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Rate of sedimentation and geochemistry of southeastern Hudson Bay, Canada

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ABSTRACT Suspended particulate matter (SPM) of Hudson Bay was estimated by collecting 60 samples at three stations and four different depths. The mean SPM in the study area is 0.642 mg/L. The sediments collected in traps indicated that the rate of accumulations increased with depth. The seasonal variations could be 2 to 4 times higher during the month of May. The rate of sedimentation estimated by 210 Pb data suggested 51 to 63 mm/100 years which is in broad agreement with the trap data.

Carbon and nitrogen together constitute more than 50% of SPM. In the trap sediments carbon ranged from 17 to 38% and nitrogen 1.6 to 6.3%. In underlying sediments, the carbon is very uniform with mean 1.96% of which more than 85% is of organic fraction.

Elemental analysis on core sediments showed uniform bulk chemistry. High Si/Al ratio indicate the source of sediments to the Bay may include other than fluvial transport. The amorphous Silica content in the sediments ranged from 0.77 to 2.36% which is 2 to 8% on total silica; in trap sediments it is more than 6%. Size studies indicated the breakdown of SPM resulting in collection of relatively more fine sediments in the deeper traps. A gradual increase of sand fraction in the underlying sediments since 1000 years indicate a change in supply of the sediments to the Hudson Bay.

INTRODUCTION

Sediments of glaciated terrain such as Hudson Bay can be classified into three types based on their formation stage from bed rock. The first two derivative sediments, till and glacio fluvial, of Hudson Bay have been studies by several workers (Andrews and Flaconer, 1969; Shilts, 1980, etc.) The third derivative stage, modern fluvial, lacustrine and recently deposited sediments have received some attention (Adshed 1983; Cumming 1969; Pelletier 1969; Leslie 1963, etc.).

Detailed mineralogical analysis of river sediments and patterns of fluvial sand composition of western Hudson Bay indicated the regional drift dispersal limits (Adishad, 1983). Geomorphology and glacial history of

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rivers flowing into western Hudson Bay was described by Cumming (1969). The first indepth study of physical oceanographic and sedimentation processes of Hudson Bay was reported by Pelletier (1969). This study concluded that the several tough positions in the bottom of the Bay are preglacial channels associated with the present Churchill, Nelson Severn and Winsik estuaries.

Sediment transport to James Bay by the river has been estimated at 41 million tonnes/year (Kranck and Ruffuman, 1982). The suspended sediments of the Bay are reported to have varied from 1 to 100 mg/L with a sharp decrease towards Hudson Bay. A similar study on Rupert Bay emphasizing the seasonal changes was reported by d'Anglejan (1980). However, no study has been reported on the rate sedimentation and geochemistry of recent sediments of Hudson Bay. The present study in the south-eastern part of Hudson Bay is an attempt to fill that gap.

METHODOLOGY

Methodology adopted to generate the data are briefly described below (details in Biksham, 1987).

Sampling

Samples were collected during two field seasons in 1985 and 1986 (Fig. 1).

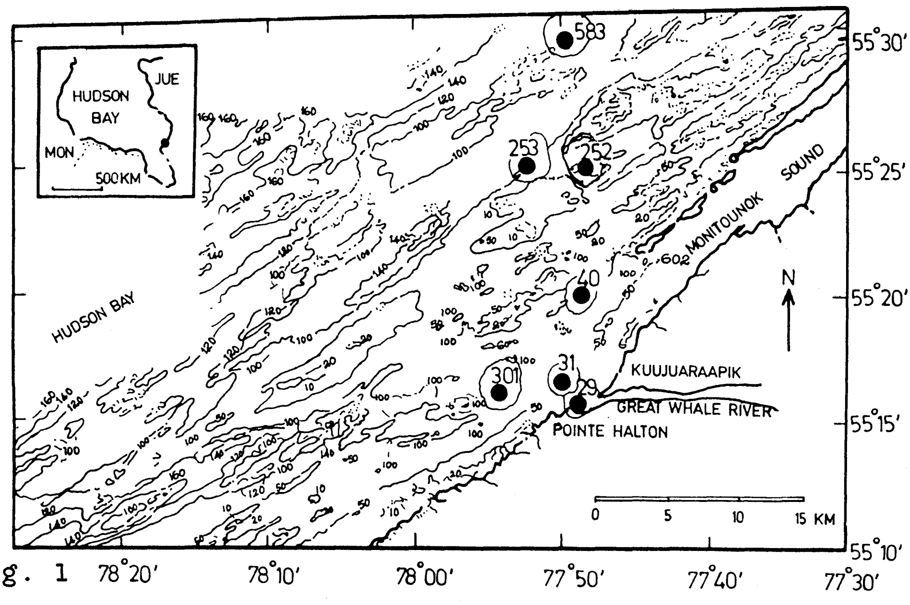

Fig. 1

SPM was collected in a vertical profile by collecting water samples at specific depths by lowering the bottles through the ice cover. The samples were filtered within

24 hours to collect SPM. Trap sediments were collected from two locations (583 and 031). Major elemental analysis was done by XRF at the Department of Geological Sciences, McGill University and other wet chemical analysis at the Institute of Oceanography. Radioactive data were determined by X-ray Assay Laboratories Limited. Carbon in core sediments were determined by GC-90 Gravimetric Carbon Determinator Model 521-275. Size analysis was by Coulter Counter Model TA.

RESULTS AND DISCUSSION

Suspended Particulate Matter (SPM)

SPM was determined at three stations (031, 040 and 583) on 60 samples from three depths. The SPM ranged from 2.976 mg/L to 0.065 mg/L. SPM is concentrated near the surface, shows a decreasing trend towards middle depth, but increases at greater depths indicating the resuspension of sediments. This is a common phenomena in other similar areas (Drake et al., 1972 and Landing, 1978). The increase of SPM with depth is not clear at station 583 because the observation point (72 m) is well above the sediment water interface (140 m). Summary of SPM (Table 1) indicate that the mean concentration of 0.641 mg/L is significantly lower than the Gulf of Alaska (Landing, 1978). SPM values decrease away from shore from 0.897 mg/L (Stn. 031) to 0.373 mg/L (Stn. 583).

Table 1 Summary of suspended particulate matter (mg/L)

Depth (m)	Stations			
	031 (4)	100 (4)	583 (8)	Mean (*)
<3	1.628	0.314	0.432	0.791
20	0.329	0.563	--	
35			0.332	0.408
45	0.734	1.079	--	
65	--	--	0.357	0.723
Mean	0.897	0.652	0.373	0.641

*Mean at different depths, 1-3; 20-35 and 45-65 metres

Rate of Sedimentation

Sediment trap data are presented in Table 2. Four levels of sediment traps (Stn. 583) showed an increase in rate of accumulation with the depth from 14.8 µg/cm^2/day at 10 m to 88 µg/cm^2/day at 72 m depth (Fig. 2). The mean rate of sedimentation at station 583 is estimated as 88 µg/cm^2/day which is equal to 38.5 mm/100 years. The high rate, 712 $\mu g/cm^2/day$, is expected at station 031 due to its proximity to the river and location of trap in the nephloid layer (Fig. 2). The rate of sediment accumulation at Stn. 583 represents the natural rate because it is more than 50 m above the sediment water interface and

Table 2 Trap sediments: Fluex estimates

St.	Depth m	wt. mg	$\mu g/cm^2$ /day	mg/cm^2 /yr	Rate mm/100 yr
583	10*	14.1	7.3	2.7	3.2
	10*	30.6	9.3	3.4	4.1
	10@	25.5	27.9	10.2	12.2 (6.5)
	35*	46.1	14.0	5.7	6.1
	35*	51.5	15.7	8.6	6.9
	35@	43.8	48.1	17.5	21.0
	35@	41.4	45.4	16.6	19.9 (13.5)
	60*	77.7	23.7	8.6	10.3
	60*	121.5	37.0	13.6	16.3
	60@	42.8	46.9	17.1	20.5
	60@	49.9	54.7	20.0	24.0 (17.8)
	74#	1150.0	103.4	37.8	45.4
	74#	800.0	71.9	26.3	31.6 (38.5)
031	26$	7650.0	655.6	239.3	287.2
	26$	8970.0	768.8	280.6	336.7 (312.0)

period of traps; * April 4 - May 1; @ May 3-8; # May 8 - July 11; $ May 13 - July 16;
wt.mg = Total weight of sediment collected

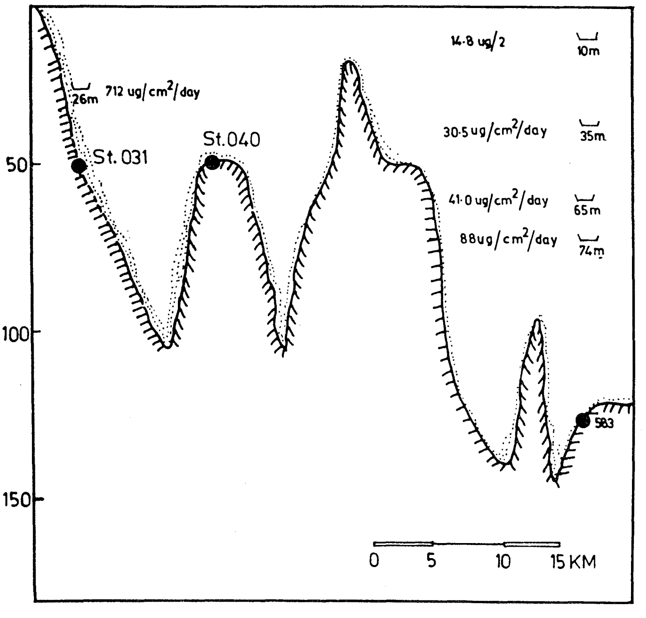

Fig. 2

well above the expected nephloid layer (Fig. 2). The traps set up during May generally show higher rates at all depths than in April. Seasonal variations could be 4 times (near surface) to two times (towards greater depth) higher.

The rate of sedimentation in lakes and estuaries is estimated by radiometric data. 210 Pb (half life 22.26 years) is a geochemical indicator of rate of sedimentation (Krishnaswamy _et al_., 1971). Two cores (583 and 040) were studied with this method (details, Biksham, 1988). The mean rate of sedimentation for 583 and 040 are 63.2 and 51.2 mm/100 yr respectively (Table 3). For station 040, an increase in rate is clearly evident in the top 3 cm column. These rates are comparable with Lake Matagami (81 mm/100 yr) and Lake Quevillon (52 mm/100 yr) of Northwest Quebec (Durham and Joshi, 1980). The rate of sedimentation at 583, 63.2 mm/100 yr is in agreement with the estimate of trap accumulation. The rate of sedimentation appears to have increased in the past 1000 years.

Table 3 Rate of sedimentation

	Station: 040			Station: 583		
Depth	dpm	*	**	dpm	*	**
0 - 1	9.49	47	56.4	8.86	56	67.2
1 - 2	6.33	67	80.0	4.95	50	60.0
2 - 3	2.93	37	44.4	3.11	62	74.4
3 - 4	2.47	42	50.4	1.56	44	52.8
4 - 5	1.83	37	44.4	1.10		
5 - 6	1.56	49	58.8			
7 - 8	0.99	34	41.5			
8 - 9	0.91	33	39.6			
9 - 10	0.86					
0 - 10		43	51.2		53	63.2

dpm: Pb 210 Dissentegration per minute per gram.
* mg/cm/year; ** mm/100 yr

Bulk Elemental Analysis

Major element analyses were done on 32 bulk samples drawn from seven gravity cores. Elemental concentrations presented are based on volatile free sediments (Table 4). Chemistry is generally uniform with respect to depth and stations. Maximum and minimum variations among major elements ranged from 1.1 (Al) to 2 (Mn, Mg, Ca and Na).

Although no definite relationship exists between depth and sediment chemistry, certain observations can be made: (a) Si is higher in the upper strata at all the locations except for Stn. 583; (b) Mn is distinctly higher in the top layer in most of the locations; (c) P is higher in the top layer at all the stations except 252; (d) Si content decreases from shore towards the middle of the bay, and (e) P and Ba decrease towards the middle of the bay.

Table 4 Summary of chemical analysis

Element	583 (9)	031 (7)	301 (7)	029 (2)	040 (3)	232 (2)	252 (2)	**
Si	28.70	30.69	29.60	31.10	30.10	27.65	29.60	1.24
Ti	0.29	0.28	0.30	0.28	0.30	0.31	0.25	1.50
Al	3.70	3.64	3.70	3.59	3.70	3.66	3.47	1.10
Fe	1.67	1.55	1.72	1.54	1.69	1.83	1.01	1.55
Mn*	462	437	502	542	452	566	462	2.10
Mg	2.51	1.86	2.30	1.67	2.04	2.86	1.61	2.11
Ca	5.38	3.72	5.20	3.53	4.12	7.06	3.98	2.10
Na	1.38	1.27	1.20	1.39	1.42	1.51	1.18	1.93
K	1.32	1.21	1.28	1.10	1.32	1.22	1.20	1.24
P*	362	403	390	445	429	439	329	1.67
Ba*	600	666	630	622	650	605	675	1.37
Co*	7	-	7	-	5	-	-	-
Cu*	12	-	-	-	-	-	-	-
Ni*	31	21	25	16	26	32	17	3.64
Zn*	44	22	36	9	38	40	24	3.06

Units = Percentages except * in µg/g volatile free
Sample numbers in brackets; ** Maximum/Minimum

Compared to the sediments of the Gulf of Alaska, Hudson Bay sediments are depleted in Al although the Si content is almost the same (around 29%). This results in a higher ratio of Si/Al (around 8%). Such a high ratio generally indicates that the source of sediments to the Bay includes other than continental transport.

Amorphous Silica was determined on 25 samples of underlying sediments and three trap sediments using the method of Eggiman et al. (1979). Amorphous silica ranged from 0.77% to 2.36% for underlying sediments and from 6.24% to 6.80% in trap sediments. Amorphous silica in sediments of Stn. 031 and 583 ranged from 4.8% to 6.8% respectively on total silica. For the individual samples, amorphous silica is 2.5% to 8.3% of the total silica. In general, a slight increase in amorphous silica is noticed towards deeper depths of the cored sediments. Amorphous silica is nearly 4 times as concentrated in the traps compared to the underlying sediments of the same location, indicating biogenic source. Studies in Gulf of Alaska also contained 2 to 6% silica of biogenic origin (Landing, 1979).

Carbon and Nitrogen analysis were done on 12 suspended sediments and 15 trap samples collected during 1986 and 1985 at stations 031 and 583.

Trap Samples

Three sets of trap samples collected during April 1986, May-July 1985 and April 1985 were analyzed for C and N.

The 1986 samples (Stn. 583) are 1.6% to 6.3% nitrogen and from 17% to 38% carbon, with C/N ratios ranging from 6 to 13. The deposition rates of Nitrogen and Carbon range from 0.08 to 0.36 µg/cm^2/day for Nitrogen and 0.85 to 4.25 µg/cm^2/day for carbon.

Similarly for the other two sets of samples, N and C showed a wide range of concentration from 0.1 to 9.8% and 1.2 to 99% respectively. No relation between C and N and depth has been noticed.

The concentrations of these elements are remarkably low when high rate sedimentation are obtained in the traps. Therefore, the rate deposition of these elements in the basin are uniform with time indicating uniform production by biological activity.

Underlying Sediments

Carbon analysis was done on 86 samples of underlying sediments from seven locations. The organic and inorganic content in the sediments range from 0.9 to 2.29% and 0.3 to 0.82% respectively. Total C ranges between 1.23% to 2.95% with a mean of 1.96%. Compared to suspended and trap sediments, the carbon content of underlying sediments is relatively low and constant with depth. The annual accumulation rates at Stns. 583 and 040 are 1.086 mg/cm^2 and 0.740 mg/cm^2 respectively.

Mineralogical Analysis

A limited number of bottom (4) and trap (3) sediment samples were studied for mineralogy by XRD. Quartz is the main mineral of Hudson Bay sediments (Table 5). The trap sediments are more than 50% quartz. Presence of feldspars indicate the low intensity of chemical weathering of source sediments. The results are comparable with sediments of western Hudson Bay (Adshead, 1983).

Table 5. Mineralogy (Stn. 583, Units = %)

	A	B
Quartz	37.6	55.2
Feldspar	41.0	24.0
Mica	2.3	--
Calcite	6.9	10.1
Dolomite	9.8	10.1
Chlorite	2.4	--

A = Underlying sediments
B = Trap sediments

<u>Particle size distributions</u> were determined for samples of suspended, trap and underlying sediments. Twenty size fractions (0.794 µ to 64.0 µ) were identified by Coulter Counter.

Suspended Particulate Matter

More than 70 percent of suspended particles are in the clay fraction with less than 5 percent as sand. No definite relation between depth and size fraction of suspended sediments are evident, but the following observations are made:

a) Near the source river (Stn. 031) the surface fine fraction is more than 80.7% but decreases to 67% at the depth indicating the resuspension of sediments near the sediment-water interface.

b) At the other two stations the sand fraction at depth decreased.

c) Increase in silt and decrease in clay at depth (from mid depths) indicate the SPM source is biogenic.

Trap Sediments

The sand fraction (›64 µ) (Stn. 583) ranged from 1.5 to 89.4%. Similarly the fines (‹1.0 µ) range from 0.5 to 28.4%. Summary of trap data (Table 6) indicate that the sand fraction (›64 µ) and Clay (‹4 µ) fraction decrease from 50 to 33% and 21 to 15% repsectively, with depth whereas silt increases from 29% (10 m) to 52% (65 m). At greater depths (74 m) the sand fraction is reduced to 4.0% with an increase in silt (to 68%) and clay (to 27%).

Table 6. Summary of size analysis, SPM

Depth m	Size Fraction	Station 031	100	583	(Mean)
0 - 5	Sand	0.8	8.2	1.7	(3.6)
	Silt	17.0	22.6	28.6	(22.7)
	Clay	82.2	69.2	69.7	(73.7)
20 - 35	Sand	4.7	4.5	3.0	(4.1)
	Silt	18.4	15.3	20.0	(17.9)
	Clay	76.8	80.2	77.0	(78.0)
40 - 60	Sand	2.9	7.5	1.2	(6.8)
	Silt	47.7	23.3	26.3	(23.7)
	Clay	66.7	69.2	72.5	(69.5)

Units; percentages

Underlying Sediments

Particle size analysis of core sediments at Stn. 583 indicate that:

a) The sand fraction in the top three cm of the core is much higher (12.6%) than the bottom layer (0.9%) with a gradual decrease with depth.

b) Clay and silt fraction increase in the bottom layer of sediments from 48.4 to 62.2% and 36.9 to 39.0% respectively.

Observations on Size Data

The above mentioned size data broadly suggest the following points:

a) Suspended sediments are significantly finer than trap and underlying sediments.

b) Increase of silt and decrease of clay in SPM towards depths may be due to currents and biogenic matter.

c) Sediment trap data indicate the breakdown of sediments and biogenic matter with depth. Such breakdown phenomena appears to be quite significant below 60 m (Table 7).

d) The top layer of sediments have similar mean grain diameter (12.5 µ) as trap sediments at a depth of 74 m (12 µ) but with a relatively higher sand fraction.

e) Gradual decrease of sand and increase of clay with depth may be due to a change in nature of supply of sediments to Hudson Bay since 1000 years.

Table 7. Size distribution of trap and core sediments

Stn. No.	Depth m	#	% of >64 µ	**
1	(<10)	4	49.0	37.3
2	(30)	4	44.7	28.6
3	(60)	4	32.8	30.2
4	(72)	2	4.0	12.2
5	(10)	3	10.7	12.5
6	(>50)	1	0.9	4.8

Stn. Nos. 1-4 Traps and 5 & 6 Underlying Sediments
- No. of samples: ** Mean grain diameter in µ

CONCLUSIONS

Rate of sedimentation in Hudson Bay seems to be in agreement with lakes of similar conditions. Very uniform bulk chemistry has been observed. A change in source of sediments in the last 1000 years is reflected in rates of sedimentation, sand size and composition, and in the Si/Al ratio.

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