4. COOPERATIVE STUDY OF UPPER OCEAN PARTICULATE FLUXES[1]

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ABSTRACT

To continue and extend our investigations of fluxes of natural particulate materials from Southern Ocean summer surface waters begun in 1987 during ODP Leg 113, we made eleven 20–37-hr deployments of drifting sediment traps during the course of ODP Leg 119. A three-trap array, with traps suspended 50, 100, and 200 m below the surface was launched, tracked, and recovered from the ice escort vessel *Maersk Master* when permitted by its schedule of ice-tending duties and logistic support for the drill ship. Most of the deployments took place in Prydz Bay (4 consecutive collections from Site 739, 3 from Site 740, 1 from Site 741, and 2 from Site 742). We also made a 1-day collection over the southern Kerguelen Plateau (Site 744) before the *Maersk Master* was released from escort service. This data report summarizes the field program and archives data on the geochemical and biochemical constituents of the trapped material.

INTRODUCTION

During Leg 113 of the Ocean Drilling Program (ODP) in January–February 1987, we launched and recovered floating sediment traps from the ice escort vessel *Maersk Master*. Using a drifting two-trap array, we sampled at several high-latitude locations in the Weddell Sea for about one week each, with 1–2-day temporal resolution (see Biggs et al., 1988, in press). When the ice escort vessel also accompanied ODP Leg 119 a year later, in December 1987–February 1988, we were able to collect comparable data from Prydz Bay and the southern Kerguelen Plateau.

To trap particulate material, we used nonclosing, gel-coated fiberglass cones fabricated by Dr. R. B. Dunbar's group at Rice University (see Dunbar, 1984; also fig. 2 in Biggs et al., 1988). The traps have a collecting cross section of 1600 cm^2, tapering to a removable basal collecting cylinder. The mouth of the trap is baffled with a carbon-fiber honeycomb material with cells 1 cm wide by 4 cm deep, which our experience on Leg 113 confirmed can quite effectively prevent the penetration of turbulent eddies into the trapping chamber. The Rice University traps are relatively simple to deploy from a ship-of-opportunity, and two people with assistance from the crew can service and then redeploy three traps in a 0.5-hr operations window.

The only modification of the drifting array for field work on Leg 119 was the addition of a third trap at 50 m below the surface (mbs), so that material was collected close to the base of the mixed layer as well as at 100 and 200 mbs. Deployment times during Leg 119 ranged from 20 to 37 hr; *in-situ* preservatives were not used. Additional details of array fabrication and tracking with a VHF radio beacon are given in Biggs et al. (1988).

Two of us (Berkowitz and Noh) conducted the sediment trapping from *Maersk Master* during Leg 119. To determine the temperature-salinity characteristics and depth of the mixed layer at each site where traps were deployed, the upper 200 m of the water column was profiled with a Sea-Bird Electronics internal-recording SEACAT SBE 19 conductivity-temperature-depth (CTD) recorder. Three CTD profiles were made at Site 738, 3 at Site 739, 4 at Site 740, 2 at Site 741, 2 at Site 742, and 1 at Site 743 before the CTD was lost on 4 February as a result of the failure of a frozen snap shackle. The CTD data summarized in Figure 1 show that the thermocline/halocline in Prydz Bay varied in depth between 20–40 mbs; thus, the uppermost trap at 50 mbs hung within 10 m (Sites 742 and 743) to 30 m (Sites 740 and 741) below the base of the mixed layer. Irrespective of location in Prydz Bay, however, there was little variation in the temperature-salinity environment below the upper 80 m of the water column; the temperature at 100 and 200 mbs averaged −1.5°C, and salinity averaged 34.4 ppt. Berkowitz and Noh also collected water samples once daily with six 5-L Niskin bottles from six different depths for analysis of ^{15}N natural abundance and estimation of the integrated photic zone plant pigment concentration.

LEG 119 COLLECTION SITES

The three-trap drifting array was released 2–4 km away from the drill ship, and it drifted an average of 8 km (4.3 nmi) per day. Table 1 gives details of these deployments, coded by consecutive collection number at each site. Most of these collections were made in Prydz Bay (4 consecutive deployments at Site 739, 3 at Site 740, 1 at Site 741, and 2 at Site 742). However, we also made a 1-day collection over the southern Kerguelen Plateau (Site 744) before *Maersk Master* was released from escort service. We failed to recover an array deployed earlier in the cruise over the southern Kerguelen Plateau at Site 738 because of *Maersk Master*'s busy schedule of ice-tending duties at that site. Sometime during the 4-day period from 10 to 14 January that the array was in the water at Site 738, the tracking buoy separated from the main array. Although the radio-equipped tracking buoy was recovered, the main array must have drifted along a different heading after the two separated, because we never found it.

Maps of the Northern Ice Limit compiled from environmental satellite imagery by the U.S. Navy–NOAA Joint Ice Center (Suitland, Maryland) indicate that the seasonal sea-ice cover started to melt back from the Leg 119 sites in mid-November 1987, and weekly time series summaries show that melting progressed rapidly (see Fig. 2). Southern Kerguelen Plateau Sites

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[1] Barron, J., Larsen, B., et al., 1989. *Proc. ODP, Init. Repts.*, 119: College Station, TX (Ocean Drilling Program).

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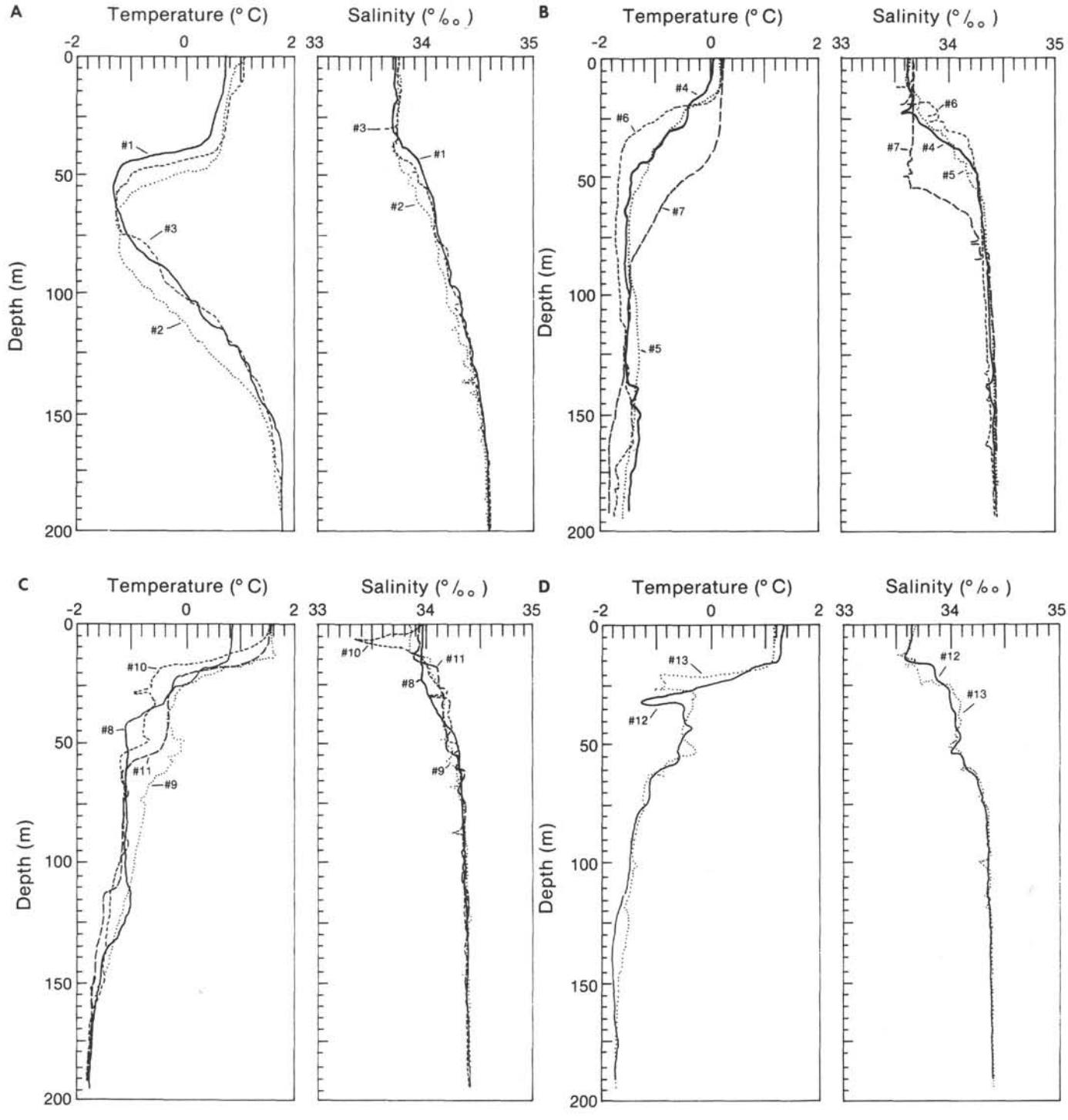

Figure 1. Temperature and salinity structure of the upper 200 m of the water column, from CTD casts. Each trace is the average of the downcast and upcast data. Numbers indicate sequential deployments. **A.** Site 738 (10, 14, and 15 January 1988). Mixed layer depth averaged 35 mbs. **B.** Site 739 (18, 19, 21, and 22 January 1988). Mixed layer depth averaged 15 mbs. **C.** Site 740 (24, 25, 26, and 27 January 1988). Mixed layer depth averaged 15 mbs. **D.** Site 741 (28 and 29 January 1988). Mixed layer depth averaged 15 mbs. **E.** Site 742 (31 January and 1 February 1988). Mixed layer depth averaged 35 mbs. **F.** Site 743 (2 February 1988). Mixed layer depth averaged 25 mbs.

738 and 744 were only 30%–50% covered by pack ice by 10 December 1987 and in open water by 24 December (6 weeks before we successfully recovered collection 744-1). Melting of the pack ice over Prydz Bay Sites 739–743 was also pretty much complete by late December, although the icebergs, growlers, and bergy bits formed by calving of the continental ice shelves remained. Thus, Prydz Bay Sites 739–743 had been in open water for about 3–5 weeks before we trapped there.

SAMPLE PREPARATION

Each time the traps were recovered, samples were scanned under a dark-field binocular microscope for the presence of "swimmers," be-

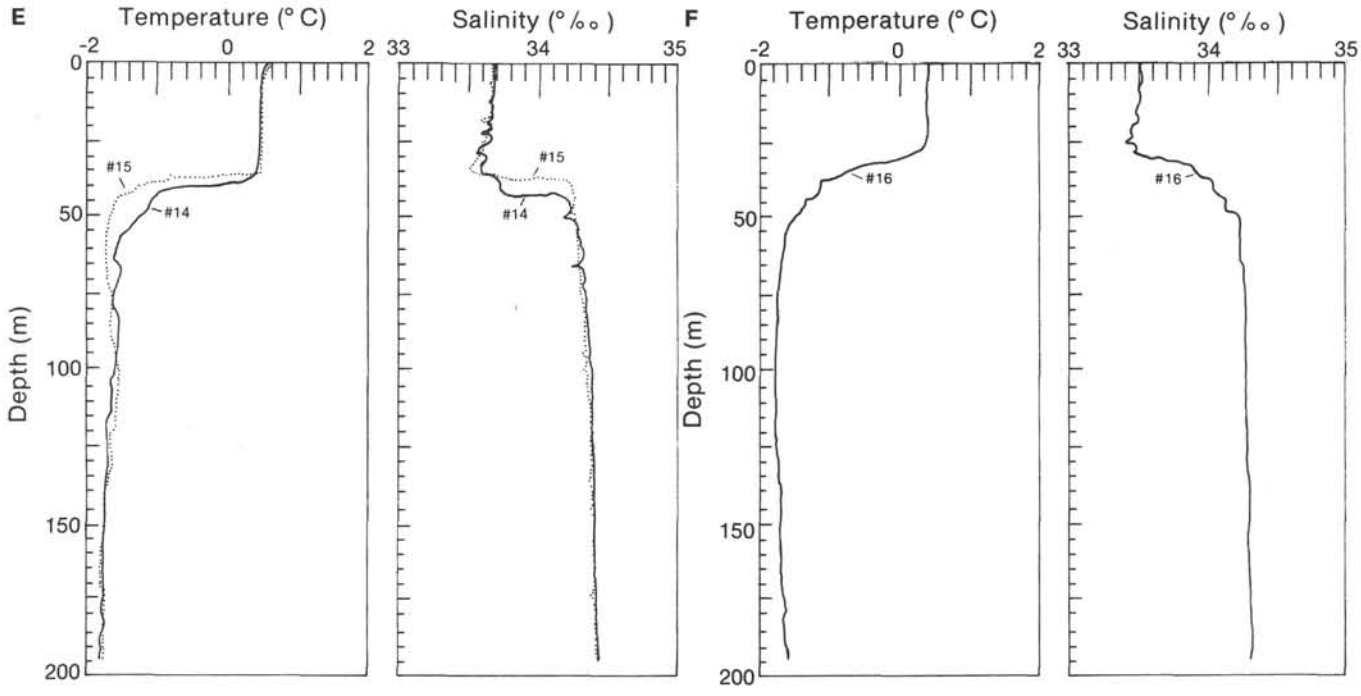

Figure 1 (continued).

Table 1. Summary of deployments of the drifting sediment trap during ODP Leg 119.

Collection	Date of recovery (1988)	Water depth (m)	Deployment	Recovery	Duration (hr)	Net drift (nmi)	Direction (degrees)
739-1	Jan. 19	423	67°18.0′S 75°02.1′E	67°19.5′S 74°48.0′E	24.5	6.1	257
739-2	Jan. 20		67°17.0′S 75°01.0′E	67°16.6′S 74°50.2′E	19.5	5.0	287
739-3	Jan. 21		67°17.8′S 75°01.3′E	67°18.2′S 74°42.9′E	23.3	6.4	267
739-4	Jan. 22		67°17.0′S 75°01.1′E	67°17.0′S 74°48.0′E	22.0	5.7	277
740-1	Jan. 25	818	68°39.0′S 76°43.0′E	68°38.5′S 76°35.0′E	37.0	4.0	294
740-2	Jan. 26		68°39.5′S 76°42.5′E	68°42.0′S 76°30.5′E	23.9	4.8	247
740-3	Jan. 27		68°41.0′S 76°42.0′E	68°42.8′S 76°31.7′E	27.9	3.1	227
741-1	Jan. 29	562	68°25.0′S 76°21.0′E	68°25.8′S 76°12.9′E	23.0	3.1	256
742-1	Feb. 1	426	67°33.0′S 75°22.0′E	67°33.8′S 75°18.2′E	23.8	1.4	260
742-2	Feb. 2		67°33.0′S 75°22.0′E	67°34.0′S 75°14.0′E	20.5	1.9	253
744-1	Feb. 6	2318	61°36.0′S 80°35.0′E	61°34.5′S 80°44.0′E	21.5	4.9	071

cause inadvertently trapped vertical migrators will bias estimates of upper-ocean particle flux (Harbison and Gilmer, 1986). As was the case on Leg 113, however, such swimmers were rarely trapped during our short-term deployments (never more than one to two pteropods or copepods per trap; these were removed and pickled separately).

Shipboard microscope observations also found that most of the trapped material consists of fecal pellets or fecal strings. Especially at Site 740 in the southern part of Prydz Bay, round green-colored fecal pellets were locally abundant in the traps at 100 and 200 mbs. Measurements of 100 of these pellets from the 200 mbs trap in each of the consecutive collections 740-1, 740-2, and 740-3 showed that they average 205 μm in diameter (n = 300; std. error = 10 μm).

After scanning, samples were split with a Motoda-style plankton splitter to ¼, ⅛, or 1/16 aliquots. One ¼ split was archived in 10% buffered Formalin, while the other splits were filtered for postcruise determination of their geochemical and biochemical constituents. For determination of plant pigments and their degradation products, ¼ splits were filtered onto Nuclepore 0.4-μm polyester filters, which were then frozen and transported on ice. For determination of biogenic silica content, ¼, ⅛, or 1/16 splits were filtered onto preweighed Nuclepore 0.4-μm polycarbonate filters, which were then dried at 60°C for 24 hr. For determination of organic content and its carbon and nitrogen isotopic composition, ¼, ⅛, or 1/16 splits were filtered onto precombusted Whatman GF/F filters, which were also dried at 60°C for 24 hr.

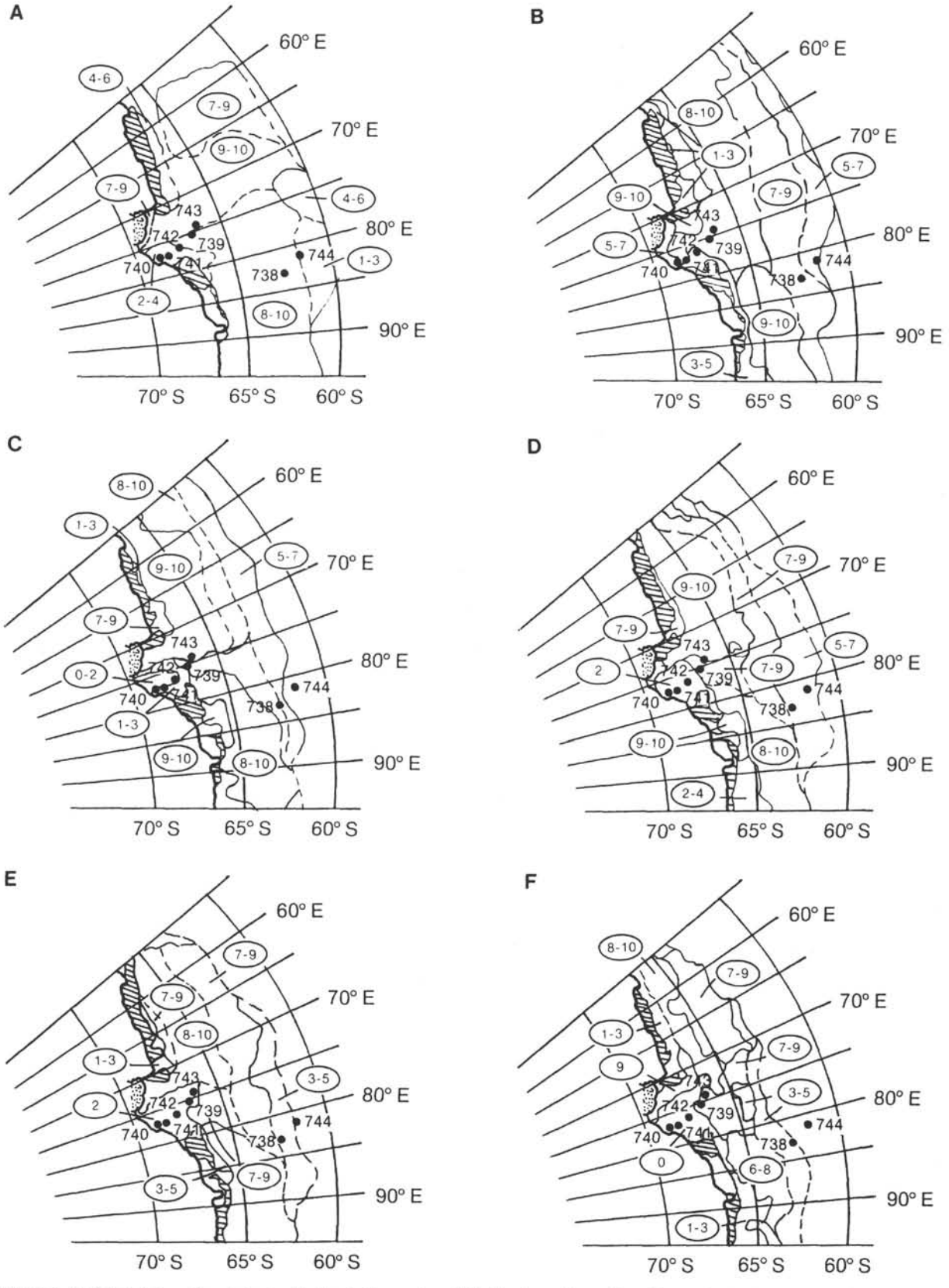

Figure 2. Aerial coverage of pack ice for the Prydz Bay sector of the Southern Ocean from November 1987 to February 1988, from a summary of the Northern Ice Limit compiled from NOAA-09, NOAA-10, and DMSP satellite imagery by the Navy-NOAA Joint Ice Center. Pack ice code 0 = open water; 1–10 = coverage in tenths. Fast ice along the continental margin is indicated by diagonal lines. **A.** 12 November 1987. **B.** 19 November 1987. **C.** 25 November 1987. **D.** 2 December 1987. **E.** 10 December 1987. **F.** 17 December 1987. **G.** 24 December 1987. **H.** 30 December 1987. **I.** 7 January 1988. **J.** 14 January 1988. **K.** 21 January 1988. **L.** 4 February 1988.

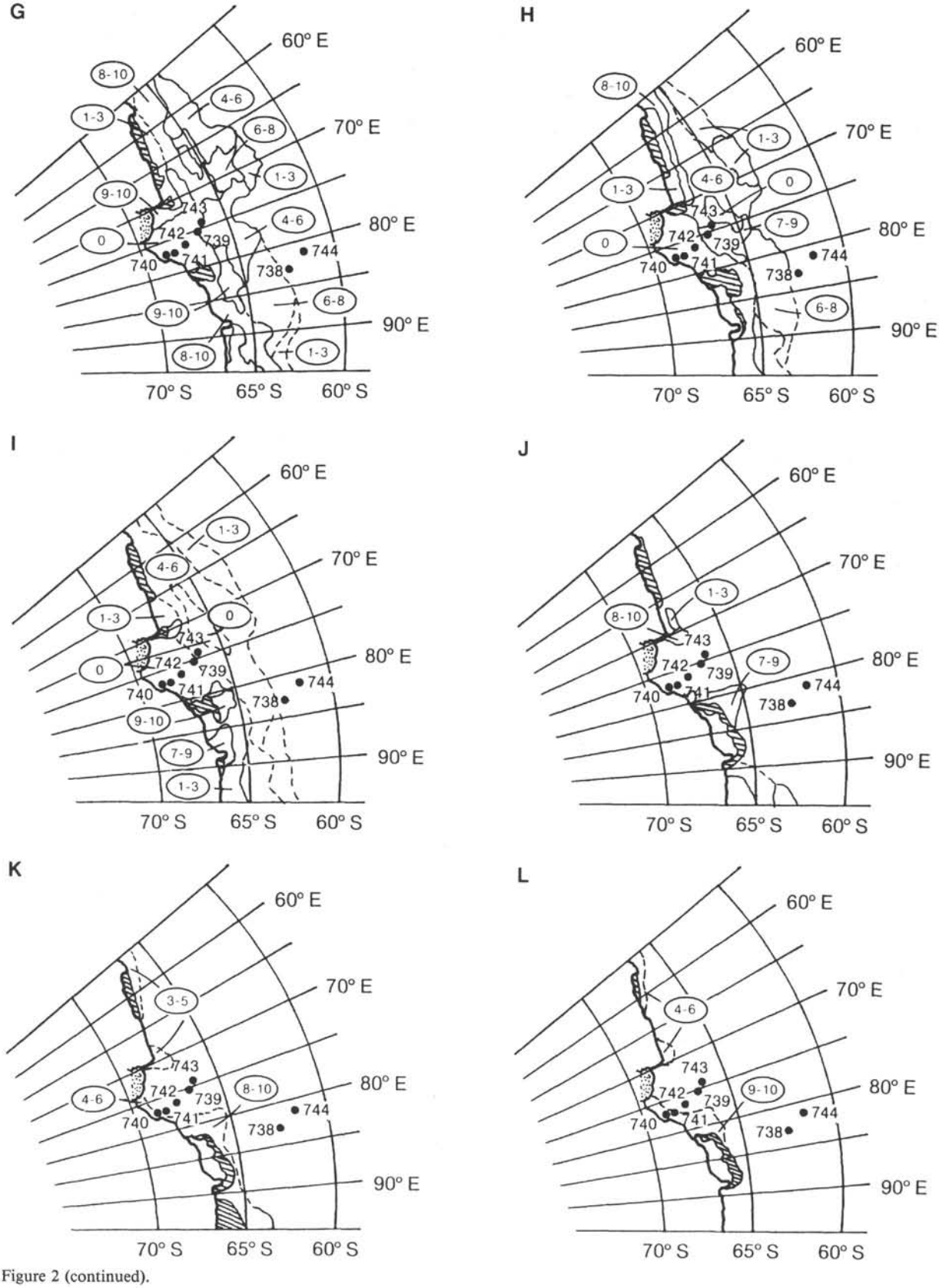

Figure 2 (continued).

To evaluate the precision of the shipboard splitting technique, replicate splits were processed from collections 739-2 and 739-3 from the 50 mbs trap and from collection 740-1 from the 200 mbs trap. Table 2 shows that total mass fluxes determined separately on pairs of 1/16 splits vary 1%, 26%, and 18% about the mean, while the mass flux biogenic silica content varies 1%, 17%, and 27% about the mean. Combustible organic carbon, combustible organic nitrogen, and total amino acid content determined separately on other pairs of 1/16 splits generally agree to within 10% (Tables 3 and 4).

MASS FLUXES AND BIOGENIC SILICA FLUXES (Analyses by D. J. DeMaster)

METHODS

After determining the weight of material on the filters, the samples were placed in individual 50-mL centrifuge tubes and an 85°C 0.2N NaOH solution was added. The centrifuge tubes were then placed in an 85°C water bath for 2 hr, and the amount of biogenic silica leached by the alkaline solution was determined according to the procedure described by DeMaster (1981).

Results

The mass fluxes intercepted by the traps at 100 and 200 mbs are similar to the values we reported for Leg 113 in the Weddell Sea, ranging from 20 to 440 mg/m^2/day (Table 2). At most sites, the largest mass fluxes were trapped at 50 mbs, although at Site 740 in the southern part of Prydz Bay round green-colored fecal pellets were locally abundant in the 200 mbs trap, resulting in two to three times more material trapped at this depth than at 50 mbsl.

The biogenic silica content of material trapped in the upper 100 m of the water column is lower than that collected on Leg 113, averaging 4.4 wt% for material intercepted in Prydz Bay and 0.4 wt% for that trapped over the southern Kerguelen Plateau Site 744. At 200 mbs, the trapped particulates average 3.4 wt% in Prydz Bay and 1.1 wt% at Site 744. Biogenic silica fluxes did not exceed 700 μmol/m^2/day (Table 2).

STABLE ISOTOPES, COMBUSTIBLE CARBON AND NITROGEN CONTENT, AND AMINO ACID COMPOSITION (Analyses by S. A. Macko)

METHODS

Dried splits for stable isotope/combustible C and N analyses were first acidified with 30% HCl to remove carbonate. After drying at 40°C, the filters were broken into small fragments and mixed with purified coarsely ground cupric oxide and pure granular copper (Alpha Resources, Inc.) for a modified Dumas combustion (Macko, 1981). The mixed sample was placed in a precombusted quartz tube, which was evacuated and then sealed and combusted for 1 hr at 850°C and allowed to cool slowly. The N_2 and CO_2 combustion products were then cryogenically purified and collected, and their stable carbon and nitrogen isotope compositions determined on a triple collector PRISM stable isotope ratio mass spectrometer (V.G. Micromass, Ltd.) Isotope compositions are reported as

$$\delta = \frac{R_{sample}}{R_{standard}} \times 1000,$$

Table 2. Mass flux and its biogenic silica component of splits of Leg 119 drifting sediment trap deployments.

Collection	Trap (mbs)	Weight of split (mg)	Biogenic silica (wt%)	Total mass per trap (mg)	Duration (hr)	Mass flux (mg/m^2/day)	Biogenic silica flux (μmol/m^2/day)
739-1	50	14.24	3.1	113.9	24.5	700	360
	100	6.59	2.8	26.4		160	75
	200	2.10	1.1	8.4		50	10
739-2	[a]50	2.80	8.8	44.8	19.5	340	505
	[a]50	2.81	8.9	45.0		350	515
	100	6.93	5.0	55.4		430	355
	200	6.81	3.9	27.2		210	135
739-3	[a]50	4.77	8.1	76.3	23.3	490	665
	[a]50	2.84	9.7	45.4		290	475
	100	8.48	4.4	67.8		440	320
	200	4.33	4.7	17.3		110	85
739-4	50	1.79	5.4	14.3	22.0	100	90
	100	4.72	4.8	37.8		260	205
	200	7.32	4.3	29.3		200	140
740-1	50	5.77	3.3	49.2	37.0	190	105
	100	4.79	2.2	19.2		80	30
	[a]200	4.29	5.0	68.6		280	235
	[a]200	6.25	6.0	100.0		400	405
740-2	50	3.27	2.6	13.1	23.9	80	35
	100	2.55	3.5	10.2		60	40
	200	2.49	4.2	19.9		120	105
740-3	50	1.55	2.2	6.2	27.9	30	15
	100	2.38	3.6	9.5		50	30
	200	3.73	2.8	14.9		80	35
741-1	50	3.20	1.8	12.8	23.0	80	25
	100	2.51	2.9	20.1		130	65
	200	2.83	2.1	11.3		70	25
742-1	50	3.17	4.5	12.7	23.8	80	60
	100	3.49	4.7	14.0		90	70
	200	2.87	2.4	11.5		70	30
742-2	50	2.24	3.1	9.0	20.5	70	35
	100	2.72	2.4	10.9		80	30
	200	2.29	2.0	9.2		70	25
744-1	50	3.08	0.4	12.3	21.5	90	5
	100	4.35	0.4	17.4		120	10
	200	0.70	1.1	2.8		20	<5

[a] Replicate 1/16 splits.

Table 3. Combustible organic content and its stable isotopic fractionation of splits of Leg 119 drifting sediment trap deployments.

Collection	Trap depth (mbs)	Split	C (mg/split)	N (mg/split)	C/N	^{15}N (ppt)	^{13}C (ppt)
739-1	50	1/8	0.64	0.067	11.1	+1.4	−26.6
739-2	[a]50	1/16	0.24	0.025	11.3	+2.9	−27.6
	[a]50	1/16	0.21	0.019	13.3	+3.2	−27.2
	100	1/8	0.39	0.040	11.5	+1.2	−26.4
739-3	[a]50	1/16	0.21	0.022	11.1	+3.8	−26.2
	[a]50	1/16	0.23	0.022	12.1	+3.4	−26.1
	100	1/8	0.23	0.023	11.8	+1.4	−26.2
739-4	50	1/8	0.37	0.039	11.1	+2.0	−27.0
	100	1/8	0.38	0.042	10.6	+1.6	−26.2
740-1	50	1/8	0.31	0.037	9.7	+3.4	−27.8
	[a]200	1/16	0.68	0.063	12.5	+2.8	−27.6
	[a]200	1/16	0.64	0.070	10.6	+2.2	−27.5
740-2	200	1/8	1.02	0.096	12.4	+2.6	−27.3
741-1	100	1/8	0.17	0.022	8.9	+3.7	−27.5

[a] Replicate 1/16 splits.

Table 4. Calculated fluxes of amino acid carbon, total combustible carbon, amino acid nitrogen, and total combustible nitrogen, based upon the data in Tables 3 and 5 for splits of Leg 119 drifting sediment trap deployments.

Collection	Trap depth (mbs)	Amino acid carbon (mg/m^2/day)	Total carbon (mg/m^2/day)	Amino acid nitrogen (mg/m^2/day)	Total nitrogen (mg/m^2/day)
739-1	50	7.9	31.3	2.7	3.3
	100	3.7	NA	1.2	NA
739-2	[a]50	8.6	29.5	2.8	3.1
	[a]50	5.9	25.8	1.8	2.3
	100	5.3	24.0	1.7	2.5
739-3	[a]50	5.2	21.6	1.9	2.3
	[a]50	6.5	23.7	2.1	2.3
	100	3.5	11.8	1.2	1.2
739-4	50	5.8	20.2	2.5	2.1
	100	6.8	20.7	2.4	2.3
740-1	50	2.7	10.1	1.0	1.2
	[a]200	12.1	44.1	4.1	4.1
	[a]200	11.8	41.5	3.8	4.5
740-2	200	6.5	51.2	2.4	4.8
741-1	100	3.2	8.9	1.1	1.1

Note: NA = not available.
[a] Replicate 1/16 splits.

where R is the abundance ratio of the heavy to the light isotope. The $\delta^{13}C$ values are reported relative to PDB, and the $\delta^{15}N$ values are relative to atmospheric N_2. The average precision on small splits is approximately ±0.2‰. Organic carbon content was determined as the quantity of CO_2 gas measured on a calibrated manometer, and nitrogen content was estimated from the ion intensity of N_2 observed in a calibrated volume of the mass spectrometer.

Amino acids were analyzed on separate filtered splits of the collected sediment trap material. These 1/8 and 1/16 splits were placed in precombusted digestion tubes that have a teflon-lined cap. Exactly 1 mL of quartz-distilled 6N HCl was added to each sample. The tubes were sealed under N_2 and heated to 100°C for 24 hr. An aliquot of the acid hydrolysate was diluted with double-quartz-distilled water and injected into an amino acid analyzer. Separation of the amino acids was by a stepwise isocratic elution on a high-performance liquid chromatography (HPLC) ion exchange column using a cation exchange 3-μm resin (St. John Assoc.). Detection was on post column orthophthaldialdehyde derivatives of the amino acids, using fluorescence detection and integration (Hare, 1972).

Results

Per filter, the combustible organic content of the trapped material is generally lower than that analyzed from the previously studied sites in the Weddell Sea. However, because of the improved instrumentation in the PRISM mass spectrometer used to analyze the Leg 119 samples, both sensitivity and precision are better for the present study than they are for the Leg 113 analyses. This is especially evident in the fact that no sample was too small to be assayed, despite having typically only one-quarter to one-half the combustible organic content of the Leg 113 material. Carbon levels per filter range from 0.17 to 1.02 mg, while nitrogen levels range from 0.019 to 0.096 mg per filter, yielding summary C/N molecular compositions in the range of 9 to 13 (Table 3).

Both the carbon and nitrogen isotopic compositions are more enriched in the heavy isotope than seen in the Leg 113 Weddell Sea collections. Isotopic fractionation of ^{13}C averages −27, with a range of ±1‰; isotopic fractionation of ^{15}N averages +2.5, also with a range of about ±1‰ (Table 3).

Amino acid analysis showed that the combustible organic fraction is rich in amino acids (probably proteins), with essentially all the combustible nitrogen accounted for as amino nitrogen and typically 30% of the combustible carbon accounted for as amino acid carbon (Table 4). In general, the decrease in amino acid content with depth correlates well with the general decrease in total combustible organics with depth. However, little difference in the relative proportion of various amino acids or of the total basic, neutral, acidic and aromatic amino acids was observed between deployments, locations, or depths (Tables 5, 6, and 7).

COMPARISON OF COMBUSTIBLE NITROGEN AND ITS STABLE ISOTOPIC FRACTIONATION BETWEEN SUSPENDED PARTICULATE MATTER COLLECTED IN NISKIN BOTTLES AND SINKING PARTICULATE MATTER INTERCEPTED BY SEDIMENT TRAPS
(Analyses by M. Altabet)

METHODS

At Woods Hole Oceanographic Institution (WHOI), a Dumas combustion technique similar to that referenced in the previous section was utilized to examine the fractionation of ^{15}N in particulate matter in 1/4, 1/8, and 1/16 splits of the sediment trap material and for that suspended in the water column. The analytical protocol was identical to that used to process the Leg 113 samples (see "Methods: WHOI," in Biggs et al., 1988); all analyses were run on a Finigan 251 mass spectrometer.

Results

Table 8 presents data from two locations in Prydz Bay. Comparison of the WHOI analytical procedures and those employed at Memorial University shows excellent agreement in the composition of the material trapped at 50 mbs in collection 739-1:

	WHOI	Memorial
$\delta^{15}N$ (per mil)	+1.4	+1.4
C/N	10.5	11.1
N flux (mg/m^2/day)	3.1	3.3

At both Sites 739 and 742, suspended particulates from the upper 33 m of the water column are more enriched in organic nitrogen (lower C/N ratios) and depleted in ^{15}N (more negative $\delta^{15}N$ signature) than those collected from lower in the water column. The latter suspended material and that intercepted by the traps are more degraded by microbial activity, as evident from the lower C/N ratios and enrichment in ^{15}N relative to ^{14}N.

Table 5. Amino acid composition of selected splits of Leg 119 drifting sediment trap deployments.

Collection	Trap depth (mbs)	Split	Asp (μmol/ split)	Thr (μmol/ split)	Ser (μmol/ split)	Glu (μmol/ split)	Gly (μmol/ split)	Ala (μmol/ split)	Val (μmol/ split)	Met (μmol/ split)	Ile (μmol/ split)	Leu (μmol/ split)	Tyr (μmol/ split)	Phe (μmol/ split)	His (μmol/ split)	Lys (μmol/ split)	Arg (μmol/ split)	Total (μmol/ split)
739-1	50	1/8	0.30	0.19	0.33	0.28	0.27	0.30	0.13	0.03	0.21	0.21	0.06	0.05	0.16	0.19	0.19	2.90
	100	1/8	0.13	0.11	0.11	0.16	0.14	0.12	0.09	0.02	0.10	0.10	0.03	0.02	0.02	0.10	0.09	1.36
739-2	[a]50	1/16	0.14	0.09	0.16	0.16	0.17	0.14	0.07	0.01	0.04	0.09	0.04	0.04	0.04	0.05	0.07	1.31
	[a]50	1/16	0.09	0.06	0.09	0.10	0.09	0.07	0.04	0.01	0.05	0.06	0.03	0.03	0.05	0.03	0.04	0.85
	100	1/8	0.20	0.11	0.18	0.18	0.12	0.12	0.06	0.02	0.09	0.09	0.04	0.06	0.08	0.09	0.08	1.52
739-3	[a]50	1/16	0.08	0.06	0.09	0.09	0.08	0.07	0.03	<0.01	0.06	0.05	0.02	0.05	0.06	0.06	0.07	0.86
	[a]50	1/16	0.11	0.06	0.10	0.12	0.12	0.09	0.05	0.02	0.09	0.08	0.03	0.05	0.06	0.07	0.04	1.10
	100	1/8	0.10	0.07	0.08	0.09	0.14	0.11	0.09	0.02	0.09	0.07	0.03	0.04	0.07	0.05	0.12	1.19
739-4	50	1/8	0.16	0.10	0.17	0.18	0.20	0.12	0.08	0.03	0.10	0.10	0.02	0.02	0.20	0.14	0.27	1.88
	100	1/8	0.24	0.10	0.22	0.26	0.28	0.20	0.10	0.02	0.14	0.16	0.06	0.06	0.12	0.10	0.18	2.24
740-1	50	1/8	0.14	0.08	0.12	0.15	0.16	0.13	0.07	0.03	0.07	0.11	0.05	0.05	0.07	0.06	0.16	1.46
	[a]200	1/16	0.34	0.22	0.29	0.30	0.31	0.30	0.26	0.06	0.17	0.30	0.07	0.13	0.18	0.15	0.23	3.28
	[a]200	1/16	0.39	0.21	0.36	0.37	0.25	0.24	0.18	0.04	0.18	0.23	0.08	0.13	0.17	0.18	0.17	3.18
740-2	200	1/8	0.25	0.13	0.23	0.23	0.22	0.20	0.11	0.02	0.08	0.15	0.04	0.08	0.21	0.14	0.19	2.30
741-1	100	1/8	0.10	0.08	0.11	0.16	0.12	0.09	0.05	0.01	0.06	0.07	0.03	0.03	0.05	0.05	0.10	1.10

[a] Replicate 1/16 splits.

Table 6. Relative amino acid composition of selected splits, based on the Leg 119 data in Table 5.

Collection	Trap depth (mbs)	Asp (%)	Thr (%)	Ser (%)	Glu (%)	Gly (%)	Ala (%)	Val (%)	Met (%)	Ile (%)	Leu (%)	Tyr (%)	Phe (%)	His (%)	Lys (%)	Arg (%)
739-1	50	10.4	6.5	11.5	9.5	9.4	10.2	4.3	1.1	7.3	7.3	2.2	1.9	5.4	6.6	6.4
	100	9.4	8.4	8.4	12.1	10.3	9.2	6.5	1.5	7.7	7.7	2.2	1.4	1.4	7.2	6.7
739-2	[a]50	10.9	7.1	12.0	12.0	12.8	10.8	5.3	0.9	3.2	6.8	3.0	3.4	3.1	3.6	5.1
	[a]50	10.8	7.0	10.5	11.8	10.6	8.6	4.8	1.5	5.8	7.1	3.4	4.1	6.1	3.4	4.5
	100	13.1	6.9	11.8	12.0	8.2	7.7	3.9	1.3	5.8	5.8	2.4	4.2	5.5	5.9	5.4
739-3	[a]50	9.2	6.5	10.0	10.1	9.0	7.6	4.0	0.4	7.2	5.4	2.4	5.4	6.7	7.5	8.7
	[a]50	10.4	5.8	8.9	11.1	10.8	8.6	4.6	1.6	8.1	7.0	3.0	4.6	5.2	6.4	3.8
	100	8.7	5.6	7.2	7.8	11.8	9.3	7.4	1.5	7.7	5.9	2.8	3.7	5.9	4.6	10.2
739-4	50	8.4	5.2	9.0	9.5	10.8	6.6	4.3	1.4	5.1	5.1	1.1	1.2	10.6	7.4	14.2
	100	10.5	4.9	9.5	11.6	12.4	9.0	4.0	0.9	6.6	7.3	2.8	2.7	5.2	4.8	7.7
740-1	50	10.1	5.5	8.1	10.6	11.1	8.8	4.5	1.8	5.2	7.5	3.3	3.1	5.0	4.5	11.0
	[a]200	10.4	6.7	8.9	9.1	9.5	9.3	7.9	1.6	4.9	8.8	2.1	3.9	5.6	4.4	6.8
	[a]200	12.4	6.7	11.4	11.6	7.7	7.5	5.5	1.4	5.6	7.3	2.4	4.1	5.3	5.8	5.3
	200	11.0	5.5	10.2	10.0	9.6	8.8	4.8	1.1	3.3	6.5	1.9	3.5	9.4	6.3	8.1
741-1	100	9.3	7.1	10.3	14.3	11.2	8.5	4.6	0.7	5.3	6.1	2.4	2.6	4.2	4.6	8.8

[a] Replicate 1/16 splits.

Table 7. Comparative abundance of acidic, neutral, aromatic, and basic amino acids, based on the data in Table 5.

Collection	Trap depth (mbs)	Asp/Glu	Gly/Ala	Tyr/Phe	Thr/Ser	Acidic (%)	Neutral (%)	Aromatic (%)	Basic (%)
739-1	50	1.09	0.92	1.18	0.56	19.9	57.6	4.1	18.4
	100	0.78	1.13	1.51	1.01	21.5	59.7	3.6	15.2
739-2	[a]50	0.91	1.19	0.88	0.59	22.9	58.9	6.4	11.8
	[a]50	0.92	1.23	0.83	0.67	22.6	56.0	7.5	14.0
	100	1.09	1.06	0.58	0.59	25.1	51.4	6.6	16.9
739-3	[a]50	0.92	1.18	0.45	0.65	19.3	50.1	7.8	22.8
	[a]50	0.94	1.26	0.66	0.65	21.5	55.4	7.6	15.5
	100	1.11	1.28	0.76	0.78	16.6	56.3	6.5	20.6
739-4	50	0.88	1.64	0.93	0.58	17.9	47.6	2.3	32.2
	100	0.91	1.37	1.03	0.52	22.1	54.6	5.6	17.7
740-1	50	0.95	1.26	1.08	0.68	20.7	52.4	6.4	20.5
	[a]200	1.14	1.02	0.54	0.75	19.5	57.8	6.0	16.8
	[a]200	1.07	1.03	0.59	0.59	24.0	53.0	6.5	16.4
740-2	200	1.10	1.09	0.55	0.54	21.0	49.8	5.5	23.7
741-1	100	0.65	1.32	0.93	0.69	23.6	53.8	5.0	17.6

[a] Replicate 1/16 splits.

Table 8. Comparison of combustible nitrogen and its stable isotopic fractionation between suspended particulate matter collected in Niskin bottles and sinking particulate matter intercepted by sediment traps, for two locations in Prydz Bay.

	Suspended particulates				Sinking particulates			
Collection	Depth (mbs)	N (μg/kg)	$\delta^{15}N$ (per mil)	C/N	Depth (mbs)	N ($mg/m^2/day$)	$\delta^{15}N$ (per mil)	C/N
739-1	0	39	+0.9	6.7				
	25	34	+0.2	6.7				
	33	65	+1.4	5.9				
	76	8	+2.3	9.6	50	3.1	+1.4	10.5
	100	4	+6.0	14.8	100	1.4	+2.7	9.1
742-1	0	28	−1.4	6.9				
	25	27	−1.6	6.6				
	33	26	−1.1	6.8				
	76	13	+2.4	8.4	50	1.0	+0.7	8.5
	100	NA	NA	NA	100	1.8	+3.0	8.2

Note: NA = not available.

Table 9. Plant pigments and their degradation products in ¼ splits of Leg 119 drifting sediment trap deployments.

Collection	Trap depth (mbs)	Chlorophyll *c*3 (ng/filter)	Chlorophyllide *a* (ng/filter)	Chlorophyll *c* (ng/filter)	Peridinin (ng/filter)	19′-butanoyloxy-fucoxanthin (ng/filter)	Fucoxanthin (ng/filter)	19′-hexanoyloxy-fucoxanthin (ng/filter)	Diatoxanthin (ng/filter)	Diadinoxanthin (ng/filter)
739-1	50	304	229	915	316	139	1352	535	77	439
	100	53	0	236	74	0	718	163	26	92
	200	9	0	55	19	0	86	59	14	14
739-2	50	35	10	226	193	0	404	184	54	131
	100	35	20	240	93	41	498	72	32	170
	200	22	0	162	65	15	348	72	15	44
739-3	50	117	0	253	122	42	298	210	31	76
	100	16	0	93	58	0	187	69	23	34
	200	10	0	117	86	0	176	92	30	42
739-4	50	131	0	370	165	39	378	328	23	78
	100	18	0	108	95	0	219	71	12	33
	200	29	0	96	103	0	176	78	12	36
740-1	50	175	79	853	515	0	2016	674	222	164
	100	100	0	386	260	0	693	532	148	115
	200	964	526	3803	2486	0	11915	4556	1474	1182
740-2	50	61	21	261	97	0	506	191	52	41
	100	35	0	152	81	0	289	171	43	30
	200	186	97	707	594	0	1209	1025	308	177
740-3	50	65	0	221	63	0	330	258	46	30
	100	20	0	113	153	0	289	165	97	40
	200	13	0	13	283	0	705	326	204	0
741-1	50	54	0	169	50	0	484	80	32	22
	100	19	0	84	37	0	257	65	50	18
	200	17	0	81	32	0	201	50	29	14
742-1	50	18	0	49	57	0	120	77	0	15
	100	0	0	52	81	0	159	87	27	39
	200	0	0	10	8	0	16	14	0	0
742-2	50	38	0	123	106	0	253	137	23	30
	100	0	0	24	19	0	67	29	0	5
	[a]200	0	0	15	18	0	60	24	7	5
744-1	50	23	0	104	0	0	241	28	25	13
	100	0	0	0	0	0	22	0	0	0
	200	0	0	8	0	0	12	5	0	3

[a] Partial sample; the Nuclepore filter tore during filtration, and some particulates went through.

PLANT PIGMENTS AND THEIR DEGRADATION PRODUCTS
(Analyses by R. R. Bidigare, M. E. Ondrusek, and Il Noh)

METHODS

HPLC procedures that we have previously described (Bidigare et al., 1985; Smith et al., 1987) were used for separating and quantifying plant pigments and their degradation products. The HPLC system was calibrated using available standards and published extinction coefficients, and the analytical protocol was the same as that for the Leg 113 samples (see Biggs et al., 1988). The analyses have a limit of quantification for each pigment of approximately 5 ng per 1/4 split.

Results

The quantitatively important parent pigments measured in the splits are chlorophylls *a* and *c*, fucoxanthin, 19′-hexanoyloxyfucoxanthin, diadinoxanthin, and carotene (Table 9). Quantitatively important chlorophyll *a* degradation products include chlorophyllide *a* (characteristic of chlorophyllase-containing diatoms), phaeophorbide *a*, and phaeophytin *a*. In addition, four phaeophorbide *a*-like derivatives that eluted after phaeophorbide *a* (P1) were found in most of the sediment trap samples; these are designated P2, P3, P4, and P5, with P5 the least polar.

Fluxes of chlorophyll *a* intercepted at 100 mbs range from 3 to 20 $\mu g/m^2$/day at Sites 741 and 742 and from 7 to 50 $\mu g/m^2$/day at Sites 739 and 740. As observed in the Leg 113 collections, the ratio of the diatom marker pigment fucoxanthin plus the prymnesiophyte marker 19′-hexanoyloxyfucoxanthin to chlorophyll *a* generally is close to unity (mean = 0.9 ± 0.2; Table 10).

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REFERENCES

Bidigare, R. R., Kennicutt, M. C., and Brooks, J. M., 1985. Rapid determination of chlorophylls and degradation products by high-performance liquid chromatography. *Limnol. Oceanogr.*, 30:432–435.

Biggs, D. C., Berkowitz, S. P., Altabet, M. A., Bidigare, R. R., DeMaster, D. J., Dunbar, R. B., Leventer, A., Macko, S. A., Nittrouer, C. A., and Ondrusek, M. E., 1988. A cooperative study of upper-ocean particulate fluxes in the Weddell Sea. *In* Barker, P. F., Kennett, J. P., et al., *Proc. ODP, Init. Repts.*, 113: College Station, TX (Ocean Drilling Program), 77–86.

Biggs, D. C., Ondrusek, M. E., and Bidigare, R. R., in press. Time-series observations of short-term variability in biogeochemical fluxes out of Weddell Sea surface waters. *Proc. SCAR Symp. Biol. Antarct., 1988.*

DeMaster, D. J., 1981. The supply and accumulation of silica in the marine environment. *Geochim. Cosmochim. Acta*, 45:1715–1732.

Dunbar, R. B., 1984. Sediment trap experiments on the Antarctic continental margin. *Antarctic J. U.S., Ann. Rev. Issue*, 19:70–71.

Harbison, G. R., and Gilmer, R. W., 1986. Effects of animal behavior on sediment trap collections: implications for the calculation of aragonite fluxes. *Deep Sea Res., Part A*, 33:1017–1024.

Hare, P. E., 1972. Ion exchange chromatography in lunar organic analyses. *Space Life Sci.*, 3:354–359.

Macko, S. A., 1981. Stable nitrogen isotope ratios as tracers of organic geochemical processes [Ph.D. dissert.]. Univ. Texas at Austin.

Smith, R. C., Bidigare, R. R., Prezelin, B. B., Baker, K. S., Brooks, J. M., 1987. Optical characterization of primary productivity across a coastal front. *Mar. Biol.*, 96:575–591.

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Table 9 (continued).

Lutein + zeaxanthin(?) (ng/filter)	Alloxanthin (ng/filter)	Chlorophyll *a* (ng/filter)	Carotene (ng/filter)	Phaeophorbide *a* + 4 derivatives					Phaeophytin *a* (ng/filter)	Phaeophytin *a'* (ng/filter)
				P1 (ng/filter)	P2 (ng/filter)	P3 (ng/filter)	P4 (ng/filter)	P5 (ng/filter)		
81	34	1663	36	305	85	1418	79	52	129	0
15	0	919	45	430	79	306	47	53	121	0
0	9	157	0	84	24	45	0	0	0	0
50	15	609	36	180	39	374	35	34	77	0
29	21	762	31	291	46	407	43	36	60	31
12	8	544	18	196	49	348	32	25	55	0
37	15	699	0	160	39	252	45	36	117	0
33	16	344	10	0	0	0	0	0	0	0
29	0	259	20	150	28	111	24	0	49	25
51	13	1033	20	217	32	321	48	25	125	0
24	0	295	0	241	63	121	0	0	58	0
0	0	253	0	169	23	76	0	0	0	0
125	37	3049	51	761	141	710	128	46	209	51
134	81	1599	12	455	108	295	93	69	176	0
1471	685	17341	427	4198	734	4523	1083	457	1782	613
25	18	1039	20	157	37	135	26	27	74	0
23	14	659	0	164	40	137	38	31	92	0
181	113	3534	98	961	200	1074	228	123	483	97
2	20	959	25	110	29	103	35	0	70	0
33	17	714	25	276	34	343	51	29	150	0
74	0	0	21	542	155	669	172	61	974	185
0	16	788	15	99	13	99	0	10	0	0
0	7	354	0	112	0	191	0	0	0	0
9	15	304	0	152	31	185	0	0	156	0
13	3	227	0	0	0	0	0	0	0	0
48	0	177	0	0	0	0	0	0	0	0
0	0	23	0	27	0	26	0	17	0	0
28	168	514	0	123	14	241	34	17	108	0
0	0	114	0	44	21	61	12	0	0	0
9	0	96	0	70	18	49	0	0	0	0
0	15	240	0	61	41	55	0	0	0	0
0	0	36	0	0	0	0	0	0	0	0
0	0	22	0	0	0	0	0	0	0	0

Table 10. Calculated fluxes of fucoxanthin, 19′-hexanoyloxyfucoxanthin, chlorophyll *a*, and total phaeopigments (in chlorophyll *a* equivalents), based on the data in Table 9.

Collection	Trap depth (mbs)	Fucoxanthin ($\mu g/m^2/day$)	19′-hexanoyloxy-fucoxanthin ($\mu g/m^2/day$)	Chlorophyll *a* ($\mu g/m^2/day$)	Total phaeopigments ($\mu g/m^2/day$)	$\frac{(F + H)}{\text{chlorophyll } a}$ [a]
739-1	50	33	13	41	75	1.1
	100	18	4	23	37	1.0
	200	2	1	4	6	0.9
739-2	50	12	6	19	33	1.0
	100	15	2	23	41	0.7
	200	11	2	17	32	0.8
739-3	50	8	5	18	24	0.7
	100	5	2	9	ND	0.7
	200	5	2	7	14	1.0
739-4	50	10	9	28	30	0.7
	100	6	2	7	19	1.0
	200	5	2	8	11	1.0
740-1	50	33	11	49	48	0.9
	100	11	9	26	11	0.8
	200	193	74	281	309	0.9
740-2	50	13	5	26	16	0.7
	100	7	4	17	18	0.7
	200	30	26	89	113	0.6
740-3	50	7	6	21	10	0.6
	100	6	4	15	27	0.6
	200	15	7	ND	77	*
741-1	50	13	2	20	9	0.7
	100	7	2	9	12	0.9
	200	5	0.8	8	8	0.8
742-1	50	3	2	6	ND	0.9
	100	4	2	4	ND	1.4
	200	0.4	0.4	0.6	3	1.3
742-2	50	7	4	15	22	0.8
	100	2	0.8	3	6	0.8
	200	2	0.7	3	6	0.9
744-1	50	7	0.8	7	7	1.1
	100	0.6	<0.1	1	ND	0.6
	200	0.3	0.1	0.6	ND	0.8

Note: ND = not detected.
[a] (Fucoxanthin + 19′-hexanoyloxyfucoxanthin)/chlorophyll *a*.