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^{137}Cs RADIOACTIVE DATING OF LAKE ONTARIO SEDIMENT CORES*

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ABSTRACT:

The distribution of ^{137}Cs in sediment cores from Lake Ontario provides estimates of the sediment accumulation rates. Geochronology with ^{210}Pb dating and distribution of Ambrosia (ragweed) pollen compare well with ^{137}Cs dating. These methods can determine with precision, changes in sedimentation occurring over the past 100 years or so. Typical sedimentation rates of 0.18-0.36 cm/yr were measured.

INTRODUCTION

An accurate knowledge of the sedimentation rate is of fundamental importance in studying and understanding modern sedimentry geochemical processes and lake development. In the past, experimental data on sedimentation rates has lacked the necessary accuracy and detail to study sediment-water exchanges in the upper 20 cm. In recent years, new radiometric techniques using ^{210}Pb and ^{137}Cs have been developed to study the sedimentation rate in the Great Lakes region.[1,2,3] Mathewes and D'Auria[4] have used the technique to date lake sediment in Western Canada and correlate their results with industrial pollutants found in the cores. Polynological methods have also been used to date sedimentation cores, since intensive regional forest clearing in the Great Lakes about 130 years ago, resulted in a marked increase in the abundance of Ambrosia (ragweed) and its pollen to lake sediments. These combined techniques allow one to date lake sediment cores with some precision over the last one-hundred years.

Recent environmental studies[5-10] of "industrially generated" polychlorinated hydrocarbons found in Great Lake sediments have been shown to have greatly increased only since 1940.

In the present study, Ge(Li) gamma-ray spectrosocopy was used to examine core samples of Lake Ontario sediments for their ^{137}Cs content in order to determine the average sedimentation rate. This information was compared with other studies using pollen, ^{210}Pb, and ^{137}Cs dating, and similar results have recently been used in determining the geochronology of environmental pollutants[4-9].

EXPERIMENTAL PROCEDURE

The sediment core samples were collected from Lake Ontario (See Fig. 1) and Lake Siskiwit (Isle Royal, Lake Superior). Core samples 15, 69 and 79 were taken by the Canadian Centre for Inland Waters (CCIW) in 1982, sample 589 in 1983, and the Lake Siskiwit samples by one of the authors, B.D. McVeety, in 1983. The cores were dried and separated into 2 cm sections before they were received. The samples extraction and clean up procedure is described in Ref. 11 for the hydrocarbons. It is estimated that greater than 99% of the ^{137}Cs remained immobile in the samples. Each sample was weighed and placed in a cylindrical sample holder whose geometry was well defined so that geometrical corrections for γ counting could be made.

^{137}Cs was detected by observing the 661.6 MeV (84.2% branching ratio) using Ge(Li) γ-ray spectroscopy. The 50 cc Ge(Li) detector was calibrated for energy and efficiency using standard NBS sources whose precisions were 2-3%. Typically, a sample was counted for about 8-12 hrs. Background was measured periodically as was the energy and efficiency calibrations. The data were stored in a 4096-channel multichannel analyzer. The ^{137}Cs peak was fit using a standard spectrum background subtract and peak integration. Statistical uncertainties of 1-10% add in quadrature with the efficiency ($\pm$2%), geometry ($\pm$2%), and sample weight ($\pm$1%) to yield total uncertainties of 3-10% in these measurements.

RESULTS AND DISCUSSION

The results of this study are listed in Table 1 where the pCi/g of ^{137}Cs content is listed for each of the core sections. These numbers are typical of the total ^{137}Cs content of lake core sediment, ranging from 1-30 pCi/g. The results from Table 1 are shown in Fig. 2. The samples from Love Canal (10 cm core) did not show an excess of ^{137}Cs above background, due probably to the fact that the canal is not a sediment basin and therefore cannot accumulate a high concentration of ^{137}Cs. These methods and techniques have been detailed in Refs. 12, 13, and 14, where radioactive fallout was routinely measured in air, water, and sediment samples. The background level of ^{137}Cs measured in this study was typically 10^{-2} γ/sec, which is about 10-20% of the maximum count rate observed.

The sedimentation rate was determined by defining the ^{137}Cs horizon by the year 1955 $\pm$2 yr. The ^{137}Cs observed in the environment today has resulted from the world-wide production from atomic bomb testing over the past 40 years or so. This fallout was dispersed into the troposphere and stratosphere and has collected in the biosphere and aquatic systems due to natural processes. Fig. 3 shows the annual deposition of ^{137}Cs to the great lakes surfaces estimated from the annual atmosphere flux of ^{137}Cs from fallout.[15] Although surface concentrations can be physically mixed due to simple diffusion or surface mixing, the effects on the ^{137}Cs horizon is not appreciably affected. The sedimentation rates determined in this study are listed in Table 2, where we compare our results with the previous results of ^{210}Pb, ^{137}Cs, and Ambrosia (pollen) dating methods. Our results are in good agreement with the previous results.[1,2,3]

The results plotted in Fig. 2 show a peak in the ^{137}Cs content between 1967 and 1970, well after the peak fallout in 1963. This supports the conjecture that fallout and pollutants continue to be deposited for many years after they are produced because of their lifetimes in the stratosphere, troposphere, and biosphere systems. This is demonstrated in the data of the ^{137}Cs body burden measured as a function of time. The mean body burden peaks approximately 1 year after the 1963 fallout peak, due mainly to the lifetime in the food chain. The estimated ^{137}Cs fallout flux on the Great Lakes was based on yearly fission-product production, not on measurements. The transport lifetime of four years affects a shift in the maximum, however, it does not affect the ^{137}Cs horizon. The yearly deposition totals are therefore composed of prompt and delayed-deposition components. The conceptualization of a major delayed-deposition mechanism in determining the geochronology of environmental pollutants such as sulfur in hydrocarbon fuels, could prove to be of much value in tracing such industrially-produced contaminants.

The transport of industrially produced chlorinated hydrocarbons[4-9] in the great lakes is less certain than that of ^{137}Cs, whose source and deposition is understood. The chlorinated hydrocarbons may originate from a combination of smoke stacks and drainage from industrial and urban wastes. However, the fact that appreciable concentrations of polychlorinated hydrocarbons were found in Lake Siskiwit core sediments, indicates that the source of those compounds was atmospheric transport formed by combustion of domestic and chemical waste.[5,6] The lake is 17 m higher than that in Lake Superior and isolated on Isle Royal so that drainage from industrial or urban wastes is impossible, making the atmosphere the only source. Combustion and air tranport therefore appears to be a major source of industrial produced pollutants in the environment.

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TABLE 1

Summary of ^{137}Cs Radioactive Dating of Lake Ontario Sediment Cores

Depth (cm)	^{137}Cs (pCi/g)			
	Core 15 (1982)	Core 69 (1983)	Core 79 (1983)	Core 589 (1984)
0-2	17.5	14.1	11.8	17.9
2-4	15.1	16.2	21.6	18.8
4-6	3.65	22.1	28.7	11.3
6-8	0.885	15.7	23.3	2.61
8-10	-	3.21	9.41	2.92
10-12	-	-	2.31	-
12-14	-	-	-	-
14-16	-	-	-	-

TABLE 2

Comparison of Approximate
Linear Sedimentation Rates (cm/yr)

Sediment Core Site* **	Dating Method ^{210}Pb	^{137}Cs	Pollen
79	-	0.38	-
KB (Robbins)	0.28	0.29	0.31
KB (Kemp)	-	-	0.96
69	-	0.31	-
E-30 (Kemp)	-	-	0.33
CB (Kemp)	-	-	0.62
589	-	0.28	-
WB (Robbins)	0.34	0.31	0.12
WB (Kemp)	-	-	0.35
15	-	0.28	-
M14 (Kemp)	-	-	0.13
Lake Siskiwit	-	0.18	-

* See Figures 1 for site location
** Ref. 2 and 3

FIGURE OF CAPTIONS

Figure 1: Location of Core Samples Reported in the Paper and Listed in Tables 1 and 2.

Figure 2: ^{137}Cs Activity (pCi/g) for the Sediment Core Samples Reported in this Paper as a Function of Depth (cm).

Figure 3: Estimated Temporal Distribution of the ^{137}Cs Atmospheric Flux (pCi/yr·cm^2) over the Great Lakes Region. The hatched areas are corrected for decay to 1983 and represent amounts of ^{137}Cs remaining.

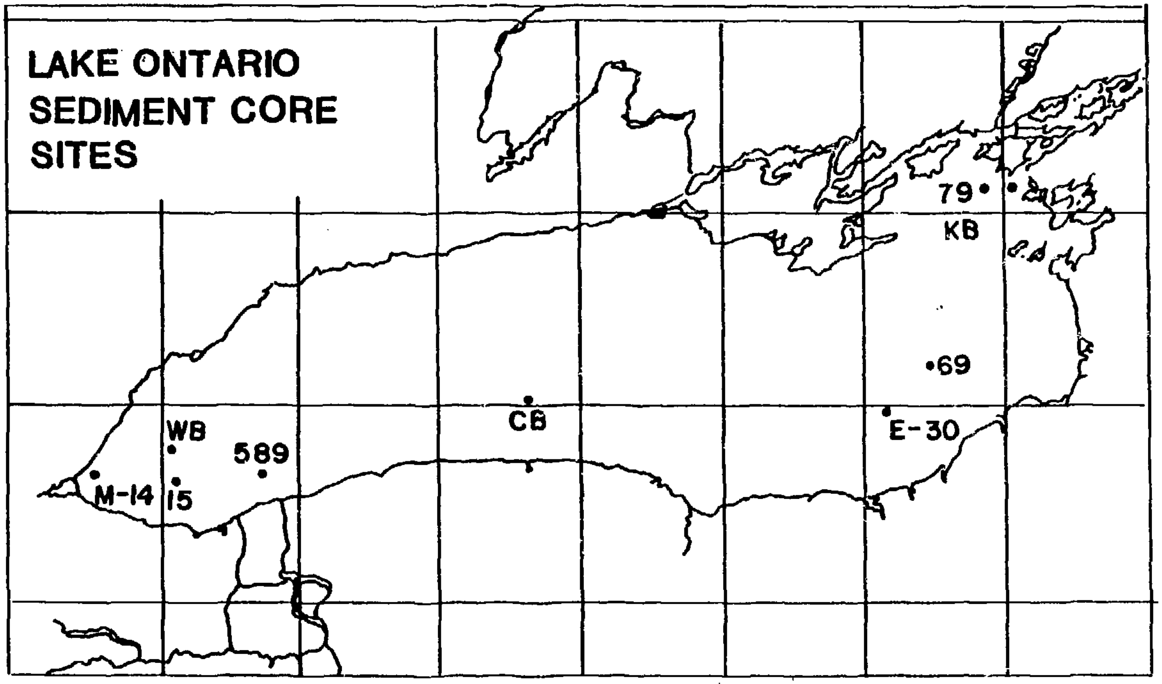
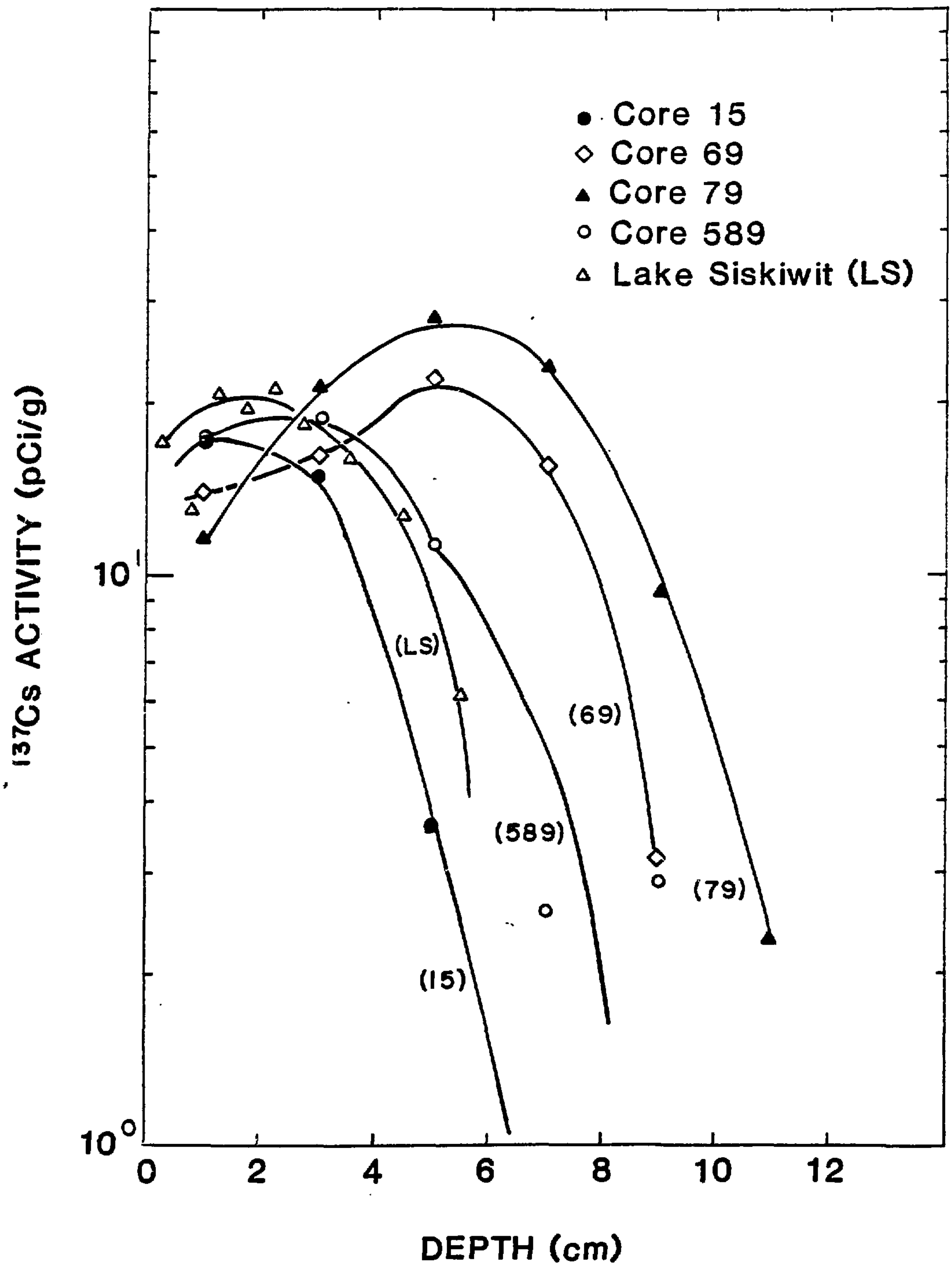


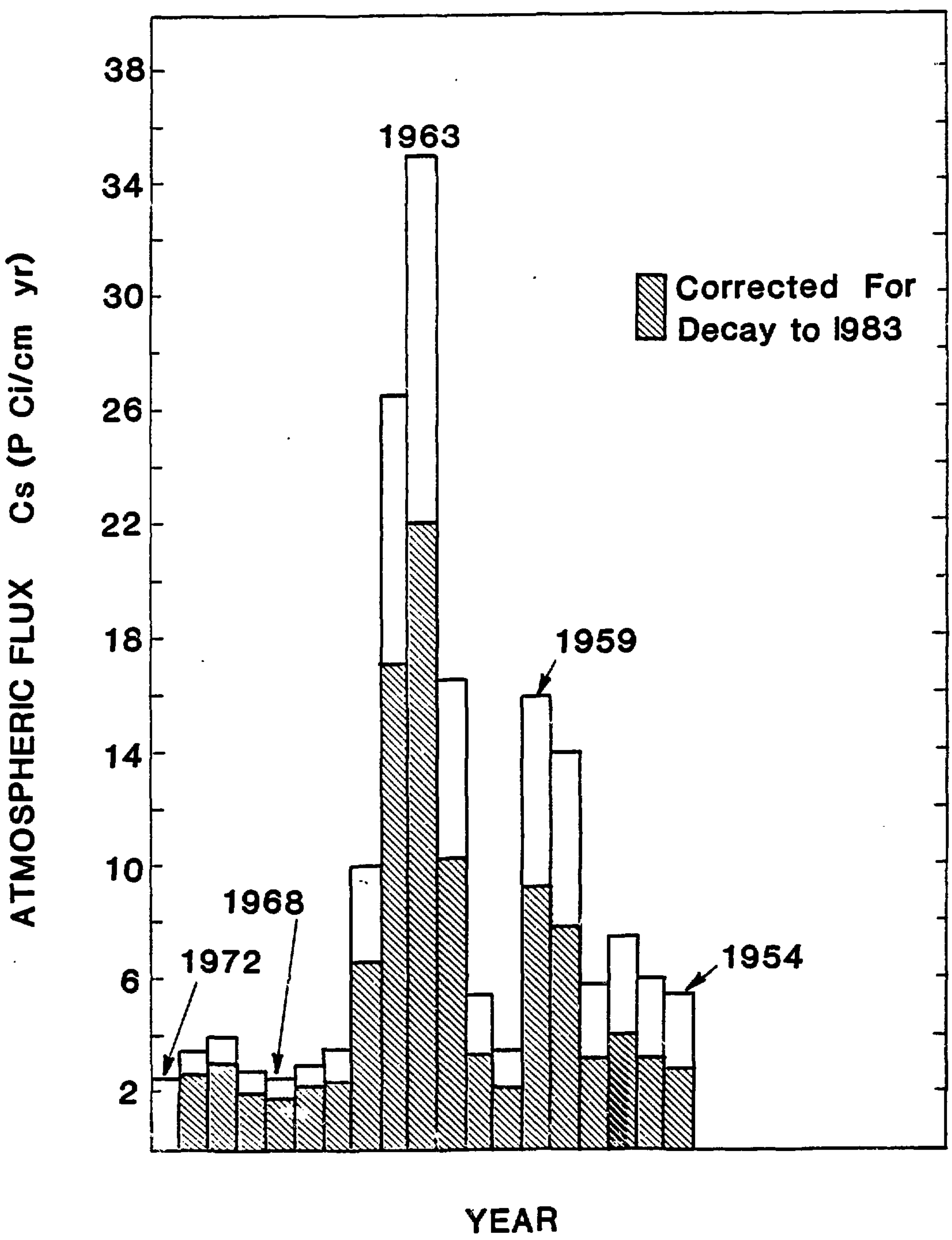
FIGURE 1

FIGURE 2



Core 15
Core 69
Core 79
Core 589
Lake Siskiwit (LS)
^{137}Cs ACTIVITY (pCi/g)
10^1
10^0
(LS)
(69)
(589)
(79)
(15)
0
2
4
6
8
10
12
DEPTH (cm)

FIGURE 3



ATMOSPHERIC FLUX Cs (P Ci/cm yr)
38
34
30
26
22
18
14
10
6
2
1963
1959
1954
1968
1972
Corrected For Decay to l983
YEAR