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Suspended Sediment Character and Distribution in McBeth Fiord, Baffin Island[1]

G.V. WINTERS[2] and J.P.M. SYVITSKI[2]

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ABSTRACT. Sediment concentration, particle-particle morphology and size data are used to identify the processes that control the distribution and dynamics of suspended sediment during the open water season in the McBeth Fiord, Baffin Island. Dominant processes include hemipelagic sedimentation below river plumes and sediment resuspension by wind-driven waves, internal waves and bottom currents, including those related to deep-water renewal. Suspended particles are composed of unflocculated mineral grains, planktonic detritus — such as from diatoms, radiolarian and dinoflagellates — and large particles of marine snow composed of mucoid stringers, fecal pellets, floccules, agglomerates and resuspended clay clasts.

Strong offshore winds are capable of temporarily removing the surface seasonal layer in the fiord. That in turn may initiate the autumn cycle of deep-water exchange. Replacement of deep water within McBeth Fiord by water from the Baffin Shelf can also introduce shelf sediment to the fiord and cause the resuspension of sediment covering the outer sill complex. Alternatively, strong onshore winds can push the surface layer to the head of the fiord and significantly increase the surface layer volume of the inner fiord. Internal wave trains associated with such a surface layer surge and travelling in a landward direction can impact on the front of the delta situated at the head of the fiord and initiate resuspension of bottom sediments.

Key words: Arctic, fiord, McBeth Fiord, suspended sediment, oceanography, wind events, resuspension

RÉSUMÉ. On se sert de données sur la concentration des sédiments, et la morphologie de particule à particule ainsi que sur la taille pour identifier les processus assurant la répartition et la dynamique des sédiments en suspension durant la saison d'eau libre dans le fjord McBeth de l'île de Baffin. Les processus dominants comprennent une sédimentation hémipélagique sous les panaches des cours d'eau et la remise en suspension des sédiments par les vagues poussées par le vent, les vagues internes et les courants de fond, y compris ceux reliés au renouvellement de l'eau profonde. Les particules en suspension se composent de granules minéraux non floculés, de détritus planctoniques tels que ceux provenant de diatomées, radiolaires et péridiniens, ainsi que de grosses particules de neige marine composée de filaments mucoïdes, de boulettes fécales, de flocules, d'agglomérats et de clastes argileux remis en suspension.

Des vents forts venant des terres peuvent enlever temporairement la couche de surface saisonnière dans le fjord, ce qui peut alors déclencher le cycle automnal de l'échange d'eau profonde. Le remplacement de l'eau profonde dans le fjord McBeth par de l'eau venant de la plateforme de Baffin peut aussi amener des sédiments de la plateforme dans le fjord et causer une remise en suspension des sédiments couvrant l'ensemble du seuil externe. D'un autre côté, des vents forts venant du large peuvent pousser la couche de surface vers la tête du fjord et causer une importante augmentation du volume de cette couche dans l'intérieur du fjord. Des séries de vagues internes associées à une telle poussée de la couche de surface et voyageant en direction des terres peuvent venir s'écraser sur le front du delta situé à la tête du fjord et causer une remise en suspension des sédiments de fond.

Mots clés: Arctique, fjord, fjord McBeth, sédiments en suspension, océanographie, événements éoliens, remise en suspension

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INTRODUCTION

There are presently few studies on the character and distribution of suspended sediment in arctic fiords (Elverhoi *et al.*, 1980: Spitsbergen; Mackiewicz *et al.*, 1984: Alaska; Gilbert, 1978, 1980a,b, 1983, and Winters *et al.*, 1985: Canadian Arctic). Knowledge on the nature of arctic fiords is therefore still fragmented and highly qualitative. Four processes of sediment delivery to arctic fiords are recognized (Syvitski, 1989): 1) ice-contact processes associated with the termini of tidewater glaciers, 2) rafting by icebergs and sea ice, 3) fluvial discharge of sediment and subsequent sedimentation under the river plume and 4) water mass exchanges, such as those associated with deep-water renewal. Our study emphasizes the latter two processes, as Syvitski *et al.* (1987) suggested that future fiord research should highlight the dynamics, structure and settling behaviour of particles, with particular emphasis on the effect of deep-water renewals.

A sill at the entrance to a fiord prevents the free exchange of water between the deeper portions of the fiord and the continental shelf. As a result, the fiord deep water alternates between periods of near stagnation and periods of higher energy flushing. The rate of exchange of the deep water is controlled by the density of the shelf water being introduced into the fiord, intensity and duration of offshore winds, sill geometry and seasonal changes in the hydrographic structure. The dynamics governing these flushing events in fiords is summarized in Gade (1972), Gade and Edwards (1980), Smethie (1981) and Syvitski *et al.* (1987). Except during the period of deep-water exchange, the sediment dynamics on the shelf will not affect the fiord environment.

Elevated concentrations of suspended sediment have been observed in the bottom waters on the Baffin Shelf adjacent to McBeth Fiord (Winters *et al.*, 1985). The Baffin Current flows southward along the continental slope of eastern Baffin Island (Coote and Jones, 1982) and may account for these elevated concentrations. These strong currents can approach fiord entrances by following the margins of troughs that dissect the shelf (Fissel *et al.*, 1981). Episodic events on the shelf proper can also generate bottom currents as high as $0.4\ m{\cdot}s^{-1}$ and may contribute to the elevated particle concentrations outside of the Baffin fiords. Thus a deep-water exchange may result in the transport of shelf sediment into the fiord environment (Syvitski and Hein, 1991). We attempt to identify this situation in McBeth Fiord, as the significance of this process could affect the interpretation of sediment core data from silled environments.

As part of the Geological Survey of Canada's project SAFE (Sedimentology of Arctic Fiords Experiment: Syvitski and Schafer, 1985), we have studied the character and distribution

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[2]Geological Survey of Canada, Bedford Institute of Oceanography, Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2

of suspended sediment in the cold water fiords of Baffin Island. These are hostile and energetic environments. Winds can develop suddenly and exceed 140 km·h^{-1}, floods can occur as glacial lakes drain rapidly into the ocean, and deep-water exchange can suddenly increase bottom currents. Episodic rather than periodic behaviour of these processes is the norm.

Our observations, made in the late summer and autumn (open water season) of 1982, 1983 and 1985, document the effects of wind-driven circulation, internal waves and deep-water exchange events on the character and distribution of suspended particles within McBeth Fiord. Our working hypothesis is that characteristics of the suspended sediment in a fiord can indicate sediment sources and mechanisms of sediment transport.

STUDY AREA

McBeth Fiord is approximately 110 km long, branching at approximately 70 km from the fiord head into two arms that open into Baffin Bay (Fig. 1). The mean width of the inner 70 km is 4.3 km and the maximum water depth is 570 m. There is a 190 m deep outer sill at the fiord mouth and an inner sill 22.5 km from the fiord head at a depth of 180 m (Fig. 1). The average tidal range is 1.0 m and a large tide is 1.3 m (Syvitski *et al.*, 1984b). The fiord is ice free for an annual average of 40 days. LeBlanc *et al.* (1988) report that McBeth Fiord merits special attention within the SAFE project as it has a very large hinterland (4070 km^2) and receives a large annual input of freshwater runoff (0.77 km^3 for the entire fiord and 0.63 km^3 for the inner 70 km). Less than 24% of the fiord hinterland is covered in glacial ice and 50% of the land is at elevations in excess of 750 m. The very large sandur, as well as raised marine terraces of mud at the fiord head, contributes 68% of the 222 000 t of suspended sediment that annually enters the fiord (after Syvitski *et al.*, 1984a; Syvitski *et al.*, 1990). A number of terrestrial glaciers contribute meltwater along the margins of the fiord as they recede at annual rates of between 10 to 25 m·a^{-1} (LeBlanc *et al.*, 1988).

Most of the river input occurs during the spring thaw in late June and early July. Glacier-fed rivers continue to discharge freshwater and sediment through most of August. The magnitude of the summer discharge of meltwater depends upon the number of warm, sunny days (Syvitski *et al.*, 1984a; Winters *et al.*, 1985). If the annual estimate of 0.63 km^3 of freshwater input were confined to the upper 70 km of the fiord, this would be equivalent to a freshwater lens 2.1 m deep. Another freshwater source is from melting of sea ice. During the winter the fiord surface freezes to a depth of 2 m. The initial ice cover contains sea salts that during the winter diffuse out of the ice. The spring sea ice contains only about 5 g·L^{-1} salt. Thus this meltwater would be equivalent to a freshwater lens 1.7 m deep.

The deep-water mass within McBeth Fiord is replaced with denser water from the lower region of the upper layer of Baffin Bay. This water mass consists of a cold core between about 50 m and 200 m capped in summer by a very shallow layer of warmer, fresher water (Coote and Jones, 1982). The central region of Baffin Bay tends to have ice cover most of the year. The cold core likely results from cooling during the previous winter, while the warmer, fresher water is produced by summer heating and the introduction of sea ice melt onto the water column. Muench (1971) described the water in the upper layer as being formed from both Arctic Ocean water that has entered through the Canadian Archipelago and Atlantic water that has entered through Davis Strait and has been diluted by runoff and cooled.

METHODS

Samples and *in situ* observations were collected during three field programs (1982, 1983 and 1985). In 1982 and 1983 field operations were conducted from research vessel CSS *Hudson* (Bedford Institute of Oceanography cruises 82-031 and 83-028: Syvitski, 1982; Syvitski and Blakeney, 1983; Asprey and Johnston, 1984; Syvitski, 1984). In 1985 observations were made from the submersible *Pisces IV* (and recorded on video film) on four separate dives (Fig. 1), supported by research vessel M/V *Pandora II* (Bedford Institute of Oceanography cruise 85-062: Syvitski *et al.*, 1985; Syvitski and Praeg, 1987).

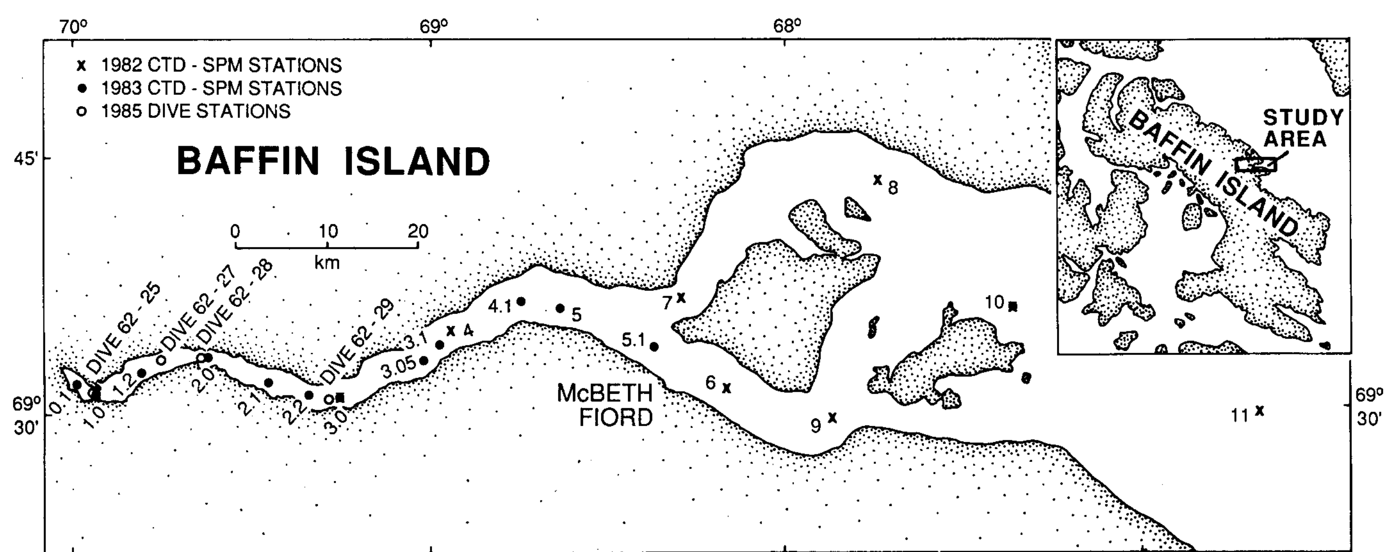

FIG. 1. Location of sampling and *in situ* measurement for stations in 1982 and 1983 and submersible dives in 1985.

In situ *measurements:* Temperature, salinity, light attenuance and depth were measured with a Guildline conductivity-temperature-depth (CTD) profiler fitted with a light attenuance meter. Two types of light attenuance meters were used: the Multi Beam Attenuance Meter (Larson, 1973) and the 0.25 m Sea Tech Transmissometer (Bartz *et al.*, 1978). These field methods are described in greater detail in Trites *et al.* (1983) and Petrie and Trites (1984).

Water sampling and subsampling: Water samples were collected in 5 L Niskin bottles with a rosette sampler that was coupled to the CTD. At nearly all stations, water samples were taken at 10 standard depths during the up-cast. Calibration salinity samples were drawn from all casts for subsequent analyses using a Guildline Autosal Model 8400 salinometer. Temperatures were measured at the selected sampling depths using reversing thermometers as a calibration of the Guildline CTD. Samples for nutrient analyses (phosphate, nitrate and silicate) were analyzed using standard methods (Strickland and Parsons, 1968) with an Auto Analyzer II. A 1 L subsample for the determination of SPM was suction-filtrated through 47 mm preweighed Nucleopore® filters having a 0.45 µm nominal pore diameter. The filtered sediments were washed with deionized water to remove sea salts and were oven dried at 50°C for 12 h. These preweighed Nucleopore® filters were reweighed and the total suspended particulate matter (SPM) concentration was determined by difference (Asprey *et al.*, 1983; Winters *et al.*, 1984).

SPM size frequency distribution: This was determined for the deflocculated size spectrum after ultrasonification of the SPM. A portion of each filtered SPM sample was dispersed by ultrasonification in a sodium hexametaphosphate solution. The resulting suspensions were analyzed for their particle size distribution with a computerized Coulter Counter Model TA11®. Two overlapping apertures of 30 and 200 µm were used, providing a particle size range (nominal volume diameters) resolution from 0.63 to 80 µm. The size distribution data are expressed in Ø units, where $Ø = -\log_2 d$, and d is the particle diameter in mm. These analyses are described in Asprey *et al.* (1983) and Winters *et al.* (1984).

SPM_{clay}: Variance in light attenuance at wavelength 680 nm, which was primarily due to variance in the concentration of clay size SPM (Winters and Buckley, 1980), were calibrated (after Vilks *et al.*, 1987) as SPM_{clay}. Only the gravimetric determination of clay size SPM could be used to calibrate this light attenuance data: $SPM_{clay} = 0.5\ C^{680}$, where C, in m^{-1}, was corrected for attenuance by water and SPM is in units of ppm = $mg \cdot L^{-1} = g \cdot m^{-3}$.

SEM/EDAX: A second 1 L subsample for SEM (scanning electron microscope) analyses was suction-filtered through a 47 mm diameter Selas Flotronic® silver filter of a 0.45 µm nominal pore diameter. A portion of each silver filter was coated with carbon and examined with a Cambridge Stereoscan® 180 scanning electron microscope equipped with an E.G. & G. ORTEC® X-ray energy-dispersive elemental analyzer (EDAX). These analyses are described in detail in LeBlanc *et al.* (1988). The technique for SEM analysis followed the established principles outlined in Syvitski and Murray (1981).

RESULTS

Water Mass Characterization

In McBeth Fiord, we observed three water mass layers in 1982 that could be discerned from temperature and salinity data (Figs. 2 and 3A; data from Trites *et al.*, 1983): 1) Temperature profiles showed a very sharp gradient or thermocline, which identified the surface layer at depths < 50 m. Surface water temperatures on the Baffin Shelf (Station 11) were as high as 2.33°C. In the outer fiord surface layer temperatures ranged from 0.23°C at Station 7 to 2.5°C at Station 8 for the northern branch and 2.14°C at Station 6 to 2.24°C at Station 9 for the southern branch. In the inner fiord surface temperatures varied from 0.88°C at Station 1 to –0.32°C at Station 4. At the base of the thermocline temperatures were <–1.25°C. 2) An intermediate and very cold layer with average temperatures between –1.4 and –1.6°C was directly below the surface layer and extended to a depth of about 200 m. This intermediate water layer was colder on the shelf (Station 11) and at Stations 6, 7, and 8 as compared to Station 9 in the outer fiord. Also the average temperature increased up fiord from Station 4 to

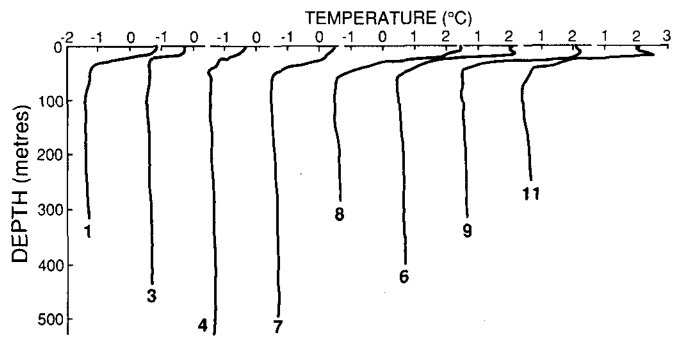

FIG. 2. *In situ* measured temperature profiles from 1982 for Stations 1, 3, 4, 6, 7, 8, 9 and 11.

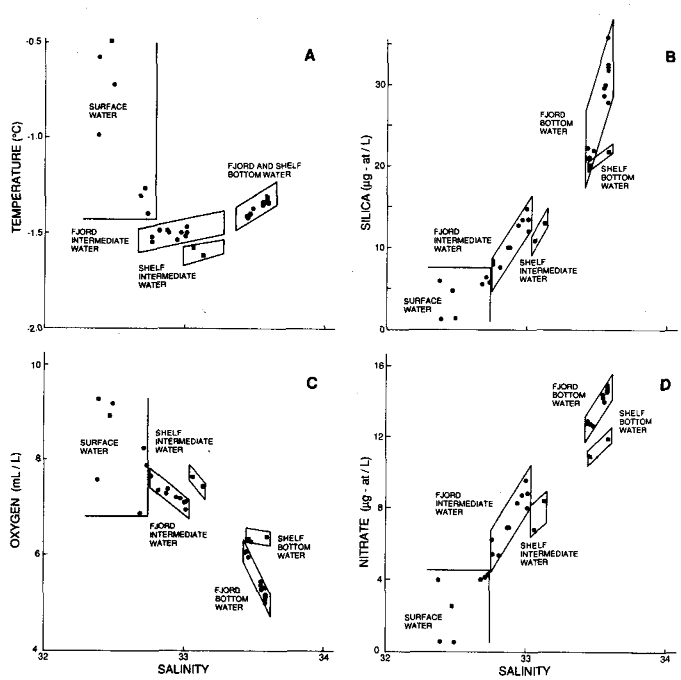

FIG. 3. Plots for 1982 water column observations, which were made at standard depths, for A) temperature vs. salinity, B) silica vs. salinity, C) oxygen vs. salinity and D) nitrate vs. salinity.

Station 1. 3) The lowest layer at depths between about 200 and 520 m is the fiord bottom water. It was a poorly stratified layer and had a minor warming trend with depth as temperatures increased from −1.4 to −1.3°C.

The differences between water masses are characterized on plots (Fig. 3) of temperature-salinity (T-S) and nutrient-salinity (silica, oxygen and nitrate). These data represent water below 20 m and from the middle fiord at Station 4 to the Baffin Shelf at Station 11. The water masses both within the fiord and on the shelf had similar T-S attributes from about 200 m to the bottom (i.e., the bottom depth was 520 m at Station 4 and 241 m at Station 11). Temperature and salinity observations on the Baffin Shelf for both the intermediate and bottom water masses were typical values for the Baffin Current (Coote and Jones, 1982; E.P. Jones, pers. comm. 1987), which flows southward in the upper layer of western Baffin Bay. The silica, oxygen and nitrate concentrations (Figs. 3B, 3C and 3D respectively) indicate only a slight difference between the bottom waters of the fiord and shelf. In the fiord bottom water the oxygen concentrations appeared to be slightly lower than the shelf bottom water. Also, the silica and nitrate concentrations appeared to be slightly higher than the shelf bottom water. But in the outer fiord at Station 8 the oxygen and silica values at the sill depth (about 200 m) were similar to those on the Baffin Shelf. In the adjacent Baffin Bay at water depths between 200 and 300 m, salinity, silica, oxygen and nitrate concentrations (Jones *et al.*, 1984) were similar to those that we observed in the bottom waters of the outer fiord.

Variations in σ_t were observed along the length of the fiord (data after Trites *et al.*, 1983). At sill depth (about 200 m), σ_t was constant along the entire length of the fiord and onto the shelf (26.91±0.01). Below sill depth, in intermediate water depths (300 m) σ_t of the inner basin was 0.07±0.01 less dense than water in either northern or southern branches of the outer fiord or on the shelf. Yet in deeper water (>400 m) the water density is again similar (σ_t = 27.00±0.01) along the entire length of the fiord and shelf.

Temporal Variation in Surface Layer Characteristics

Strong winds occurred both in 1982 and 1983, with significant effects on the depth of freshwater in the surface layer. The equivalent depth of the freshwater before mixing (D_{FW}) can be calculated using a mass balance equation such that $D_{FW} = [\Sigma(s_o - s_x)\, \partial D]/s_o$, where s_o was the salinity of the underlying water ($s_o = 32$), s_x was the observed salinity and D was depth.

Immediately prior to our arrival in McBeth Fiord on 18 September 1982, strong *down-fiord* winds up to 150 km·h^{-1} were observed in the area (Trites *et al.*, 1983). D_{FW} was 0.5 m at the fiord head (Station 1) and <0.1 m in the central fiord (Stations 3 and 4). In the outer fiord, the D_{FW} increased seaward: in the northern arm of the fiord D_{FW} increased from 0.6 m at Station 7 to 1.9 m at Station 8, and in the southern arm it increased from 2.0 m at Station 6 to 2.2 m at Station 9. Outside of the fiord, on the Baffin Shelf (Station 11), D_{FW} was 1.1 m.

The inner 45 km of McBeth Fiord was repeatedly monitored to a depth of 100 m over the following 36 h period. The concentrations of SPM_{clay} (Figs. 4A, 4B and 4C for 29 September, 30 September and 1 October 1983 respectively), salinity data (Figs. 4D, 4E and 4F) and temperature data (Figs. 4G, 4H and 4I) were used to delineate the limits of the surface layer. Between Stations 0.2 and 3.1, the surface layer was approximately delineated by the halocline between salinities of 31 and 32, the 0°C temperature isopleth or the 0.2 mg·L^{-1} SPM_{clay} isopleth. However at the head of the fiord between Stations 0.1 and 0.2, SPM_{clay} isopleths define a vertical front for suspended

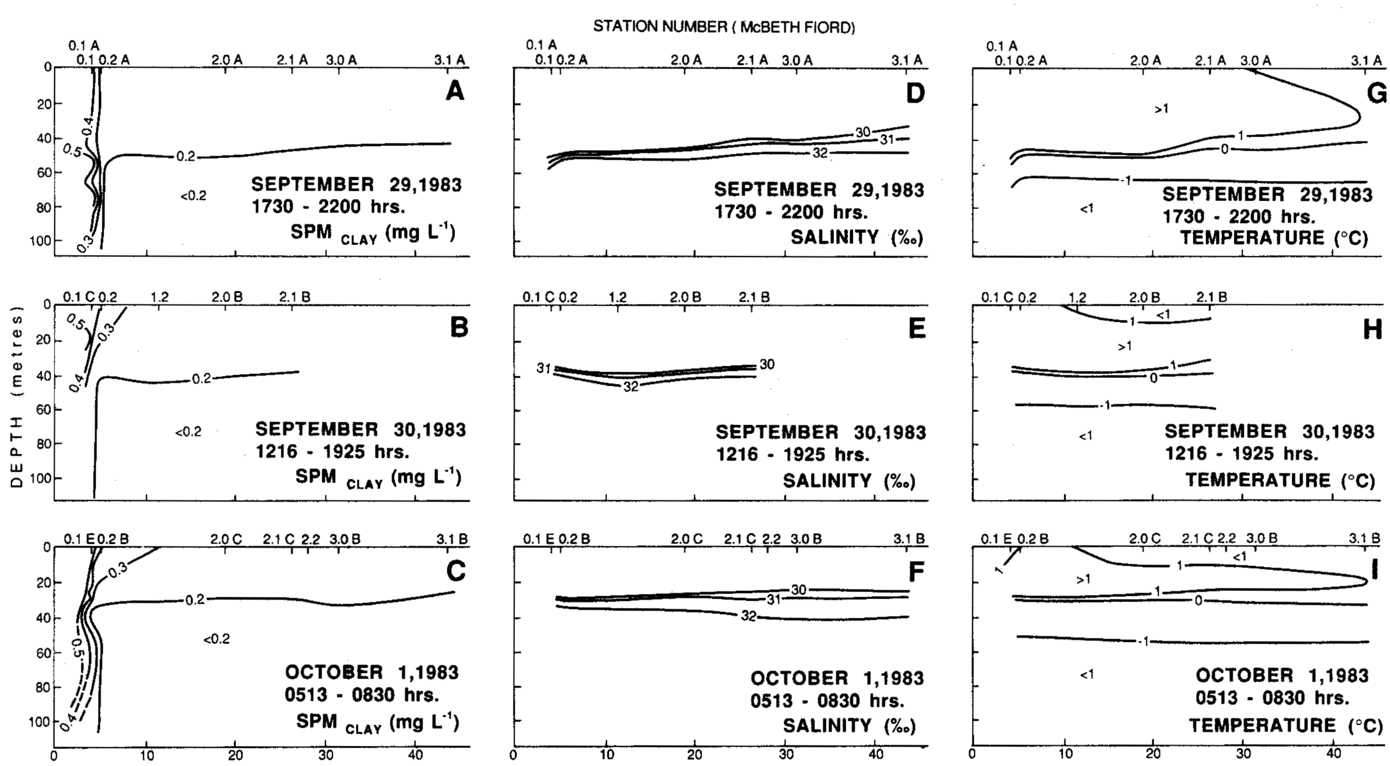

FIG. 4. Light attenuance derived SPM_{clay} concentrations for: A) 29 September, B) 30 September and C) 1 October. Salinity observed on: D) 29 September, E) 30 September and F) 1 October. Temperature observed on: G) 29 September, H) 30 September and I) 1 October.

sediment that cuts across the horizontal isopleths of salinity and temperature.

Immediately prior to our arrival on 29 September 1983, strong *up-fiord* winds (100-150 $km \cdot h^{-1}$) occurred in a neighbouring fiord. During our arrival in McBeth Fiord, the up-fiord winds began to relax. The surface layer was approximately 53 m deep near the fiord head at Station 0.2 and approximately 43 m deep 45 km seaward at Station 3.1. The depth of the surface layer 36 h later was approximately 30 m throughout the upper 45 km of the fiord. During the wind event the volume of the surface layer in the upper 45 km of the fiord had been increased by approximately 60%. The volume of water moved by this wind event could sustain an average water velocity in the surface layer at Station 3.1 of approximately 26 $cm \cdot s^{-1}$ for 36 h. After the wind velocity had dropped to zero and the fiord surface returned to calm, a rhythmic fluctuation in sea level was observed at the delta face. Observers on the tidal flats reported that the water level rose and fell approximately 10 cm in 20 s cycles.

In Situ *Suspended Sediment Observations*

From analyses of the *in situ* floc camera data (after Syvitski and Heffler, 1983), the SPM was primarily composed of finely divided particulate matter in the upper portions of the water column. As water depth or distance from the head of the fiord increased, the concentration of SPM greater than 1 mm increased. The size of the larger stringers increased to 20 mm. Submersible observations of the SPM support the floc camera data, except that they suggest a larger particle size. The first dive (62-25) was within 7 km of the fiord head, where the water was 180 m deep. SPM was concentrated in the surface layer to a depth of 80 m. The visibility in the surface water increased fourfold below the seasonal upper layer. The SPM visually appeared as small, inorganic, uniformly distributed particles. Seaward at dive locations 62-27 and 62-28, similar stratification of SPM was observed, but with the presence of Oikopleura and their gelatinous housings (see Syvitski *et al.*, 1983). The Oikopleura formed a distinct layer above depths of 45 m at locations 62-27 and 62-28. At dive site 62-29 the Oikopleura layer thickened to a depth of 60 m and floccules and stringers (containing attached floc) up to 10 cm in length were present throughout the water column. The stringer size and numbers increased with water depth.

Filtered SPM Observations

Below is a description of the character of the SPM as it is determined from SEM (scanning electron microscope) analyses (LeBlanc *et al.*, 1988) for filtered SPM from Station 1 at the head of the fiord to Station 11 on the Baffin Shelf. This is our most extensive data set for determining the SPM character with samples collected during 18 and 19 September 1982.

Station 1.0: The surface waters were rich in radiolarian, picoplankton (Sieburth *et al.*, 1978; Platt and Li, 1986), fecal pellets and numerous unflocculated mineral grains <10 μm in diameter. Some floccules were composed of clay rosettes (similar to the example in Fig. 5b for Station 4 at 20 m). Below the halocline (50 m), most of the suspended sediment was present in the form of large inorganic floccules (30-300 μm) instead of individual grains (Fig. 6a). In the near bottom water (312 m), many of the floccules were coated with a thin organic coating (Fig. 6b). Pennate diatoms were common to the deep-water samples.

Station 3.0: SPM was similar to Station 1, although there was a higher concentration of chain diatoms, concentric diatoms and mucoids in the surface waters (upper 20 m of the water column). Picoplankton (Fig. 6c) was in the form of concentric diatoms. The mucoids consisted of organic and gelatinous particles with no obvious internal structure. Both fecal pellets (Fig. 6d) and floccules of phyllosilicate minerals contained high concentrations of Si. Below the halocline, the floccules of diatoms and phyllosilicate minerals dominated the SPM, similar to Station 1 (Fig. 6a), although the presence of mica and biogenic detritus increased (Fig. 5a).

Station 4: The SPM was similar to observations from Stations 1 and 3 (including the presence of fluvial clay clasts in surface waters) but with a higher concentration of biogenic detritus. Mud clumps, irregular clusters of clay and fine silt size particles attached to larger sand size biotite grains (Fig. 5c) were collected 5 m above the sea floor (water depth of 520 m).

Station 6: The concentration of biogenic detritus continued to increase from Station 4 to Station 6, as did the size of the agglomerates and floccules, which became quite large (Figs. 5d, 7a and 7b). The abundance of chain diatoms and flagellate matting was very high, and mineral grains or biogenic material were attached to the gelatinous filaments (Fig. 7b). Some of the filaments, such as the flagellate stringers with attached floccules in Figure 5d, were as large as a few mm in length.

Station 7: The upper portion of the water column was dominated by biogenic detritus, fecal pellets and phytoplankton. However, the sample collected closest to the sea floor (490 m) contained floccules of mica and other mineral grains, as well as a large mucoid (Figs. 7c and 7d) with an internal structure similar to that of a flagellate preserved.

Stations 8 and 9: The trend of increasing concentration of biogenic detritus continued from Station 7 to Station 8 and from Station 6 to Station 9 (see Fig. 1). The SPM was over-

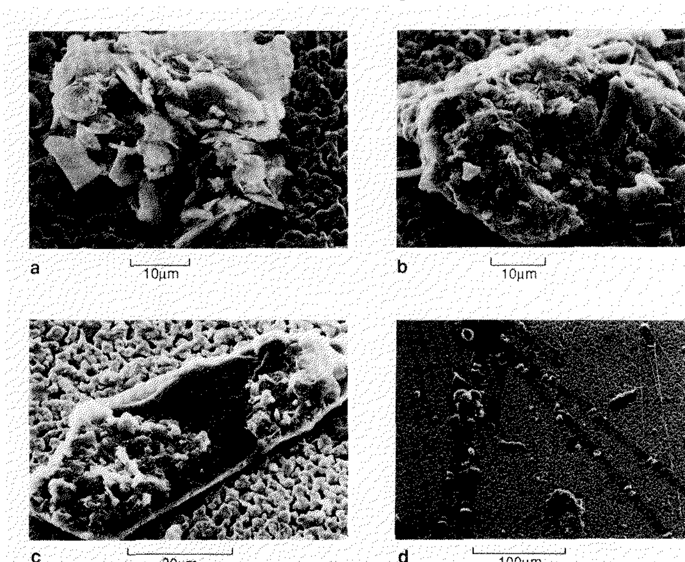

FIG. 5. Scanning electron micrographs of SPM particles: a) floccule with micas and biogenic detritus from 100 m of water at Station 3; b) very compact floccule, possibly an example of a fluvial-derived ripped-up clay clast, from 20 m of water at Station 4; c) grain of biotite with attached particles, typical of resuspended sediment, from the bottom water (520 m) at Station 4; d) flagellate stringers with attached floccules from 20 m of water at Station 6. The background, which is apparent in the SEM pictures, is the matrix of the silver filters.

whelmed by phytoplankton and fecal pellets. Figure 8a is a typical example of SPM in the surface layer and shows a large mucoid, flagellate matting, chain diatoms and scattered but relatively rare mineral grains. Of special interest was the presence of clasts composed of a sand-size mica with attached clay aggregates (Fig. 8b) at Station 8 in the sample collected near, 5 m above, the sea floor (287 m).

Station 11: The surface waters were still dominated by phytoplankton, biogenic detritus and mucoids; however, the number of recognized fecal pellets was low. The presence of mineral grains and floccules of mineral grains was higher, especially in the lower portions of the water column, where both floccules and individual particles were abundant (Fig. 8c). Near the sea floor the SPM was predominantly mineral grains (Fig. 8d).

Size Distribution of the Deflocculated SPM

The size distribution of the deflocculated SPM was determined to supplement the *in situ* data and to interpret the dynamics and interactions of the various lithogenic and biogenic fractions. In 1982, the mean grain size of the deflocculated SPM ranged from 6.2 to 7.7 Ø (13.6-4.8 μm), which corresponded to a range in clay content from 14 to 46% respectively. The remaining SPM fraction was composed primarily of silt and fine sand particles. The depth integrated particle size data were used to determine the mean grain size at each station. In the inner fiord basin the average for the mean grain size was 7.25 Ø (6.6 μm), of which 36.6% of the SPM mass was of clay size. The outer portion of the fiord contained coarser SPM components and had an average mean grain size of 7.0 Ø, or 7.8 μm (29.3% as clay).

In 1983, the average mean grain size of the deflocculated SPM was slightly finer than in 1982. It ranged from 6.6 to 7.9 Ø (10.3-4.2 μm), which corresponded to a range in clay content of 17 to 55% respectively. An average mean grain size value of 7.3 Ø, or 6.3 μm (36.8% clay) was determined for both the inner and outer fiord. This averaged value was similar to the 1982 observation for the inner fiord.

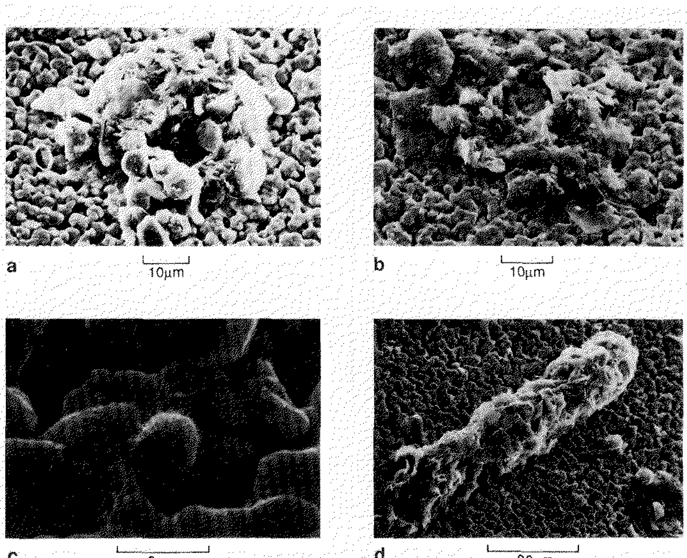

FIG. 6. Scanning electron micrographs of SPM particles: a) floccule of diatoms and phyllosilicates from 50 m of water at Station 1; b) inorganic floccule with a light organic coating from 312 m of water at Station 1; c) picoplankton, 2 μm in diameter, from 20 m of water at Station 3; d) Si-rich fecal pellet from 20 m of water at Station 3. The background, which is apparent on these SEM pictures, is the matrix of the silver filters.

The deflocculated SPM was further characterized by analyses of the sediment size frequency distribution (Figs. 9 and 10 for 1982 and 1983 respectively). Samples collected from the upper portion of the water column at any given location usually had similar characteristic distributions (e.g., Figs. 9A and 10A), even though the character of the distributions changed with distance from the head of the fiord (Fig. 9B). Surface

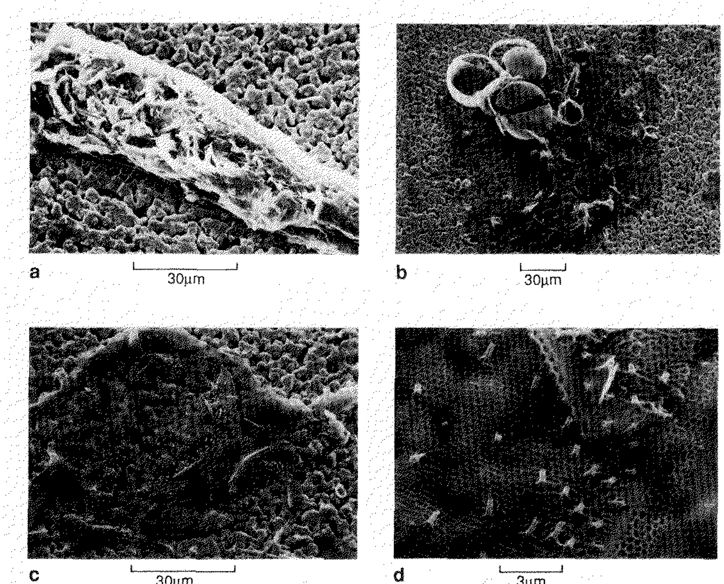

FIG. 7. Scanning electron micrographs of SPM particles: a) Si-rich (98%) fecal pellet from 30 m of water at Station 6; b) large mucoid agglomerate with remnant diatoms from 30 m of water at Station 6; c) mucoid (possibly from a flagellate) with the internal structure preserved, from 10 m of water at Station 8; d) close-up of "c". The background, which is apparent in the SEM pictures, is the matrix of the silver filters.

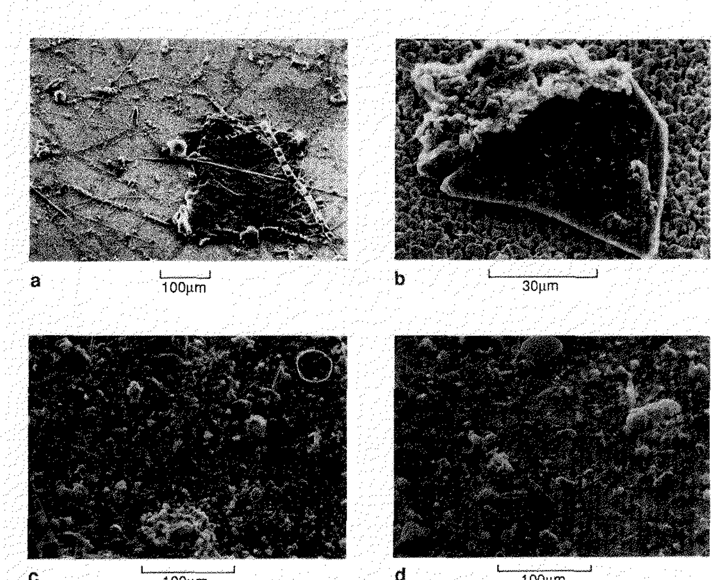

FIG. 8. Scanning electron micrographs of SPM particles: a) large mucoid, flagellate matting, chain diatoms and scattered and rarer mineral grains from 10 m at Station 8; b) mica grain with clay aggregate attached, typical of a rip-up clast from mobilized bottom sediment, from the bottom water (287 m) at Station 8; c) overview of SPM, with a higher than usual concentration of inorganic mineral grains, from 200 m of water at Station 11; d) overview of SPM from the bottom water (241 m) at Station 11 is similar to "c" with a high concentration of individual mineral grains. The background, which is apparent in the SEM pictures, is the matrix of the silver filters.

samples from near the fiord head (Fig. 9B) had both a coarse and a fine lithogenic mode (4.5 Ø, or 44.4 μm, and 9.5 Ø, or 1.4 μm, respectively). Seaward of these samples (Fig. 9B) the fine mode disappeared and the coarse lithogenic mode was replaced by a finer (5.5 Ø, or 22.1 μm) mode that was related to an increase in phytoplankton cells (Fig. 8A). Occasionally the phytoplankton mode was pronounced at 30 or 50 m water depths (e.g., Fig. 10D) and was associated with the pronounced gradient observed in the light attenuance data. A biogenic (diatomaceous) size mode (5.5 Ø, or 22.1 μm) was very prominent in the surface water (Fig. 10B). Also, the 1982 data for the outer fiord showed that this biogenic mode was prominent in both the surface and intermediate water masses (Fig. 9C).

The bottom waters contained SPM with size frequency distributions different from the surface waters (Figs. 9C, 10B and 10C). They did not have a mode considered associated with phytoplankton cells, but rather had a more uniform representation of all size intervals. These unique size frequency distributions closely resemble the size frequency distributions of the fiord's sea floor sediment (Clattenberg *et al.*, 1983).

Annual Variation in SPM Characteristics

SPM concentrations of the inner fiord for 1982 are compared with those for 1983 (Figs. 11a and 11b respectively). In 1982, concentrations ranged from <0.4 $mg \cdot L^{-1}$ in the intermediate water mass to >2.0 $mg \cdot L^{-1}$ near the sea floor. The highest concentrations were observed near the sea floor adjacent to the inner sill. These bottom water concentrations were high on both sides of the sill; however they were higher on the seaward side (1.5 $mg \cdot L^{-1}$ and 2.0 $mg \cdot L^{-1}$ respectively). In 1983, concentrations ranged from <0.2 $mg \cdot L^{-1}$ in the intermediate water mass to >0.6 $mg \cdot L^{-1}$ near the delta front and near the sea floor inside the inner sill. Most of the SPM appeared to originate at the delta front.

DISCUSSION

Offshore Wind Event

In 1982, immediately prior to our arrival, strong offshore winds (100-150 $km \cdot h^{-1}$) appear to have altered the surface layer of the fiord and the adjacent coastal waters. The amount of freshwater present in the surface layer (determined as D_{FW} from salinity observations) was minimal in the central fiord (D_{FW} = 0.1 m) and at a maximum in the southern branch of the outer fiord (D_{FW} = 2.2 m at Station 9 and D_{FW} = 2.0 m at Station 8). The surface water on the shelf contained less freshwater than the outer fiord (D_{FW} = 1.1 m at Station 11). Note, the maximum annual amount of freshwater in the surface layer of the fiord (i.e., from river discharge and sea ice melt) is 3.8 m before mixing and removal out of the fiord. These data and other observations for temperature indicate that the offshore wind event pushed the surface layer seaward and the wind transport of the surface layer was along the southern branch of the outer fiord. The remnants of the surface layer were still present at Stations 6 and 9. A large portion of the surface layer outside the fiord at Station 11 may have also been blown seaward by offshore winds. When offshore winds thin the surface seasonal water mass on the shelf, this can elevate the deeper and denser water to sill depth through coastal upwelling. Then the replacement of the fiord surface water with deeper water from the Baffin Shelf may have initiated the fall deep-water exchange cycle.

Denser shelf water appears to have been entering the bottom water of the fiord, including the inner fiord basin, based

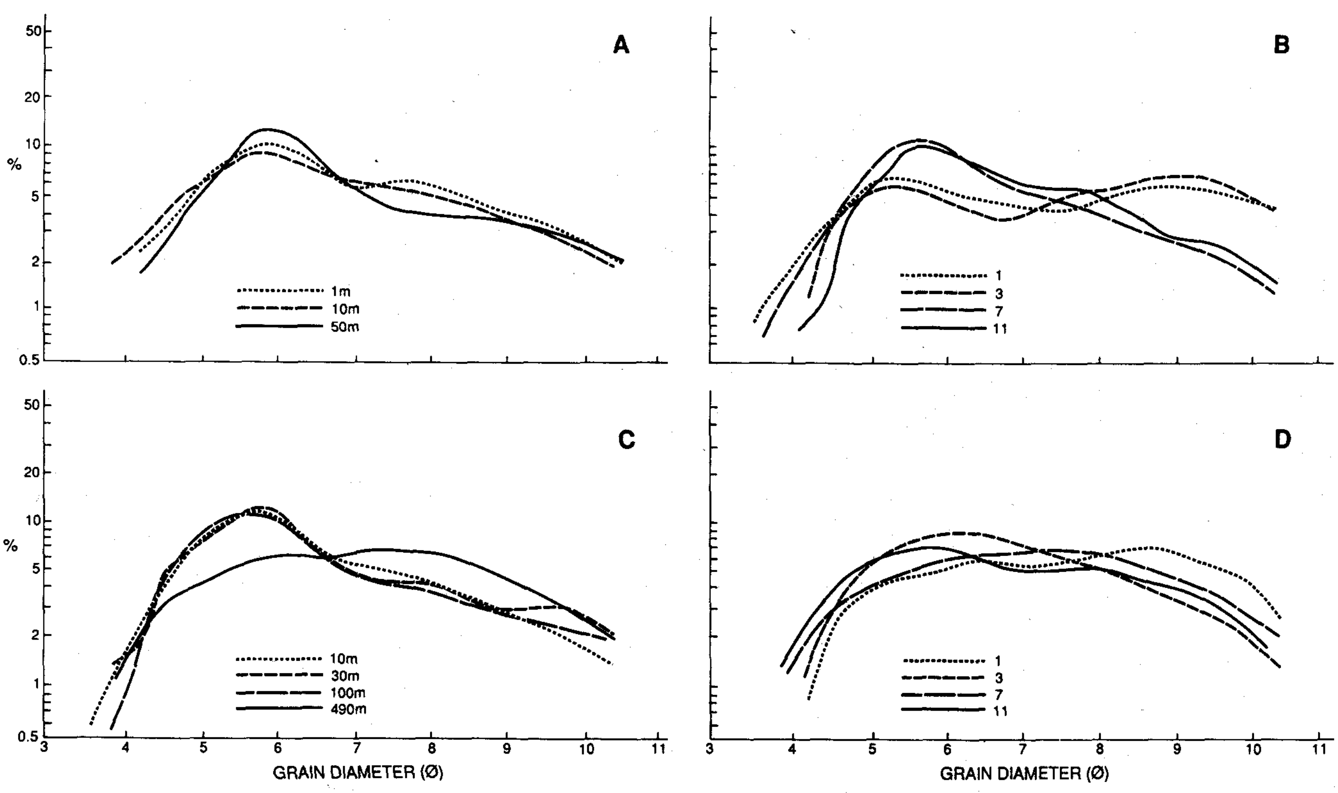

FIG. 9. Suspended sediment size frequency distributions for 18 and 19 September 1982 from: A) Station 6 at depths 1, 10 and 50 m; B) Stations 1, 3, 7 and 11 at a depth of 10 m; C) Station 7 at depths of 10, 30, 100 and 490 m; and D) near-bottom samples for Stations 1 (312 m), 3 (435 m), 7 (490 m) and 11 (241 m).

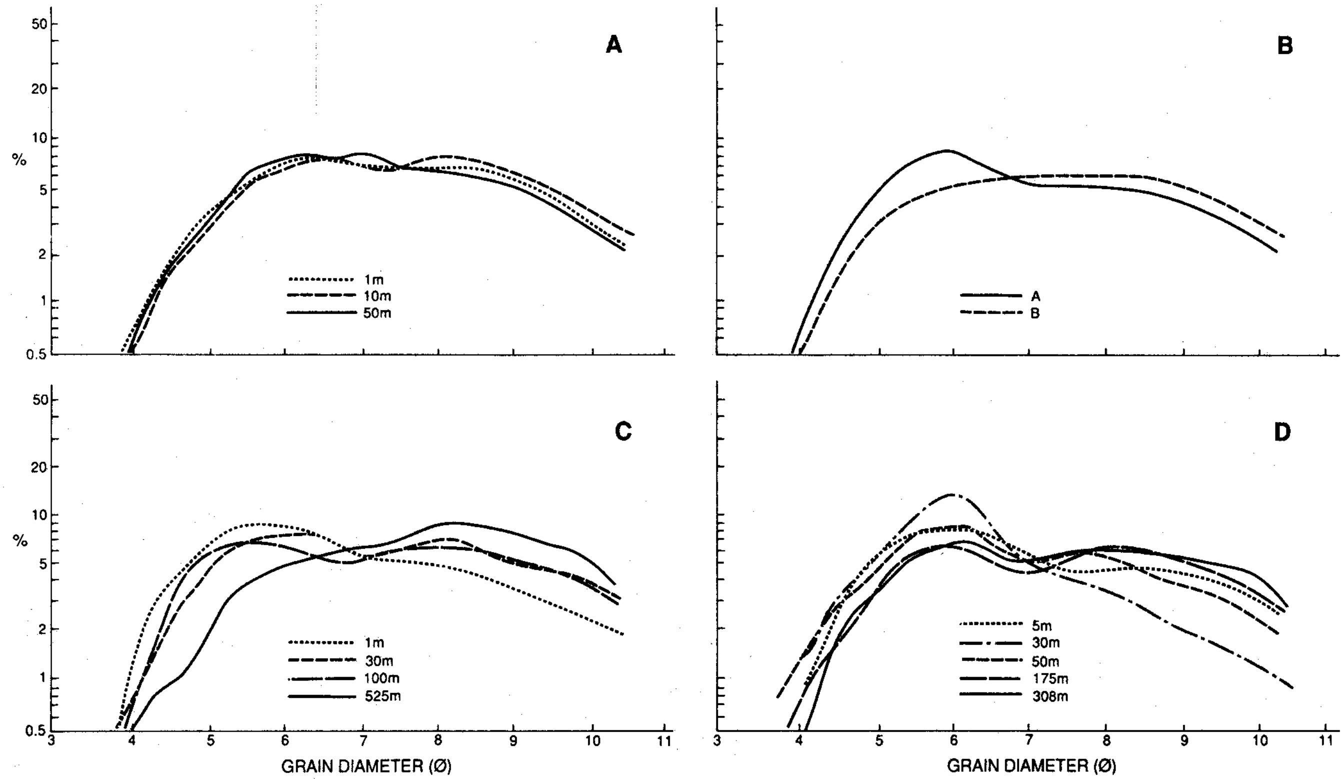

FIG. 10. Suspended sediment size frequency distributions for 29 and 30 September and 1 October 1983 from: A) Station 0.1c at depths 1, 10 and 50 m; B) average surface water observations, A, and average bottom water observations, B, for all stations; C) Station 3.05 at depths 1, 30, 100 and 525 m; and D) Station 2.1B at depths 5, 30, 50, 175 and 308 m.

on similar water density values ($\Delta\sigma_T = 0.01$). We note that this process was ongoing, for the intermediate water mass of the inner fiord was less dense than similar water depths in the outer fiord region ($\Delta\sigma_T = 0.07$).

During this period of offshore wind, much of the suspended sediment was composed of fine silt and clay-size material, dominated by micas, and phytoplankton. This fine sediment was present as floccules, mucoid fragments with sediment adhering to the surface, clay clasts and fecal pellets. Two types of clasts were present: 1) *Fluvial clasts* stripped from raised marine terraces and present in the surface waters near the head of the fiord to Station 4 — these clasts have a particle morphology similar to clasts described by Syvitski and Murray (1981) and attributed to fluvial origin. The McBeth River is eroded deeply into raised marine clay deposits. The coarser mode observed in our size frequency distributions (Fig. 9) may relate to bed-material transport of the McBeth River (at the fiord head), whereas the finer mode reflects the fluvial erosion of the raised marine clay terraces. 2) *Resuspended clasts*, composed of a sand-size mica grain with attached clay or mud clumps, were present near the sea floor in both the middle fiord (Station 4) and the northern branch of the outer fiord (Stations 7 and 8). We suggest that these clasts were resuspended from the sea floor, as they have a much higher bulk density than typical pelagic floccules or planktonic fecal pellets. The Baffin Current dominates the near bottom waters on the Baffin Shelf (Coote and Jones, 1982) and may be responsible for the elevated concentration of mineral grains in the SPM. The size frequency distribution similarities between the near sea floor water samples and the sea floor samples coupled with the increased turbidity near the sea floor also support the notion of resuspension.

We also note a source change of near bottom SPM components with distance from the fiord head (Fig. 9D). Nearest the fiord head, deep water did contain the largest proportion of lithogenic particles and lacked a coarse biogenic mode as compared to samples from the Baffin Shelf (*cf.* Station 1 with Station 11: Fig. 9D). Observations for Station 11 revealed a higher bottom concentration (>3.0 mg·L^{-1}) of suspended sediment on the Baffin Shelf than was observed in the fiord. These elevated concentrations may be associated with seasonally high currents on the Baffin Shelf. A bottom water concentration maximum was also observed at Station 8 (SPM >1.0 mg·L^{-1}). This may have been an indication that as bottom water was entering through the northern entrance of the fiord it was also transporting SPM from the Baffin Shelf into the fiord.

Onshore Wind Event

Prior to our arrival in 1983, strong up-fiord winds (100-150 km·h^{-1}) appear to have pushed the surface layer to the head of the fiord and temporarily increased the surface layer volume of the inner 45 km of the fiord by 60% (Fig. 4). Upon cessation of the up-fiord winds and the relaxation of the surface layer, internal waves were generated that struck the delta and resuspended even more sediment.

As the up-fiord winds relaxed, the surface layer was approximately 53 m deep near the fiord head at Station 0.2 and approximately 43 m deep 45 km seaward at Station 3.1. The depth of the surface layer 36 h later was approximately 30 m throughout the upper 45 km of the fiord. The volume of water moved by this wind event could sustain an average water velocity in the surface layer at Station 3.1 of approximately 26 cm·s^{-1} for 36 h.

After the wind velocity had dropped to zero and the fiord surface returned to calm, a rhythmic fluctuation in sea level was observed at the delta face. Observers on the tidal flats reported that the water level rose and fell approximately 10 cm in 20 s cycles. These fluctuations provide evidence of internal waves caused by relaxation of the surface layer. Water mass circulation appears to have responded in a similar manner to that observed in Inugsuin Fiord, Baffin Island, during September 1982 (A. Hay, pers. comm. 1983). After the cessation of 130 km·h^{-1} winds in Inugsuin Fiord and the relaxation of the surface layer, breaking internal waves were identified by acoustic profiling. The Inugsuin surge front travelled at approximately 60 cm·s^{-1} and was thought capable of causing a massive resuspension event. Data from Winters (1983) and Buckley and Winters (1983) indicate that in the channel of the Miramichi Estuary periodical spring tidal surges with bottom currents of 20-40 cm·s^{-1} can resuspend sediment and sustain concentrations of 20-70 mg·L^{-1} respectively for short periods.

The initial resuspension at the delta front was caused by wind-driven waves as the surface layer was pushed to the head of the fiord. The highest SPM_{clay} concentrations at Station 0.1 were 0.5 mg·L^{-1} (Fig. 4A) and were observed below the surface layer at depths >50 m. Slightly lower concentrations of 0.4 mg·L^{-1} were observed in the surface layer. The resuspended sediment appeared to settle in deeper water. Upon cessation of up-fiord winds the surface layer began flowing seaward and a subsurface compensating current was established with water flowing towards the head of the fiord below the halocline. The internal waves that formed at the interface of these two opposing currents struck the delta and resuspended more sediment. When the 0.3, 0.4 and 0.5 mg·L^{-1} isopleths in Figure 4A are compared with those in Figures 4B and 4C, it is apparent that the higher concentrations of suspended sediment were entering the surface layer. Some of this resuspended sediment moved seaward in the surface layer.

Annual Variation in SPM Characteristics

The observed SPM concentrations were higher in 1982 than in 1983 (Fig. 11) and the concentration maxima near the sea floor may be indicative of sediment resuspension by bottom currents. Also, the lesser bottom maximum on the inward side of the sill may indicate that the inward movement of water over the sill initiated bottom sediment resuspension proximal to this sill.

Textural analyses for 1982 and 1983 (Figs. 12a and 12b respectively) show that the SPM was coarsest near the sea floor on the seaward side of the sill in 1982 and in the surface water mass during 1983. Because coarse SPM settles more rapidly, zones of a lower concentration of clay are closer to points of sediment input. This suggests that in 1982 the SPM in the bottom maxima originated on the outer side of the sill, where the bottom currents were highest. In 1983, although most of the SPM was entering the surface water at the delta front, a significant input of coarse material was also coming from a side entry glacier near Station 2.1.

CONCLUSIONS

Suspended sediment properties were sensitive to water mass movement in McBeth Fiord and other fluvial and wind-driven processes that control particle suspension and sedimentation. Suspended sediment was mostly composed of large particles, such as mucoid stringers, fecal pellets, floccules, fluvial-introduced clay clasts and clasts resuspended from the sea floor. These large particles were composed of numerous fine silt and

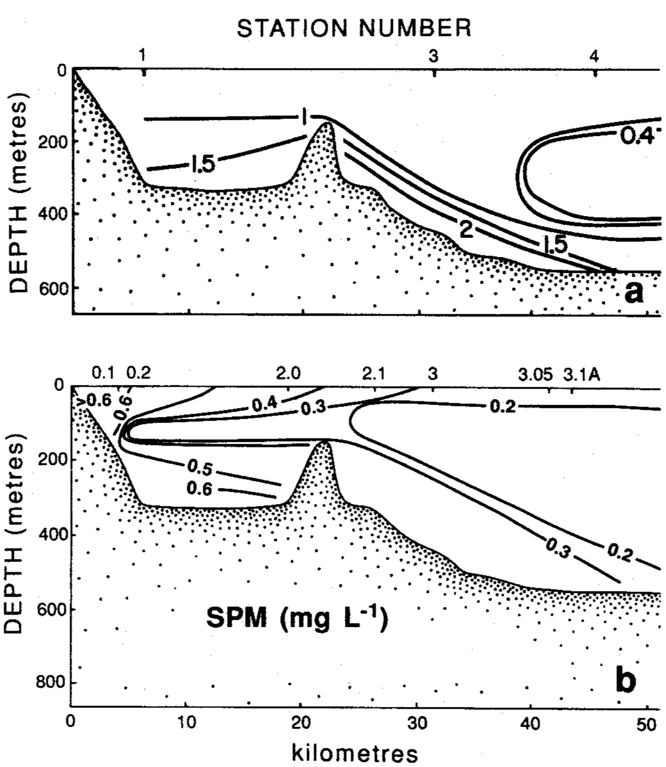

FIG. 11. SPM concentrations from the inner 50 km of the fiord for observations made during a) 1982 and b) 1983.

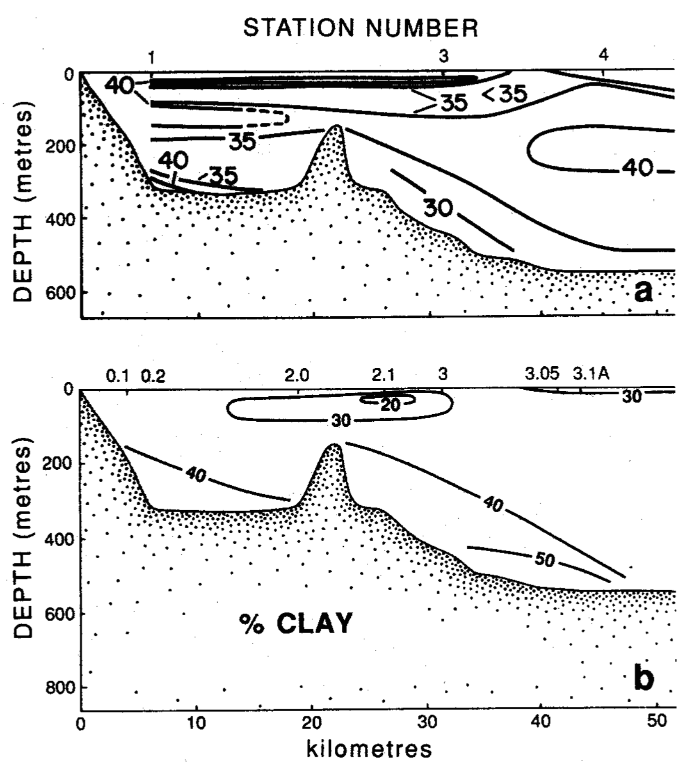

FIG. 12. Percentage of clay determined from textural analyses of the SPM from the inner 50 km of the fiord for the observations made during a) 1982 and b) 1983.

clay size grains. However, the surface waters of the inner fiord were dominated by radiolarian, picoplankton, fecal pellets and numerous unflocculated mineral grains. Occasionally phytoplankton dominated the suspended sediment concentrations in the intermediate water masses.

In 1982, immediately prior to our arrival, strong offshore winds pushed the surface layer of the fiord and adjacent coastal waters seaward and may have initiated the fall deep-water exchange cycle. The SPM concentration, grain size properties and particle morphology are all consistent with bottom sediment resuspension in the northern entrance to the fiord and in the inner fiord.

In 1983 onshore winds pushed the surface layer to the head of the fiord and temporarily increased the surface layer volume of the inner 45 km of the fiord by 60%. Sediment was resuspended at the delta front initially by wind-driven waves. Upon cessation of the up-fiord winds and the relaxation of the surface layer, internal waves were generated that struck the delta and resuspended even more sediment.

During the late summer to autumn observation periods the highest suspended sediment concentrations were within the Baffin Shelf bottom waters. The episodic replacement of the deep water in the fiord by water from shelf waters contributed sediment to the fiord from the shelf. Further research is essential to evaluate the importance of this process. Modellers must consider the possibility that a significant amount of marine sediment from the shelf may enter a silled environment.

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REFERENCES

ASPREY, K.W., and JOHNSTON, L. 1984. Report on CSS HUDSON cruise 83-028, Baffin Island Fjord. Geological Survey of Canada, Open File Report 1004. 189 p.

ASPREY, K.W., BISHOP, P., BLAKENEY, C., LeBLANC, W., SYVITSKI, J.P.M., and WINTERS, G. 1983. Suspended particulate matter data. In: Syvitski, J.P., and Blakeney, C.P., compilers. Sedimentology of arctic fjords experiment: HU 82-031 data report. Vol. 1. Canadian Data Report of Hydrography and Ocean Sciences No. 12:5-1 to 5-30.

BARTZ, R., ZANEVELD, R.T., and PAK, H. 1978. A transmissometer for profiling and moored observations. Proceedings of the Photo-Optical Instrumentation Engineers 160 Ocean Optics V:102-110.

BUCKLEY, D.E., and WINTERS, G.V. 1983. Geochemical transport through the Miramichi Estuary, New Brunswick, Canada. Canadian Journal of Fisheries and Aquatic Sciences 40:162-182.

CLATTENBURG, D., COLE, F., KELLY, B., LeBLANC, W., BISHOP, P., RASHID, M., SCHAFER, C.T., and SYVITSKI, J.P.M. 1983. SAFE: 1982 bottom grab samples. In: Syvitski, J.P.M., and Blakeney, C.P., compilers. Sedimentology of arctic fjords experiment: HU 82-031 data report. Vol. 1. Canadian Data Report of Hydrography and Ocean Sciences No. 12:8-1 to 8-94.

COOTE, A.R., and JONES, E.P. 1982. Nutrient distributions and their relationships to water masses in Baffin Bay. Canadian Journal of Fisheries and Aquatic Sciences 39:1210-1214.

ELVERHOI, A., LIESTOL, O., and NAGY, J. 1980. Glacial erosion, sedimentation and microfauna in the inner part of Kongsfjorden, Spitsbergen. Norsk Polarinstitutt Skrifter 172:33-58.

FISSEL, D.B., LEMON, D.D., and BIRCH, J.R. 1981. The physical oceanography of western Baffin Bay and Lancaster Sound. Environmental Studies No. 25. Ottawa: Department of Indian and Northern Affairs. 293 p.

GADE, G.H. 1972. Deep water exchanges in a sill fjord: A stochastic process. Journal of Physical Oceanography 3:213-219.

GADE, G.H., and EDWARDS, A. 1980. Deep-water renewal in fjords. In: Freeland, H.J., Farmer, D.M., and Levins, C.D., eds. Fjord Oceanography. New York: Plenum Press. 453-489.

GILBERT, R. 1978. Observations on oceanography and sedimentation at Pangnirtung Fiord, Baffin Island. Maritime Sediments 14:1-9.

______. 1980a. Environmental studies in Maktack, Coronation and North Pangnirtung Fiord, Baffin Island, N.W.T. Unpubl. final report of research supported by Petro Canada Exploration Inc., NSERC and Department of Geology, Queen's University, Kingston, Ontario, Canada K7L 3N6. 97p.

______. 1980b. Observations on the sedimentary environments of fjords on Cumberland Peninsula, Baffin Island. In: Freeland, H.J., Farmer, D.M., and Levins, C.D., eds. Fjord oceanography. New York: Plenum Press. 633-638.

______. 1983. Sedimentary processes of Canadian arctic fiords. Sedimentary Geology 36:147-175.

JONES, E.P., DYRSSEN, D., and COOTE, A.R. 1984. Nutrient regeneration in deep Baffin Bay with consequences for measurements of the conservative tracer NO and fossil fuel CO_2 in the oceans. Canadian Journal of Fisheries and Aquatic Sciences 41:30-35.

LARSON, E. 1973. An *in situ* optical beam attenuance meter. Bedford Institute of Oceanography, Report Series BI-R-73-3. Dartmouth, Nova Scotia, Canada B2Y 4A2. 74 p.

LeBLANC, K.W.G., SYVITSKI, J.P.M., and MAILLET, L. 1988. Examination of the suspended particulate matter within arctic fjords. Geological Survey of Canada Open File Report 1733. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 302 p.

MACKIEWICZ, N.E., POWELL, R.D., CARLSON, P.R., and MOLNIA, B.F. 1984. Interlaminated ice-proximal glacimarine sediments in Muir Inlet, Alaska. Marine Geology 57:113-147.

MUENCH, R.D. 1971. The physical oceanography of the northern Baffin Bay Region. The Baffin Bay – North Water Project. Scientific Report 1. Washington, D.C.: Arctic Institute of North America. 150 p.

PETRIE, W.M., and TRITES, R.W. 1984. Synoptic oceanography: Baffin Island fjords, cruise 83-028. In: Sedimentology of arctic fjords experiment: HU 83-028 data report. Vol. 2. Syvitski, J.P., compiler. Canadian Data Report of Hydrography and Ocean Sciences No. 28:2-1 to 2-133.

PLATT, T., and LI, W.K.W. 1986. Photosynthetic picoplankton: Creatures small and great. BIO REVIEW 86:8-12. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2.

SIEBURTH, J.M., SMETACEK, V., and LENZ, J. 1978. Pelagic ecosystem structure: Heterotrophic compartments of the plankton and their relationship to plankton size fractions. Limnology and Oceanography 23:1256-1263.

SMETHIE, W.M., Jr. 1981. Vertical mixing rates in fiords determined using radon and salinity as tracers. Estuarine, Coastal and Shelf Sciences 12:131-153.

STRICKLAND, J.D.H., and PARSONS, T.R. 1968. A practical handbook of seawater analyses. Fisheries Research Board of Canada Bulletin 167.

SYVITSKI, J.P.M. 1982. Cruise report: C.S.S. HUDSON 82-031. Geological Survey of Canada, Open File Report 897, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 77 p.

______. 1984. Sedimentology of arctic fjords experiment: HU83-028 data report. Vol. 2. Canada Data Report of Hydrography and Ocean Science No. 28. 1130 p.

______. 1989. On the deposition of sediment within glacier-influenced fjords: Oceanographic controls. Marine Geology 85:301-329.

SYVITSKI, J.P.M., and BLAKENEY, C.P. 1983. Sedimentology of arctic fjords experiment: HU 82-031 data report. Vol. 1. Canadian Data Report of Hydrography and Ocean Science No. 12. 935 p.

SYVITSKI, J.P.M., and HEFFLER, D.E. 1983. The floc camera. BIO REVIEW 83:50-51. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2.

SYVITSKI, J.P.M., and HEIN, F.J. 1991. Sedimentology of an arctic basin, Itirbilung Fjord, Baffin Island, Canada. Geological Survey of Canada Paper 91-11. 67 p.

SYVITSKI, J.P.M., and MURRAY, J.W. 1981. Particle interactions in fjord suspended sediment. Marine Geology 39:215-242.

SYVITSKI, J.P.M., and PRAEG, D.B. 1987. Sedimentology of arctic fjords experiment: Data report. Vol. 3. Canada Data Report of Hydrography and Ocean Science No. 54. 468 p.

SYVITSKI, J.P.M., and SCHAFER, C.T. 1985. Sedimentology of arctic fjords experiment (SAFE): Project Introduction. Arctic 38:264-270.

SYVITSKI, J.P.M., BURRELL, D.C., and SKEI, J.M. 1987. Fjords: Processes and products. New York: Springer-Verlag. 379 p.

SYVITSKI, J.P.M., FARROW, G.E., TAYLOR, R., GILBERT, R., and EMORY-MOORE, M. 1984a. SAFE: 1983 delta survey report. In: Syvitski, J.P., compiler. Sedimentology of arctic fjords experiment: HU 83-028 data report. Vol. 2. Canadian Data Report of Hydrography and Ocean Sciences No. 28:18-1 to 18-91.

SYVITSKI, J.P.M., LAMPLUGH, M., and KELLY, B. 1984b. Fjord morphology. In: Syvitski, J.P., compiler. Sedimentology of arctic fjords experiment: HU 83-028 data report. Vol. 2 Canadian Data Report of Hydrography and Ocean Sciences No. 28:20-1 to 20-27.

SYVITSKI, J.P.M., LeBLANC, K.W.G., and CRANSTON, R.E. 1990. The flux and preservation of organic carbon in Baffin Island fjords. In: Dowdeswell, J.A., and Scorse, J.D., eds. Glaciomarine environments: Processes and sediments. Geological Society Special Publication No. 53. London: The Geological Society. 177-199.

SYVITSKI, J.P.M., SCHAFER, C.T., ASPREY, K.W., HEIN, F.J., HODGE, G.D., and GILBERT, R. 1985. Sedimentology of arctic fjords experiment: PA-85-062 expedition report. Geological Survey of Canada Open File Report 1234. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 79 p.

SYVITSKI, J.P.M., SILVERBERG, N., OUELLET, G., and ASPREY, K.W. 1983. First observations of benthos and seston from a submersible in the lower St. Lawrence estuary. Geographie Physique et Quaternaire 37:227-240.

TRITES, R.W. 1985. Oceanographic reconnaissance of selected Baffin Island fjords. Distribution and dynamics of suspended particulate matter in Baffin Island fjords. In: Syvitski, J.P., and Vilks, G., eds. Arctic land-sea interaction, 14th Arctic Workshop. Geological Survey of Canada Open File Report 1223. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 54-55.

TRITES, R.W., PETRIE, W.M., HAY, A.E., and DEYOUNG, B. 1983. Synoptic oceanography: Baffin Island fjords, Cruise 82-031. In: Syvitski, J.P., and Blakeney, C.P., compilers. Sedimentology of arctic fjords experiment: HU 82-031 data report. Vol. 1. Canadian Data Report of Hydrography and Ocean Sciences No. 12:2-1 to 2-129.

VILKS, G., DEONARINE, B., and WINTERS, G. 1987. Late Quaternary marine geology of Lake Melville, Labrador. Geological Survey of Canada Paper 87-22. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 49 p.

WINTERS, G.V. 1983. Modeling suspended sediment dynamics of the Miramichi Estuary, New Brunswick, Canada. Canadian Journal of Fisheries and Aquatic Sciences 40(Supp. 1):105-116.

WINTERS, G.V., and BUCKLEY, D.E. 1980. *In situ* determination of suspended particulate matter and dissolved organic matter concentrations in an estuarine environment by means of an optical beam attenuance meter. Estuarine and Coastal Marine Sciences 10:455-466.

WINTERS, G.V., SYVITSKI, J.P.M., KELLY, B., and CLATTENBURG, D. 1984. SAFE: 1983 light attenuance and suspended particulate matter data. In: Syvitski, J.P.M., compiler. Sedimentology of arctic fjords experiment: HU 83-028 data report. Vol. 2. Canadian Data Report of Hydrography and Ocean Sciences No. 28:4-1 to 4-127.

WINTERS, G.V., SYVITSKI, J.P.M., and MAILLET, L. 1985. Distribution and dynamics of suspended particulate matter in Baffin Island fjords. In: Syvitski, J.P.M., and Vilks, G., eds. Arctic land-sea interaction, 14th Arctic Workshop. Geological Survey of Canada Open File Report 1223. Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2. 73-77.