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Summary

A riverine sediment core was dated from the St. Lawrence River, Ontario. The ^{210}Pb profile of the sediment core was used to determine the chronological age of the sediment as well as the sedimentation rate. The mean specific gravity was determined to be 2.512 $g \cdot cm^{-3}$. The sedimentation rate was calculated to be 0.79 $cm \cdot yr^{-1}$ for core 079 using a CIC model.
The average mass sedimentation rate was determined to be 0.16 $g \cdot cm^{-2} \cdot yr^{-1}$ using the CIC1 model, 0.18 $g \cdot cm^{-2} \cdot yr^{-1}$ using the CIC2 model, and 0.16 ± 0.03 $g \cdot cm^{-2} \cdot yr^{-1}$ using the CRS model.

INTRODUCTION

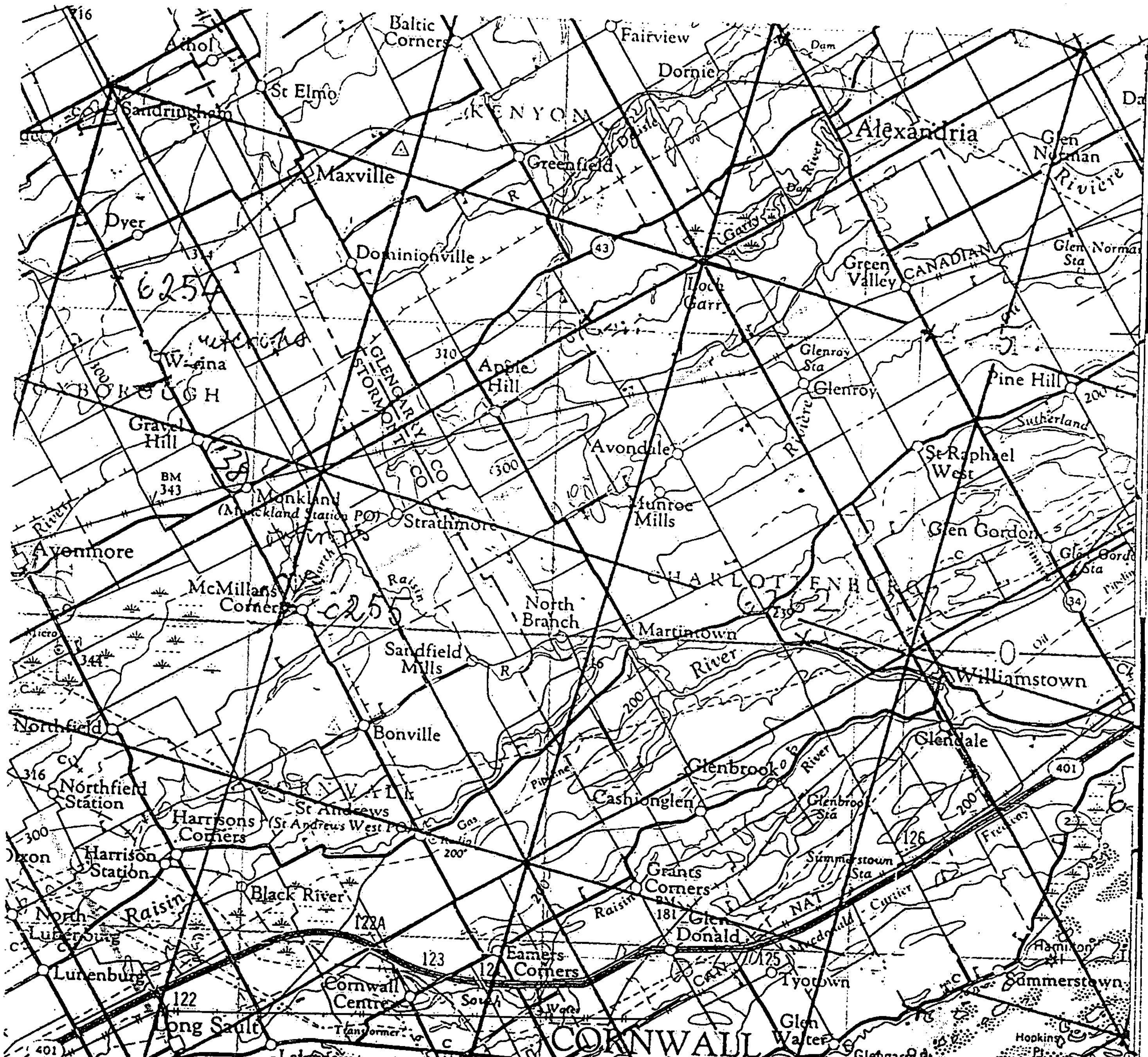
In this study, a core (079) taken from the St. Lawrence River (Station 3-1), near Cornwall, Ontario, was dated using a ^{210}Pb method (Eakins and Morrison, 1978). The core was collected by Technological Operations personnel (National Water Research Institute, Burlington) and submitted for analysis by N. Rukavina (CCIW, NWRI). Other eastern Canadian cores have been dated using this method (Turner and Delorme, 1988a-b, 1989a-g, 1990, 1992; Turner, 1990a-e, 1991a-g, 1992a-c, 1993a-d, 1994a-b, 1995a-g, 1996).

LOCATION AND CORE PREPARATION

The location of the sample site from which the core was taken (Station 3-1; 45°1'25.489"N, 74°40'59.434"W) is shown in Figure 1. On August 5, 1993, the St. Lawrence River was cored using a benthos corer (6.67 cm diameter) at a water depth of 9 m. Core 079 was transported to Burlington, Ontario where it was placed in cold storage. On October 10, 1995, core 079 was subsectioned into 1-cm intervals giving thirty-eight (38) samples. The samples were then weighed, freeze-dried, and then re-weighed. These weights were used to calculate porosity and the uncompacted depth (see Appendices A - B, Delorme, 1991). A plot of porosity versus uncompacted mid-depth and cumulative dry weight for core 079 is shown in Figure 2. The porosity profile illustrates a slight change in lithology for several samples (between uncompacted mid-depths 43.37 and 68.91). The decrease in porosity in this region may indicate an increase in particle size.

Specific Gravity was determined using an automated Accupyc pycnometer (Micromeritics, 1992). Mean specific gravity for the sediments of core 079 is 2.512 ± 0.032 $g \cdot cm^{-3}$ based on 9 samples and 45 determinations (see Appendix C this report).

Figure 1. Location map of the sampling site for core 079, St. Lawrence River, Ontario.



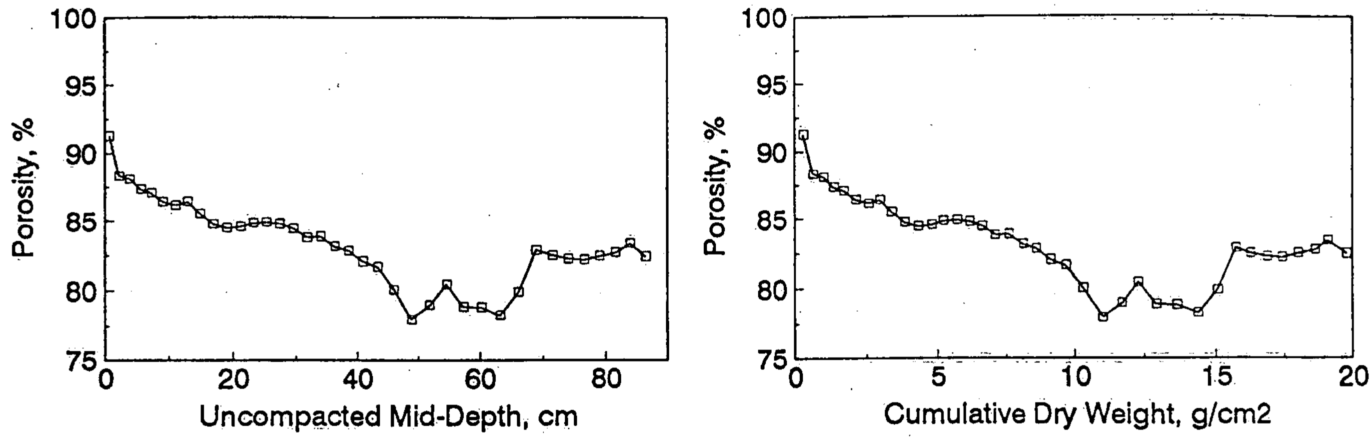


Figure 2. Distribution of porosity with uncompacted mid-depth or cumulative dry weight for core 079.

METHOD

Laboratory Procedures

Homogeneous portions of 23 samples (Table 1, including 2 sets of replicates) from core 079 were treated using a variation on the Eakins and Morrison (1978) polonium distillation procedure. Details of the laboratory procedure are found in a laboratory manual (Turner, 1990).

Following grinding and homogenizing, 1 g (upper core) to 3 g (lower core) of sediment were treated with concentrated HCl to remove carbonate materials, then mixed with approximately 10 dpm ml^{-1} of ^{209}Po spike in a test tube. The ^{209}Po spike was prepared on September 6, 1991 at 6.07 dpm/ml activity. The test tube and contents were then placed in an oven at 110°C until dry.

After cooling, glass wool plugs (one to hold the sediment at the bottom of the tube, one dampened to catch polonium at the opening of the tube) were inserted, then the tubes were placed into a tube furnace and heated to 700°C for ½ hr to distill the polonium from the sediments. At this temperature, polonium passes easily from the sediment, through the dry wool plug and does not condense until reaching the wet wool plug outside the furnace.

After cooling, the tube was cut, and the upper part containing the damp glass wool (condenser) was digested in concentrated HNO_3 under reflux (to destroy organic material). The residue was then filtered and the filtrate boiled down and digested with two HCl treatments to remove any remaining traces of HNO_3.

The polonium was then plated from the remaining solution onto a finely polished silver disk. The disk was counted in an alpha spectrometer. ^{209}Po was identified by its 4.88 MeV alpha particle, and ^{210}Po by its 5.305 MeV alpha particle. The ^{210}Po counts obtained from the spectrometer were compared to the ^{209}Po counts (of known activity) to determine the activity of ^{210}Po in the sediment sample.

Sediment Dating Theory

Dating of sediments has been actively pursued for several decades (Robbins and Edgington, 1975; Matsumoto, 1975; Appleby and Oldfield, 1978; and Farmer, 1978). Sedimentation rates are derived using either the CIC (constant initial concentration of unsupported ^{210}Pb; Robbins and Edgington, 1975; Matsumoto, 1975) or the CRS (constant rate of supply; Appleby and Oldfield, 1978) model. The CIC model assumes a constant sedimentation rate over the time period in which unsupported ^{210}Pb is measured. The CRS model assumes a variable sedimentation rate. Both models assume a constant flux of unsupported ^{210}Pb to the sediment/water interface. Depth can be corrected for sediment compaction in the CIC model using sediment porosity measurements, otherwise cumulative dry weight is used. Sediment compaction is accounted for in the CRS model by dealing with cumulative dry weight instead of sediment depth.

The profile of ^{210}Pb in a sediment core can be described as follows:

$$A_{Tx} = (A_{Uo})e^{-\lambda t} + A' \qquad (1a)$$

where A_{Tx} is the total activity of ^{210}Pb in the sample in $pCi \cdot g^{-1}$ dry wt at depth x, and of age t.

A' is the activity of ^{210}Pb supported by ^{226}Ra in $pCi \cdot g^{-1}$ dry wt (represented by constant ^{210}Po activities attained at depth),

A_{Uo} is the unsupported activity of ^{210}Pb at the sediment/ water interface in $pCi \cdot g^{-1}$ dry wt,

λ is the radioactive decay constant for ^{210}Pb ($0.693/22.26\ yr^{-1} = 0.0311\ yr^{-1}$),

And since $A_{Ux} = A_{Tx} - A'$ then $A_{Ux} = (A_{Uo})e^{-\lambda t}$ (1b)

where A_{Ux} is the unsupported activity of ^{210}Pb in the sample in $pCi \cdot g^{-1}$ dry wt at depth x,

<u>The Constant Initial Concentration (CIC) Model</u>:

In the following derivations, <u>equations</u> which refer to the usage of cumulative dry weight instead of uncompacted depth in the CIC model are designated with an 'a'.

In the CIC model, uncompacted mid-depth, z, can be used instead of natural depth, x, to compensate for sediment compaction. Otherwise cumulative dry weight is used. The uncompacted mid-depth is calculated from uncompacted thickness (Delorme 1991).

$$t_{ui} = \{(\phi_o - \phi_i)/(1 - \phi_o)\} + (TV_i * V_q) \quad (2)$$

where t_{ui} is the uncompacted thickness of the i^{th} sample,

ϕ_i is the porosity of the i^{th} sample expressed as a percentage,

ϕ_o is the porosity at the sediment-water interface calculated by regressing the top four sample porosities (ϕ_i) against natural mid-depth, and ϕ_o = y intercept,

TV_i is the total volume of the i^{th} sample,

V_q is the volume of a cylinder 1 cm high and surface area equal to either the inside of the core tube or the stainless steel extrusion ring, whichever is appropriate.

The CIC model assumes a constant sedimentation rate (or mass sedimentation rate) over the time period in which unsupported ^{210}Pb is measured, thus

$$t = z/S_o \quad (3)$$

$$t = c/\omega \quad (3a)$$

where S_o is the sedimentation rate in $cm \cdot yr^{-1}$ at the sediment/

water interface,

z is uncompacted mid-depth,

c in cumulative dry weight in $g \cdot cm^{-2}$,

ω is the mass sedimentation rate in $g \cdot cm^{-2} \cdot yr^{-1}$.

The total ^{210}Pb activity at the sediment water interface is:

$$A_{To} = (P/\omega) \tag{4}$$

where P is the flux of ^{210}Pb at the sediment water interface in $pCi \cdot cm^{-2} \cdot yr^{-1}$, (assumed constant).

Substituting equations (3) [and (3a)] and (4) into equation (1a) gives:

$$A_{Tz} = (P/\omega) e^{-z\lambda/S_o} + A' \tag{5}$$

or

$$A_{Tx} = (P/\omega) e^{-c\lambda/\omega} + A' \tag{5a}$$

Equation (5) or [5(a)] can be simplified using natural logarithms:

$$\ln(A_{Tz} - A') = \ln(P/\omega) - (\lambda/S_o) z \tag{6}$$

$$\ln(A_{Tx} - A') = \ln(P/\omega) - (\lambda/\omega) c \tag{6a}$$

The form of the equation is $y = b + (m)\ x$

A graphical solution for P/ω (the y-intercept) and λ/S_o [or (λ/ω)] (the slope of the line) is possible from a plot of x and y {z vs $\ln(A_z - A')$} [or c vs $\ln(A_x - A')$] (see Figure 4). As λ is known, then S_o [or ω] can be calculated.

$$S_o = \lambda/\text{slope} = \lambda/(m) \tag{7}$$

$$\omega = \lambda/\text{slope} = \lambda/(m) \tag{7a}$$

When using uncompacted depth, the mass sedimentation rate ω ($g \cdot cm^{-2} \cdot yr^{-1}$) is represented by:

$$\omega = S_o\ (1 - \phi_o)\ \rho_s = S_i\ (1 - \phi_i)\ \rho_s \tag{8}$$

where ρ_s is the density of the solid phase of the sample (assumed constant),

S_i is the sedimentation rate ($cm \cdot yr^{-1}$) at a given uncompacted mid-depth z.

The flux at the sediment/water interface P ($pCi \cdot cm^{-2} \cdot yr^{-1}$) can be calculated from the y-intercept and mass sedimentation rate.

$$P = \omega \, (e^{b}) \tag{9}$$

Using equation (6) [or (6a)] the time 't' in years since the sample was deposited is given by:

$$t = \frac{\ln (A_{Tz} - A') - \ln(P/\omega)}{(-\lambda)} = \frac{z}{S_o} \tag{10}$$

or

$$t = \frac{\ln (A_{Tx} - A') - \ln(P/\omega)}{(-\lambda)} = \frac{c}{\omega} \tag{10ai}$$

which can be written as:

$$t = -\frac{1}{\lambda} \ln \frac{(A_{Tz} - A')}{A_{To}} = \frac{z}{S_o} \text{ or } = \frac{c}{\omega} \tag{10aii}$$

The uncompacted mid-depth (cm) divided by the sedimentation rate ($cm \cdot yr^{-1}$) [or cumulative dry weight, ($g \cdot cm^{-2}$) divided by mass sedimentation rate ($g \cdot cm^{-2} \cdot yr^{-1}$)] gives t.

<u>The Constant Rate of Supply (CRS) Model</u>:

Since the CRS model assumes a constant rate of supply, then

$$P = A_{Ui} * \omega_t \tag{11}$$

where P is the flux of ^{210}Pb at the sediment water interface in $pCi \cdot cm^{-2} \cdot yr^{-1}$, (assumed constant)

A_{Ui} is the initial activity of unsupported ^{210}Pb in sediment of age t

ω_t is the dry Mass Sedimentation Rate ($g \cdot cm^{-2} \cdot yr^{-1}$) at time t.

Sediment laid down during time period δt occupies a layer of thickness (δx):

$$\delta x = \frac{\omega_t}{\rho_x} \delta t \tag{12}$$

were ρ_x is the dry mass/unit wet volume of the sample ($g \cdot cm^{-3}$) at depth x.

$$\rho_x = \frac{d\omega}{dx} \qquad (13)$$

The rate of change of depth is

$$\dot{x} = \frac{\omega}{\rho_x} \qquad (14)$$

where ' denotes differentiation with regards to t.

and $$\dot{x}\,\rho_x = \omega = \dot{x}_o\,\rho_o \qquad (15)$$

Equation (15) combines with (1b) to give

$$\dot{x}\,\rho_x\,A_{Ux} = \dot{x}_o\,\rho_o\,(A_{Uo})e^{-\lambda t} \qquad (16)$$

Let $$B(x) = \int_x^{\infty} \rho_x * A_{Ux}\,dx = \int_x^{\infty} A_{Ux}\,d\omega \qquad (17)$$

represent the total residual or cumulative unsupported ^{210}Pb beneath sediments of depth x,

and $$B(0) = \int_o^{\infty} \rho_o * A_{Uo}\,dx = \int_o^{\infty} A_{Uo}\,d\omega \qquad (18)$$

represent the total residual unsupported ^{210}Pb in the sediment column, then

$$B(x) = B(0)e^{-\lambda t} \qquad (19)$$

The age of layer at depth x is thus:

$$t = -\frac{1}{\lambda}\ln\frac{B(x)}{B(0)} \qquad (20)$$

where B(x) and B(0) are calculated by direct numerical integration of the ^{210}Pb profile (the plot of unsupported activity versus cumulative dry weight).

The mass sedimentation rate is calculated by dividing the change in the mid-sample cumulative dry weight by the difference of time in years for the sample analyzed.

The mean ^{210}Pb supply rate (flux) is calculated from

$$P = \lambda\,B(0) \qquad (21)$$

Quality Assurance/Quality Control

Quality Assurance: Collection and Preparation of Core Samples

The samples for core 079 were collected using a benthos coring device. When the core was extruded, the outer smeared portion was removed using a stainless steel ring to prevent contamination of sediments from above (following the procedure outlined by Delorme, 1991).

The samples were freeze-dried using a standard procedure. Minimum loss of water from each sample was achieved by keeping tight lids on the vials before weighing and freeze drying. There was no transfer of sediments from the vials until freeze-drying was complete and the dry weights obtained.

Test runs for quality control on the alpha spectrometry equipment were last done in January, 1996.

Quality Control: Contamination and Method Checks

Blanks (no sample, no spike), were run through the same analytical procedures as samples, to determine if there was contamination from analytical reagents. Blanks, prepared at the same time as the sediment samples, exhibited a background activity of 0.03 dpm when run in all detectors, an activity comparable to empty sample holders.

Yield tracer solutions (no sediment sample) were also run through the analytical procedure. No counts above background were detectable in the ^{210}Po region of the spectra for disks prepared using only the spike (no sample), indicating no polonium (^{210}Po) contamination in the analyses from spike solutions.

Quality Assurance: System Checks

The alpha spectrometer has been monitored since May of 1988. Sample chambers are examined on a monthly basis for contamination. Empty sample holders give a background count rate of 0.01 dpm which equals the equipment specifications.

RESULTS

Table 1 lists the ^{210}Po activities for the 23 samples prepared for core 079. Figure 3 depicts the ^{210}Po activity profile with depth and cumulative dry weight. The symbols used in figure 3 indicate which detector was used during sample analysis. Circles, triangles and squares represent detectors 3, 2 and 1 respectively.

Table 1. Activity of ^{210}Po in Core 079 Sediment.

Sample	Cum. Dry Wt. g/cm^2	Uncomp. Mid Depth cm	^{210}Po dpm/g	DET No.
1	0.30	0.74	12.8	1
3	1.02	3.97	13.4	2
5	1.73	7.39	11.8	2
7	2.57	11.11	10.3	3
9	3.37	14.89	10.4	2
11	4.31	19.03	9.6 ± 0.3	1/2/3
11R	4.31	19.03	9.3 ± 0.1	1/2/3
11R2	4.31	19.03	9.6 ± 0.1	1/2/3
13	5.21	23.27	8.9	3
15	6.16	27.50	9.4	1
17	7.09	31.75	8.4	2
19	8.12	36.28	7.2	3
20	8.60	38.58	7.5	3
21	9.13	40.91	6.8	3
22	9.69	43.37	6.5	1
26	12.29	54.57	4.8	2
30	15.07	66.16	4.0	1
31	15.72	68.91	5.9 ± 0.1	1/2/3
31R	15.72	68.91	5.8 ± 0.2	1/2/3
31R2	15.72	68.91	5.9 ± 0.3	1/2/3
33	16.88	73.97	5.4	1
35	18.02	79.07	5.1	3
38	19.78	86.53	6.0	1

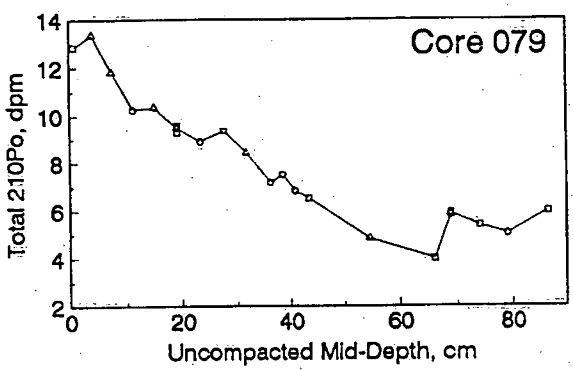
Figure 3 shows samples 26 and 30 to have depressed activity values relative to samples deeper in the core. These samples are also located in the zone of decreased porosity observed in Figure 2. The depressed porosity likely arises from an increase in sandy material. This type of material does not retain ^{210}Po as well as organic matter and clay minerals, thus leading to depressed activity. Data from samples 26 and 30 were not used in the final analysis.

Reproducibility of Results

Two slices from core 079 were chosen to have the analysis for ^{210}Po repeated. These are listed in Table 2. The ^{210}Po activities are given in Table 1.

Table 2 Reproducibility of St. Lawrence River analyses.

Core	Sample	Uncompacted Mid Depth	^{210}Po activity Mean ±Std Deviation
079	11	19.0	9.5 ± 0.1
	31	68.9	5.9 ± 0.1



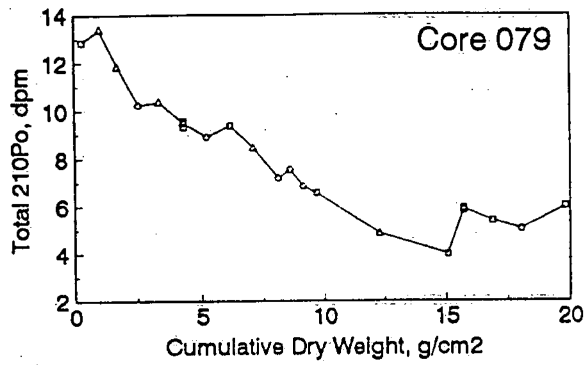


Figure 3. Distribution of Total ^{210}Po activity in $dpm \cdot g^{-1}$ in relation to uncompacted mid-depth and cumulative dry weight for core 079.

During the analysis of the St. Lawrence River core, a concern arose as to the determination of background. The activity measured in the lower portion of core 079 was high in comparison to other cores from the same region. The core site is not located in an area where high background activity might be natural (ie granitic bedrock), nor is it located near a known source of isotopic contamination (ie uranium processing plant). To ascertain wether core 079 was long enough to have reached background activity levels, three cores acquired from nearby sites were tested for background activity. The activity measured from the bottommost samples in these cores (5.4, 4.9, and 5.4) were similar to that of core 079. Unfortunately these cores were not much longer than core 079, thus there was no guarantee that these values reflected true background.

Data analysis using the CIC and CRS models was performed assuming that the activity profile described decay to background, even though background activity could not be confirmed.

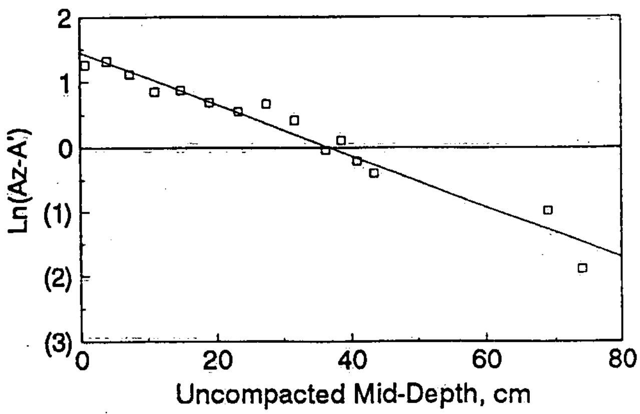


Figure 4. The distribution of uncompacted mid-depth against $\ln(A_z - A')$ for core 079. The y intercept of the regression line = 1.4548, the slope = -0.0396.

^{210}Pb Analysis of St. Lawrence River core 079, using the CIC model.

For the first CIC model, the unsupported activity is plotted against uncompacted mid-depth (Figure 4) using the expanded equation (6). Based on the graphical solution, the y-intercept is $\ln(P/\omega)$ = 1.4548 and the slope of the line (λ/S_o) is -0.0396 (see Appendix D). Samples 1 to 15 were used to calculate an average sedimentation rate of 0.79 $cm \cdot yr^{-1}$, an average mass sedimentation rate of 0.16 $g \cdot cm^{-2} \cdot yr^{-1}$ and a flux of 0.68 $pCi \cdot cm^{-2} \cdot yr^{-1}$. The mean dates calculated for each core section, based on a division of the uncompacted mid-depth by the sedimentation rate (equation 3), are given in Appendix G. The '±' values are two standard deviations based on data calculated for the top, bottom, and mid-depth of the sample.

For the second CIC model, the unsupported activity is plotted against cumulative dry weight (Figure 5) using the expanded equation (6a). Based on the graphical solution, the y-intercept is $\ln(P/\omega)$ = 1.4266 and the slope of the line (λ/ω) is -0.1771 (see Appendix E). Samples 1 to 15 were used to calculate an average mass sedimentation rate of 0.18 $g \cdot cm^{-2} \cdot yr^{-1}$ and a flux of 0.73

$pCi \cdot cm^{-2} \cdot yr^{-1}$. The dates calculated for each core section, based on a division of the cumulative dry weight by the mass sedimentation rate (equation 3a) are given in Appendix G. The '±' values are two standard deviations based on data calculated for the top, bottom, and mid-section of the sample.

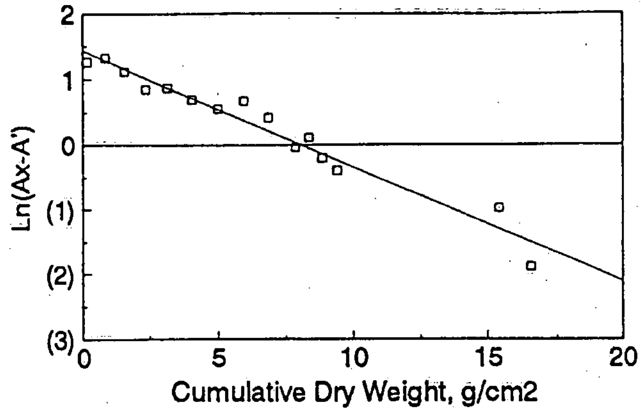


Figure 5. The distribution of cumulative dry weight against $\ln(A_x - A')$ for core 079. The y intercept of the regression line = 1.4266, the slope = -0.1771.

Ideally, the CIC1 and CIC2 models should give almost identical results. A difference in the mass sedimentation rates and atmospheric fluxes determined from the CIC1 and CIC2 models may indicate a problem in the calculation of uncompacted mid-depth. A comparison of the mass sedimentation and atmospheric flux rates for this core shows good agreement.

^{210}Pb Analysis of St. Lawrence River core 079, using the CRS model.

For the CRS model, the unsupported activity is plotted against cummulative dry weight (Figure 3). The profile is integrated to determine B(0) and B(x) and calculate time (see Appendix F) according to equation 20. Since not all samples were analyzed for ^{210}Pb activity, a multiple regression analysis was performed to obtain the dates for each core section as given in Appendix G. Samples 1 to 16 were used in this example to calculate an average mass sedimentation rate of 0.16 ± 0.03 $g \cdot cm^{-2} \cdot yr^{-1}$ and flux of 0.72 $pCi \cdot cm^{-2} \cdot yr^{-1}$. The variation in mass sedimentation rate in core 079 is illustrated in figure 6.

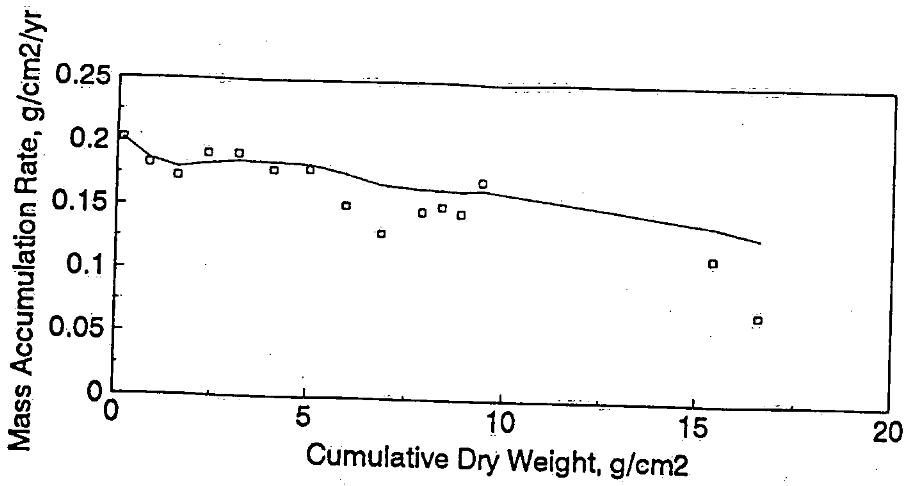


Figure 6. Plot of mass sedimentation rate versus cumulative dry weight for core 079. Points represent mass sedimentation rates determined from integrated area defined by activity and cumulative dry weight for the sample, the line represents the running mean of the mass sedimentation rate.

Comparison of CIC and CRS ^{210}Pb Analysis.

Table 3 lists mass sedimentation and atmospheric flux rates as calculated from the CIC and CRS models. The rates are in good agreement. The year corresponding to individual core sections (Appendix G) as determined by the CIC and CRS models are plotted against cumulative dry weight in Figure 7. Figure 7 shows a very close agreement between the two models down to an approximate compacted depth of 23 cm or a year of 1935. This indicates that the assumption of a 'constant sedimentation rate' for the CIC model is valid from a depth of 23 cm (1935) to the surface. Below 23 cm, a change in activity and porosity indicate a variation in source material which may have been accompanied by a variable sedimentation rate.

Table 3. Summary of Mass Sedimentation Rate and Atmospheric Flux.

Model	Average Mass Sedimentation Rate $g \cdot cm^{-2} \cdot yr^{-1}$	Atmospheric Flux $pCi \cdot cm^{-2} \cdot yr^{-1}$
CIC1	0.16	0.68
CIC2	0.18	0.73
CRS	0.16 ± 0.033*	0.72

* Based on incremental mass sedimentation rates (Appendix F)

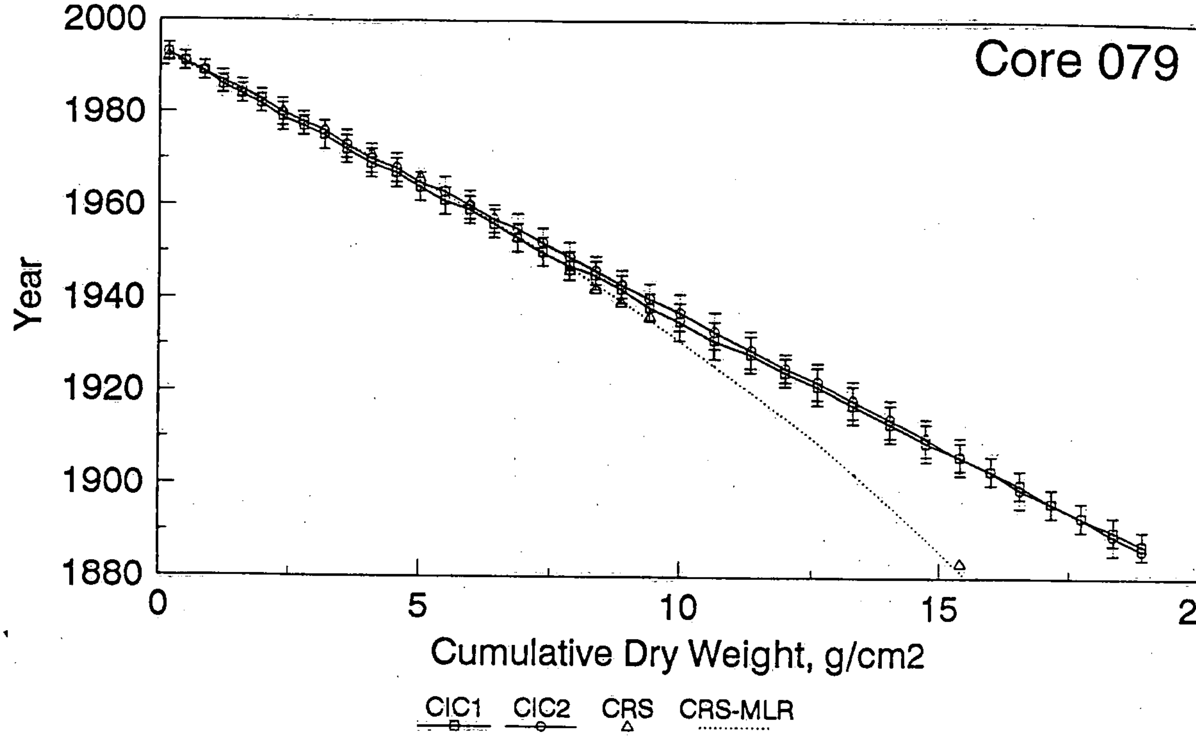


Figure 7. Plot of the Year determined from CIC (squares and circles)/CR (triangles) models versus cumulative dry weight for Core 079.

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Turner, L.J. and L.D. Delorme. 1988b. ^{210}Pb dating of lacustrine sediments from Lake St. Clair, (cores 140 and 144). National Water Research Institute, Burlington, Ontario, Technical Note LRB-88-10, 13p.

Appendices

Appendix A: Wet and dry weights for core 079.

079 Core Number Station 3 Core 1
34.9416 Surface area cm^2, 6.67 cm Tube diameter
19.0117 Surface area cm^2, 4.92 cm Cutter diameter
0 NUMBER OF SAMPLES BELOW THE SURFACE BEFORE THE DIAMETER CHANGES TO CUTTER DIAMETER; IF "ZERO" SURFACE AREA =19.0117 OR VALUE OF LINE 3.

Sample Number	Wet* Wt.	Dry* Wt.	Vial Wt.	Spec. Grav.
1	42.18	18.11	12.36	2.51**
2	38.90	19.11	12.57	2.51
3	40.11	19.24	12.20	2.51
4	37.55	19.03	12.32	2.51
5	37.95	19.41	12.52	2.51**
6	39.59	20.15	12.51	2.51
7	41.23	20.80	12.56	2.52
8	38.60	19.86	12.45	2.52
9	38.84	20.59	12.81	2.53
10	40.53	21.42	12.74	2.53**
11	41.16	21.17	11.92	2.53
12	41.00	21.25	12.18	2.52
13	38.16	20.36	12.38	2.52
14	43.19	21.90	12.39	2.52
15	39.91	20.75	12.15	2.51**
16	39.42	20.76	12.15	2.51
17	39.67	20.95	11.88	2.51
18	39.94	20.04	10.43	2.52
19	39.97	20.41	10.46	2.52
20	38.82	21.32	12.21	2.52**
21	41.16	22.79	12.66	2.53
22	41.58	22.83	12.16	2.53
23	43.09	24.47	12.69	2.54
24	42.53	23.91	10.48	2.55
25	44.31	25.01	11.89	2.56**
26	39.60	21.52	10.34	2.55
27	39.97	22.34	10.32	2.55
28	44.76	24.34	10.40	2.54
29	45.56	25.93	12.09	2.54
30	45.96	25.66	12.75	2.54**
31	46.75	22.77	10.35	2.52
32	39.42	20.44	10.42	2.49
33	45.34	22.58	10.46	2.47
34	40.82	20.99	10.47	2.45
35	44.91	23.59	12.60	2.43**
36	47.89	24.14	12.01	2.45
37	37.90	20.82	12.41	2.47
38	49.85	25.30	12.28	2.49**

*Includes Vial Weight

**Measured specific gravity. Other values calculated by linear regression.

Appendix B: Calculation of porosity and uncompacted depths given sample wet and dry weights, (Delorme, 1991) and specific gravity for core 079. Time in years calculated from CIC1 sedimentation rate data.

Samp Numb	Wet Wt. g	Dry Wt. g	Cumm. Dry Wt g/cm^2	Water Cont. cm^3	Sed. Vol. cm^3	Total Vol. cm^3	Comp. Thick cm	Comp. Depth cm	Comp. Mid-pt cm	Sample Poros. %	Uncomp Thick. cm	Uncomp Depth cm	Uncomp Mid-pt cm	Time B.P. Years
1	29.82	5.76	0.30	24.06	2.29	26.36	1.39	1.39	0.69	91.31	1.47	1.47	0.74	0
2	26.33	6.54	0.65	19.79	2.60	22.39	1.18	2.56	1.98	88.38	1.63	3.10	2.29	2
3	27.91	7.05	1.02	20.86	2.81	23.67	1.24	3.81	3.19	88.15	1.73	4.83	3.97	5
4	25.23	6.71	1.37	18.52	2.67	21.19	1.11	4.92	4.37	87.39	1.69	6.52	5.68	7
5	25.43	6.89	1.73	18.54	2.74	21.29	1.12	6.04	5.48	87.11	1.73	8.25	7.39	9
6	27.07	7.64	2.13	19.43	3.04	22.47	1.18	7.23	6.63	86.47	1.87	10.12	9.19	11
7	28.67	8.24	2.57	20.43	3.27	23.70	1.25	8.47	7.85	86.19	1.97	12.09	11.11	14
8	26.15	7.40	2.96	18.75	2.94	21.68	1.14	9.61	9.04	86.46	1.83	13.92	13.01	16
9	26.04	7.78	3.37	18.26	3.08	21.33	1.12	10.73	10.17	85.56	1.93	15.85	14.89	18
10	27.79	8.68	3.82	19.11	3.43	22.54	1.19	11.92	11.33	84.79	2.09	17.94	16.90	21
11	29.24	9.25	4.31	19.99	3.66	23.65	1.24	13.16	12.54	84.52	2.18	20.12	19.03	24
12	28.82	9.07	4.79	19.75	3.59	23.35	1.23	14.39	13.78	84.61	2.15	22.27	21.20	26
13	25.78	7.98	5.21	17.80	3.17	20.97	1.10	15.49	14.94	84.88	1.99	24.26	23.27	29
14	30.80	9.51	5.71	21.29	3.78	25.07	1.32	16.81	16.15	84.92	2.20	26.46	25.36	32
15	27.77	8.60	6.16	19.16	3.43	22.59	1.19	18.00	17.41	84.83	2.09	28.55	27.50	34
16	27.27	8.61	6.61	18.66	3.43	22.08	1.16	19.16	18.58	84.48	2.10	30.65	29.60	37
17	27.79	9.07	7.09	18.72	3.61	22.33	1.17	20.34	19.75	83.84	2.20	32.85	31.75	40
18	29.50	9.60	7.59	19.90	3.82	23.72	1.25	21.59	20.96	83.90	2.26	35.11	33.98	43
19	29.51	9.96	8.12	19.56	3.96	23.51	1.24	22.82	22.20	83.18	2.34	37.45	36.28	46
20	26.60	9.10	8.60	17.50	3.61	21.11	1.11	23.93	23.38	82.88	2.25	39.70	38.58	49
21	28.50	10.13	9.13	18.38	4.01	22.38	1.18	25.11	24.52	82.10	2.42	42.12	40.91	52
22	29.42	10.66	9.69	18.76	4.21	22.96	1.21	26.32	25.71	81.68	2.50	44.62	43.37	55
23	30.41	11.78	10.31	18.63	4.63	23.26	1.22	27.54	26.93	80.08	2.72	47.34	45.98	58
24	32.05	13.43	11.02	18.62	5.26	23.89	1.26	28.80	28.17	77.97	3.01	50.35	48.85	62
25	32.42	13.12	11.71	19.30	5.13	24.42	1.28	30.08	29.44	79.00	2.91	53.26	51.81	65
26	29.26	11.18	12.29	18.08	4.38	22.45	1.18	31.26	30.67	80.51	2.62	55.88	54.57	69
27	29.65	12.02	12.93	17.63	4.72	22.35	1.18	32.44	31.85	78.90	2.81	58.69	57.29	72
28	34.36	13.93	13.66	20.43	5.47	25.90	1.36	33.80	33.12	78.86	3.01	61.70	60.20	76
29	33.47	13.84	14.39	19.63	5.45	25.08	1.32	35.12	34.46	78.27	3.04	64.74	63.22	80
30	33.21	12.91	15.07	20.30	5.09	25.39	1.34	36.46	35.79	79.95	2.84	67.58	66.16	84

Appenix B continued.

Samp Numb	Wet Wt. g	Dry Wt. g	Cumm. Dry Wt g/cm^2	Water Cont. cm^3	Sed. Vol. cm^3	Total Vol. cm^3	Comp. Thick cm	Comp. Depth cm	Comp. Mid-pt cm	Sample Poros. %	Uncomp Thick. cm	Uncomp Depth cm	Uncomp Mid-pt cm	Time B.P. Years
31	36.41	12.42	15.72	23.98	4.94	28.92	1.52	37.98	37.22	82.92	2.66	70.24	68.91	87
32	29.00	10.02	16.25	18.98	4.02	23.00	1.21	39.19	38.58	82.54	2.39	72.63	71.44	90
33	34.88	12.11	16.88	22.77	4.89	27.66	1.46	40.64	39.91	82.31	2.67	75.30	73.97	94
34	30.34	10.51	17.44	19.83	4.28	24.11	1.27	41.91	41.28	82.24	2.49	77.79	76.55	97
35	32.31	10.99	18.02	21.32	4.52	25.83	1.36	43.27	42.59	82.52	2.55	80.34	79.07	100
36	35.88	12.13	18.65	23.75	4.94	28.69	1.51	44.78	44.02	82.77	2.66	83.00	81.67	103
37	25.49	8.41	19.10	17.08	3.40	20.48	1.08	45.86	45.32	83.40	2.15	85.15	84.08	106
38	37.57	13.02	19.78	24.55	5.22	29.77	1.57	47.42	46.64	82.46	2.76	87.91	86.53	110

Appendix C. Specific gravity determination.

The specific gravities ($g \cdot cm^{-3}$) of St. Lawrence River sediments were determined using an automated Accupyc pycnometer (Micromeritics, 1992).

Sample	No. of Tests	Uncompacted Mid Depth	Specific Gravity	Mean
1	5	0.74	2.513 ± 0.002	
5	5	7.39	2.510 ± 0.005	
10	5	16.90	2.530 ± 0.001	
15	5	27.50	2.511 ± 0.002	
20	5	38.58	2.518 ± 0.001	
25	5	51.81	2.559 ± 0.001	
30	5	66.16	2.535 ± 0.002	
35	5	79.07	2.434 ± 0.002	
38	5	86.53	2.494 ± 0.001	2.512 ± 0.032

Appendix D. Lead Sedimentation Rate Analysis, CIC1 Model.

$$\ln (A - A') = \ln (4.2835) - 3.958E\text{-}2\ (Z) \qquad R = -0.976$$

where $(A - A')$ = unsupported ^{210}Pb in $pCi \cdot g^{-1}$,
and Z = uncompacted depth in cm.
based on data from lines 1 to 15

Specific Gravity = 2.512 $g \cdot cm^{-3}$ P/ω = 4.283 ω = 0.158

The initial porosity at the sediment/water interface is 92.01

Atmospheric flux rate at the time of collection 1993.597 is 1.501 $dpm \cdot cm^{-2} \cdot yr^{-1}$ or 0.676 $pCi \cdot cm^{-2} \cdot yr^{-1}$

Supported ^{226}Ra activity = 2.275 $pCi \cdot g^{-1}$ or 5.050 $dpm \cdot g^{-1}$

Sedimentation Rate = 0.786 $cm \cdot yr^{-1}$

Mass Sedimentation Rate = 0.158 $g \cdot cm^{-2} \cdot yr^{-1}$

SUMMARY OF ^{210}Pb ANALYSES

Uncomp Depth cm.	Porosity	Total ^{210}Pb $dpm \cdot g^{-1}$	Total ^{210}Pb $pCi \cdot g^{-1}$	Unsupp. ^{210}Pb $dpm \cdot g^{-1}$	Unsupp. ^{210}Pb $pCi \cdot g^{-1}$	Sed. Rate $cm \cdot yr^{-1}$	Years (*)
0.74	0.9131	12.855	5.791	7.805	3.516	0.7647	1994
3.97	0.8815	13.366	6.021	8.316	3.746	0.7398	1988
7.39	0.8711	11.834	5.331	6.784	3.056	0.7530	1984
11.11	0.8619	10.251	4.618	5.201	2.343	0.7171	1978
14.89	0.8556	10.351	4.663	5.301	2.388	0.7499	1974
19.03	0.8452	9.492	4.276	4.442	2.001	0.7137	1967
23.27	0.8488	8.904	4.011	3.854	1.736	0.7519	1963
27.50	0.8483	9.373	4.222	4.323	1.947	0.7275	1956
31.75	0.8384	8.434	3.799	3.384	1.524	0.7312	1950
36.28	0.8318	7.181	3.235	2.131	0.960	0.7050	1942
38.58	0.8288	7.519	3.387	2.469	1.112	0.7440	1942
40.91	0.8210	6.846	3.084	1.796	0.809	0.7200	1937
43.37	0.8168	6.540	2.946	1.490	0.671	0.7087	1932
68.91	0.8292	5.886	2.651	0.836	0.377	0.6438	1887
73.97	0.8231	5.385	2.426	0.335	0.151	0.6496	1880
79.07	0.8252	5.050	2.275	0.000	0.000	0.6740	1876
86.53	0.8246	5.998	2.702	0.948	0.427		

(*) Year calculated using the sedimentation rate of the sample

Appendix E. Lead Sedimentation Rate Analysis, CIC2 Model.

$\ln (A - A') = \ln (4.1648) - 0.1771 (X)$ $R = -0.977$

where $(A - A')$ = unsupported ^{210}Pb in $pCi \cdot g^{-1}$,
and X = cumulative dry weight in $g \cdot cm^{-2}$
based on data from lines 1 to 15

Specific Gravity = 2.512 $g \cdot cm^{-3}$ P/ω = 4.165 ω = 0.176

The initial porosity at the sediment/water interface is 92.01

Atmospheric flux rate at the time of collection 1993.579 is 1.625 $dpm \cdot cm^{-2} \cdot yr^{-1}$ or 0.732 $pCi \cdot cm^{-2} \cdot yr^{-1}$

Supported ^{226}Ra activity = 2.275 $pCi \cdot g^{-1}$ or 5.050 $dpm \cdot g^{-1}$

Mass Sedimentation Rate = 0.176 $g \cdot cm^{-2} \cdot yr^{-1}$

SUMMARY OF ^{210}Pb ANALYSES

MidSam Cum. DryWt. $g \cdot cm^{-2}$	Porosity	Total ^{210}Pb $dpm \cdot g^{-1}$	Total ^{210}Pb $pCi \cdot g^{-1}$	Unsupp. ^{210}Pb $dpm \cdot g^{-1}$	Unsupp. ^{210}Pb $pCi \cdot g^{-1}$	Years (*)
0.15	0.9131	12.855	5.791	7.805	3.516	1994
0.83	0.8815	13.366	6.021	8.316	3.746	1989
1.55	0.8711	11.834	5.331	6.784	3.056	1985
2.35	0.8619	10.251	4.618	5.201	2.343	1980
3.16	0.8556	10.351	4.663	5.301	2.388	1976
4.07	0.8452	9.492	4.276	4.442	2.001	1970
5.00	0.8488	8.904	4.011	3.854	1.736	1965
5.93	0.8483	9.373	4.222	4.323	1.947	1960
6.85	0.8384	8.434	3.799	3.384	1.524	1955
7.86	0.8318	7.181	3.235	2.131	0.960	1949
8.36	0.8288	7.519	3.387	2.469	1.112	1946
8.86	0.8210	6.846	3.084	1.796	0.809	1943
9.41	0.8168	6.540	2.946	1.490	0.671	1940
15.40	0.8292	5.886	2.651	0.836	0.377	1906
16.56	0.8231	5.385	2.426	0.335	0.151	1899
17.73	0.8252	5.050	2.275	0.000	0.000	1893
19.44	0.8246	5.998	2.702	0.948	0.427	

(*) Year calculated using the mass sedimentation rate of the sample

Appendix F. Lead Sedimentation Rate Analysis, CRS Model.

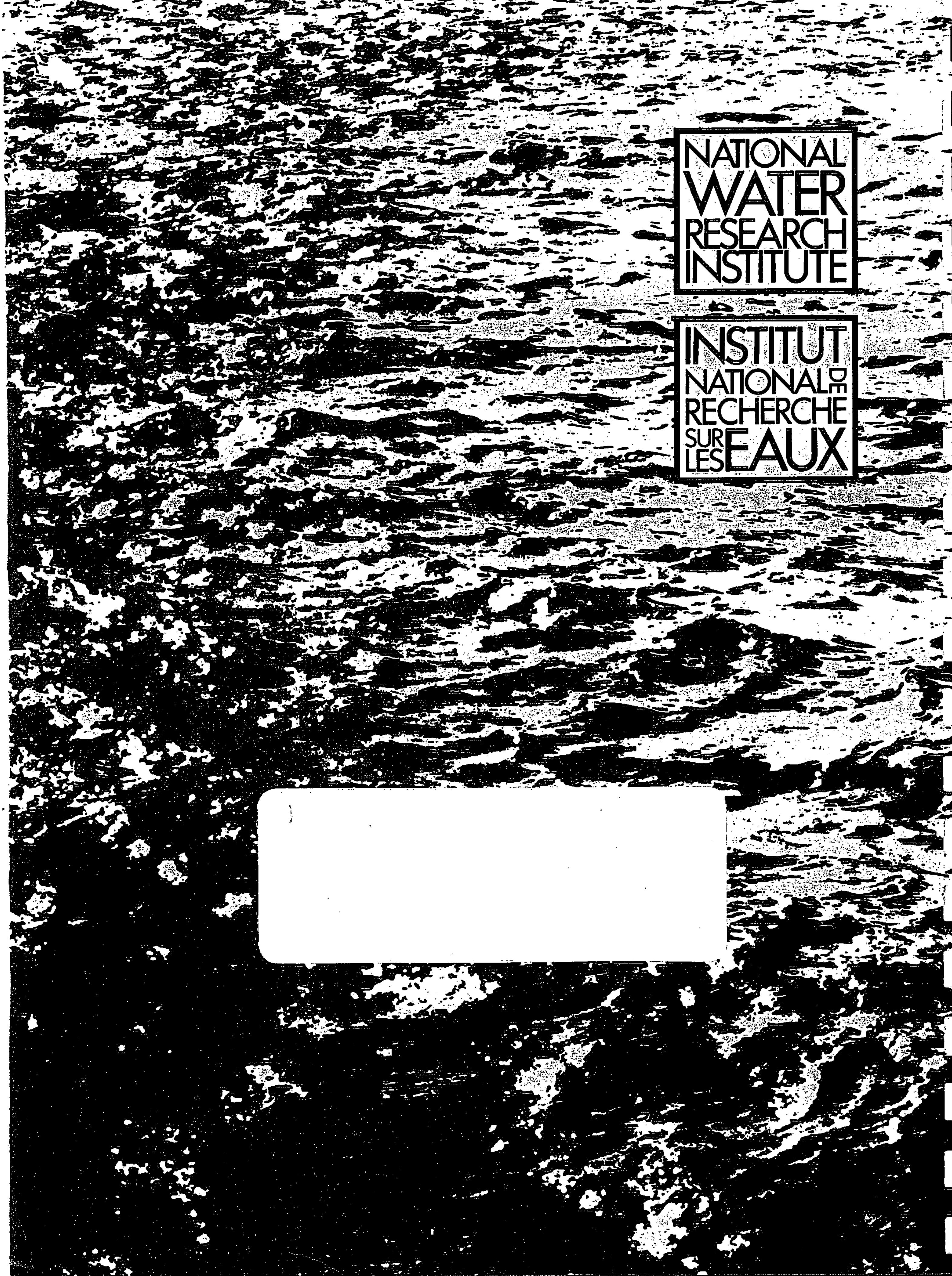
Depth Uncomp Mid-Pt cm	Cum. Dry Wt g/cm2	MidScn Cum. Dry Wt g/cm2	Unsupp. Activity pCi/g	Area pCi/cm2	Cum. Area pCi/cm2	Time B.P.* Years	Cum.Avg Mass SedRate g/cm2/yr	Date	Mass SedRate g/cm2/yr
0.74	0.30	0.15	3.516	0.527	0.527	0.741	0.202	1992	0.202
3.97	1.02	0.83	3.516	2.487	3.014	4.487	0.186	1989	0.183
7.39	1.73	1.55	3.746	2.432	5.446	8.627	0.180	1984	0.173
11.11	2.57	2.35	3.056	2.159	7.606	12.812	0.183	1980	0.191
14.89	3.37	3.16	2.343	1.928	9.533	17.073	0.185	1976	0.191
19.03	4.31	4.07	2.388	1.975	11.508	22.117	0.184	1971	0.178
23.27	5.21	5.00	2.001	1.747	13.255	27.353	0.183	1966	0.179
27.50	6.16	5.93	1.736	1.722	14.977	33.514	0.177	1960	0.152
31.75	7.09	6.85	1.947	1.588	16.566	40.481	0.169	1953	0.131
36.28	8.12	7.86	1.524	1.248	17.814	47.265	0.166	1946	0.148
38.58	8.60	8.36	0.960	0.523	18.337	50.598	0.165	1942	0.152
40.91	9.13	8.86	1.112	0.485	18.822	54.031	0.164	1939	0.147
43.37	9.69	9.41	0.809	0.403	19.226	57.193	0.165	1936	0.172
68.91	15.72	15.40	0.671	3.135	22.361	109.614	0.140	1883	0.114
73.97	16.88	16.56	0.377	0.309	22.670	126.298	0.131	1867	0.070
							0.172	Average	0.159
							0.018	Std.Dev.	0.033

*B.P. = 1993
Based on data from lines 1 to 16
Total Area equals 23.12291
Atmospheric flux rate at the time of collection 1993.597 is 0.72 $pCi \cdot cm^{-2} \cdot yr^{-1}$

Appendix G. Mean date calculated for each core slice.

Sample	Uncompacted Mid Depth in cm	Cum. Dry Wt. g-cm-2	Cum. Dry Wt. Mid Sam	CIC1 Year	CIC2 Year	CRS* Year
1	0.74	0.30	0.15	1993 ± 2	1993 ± 2	1992
2	2.29	0.65	0.47	1991 ± 2	1991 ± 2	1990
3	3.97	1.02	0.83	1989 ± 2	1989 ± 2	1989
4	5.68	1.37	1.19	1986 ± 2	1987 ± 2	1987
5	7.39	1.73	1.55	1984 ± 2	1985 ± 2	1985
6	9.19	2.13	1.93	1982 ± 2	1983 ± 2	1983
7	11.11	2.57	2.35	1979 ± 3	1980 ± 3	1980
8	13.01	2.96	2.76	1977 ± 2	1978 ± 2	1978
9	14.89	3.37	3.16	1975 ± 3	1976 ± 2	1976
10	16.90	3.82	3.59	1972 ± 3	1973 ± 3	1973
11	19.03	4.31	4.07	1969 ± 3	1970 ± 3	1971
12	21.20	4.79	4.55	1967 ± 3	1968 ± 3	1968
13	23.27	5.21	5.00	1964 ± 3	1965 ± 2	1965
14	25.36	5.71	5.46	1961 ± 3	1963 ± 3	1962
15	27.50	6.16	5.93	1959 ± 3	1960 ± 3	1959
16	29.60	6.61	6.39	1956 ± 3	1957 ± 3	1956
17	31.75	7.09	6.85	1953 ± 3	1955 ± 3	1953
18	33.98	7.59	7.34	1950 ± 3	1952 ± 3	1950
19	36.28	8.12	7.86	1947 ± 3	1949 ± 3	1947
20	38.58	8.60	8.36	1945 ± 3	1946 ± 3	1943
21	40.91	9.13	8.86	1942 ± 3	1943 ± 3	1940
22	43.37	9.69	9.41	1938 ± 3	1940 ± 3	1935
23	45.98	10.31	10.00	1935 ± 4	1937 ± 4	1931
24	48.85	11.02	10.67	1931 ± 4	1933 ± 4	1926
25	51.81	11.71	11.36	1928 ± 4	1929 ± 4	1920
26	54.57	12.29	12.00	1924 ± 3	1925 ± 3	1914
27	57.29	12.93	12.61	1921 ± 4	1922 ± 4	1909
28	60.20	13.66	13.30	1917 ± 4	1918 ± 4	1903
29	63.22	14.39	14.02	1913 ± 4	1914 ± 4	1896
30	66.16	15.07	14.73	1909 ± 4	1910 ± 4	1888
31	68.91	15.72	15.40	1906 ± 3	1906 ± 4	1881
32	71.44	16.25	15.99	1903 ± 3	1903 ± 3	
33	73.97	16.88	16.56	1900 ± 3	1899 ± 4	
34	76.55	17.44	17.16	1896 ± 3	1896 ± 3	
35	79.07	18.02	17.73	1893 ± 3	1893 ± 3	
36	81.67	18.65	18.33	1890 ± 3	1889 ± 4	
37	84.08	19.10	18.88	1887 ± 3	1886 ± 2	

* Calculation based on a Multiple Linear Regression with an R^2 of 0.9994 and a Standard Error of 0.9226.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