by GC/MS analysis will be presented in a subsequent report.

5.2.3 Aromatic hydrocarbons

The gravimetric data on aromatic fractions generally correspond to those of the respective aliphatic fractions. The largest concentrations are near the Shelikof Strait, in Coal Bay and at station 265. The gas chromatographic traces of the aromatic fractions show a complex mixture. In some cases, very few peaks were resolved because of the small amount of material present (stations 234, 245, 247 and 217). Analysis of specific aromatic compounds based on GC/MS will be presented in a later report.

VIII. Conclusions

1. Alkanes in Marine Sediments

The alkanes in sediments of the study areas generally show a bimodal distribution, typical of a mixture of marine and terrestrial hydrocarbons. An odd-carbon predominance characteristic of terrigenous plant wax material is evident in most stations from Beaufort Sea, Norton Sound and Cook Inlet, suggesting the influx of major river waters in the area. Kodiak Shelf sediments show relatively less terrestrial and more marine input. In short, the absence of unresolved complex mixture and the distribution pattern of n-alkanes and extended triterpanes in most of the stations studied, can be attributed to recent biogenic sources characteristic of unpolluted environments.

Some of the stations in Norton Sound, suspected to be near natural gas seeps, do not show hydrocarbon distributions, characteristic of petroleum.

A few stations in Cook Inlet around Shelikof Strait and Barren Islands, show a moderate level of unresolved complex mixture, which could result from petroleum leakage through surface faults around the Barren Islands and off Cape Douglas. This needs confirmation by detailed periodic analyses of samples.

Station 265, just north of Kalgin Island shows a typical weathered petroleum distribution, which is probably derived from petroleum contamination originating in Upper Cook Inlet from production and transport of oil.

2. Aromatic Hydrocarbons

The distribution of PAH compounds is complex in contrast to that of n-alkanes in all the sediments studied.

Beaufort Sea sediments contain PAH and their arenes characteristic of pyrolytic and probably fossil sources.

Norton Sound and Kodiak Shelf sediments contain predominantly pyrolytic arenes.

Perylene, 1,12 benzoperylene and coronene, whose origin is presently not clear, have been detected in all sediment extracts analyzed by GC/MS.

Cadalene, simonellite and retene found in the sediments can be considered as terrigenous markers. It is not clear to what extent these compounds are being produced from precursors occurring in land plants, or derived from fossil hydrocarbon deposits of coal, oil and peat.

IX. Needs for Further Study

The present study is mainly a general investigation of the hydrocarbon levels in marine sediments in the Alaskan Seas. More concentrated efforts, such as frequent and periodic sampling and analyses of sediments is required in the immediate vicinity of the drilling sites; this will help in monitoring more accute environmental changes which may result from the drilling activities and the concomitant increased marine traffic.

Periodic sampling and analyses is required in areas suspected to be influenced by seeps. Hydrocarbon data should be periodically obtained at different seasons.

X. Fourth Quarter (January-March, 1979) - Summary of Operations

Laboratory Activity:

Aliphatic fractions of summer 1978 Cook Inlet samples and aromatic fractions of spring and summer samples have been measured by gas chromatography. Gas chromatographic data and characteristic parameteters of the aliphatic hydrocarbons from the summer cruise are given in Tables 17 and 18, included in the annual report.

GC/MS analyses of selected samples will be carried out shortly.

Interlaboratory calibration samples were analyzed and the data sent to Drs. D.W. Brown and J. Calder.

A milestone chart is enclosed.

Mr. David Meredith from our group attended the meeting in Seattle, Washington, on March 15, 1979, in conjunction with the 1979 Norton Sound Cruise.

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MILESTONE CHART

0 - Planned Completion Date

X - Actual Completion Date
(to be used on quarterly updates)

RU # 480 PI: I.R. Kaplan and M.I. Venkatesan

Major Milestones: Reporting, and other significant contractual requirements; periods of field work; workshops; etc.

		1978					1979								
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Field Sampling								0		0					
Sample Analysis and Processing												0			
Quarterly Reports	X			X						X			X		
Annual Report							X								
Final Report															0

Table 1. Beaufort Sea Samples (1976 Cruises).

Station[1]	Lat (N)	Long (W)	Depth (m)	Rating[2]	Total Carbon %	Organic Carbon %	Weight[3] (gr)	Non Saponi-fiable Fr.[4] (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
1	70°32'	147°33'	27	3	3.20	0.89	124.57	113.11	14.313	9.424
2	70°39'	147°37'	26	2	2.68	0.74	98.66	130.55	24.883	15.488
3	70.47'	148°02'	25	3	3.05	0.91	52.76	183.66	41.016	18.707
4	70°57'	149°33'	25	3	2.45	0.63	69.97	152.78	36.301	14.106
5	71°08'	151°19'	23	2	2.11	0.83	104.05	163.96	28.429	13.993
6	71°43'	151°47'	1750	3	2.75	1.01	37.35	231.59	19.866	12.557
7	71°22'	152°20'	60	3	2.52	0.79	84.96	132.06	12.830	8.463
8	71°19'	152°32'	50	2	2.13	0.39	110.85	147.86	16.460	12.648
9	71°08'	152°57'	22	3	2.49	0.68	75.73	201.37	23.729	9.402
10	71°23'	154°21'	29	3	2.58	0.63	54.01	220.52	34.531	14.590
11B	71°36'	155°32'	197	2	2.63	0.51	179.18	110.28	22.436	12.150

1. All are surface samples. 11B is bulk.
2. Quality of sample recovery based on a subjective scale of 5 (excellent) to 1 (poor).
3. Extracted (salt free) dry sediment.
4. Elemental sulfur was detected in only one sample (No. 11).

Table 2. Aliphatic Hydrocarbon Concentrations (ng/g) in Beaufort Sea Sediment Samples, 1976 Cruise (Part I:n-C_{15}-n-C_{23})

Station *	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
1	27.39	29.1	46.9	27.5	53.1	19.3	84.4	86.8	136.2	118.3	221.6
2	n.d.	13.1	26.9	15.6	30.0	11.9	45.5	46.1	68.2	59.6	105.2
3	n.d.	17.3	47.7	28.2	63.8	18.8	105.9	104.4	176.4	146.4	314.1
4	45.2	59.5	96.3	62.9	94.4	30.9	126.0	121.9	173.9	152.9	270.3
5	30.0	35.9	60.5	40.1	64.3	19.0	98.0	94.4	164.4	140.7	278.4
6	33.3	39.2	62.9	37.2	69.8	20.5	119.0	111.2	186.5	196.9	469.5
7	36.5	39.2	53.9	37.9	47.3	14.8	63.6	56.9	95.2	90.5	200.8
8	35.3	45.6	77.4	52.8	77.4	21.1	112.2	107.5	157.4	181.1	409.2
9	29.6	36.0	61.4	37.0	69.3	21.4	110.3	105.1	194.4	158.9	342.9
10	27.9	32.4	69.5	41.7	79.2	22.1	127.3	122.4	197.6	214.3	530.0
11	30.5	34.4	47.2	34.7	39.2	20.8	52.6	48.5	43.2	77.4	186.2

Table Aliphatic Hydrocarbon Concentrations (ng/g) in Beaufort Sea Sediment Samples, 1976 Cruise (Part II:n-C_{24}-n-C_{34})

Station*	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
1	109.7	238.7	81.0	429.4	91.5	506.5	49.9	460.6	40.2	151.2	23.9
2	51.1	112.2	30.3	202.2	42.5	276.3	n.d.	247.9	n.d.	85.7	n.d.
3	129.8	324.1	89.0	5.3	0.8	6.0	0.4	5.5	0.3	n.d.	n.d.
4	128.7	263.0	72.3	418.2	84.6	540.4	n.d.	474.5	n.d.	n.d.	n.d.
5	123.8	298.8	83.8	444.0	89.6	526.7	25.1	444.9	22.7	161.0	n.d.
6	197.1	489.2	160.2	764.2	132.3	739.4	83.2	754.8	23.8	270.6	n.d.
7	88.2	214.4	66.4	324.2	58.7	316.3	34.9	298.5	11.6	105.3	n.d.
8	170.1	431.7	115.7	640.1	94.8	650.2	38.3	593.0	31.9	199.6	n.d.
9	144.2	342.4	119.3	526.5	93.6	555.4	58.2	527.3	17.2	190.0	21.7
10	203.9	529.5	148.4	773.8	134.8	790.8	63.4	750.1	37.3	250.6	n.d.
11	71.4	232.2	35.7	316.0	n.d.	256.7	n.d.	250.4	n.d.	92.3	n.d.

n.d. = not determined, too low to be calculated accurately.

* = all samples are surface; 11 is bulk.

Table 3. Characteristic Parameters for Beaufort Sea Hydrocarbons (1976 cruise)

Station	$\frac{\text{Non-saponifiable fr.}}{\text{Organic carbon}}$ (x10^4)	$\frac{\text{Alkanes}}{\text{Org. C}}$ (x10^4)	$\frac{\text{Pristane}}{n\text{-}C_{17}}$	$\frac{\text{Phytane}}{n\text{-}C_{18}}$	$\frac{\text{Pristane}}{\text{Phytane}}$	$\frac{\text{Odd}}{\text{Even}}$
1	127.1	3.41	0.59	0.36	1.60	3.37
2	176.4	2.03	0.58	0.40	1.32	4.29
3	201.8	1.75	0.59	0.29	1.82	1.78
4	242.5	4.43	0.65	0.33	2.04	3.37
5	197.5	3.91	0.66	0.30	2.11	3.58
6	229.3	4.91	0.59	0.29	1.82	3.57
7	167.2	2.88	0.70	0.31	2.55	3.25
8	379.1	10.88	0.68	0.27	2.50	3.83
9	296.1	5.53	0.60	0.31	1.73	3.53
10	350.0	8.17	0.60	0.28	1.89	3.91
11	216.2	3.67	0.73	0.53	1.67	5.00

Table 4. Norton Sound Sediment Samples (1976 Cruises).

Station[1]	Lat (N)	Long (W)	Depth (m)	Rating[2]	Total Carbon %	Organic Carbon %	Weight[3] (gr)	Non Saponifiable Fr.[4] (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
47	64°25'	165°29.90'	15	3	1.02	0.93	104.42	77.95	9.644	7.470
49	63°27.77'	163°52.57'	10	3	1.40	1.12	84.74	199.91	24.782	4.130
70	65°6.13'	167°40.40'	31	4	0.37	0.31	153.58	8.47	2.207	6.186
88B	65°46.01'	168°05.51'	9	1	0.84	0.53	70.58	119.58	3.953	5.682
105	64°49.00'	166°44.00'	15	2	1.29	0.93	124.13	18.05	1.845	0.886
121	63°52.99'	163°01.34'	20	0	1.37	1.18	-	-	-	-
125	64°00.12'	162°24.60'	18	3	0.98	0.55	127.95	51.97	0.141	2.438
131	64°23.60'	161°49.27'	17	4	0.96	0.44	97.07	135.47	9.035	2.988
137	63°40.89'	161°13.29'	14	3	-	-	72.61	221.32	17.766	4.531
147	63°47.00'	163°41.50'	17	2	0.87	0.33	111.23	104.38	6.779	2.293
152	64°05.00'	164°26.50'	22	2	0.50	0.35	-	-	-	-
154	63°45.08'	164°37.43'	18	2	1.25	0.99	86.08	209.69	16.264	4.182
156	63°28.39'	165°19.28'	17	3	1.40	1.30	97.63	104.89	7.119	5.511
157S	63°18.11'	165°03.26'	8	1	1.16	0.82	-	-	-	-
160S	62°54.50'	165°08.15'	10	1	2.40	0.70	-	-	-	-
162	63°02.80'	165°53.99'	21	3	1.26	0.92	120.88	45.09	2.316	2.316
166S	63°14.62'	167°02.21'	26	1	1.54	1.16	161.30	39.99	1.097	0.756
168S	63°26.25'	166°29.64'	28	1	1.33	1.10	150.44	57.03	3.191	2.180
169S	63°34.79'	166°05.53'	27	1	1.09	0.33	137.47	117.12	2.619	4.001
170S	63°41.72'	165°45.81'	25	2	0.87	0.52	128.86	62.86	4.439	2.208
172S	64°00.10'	165°29.25'	20	1	1.36	0.87	115.55	80.14	10.904	3.773
174S	64°21.15'	165°00.40'	36	2	1.48	0.82	160.13	53.21	3.872	2.005

1. Samples are 0-2 cm except B- Bulk and S- Surface.
2. Quality of sample recovery based on a subjective scale of 5 (excellent) to 1 (poor).
3. Extracted (salt free) dry sediment.
4. No elemental sulfur was detected in this group of samples.

Table 5. Aliphatic Hydrocarbon Concentrations in Norton Sound Sediment Samples (ng/g), 1976 cruise
(Part I)

Station	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
47	n.d.	n.d.	10.7	n.d.	11.9	n.d.	35.0	43.7	164.5	142.4	384.3
49	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	45.9	61.3	226.2	201.8	552.0
70	n.d.	0.1	0.3	0.8	0.4	0.1	0.6	0.5	0.6	0.6	0.7
88	6.9	4.5	10.0	20.3	2.5	9.5	19.3	13.3	257.4	14.6	23.1
105	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.6	2.9	8.3
125	1.6	1.4	3.5	1.4	3.7	0.7	9.0	9.8	n.d.	26.5	66.4
131	n.d.	n.d.	21.3	n.d.	n.d.	n.d.	30.6	37.7	174.7	150.5	469.9
137	n.d.	n.d.	13.1	n.d.	18.5	n.d.	61.9	85.5	291.1	283.7	761.3
147	4.6	n.d.	14.4	n.d.	11.3	n.d.	32.2	37.2	113.6	100.0	262.8
154	n.d.	n.d.	13.4	n.d.	15.8	n.d.	51.0	58.2	215.4	182.2	501.8
156	n.d.	n.d.	15.7	n.d.	15.1	n.d.	40.4	49.0	178.3	158.2	446.3
162	1.1	1.1	2.4	1.2	2.1	n.d.	5.6	5.6	21.5	16.9	46.8
166	n.d.	n.d.	0.9	0.6	0.6	n.d.	1.3	1.5	4.3	4.6	12.8
168	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9.1	11.2	42.8	40.2	128.2
169	3.2	2.6	6.2	3.6	4.3	1.0	9.4	10.1	31.6	29.7	83.2
170	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.3	63.2	66.5	218.3
172	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	84.3	67.0	261.3
174	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.7	13.5	56.2	54.5	261.3

n.d. = not determined, too low to be calculated accurately.

Table 5. Aliphatic Hydrocarbon Concentrations in Norton Sound Sediment Samples (ng/g), 1976 Cruise

(Part II)

Station	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}	Total n-alkanes (μg/g)
47	1.4	434.1	111.5	740.1	82.1	539.6	131.4	480.5	21.1	143.9	n.d.	3.277
49	200.9	624.4	154.9	1351.9	139.5	956.2	47.4	114.1	n.d.	266.3	n.d.	5.688
70	0.6	0.7	0.5	0.9	0.5	1.3	0.4	1.0	0.3	0.3	n.d.	0.0102
88	17.0	31.1	20.4	75.6	32.6	57.4	7.8	59.1	10.7	18.5	6.2	0.6880
105	3.2	9.7	n.d.	19.1	n.d.	13.2	n.d.	15.6	n.d.	n.d.	n.d.	0.0745
125	28.0	78.9	25.0	151.4	21.2	106.0	12.4	99.0	6.3	31.5	3.3	0.6876
131	169.6	647.4	169.1	1490.2	167.9	1098.0	925.3	1051.9	28.6	310.1	n.d.	7.184
137	316.4	883.7	292.0	1861.0	243.9	1362.1	344.9	1296.7	87.9	448.6	42.2	8.694
147	108.5	299.6	79.3	533.7	52.3	310.4	168.4	16.6	n.d.	71.2	n.d.	2.241
154	177.4	594.9	149.1	1375.4	132.6	879.1	67.6	63.8	n.d.	40.7	n.d.	5.451
156	169.1	557.7	132.1	1304.0	119.9	821.6	59.1	702.0	38.7	224.7	--	5.061
162	17.4	53.5	14.3	107.5	10.6	63.4	5.1	52.2	3.5	15.9	1.4	0.4477
166	5.8	16.9	5.0	36.6	4.6	26.9	2.2	24.6	1.3	7.5	n.d.	0.1571
168	50.5	167.1	48.4	347.0	43.5	255.1	33.4	230.5	9.1	64.4	n.d.	1.481
169	34.4	127.5	38.9	199.5	26.5	143.5	14.9	132.6	8.3	43.1	3.6	0.9540
170	79.7	288.3	73.9	631.2	62.1	443.5	72.6	432.2	7.7	117.6	n.d.	2.573
172	68.2	339.3	65.0	616.9	60.8	521.0	168.1	454.1	78.5	109.6	n.d.	2.894
174	59.2	201.2	52.9	416.7	46.0	285.3	75.5	272.5	7.7	72.6	n.d.	1.792

n.d. = not determined, too low to be calculated accurately.

Table 6. Characteristic Parameters for Norton Sound Hydrocarbons (1976)

Station	$\frac{\text{Non. Sap. Fr.}}{\text{Org. C}}$ (x 10^4)	$\frac{\text{n-alkanes}}{\text{Org. C}}$ (x 10^4)	$\frac{\text{Pristane}}{\text{n-}C_{17}}$	$\frac{\text{Phytane}}{\text{n-}C_{18}}$	$\frac{\text{Pristane}}{\text{Phytane}}$	$\frac{\text{Odd}}{\text{Even}}$
47	83.82	3.74	0.38*	0.20*	2.00*	5.38
49	178.49	5.08	0.30*	0.14*	1.50*	6.06
70	27.32	0.03	2.66	0.25	8.00	1.65
88	225.62	1.30	2.03	3.80	2.14	4.11
105	19.41	0.08	n.d.	n.d.	n.d.	11.21
125	94.49	1.25	0.40	0.19	2.00	4.02
131	307.89	16.32	n.d.	n.d.	n.d.	2.80
137	--	--	0.64*	0.18*	3.00*	4.07
147	316.30	6.79	0.60*	0.36*	1.80*	2.85
154	211.81	5.51	0.64*	0.17*	3.60*	5.69
156	80.69	3.89	0.50*	0.19*	2.67*	5.57
162	107.36	0.49	0.50	0.23*	2.00*	4.75
166	34.47	0.14	0.67	0.23*	4.00*	5.16
168	51.85	1.35	0.58*	0.17*	3.50*	5.26
169	354.91	2.89	0.58	0.23	3.60	4.47
170	120.88	4.95	0.46*	n.d.	n.d.	5.80
172	92.11	3.33	n.d.	n.d.	n.d.	4.70
174	64.89	2.19	2.00*	2.20*	6.00*	4.50

* Approximate values based on measured peak heights

Table 7. Norton Sound Sediment Samples (1977 Cruises).

Station[1]	Latitude (N)	Longitude (W)	Depth (m)	Rating[2]	Total C(%)	Org. C (%)	Weight[3] (gr)	Non-Saponi-[4] fiable Fr. (ppm)	Aliphatic Fraction (ppm)	Aromatic Fraction (ppm)
34 0-2cm	64°52.30'	167°39.65'	32	3	0.35	0.12	160.71	4.72	0.809	0.678
35 0-2cm	65°14.90'	167°45.70'	52	3	0.67	0.59	121.01	100.74	2.248	1.132
39 surf.	64°07.09'	171°18.00'	34	2	1.54	0.38	174.11	7.98	0.643	0.247
41 surf.	64°02.75'	171°36.10'	27	2	0.91	0.44	171.15	50.83	2.466	0.847
42 surf.	63°58.40'	169°22.65'	39	3	1.76	0.32	114.48	114.26	4.444	1.922
43 0-2cm	63°57.85'	167°48.03'	35	4	0.63	0.60	156.38	23.42	1.010	1.714
44 0-2cm	63'45.40'	167°00.50'	31	4	0.66	0.52	128.89	34.06	2.072	0.900
48 surf.	62°58.20'	165°16.25'	10	2	9.08	4.23	95.38	83.16	5.829	5.012
14 IK 0-3cm	64°14.80'	165°25.50'	18	-	1.12	0.28	86.41	67.93	5.360	1.296
17 SV 0-3cm	64°05.10'	165°28.62'	19	-	1.09	0.86	121.21	68.48	14.066	2.228
17 0-3cm	64°05.10'	165°28.62'	19	-	0.31	0.24	99.74	49.43	5.494	2.667
17 IK160cm	64°05.10'	165°28.62'	19	-	0.64	0.50	111.12	17.19	3.150	0.855

[1] Samples 14-17 belong to a different program

[2] Quality of sample recovery based on a subjective scale of 5 (excellent) to 1 (poor).

[3] Extracted (salt free) dry sediment.

[4] Small amounts of elemental sulfur were detected in samples: 39, 41, 42, 44 and 14 IK.

Table 8. Aliphatic Hydrocarbon Concentrations (ng/g) in Norton Sound Sediment Samples, 1977 Cruise (Part I: n-C_{17}-n-C_{24})

Station	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}	n-C_{24}
34 0-2 cm	n.d.	n.d.	n.d.	n.d.	0.9	1.2	3.2	3.3	7.7	3.3
35 0-2 cm	1.4	2.4	1.5	n.d.	3.2	4.0	13.2	13.4	39.8	17.2
39 surf	0.2	0.3	0.3	n.d.	0.7	0.8	1.8	2.0	5.1	2.8
41 surf	n.d.	n.d.	n.d.	n.d.	1.3	1.8	6.0	6.1	18.0	8.8
42 surf	1.7	3.2	1.8	n.d.	9.7	7.1	23.7	22.3	63.8	27.8
43 0-2 cm	1.2	1.3	1.2	n.d.	3.5	3.9	12.1	11.8	1.6	14.2
44 0-2 cm	n.d.	n.d.	0.6	n.d.	1.7	2.5	9.2	14.3	34.5	22.3
48 surf	4.0	5.6	5.1	n.d.	16.7	17.3	66.3	43.3	136.5	47.5
14 IK 0-3 cm	4.4	n.d.	4.6	n.d.	11.1	13.1	42.3	36.8	104.2	42.7
17 0-3 cm	2.7	n.d.	4.5	n.d.	14.6	18.3	63.0	55.3	149.3	59.2
17SV 0-3 cm	n.d.	n.d.	n.d.	n.d.	22.7	15.6	54.5	49.2	138.0	53.6
17 IK 160cm	n.d.	n.d.	n.d.	n.d.	3.1	6.2	23.0	25.4	72.4	32.1

Table . Aliphatic Hydrocarbon Concentrations (ng/g) in Norton Sound Sediment Samples, 1977 Cruise (Part II: n-C_{25}-n-C_{34})

Station	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
34 0-2 cm	8.6	3.2	18.9	2.9	14.9	1.4	14.7	0.9	4.9	n.d.
35 0-2 cm	52.2	16.9	117.8	16.5	95.4	10.4	101.0	6.6	32.3	2.6
39 surf	7.8	3.0	19.6	3.1	17.0	0.4	19.2	1.3	6.2	0.7
41 surf	24.7	8.8	49.5	8.6	41.1	4.0	41.2	2.4	11.6	n.d.
42 surf	79.7	27.1	170.2	27.5	142.8	16.0	148.1	10.2	45.2	3.2
43 0-2 cm	41.6	14.2	88.6	13.5	70.2	7.6	69.4	4.6	21.9	2.0
44 0-2 cm	34.1	13.0	49.5	6.3	28.4	0.9	22.8	n.d.	6.4	n.d.
48 surf	185.1	39.1	459.0	39.4	260.8	14.7	190.7	9.9	59.6	n.d.
14 IK 0-3cm	129.9	35.9	284.8	32.6	201.6	18.1	186.8	11.7	62.5	n.d.
17 0-3 cm	180.5	53.7	409.0	46.8	292.4	26.1	268.0	16.1	87.3	6.6
17SV 0-3cm	166.1	45.0	367.6	40.3	256.2	18.4	223.8	12.1	71.7	n.d.
17 IK 160cm	96.7	28.4	218.7	26.5	176.6	16.1	163.9	7.6	49.9	n.d.

n.d. = not determined, too low to be calculated accurately

Table 9. Characteristic Parameters for Norton Sound Hydrocarbons (1977 Cruise)

Station	Non-Saponifiable Fr. / Organic Carbon (x 10^4)	Alkanes / Org. Carbon (x10^4)	Pristane / n-C_{17}	Phytane / n-C_{18}	Pristane / Phytane	Odd / Even
34 (0-2 cm)	39.3	0.75	1.38	0.14*	2.0*	4.55
35 (0-2 cm)	170.7	0.87	1.67	0.22*	7.0*	5.15
39 (Surf)	2.1	0.24	1.44	0.33*	2.5*	5.35
41 (Surf)	115.5	0.53	1.0*	0.25*	4.0*	4.78
42 (Surf)	357.1	2.60	1.82	0.25*	5.5*	4.78
43 (0-2 cm)	39.0	0.64	1.06	0.16*	6.5*	4.22
44 (0-2 cm)	65.5	0.48	1.44	0.13*	6.0*	3.21
48 (Surf)	19.6	0.38	1.38	0.17*	5.0*	6.37
14 IK (0-3 cm)	242.6	4.37	0.55	0.23*	3.1*	5.26
17 (0-3 cm)	79.6	2.04	2.03	0.19*	1.3*	5.12
17 SV (0-3 cm)	206.0	6.40	0.5*	0.17*	2.0*	5.67
17 IK (160 cm)	34.4	1.91	0.5*	0.17*	4.0*	5.34

* Approximate values based on measured peak heights.

Table 10. Kodiak Shelf Sediment Samples (1976 Cruises)

Station[1]	Lat (N)	Long (N)	Depth (m)	Rating[2]	Total Carbon %	Organic Carbon %	Weight[3] (gr)	Non Saponi-fiable Fr.[4] (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
52	58°24.42'	151°13.80'	52	4	5.13	0.34	125.65	42.22	1.202	2.149
57	57°50.94'	150°03.74'	194	3	0.67	0.36	130.01	28.31	1.438	1.415
60	57°45.96'	149°37.41'	444	4	0.68	0.31	150.64	37.71	2.151	2.835
68	57°28.10'	151°28.7'	154	3	0.86	0.60	87.53	69.46	2.285	1.428
72	57°24.2'	151°05.1'	92	2	0.71	0.23	131.97	22.28	1.569	0.887
75	57°45.80'	151°08.05'	70	3	3.91	0.33	106.87	33.22	2.059	0.356
80	58°01.50'	151°21.90'	81	4	2.29	0.35	173.98	12.99	0.506	0.466
80'	58°01.50'	151°21.90'	81	4	-	-	174.43	24.94	0.699	0.585
81	58°05.21'	151°14.55'	143	4	1.13	0.50	72.83	71.13	2.650	2.856
87	57°36.50'	151°47.65'	132	4	0.90	0.45	87.35	29.19	0.790	1.534
92	56°56.5'	152°33.0'	167	2.5	1.91	1.17	64.94	130.89	5.128	6.637
93	56°53.45'	152°40.90'	128	5	1.33	1.01	82.92	26.05	1.869	2.267
97	56°40.10'	153°10.02'	147	4	2.95	2.45	57.02	98.74	4.209	5.156
98	56°38.00'	153°16.00'	145	3	3.10	2.15	61.39	205.08	7.786	10.881
130	58°42.35'	149°03.38'	149	2	1.25	0.91	170.33	36.63	1.867	2.971

1. Samples are 0-2 cm except 80' which is 2-4 cm.
2. Quality of sample recovery based on a subjective scale of 5 (excellent) to 1 (poor).
3. Extracted (salt free) dry sediment.
4. Elemental sulfur was detected in only one sample (No. 92).

Table 11. Aliphatic Hydrocarbon Concentrations (ng/g) in Kodiak Shelf Sediment Samples, 1976 Cruise (Part I: n-C_{15}-n-C_{23})

Station	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
52	2.2	2.3	3.4	5.9	2.9	0.7	3.7	3.0	4.1	3.4	4.2
57	0.7	1.1	1.9	6.2	1.9	0.6	2.7	2.1	2.4	2.1	2.6
60	3.7	3.8	5.9	15.8	7.2	2.0	10.6	10.5	12.1	11.4	13.5
68	2.2	1.5	2.7	10.4	2.8	1.0	6.0	4.5	8.7	4.7	6.6
72	n.d.	n.d.	1.3	n.d.	1.5	n.d.	4.3	5.8	22.1	21.7	61.8
75	0.5	0.6	1.0	3.9	1.1	0.3	1.6	1.2	1.5	1.4	1.6
80	0.1	0.1	0.2	0.4	0.2	0.1	0.5	0.5	0.8	0.6	0.8
80'	0.5	0.5	1.1	5.7	1.1	0.3	1.7	1.4	2.0	1.5	1.9
81	6.0	4.4	7.8	30.4	8.5	2.8	15.6	13.3	21.9	16.0	22.8
87	n.d.	n.d.	n.d.	n.d.	0.2	n.d.	0.5	0.5	1.1	0.7	1.1
92	17.0	11.8	20.1	43.0	20.7	6.7	39.3	29.2	48.9	32.8	46.1
93	2.4	1.6	3.0	10.4	3.0	n.d.	5.5	4.9	10.0	8.2	12.7
97	1.7	1.6	4.5	10.0	6.2	6.2	14.0	12.1	21.2	15.4	21.8
98	3.1	2.4	4.3	8.8	4.4	n.d.	7.9	6.0	8.9	6.8	9.5
130	2.9	3.0	4.7	9.2	6.4	2.1	10.7	11.1	11.6	11.7	13.2

Table Aliphatic Hydrocarbon Concentrations (ng/g) in Kodiak Shelf Sediment Samples, 1976 Cruise (Part II: n-C_{24}-n-C_{34})

Station	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
52	3.4	4.6	2.7	6.3	3.3	7.9	2.6	9.4	1.4	3.3	1.1
57	2.1	3.5	2.3	4.8	2.1	4.8	0.8	3.5	n.d.	1.1	n.d.
60	11.2	14.7	9.9	17.9	10.7	23.1	7.2	23.5	5.7	9.6	5.8
68	4.7	8.4	4.4	15.5	6.2	12.7	3.6	13.8	22.8	1.3	4.1
72	26.5	79.5	25.4	143.8	19.5	110.4	21.5	104.8	1.6	n.d.	16.0
75	1.3	1.4	0.9	1.9	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
80	0.6	0.9	0.6	1.3	0.6	1.1	0.3	1.5	0.2	0.5	0.1
80'	1.3	1.8	1.0	2.9	1.5	3.3	0.7	3.3	0.5	1.3	0.5
81	14.3	23.2	14.0	37.5	16.7	38.0	10.3	40.0	7.9	14.3	4.5
87	0.9	1.5	0.8	3.1	1.2	2.9	0.7	2.5	0.4	1.1	n.d.
92	31.7	60.1	32.9	105.3	47.2	100.8	23.1	104.8	174.5	11.3	7.8
93	10.5	20.6	12.1	40.0	14.5	39.6	9.6	43.6	6.3	15.4	3.0
97	15.7	30.7	17.0	60.9	21.5	59.7	14.3	67.3	109.7	5.5	4.3
98	6.8	13.5	6.8	24.9	7.7	24.5	4.3	27.5	n.d.	8.6	n.d.
130	11.5	15.5	11.8	19.7	12.1	19.2	8.7	19,2	1,8	8,1	3,1

n.d. = too low to be determined accurately.

Table 12. Characteristic Parameters for Kodiak Shelf Hydrocarbons (1976 Cruise)

Station	Non-Saponifiable Fr. / Organic Carbon (x 10^4)	Alkanes / Org. Carbon (x 10^4)	Pristane / n-C_{17}	Phytane / n-C_{18}	Pristane / Phytane	Odd / Even
52	124.2	0.24	1.7	0.9	2.3	1.9
57	78.6	0.14	3.2	1.3	2.4	1.9
60	121.6	0.77	2.6	0.5	6.1	1.7
68	115.8	0.29	3.9	0.4	10.4	1.7
72	96.9	2.89	0.5*	0.2*	3.0*	3.8
75	100.7	0.08	4.0	0.3	12.2	0.8
80	37.1	0.03	2.5	0.3	6.2	2.1
80'	--	--	5.2	0.3	17.7	1.8
81	142.3	0.74	3.9	0.3	10.8	2.1
87	64.9	0.04	2.2*	0.3*	4.5*	2.6
92	111.9	0.87	2.1	0.3	6.4	1.3
93	25.8	0.27	3.4	0.3*	2.8*	2.6
97	40.3	0.21	2.2	0.3	4.0	1.3
98	95.4	0.09	2.0	0.0	6.0	2.8
130	40.2	0.24	1.9	0.3	4.4	1.5

* Approximate values based on measured peak heights.

Table 13. Cook Inlet Sediment Samples (1978 - Spring Cruise)

Station* No.	Latitude (N)	Longitude (W)	Depth (m)	Total Carbon (%)	Org. Carbon (%)	Nonsapon. Fr. (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
201	59°12.5'	153°52.6'	22	0.61	0.94	39.09	4.49	3.24
203	59°05.8'	153°29.5'	38	0.55	0.80	13.81	1.24	1.05
204	59°13.7'	153°39.4'	34	0.45	0.69	44.51	2.12	1.91
211	59°26.1'	153°37.5'	19	0.33	1.26	20.41	1.27	1.26
212	59°32.6'	153°20.9'	26	0.42	0.69	20.09	1.58	1.42
213	59°29.9'	153°14.0	33	0.59	0.65	16.06	1.14	1.27
214	59°17.9'	153°13.2'	53	0.45	0.54	25.83	1.41	1.35
233	59°48.9'	152°55.6'	14	0.41	0.58	32.24	2.27	2.06
233R	59°48.9'	152°55.6'	14	-	-	32.67	2.70	2.45
234	59°38.2'	152°56.4'	38	0.35	0.93	13.86	0.99	0.61
245	60°07.8'	152°16.7'	46	0.42	0.63	11.01	1.17	1.01
247	59°58.3'	152°34.1'	20	0.20	0.41	7.97	1.02	0.87
255	60°18.8'	151°37.0'	42	0.25	0.78	57.07	1.45	14.10
265	60°34.7'	151°49.5'	16	0.15	0.35	95.09	28.81	8.74
370	58°17.0'	154°02.6'	112	0.71	0.91	51.76	3.09	3.66
380	58°38.4'	153°26.0'	57	0.63	0.83	24.85	2.91	1.72
390	58°53.5'	153°11.0'	170	0.47	0.61	27.77	2.13	2.56
394	58°51.3'	153°08.2'	171	0.72	1.11	42.59	2.06	3.83

* All samples are 0-2 cm; R = replicate

Table 14. Aliphatic Hydrocarbon Concentrations (ng/g) in Cook Inlet Sediment Samples, Spring 1978 Cruise. (Part I: n-C_{15}-n-C_{23})

Station*	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
201	15.0	5.1	11.8	11.6	8.9	3.5	13.9	12.7	28.3	23.6	62.1
203	n.d.	n.d.	0.6	0.6	0.9	0.2	2.1	2.7	6.4	5.5	14.7
204	0.7	1.2	3.3	3.2	3.9	1.0	7.5	6.6	14.4	13.0	32.7
211	2.4	2.5	4.7	5.7	4.6	1.7	7.9	7.9	16.1	12.7	31.4
212	n.d.	n.d.	0.6	0.8	1.2	0.3	2.9	3.4	7.3	6.0	14.9
213	0.3	0.5	1.3	1.3	1.6	0.4	2.8	2.9	6.4	5.4	14.0
214	1.1	1.4	2.8	2.7	3.7	0.7	6.2	5.5	9.8	8.3	19.6
233	4.0	4.6	6.6	7.7	7.3	1.6	11.0	10.5	18.6	15.4	34.1
233R	0.4	1.1	3.2	3.4	4.4	1.0	9.4	8.7	19.6	14.1	31.5
234	0.4	0.4	0.8	0.7	0.8	0.2	1.2	0.9	1.2	1.3	1.8
245	n.d.	n.d.	0.4	0.5	0.7	n.d.	1.3	1.5	5.8	2.7	6.7
247	n.d.	0.3	0.9	2.2	1.4	0.8	2.5	2.4	3.5	3.7	5.7
255	1.3	1.2	2.0	2.6	1.7	0.5	2.6	2.5	4.6	3.8	7.9
265	8.0	13.0	27.3	14.9	42.3	19.4	65.2	75.1	50.2	38.6	35.2
370	23.3	50.2	20.4	26.3	18.9	6.2	28.9	23.2	49.0	31.7	76.0
380	0.2	0.4	1.0	1.4	1.0	0.3	1.9	2.3	5.7	4.7	12.7
390	1.6	1.8	3.2	5.9	3.7	1.2	6.5	6.2	10.7	9.1	19.3
394	11.4	12.0	18.7	32.9	19.7	6.8	26.4	23.0	31.8	22.8	32.7

* All samples are 0-2 cm, R = replicate, n.d. = too low to be determined accurately.

Table 14. Part II (n-C_{24} - n-C_{34})

Station*	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
201	28.4	103.9	28.3	282.8	30.2	178.8	18.1	139.7	12.4	52.4	4.9
203	6.2	24.4	6.7	67.9	6.9	42.7	2.8	32.0	2.7	12.0	1.4
204	14.3	51.5	14.4	105.4	12.9	80.5	13.5	55.6	10.0	20.6	1.8
211	14.9	50.6	17.9	138.8	12.8	73.9	10.5	48.9	4.5	15.3	1.0
212	7.3	24.2	7.4	47.4	6.3	32.1	7.0	24.6	4.1	8.6	0.8
213	6.6	25.5	7.0	56.2	7.0	44.2	3.9	30.5	3.2	12.0	1.5
214	9.4	33.0	9.9	62.9	7.9	46.8	8.2	28.3	4.5	7.8	0.7
233	15.6	51.2	14.4	113.1	12.3	78.8	9.8	49.9	5.6	18.3	1.3
233R	16.2	47.7	13.0	92.7	10.0	47.1	12.7	31.7	5.3	9.2	0.9
234	0.9	2.4	0.6	4.8	4.1	5.4	0.1	3.8	1.2	0.4	n.d.
245	3.3	13.6	4.2	28.3	3.6	21.8	2.1	15.0	4.6	1.3	0.9
247	4.8	10.0	5.8	21.2	5.9	17.9	3.8	12.2	2.4	5.2	1.5
255	4.2	12.2	4.5	22.8	3.6	18.8	3.5	13.9	4.1	5.0	0.5
265	51.2	42.0	40.5	30.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
370	37.1	133.0	36.9	388.7	34.4	221.3	35.9	171.9	16.8	65.1	7.6
380	5.7	23.8	6.6	69.9	7.3	43.1	3.8	31.0	2.7	11.8	1.2
390	12.3	30.5	9.7	70.4	10.5	47.9	8.7	33.4	3.4	11.2	2.1
394	23.7	45.4	34.3	95.7	33.2	79.0	28.6	71.0	12.8	27.7	6.7

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* All samples are 0-2 cm, R = replictae, n.d. = too low to be determined accurately

Table 15. Characteristic Parameters for Cook Inlet Hydrocarbons (Spring, 1978)

Station	$\frac{\text{Nonsap. fr.}}{\text{Org. C}}$ (x 10^4)	$\frac{\text{Alkanes}}{\text{Org.C}}$ (x10^4)	$\frac{\text{Pr.}}{\text{n-C}_{17}}$	$\frac{\text{Phy.}}{\text{n-C}_{18}}$	$\frac{\text{Pr.}}{\text{Phy.}}$	$\frac{\text{Odd}}{\text{Even}}$
201	64.08	1.74	0.98	0.39	3.34	5.15
203	25.11	0.44	1.07	0.24	2.66	5.66
204	98.91	1.02	0.97	0.27	3.01	4.06
211	61.85	1.45	1.22	0.37	3.34	4.36
212	47.83	0.50	1.34	0.26	2.56	3.74
213	27.22	0.40	0.95	0.28	2.86	4.93
214	57.40	0.62	0.97	0.20	3.66	3.67
233	78.63	1.17	1.17	0.21	4.96	3.93
233R	--	--	1.06	0.22	3.48	3.39
234	39.60	0.09	0.87	0.20	4.09	2.09
245	26.21	0.29	1.25	0.22	2.50	3.99
247	39.85	0.55	2.52	0.57	2.79	2.47
255	228.28	0.48	1.33	0.32	4.87	3.02
265	633.93	3.60	0.55	0.46	0.77	1.06
370	72.90	2.07	1.29	0.33	4.28	4.03
380	39.44	0.38	1.45	0.28	4.99	5.65
390	59.09	0.64	1.85	0.33	4.87	3.48
394	59.15	0.92	1.76	0.34	4.88	2.03

R = replicate

Table 16. Cook Inlet Sediment Samples (1978 - Summer Cruise)

Station No.*	Latitude (N)	Longitude (W)	Depth (m)	Total C (%)	Org. C (%)	Nonsapon. Fr. (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
204	59°13.8'	153°39.7'	33	0.67	0.82	25.12	1.42	1.48
205	59°06.7'	152°40.4'	138	0.42	1.23	38.88	1.14	1.06
206	59°09.5'	153°06.5'	90	0.38	0.60	26.65	0.88	1.86
212	59°32.0'	153°21.0'	24	0.61	1.10	23.99	2.14	1.54
215	59°22.4'	152°48.3'	78	0.49	0.51	7.73	0.48	0.63
217	59°21.7'	152°22.8'	71	0.25	0.34	16.51	0.44	0.42
234	59°38.3'	152°55.7'	39	0.30	1.02	34.09	1.94	0.96
378	58°01.9'	153°28.2'	92	--	--	38.10	1.26	2.61
384	58°30.5'	153°14.5'	176	0.73	0.89	48.39	2.00	3.66
388	58°27.4'	152°56.1'	214	1.16	1.57	108.60	5.81	9.97
390	58°53.6'	153°10.8'	165	0.57	0.80	32.15	1.97	1.89
398	58°49.3'	152°12.0'	--	0.44	6.22	84.04	0.07	2.48
UC100	59°01.2'	152°28.8'	150	0.31	1.02	21.67	0.99	0.75
UC200	59°01.0'	153°32.4'	150	0.38	1.56	33.03	1.24	1.35
UC300	58°28.3'	153°45.6'	101	0.69	1.02	94.82	4.55	5.16
CB8	59°39.4'	151°16.6'	--	0.93	1.53	117.95	13.08	7.24
CB8R	59°39.4'	151°16.6'	--	--	--	90.05	9.43	7.68

* All samples are 0-2 cm.

R = replicate

Table 17. Aliphatic Hydrocarbon Concentrations in Cook Inlet Samples: Summer (1978)(ng/g)

Part I (n-C_{15} - n-C_{23})

Station	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
204	0.4	0.7	2.1	2.0	2.2	1.8	4.1	3.2	6.7	5.3	14.1
205	n.d.	0.5	1.3	2.0	1.8	0.7	3.3	3.4	5.1	4.7	6.6
206	n.d.	n.d.	0.4	1.2	0.7	n.d.	1.4	4.1	2.3	1.9	4.6
212	0.7	1.3	3.6	3.4	3.7	1.1	7.2	5.3	5.6	7.6	19.5
215	n.d.	n.d.	0.1	0.2	0.2	n.d.	0.6	1.3	1.8	2.1	4.7
217	n.d.	n.d.	0.3	1.2	0.4	0.1	0.6	4.5	0.6	0.7	1.2
234	22.7	28.5	29.2	11.2	25.6	5.4	25.7	22.5	16.9	15.0	14.8
378	1.4	1.1	2.0	4.5	2.3	0.9	4.8	4.2	7.2	5.1	8.3
384	2.4	2.6	4.5	9.8	4.9	1.5	7.6	6.3	8.9	7.4	16.2
388	9.4	6.6	10.8	37.1	11.0	3.7	16.6	16.6	20.0	14.9	20.3
390	2.3	2.6	4.6	8.8	4.5	1.6	7.3	6.2	10.4	8.8	17.7
398	1.3	2.1	4.3	11.1	4.3	1.4	5.5	5.4	5.0	4.2	4.4
UC 100	0.1	0.2	0.6	0.7	1.0	0.3	2.0	2.2	3.8	3.0	3.6
UC 200	0.6	1.0	2.0	6.3	2.3	0.8	3.9	4.0	6.4	5.6	6.7
UC 300	1.3	2.3	8.3	15.5	9.6	2.9	17.7	16.9	36.0	29.1	85.5
CB 8	3.6	1.4	6.2	7.5	2.3	4.7	7.3	60.7	41.1	27.2	89.0
CB 8R	1.5	1.0	4.5	5.9	5.5	2.9	14.8	37.3	42.2	39.7	103.4

n.d. = too low to be determined accurately

R = replicate

Table 17 : Part II (n-C_{24} - n-C_{34})

Station	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
204	6.6	26.8	7.3	62.9	7.3	49.6	6.9	35.2	3.7	13.3	2.3
205	5.2	9.8	6.1	18.5	7.0	19.1	6.1	25.7	4.5	10.1	2.6
206	2.5	8.0	3.3	16.2	3.6	22.6	4.8	16.1	2.1	5.9	0.8
212	8.9	35.1	10.2	80.9	10.3	70.0	9.8	50.1	5.0	19.0	1.8
215	2.9	5.8	2.4	8.4	2.2	12.3	2.9	9.7	3.1	3.3	0.4
217	0.8	1.7	0.9	4.4	1.0	8.9	0.7	3.0	0.3	0.9	n.d.
234	13.2	14.8	8.0	16.4	4.9	10.8	2.7	9.7	2.0	3.2	n.d.
378	5.4	14.5	5.6	34.0	5.5	22.1	4.2	29.0	3.1	10.8	1.5
384	9.4	23.9	9.3	48.7	38.4	30.5	22.4	11.2	1.6	n.d.	n.d.
388	13.1	24.1	12.3	41.7	8.9	35.3	5.5	35.8	26.9	12.2	n.d.
390	9.4	32.5	11.5	72.2	10.1	67.0	2.4	38.3	14.2	3.5	n.d.
398	3.6	5.0	3.8	6.6	3.6	6.4	3.0	8.5	2.1	3.6	1.1
UC 100	2.9	3.9	2.7	5.5	2.6	5.4	1.8	7.3	1.3	2.8	0.7
UC 200	5.5	7.4	5.0	10.4	4.8	10.4	3.2	13.6	2.5	5.2	1.3
UC 300	48.5	117.7	36.1	262.0	31.6	142.9	31.5	115.2	75.5	40.0	5.6
CB 8	36.4	152.1	37.8	332.4	37.7	263.7	28.4	181.8	11.3	53.7	3.0
CB 8R	55.7	176.7	45.8	388.3	45.3	331.4	33.8	240.3	16.0	72.4	5.7

n.d. = too low to be determined accurately

R = replicate

TABLE 18. Characteristic Parameters for Cook Inlet Hydrocarbons (Summer, 1978)

Station	Nonsap. / O.C (x 10^4)	n-Alkanes / O.C. (x 10^4)	Pristane / n-C_{17}	Phytane / n-C_{18}	Pristane / Phytane	Odd / Even
204	37.49	0.39	0.96	0.82	1.10	4.78
205	92.57	0.34	1.64	0.37	3.02	2.36
206	70.13	0.27	3.09	0.27	6.67*	3.25
212	39.33	0.59	0.94	0.28	3.19	4.60
215	15.78	0.13	1.38	0.35*	2.0*	2.67
217	66.04	0.12	4.55	0.25	12.71	2.34
234	113.63	1.02	0.16	0.21	0.86	1.23
378	--	--	2.24	0.37	5.19	3.47
384	66.29	0.35	2.19	0.30	6.66	1.50
388	93.62	0.30	3.45	0.34	10.09	1.91
390	56.40	0.57	1.92	0.36	5.39	3.67
398	191.00	0.19	2.56	0.32	8.08	1.52
UC100	69.90	0.17	1.30	0.28	2.58	1.89
UC200	86.92	0.27	3.19	0.32	8.28	1.88
UC300	137.42	1.61	1.87	0.31	5.30	2.88
CBI 8	126.83	1.48	1.20	2.10	1.58	4.59
CBII 8R	96.83	1.79	1.32	0.52	2.04	4.81

* Approximate values based on measured peak heights.

R = replicate

TABLE 19. Polycyclic Aromatic Hydrocarbons in Sediment Samples Analyzed by GC-MS (in ppb)

	Beaufort Sea 1976		Norton Sound 1976		Norton Sound 1977		Kodiak Shelf 1976	
	Station 1	Station 7	Station 131	Station 166	Station 35	Station 43	Station 80	Station 98
O-xylene (XYL)	13.0	--	--	T	T	--	--	--
Isopropylbenzene (IPB)	T	--	--	--	--	--	--	--
n-Propylbenzene (NPB)	T	--	--	T	T	--	--	--
Indan (IND)	T	--	--	--	--	--	--	--
1,2,3,4-Tetramethylbenzene ITMB)	T	--	--	T	--	--	--	--
Naphthalene (NPH)	2.0	T	T	T	T	--	--	1.5
2-Methylnaphthalene (2MN)	11.5	6.9	T	T	T	T	T	T
1-Methylnaphthalene (1MN)	7.9	5.7	T	T	T	T	T	T
Biphenyl (BPH)	3.2	2.4	T	T	T	T	T	T
2,6-Dimethylnaphthalene	--	9.0	T	T	--	--	0.3	3.3
Dimethylnaphthalenes (DMN)[1]	--	12.9	T	T	--	--	0.4	6.5
Trimethylnaphthalenes (TMN)	--	--	T	T	T	T	0.6[3]	6.0
Fluorene (FLU)	1.7	8.1[2]	T	--	T	T	T	6.1
Dibenzothiophene (DBT)	6.0	--	--	--	--	--	--	--
Phenanthrene (PHN)	32.9	31.3	4.2[3]	0.2	1.9[3]	0.8[3]	2.2[3]	43.8
Anthracene (ANT)	T	T	--	--	T	T	--	T
Methylphenanthrenes (MPH)	78.0	86.6	0.6	T	--	0.2	1.7	37.2
Fluoranthene (FLA)	12.2	23.1	T	0.1	0.5	T	0.7	18.9
Pyrene (PYR)	16.5[4]	25.7[4]	2.2[4]	0.1[4]	0.2	T	0.3	15.1[4]
Benz[a]anthracene (BAA)	--	--	--	--	T	--	T	--
Chrysene (CHR)	21.2	28.6	3.0[3]	0.6	T	0.4	0.5	40.4
Benz[e]pyrene (BEP)	T	T	T	T	--	--	T	T
Benz[a]pyrene (BAP)	T	T	--	--	T	T	--	T
Perylene (PER)	10.0	40.8	9.8	T	T	1.3	T	T
Simonellite (SIM)	See PYR	See PYR	--	See PYR	T	T	--	See PYR
Cadalene (CAD)	--	14.4	0.3	T	--	--	T	--
Retene (RET)	29.1	62.1	2.8[3]	--	T	3.1[3]	0.5[3]	18.8[3]

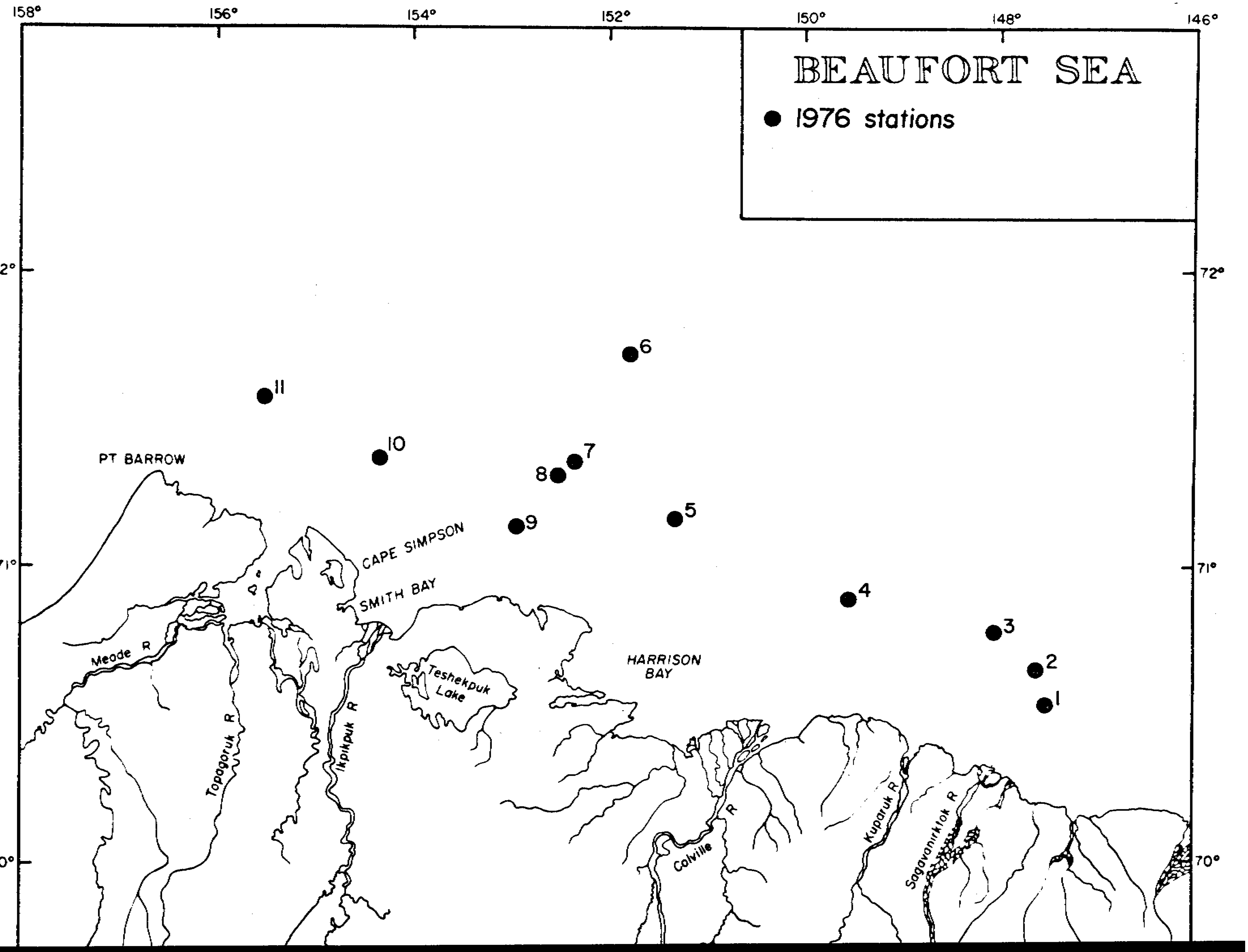
T = trace

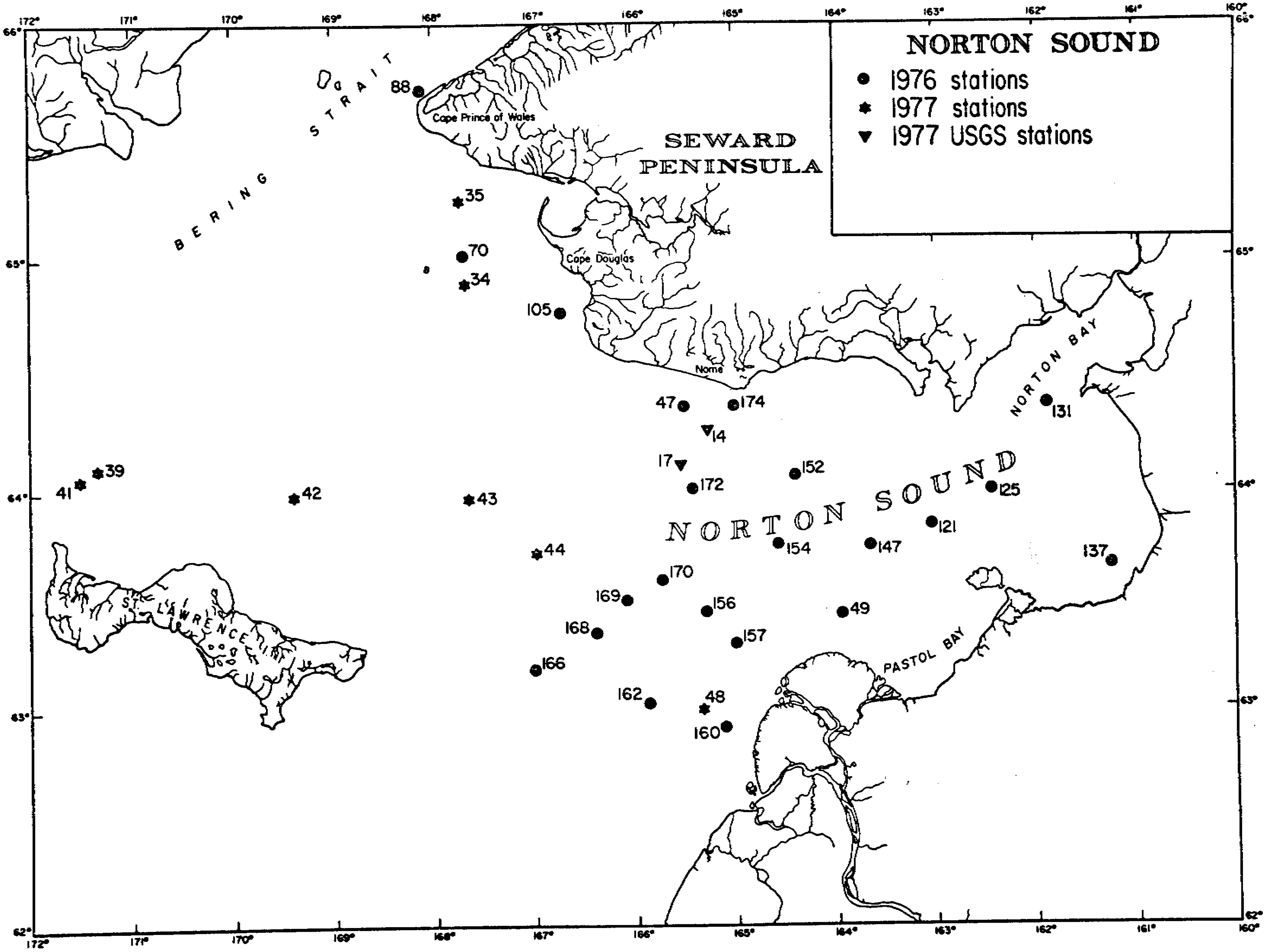
[1] - Excludes 2,6-dimethylnaphthalene when identified

[2] - Coelutes with dimethylnaphthalene

[3] - Coelutes with unknown compound

[4] - Coelutes with simonellite


BEAUFORT SEA
● 1976 stations
158°
156°
154°
152°
150°
148°
146°
72°
71°
70°
1
2
3
4
5
6
7
8
9
10
11
PT BARROW
CAPE SIMPSON
SMITH BAY
HARRISON BAY
Teshekpuk Lake
Meade R
Topagoruk R
Ikpikpuk R
Colville R
Kuparuk R
Sagavanirktok R


NORTON SOUND
● 1976 stations
✱ 1977 stations
▼ 1977 USGS stations
SEWARD PENINSULA
BERING STRAIT
Cape Prince of Wales
Cape Douglas
Nome
NORTON BAY
NORTON SOUND
PASTOL BAY
ST. LAWRENCE I.
88
35
70
34
105
47
174
14
17
152
172
131
125
121
154
147
137
39
41
42
43
44
170
169
156
49
168
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162
48
160
172°
171°
170°
169°
168°
167°
166°
165°
164°
163°
162°
161°
160°
66°
65°
64°
63°
62°

FIG. 2

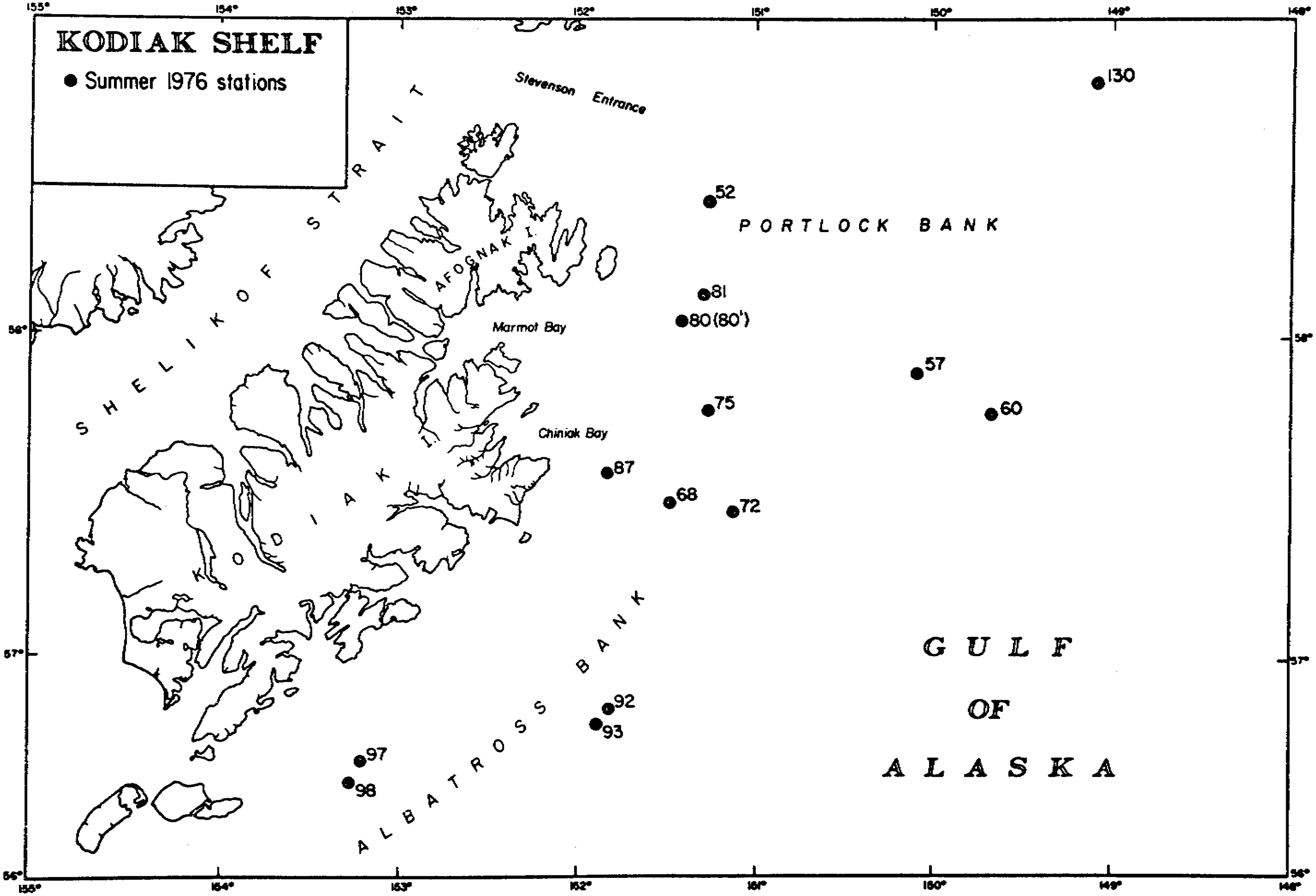

KODIAK SHELF
● Summer 1976 stations
155°
154°
153°
152°
151°
150°
149°
148°
58°
57°
56°
SHELIKOF STRAIT
Stevenson Entrance
AFOGNAK I.
Marmot Bay
Chiniak Bay
KODIAK ISLAND
PORTLOCK BANK
ALBATROSS BANK
GULF OF ALASKA
130
52
81
80(80')
57
75
60
87
68
72
92
93
97
98

FIG. 3

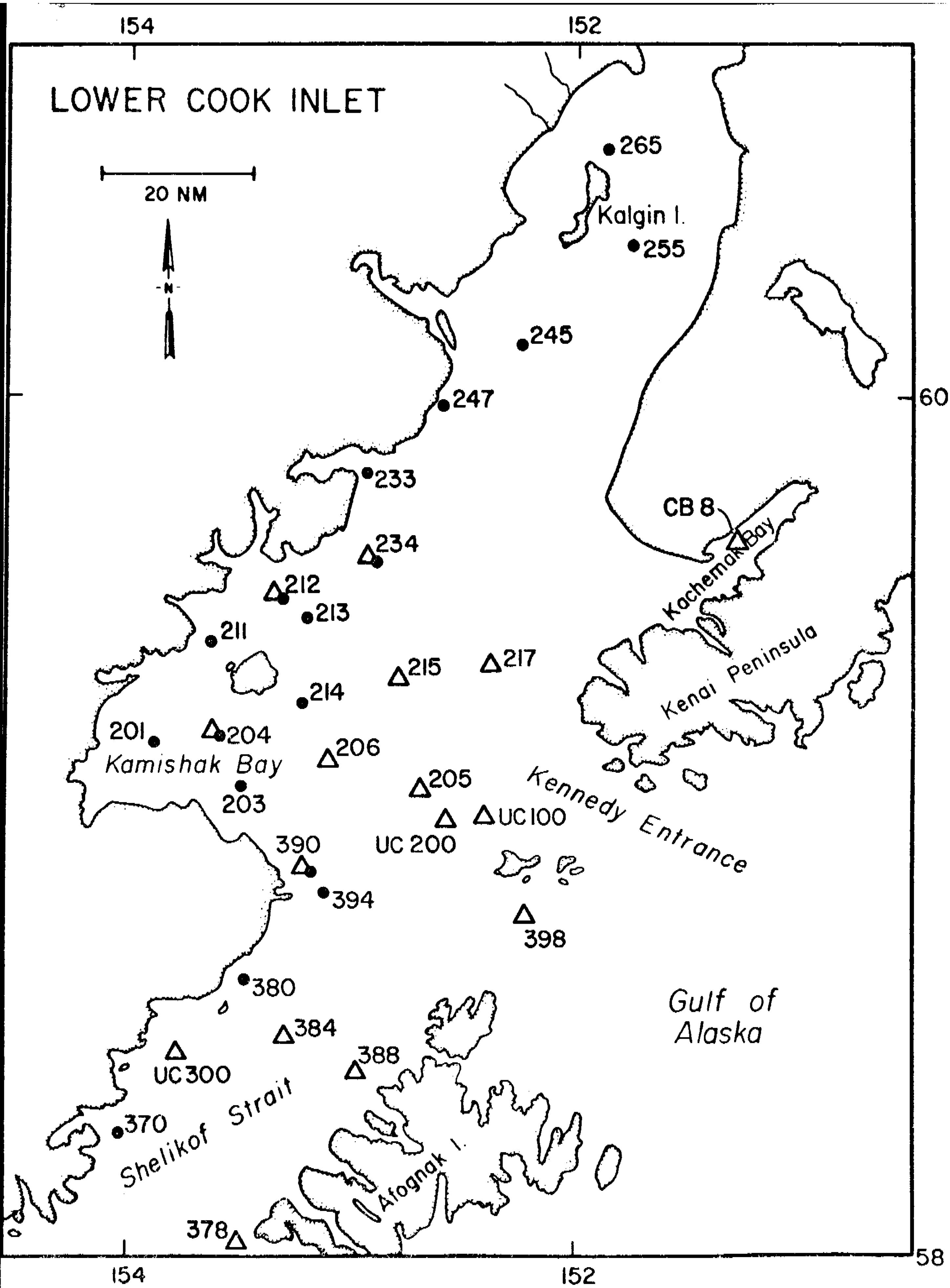
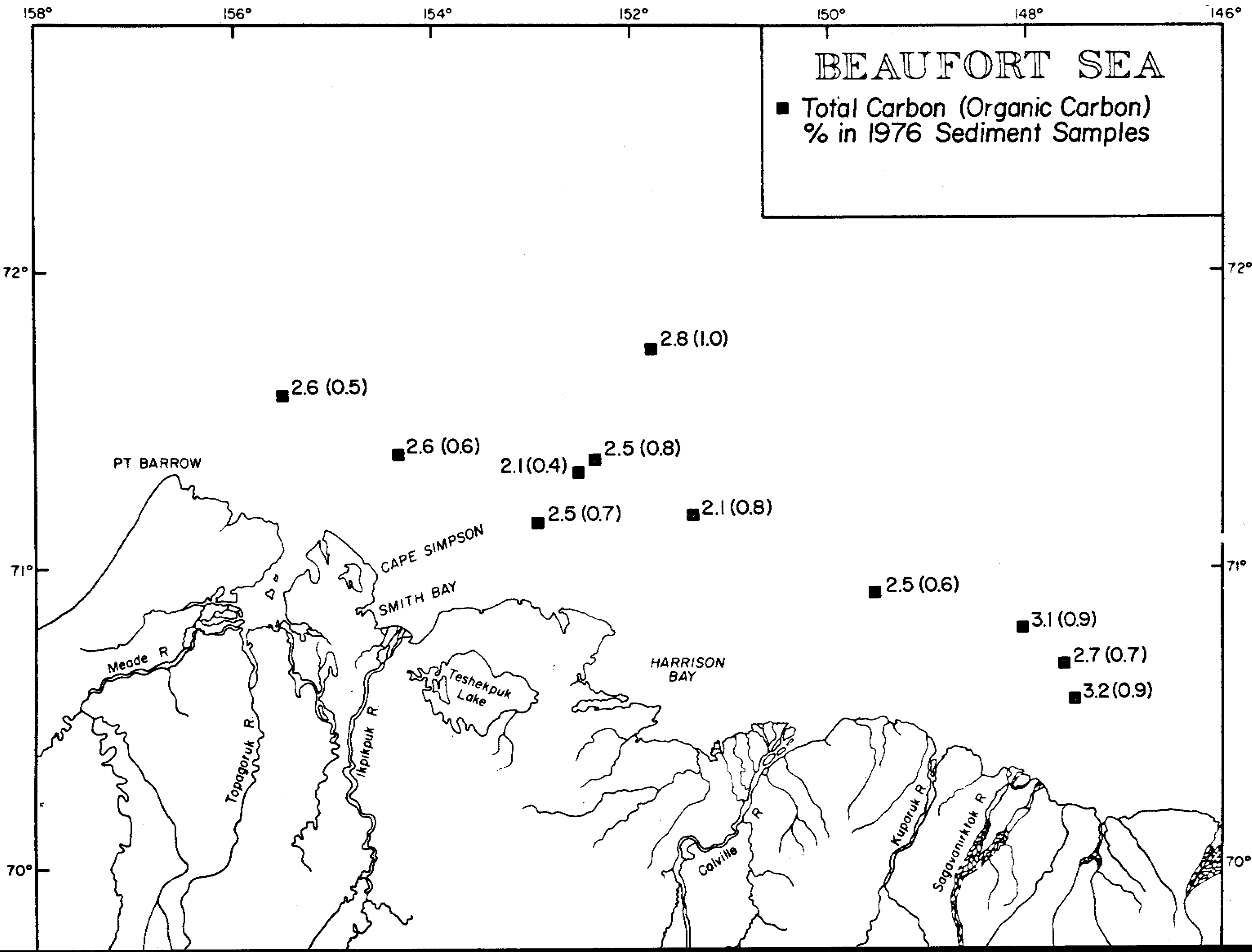


Fig. 4 ● 1978 spring samples. △ 1978 summer samples


BEAUFORT SEA
■ Total Carbon (Organic Carbon) % in 1976 Sediment Samples
158°
156°
154°
152°
150°
148°
146°
72°
71°
70°
2.8 (1.0)
2.6 (0.5)
2.6 (0.6)
2.1 (0.4)
2.5 (0.8)
2.5 (0.7)
2.1 (0.8)
2.5 (0.6)
3.1 (0.9)
2.7 (0.7)
3.2 (0.9)
PT BARROW
CAPE SIMPSON
SMITH BAY
HARRISON BAY
Teshekpuk Lake
Meade R
Topagoruk R
Ikpikpuk R
Colville R
Kuparuk R
Sagavanirktok R

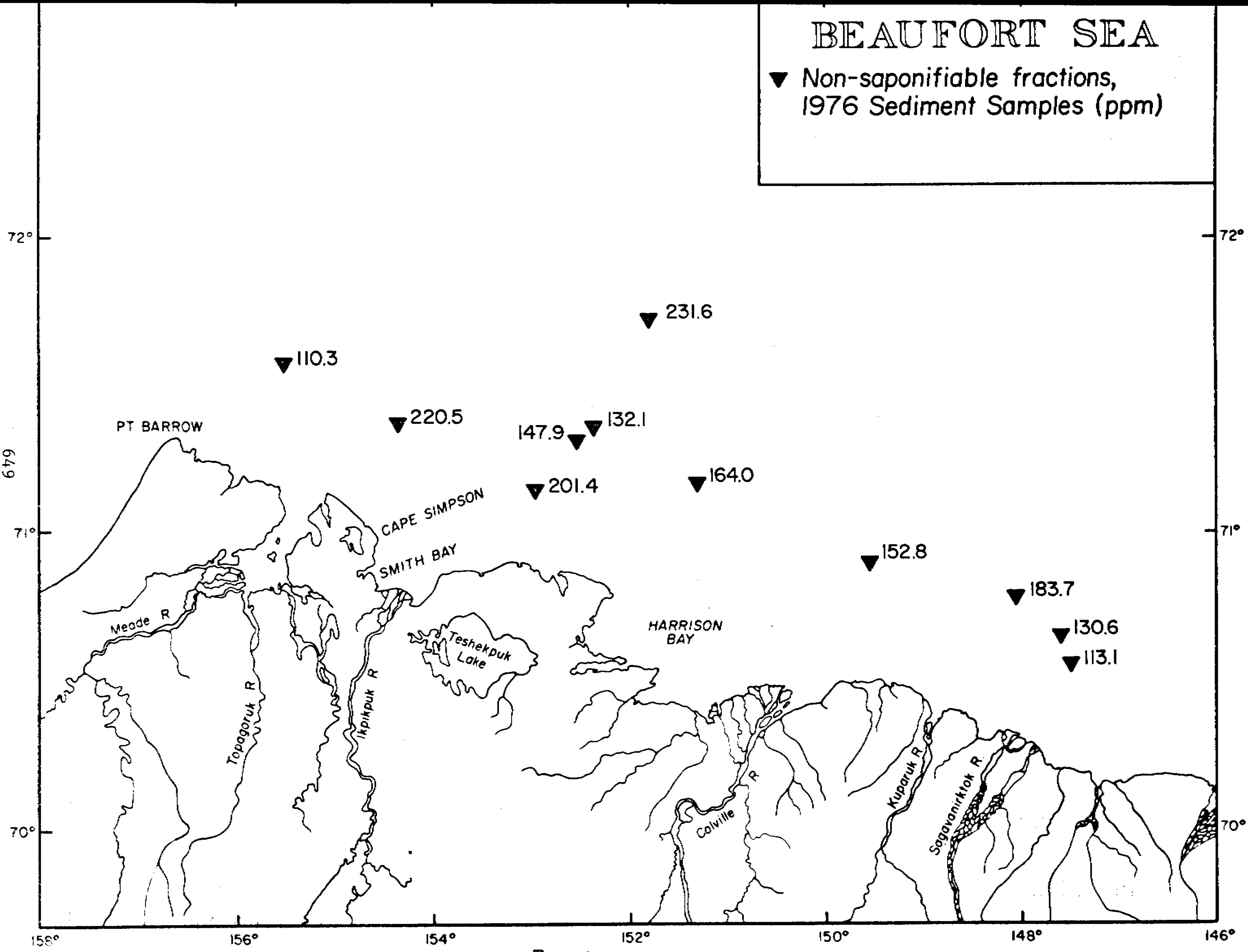
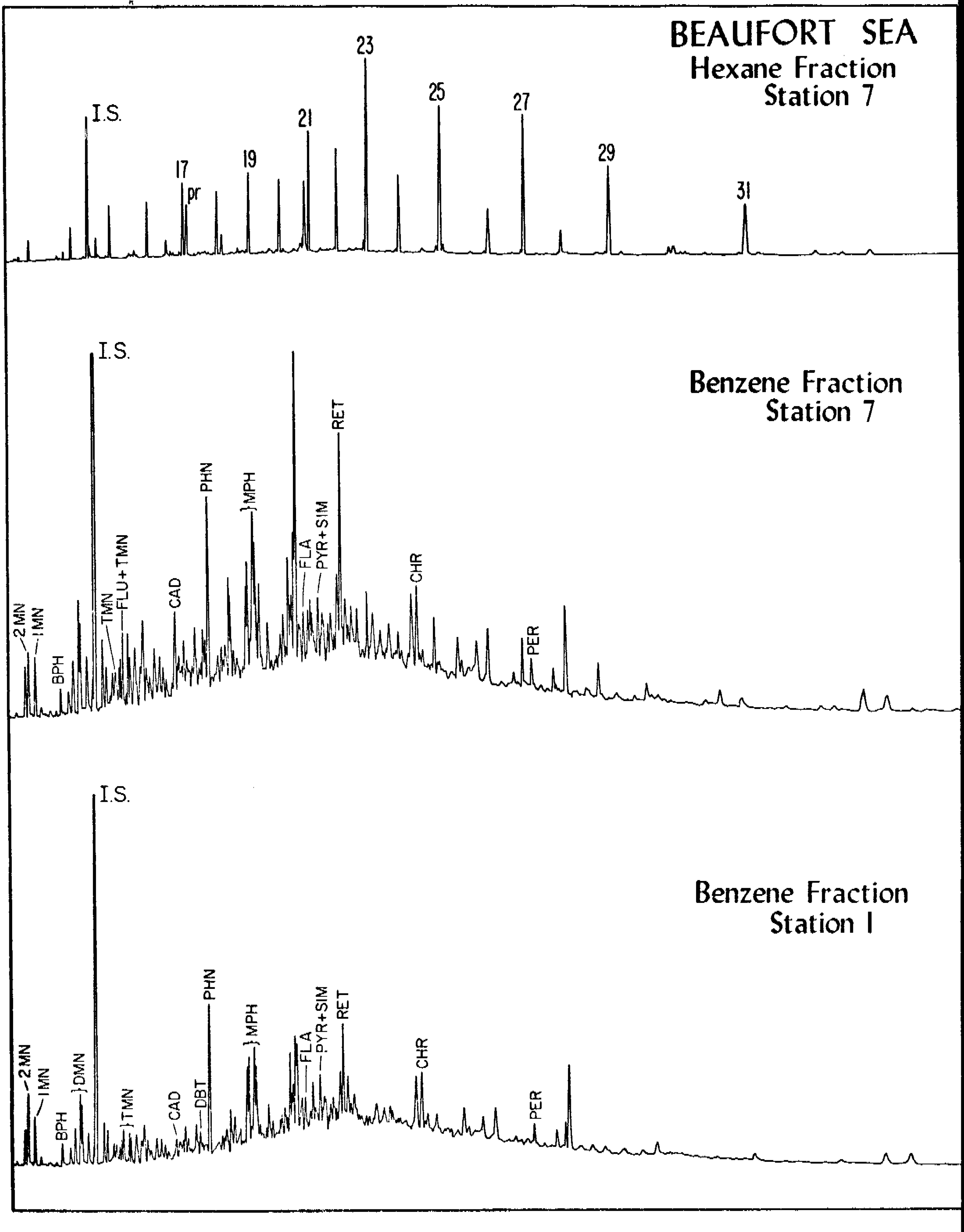

BEAUFORT SEA
▼ Non-saponifiable fractions, 1976 Sediment Samples (ppm)
231.6
110.3
220.5
147.9
132.1
164.0
201.4
152.8
183.7
130.6
113.1
PT BARROW
CAPE SIMPSON
SMITH BAY
HARRISON BAY
Teshekpuk Lake
Meade R
Topagoruk R
Ikpikpuk R
Colville R
Kuparuk R
Sagavanirktok R
72°
71°
70°
158°
156°
154°
152°
150°
148°
146°

FIG. 6


BEAUFORT SEA

Hexane Fraction
Station 7

Benzene Fraction
Station 7

Benzene Fraction
Station I

FIG. 7

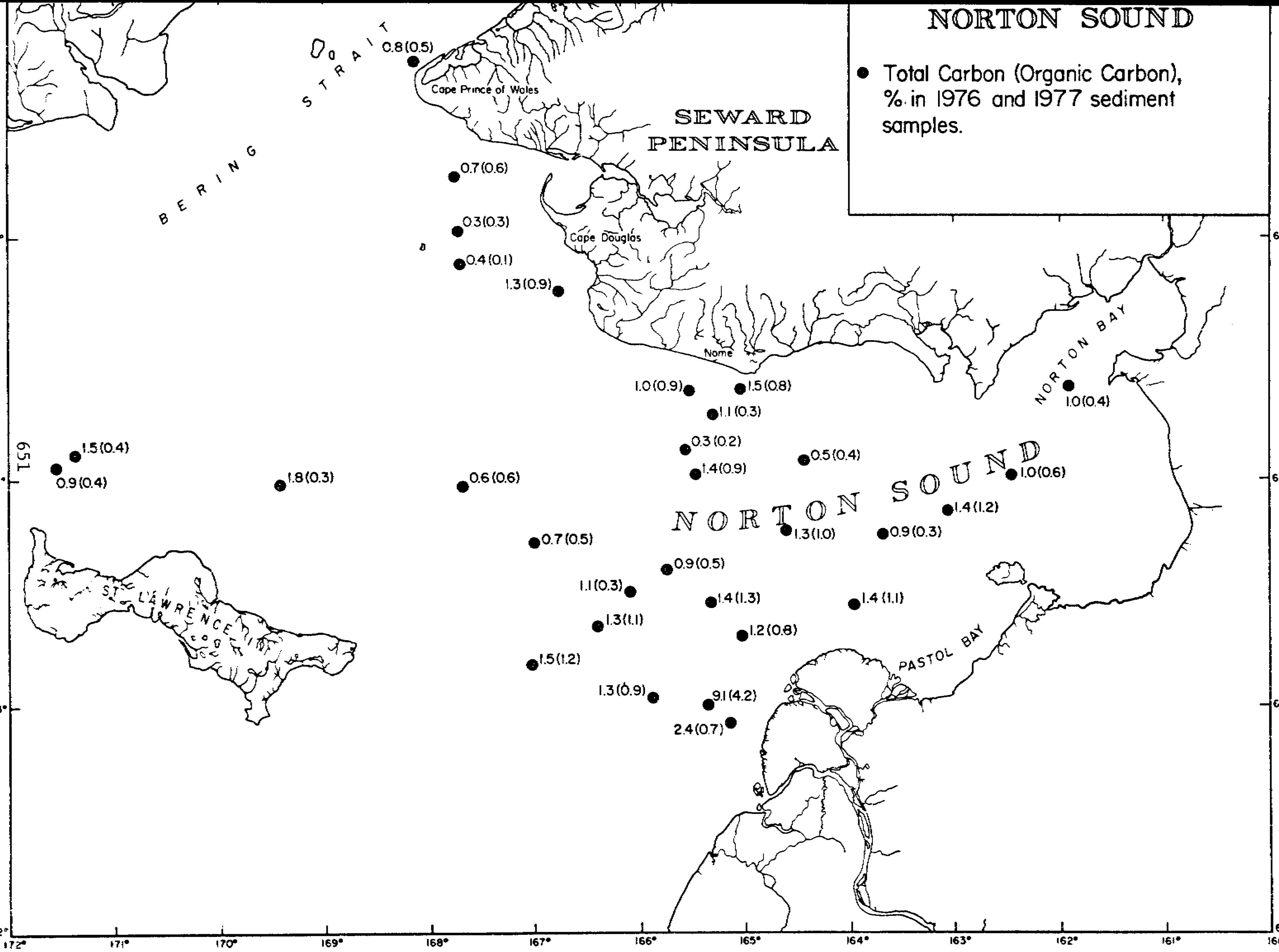
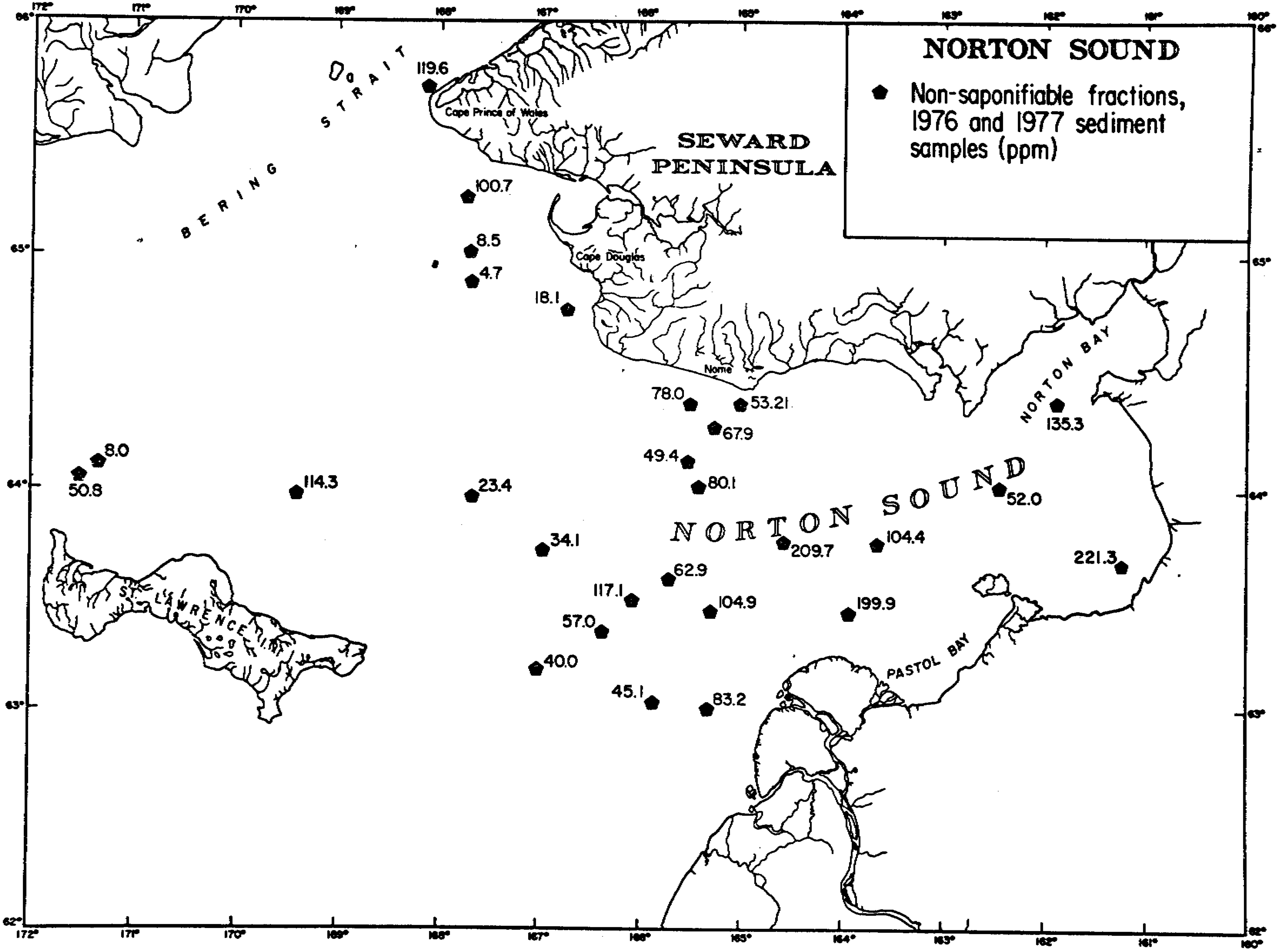

NORTON SOUND
● Total Carbon (Organic Carbon), % in 1976 and 1977 sediment samples.
SEWARD PENINSULA
BERING STRAIT
Cape Prince of Wales
Cape Douglas
Nome
NORTON BAY
NORTON SOUND
PASTOL BAY
ST. LAWRENCE I.
0.8(0.5)
0.7(0.6)
0.3(0.3)
0.4(0.1)
1.3(0.9)
1.0(0.9)
1.5(0.8)
1.1(0.3)
0.3(0.2)
0.5(0.4)
1.4(0.9)
1.0(0.4)
1.0(0.6)
1.5(0.4)
0.9(0.4)
1.8(0.3)
0.6(0.6)
1.4(1.2)
1.3(1.0)
0.9(0.3)
0.7(0.5)
0.9(0.5)
1.1(0.3)
1.4(1.3)
1.4(1.1)
1.3(1.1)
1.2(0.8)
1.5(1.2)
1.3(0.9)
9.1(4.2)
2.4(0.7)
65°
64°
63°
62°
172°
171°
170°
169°
168°
167°
166°
165°
164°
163°
162°
161°
160°

FIG. 3


NORTON SOUND
● Non-saponifiable fractions, 1976 and 1977 sediment samples (ppm)
SEWARD PENINSULA
BERING STRAIT
Cape Prince of Wales
Cape Douglas
Nome
NORTON BAY
NORTON SOUND
PASTOL BAY
ST. LAWRENCE
119.6
100.7
8.5
4.7
18.1
78.0
53.21
67.9
49.4
80.1
135.3
8.0
50.8
114.3
23.4
52.0
34.1
209.7
104.4
221.3
62.9
117.1
104.9
199.9
57.0
40.0
45.1
83.2
172°
171°
170°
169°
168°
167°
166°
165°
164°
163°
162°
161°
160°
66°
65°
64°
63°
62°

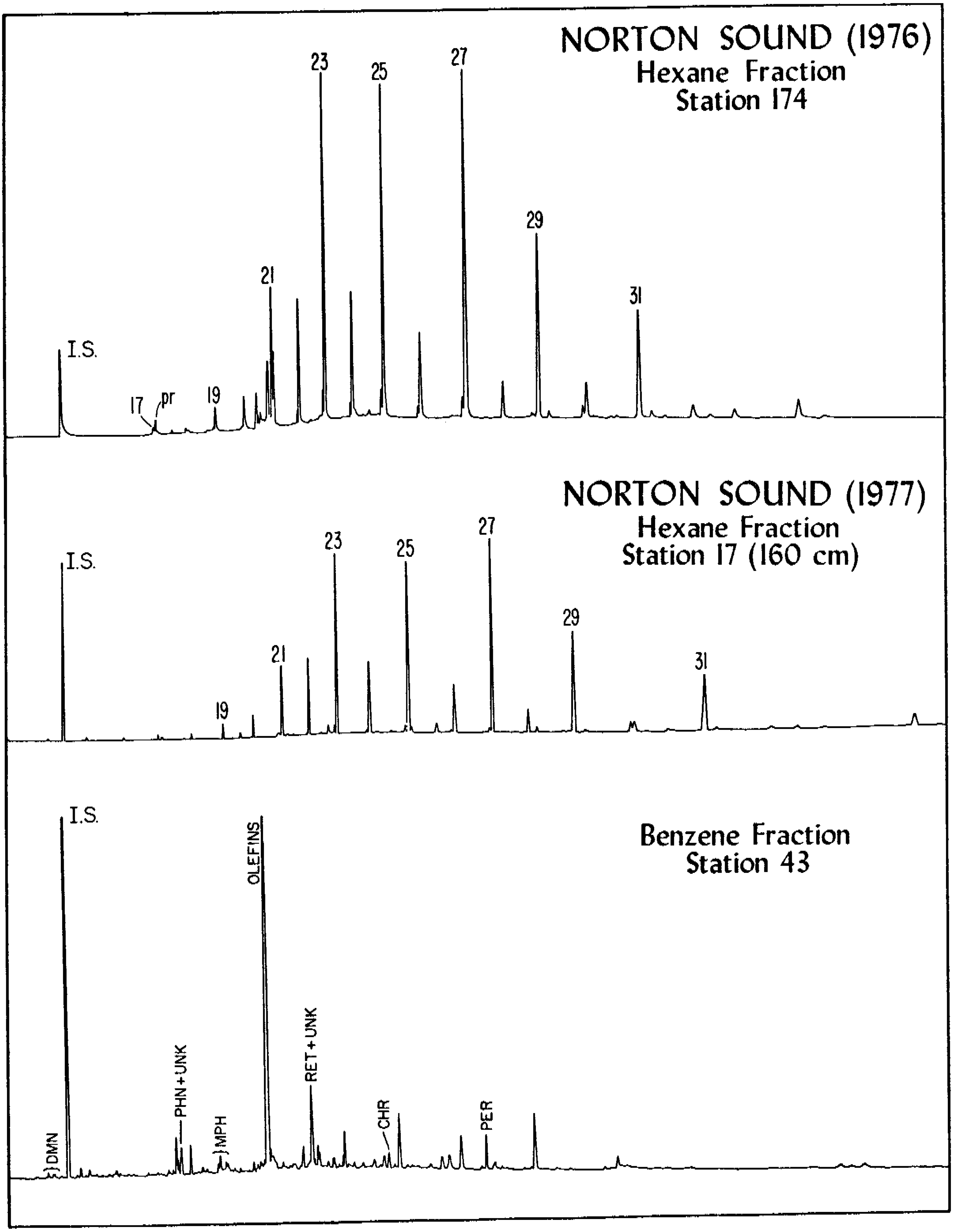

NORTON SOUND (1976)
Hexane Fraction
Station 174
I.S.
17
pr
19
21
23
25
27
29
31
NORTON SOUND (1977)
Hexane Fraction
Station 17 (160 cm)
I.S.
19
21
23
25
27
29
31
Benzene Fraction
Station 43
I.S.
DMN
PHN+UNK
MPH
OLEFINS
RET+UNK
CHR
PER

FIG. 10

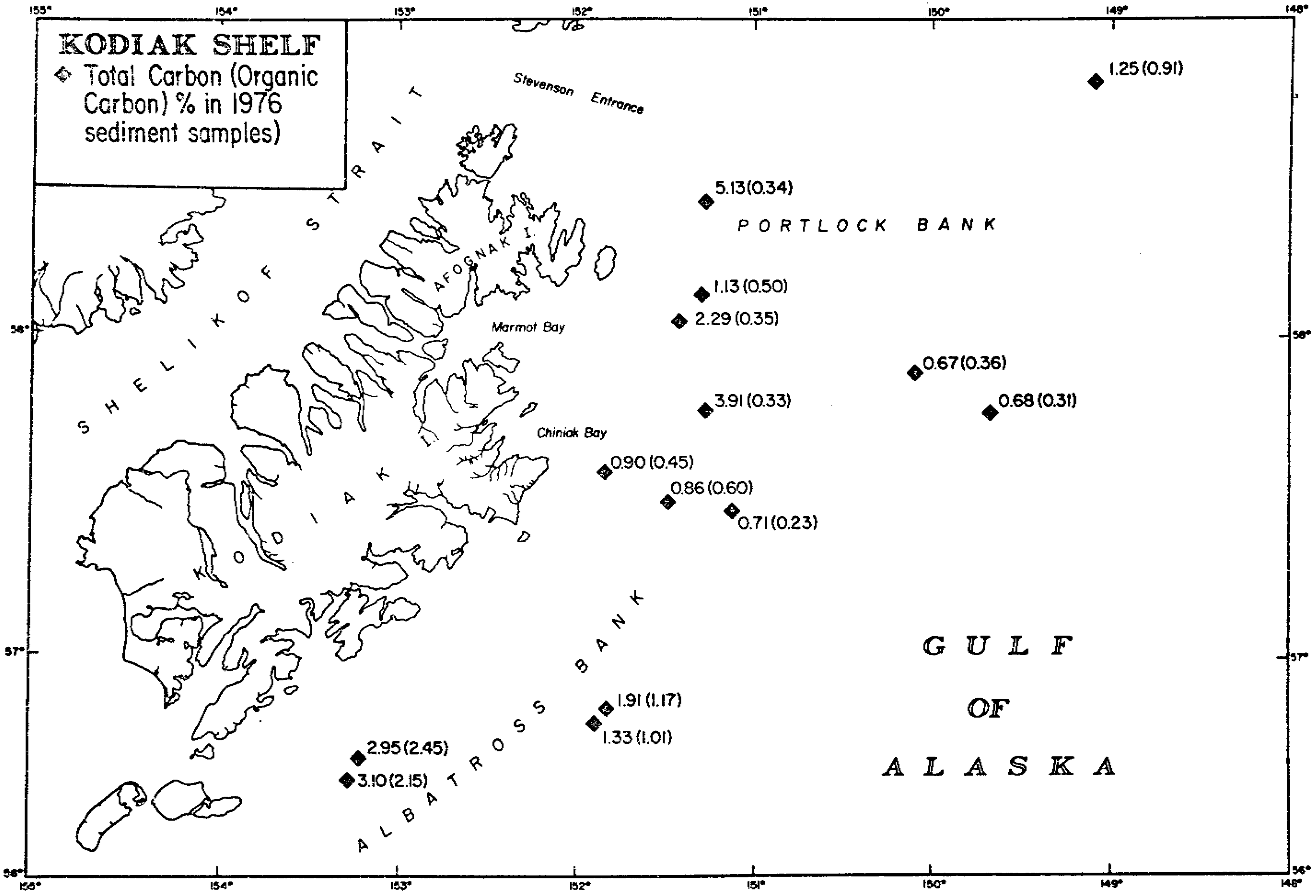
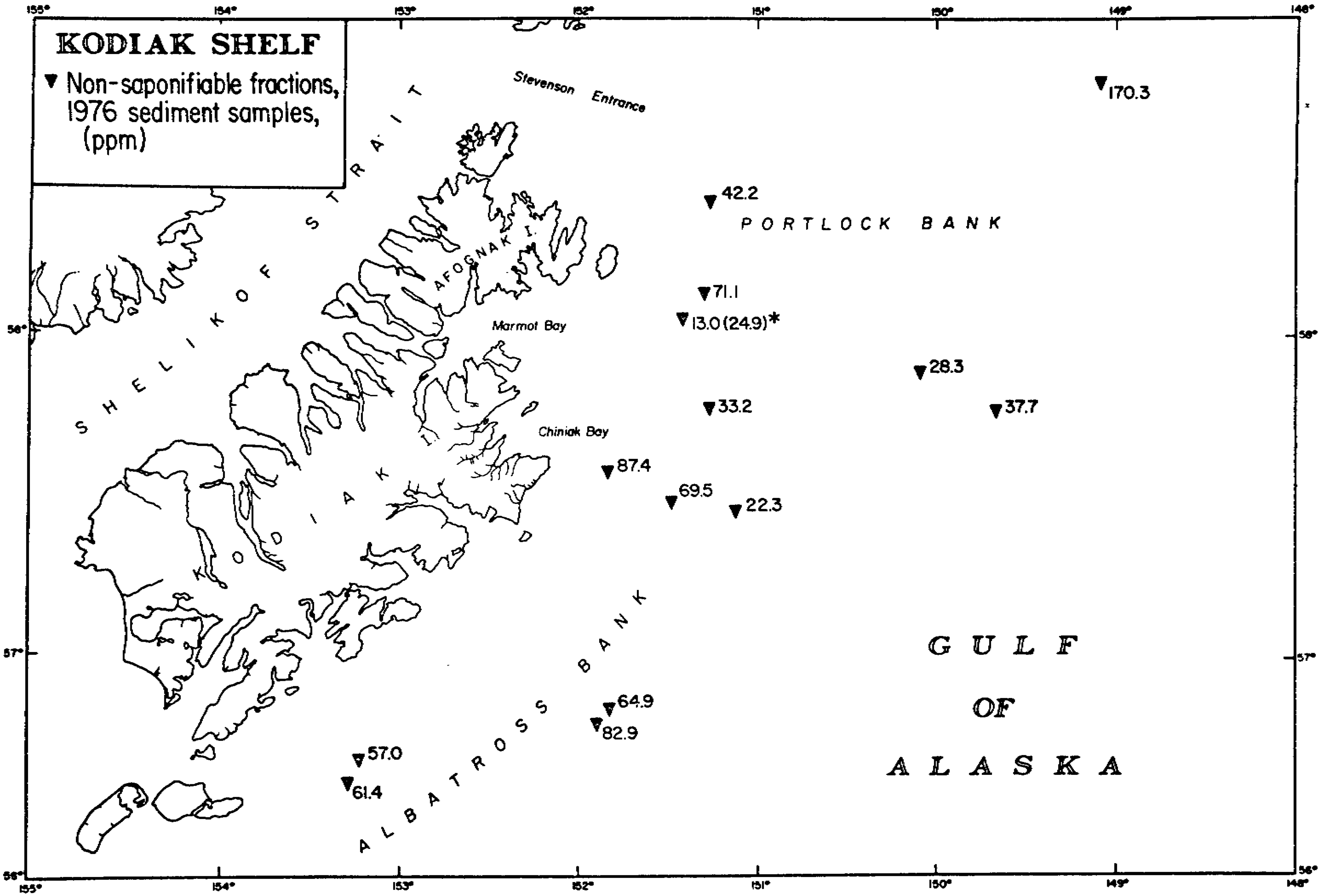

KODIAK SHELF
◆ Total Carbon (Organic Carbon) % in 1976 sediment samples)
155°
154°
153°
152°
151°
150°
149°
148°
58°
57°
56°
Stevenson Entrance
SHELIKOF STRAIT
AFOGNAK I.
KODIAK ISLAND
Marmot Bay
Chiniak Bay
PORTLOCK BANK
ALBATROSS BANK
GULF OF ALASKA
1.25 (0.91)
5.13 (0.34)
1.13 (0.50)
2.29 (0.35)
0.67 (0.36)
0.68 (0.31)
3.91 (0.33)
0.90 (0.45)
0.86 (0.60)
0.71 (0.23)
1.91 (1.17)
1.33 (1.01)
2.95 (2.45)
3.10 (2.15)

FIG. 11



*This sample 2-4 cm.

FIG.12

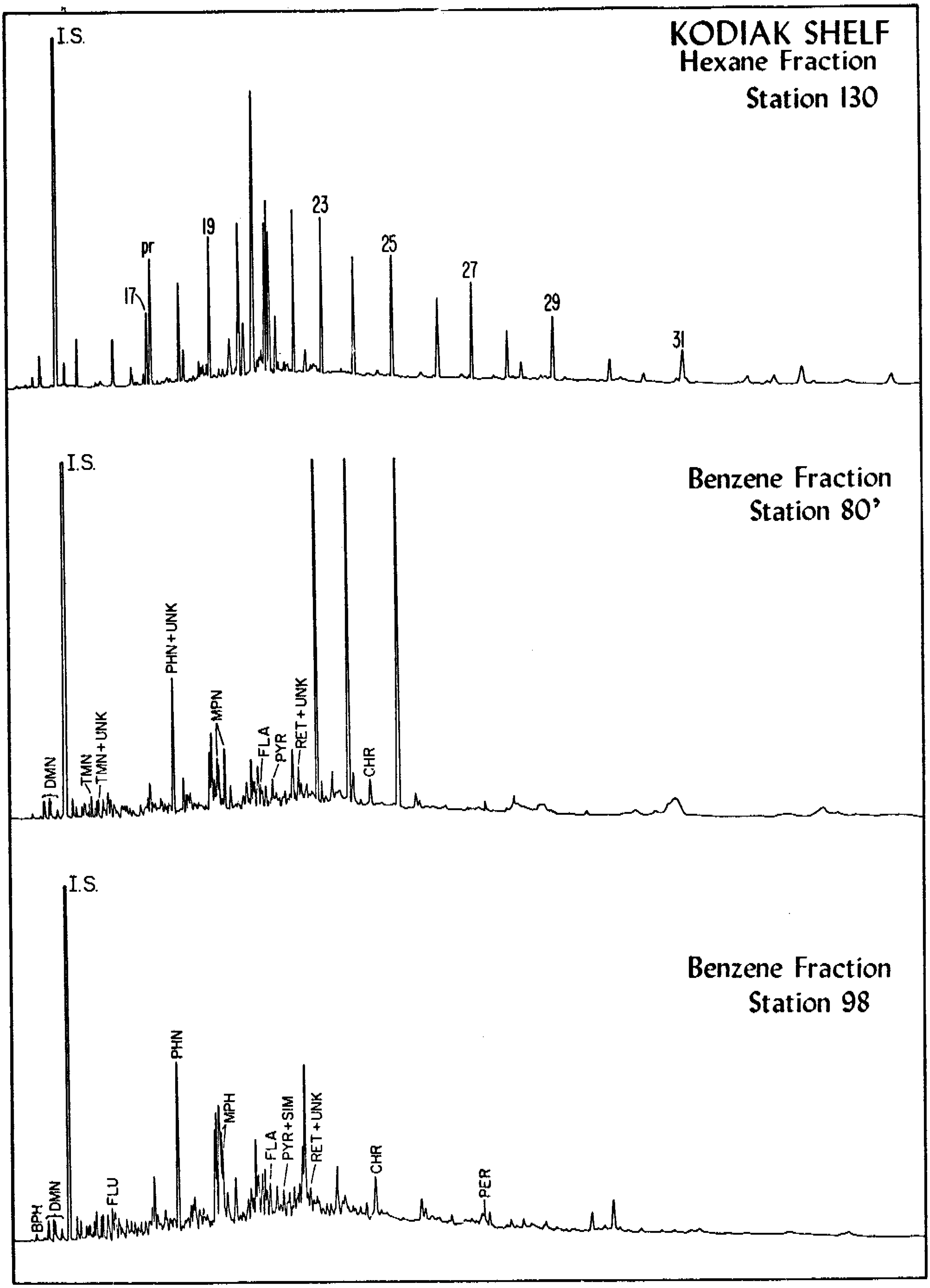

KODIAK SHELF
Hexane Fraction
Station 130
I.S.
17
pr
19
23
25
27
29
31
I.S.
Benzene Fraction
Station 80'
DMN
TMN
TMN+UNK
PHN+UNK
MPN
FLA
PYR
RET+UNK
CHR
I.S.
Benzene Fraction
Station 98
BPH
DMN
FLU
PHN
MPH
FLA
PYR+SIM
RET+UNK
CHR
PER

FIG. 13

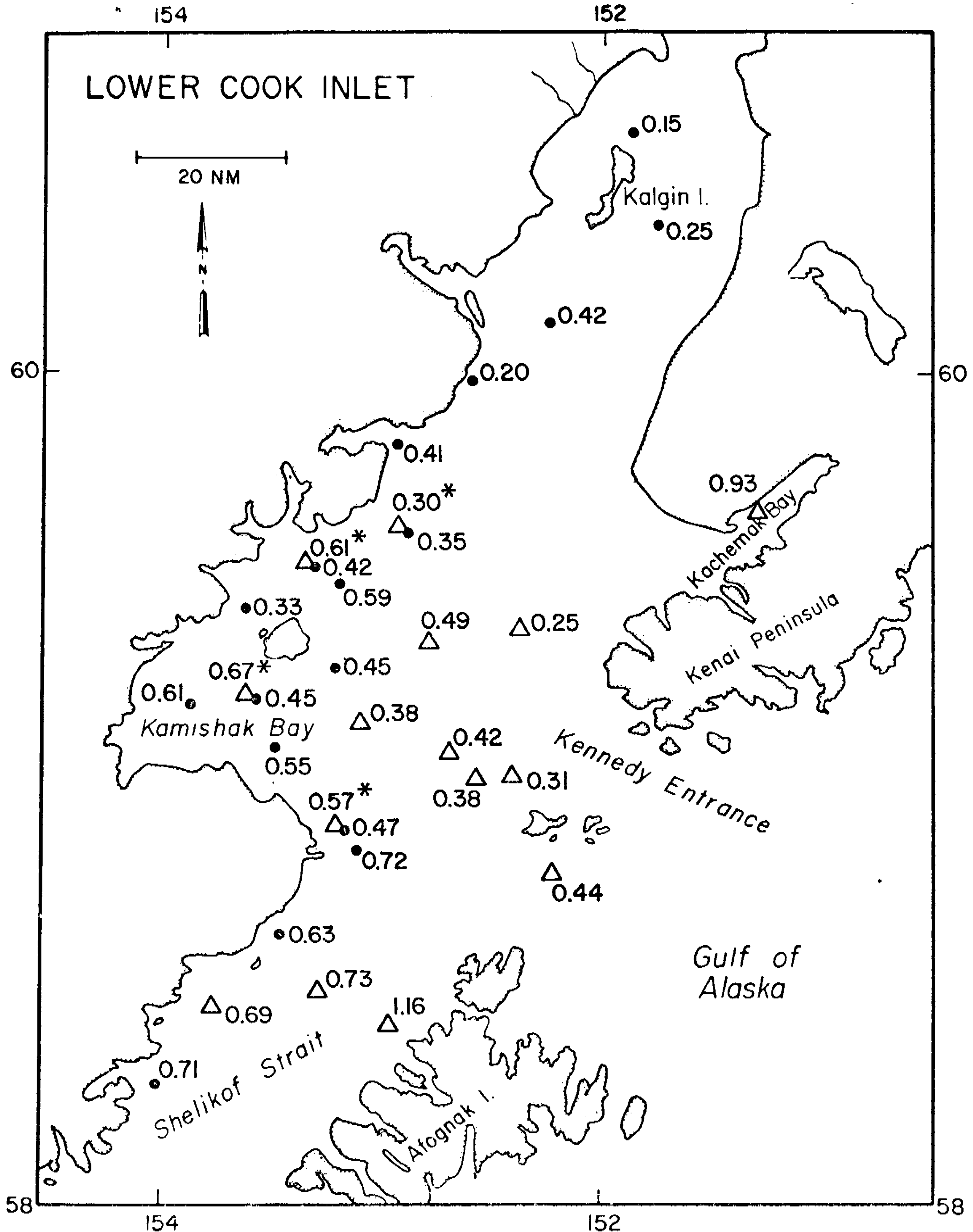


FIG. 14 TOTAL ORGANIC CARBON (%) IN (●) SPRING AND (△) SUMMER SAMPLES; (✳) SUMMER SAMPLES.

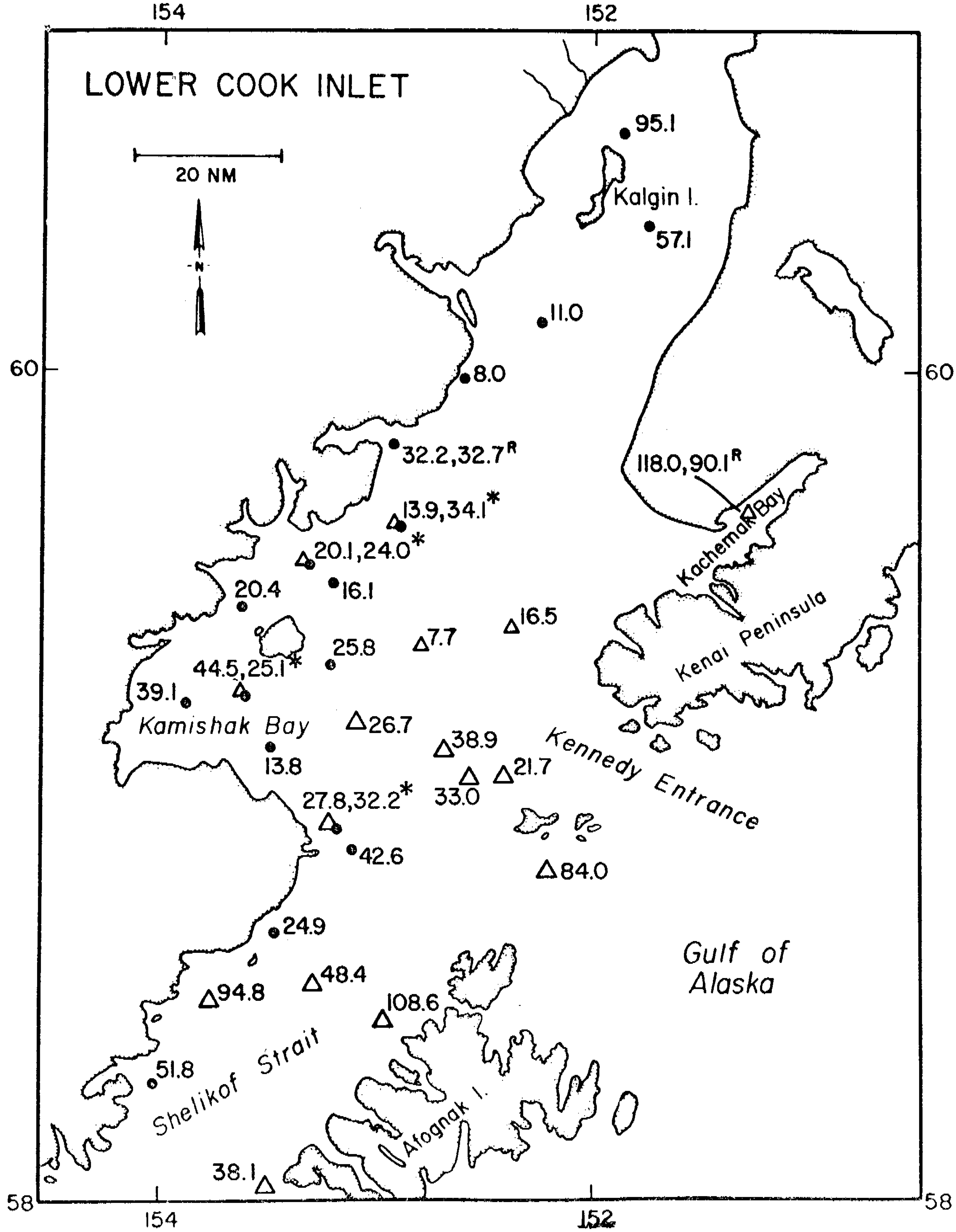


FIG.15 NONSAPONIFIABLE FRACTIONS IN PPM.

* = SUMMER SAMPLES; R = REPLICATE

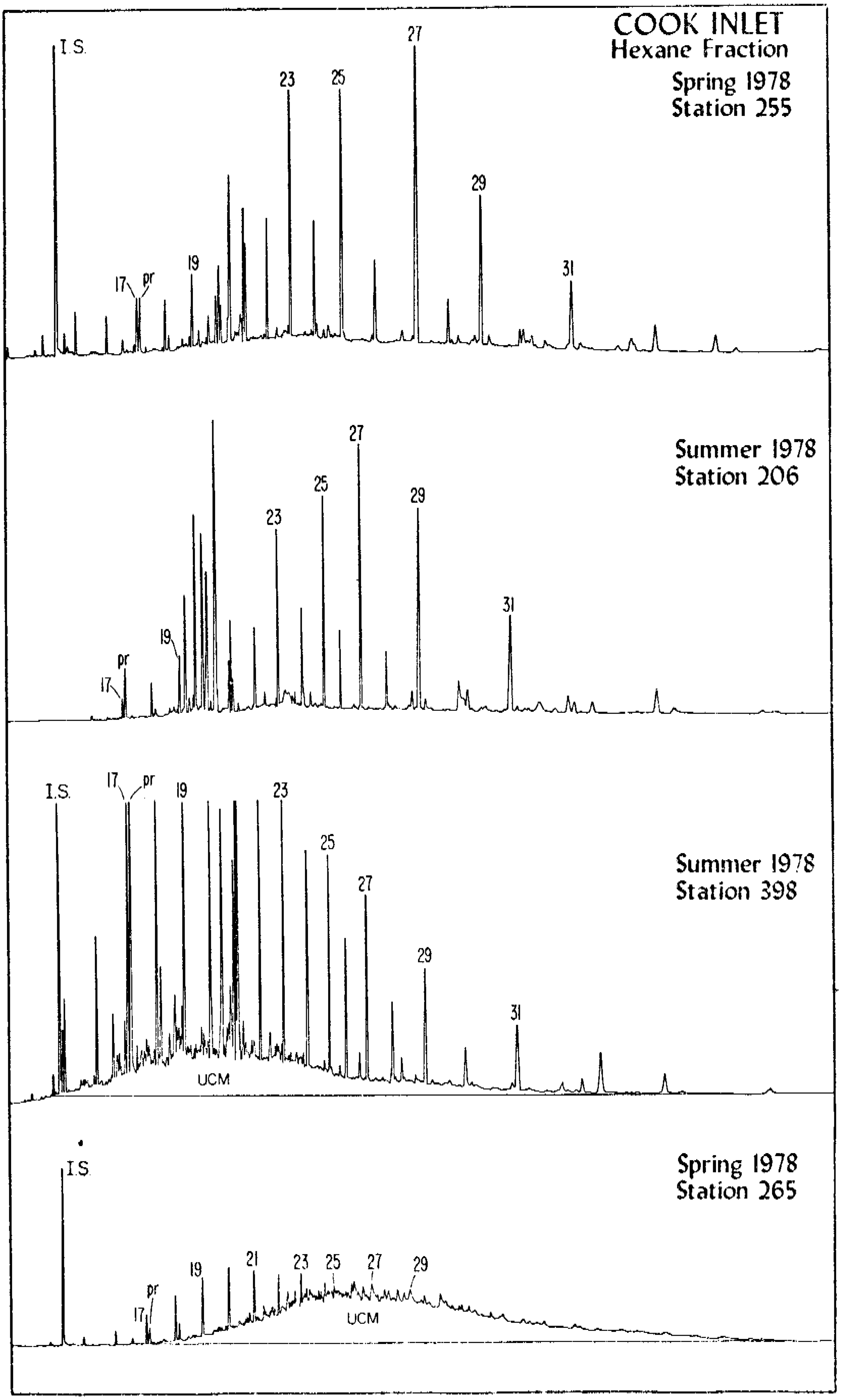

COOK INLET
Hexane Fraction
Spring 1978
Station 255
I.S.
17
pr
19
23
25
27
29
31
Summer 1978
Station 206
17
pr
19
23
25
27
29
31
Summer 1978
Station 398
I.S.
17
pr
19
23
25
27
29
31
UCM
Spring 1978
Station 265
I.S.
17
pr
19
21
23
25
27
29
UCM

FIG.16

ANNUAL REPORT

April 1, 1978 - April 1, 1979

Research Unit 506

NATURAL DISTRIBUTION AND ENVIRONMENTAL BACKGROUND OF TRACE HEAVY METALS IN ALASKAN SHELF AND ESTUARINE AREAS

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and
Keith H. Abel

Principal Investigators

BATTELLE-NORTHWEST LABORATORIES
Richland, Washington 99352

TABLES

FIGURES

TABLE OF CONTENTS

I. SUMMARY

Sediment composition data reported completes baseline coverage for all shelf study areas and indicates general shelf sediment composition. General regional trends are visible from shelf study area to study area. Variability of elemental composition data within a given shelf area indicates non-uniform sediment distribution on the continental shelf. The available fraction of Co, Sc, Fe, Mn, and V in organic species released by 30% hydrogen peroxide was minimal. A substantial fraction - 5 to 30% for Co, Fe, and V, 1 to 10% for Sc, and 20 to 100% for Mn - of these metals was available as determined by a 0.3N HCl leaching. The smaller fraction of Sc leached indicates minimal structural damage was done to aluminosilicate minerals during the hydrochloric acid leach.

Time series suspended particulate studies indicate general trends in suspended sediment composition during the tidal cycle in Cook Inlet. However, interpretation of this study was hampered by comparable variability associated with replicate samples and errors associated with analytical procedures, although analytical errors were less than 5% for most elements.

Dissolved vanadium concentrations were again uniform in shelf waters although a slight decrease in August 1978 was noted. Dissolved manganese was also determined and was found in the range of 0.1 to 1.85 μg/ℓ in Cook Inlet. Higher values were noted in Shelikof Strait associated with nepheloid layers.

Vanadium concentrations in Alaskan Shelf biological materials showed very low levels in rock sole, pollock and king crab, values ranging from <10 to 97 ng/g dry weight. Fucus and mytilus ranged from 0.3-0.9 μg/g dry weight while neptunia showed higher levels of approximately 2.5 μg/g.

II. INTRODUCTION

The projected recovery of crude oil from the Alaskan continental shelves carries with it the risk of altering this environment by physical perturbations or spillage of crude oil. Such disturbances could result in detrimental impacts on the natural cycling of trace heavy metals in the shelf environment. It is therefore necessary to determine pre-development evaluations of the trace metal distributions and behavior in promising shelf areas so that any future contamination may be identified, quantified and assessed.

The primary objective of this study is to determine environmental baseline concentrations of selected heavy metals in seawater (both dissolved and suspended fractions), in sediments, and in selected marine "indicator organisms" of the Alaskan Outer Continental Shelf study area.

The research plan that has been formulated was designed to complement the University of Alaska's program under the direction of Dr. David C. Burrell by measuring those trace metals most amenable to neutron actuation analysis. Of the total suite of elements measured in the overall program we have concentrated our efforts on the analyses of V, Mn, Fe, and Cr in seawater, biota and sediments. We do, however, measure additional major and trace metals automatically detected by the instrumental neutron activation analysis methods which we employ.

The work reported for this period centers around the analyses of samples collected in Cook Inlet during participation in two field cruises on May 4-15, 1978 and August 25-September 5, 1978. We also report the results of analyses of sediments from the Beaufort Sea, Chukchi Sea, Norton Sound and the Shelikof Strait, and the analyses of vanadium in biota from various shelf areas.

III. CURRENT STATE OF KNOWLEDGE

Trace metal distribution within the study areas presented herein were virtually non-existent prior to conducting this work. Therefore, the current state of knowledge concerning trace metal distributions is represented by the results of our work and the data supplied by Dr. D. C. Burrell and Dr. R. A. Feely. The results and discussion of our data are presented in the following sections.

IV. STUDY AREAS

Sediment samples from the Beaufort Sea, Chukchi Sea, Norton Sound, Cook Inlet and Shelikof Strait have been analyzed for trace metal content. The sample locations are shown in Figures 1-4. In addition to the above samples, selected sediments from the Bering Sea grid and the Eastern GOA and Western GOA sampling stations have been reanalyzed to determine the "available" fraction of trace metals as determined by the H_2O_2-HCL leaching procedure concurrently used by Burrell and Feely. The locations of these stations are shown in Figures 5-7.

Selected biological samples have been analyzed for vanadium and the locations of the interested species are shown in Figure 8.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Sediment samples were collected using a HAPS corer and the cores were immediately extruded and sectioned into 1-cm slabs. The top cm only was usually analyzed, since previous studies have shown that no significant, systematic variability occurs in the depth distribution (to 20-cm depth) of trace metals in the core. Seawater samples were collected in 10-liter Niskin Go-Flo bottles and the seawater was filtered immediately by pressurizing the Niskin bottles with filtered nitrogen gas and using in-line, all-plastic filtration assemblies loaded with 0.4μm Nuclepore filters. The filtered seawater was acidified to a pH of 1 by the addition of Ultrex HCL and stored in carefully, precleaned one or two liter polyethlyene bottles. The filters were rinsed with high purity water and encapsulated in polythylene vials for neutron activation analyses. Seawater samples were collected in Cook Inlet and the Shelikof Strait for trace metal analysis during the May and August 1978 cruise legs of the Discoverer.

Sediment samples were analyzed for total trace metal contents and replicate aliquots were used for determining "available" fractions of trace metals by the sequential leaching technique reported by Malo.(1) The leaching method consists of exposure to 30% hydrogen peroxide for 24 hours or a steam bath, to destroy organic matter. This is followed by leaching with 0.3N HCl for 30 minutes at a temperature slightly below boiling. The 30% peroxide and 0.3N HCl soluble phases were then analyzed for the elements of interest. Separate sediment aliquots were analyzed on a "whole rock" basis in order to give a basis for leaching percentages.

Seawater samples from Cook Inlet and Shelikof Strait were analyzed for soluble vanadium by coprecipitating the vanadium from 100 ml of seawater on iron hydroxide. The iron hydroxide was centrifuged, rinsed with high purity water, encapsulated in polyethylene vials, and neutron activated at the Washington State University research reactor. The vanadium concentrations were determined by measuring the short-lived ^{52}V activation product. The precision and accuracy of the method was determined by spiking samples with ^{48}V tracer.

Manganese concentrations in Cook Inlet and Shelikof Strait seawater were determined by extracting 800 ml of seawater with 8-hydroxy-quinoline in chloroform. The manganese was back-extracted into 0.1N Ultrex HNO_3, which was evaporated and transferred into polyethylene irradiation vials. Manganese concentrations were determined by measuring the ^{56}Mn activation product. Manganese-54 tracers were used to determine the accuracy and precision of the method.

Vanadium concentrations in selected biota were measured by neutron activation analysis after separating and preconcentrating the vanadium from several grams of tissue. The tissue samples were digested in hot aqua regia, diluted and the vanadium was separated using the iron hydroxide coprecipitation method used in the seawater analysis. The samples were neutron activated in a ^{252}Cf fueled sub-critical neutron multiplication

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(1) B.A. Malo. Partial Extraction of Metals from Aquatic Sediments. Environ. Sci. & Technol.,V. 11,p. 277-282.

facility at our laboratory and the vanadium was determined by measuring the ^{52}V activation product. The precision and accuracy of this method was evaluated using the NBS Standard Reference Material, orchard leaf, and by using ^{48}V tracers.

VI. and VII. RESULTS AND DISCUSSION

SEDIMENT SURVEYS

Results of the recent sediment analyses are presented in Tables 1-3. For the most part, the concentrations of major and trace elements in surface (0-2 cm) sediments in the Beaufort Sea, Chukchi Sea, Norton Sound, Shelikof Strait and Cook Inlet were very similar to values previously observed in the Bering Sea, Western GOA and Eastern GOA. Notable exceptions are several stations exhibiting very low vanadium concentrations, Stations N-26, N-20, and N-1 in Norton Sound, Stations C-20 and C-23 in the Chukchi Sea and Station CB-6 in Cook Inlet. The vanadium content of sediments at these locations are about 1/3 to 1/2 of the regional average concentrations in the Bering Sea and the eastern and western GOA.

An unusually high manganese concentration (about twice the regional average concentration) in sediments at Shelikof Strait Station SS-2 was observed. This is an area of anomalously high manganese concentrations in suspended particulates observed by Feely.

Relatively high arsenic concentrations were observed in Beaufort Sea sediments, which averaged 26 ppm, a value 5 to 7 times higher than the regional average concentration in the Bering Sea, Eastern GOA and Western GOA. At Station B-8 in the Beaufort Sea the arsenic concentration in surface (0-2 cm) sediments was 54.6 ppm, the highest concentration observed in Alaskan Shelf sediments. Arsenic concentrations were also 2 to 3 times higher in Chukchi Sea and Norton Sound sediments compared to the Bering Sea, Western GOA and Eastern GOA.

Chromium concentrations at Chukchi Sea Stations C-3, C-7 and C-10 were 2 to 5 times higher than normal and probably reflect riverline sediment deposits in Katzebue Sound.

"AVAILABLE" TRACE METALS IN SEDIMENTS

The "available" fractions of trace metals in surficial sediments is arbitrarily defined as the fractions leached by dilute solutions of H_2O_2 and HCl.

The "available" vanadium concentrations are presented in Table 4. Total vanadium concentrations were measured on separate sediment aliquots so that the "available" fraction could be determined. The fraction leached by the H_2O_2 treatment (supposedly organically bound vanadium) was usually small and ranged from 1.17 to 7.63 μg/g of dry sediments, or about 1 to 6% of the total vanadium present in the sediments. The 0.3M HCl treatment released significantly more vanadium than the H_2O_2, ranging from 7.7 to 28.3 μg/g dry sediment, or about 3 to 24% of the total vanadium present. The combined "available" fraction (H_2O_2 + HCl leachable) ranged from 5 to 29% of the total vanadium in the sediment. No systematic geographical trends in the amounts of "available" vanadium were observed from region to region, but considerable differences in "available" vanadium (by factors of 2 to 3) were often observed within regions. This is not unexpected, however, since sediment types and textures vary considerably within each Alaskan shelf region.

The "available" manganese fractions, determined by the same technique, are presented in Table 5. The total "available" manganese was much higher than for vanadium, and ranged from 21 to 82% of the total manganese present in the sediments. Usually, less than 1% of the manganese was leached by the H_2O_2 treatment; the 0.3M HCl treatment removed, by far, the majority of the "available" manganese.

"Available" fractions of Fe, Co, and Sc were also determined and are shown in Table 6. Peroxide exposure released very small fractions of these elements, well less than 1% in all cases, indicating minimal organic association in the sediments. However, differing behaviors are noticeable during the hydrochloric acid leaching. Only 1 to 10% of the scandium was available during hydrochloric acid leaching, in fact ranging from 1.63 to 4.97% in all cases except one where 9% was available. This indicates the weak acid exposure was minimally degrading the silicate minerals as should be the case. The Fe and Co fractions available via hydrochloric acid leaching ranged from 4.5 to 27.4% and 10.6 to 59.1%, respectively.

The available Fe, Co, and Sc in Cook Inlet and Shelikof Strait were relatively uniform averaging 15.4% ± 1.6%, 33.1% ± 2.3% and 3.83% ± 0.79% for the elements respectively where the ± is one standard deviation. The variability in the available fraction of Fe, Co, and Sc in the Eastern Gulf, Bristol Bay, and Western Gulf of Alaska areas was far higher; ranges to as much as approximately a factor of 4 within the study area for Fe, and to a factor of 5 for Sc were observed.

SUSPENDED PARTICULATE COMPOSITION

Elemental composition of suspended particulates in the water column were determined for samples obtained in Cook Inlet and Shelikof Strait during the May 1978 and August 1978 Discoverer cruise legs. These are shown in Table 7. The suspended particulate levels (μg/ℓ of seawater) appeared similar on the two dates except for Station CB-1 where larger differences in Al and Mn concentrations are noted. The samples in Shelikof Strait were taken simultaneously with Feely during the August cruise in the near-bottom nepheloid layers. Elevated Al, Mn, and V concentrations are present in these samples. There are noticeable differences in the Mn/Al ratios in the Cook Inlet and Shelikof Strait area. The Cook Inlet average ratio of Al/Mn is 0.024/1 while in Shelikof Strait the ratio is 0.051/1.

The error about these ratios is large, ∿50%, so the difference may not be statistically valid. However, Stations SS-6 and SS-13 samples show ratios of >0.80/1.0, much higher than those observed in Cook Inlet.

Suspended particulates were also analyzed at the time series station occupied at CB-10 during the August 1978 cruise leg. As shown in Tables 8, 9, and 10, variability during the tidal cycle occurs during the sampling interval from $t = 0$ hr through $t = 48$ hr. However, the 1σ statistical error associated with the elemental concentration for most elements is generally greater than the differences observed in concentrations over the 8-hr sampling intervals, indicating the variability may not be statistically valid. It should be pointed out that fault does not lie in the analytical method being imprecise, for the 1σ errors for aluminum, manganese, arsenic, lanthanium, and samarium are 5% or less. Thus, this indicates changes in the suspended particulate composition are approximately equal to or less than 5% over the sampling intervals. The variability of the replicate samples at t = 0 hr indicates that sample variability is of similar magnitude to change in the water column from sampling interval to sampling interval.

DISSOLVED MANGANESE AND VANADIUM

Seawater samples for the May 1978 and August 1978 Discoverer legs were analyzed for soluble vanadium and manganese. Vanadium concentration in Cook Inlet and Shelikof Strait were very uniform and similar to concentrations observed during previous cruises on the Alaskan Shelf, as shown in Table 11. The August samples appear slightly lower in Cook Inlet at Stations CB-1 through CB-9 as well as at the time series station CB-10. This may reflect the fact that the annual peak of glacial meltwater is occurring at this time of year. The vanadium concentration of 0.62 μg/ℓ at SS-13 is the lowest encountered in Alaskan waters to date and at present unexplained, although we believe the value is accurate.

Dissolved manganese concentrations during May were well below 1 μg/ℓ, ranging from 0.11 μg/ℓ to 0.64 μg/ℓ. The August Cook Inlet samples were considerably higher in dissolved manganese, ranging from 0.29 to 1.85 μg/ℓ. In Cook Inlet the higher dissolved manganese levels observed in August may also be attributable to glacial meltwater. The samples from Shelikof Strait at Stations SS-2 and SS-6 were extremely high, 7.28 and 6.8 μg/ℓ, respectively. These samples were obtained at depths within nepheloid layers and the values may be indications of the presence of colloidal material < 0.4 μ.

VANADIUM CONCENTRATION IN ALASKAN BIOTA

The final task during the research program for the past year was determination of vanadium concentrations in Alaskan Shelf Biota. Vanadium was determined by a chemical separation procedure involving wet ashing with HNO_3

and H_2SO_4 followed by preconcentration via co-precipitation with iron hydroxide prior to neutron activation analysis. The procedure was developed and verified through the use of both NBS Standard Reference Material orchard leaves and ^{48}V radio tracer. Concentrations in rock sole, pollock, king crab, fucus, mytilus, and neptunia supplied to us by Dr. D. Burrell of University of Alaska are shown in Table 13. The fish tissue from rock sole and pollock are well below 0.1 µg/g dry weight in vanadium, as is crab tissue. Fucus, mytilus, and neptunia show considerably higher levels of 0.3-0.9 ppm for fucus, 0.2-0.8 ppm for mytilus, and ∿2.5 ppm for neptunia on a dry weight basis.

VIII. CONCLUSIONS

With the completion of the sediment analyses in the Beaufort Sea, Norton Sound, and the Chukchi Sea, baseline coverage has been achieved in all the areas of interest for the Alaskan Shelf Program. The data generated indicate the Alaskan Shelf is fairly typical of other continental shelf areas. General regional trends have been noted in previous reports related to differing the mineralogy differences in the different shelf areas. Patchy distributions, or high variability has been noted for some elements typical of varying sedimentary conditions. Variations of elemental composition with depth have not been noted in the surficial sediments down to 20-25 cm.

The determination of "available" metals reported herein indicate that only a very small percentage, generally less than 1% of the metals examined - V, Mn, Fe, Co, and Sc - are associated with organic phases which are degraded by 30% hydrogen peroxide. The hydrochloric acid leachable fraction (0.3<u>N</u> HCl) of these metals was somewhat higher: 10 to 30% for vanadium and cobalt, 1 to 10% for scandium, 5 to 30% for iron and 20 to 100% for manganese.

Suspended particulate studies at the time series station CB-10 during the August 1978 cruise indicated general trends of elemental variation during the tidal cycle. However, the variability between replicate suspended matter samples was as great as the variability during the tidal cycle. Precision of analytical data, although excellent, produced confidence intervals which were also of comparable size to the changes in elemental distribution during the tidal cycle.

Suspended matter at other stations in Cook Inlet and Shelikof Strait showed highly variable suspended matter concentration. Sampling within nepheloid layers in Shelikof Strait also indicated elevated manganese/aluminum ratios in comparison to Cook Inlet stations.

Dissolved vanadium concentrations in the Alaskan shelf waters again illustrated the relative uniformity of vanadium in shelf waters. A slight decrease of vanadium in surface waters of Cook Inlet was noted in August 1978 and is perhaps related to the influx of glacial meltwater during this period. Dissolved manganese concentrations were also determined in Cook Inlet and Shelikof Strait, values ranging from 0.1 to slightly less than 2 μg/ℓ in Cook Inlet surface waters. Higher dissolved manganese values were noted in the Shelikof Strait in samples obtained from within nepheloid layers.

Finally, vanadium concentration of selected Alaskan Shelf biological materials were determined. These range from a few ng/g for two species of finfish, rock sole and pollock, and Alaskan king crab. Intertidal organisms, fucus and mytilus, showed considerably higher vanadium levels. These ranged from approximately 0.3 to 0.8 μg/g dry weight for fucus and mytilus. Neptunia showed much higher levels than either finfish or intertidal fucus and mytilus. The samples analyzed indicated levels of 2.5 μg/g dry weight.

TABLE 1

ALASKA OCS SURFICIAL SEDIMENT (0-2 cm)
ELEMENTAL CONCENTRATIONS (ppm dry weight except where noted)

	Al (%)	Ti (%)	Mn	V
BEAUFORT SEA				
Station B-1	8.00±0.28	0.56±0.14	506±37	176±32
B-3	5.34±0.18	0.31±0.07	369±22	122±12
B-7	6.59±0.22	0.51±0.10	444±25	150±14
B-8	7.26±0.24	0.46±0.11	1008±49	163±15
B-12	6.08±0.21	0.42±0.09	491±26	117±12
NORTON SOUND				
Station N-1	5.35±0.18	0.45±0.09	344±21	82±10
N-5	6.18±0.21	0.46±0.10	586±30	113±12
N-9	7.32±0.24	0.36±0.09	544±29	149±14
N-15	5.88±0.20	0.45±0.09	458±25	102±11
N-20	5.57±0.19	0.46±0.09	396±23	73±10
N-26	4.43±1.5	0.36±0.08	417±54	56±9
CHUKCHI SEA				
Station C-3	4.76±0.16	0.47±0.09	428±24	87±11
C-7	4.31±0.15	0.32±0.08	405±23	91±10
C-10	6.11±0.21	0.46±0.09	432±24	109±12
C-20	3.36±0.12	0.22±0.06	243±16	66±8
C-23	1.70±0.06	0.16±0.04	143±10	37±8
C-25	5.15±0.17	0.42±0.09	359±21	106±11
SHELIKOF STRAIT				
Station SS-2	7.66±0.26	0.46±0.10	820±40	148±14
SS-2, surface <0.2 cm	7.50±0.26	0.51±0.15	1810±90	142±19
SS-4	7.68±0.26	0.54±0.11	966±46	106±13
SS-5	8.01±0.27	0.34±0.10	867±43	142±15
SS-8	8.21±0.27	0.48±0.11	800±40	149±15
SS-10	7.59±0.25	0.53±0.11	761±38	112±13

TABLE 1 (cont)

COOK INLET		Al(%)	Ti(%)	Mn	V
Station	CB-1	7.70±0.26	0.38±0.10	698±35	96±13
	CB-3	7.58±0.26	0.56±0.11	726±36	110±14
	CB-6	6.05±0.21	0.26±0.08	415±23	61±11
	CB-7	7.20±0.25	0.42±0.10	652±33	114±14
	CB-8	8.41±0.29	0.51±0.11	784±39	148±16
WESTERN GULF					
Station	WG 105	5.48±0.19	0.29±0.08	672±34	89±11
	WG 120	7.31±0.25	0.45±0.10	989±43	140±14
	WG 133	8.46±0.29	0.74±0.16	1380±70	216±21
BRISTOL BAY					
Station	MB-8	7.02±0.24	0.50±0.10	692±35	132±13
	MB-12	6.63±0.23	0.31±0.09	574±29	95±13
	MB-41	5.36±0.19	0.39±0.09	448±24	89±11
EASTERN GULF					
	EG-33	5.76±0.20	0.31±0.09	567±28	120±13
	EG-44	7.45±0.26	0.58±0.11	777±38	132±15
	EG-58	8.36±0.29	0.46±0.11	837±40	174±17

TABLE 2

ELEMENTAL COMPOSITION OF SURFICIAL SEDIMENTS FROM SELECTED ALASKAN OCS STUDY AREAS

(ppm dry weight except where noted)

NORTON SOUND

Station	Na(%)	K(%)	As	La	Sm
N-1	2.03±0.01	1.88±0.24	7.8±1.1	24.6±1.1	3.5±0.1
N-5	2.02±0.01	1.65±0.22	11.8±1.2	30.2±0.9	4.4±0.1
N-9	2.31±0.01	2.14±0.24	19.8±1.1	36.8±0.8	5.5±0.1
N-15	2.01±0.01	1.14±0.18	10.7±1.0	29.0±0.7	4.2±0.1
N-20	1.65±0.01	1.60±0.19	6.9±0.8	31.2±0.8	4.7±0.1
N-26	1.72±0.01	1.29±0.17	8.3±0.8	19.7±0.6	3.3±0.1

CHUKCHI SEA

Station	Na(%)	K(%)	As	La	Sm
C-3	1.38±0.01	1.05±0.14	9.3±0.9	28.0±0.9	4.3±0.1
C-7	1.12±0.01	0.97±0.12	8.4±0.9	33.3±0.9	4.7±0.1
C-10	1.23±0.01	0.62±0.11	6.9±0.7	22.5±0.7	3.6±0.1
C-14	2.49±0.01	1.45±0.16	11.7±1.0	30.6±0.9	4.7±0.1
C-20	1.20±0.01	0.59±0.10	13.5±0.7	17.6±0.6	2.8±0.1
C-23	0.53±0.01	0.32±0.07	23.3±0.6	13.8±0.5	2.1±0.1
C-25	1.66±0.01	1.61±0.15	13.9±0.9	27.1±0.5	4.4±0.1

BEAUFORT SEA

Station	Na(%)	K(%)	As	La	Sm
B-1	1.10±0.01	2.16±0.14	17.6±0.9	35.3±0.6	5.1±0.1
B-3	0.89±0.01	1.65±0.12	15.7±0.8	37.3±0.6	5.1±0.1
B-7	0.95±0.01	1.99±0.13	17.9±0.9	34.8±0.6	5.2±0.1
B-8	3.19±0.01	2.72±0.23	54.6±1.4	35.0±0.7	5.3±0.1
B-12	2.07±0.01	1.68±0.18	22.9±1.0	32.0±0.6	5.0±0.1

TABLE 2 (cont)

COOK INLET

Station	Na(%)	K(%)	As	La	Sm
CB-1	2.60±0.01	1.28±0.19	8.07±0.9	22.4±0.6	3.8±0.1
CB-3	2.55±0.01	1.50±0.18	6.1±0.9	22.2±0.6	3.9±0.1
CB-6	2.13±0.01	1.49±0.15	7.8±0.8	11.7±0.5	2.0±0.1
CB-7	2.61±0.01	1.34±0.19	7.7±0.9	16.2±0.6	3.0±0.1
CB-8	2.46±0.01	1.24±0.20	12.4±1.0	23.6±0.6	4.3±0.1

SHELIKOF STRAIT

Station	Na(%)	K(%)	As	La	Sm
SS-2 Surface	3.82±0.01	1.71±0.27	11.4±1.1	18.7±0.7	3.8±0.1
SS-2	3.10±0.01	1.39±0.25	9.6±1.2	20.0±0.6	4.1±0.1
SS-4	3.00±0.01	1.56±0.21	10.7±1.1	15.1±0.6	3.3±0.1
SS-5	3.55±0.01	1.56±0.24	10.8±1.1	23.1±0.6	4.4±0.1
SS-8	3.25±0.01	1.85±0.22	14.1±1.1	22.2±0.7	4.4±0.1
SS-10	3.30±0.01	1.45±0.24	8.5±1.4	20.7±0.7	4.2±0.1

TABLE 3

ALASKAN OCS SURFICIAL SEDIMENT COMPOSITION

(ppm EXCEPT WHERE NOTED)

		Sc	Cr	Fe(%)	Co	Sb	Ba	Cs	Eu	Tb	Ta	Th
NORTON SOUND												
STATION	N-1	9.40 ± 0.08	96 ± 2	2.34 ± 0.07	8.49 ± 0.05	0.68 ± 0.06	790 ± 30	1.85 ± 0.09	0.92 ± 0.03	0.58 ± 0.05	0.68 ± 0.05	5.48 ± 0.07
	N-5	11.52 ± 0.08	83 ± 1	3.16 ± 0.08	12.53 ± 0.17	0.97 ± 0.05	730 ± 20	0.66 ± 0.05	1.08 ± 0.02	0.78 ± 0.06	0.75 ± 0.08	7.36 ± 0.06
	N-9	16.98 ± 0.08	114 ± 2	4.92 ± 0.09	19.05 ± 0.10	1.79 ± 0.08	970 ± 30	5.61 ± 0.17	1.36 ± 0.02	0.84 ± 0.06	0.93 ± 0.09	11.6 ± 0.1
	N-15	10.49 ± 0.08	71 ± 1	2.76 ± 0.05	11.27 ± 0.23	1.03 ± 0.07	620 ± 30	2.42 ± 0.10	1.03 ± 0.03	0.69 ± 0.06	0.65 ± 0.07	6.62 ± 0.07
	N-20	8.00 ± 0.06	67 ± 1	2.10 ± 0.04	9.31 ± 0.06	0.76 ± 0.04	670 ± 20	2.44 ± 0.08	1.02 ± 0.02	0.64 ± 0.05	0.72 ± 0.07	6.92 ± 0.06
	N-26	8.80 ± 0.09	47 ± 1	2.49 ± 0.05	7.29 ± 0.08	0.84 ± 0.06	520 ± 30	2.18 ± 0.09	0.87 ± 0.02	0.62 ± 0.05	1.32 ± 0.13	4.75 ± 0.06
CHUKCHI SEA												
STATION	C-3	8.62 ± 0.04	229 ± 3	2.26 ± 0.01	8.48 ± 0.05	0.73 ± 0.04	540 ± 20	1.97 ± 0.05	0.92 ± 0.01	0.42 ± 0.01	0.65 ± 0.04	6.46 ± 0.07
	C-7	8.29 ± 0.03	333 ± 4	2.47 ± 0.02	11.46 ± 0.08	0.69 ± 0.05	480 ± 20	2.08 ± 0.08	0.90 ± 0.02	0.41 ± 0.02	0.62 ± 0.05	6.79 ± 0.08
	C-10	6.81 ± 0.04	247 ± 3	1.91 ± 0.01	7.24 ± 0.07	0.49 ± 0.03	430 ± 20	1.27 ± 0.04	0.78 ± 0.01	0.35 ± 0.01	0.58 ± 0.05	4.20 ± 0.05
	C-14	12.46 ± 0.04	93 ± 1	3.37 ± 0.01	11.68 ± 0.24	0.98 ± 0.07	730 ± 40	3.61 ± 0.10	1.11 ± 0.02	0.54 ± 0.02	0.81 ± 0.06	8.15 ± 0.10
	C-20	4.67 ± 0.03	80 ± 1	1.80 ± 0.01	7.31 ± 0.12	0.58 ± 0.03	650 ± 20	1.46 ± 0.03	0.65 ± 0.01	0.34 ± 0.01	0.34 ± 0.02	3.87 ± 0.44
	C-23	3.31 ± 0.01	150 ± 2	1.89 ± 0.01	5.57 ± 0.03	0.50 ± 0.02	660 ± 20	0.87 ± 0.03	0.49 ± 0.01	0.25 ± 0.01	0.17 ± 0.02	2.36 ± 0.03
	C-25	4.74 ± 0.02	41 ± 2	1.42 ± 0.01	4.98 ± 0.02	0.40 ± 0.03	---	1.47 ± 0.04	0.48 ± 0.01	0.24 ± 0.02	0.33 ± 0.03	3.43 ± 0.06
BEAUFORT SEA												
STATION	B-1	12.79 ± 0.02	82 ± 3	3.53 ± 0.02	13.93 ± 0.07	0.88 ± 0.04		7.28 ± 0.11	1.01 ± 0.02	0.49 ± 0.04	0.81 ± 0.07	10.1 ± 0.2
	B-3	10.16 ± 0.04	85 ± 3	2.97 ± 0.03	11.76 ± 0.07	0.70 ± 0.04		5.48 ± 0.09	1.01 ± 0.02	0.47 ± 0.04	0.70 ± 0.07	9.13 ± 0.15
	B-7	12.96 ± 0.02	95 ± 4	3.81 ± 0.03	15.03 ± 0.10	0.72 ± 0.06		6.46 ± 0.12	1.13 ± 0.03	0.52 ± 0.04	0.83 ± 0.08	9.94 ± 0.18
	B-8	15.77 ± 0.02	97 ± 4	5.48 ± 0.06	17.05 ± 0.09	1.20 ± 0.06		7.92 ± 0.13	1.19 ± 0.03	0.53 ± 0.04	0.84 ± 0.08	10.7 ± 0.2
	B-12	12.21 ± 0.06	89 ± 4	3.72 ± 0.04	12.93 ± 0.07	0.74 ± 0.05		5.93 ± 0.10	1.06 ± 0.02	0.51 ± 0.04	0.81 ± 0.07	9.29 ± 0.16
COOK INLET												
STATION	CB-1	13.23 ± 0.02	65 ± 2	3.52 ± 0.01	12.82 ± 0.06	0.72 ± 0.04		2.38 ± 0.05	0.72 ± 0.01	0.33 ± 0.02	0.45 ± 0.03	5.22 ± 0.07
	CB-3	7.39 ± 0.05	35 ± 1	2.04 ± 0.01	8.23 ± 0.04	0.48 ± 0.03		1.33 ± 0.04	0.65 ± 0.01	0.28 ± 0.02	0.38 ± 0.03	2.47 ± 0.05
	CB-7	12.77 ± 0.03	69 ± 2	3.33 ± 0.02	14.68 ± 0.12	0.63 ± 0.07		2.33 ± 0.07	0.84 ± 0.02	0.35 ± 0.02	0.51 ± 0.06	4.31 ± 0.10
	CB-8	18.97 ± 0.16	108 ± 3	5.15 ± 0.02	20.80 ± 0.11	2.15 ± 0.10		4.85 ± 0.11	1.11 ± 0.02	0.45 ± 0.03	0.70 ± 0.07	5.84 ± 0.12
SHELIKOF STRAIT												
STATION	SS-2 (SURFACE)	16.80 ± 0.03	82 ± 2	4.94 ± 0.02	20.04 ± 0.11	1.23 ± 0.09		4.19 ± 0.09	0.94 ± 0.02	0.41 ± 0.04	0.62 ± 0.07	5.50 ± 0.11
	SS-2	17.26 ± 0.03	85 ± 2	4.82 ± 0.02	19.63 ± 0.11	1.27 ± 0.08		4.45 ± 0.10	1.00 ± 0.02	0.51 ± 0.04	0.84 ± 0.08	5.80 ± 0.13
	SS-4	16.74 ± 0.04	47 ± 2	4.62 ± 0.03	17.84 ± 0.19	0.77 ± 0.11		2.17 ± 0.15	0.91 ± 0.03	0.35 ± 0.04	0.30 ± 0.06	3.50 ± 0.18
	SS-5	17.55 ± 0.03	98 ± 3	4.95 ± 0.02	19.61 ± 0.27	1.22 ± 0.09		4.76 ± 0.11	1.02 ± 0.02	0.46 ± 0.04	0.75 ± 0.08	6.60 ± 0.15
	SS-8	18.45 ± 0.03	101 ± 3	5.22 ± 0.02	21.00 ± 0.28	1.17 ± 0.08		5.02 ± 0.10	1.05 ± 0.02	0.53 ± 0.04	0.72 ± 0.08	6.64 ± 0.14
	SS-10	16.2 ± 0.03	73 ± 2	4.29 ± 0.02	15.98 ± 0.33	0.93 ± 0.08		3.34 ± 0.10	0.97 ± 0.02	0.42 ± 0.04	0.54 ± 0.07	5.66 ± 0.14

TABLE 4

"AVAILABLE" VANADIUM IN ALASKAN OCS SEDIMENTS (μg/g DRY WT SEDIMENT) DETERMINED BY A SEQUENTIAL HYDROGEN PEROXIDE AND 0.3 M HCl LEACHING TECHNIQUE*

	H_2O_2 Leachable	0.3M HCl Leachable	Total "Available" Vanadium	(%)**
COOK INLET				
Station CB-1	4.52±0.17	23.4±1.9	27.9±1.9	(29%)
CB-3	1.17±0.06	10.0±1.1	11.2±1.1	(10%)
CB-6	1.63±0.07	4.21±0.44	5.84±0.45	(10%)
CB-7	2.77±0.11	11.4±1.0	14.2±1.0	(12%)
CB-8	11.8±0.4	26.8±1.9	38.6±1.9	(26%)
SHELIKOF STRAIT				
Station SS-2	4.68±0.17	16.2±1.2	20.9±1.2	(14%)
SS-5	1.17±0.05	12.6±1.3	13.8±1.2	(10%)
SS-8	4.06±0.15	11.0±0.7	15.1±0.7	(10%)
SS-10	2.14±0.08	9.3±0.6	11.4±0.6	(10%)
BRISTOL BAY				
Station MB-8	6.84±0.26	28.3±2.2	35.1±2.2	(27%)
MB-12	4.17±0.16	16.1±1.4	20.3±1.4	(21%)
MB-41	5.91±0.23	24.8±2.0	30.7±2.0	(34%)
EASTERN GULF OF ALASKA				
Station EG-33	7.63±0.28	20.7±1.7	28.3±1.7	(24%)
EG-44	2.73±0.10	13.2±1.1	15.9±1.1	(12%)
EG-58	2.53±0.10	26.1±2.0	28.6±2.0	(16%)
WESTERN GULF OF ALASKA				
Station WG-105	2.18±0.09	11.2±1.0	13.4±1.0	(15%)
WG-120	2.81±0.10	11.9±0.8	14.7±0.8	(11%)
WG-133	3.36±0.13	7.7±0.9	11.1±0.9	(5%)
BLANK	<0.055	0.063±0.011	----	
	<0.053	0.080±0.013	----	
	<0.024			

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*Malo, Environ, Sci. Technol. V.11, pp. 277, 1977.
**Percent of total vanadium in sediments

TABLE 5

"AVAILABLE" MANGANESE IN ALASKAN OCS SEDIMENTS (μg/g DRY WT SEDIMENT) DETERMINED BY A SEQUENTIAL HYDROGEN PEROXIDE AND 0.3 M HCl LEACHING TECHNIQUE*

	H_2O_2 Leachable	0.3M HCl Leachable	Total "Available" Manganese (%)**	
COOK INLET				
Station CB-1	8.86±0.62	515±26	524±26	75%
CB-3	2.54±0.43	353±18	356±18	49%
CB-6	0.40±0.17	166±12	166±12	40%
CB-7	5.51±0.45	242±17	248±17	38%
CB-8	4.57±0.47	439±31	444±31	57%
SHELIKOF STRAIT				
Station SS-2	7.06±0.79	306±22	313±22	51%
SS-5	6.50±0.71	295±21	302±21	49%
SS-8	7.54±1.11	293±21	301±21	--
SS-10	13.0 ±1.3	241±17	254±17	37%
EASTERN GULF OF ALASKA				
Station EG-33	3.29±0.47	464±24	467±24	82%
EG-44	2.80±0.31	374±19	377±19	49%
EG-58	1.54±0.43	510±26	512±26	61%
WESTERN GULF OF ALASKA				
Station WG-105	--	714±37	714±37	106%
WG-120	6.03±0.31	350±18	356±18	40%
WG-133	10.1 ±0.8	280±14	290±14	21%
BRISTOL BAY				
Station MB-8	12.1 ±1.0	385±20	397±20	57%
MB-12	5.72±0.61	123±6	129±6	22%
MB-41	6.39±0.51	185±9	191±9	43%
BLANK	----	----		

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*Malo, Environ. Sci. Technol. V.11, p 277

**Percentage of total manganese in sediments

TABLE 7

ELEMENTAL CONCENTRATIONS (>0.4 μm) IN COOK INLET AND SHELIKOF STRAIT SUSPENDED PARTICULATES (μg/ℓ OF SEAWATER)

COOK INLET	Date	Depth	Al	Ti	Na	Mn	V
Station CB-1	5/78	Sfc.	235±9	10.3±6.0	440±30	3.05±0.13	0.56+0.12
CB-1	8/78	15M	13.5±4.9	8.8±5.6	650±40	0.39±0.06	<0.18
CB-2	5/78	Sfc.	192±5	11.4±4.5	380±30	2.10±0.10	0.25±0.07
CB-2	8/78	20M	185±5	9.5±4.8	570±40	2.39±0.11	0.40±0.09
CB-3	8/78	20M	16.7±2.0	<4.8	230±20	0.18±0.03	<0.08
CB-4	8/78	15M	41.6±1.6	4.6±2.1	210±10	0.52±0.03	<0.06
CB-5	8/78	30M	10.3±2.8	7.7±4.3	570±40	0.54±0.07	<0.14
CB-6	5/78	Sfc	19.2±1.7	5.7±3.3	260±20	0.40±0.05	<0.09
CB-6	8/78	20M	9.0±2.2	<8.4	410±30	0.34±0.06	<0.12
CB-7	5/78	Sfc	29.6±3.5	<11.4	670±50	0.73±0.07	<0.17
CB-7	8/78	15M	23.2±3.4	10.4±5.1	660±70	0.69±0.07	<0.15
CB-8	5/78	Sfc	119±5	9.1±5.7	520±40	3.46±0.14	0.31±0.08
CB-8	8/78	15M	153±5	10.7±4.2	280±20	3.85±0.15	0.36±0.07
SHELIKOF STRAIT							
Station SS-2	8/78	267M	411±11	24.2±9.0	680±50	14.6±0.5	0.66±0.14
SS-4	8/78	131M	37.7±1.7	<4.0	170±10	0.93±0.04	0.11±0.03
SS-6	8/78	203M	142±6	<12	510±30	11.4±0.4	0.27±0.09
SS-11	8/78	130M	21.2±1.5	3.3±1.6	150±10	0.59±0.03	<0.06
SS-13	8/78	147M	74±3	<6.2	260±20	6.5±0.2	0.15±0.05

TABLE 8

COOK INLET -TIME SERIES - SUSPENDED PARTICULATE MATTER >0.4 μm. STATION CB-10

Discoverer, August 1978

	Al(%)	Ti(%)	Mn (ppm)	V (ppm)
t = 0 hr	8.57±0.29	0.73±0.13	1139±53	168±16
t = 0 hr	8.16±0.28	0.49±0.11	1098±51	177±16
t = 0 hr	8.24±0.28	0.44±0.10	1081±50	151±15
t = 8 hr	9.79±0.33	0.32±0.11	1090±51	158±17
t = 8 hr	8.25±0.29	0.55±0.12	1133±54	154±18
t = 16 hr	8.08±0.29	0.48±0.11	1023±48	142±15
t = 24 hr	7.70±0.27	0.52±0.12	927±44	136±15
t = 32 hr	7.68±0.26	0.46±0.11	986±46	141±15
t = 40 hr	6.64±0.23	0.36±0.09	1009±47	127±14
t = 40 hr	8.52±0.28	0.36±0.09	1064±49	151±16
t = 40 hr	8.31±0.29	0.52±0.09	1006±48	140±16
t = 48 hr	7.89±0.27	0.56±0.12	994±47	143±16

TABLE 9

COOK INLET TIME SERIES - SUSPENDED PARTICULATE MATTER

>0.4 μm - STATION CB-10

DISCOVERER, August 1978

Station	Na(%)	K(%)	As(ppm)	La(ppm)	Sm(ppm)
t = 0 hr	3.43±0.01	2.86±0.36	26.1±1.4	27.9±0.8	5.1±0.1
t = 0 hr	3.27±0.01	2.60±0.32	21.9±1.3	25.6±0.7	4.6±0.1
t = 8 hr	3.61±0.01	2.97±0.39	22.4±1.5	26.6±0.8	5.1±0.1
t = 16 hr	3.20±0.01	2.68±0.39	19.1±1.4	23.3±0.7	4.2±0.1
t = 24 hr	4.57±0.01	2.52±0.44	19.3±1.6	26.3±0.8	4.9±0.1
t = 32 hr	3.50±0.01	2.51±0.41	20.5±1.4	25.1±0.8	4.6±0.1
t = 40 hr	2.70±0.01	1.48±0.20	17.8±1.0	23.5±0.6	4.4±0.1

TABLE 10

VARIATION OF ELEMENTAL COMPOSITION IN SUSPENDED PARTICULATES (>0.4 μ) WITH TIME

Discoverer, August 1978

(ppm EXCEPT WHERE NOTED)

	Sc	Cr	Fe(%)	Co	Sb	Cs	Eu	Tb	Ta	Th
COOK INLET										
TIME SERIES CB-10										
t = 0 hr	21.52 ± 0.07	122 ± 4	6.40 ± 0.03	25.92 ± 0.23	1.91 ± 0.08	7.04 ± 0.10	1.19 ± 0.02	0.67 ± 0.04	0.92 ± 0.07	8.92 ± 0.15
t = 0 hr	20.84 ± 0.06	120 ± 4	6.14 ± 0.04	24.77 ± 0.25	1.75 ± 0.08	6.77 ± 0.10	1.20 ± 0.02	0.70 ± 0.04	0.91 ± 0.07	8.67 ± 0.15
t = 8 hr	19.17 ± 0.05	109 ± 4	5.68 ± 0.02	23.17 ± 0.18	1.54 ± 0.07	6.47 ± 0.09	1.09 ± 0.01	0.59 ± 0.04	0.86 ± 0.07	7.66 ± 0.14
t = 16 hr	17.23 ± 0.06	98 ± 4	4.97 ± 0.04	19.55 ± 0.21	1.41 ± 0.09	5.29 ± 0.11	1.01 ± 0.02	0.54 ± 0.04	0.76 ± 0.05	6.81 ± 0.19
t = 24 hr	21.07 ± 0.03	123 ± 4	6.14 ± 0.03	24.44 ± 0.11	1.71 ± 0.11	6.75 ± 0.14	1.21 ± 0.02	0.75 ± 0.05	0.93 ± 0.09	8.55 ± 0.20
t = 32 hr	19.21 ± 0.02	114 ± 4	5.68 ± 0.05	23.25 ± 0.31	1.56 ± 0.10	6.28 ± 0.12	1.10 ± 0.02	0.63 ± 0.04	0.93 ± 0.09	7.60 ± 0.21
t = 40 hr	16.08 ± 0.08	88 ± 2	4.65 ± 0.02	19.56 ± 0.10	1.43 ± 0.08	4.88 ± 0.09	0.96 ± 0.02	0.46 ± 0.03	0.74 ± 0.07	6.77 ± 0.12

TABLE 11

DISSOLVED (<0.4 µm) VANADIUM CONCENTRATIONS (µg/ℓ) in IN COOK INLET AND SHELIKOF STRAIT WATERS

	Cook Inlet	May 1978 - (Depth)	August 1978 - (Depth)
Station -	CB-1	1.54±0.11 (sfc)	1.15±0.10 (15 M)
	CB-2	---	---
	CB-3	---	1.14±0.10
	CB-4	1.49±0.10 (sfc)	1.19±0.10 (15 M)
	CB-5	---	1.11±0.18 (30 M)
	CB-6	1.53±0.11 (sfc)	1.36±0.09 (20 M)
	CB-7	1.99±0.13 (sfc)	1.26±0.09 (15 M)
	CB-8	1.51±0.10 (sfc)	1.26±0.09 (15 M)
	CB-9	1.44±0.10 (sfc)	---

Time Series Station CB-10 - August 1978 Depth = 15M

t = 0 hr	1.12±0.08
t = 8 hr	1.25±0.09
t = 16 hr	1.22±0.09
t = 40 hr	1.17±0.09
t = 48 hr	1.07±0.08

	Shelikof Strait	August 1978 - (Depth)
Station -	SS-2	1.28±0.14 (273 M)
	SS-4	1.44±0.15 (131 M)
	SS-6	1.41±0.15 (201 M)
	SS-11	1.42±0.12 (145 M)
	SS-13	0.62±0.05 (147 M)

TABLE 12

DISSOLVED (<0.4 µm) MANGANESE CONCENTRATIONS (µg/ℓ) IN
COOK INLET AND SHELIKOF STRAIT WATERS

	Cook Inlet	May 1978 -(Depth)		August 1978 -(Depth)	
Station -	CB-1	0.48±0.06	(sfc)	1.85±0.20	(15 M)
	CB-2			1.23±0.13	(20 M)
	CB-3			0.29±0.04	(20 M)
	CB-4	0.25±0.04	(sfc)	0.79±0.09	(15 M)
	CB-5	<0.2	(sfc)	0.34±0.04	(30 M)
	CB-6	0.29±0.04	(sfc)	0.31±0.04	(20 M)
	CB-7	0.11±0.02	(sfc)	0.95±0.11	(15 M)
	CB-8	0.16±0.03	(sfc)	0.82±0.09	(15 M)
	CB-9	0.64±0.07	(sfc)		

	Shelikof Strait	August 1978 - (Depth)	
Station -	SS-2	7.28±0.74	(273 M)
	SS-4	0.55±0.07	(131 M)
	SS-6	6.8±0.7	(201 M)
	SS-13	0.03±0.01	(147 M)

TABLE 13

VANADIUM CONCENTRATIONS IN SELECTED ALASKAN OCS BIOLOGICAL MATERIALS

ROCK SOLE	Ng V/g Tissue (Dry Weight)
Miller Freeman Station	
#34	55 ± 19
#13	<10
#27	20 ± 16
#43	29 ± 13
#44	69 ± 18
POLLOCK	
Miller Freeman Station	
#11	97 ± 20
#17	44 ± 16
#36	23 ± 13
#39	<16
#42	<14
#45	<19
CRAB	
Miller Freeman Station	
#12	<14
#26	<18
#48	23 ± 11
#40	24 ± 16
#37	44 ± 14
FUCUS	
Cape Nukshak	830 ± 24
Sundstrom Isl.	483 ± 13
Otter Isl.	945 ± 14
Anchor Cove	319 ± 16
Unalaska Isl.	318 ± 48

TABLE 13 (cont)

MYTILUS	Ng V/g Tissue (Dry Weight)
Otter Isl.	783 ± 13
Cape Nukshak	226 ± 33
Sundstrom Isl.	501 ± 20
Cape Nukshak	389 ± 18
Unalaska Isl.	520 ± 53
NEPTUNIA	
Miller Freeman Station	
#15	2670 ± 110
#19	2470 ± 100

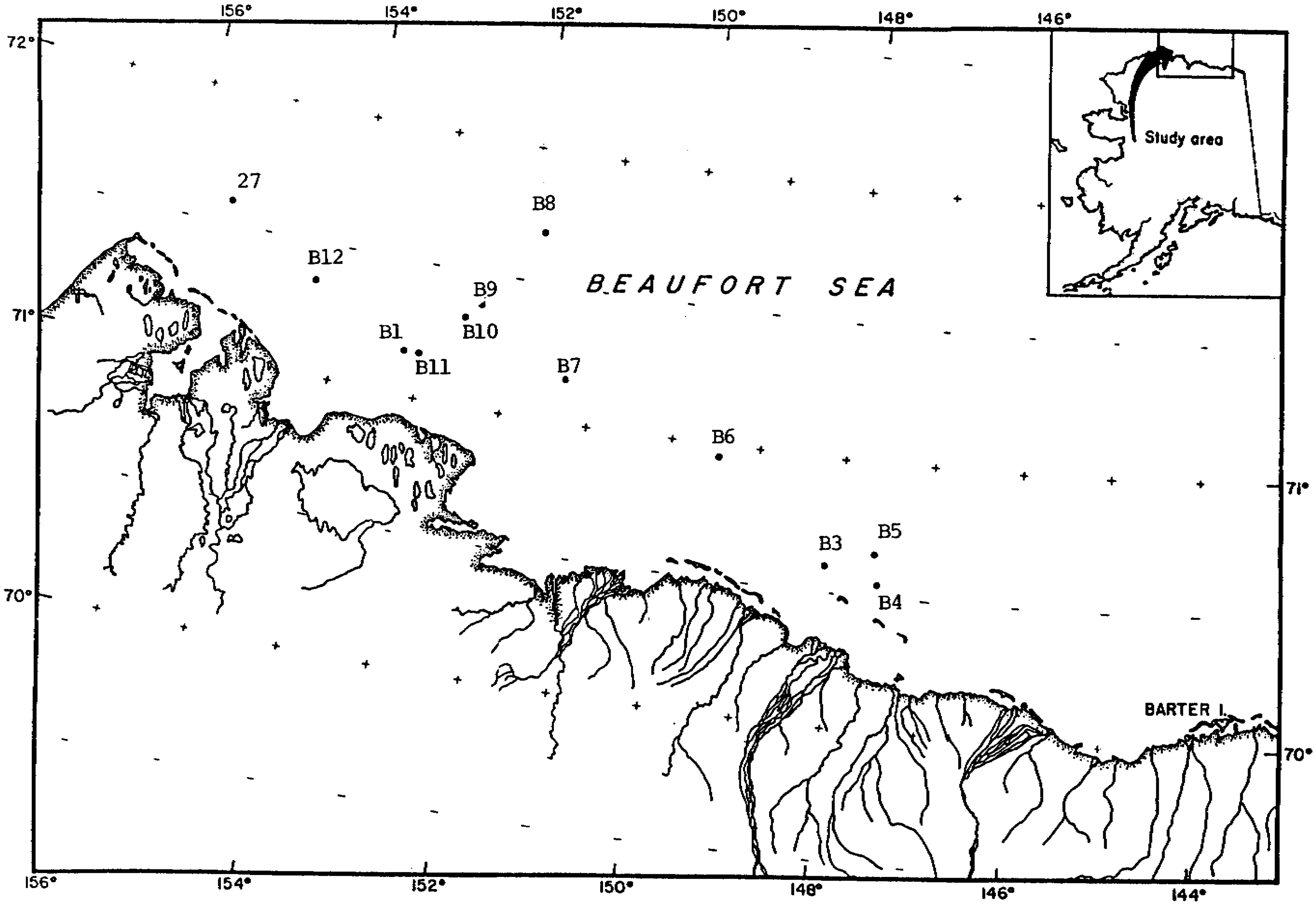

FIGURE 1. Sampling Stations in the Beaufort Sea <u>Glacier</u>, August 1976

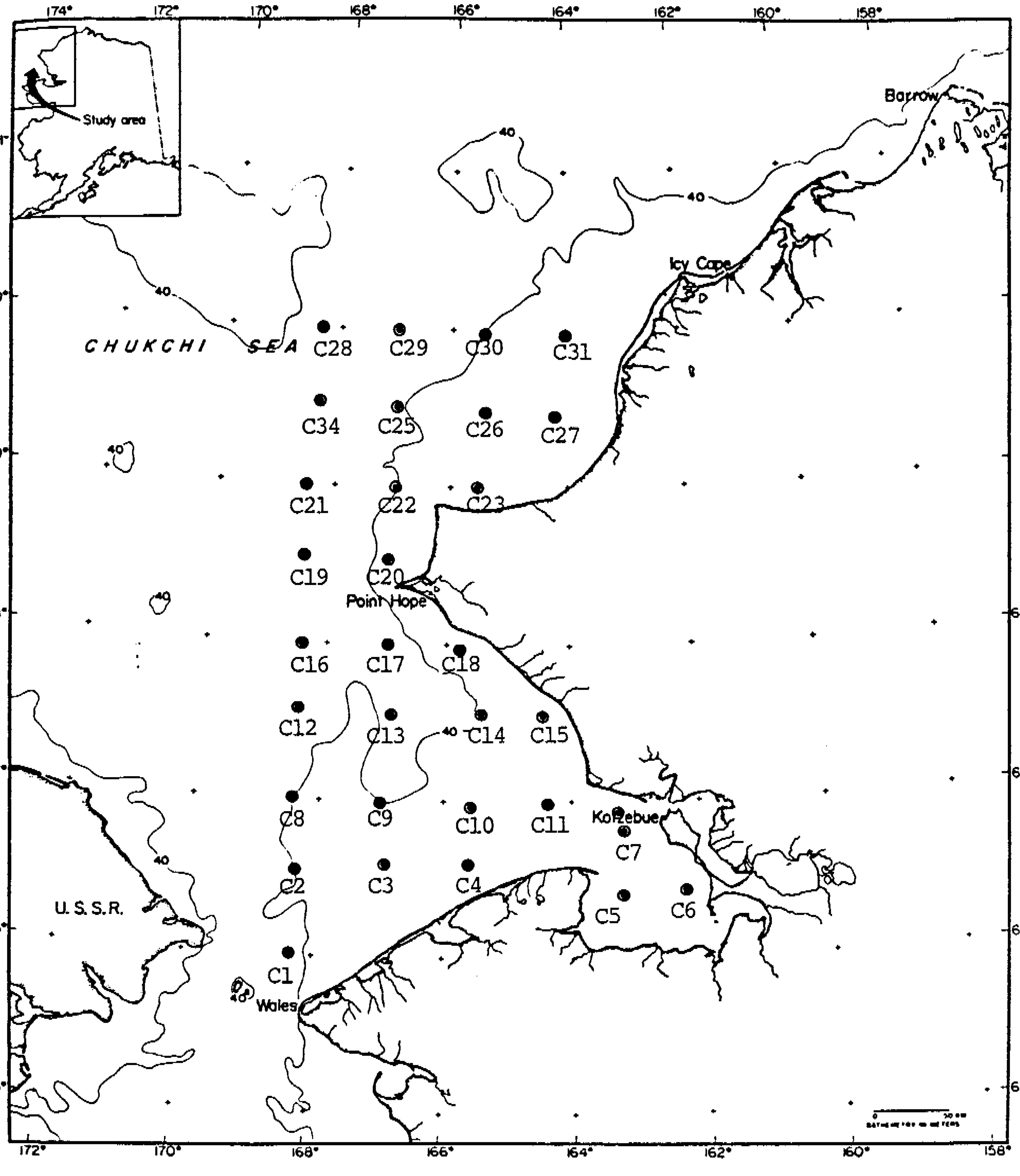

FIGURE 2. Sampling Stations in the Chukchi Sea
Discoverer, September 1976

FIGURE 2 (continued)

S. CHUKCHI SEA

Discoverer Leg IV - September 8-24, 1976
Station localities and operations

Station No.	Depth	Latitude	Longitude	Sampling Operations
C 1	53	65°59.8	168°20.5	van Veen Grab, water
C 2	49	66°30.1	168°24.1	van Veen Grab, water
C 3	31	66°30.5	167°01.6	van Veen Grab, HAPS, water
C 4	15.5	66°30.0	165°39.2	van Veen Grab
C 5	14	66°18.1	163°13.5	van Veen Grab, HAPS, water
C 6	15	66°23.3	162°14.4	van Veen Grab, HAPS, water
C 7	14	66°44.5	163°17.0	van Veen Grab, HAPS, water
C 7A	13.5	66°52.5	163°09.4	van Veen Grab, HAPS, water
C 8	35	67°00.3	168°26.2	van Veen Grab, water
C 9	42	67°00.2	167°01.9	van Veen Grab, HAPS, water
C10	24	66°58.0	165°46.9	van Veen Grab, HAPS, water
C11	26.5	67°00.0	164°20.0	van Veen Grab
C12	48	67°31.6	168°20.0	van Veen Grab, HAPS, water
C13	46.5	67°30.3	167°02.5	van Veen Grab, HAPS, water
C14	38.5	67°28.9	165°39.5	van Veen Grab, HAPS, water
C15	17	67°26.2	164°18.2	van Veen Grab, HAPS, water
C16	59	68°01.2	168°28.6	van Veen Grab, HAPS, water
C17	52	67°58.8	167°01.5	van Veen Grab, water
C18	28	67°57.3	155°47.8	van Veen Grab, water
C19	52	68°30.0	168°22.0	van Veen Grab, HAPS, water
C20	31.5	68°28.1	167°03.0	van Veen Grab, HAPS, water
C21	51	69°00.3	168°29.3	van Veen Grab
C22	46	68°59.2	166°59.7	van Veen Grab, HAPS
C23	20	69°00.9	165°37.0	van Veen Grab, HAPS
C24	51	69°30.0	168°21.9	van Veen Grab, HAPS
C25	46	69°30.0	167°04.1	van Veen Grab, HAPS
C26	33	69°30.1	165°32.0	van Veen Grab
C27	22	69°29.5	164°11.2	van Veen Grab
C28	45	70°00.7	168°19.4	van Veen Grab
C29	46.5	70°00.0	167°01.2	van Veen Grab, HAPS
C30	40	69°58.5	165°33.4	van Veen Grab
C31	30	69°58.1	164°00.4	van Veen Grab

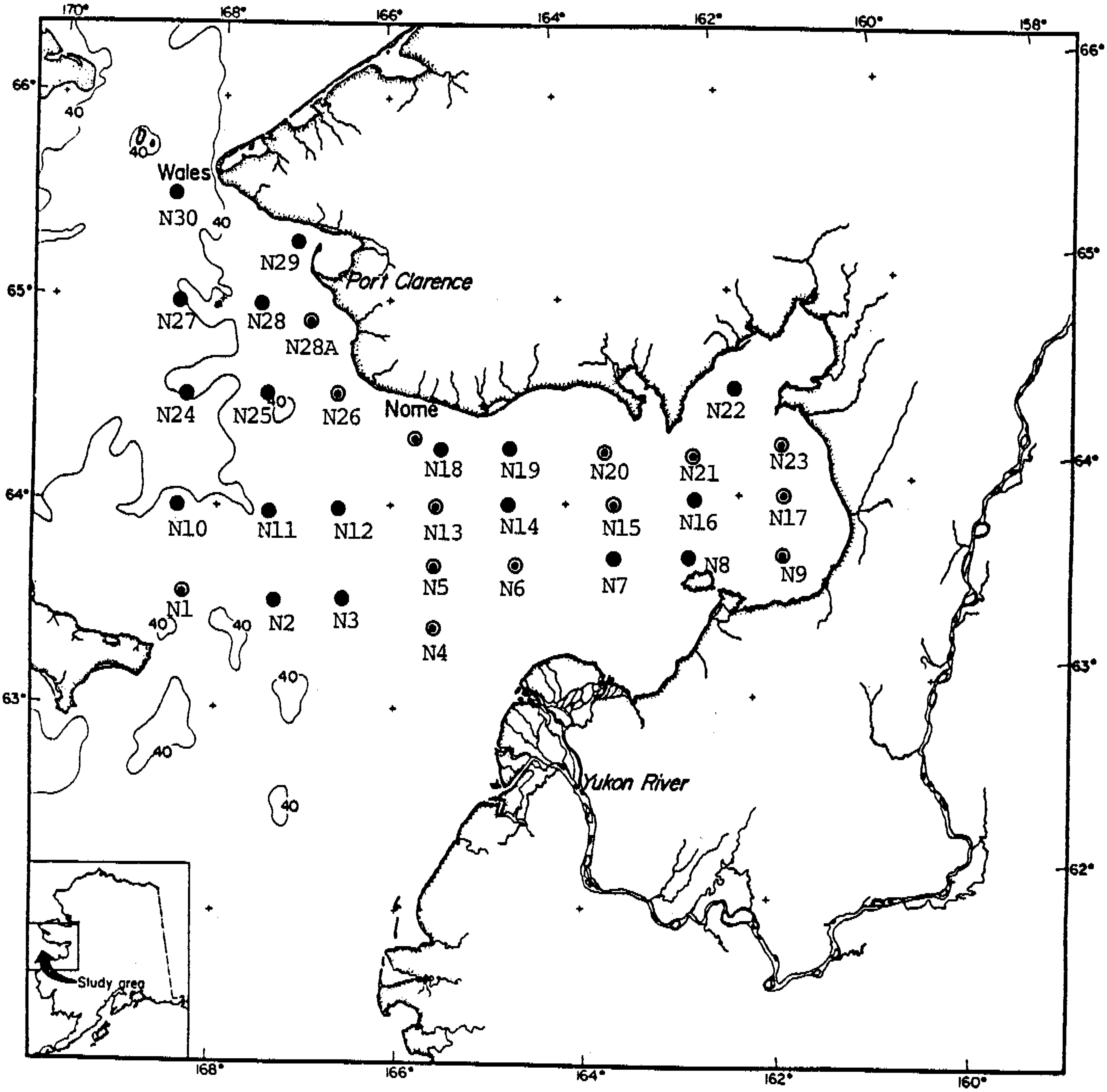

FIGURE 3. Sampling Stations in Norton Sound
Discoverer, September 1976

FIGURE 3 (continued)

NORTON SOUND (N. BERING SEA)

Discoverer Leg IV - September 8-24, 1976
Station localities and operations

Station No.	Depth	Latitude	Longitude	Sampling Operations
N 1	29 m	63°31.8	168°32.2	van Veen Grab, HAPS, water
N 2	29	63°30.6	167°29.0	van Veen Grab, water
N 3	26.5	63°29.9	166°29.7	van Veen Grab, water
N 4	21	63°19.7	165°29.9	van Veen Grab, HAPS water
N 5	22	63°39.5	165°32.1	van Veen Grab, HAPS water
N 6	13	63°38.4	164°31.0	van Veen Grab, HAPS water
N 7	15	63°38.2	163°30.3	van Veen Grab, water
N 8	15.5	63°42.0	162°28.5	van Veen Grab
N 9	15	63°41.5	161°31.1	van Veen Grab, HAPS, water
N10	37.5	64°01.0	168°26.0	van Veen Grab
N11	40	64°00.4	167°32.1	van Veen Grab
N12	31	63°59.2	166°29.8	van Veen Grab
N12D	26	64°23.5	165°44.8	van Veen Grab, HAPS, water
N13	20	63°59.7	165°29.7	van Veen Grab, HAPS
N14	20	64°01.2	164°28.7	van Veen Grab, water
N15	20	64°00.3	163°30.5	van Veen Grab, HAPS, water
N16	19	64°00.0	162°30.0	van Veen Grab
N17	18.5	64°00.0	161°30.3	van Veen Grab, HAPS, water
N18	23	64°20.2	165°30.0	van Veen Grab
N19	15.5	64°19.4	164°30.4	van Veen Grab
N20	20	64°20.1	163°31.0	van Veen Grab, HAPS, water
N21	19	64°15.25	162°29.7	van Veen Grab, HAPS, water
N22	13	63°30.3	162°00.5	van Veen Grab, water
N23	15	64°17.5	161°30.7	van Veen Grab, HAPS, water
N24	40	64°29.7	168°28.3	van Veen Grab, water
N25	31	64°29.6	167°29.6	van Veen Grab, water
N26	28	64°30.2	166°31.5	van Veen Grab, HAPS, water
N27	46.5	65°00.5	168°26.7	van Veen Grab, water
N28	30	65°00.1	167°31.5	van Veen Grab
N28A	24	64°44.6	167°01.0	van Veen Grab, HAPS
N29	14.5	65°17.8	167°00.4	van Veen Grab
N30		65°30.5	168°31.0	van Veen Grab, water

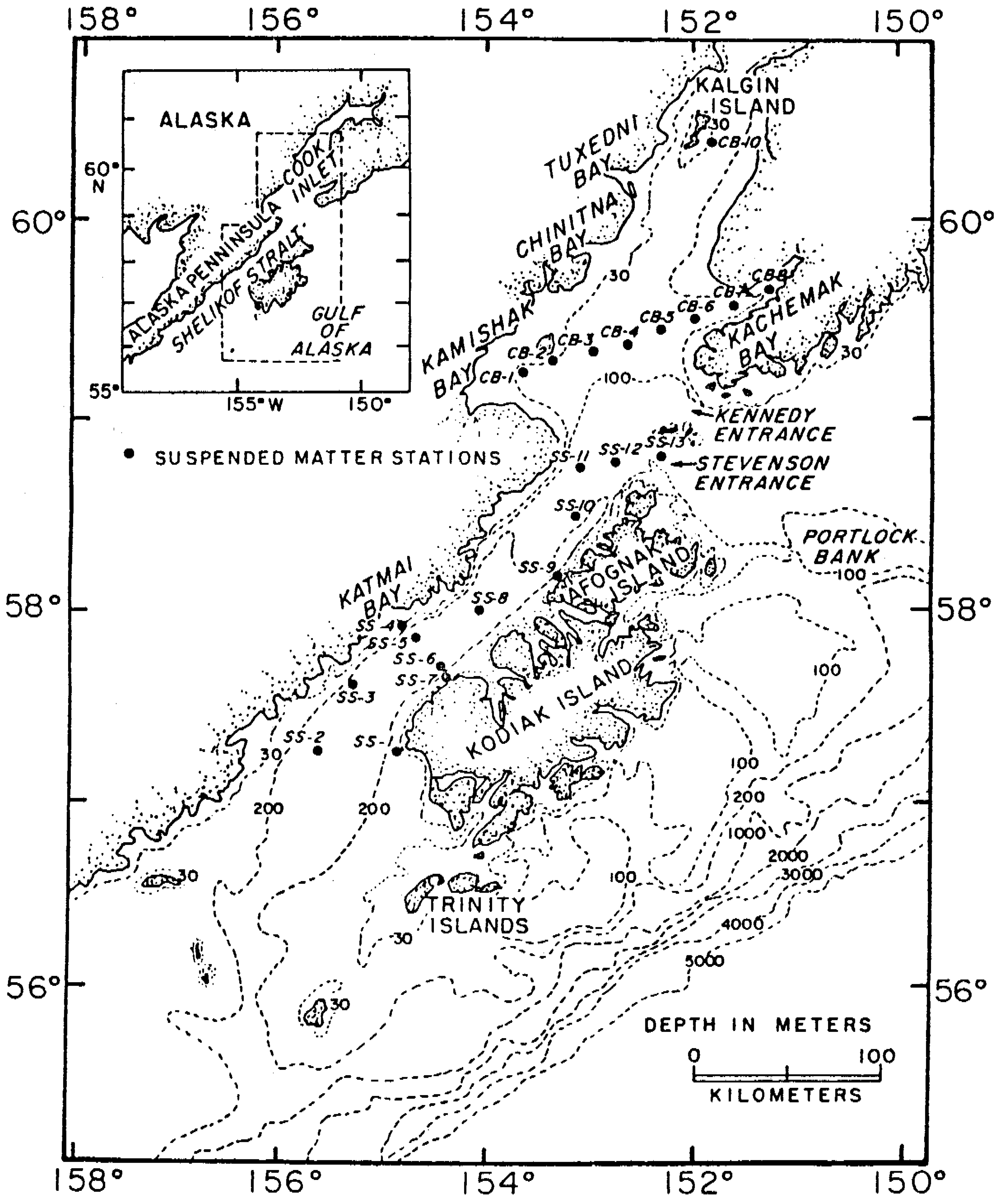

FIGURE 4. Sampling Stations in Cook Inlet and Shelikof Strait
<u>Discoverer</u>, August 1978

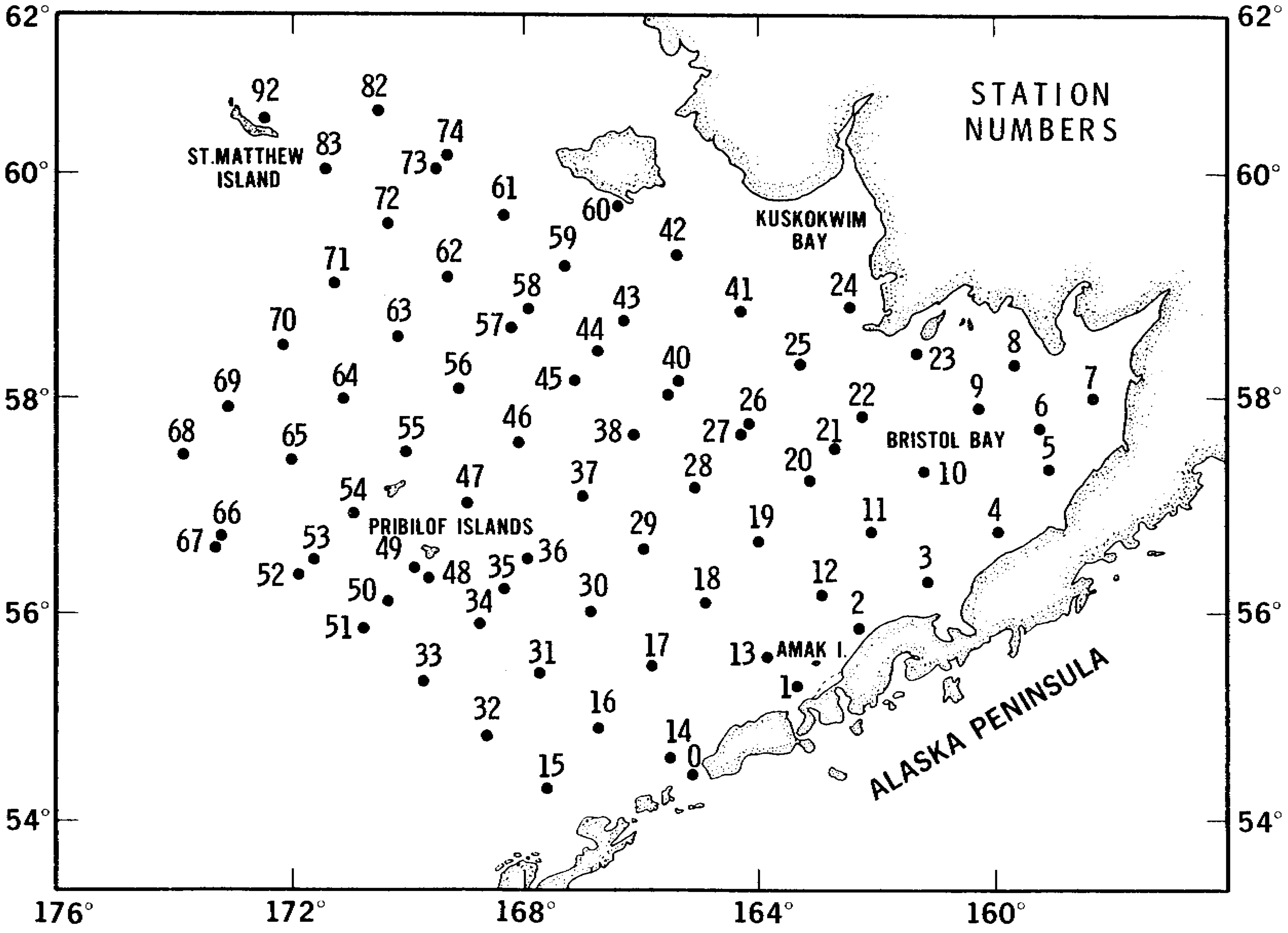

Figure 5. Sampling Locations in the Bering Sea

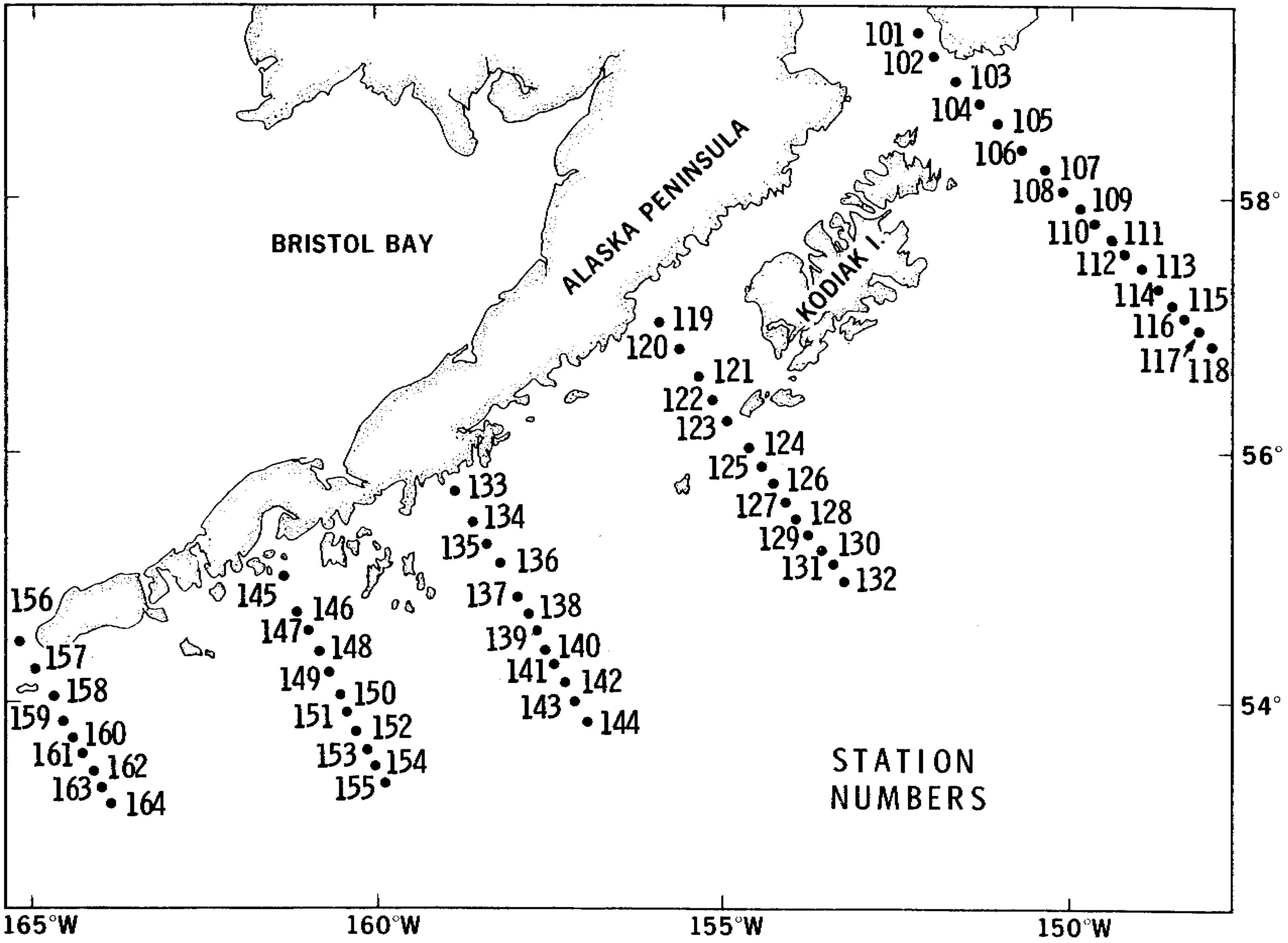

FIGURE 6. Sampling Locations in the NW Gulf of Alaska

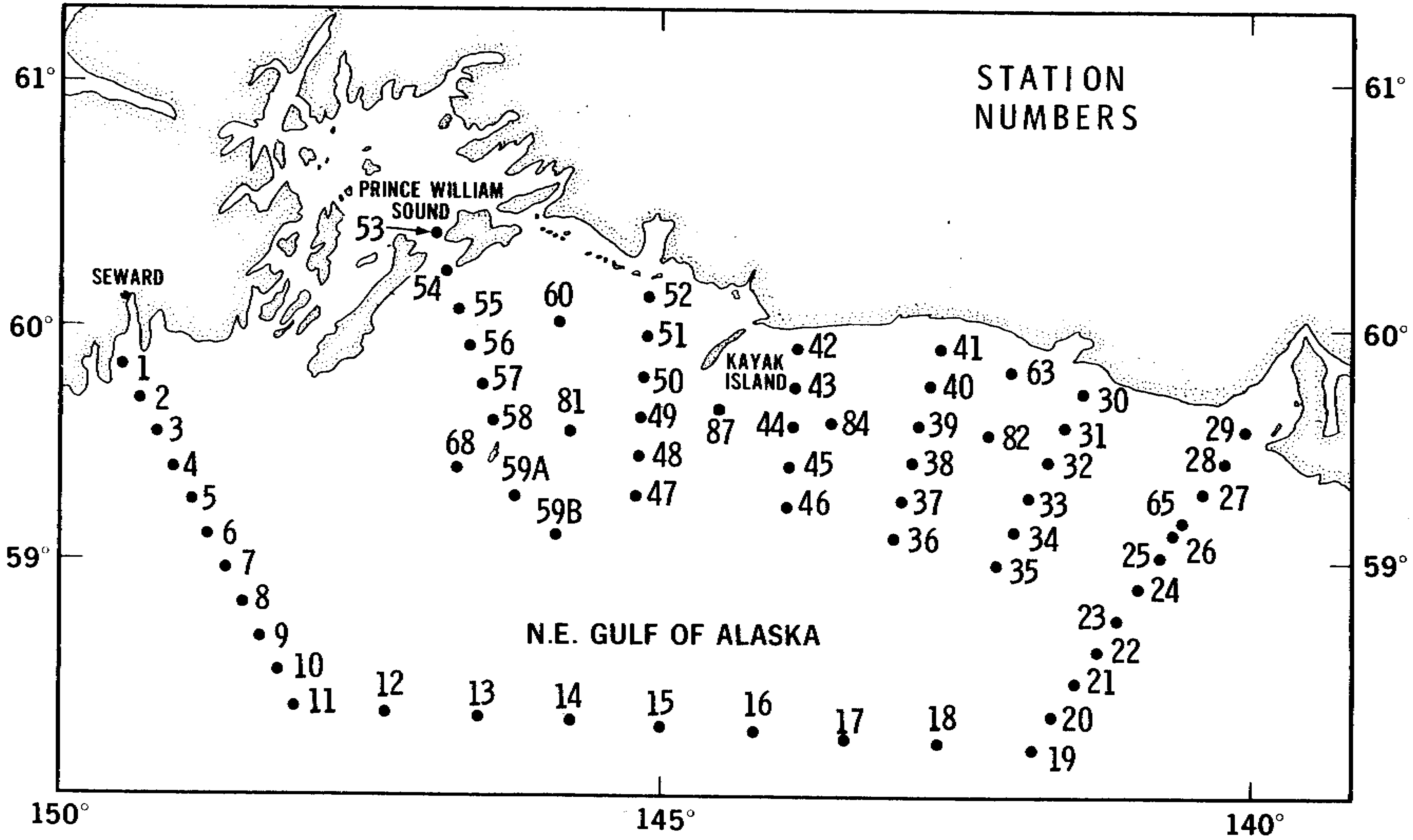

FIGURE 7. Sampling Stations in the NE Gulf of Alaska

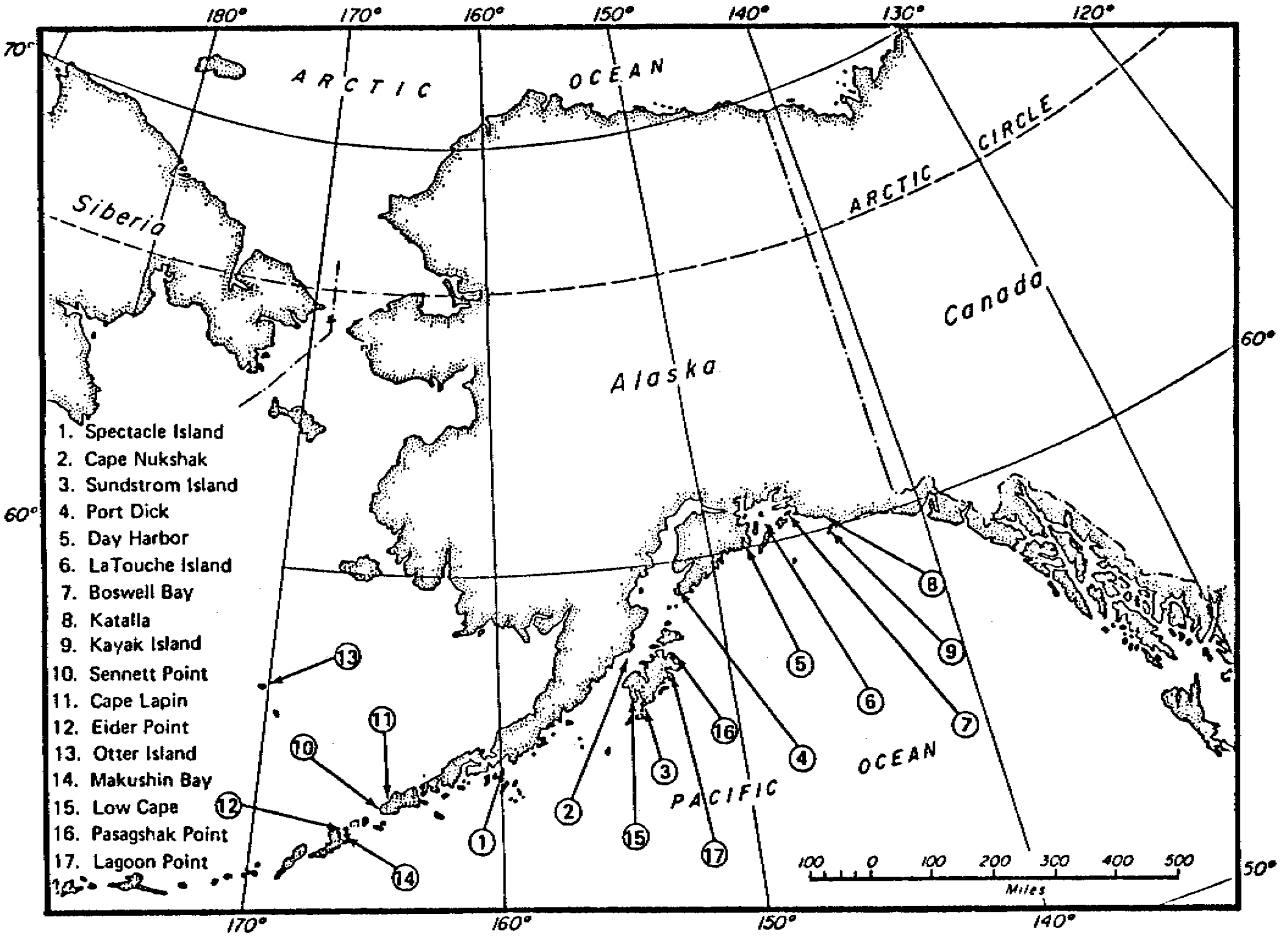

FIGURE 8. Sampling Locations for Intertidal Biota

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