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Spatial and Temporal Variations
of Chromium in Sediments
of the Great Lakes

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Sangjo Jeong

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Spatial and Temporal Variations of Chromium in Sediments of the Great Lakes

By

Sangjo Jeong

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ABSTRACT

SPATIAL AND TEMPORAL VARIATIONS OF CHROMIUM IN SEDIMENTS OF THE GREAT LAKES

By

Sangjo Jeong

Trace metal loadings are known to have increased in the Great Lakes ecosystem as a result of anthropogenic inputs. There is little information specifically addressing chromium loadings. Therefore, the vertical concentration profiles of chromium in sediment cores were measured from Lakes Superior, Michigan, and Ontario in an attempt to determine spatial and temporal variations. Sediment cores were sectioned under air at 0.5 to 1 cm increments to depths of approximately 40 cm. Chromium was extracted from the sediment by HNO_3 digestion in a microwave and its concentration determined in the leachate by atomic absorption spectroscopy. Sedimentation rates were determined by ^{210}Pb dating of the sediment cores.

Pre-industrial concentrations of chromium were determined and subtracted from total chromium concentrations to estimate anthropogenic concentrations. Chromium inventories and accumulation rates were then determined for each core. These values were adjusted for sediment focusing using ^{210}Pb derived focusing factors. Sediment metal accumulation rates were compared to estimated atmospheric deposition rates obtained from preview studies of the Great Lakes region.

The results are that pre-industrial concentrations of chromium are typical for soils in the Great Lakes region. Only Lake Ontario and Michigan exhibit anthropogenic enrichments of chromium in the sediments. Sediment profiles in

Lakes Ontario and Michigan indicate that the rates of anthropogenic chromium loading to the Great Lakes region is decreasing. When compared to sediment accumulation rates by -- (atmospheric accumulation rate/ focusing-corrected sediment accumulation rate) x 100 -- the following percentages are result : Lake Superior (6-15%), Lake Michigan (4-11%), and Lake Ontario (2-7%). Focusing corrected inventories are higher in Lake Ontario than Lake Michigan. However inventories are similar throughout depositional basins within each lake. The results are interpreted to indicate that there is a small atmospheric component to chromium inputs to the Great Lakes and that the relative importance of this input decreases from Lake Superior to Lake Ontario.

For the hope of peace in the Korean peninsula....

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

General Introduction

The Great Lakes basin (> 150,000 km^2) contains 20% of world's surface fresh water (excluding ice); is highly industrialized; and host 20% of the U.S. population and 60% of the Canadian population (Berg and Johnson, 1978; Heft, 1993). About 40 million people use the Great Lakes as a source of drinking water and for industrial, commercial, and recreational purposes. The hydrologic and morphometric features of the Great Lakes are shown in Figure 1 and Table 1, respectively.

One of the greatest concerns confronting the Great Lakes region is the contamination of water and air by persistent toxic substances (Arimoto, 1989). Heavy metals are toxic environmental pollutants and threaten not only aquatic life, but the quality of drinking water. High concentrations of trace elements such as Hg, Pb, and Cd in the surface sediments relative to the subsurface sediments in Lake Superior, Lake Michigan, and Lake Ontario are believed to be the result of the recent anthropogenic loading of these elements (Kemp et al., 1978). The predominant sources of chemical constituents in the Great Lakes are thought to be derived from the atmosphere (Schmidt and Andren, 1984; Eisenreich et al., 1986). Other sources are riverine input, direct industrial and municipal effluents, groundwater seepage, and coastal erosion.

The Great Lakes are particularly susceptible to atmospheric deposition of contaminants because of large ratios of surface area to basin area, long water residence times, and their location near and downwind of major industrial or urban

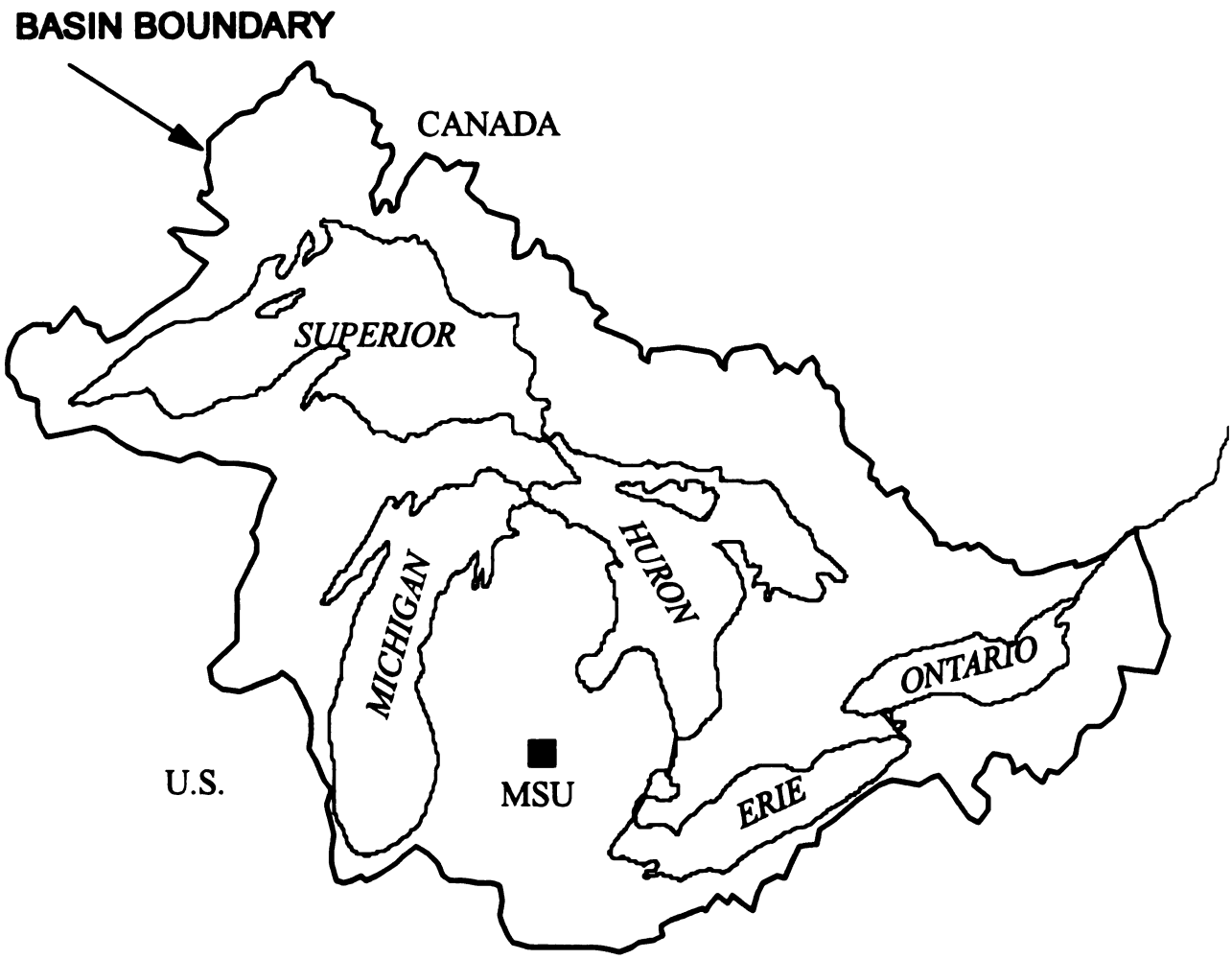

Figure 1. Basin boundary of the Great Lakes.

Table 1. Physical parameters of the Great Lakes (from Eisenreich et al., 1992b)

	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Drainage area (km^2)	127700	118100	133900	58790	70700
Surface Area (km^2)	82100	57800	59700	25700	19520
Bottom sediment area (km^2)	4.1	2.9	3.0	2.1	0.75
Mean depth (m)	149	85	59	19	86
Maximum depth (m)	406	281	228	60	244
Volume (km^3)	12230	4920	3537	483	1636
Mean inflow (10^{10} m^3 /year)	-	-	12	19	21
Tributary inflow (10^{10} m^3 /year)	5.4	2.9	5.1	2.2	3.0
Mean outflow (10^{10} m^3 /year)	7.1	4.9	18	21	25
Annual precipitation (m/year)	0.76	0.79	0.76	0.84	0.89
Water residence time (year)	127	100	20	2.3	6.5
Sedimentation rate (g/m^2 year)	200	400	220	1000	400

centers (Eisenreich et al., 1981). Over the last 200 years, major sources of contaminants in the atmosphere of the Great Lakes include pesticides, mining activities, and fossil fuel combustion (coal and gas).

There is relatively little information specifically applying to chromium loading in the Great Lakes. Using the sediment profiles of Lake Superior, Lake Michigan, and Lake Ontario, this study presents spatial and historical distributions of chromium, magnitude of anthropogenic loading of chromium, and an estimate of the proportion of atmospheric loading relative to non-atmospheric inputs.

Anthropogenic and natural loads of trace metals to lake sediments have been estimated for many lakes using vertical profiles of metal concentrations (Kemp and Thomas, 1976; Galloway and Likens, 1979; Evans and Dillon, 1982; Kemp et al., 1978; Johnson et al., 1986; Johnson and Nicholls, 1988). Natural sources for trace metals include glacial and soil deposits occurring in erodable shorelines and in the tributary watersheds. Contaminants in the sediments are usually more highly concentrated in the fine particles than in the coarser particles due to the high surface area of fine particles (Dong et al., 1984). Increase of the trace metal loading to recent sediment profiles can be usually explained by derivation from anthropogenic sources including loading from the atmosphere to undeveloped lakes (Johnson, 1987).

Statement of Purposes

The goal of this study is to determine the spatial and temporal variation of chromium in the Great Lakes using sediment cores. Sediments are especially useful for studying the spatial and temporal distribution of trace metals since they display fairly static sample type rather than the transient samples provided by water and biota (Mueller et al., 1989).

More specifically, information from chromium concentration profiles in the sediments, chromium concentration in air and precipitation, and ^{210}Pb data of the Great Lakes, will be used to:

(1) determine the spatial distribution of anthropogenic chromium loadings,

(2) determine the change in magnitude of historical anthropogenic chromium inputs,

(3) calculate chromium anthropogenic inventories,

(4) estimate present day sediment-accumulation rate of chromium,

(5) calculate atmospheric deposition rate of chromium, and

(6) estimate the relative proportion of atmospheric deposition to sediment loadings.

Hypothesis

The main purpose of this research is to determine the extent of the anthropogenic loading of chromium in the Great Lakes. This knowledge will help to identify the sources of contaminants. This is essential for understanding the problems of contaminants in the environment and for effective restoration. It is hypothesized that the most important source for chromium to the Great Lakes is atmospheric deposition. It is assumed that if this hypothesis is true then the inventories of chromium should be same throughout the Great Lakes. The inventory of metal which concentrated in sediments is total mass amounts of metal in the core. In this study, the anthropogenic inventory will be investigated. It is thought that atmospheric deposition is highly dispersed, affecting near shore and mid lake areas nearly alike. Thus, the inventory of metals derived from anthropogenic sources in the sediment should be same throughout the Great Lakes.

Biogeochemistry of Chromium

The Distribution of Chromium in the Environment

Chromium is a common element, present in low concentrations ranging from less than 0.1 $\mu g/m^3$ in air to 4 g/kg in soils (World Health Organization, 1988). Chromium concentration in the air of non-industrialized areas is less than 0.1 $\mu g/m^3$. The background atmospheric chromium concentrations were estimated at the South Pole, as 5.3 ± 3.0 pg/m^3 with a range of 2.5 to 10 pg/m^3 (Zoller et al., 1974). However, the extensive use of chromium for the production of chrome alloys, chrome-plated metals, cement, pigments, various chemicals, and the combustion of many materials increase airborne chromium levels. Most chromium in the atmosphere exists as particulates (Towill et al., 1978). Due to its high boiling point, chromium vapor condenses as an oxide on the surface of particles (Moore and Ramamoorthy, 1984). Depending on the climatic conditions, atmospheric chromium can be blown over long distances and deposited on land or water by dry and wet deposition. As of 1973, the Great Lakes area received 29% of the total chromium emissions of United States (Towill et al., 1978).

The most dominant ore mineral of chromium is chromite, $FeCr_2O_3$, and would theoretically contain 68% chromic oxide (Gephart, 1982). Chromium in the earth's crust is incorporated in crystal lattice structure of the spinel group and other silicates such as pyroxenes through the replacement of Fe^{3+}, Al^{3+}, and Mg^{2+} by Cr^{3+}. The chromium content of natural solids varies according to the type and nature of underlying parent rocks, geographic region, and age of soil. High concentrations (average 1800 ppm) of chromium are present in ultramafic and serpentinite rocks, while low concentrations (about 10 ppm) are found in granite and limestones. Shales, river suspended matter and soils typically exhibit high

levels of chromium (Robertson, 1975; Salomons and De Groot, 1978). Chromium in soils is relatively insoluble and its concentrations are constant with depth.

Chromium concentrations in most surface fresh water are low. Kopp and Kroner (1968) detected dissolved chromium concentration from the surface water samples in the United States of America ranged from 0 to 112 μg/L with a mean concentration of 9.7 μg/L. Higher concentrations of chromium were contributed by run off from urban and industrialized areas. The principal sources of chromium emissions which contains relatively toxic form, Cr^{6+}, into surface waters are metal finishing processes such as electroplating. In fresh waters, anthropogenically introduced soluble Cr^{6+} is reduced to Cr^{3+}, which is far more stable in the aquatic environment and removed by subsequent sorption to particulates and sediments (Pfeiffer et al., 1980; Moore and Ramamoorthy, 1984).

Aqueous Geochemistry of Chromium

Chromium is a transition series element, a member of periodic group VI a, and atomic number 24. The ground state of the electron configuration of chromium is [Argon] $3d^5 4s^1$. Oxidation states range from -2 to +6. The most common and stable oxidation state of chromium in natural environments is Cr^{3+} derived primarily from the weathering of ultramafic rocks. Hexavalent chromium in the environment is mostly derived from human activities.

A number of physical, chemical, and biological processes affect the fate of chromium in the aquatic environments (Figure 2). The primary types of reactions that control the distribution of Cr^{3+} and Cr^{6+} are oxidation-reduction reactions in the aquatic environment. Under redox conditions, Cr^{3+} is the most stable chromium valence or oxidation state in the natural aquatic environments. Interconversion of Cr^{3+} and Cr^{6+} can take place in the presence of other redox

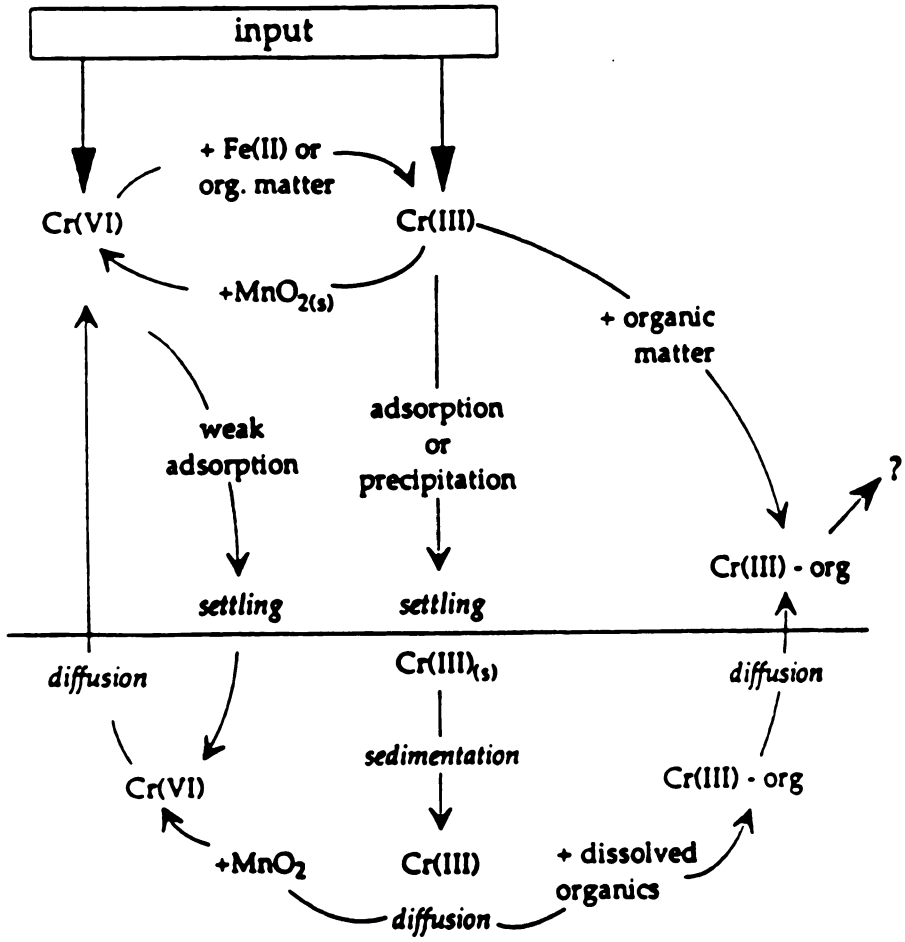

Figure 2. Chromium cycling in aquatic environment (from Richard and Boung, 1991).

couples such as Fe^{2+}/Fe^{3+}, Mn^{2+}/Mn^{4+}, $H_2O/O_2(aq)$, NO_2/NO_3, S^{2-}/SO_4^{2-}, or CH_4/CO_2 (Richard and Boung, 1991).

Hexavalent chromium is a strong oxidizing agent in aqueous solution existing as a component of a complex anion such as chromate (CrO_4^{-2}), hydrochromate ($HCrO_4^{-}$), and dichromate ($Cr_2O_7^{-2}$). The hexavalent chromium anion forms very soluble, mobile species in the aquatic environment. Chromium (VI) is reduced to chromium (III) with Fe^{2+}, dissolved sulfides, and certain organic matter such as simple amino-acids (Schroeder and Lee, 1975) or humic or fulvic acid materials (Boyko and Goodgame, 1986). The dissolved Fe^{2+} ions are generated by weathering of Fe^{2+}containing minerals (biotite, etc.) and some industrial wastes. Chromium (VI) is mainly reduced in acidic conditions (Grove and Ellis, 1980; Stollenwerk and Grove, 1985). Chromium (III) readily precipitates as insoluble chromium hydroxides.

Trivalent chromium is oxidized to hexavalent chromium by dissolved oxygen and manganese oxides. Oxidation rate of Cr^{3+} at room temperature by dissolved oxygen is very slow. Most Cr^{3+} oxidation is related to the amount and the surface area of manganese oxide in aquatic environments (Eary and Rai, 1987; Schroeder and Lee, 1975; Takacs, 1988). This oxidation occurs in three steps; (1) adsorption of Cr^{3+} onto manganese oxide (MnO_2) surface sites, (2) oxidation of Cr^{3+} to Cr^{6+} and reduction of Mn^{4+} to Mn^{2+}, (3) desorption of the reaction products (Richard and Boung, 1991).

Adsorption is a physicochemical process by which aqueous species adhere to the surface of particulate matter. Adsorption mechanisms include ion exchange, electrical double layer ion interactions, surface complexation of hydrolyzable ions, and surface ionization and complexation (Westall and Hohl, 1980). Although Cr^{6+} has a strong affinity for organic matter, it is not readily adsorbed to inorganic materials such as clays, ferric and manganese oxides. Adsorption of hexavalent

chromium to hydroxyl-specific surface sites is a surface complexion reaction (Richard and Boung, 1991). Chromium (VI) is more strongly adsorbed on adsorbents which are positively charged at pH < 7 (Davis and Leckie, 1980). Amacher et al. (1988) reported that the adsorption of chromate on soils showed an initial reversible reaction that reached equilibrium within 24 h, but followed that further adsorption a much slower irreversible reactions. They suggested the latter step may be related to coprecipitation or internal diffusion.

Chromium (III) is strongly adsorbed by Fe and Mn oxides, clay minerals (Dreiss, 1986; Rai et al., 1984). The adsorption of Cr^{3+} to clay is 30-300 times higher than Cr^{6+} (Griffin et al., 1977). The adsorption of Cr^{3+} to the soils increases with pH (Griffin et al., 1977; Rai et al., 1984) and is also organic matter content (Payà Pérez et al., 1988). Adsorption depends on the presence of other inorganic cations or dissolved organic ligands in solution (Richard and Boung, 1991).

Chromium has a potential to be bioaccumulated in indigenous biota because it is an essential micronutrient. Chromium (VI) is readily adsorbed by tissues due to the presence as soluble anionic complexes in natural waters (Kuhert et al., 1976). However, the particulate form of trivalent chromium is less readily adsorbed by tissues (Sherwood and Wright, 1976). Under common pH/Eh conditions, chromium precipitates as hydroxides and oxides precipitate, and is thus not readily bioavailable (Jan and Young, 1978).

Sedimentation and burial are the dominant removal pathway of contaminants from the water column due to the strong affinity of many contaminants for particulate matter and the long hydraulic residence times of the Great Lakes (Allan, 1975; Förstner, 1976; Eadie et al., 1983). Once on the lake bottom, metals sorbed to sediment can be affected by early diagenetic processes. Early diagenesis is chemical and physical changes mostly driven by microbial

processes occurring in a sediment during burial to a few hundred meters (Berner, 1980). Early diagenetic processes operating above the redox zone are important in determining potential bioavilability and release elements to the water column (Matty, 1992). Sediment conditions, however, affect the distribution and remobilization of chromium. For example, the distribution of chromium in the upper portion of sediment is related to Eh-pH condition and selective adsorption onto Fe hydroxides, MnO_2, and organic matter (Mothersill, 1977). The extent of chemical diagenesis depends on not only the chemical characteristics of contaminants but the geochemical environment to which the contaminant is subjected.

In order to interpret the distribution of contaminants in sediments, processes such as diffusion, resuspension, advection, bioturbation, chemical and biological reactions, and time dependent changes in contaminant flux need to be considered.

II. Methods

Sediment cores were collected from Lake Superior (Figure 3), Lake Michigan (Figure 4), and Lake Ontario (Figure 5) using the box sampling capabilities of the R/V *Lake Guardian* (U.S.E.P.A.), R/V *Seward-Johnson*, and R/S *Johnson Sea-Link II* (NOAA-NURC) during the summers of 1988, 1990, 1991, 1992, and 1993. Sediment core samples were digested using a microwave-nitric acid digestion technique. The leachate was analyzed for chromium using graphite-furnace atomic absorption spectroscopy.

To understand chromium concentration versus sediment depth profiles, however, some terms need to be defined. Figure 6 is a typical profile of chromium concentration in sediment versus depth. The background depth is the depth in a core where the concentration of chromium becomes relatively constant. The background concentration is the average concentrations of all sample segments below the background depth. This concentration of chromium in the sediments is derived from natural sources. Peak is the highest anthropogenic chromium concentration. Surficial concentration is concentration of chromium in the uppermost sectioned interval of the sediment cores. Inventory means that total mass of chromium in the core by the anthropogenic input. The inventory is corrected by focusing factor using ^{210}Pb.

Sampling

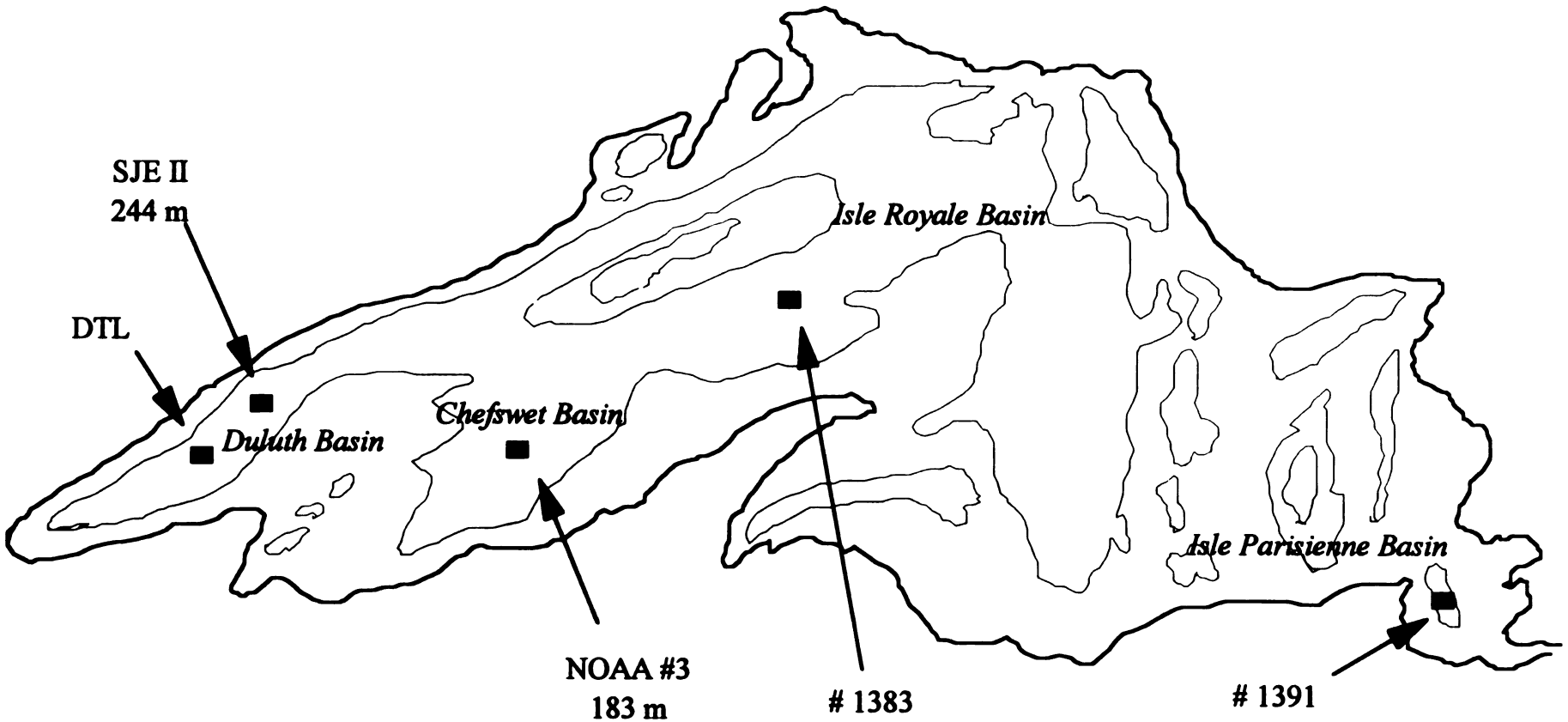

Figure 3. Sampling sites and depositional basin of Lake Superior.

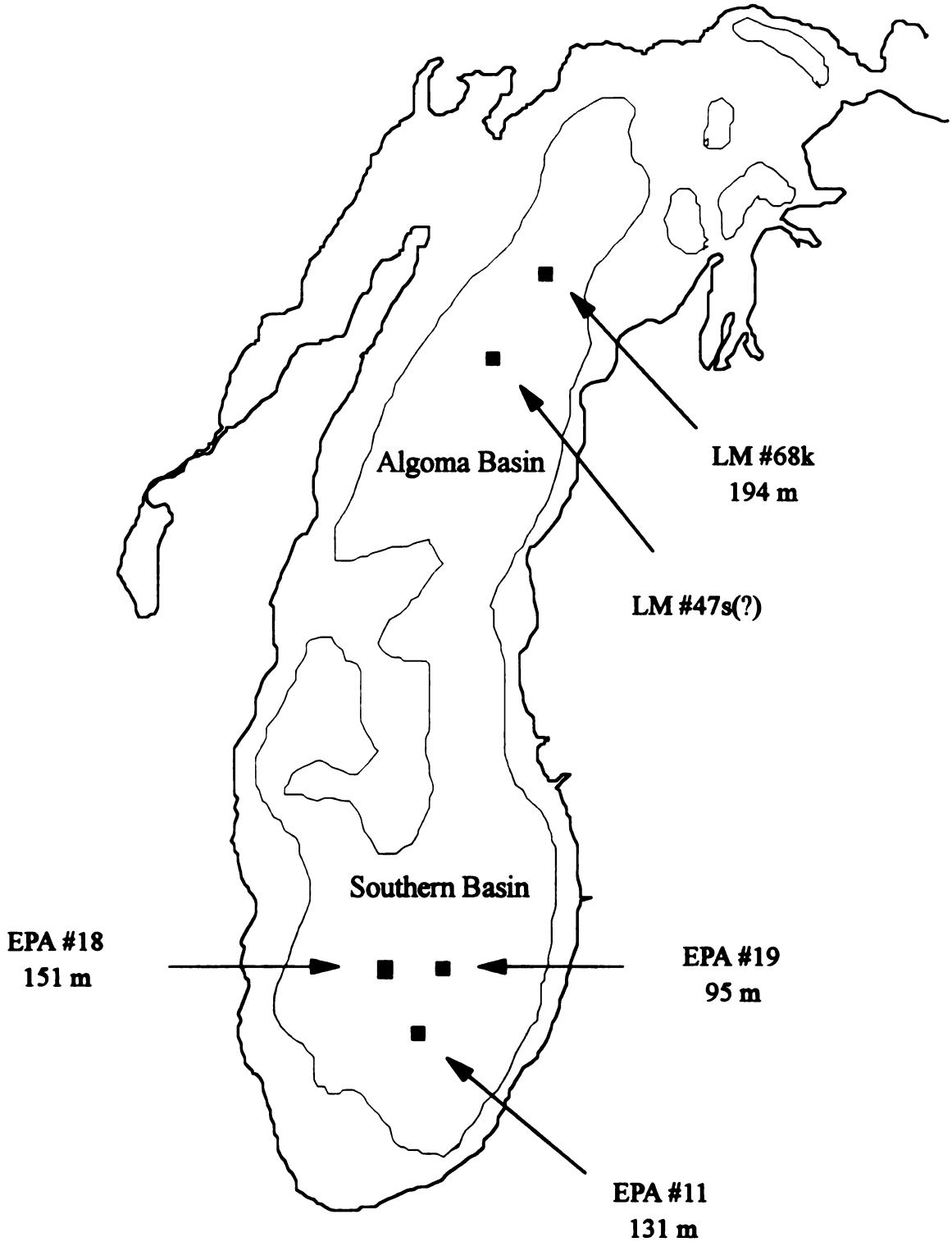

Figure 4. Sampling sites and depositional basin of Lake Michigan.

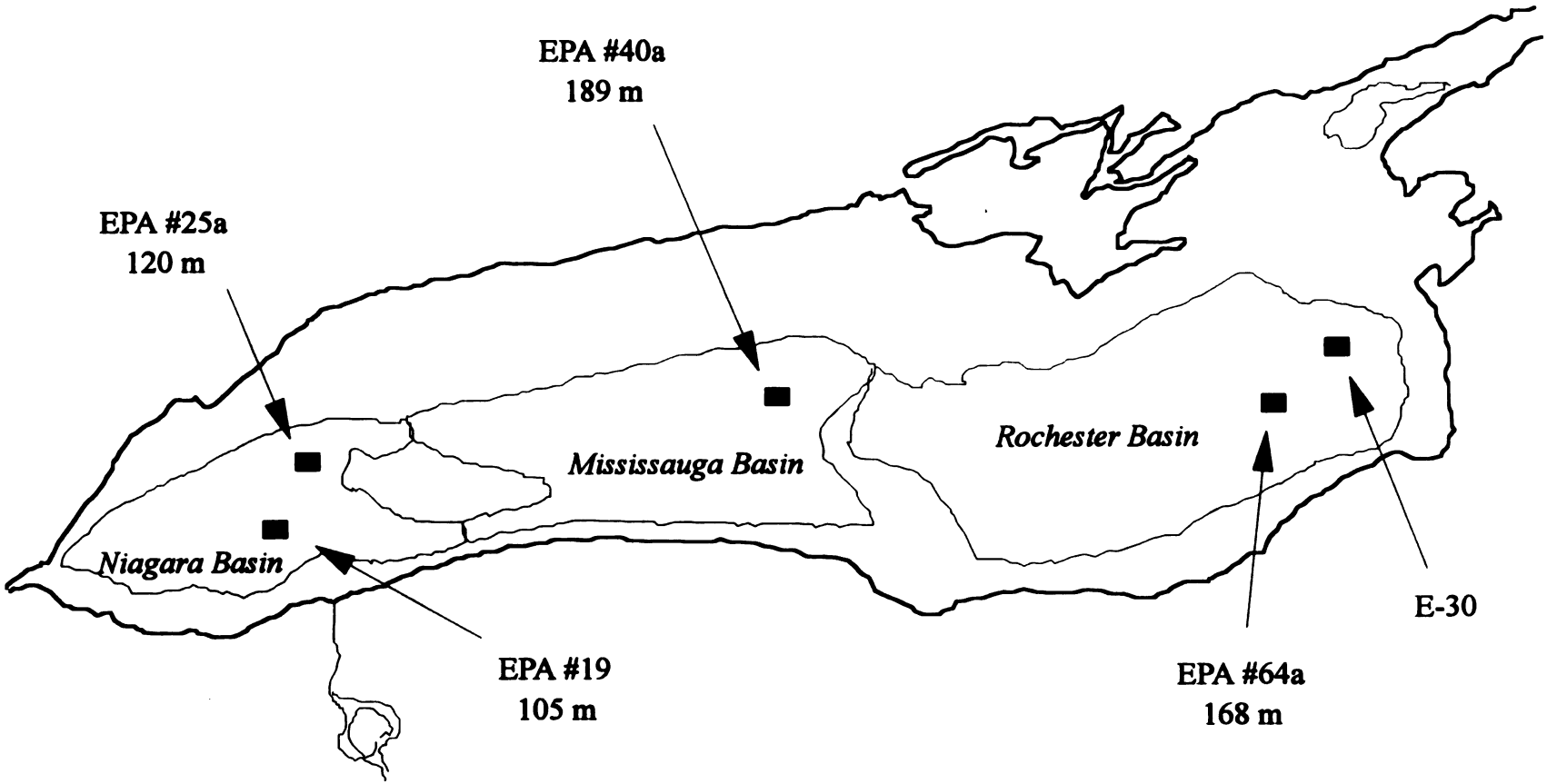

Figure 5. Sampling sites and depositional basin of Lake Ontario.

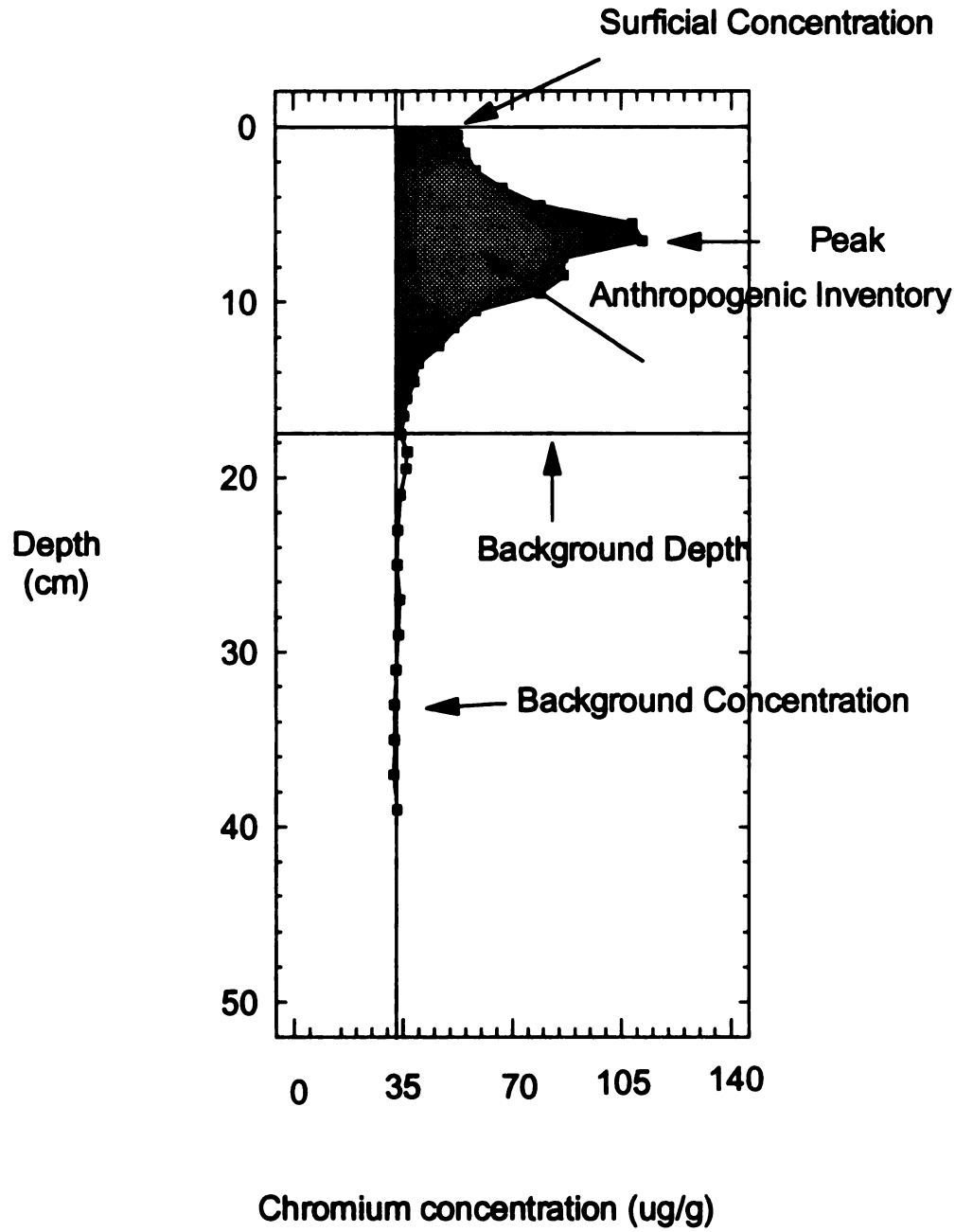

Figure 6. Terms used in the depth versus chromium concentration profiles.

Deep basins within each lake were chosen as sampling sites because these are the areas of active accumulation of fine-grained sediment and associated contaminants through the process of sediment focusing. Sediment focusing is the movement of sediment toward deeper zones or quiescent zones of the lake usually resulting from periodic turbulence (Likens and Davis, 1975), slumping/sliding of material on slopes, or current erosion/deposition (Hilton et al., 1986). Sediment samples were obtained by using a stainless steel box coring device (30 cm x 30 cm x 70 cm). This device was lowered slowly into the sediment in order to obtain undisturbed sediment samples. Then, PVC core tubes (3") were inserted into the sediment under vacuum to avoid compacting of the sediment and 5 cm away from the sides of the box core to avoid contamination from "ledge" effects. After all subcore tubes; those for ^{210}Pb, trace metal, and organic analyses, were inserted in the box core, the bottoms of the tubes were sealed by rubber stopper. The tops of subcore were covered with polyethylene caps to further prevent contamination of the sediment core. The sediments were sectioned into 0.5 cm, 1 cm or 2 cm intervals using a hydraulic extrusion device. The tubes were double stoppered on the bottom and placed on the extruder to prevent water from coming in contact with the sediment at the bottom of the core. Sediments in contact with the sides of core tube were scraped away using a teflon spatula before sectioning. The sections were transferred into individual acid-cleaned polyethylene bottles and frozen until sample preparation.

Sample Treatment

Trace metals were extracted from sediment by chemical extraction. Instra^{TM} grade HNO_3 (15M) were used as the chemical leaching agent during

sediment digestion in a CEM model 81 microwave with pressure controller. The extraction method was suggested by Hewitt and Reynolds (1990).

After the frozen samples thawed at room temperature overnight, about 5 grams of sediment were weighed and dried for 24 hours at 50 °C in a convection oven. Porosity of the sediment was determined from the wet sample weight and dry sample weight. Dried samples were ground into a fine powder by use of a ceramic mortar and pestle and 0.50 grams of sample weighed and placed into an individual 100 ml polyethylene reaction vessel. Ten milliliters of HNO_3 were added to each vessel. Eleven samples and one blank were digested at the same time. One of the sample vessels was connected with the pressure controlling device to regulate pressure (150 psig). The microwave program was set to 15 minutes with 100% power; 15 minutes with 0 power and until the pressures were less than 5 psig. After digestion 90 ml of DDW was added to dilute each sample. The sample leachate, filtered through 0.45μm acid-cleaned Nucleopore membrane filters, were stored at 4 °C until analysis.

Analysis

Leachates were analyzed by graphite-furnace atomic absorption spectrometry using a Perkin-Elmer Zeeman 5100 with HGA 600 furnace and auto sampler. The standard solution was made using 1000 ppm ± 1 % chromium reference solution of Fisher Scientific. Matrix modifier and calibration blank were made using 0.05 mg of $Mg(NO_3)_2$ and 1 ml of HNO_3 dilute in 25 ml of DDW, respectively (Perkin-Elmer, 1985). The sample was injected into the furnace chamber by an automatic pipeting arm. The pipet arm collected 5 μl of matrix modifier, 10 μl of diluent, and 10 μl of sample and injected it onto a L'vov platform within the furnace chamber. The L'vov platform allows a more uniform

atomization of sample and enables one to acquire more precise results. The graphite-furnace were controlled by 5 step programs; drying (140 °C, 55 sec), thermal pretreatment (1550°C, 30 sec), atomization (2500°C, 10 sec), clean out (2630°C, 5 sec), and cool down.

Clean Procedures

All phases of this study were conducted using clean techniques. For example, the laboratory was supplied with filtered air and sealed against dust and contaminants from the outside. All materials used in the sample processing such as bottles, syringes, spatulas, scoops, and reaction vessels were washed 4 times with DDW from Corning model AG-22 still. These materials were soaked in 10% HCl (analytical reagent grade) for 24 hours, then rinsed 4 times in DDW. These were maintained in water bath for 24 hours, then dried in a laminar clean hood supplied with filtered air from a class 100 filter. These are capped and sealed in plastic bags for transportation to sampling sites and for storage. All samples and equipment were handled only with the use of sterile, latex examination type gloves.

Quality Assurance and Quality Control Procedures

The results of quality control procedures are shown in Appendix B. To evaluate the accuracy of the analytical method and maintain data quality, the analytical procedure was performed on National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) #2704 (Buffalo River Sediment, New York) an inorganic reference material (Epstein et al., 1989). The certified value for this standard material is 135 ± 5 μg/g. However, the concentrations of chromium in these sample results of repeated analyses of SRM #2704 were significantly lower than the certified value, on the average 87.3 μg/g, or 65% recovery. The NIST values for chromium in SRM #2704 were based on

determination by Instrumental Neutron Activation Analysis and Direct-Current Plasma Emission Spectrometry (Epstein et al., 1989). The digestion methods using HNO_3 and a microwave oven do not extract total amounts of chromium from all geological materials (Sulcek and Povondra, 1989). However, most of anthropogenic metals in sediments are associated with organic matter and clay surfaces (Hewitt and Reynolds, 1990). These results agree with those of Hewitt and Reynolds (1990) and Rowan and Kalff (1993). RSD values for SRM #2704 of this study were < 6%.

The measurement of chromium concentration in each leachate sample was made three times. The RSDs were required by U.S.E.P.A. to be less than 15% for the replicates of the sample (Eisenreich et al., 1990). If RSDs exceeded 15%, the sample was reanalyzed up to two more times. If the RSD value still exceeded 15%, the sample was discarded. In addition, one or two samples per sediment core were subsplit to three samples and analyzed separately. The RSD values of subsplits were required to be less than 20%. The correlation coefficient of the standard calibration curve was required to be greater than 0.95.

Lead-210 Dating and Sediment Focusing

Lead-210 dating is an important and widely used method for determining the age, sedimentation rates, and the history of anthropogenic inputs of sediments in lacustrine and near shore marine systems (Shirahata et al., 1980; Evans and Dillon, 1982; Evans et al., 1986; Beroit and Hemond, 1991). There are two kinds of ^{210}Pb in sediments; supported and unsupported. Supported ^{210}Pb, produced by in situ decay of ^{226}Rn, is generally small in concentration and has nearly constant activity. Unsupported ^{210}Pb is supplied from the atmosphere to sediments. Major amounts of ^{222}Rn, as the gaseous daughter of ^{238}U, volatilize from earth crust to

the atmosphere. Lead-210, adsorbed to natural aerosols and particles as decay product of ^{222}Rn, are redistributed with respect to original source material (Junge, 1963; Robbins, 1978).

The inventory of metals is affected by sediment focusing. A focusing factor can be used to normalize the data throughout the Great Lakes region and to account for variable sedimentation rates between the sampling sites (Rapaport and Eisenreich, 1988; Eisenreich et al., 1989). The expected ^{210}Pb inventory from atmospheric deposition in sediment of the Great Lakes region is 15.5 pCi/cm^2 (Golden et al., 1993; Urban et al., 1990; Eisenreich, 1993 personal communication). The ^{210}Pb inventory is measured in sediments at each sampling site. If there has been sediment focusing then the ^{210}Pb inventory will be greater than 15.5 pCi/cm^2. Therefore, the amount of sediment focused into the deposition site can be determined from the following focusing factor:

$$FF = {}^{210}Pb \text{ measured inventory} / {}^{210}Pb \text{ expected inventory}$$

The metal inventory at a site is divided by the focusing factor to obtain a sediment-focused corrected inventory.

A single subcore from each box core was sectioned and dated using ^{210}Pb methods at the University of Minnesota. Sediments were analyzed using a modification of the method reported in Eakin and Morrison (1978). Lead-210 radio-isotope dating techniques such as constant flux/constant sedimentation and constant rate of supply were used to calculate the date of sediment cores, focusing factors, and sediment accumulation rates. Sedimentation rate through time was calculated by linear relationship between log unsupported ^{210}Pb activity and cumulative dry mass with depth (Robbins, 1978).

III. Results

Shipboard description of sediment cores (Appendix A) and measured chromium concentrations (Appendix C) in the sediment are shown as a function of depth in Figures 7 through 13 and year in Figures 14 through 19.

Pre-industrial (background) concentrations of chromium were determined and subtracted from total chromium concentrations to estimate the rate and extent of anthropogenic accumulations. The background concentrations of Lake Michigan and Lake Ontario range from 26-38 μg/g. Those of Lake Superior are higher that about 50 μg/g except #1391 (Figure 20).

In the Lakes Michigan and Ontario, the highest concentrations of chromium are generally in the upper portion of profiles. Surface concentrations in sediment cores exceeded background concentrations by 1 to 3.6 times in Lakes Michigan and Ontario. The profiles show that total chromium loading to the sediments has been decreasing to present.

Chromium loading at LM #68k and EPA #40a suddenly increased around 1900, and decreased around 1970. The increasing and decreasing time of chromium loading around the Great Lakes region was similar.

Chromium concentration profiles from Lake Superior are unlike those in Lakes Michigan and Ontario. Background concentrations of chromium in Lake Superior are higher than Lakes Michigan and Ontario; probably due to the weathering of the metamorphosed rocks of the Canadian shield (Thomas and Mudroch, 1979). Chromium concentrations at site DTL and SJE II decrease to

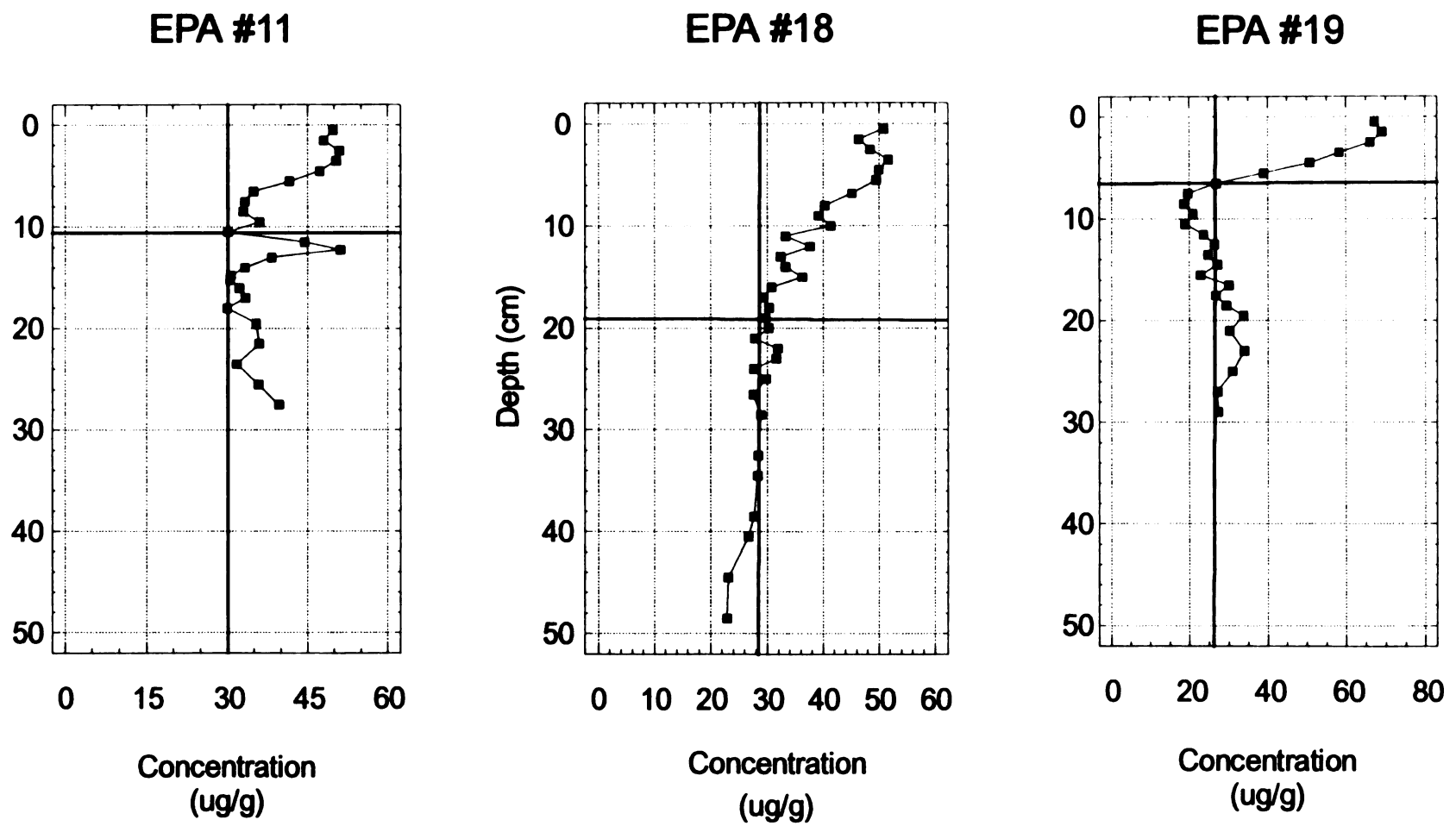

Figure 7. Chromium concentration profiles in the southern basin of Lake Michigan.

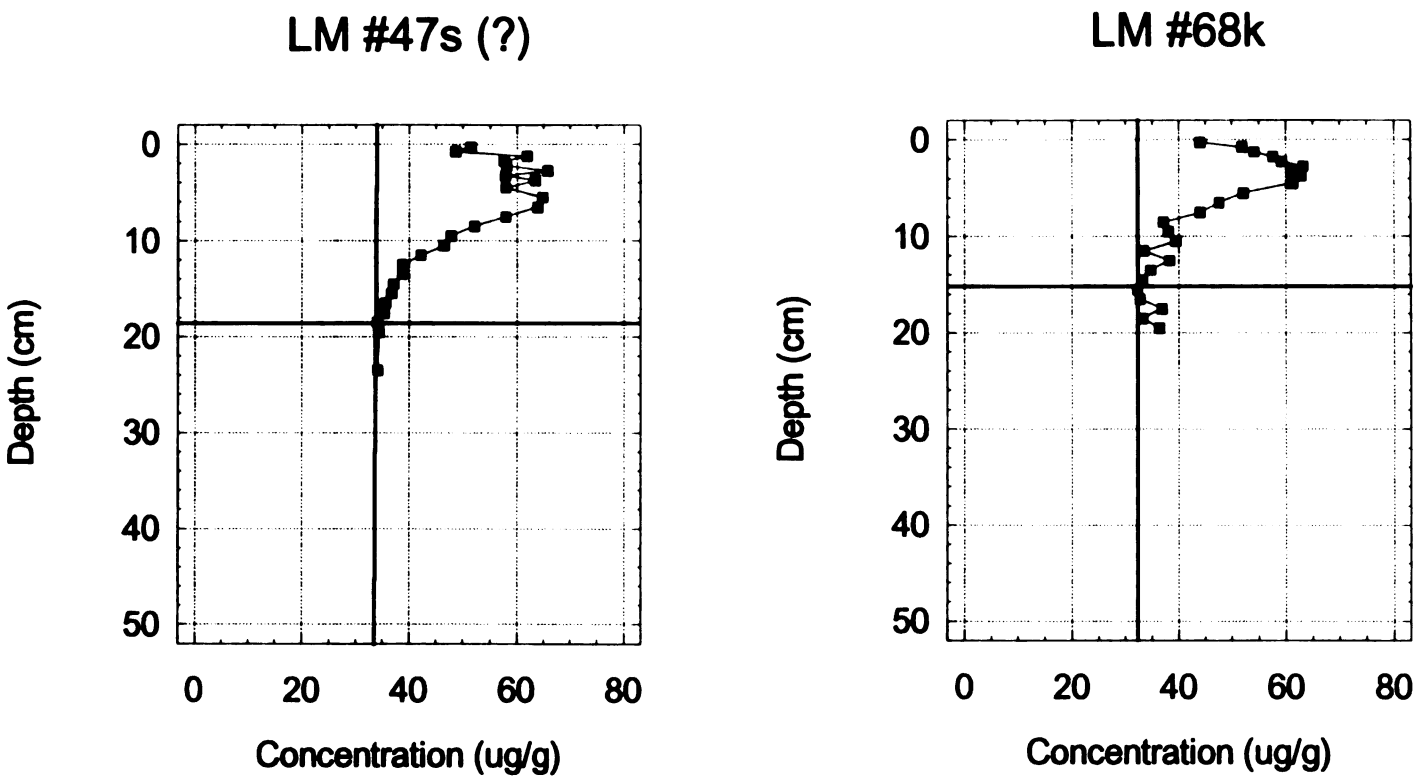

Figure 8. Chromium concentration profiles in the Algoma basin of Lake Michigan.

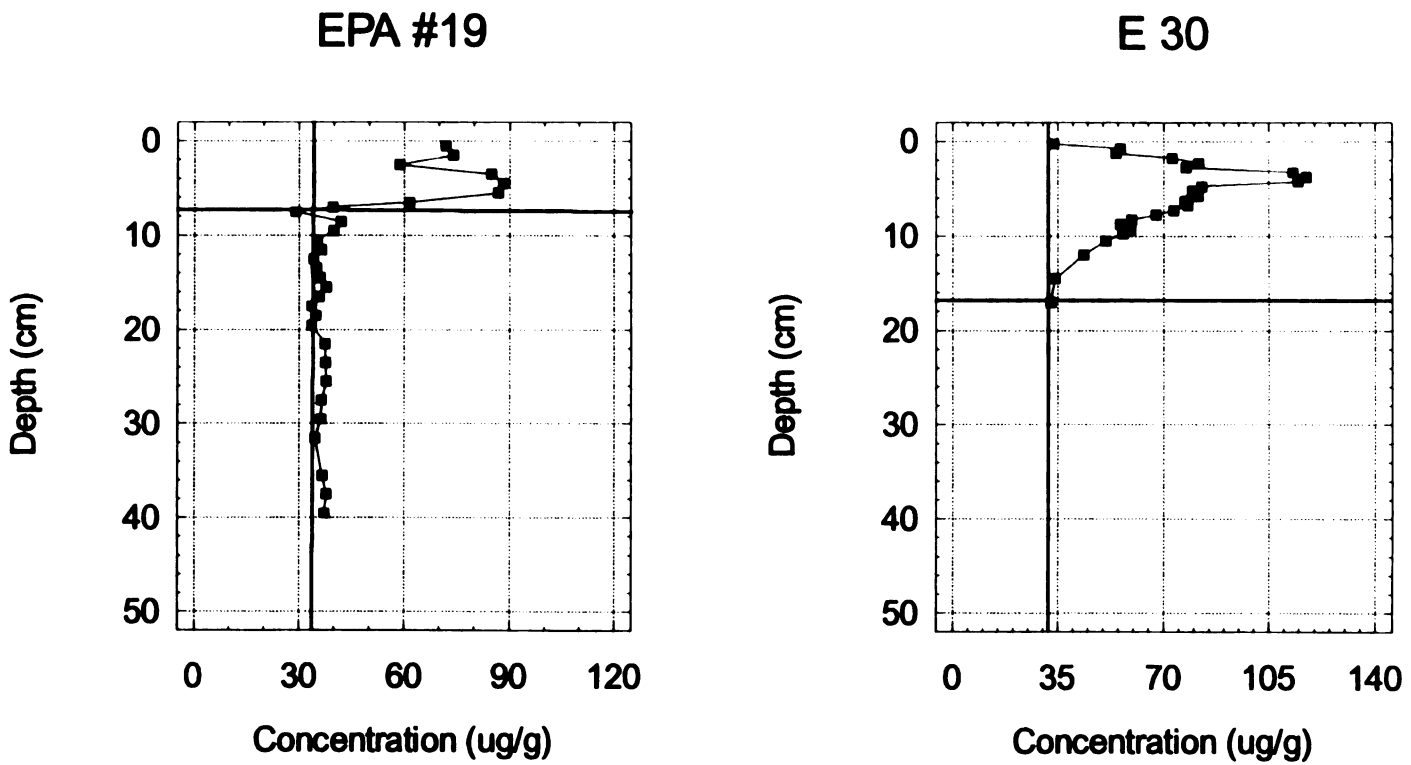

Figure 9. Chromium concentration profiles in the Niagara basin (EPA #19) and Rochester basin (E 30) of Lake Ontario.

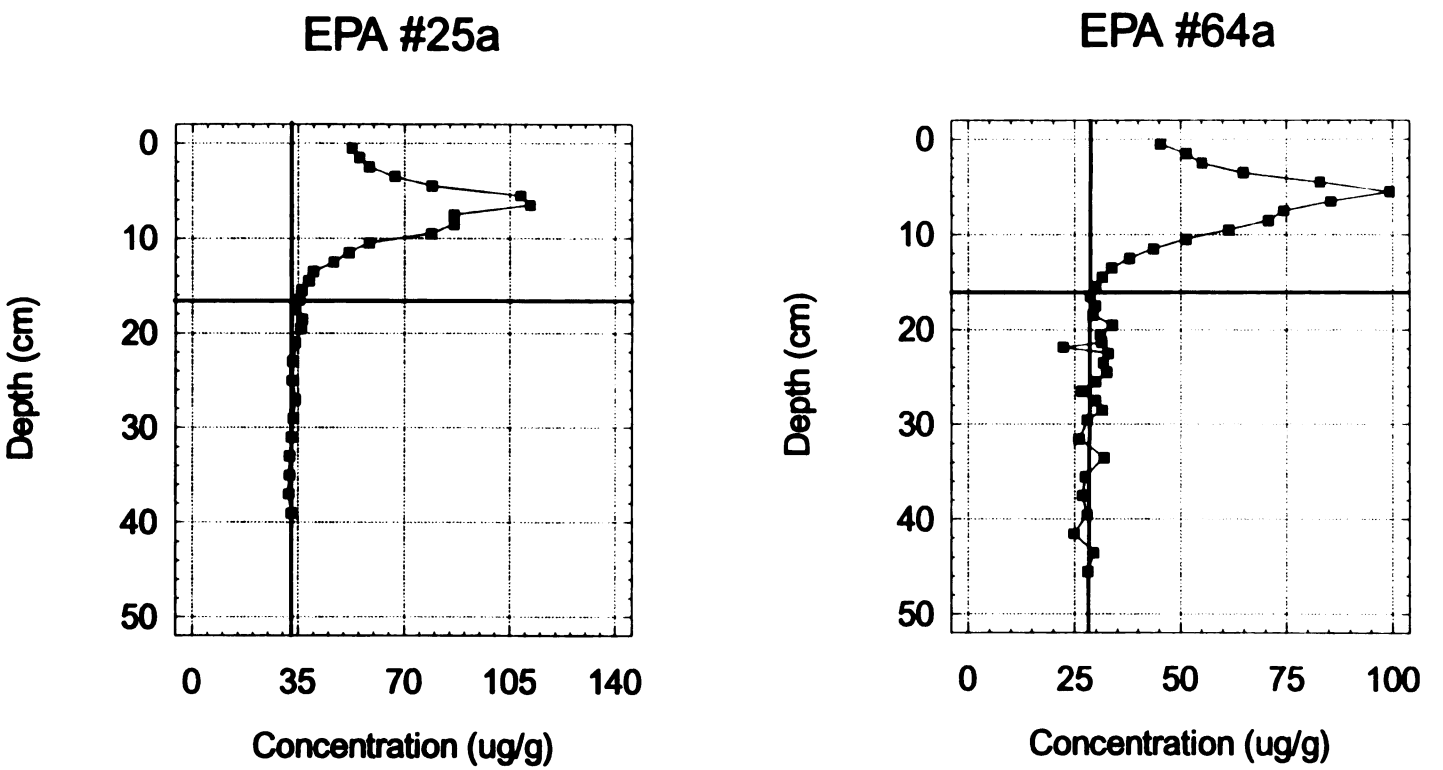

Figure 10. Chromium concentration profiles in the Niagara basin (EPA #25a) and Rochester basin (EPA #64a) of Lake Ontario.

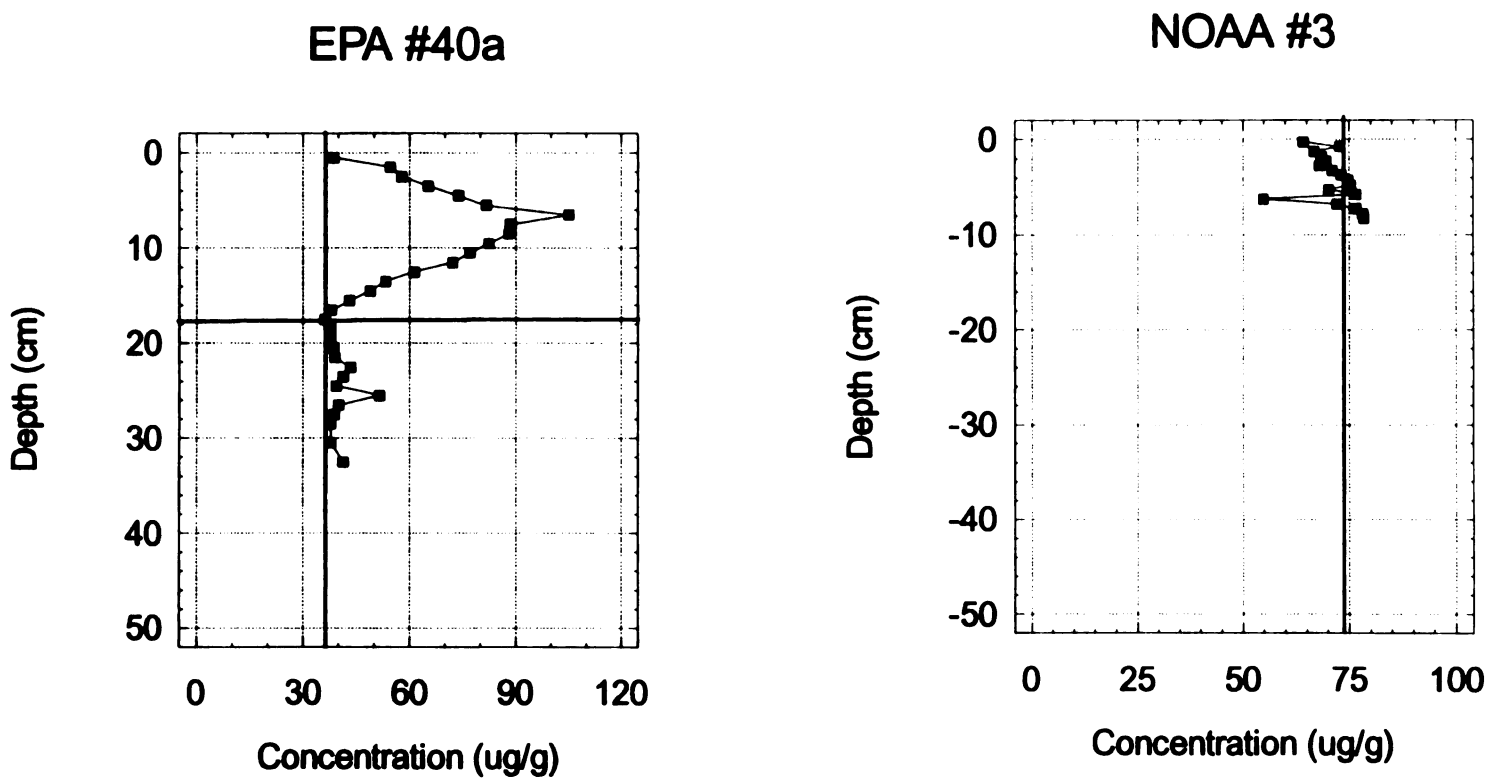

Figure 11. Chromium concentration profiles in the Mississauga basin (EPA #40a) of Lake Ontario and Chefswet basin (NOAA #3) of Lake Superior.

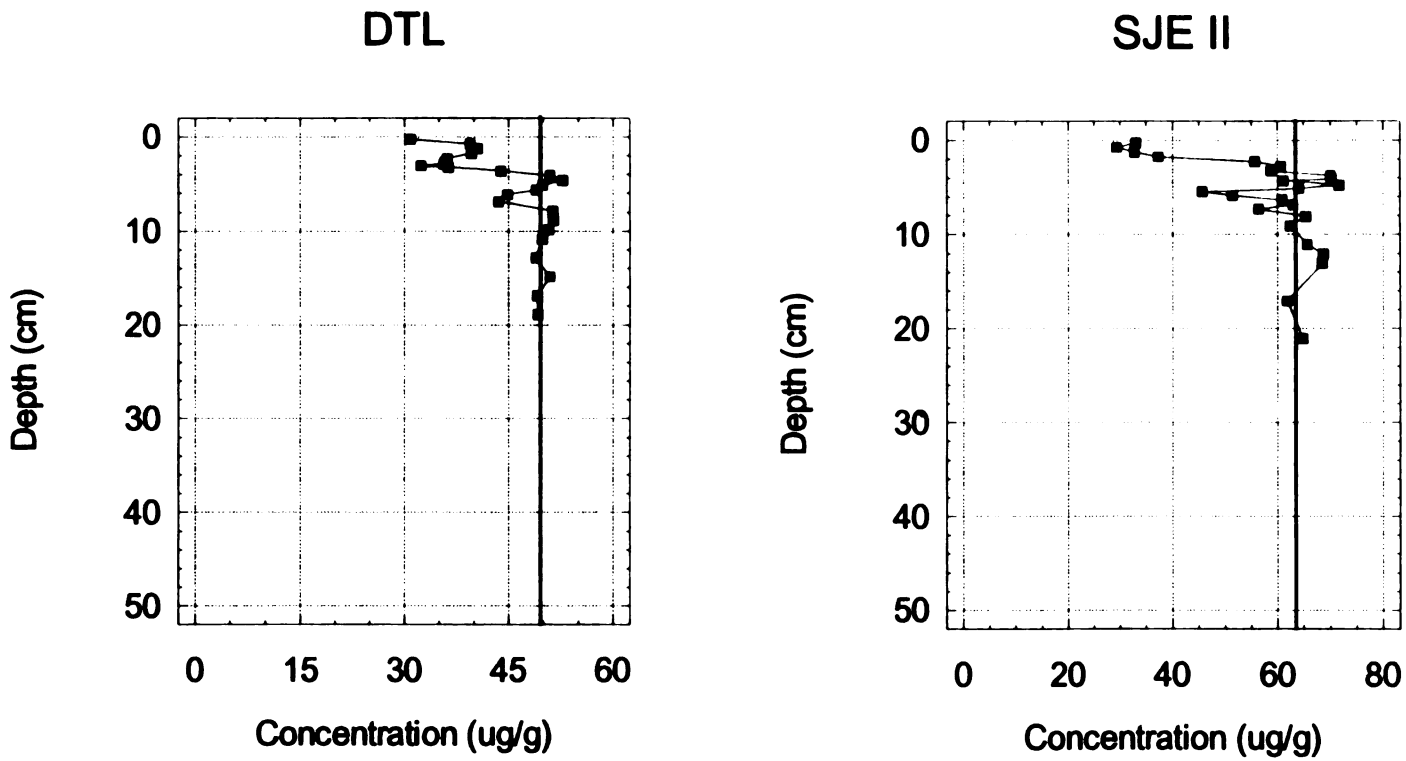

Figure 12. Chromium concentration profiles in the Duluth basin of Lake Superior.

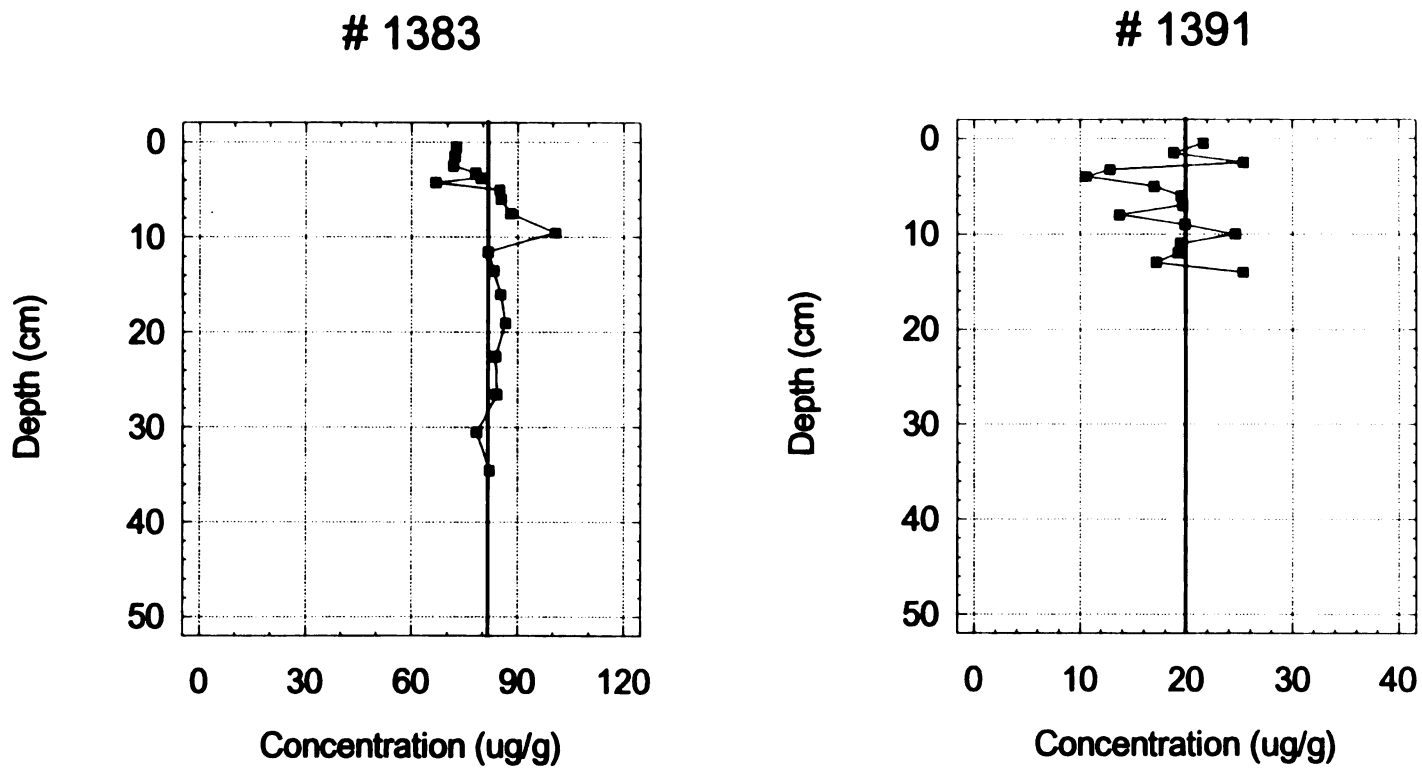

Figure 13. Chromium concentration profiles in the Isle Royale Basin (#1383) and Isle Parisienne Basin (#1391) of Lake Superior.

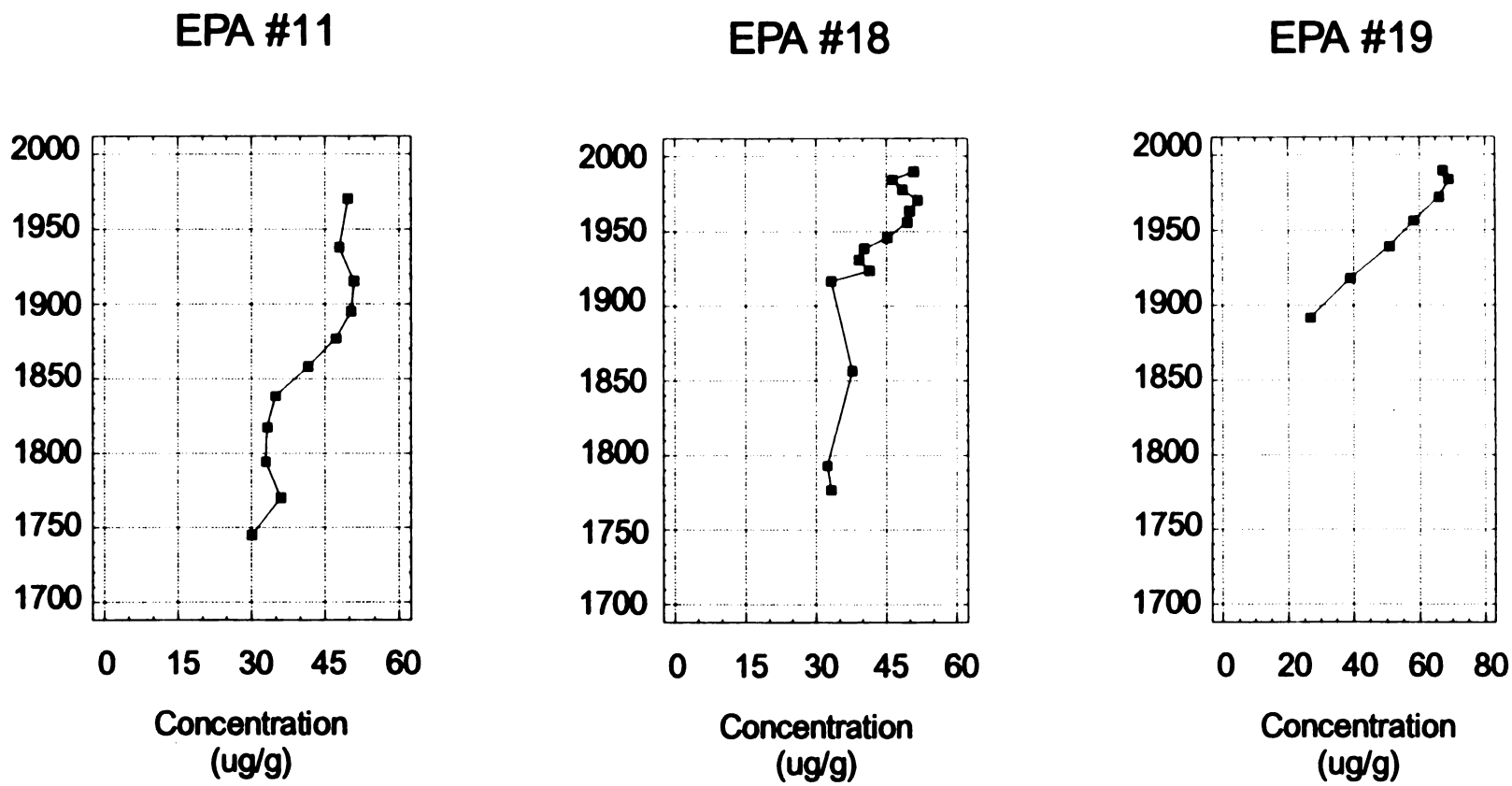

Figure 14. Chromium concentrations versus year in the southern basin of Lake Michigan.

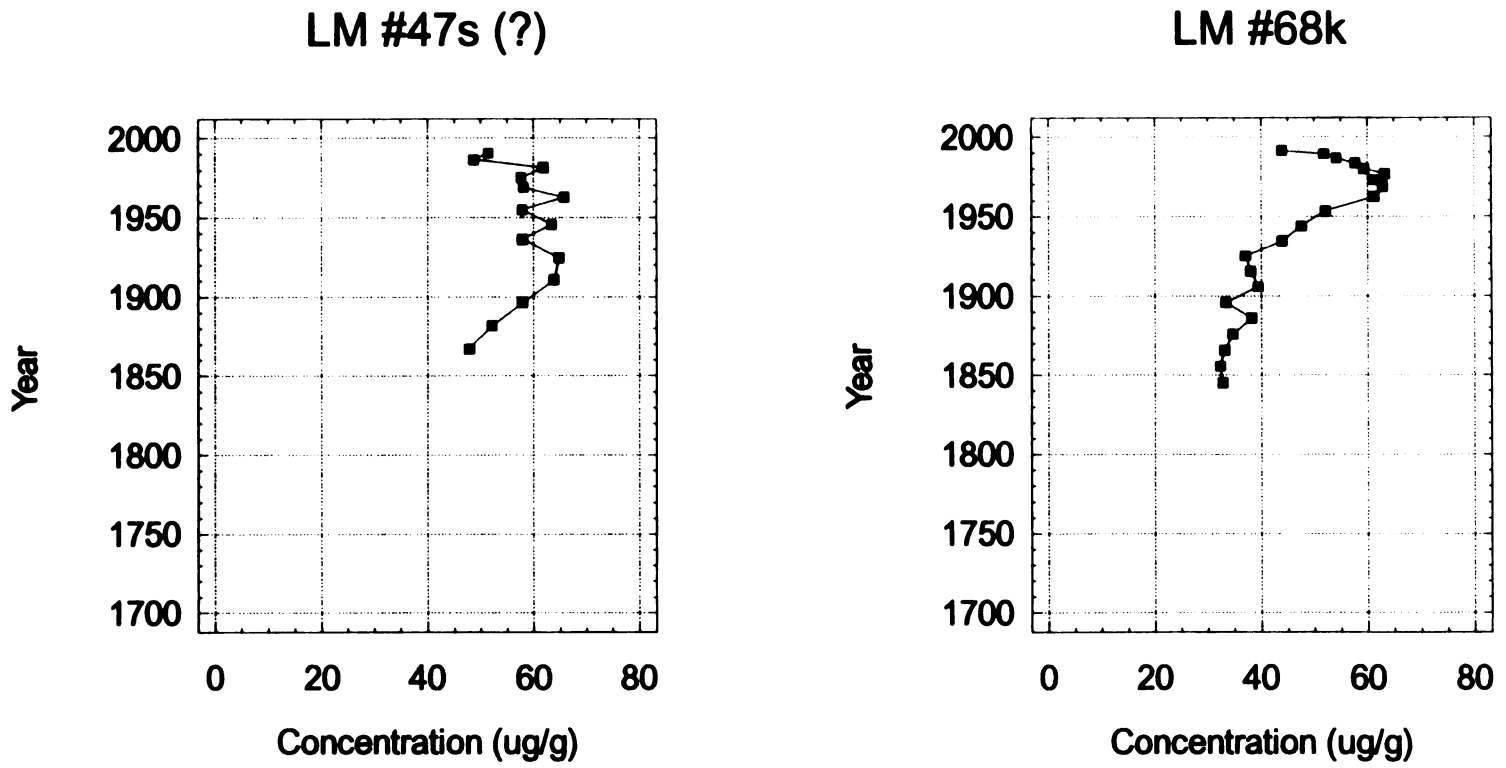

Figure 15. Chromium concentrations versus year in the Algoma basin of Lake Michigan.

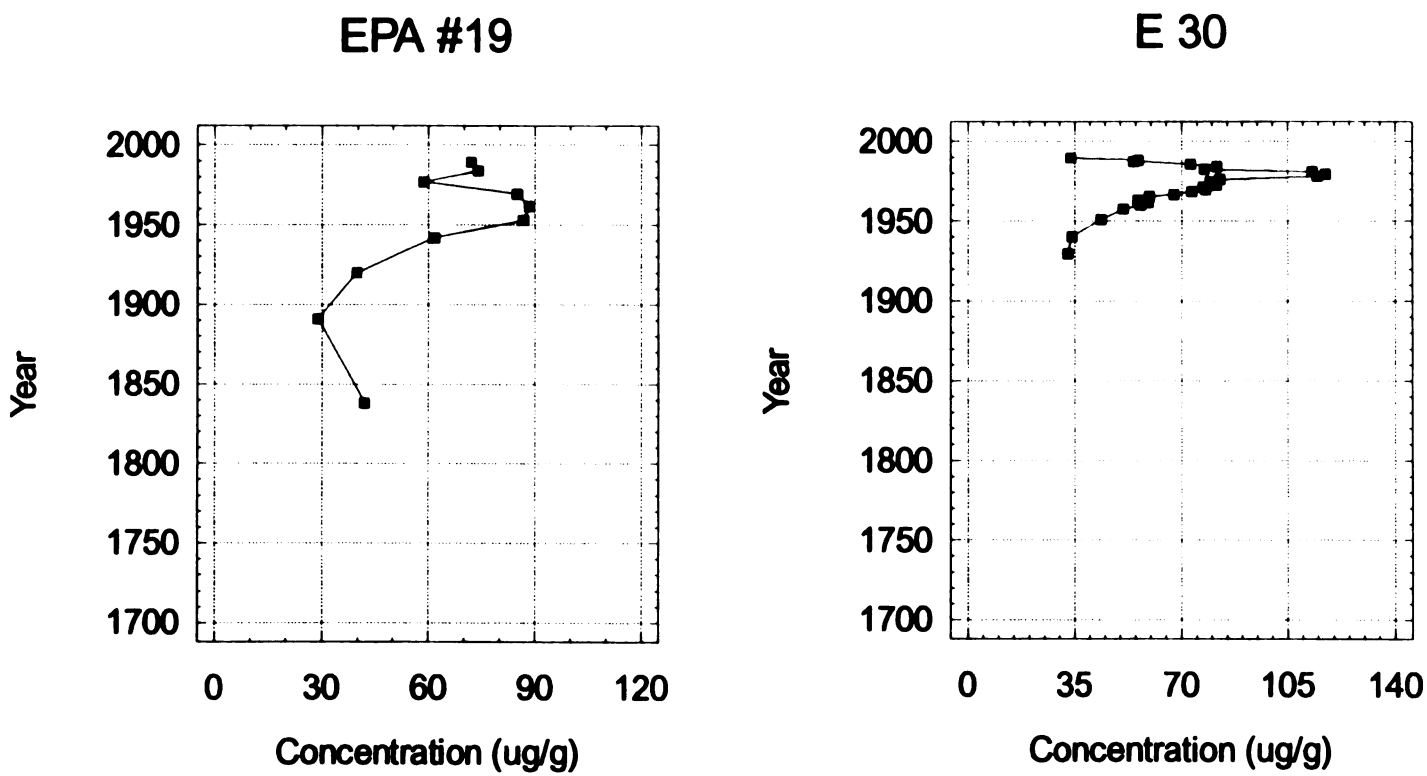

Figure 16. Chromium concentrations versus year in the Niagara basin (EPA #19) and Rochester basin (E 30) of Lake Ontario.

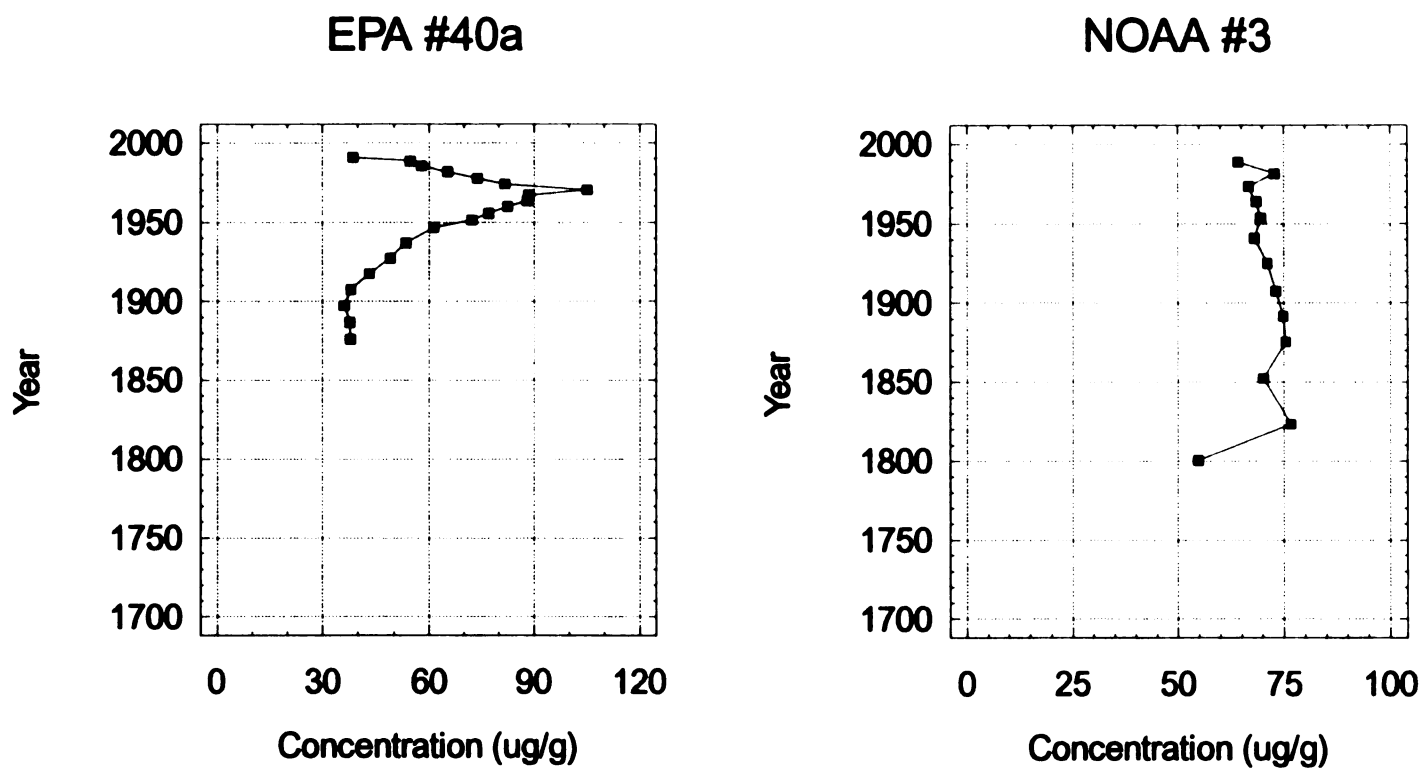

Figure 17. Chromium concentrations versus year in the Mississauga Basin (EPA #40a) of Lake Ontario and Chefswet basin (NOAA #3) of Lake Superior.

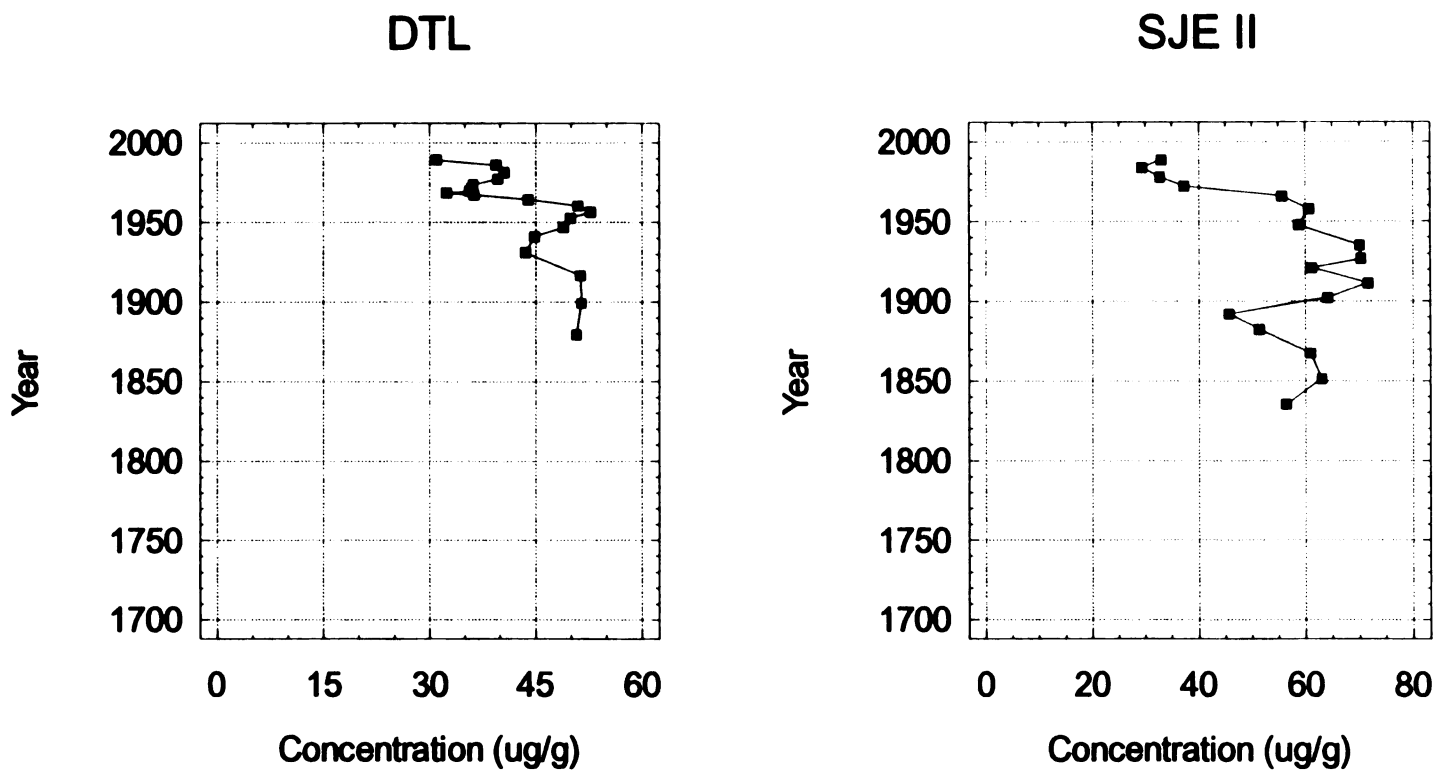

Figure 18. Chromium concentrations versus year in the Duluth basin of Lake Superior.

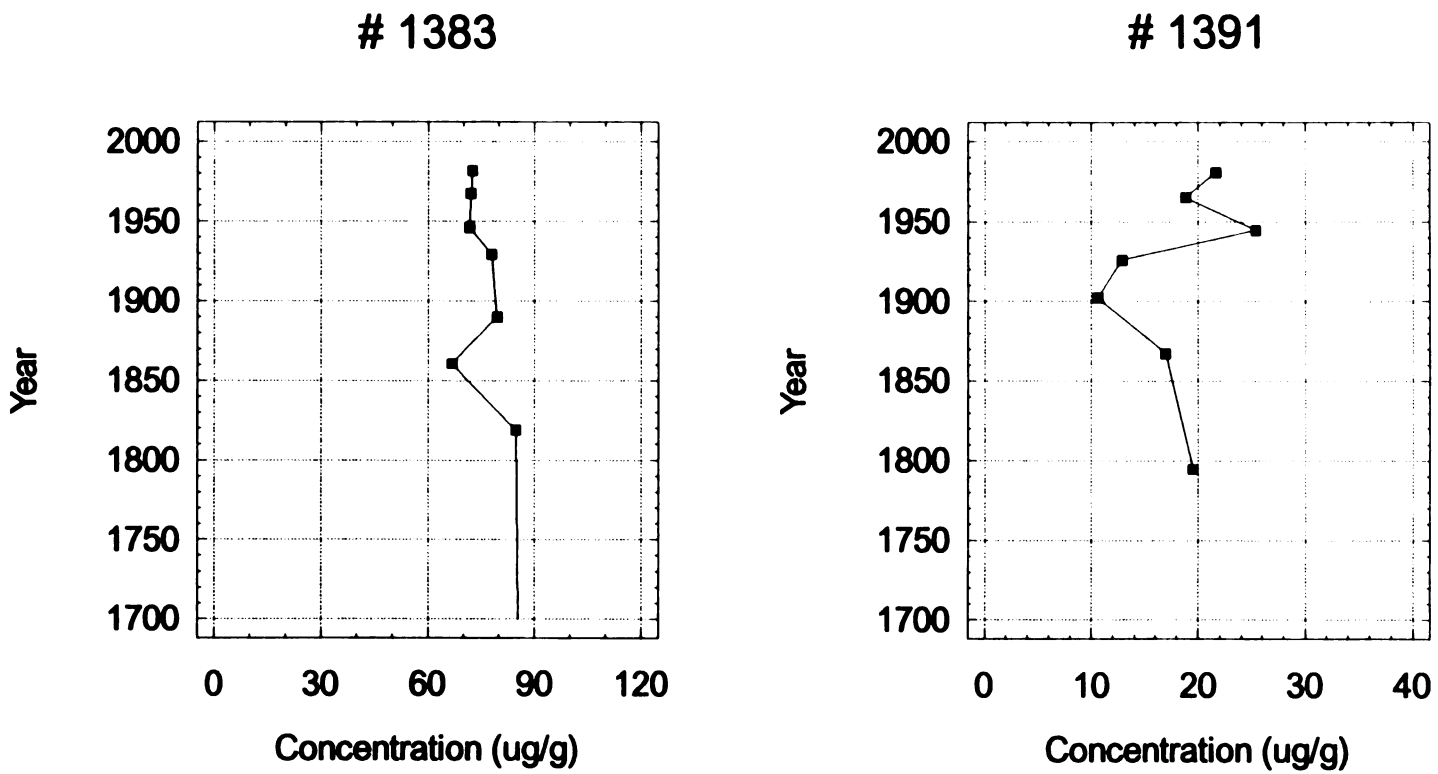

Figure 19. Chromium concentrations versus year in the Isle Rayale basin (#1383) and Isle Parisienne basin (#1391) of Lake Superior.

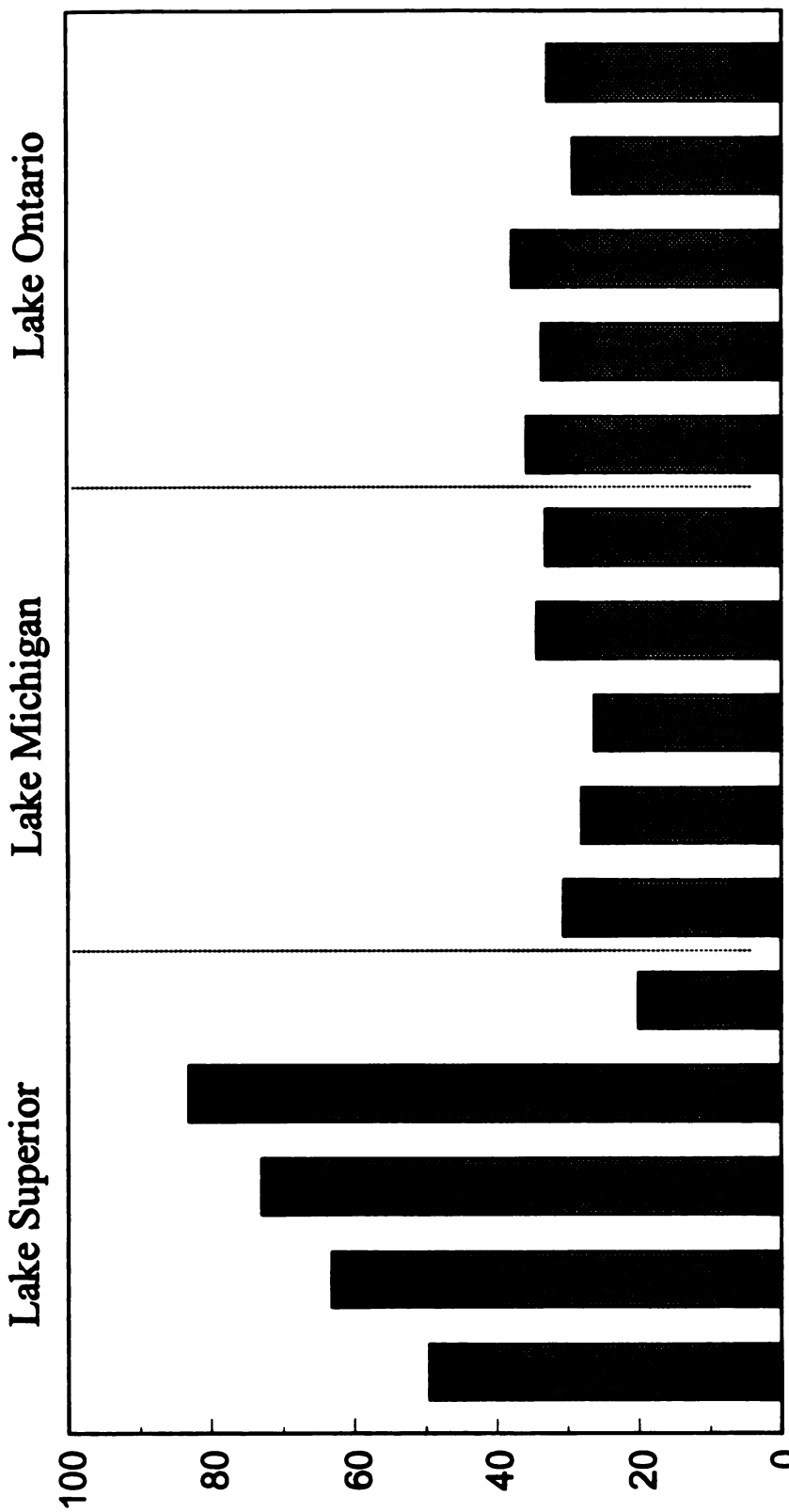

Figure 20. Background concentration of chromium in the Great Lakes.

Superior are higher than Lakes Michigan and Ontario; probably due to the weathering of the metamorphosed rocks of the Canadian shield (Thomas and Mudroch, 1979). Chromium concentrations at site DTL and SJE II decrease to present from about 5 cm with no peak concentration. At site #1383, NOAA #3, and #1391, chromium concentrations are relatively constant through the depth. Site #1391 has much lower chromium concentration than the other cores because of the coarser texture of these sediments (Kemp et al., 1978).

The sediment profile of Lake Superior did not show anthropogenic enrichments of chromium. Perhaps, there is no anthropogenic input or anthropogenic input is significantly lower than background concentration of chromium. The variations of chromium concentration in sediment cores could be the disparity in sediment types. The chromium concentrations of the Duluth basin were significantly depleted in the top 5 cm of the sediment profiles possibly because of dilution by taconite tailings. The U.S. Dept. Int. Rept (1969) states that 67,000 ton of tailings daily were released into Lake superior from the Reserve Mining Company's taconite processing plant at Silver Bay since 1955. Kemp et al. (1978) stated that the tailing layer contend high silt (75%), Si, Fe, and Mn concentrations, but lower concentrations of major trace and nutrient elements. Unfortunately, the concentration of chromium in the taconite tailings is not known. Therefore, this interpretation remains as one possibility. The second possibility is ratio of organic to clastic as a function of early diagenesis. The third possibility is dilution by anthropogenic input with lower chromium content.

IV. Discussion

Background Concentrations

The ranges of chromium background concentrations in this study are similar to ranges found by previous researchers (Table 2). The data are also similar to soil in the Great Lakes region. In this study background concentration were highest in Lake Superior due to the weathering of the metamorphosed rocks of the Canadian shield. The Canadian shield consists of intrusive igneous and metamorphic rocks. These contain relatively high concentration of chromium than platform and basin of lakes Michigan and Ontario. Site #1391 shows much lower chromium background concentration than the other cores in Lake Superior. However, this value is similar to that of Lake Michigan because site #1391 is located in Michigan basin (Figure 20). Background concentrations of chromium in Lake Michigan and Ontario are similar.

Sediment Accumulation Rates for Chromium

The mass sedimentation rate can be calculated using ^{210}Pb data. Calculations of accumulation rates and dating depth increments in the sediment help to make interpretation from cores affected by compaction and early diagenesis (Norton and Kahl, 1987; Urban et al., 1990). Robbins (1978) states that the sediment dating of undisturbed, unmixed sediment was determined as follows:

$$A(z) = As \times EXP\ (-kz/W)$$

where

Table 2. Background concentrations of chromium in preliminary background values for sediments of the Great Lakes region and in the soils of U.S.

Study Area	Range or means of concentration (μg/g)	Reference
Lake Michigan	***26.2 - 34.2***	This Study
	50	Mudroch et al., 1988
Southern Lake Michigan	20-40	Leland et al., 1974
Lake Ontario	***29.2 - 37.66***	This Study
	63 - 86	Mudroch et al., 1988
Lake Superior	***20 - 83.06***	This Study
	26.1 - 73.1	Mudroch et al., 1988
	44.1	Kemp et al., 1978
Lake Huron	36.9	Kemp et al., 1978
Lake Simcoe, Canada	45.8	Johnson et al., 1988
Georgian Bay	79.9	Johnson, 1983; Kemp et al., 1978
14 lakes in Ontario, Canada	43.4	Johnson, 1987
mean of soils[1]	48.66	Connor and Shacklette, 1975
Range of soil means[2]	11 - 78	Connor and Shacklette, 1975
Range of all data[3]	< 1 - 1500	Connor and Shacklette, 1975

[1] Mean values were calculated for chromium concentrations in soils from various areas of the U.S.
[2] Range of means is the range of the means for chromium concentrations in soil sites used to calculate the mean in [1].
[3] Range of all data is the range of all data used to calculate the means for chromium concentrations in soils from various areas of U.S. The total number of samples analyses for chromium is > 1,000.

A(z) = the unsupported ^{210}Pb (part of sediment ^{210}Pb arising from dry or wet deposition of airborne ^{210}Pb and not supported by soil Ra) activity
As = the unsupported ^{210}Pb activity at the sediment-water interface
k = the decay constant (0.0311 $year^{-1}$)
z = the cumulative dry mass of sediment
W = the sedimentation rate (g/cm^2 year)

Sediment accumulation rates of chromium were calculated as follows (Golden et al., 1993):

$$\text{Accum } (\mu g/m^2 \text{ year}) = \text{Csed} \times W \times 10^4$$

where

Accum = chromium accumulation rate ($\mu g/m^2$ year)
Csed = concentration of chromium in surficial sediment ($\mu g/g$ dry weight)
W = mass sedimentation rate (g/cm^2 year) based on ^{210}Pb dating
10^4 = units conversion factor ($cm^2 \Rightarrow m^2$)

The surface-sediment concentrations of chromium were taken as the concentration in the topmost 1 or 0.5 cm layers. The accumulation rates of chromium in the sediment cores were corrected using the focusing factor. The focusing-corrected sediment accumulation rate can be used in an entire lake. The sedimentation rates (Table 3) were calculated by Golden et al. (1993). A variable model was found best to describe sedimentation rates in cores from Lake Superior, while a constant model was found that to describe sedimentation rates in cores from Lakes Michigan and Ontario. The present mean accumulation rate of chromium is highest in Lake Ontario and lowest in Lake Superior (Table 3). Present day chromium loadings into the sediments are 5.3×10^6 kg/year, 5.4×10^6 kg/year, and 3.0×10^6 kg/year for Lakes Superior, Michigan, and Ontario, respectively (Table 3).

Table 3. Sediment accumulation rates for chromium in Lakes Superior, Michigan, and Ontario.

Lake	Surface area (10^{10} m^2)	Sites	Sed. Rate[1] (g/cm^2yr)	Surf. Con.[2] ($\mu g/g$)	Accum[3] ($\mu g/m^2yr$)	FF[4]	Accum/FF[5] ($\mu g/m^2yr$)	Accum/FF[6] (kg/yr)
Superior	82.1	DTL	0.0342	30.90	10567.8	1.48	7140.4	5.8 E6
		SJE II	0.0267	32.98	8805.7	1.26	6988.6	5.7 E6
		NOAA #3	0.0123	64.20	7896.6	1.14	6926.8	5.7 E6
		#1383	0.0390	72.55	28294.5	3.21	8814.5	7.2 E6
		#1391	0.0200	21.63	4326.0	1.79	2416.7	2.0 E6
						Average	6457.4	5.3 E6
Michigan	57.8	EPA#11	0.0160	49.73	7956.8	1.999	3980.4	2.3 E6
		EPA#18	0.0390	50.81	19815.9	2.434	8141.3	4.7 E6
		EPA#19	0.0230	67.24	15465.2	1.217	12707.6	7.3 E6
		LM #47s(?)	0.0350	51.46	18011.0	1.5	12007.3	6.9 E6
		LM #68k	0.0280	43.91	12294.8	1.267	9703.9	5.6 E6
						Average	9308.1	5.4 E6
Ontario	19.5	EPA#19	0.0302	71.85	21698.7	1.06	20470.5	4.0 E6
		EPA #40a	0.0639	38.58	24652.6	1.705	11459.0	2.8 E6
		E 30	0.0666	33.78	22497.5	2.04	11028.2	2.2 E6
						Average	15319.2	3.0 E6

Sed. Rate[1] = sedimentation rate. Surf. Con.[2] = surface concentration. Accum[3] = sediment accumulation rates.
FF[4] = focusing factor. Accum/FF[5] = focusing-corrected sediment accumulation rates.
Accum/FF[6] = focusing-corrected sediment accumulation rates based on the surface area of lakes.

Atmospheric Deposition of Chromium

An estimate of the relative proportion of recent atmospheric loadings of chromium sediment can be made by the comparing recent accumulation rates in surface sediments with atmospheric deposition rates. Atmospheric deposition consists of both wet and dry depositions. Wet deposition is thought to be more important than dry particle deposition in the Great Lakes (Mackay et al., 1986; Eisenreich, 1987; Eisenreich, 1992b). However, dry deposition may be dominant when the contaminants are associated with large particles (Murphy, 1984). Wet deposition fluxes were calculated by the following relationship (Eisenreich et al., 1992a).

$$F(wet) = C_{T,rain} \times P$$

where

F(wet) = the wet only flux ($\mu g/m^2$ year)
$C_{T,rain}$ = the total concentration of chromium in rain ($\mu g/m^3$)
P = annual precipitation intensity (m/year)

Dry particle deposition was calculated as follows (Eisenreich et al., 1992a):

$$F(dry) = C_{T,air} \times \varnothing \times V_d \times f_d \times C$$

where

F(dry) = the dry particle flux of chromium ($\mu g/m^2$ year)
$C_{T,air}$ = the total air concentration of chromium ($\mu g/m^3$)
$\varnothing$ = the fraction of chemical in the particle phase in the season of interest
V_d = the dry particle deposition velocity (0.2 cm/sec)
f_d = the fraction of the year not raining or snowing (0.9)
C = the units correction factor

The atmospheric dry deposition rates of chromium in the Great Lakes were calculated from the data sources list on Table 4. Some of the data were given as less than the detection limit. Therefore, the ranges of mean loadings were estimated by considering concentrations below detection limits as zero for a minimum loading or at the detection limit for a maximum loading.

The atmospheric wet deposition rates of chromium in the Great Lakes are calculated from the data of the Great Lakes Atmospheric Deposition (GLAD) network (U.S.E.P.A., 1994). The data set consists of the atmospheric measurements of chromium concentrations from over thirty sites around the Great Lakes region. Chromium concentrations in wet deposition have declined from 1983 to 1991 (Figure 21). This trend is similar to the trends of chromium in the sediment profiles. The average of chromium concentrations from 1988 to 1991, was used in the calculates of the wet deposition rates.

Wet deposition rates of chromium are lower than dry deposition rates which is contrary to previous assumptions. The total atmospheric deposition rate is highest in Lake Ontario and Lowest in Lake Superior. The relative proportion of atmospheric contributions to sediment accumulation rates is calculated by dividing the atmospheric deposition rates by focusing-corrected sediment accumulation rates (Table 6). The sediment accumulation rates of Lakes Superior, Michigan, and Ontario are contributed by atmospheric deposition as 6-15%, 4-11%, and 2-7%, respectively. Atmospheric deposition does not appear to be a major source of chromium loading into the Great Lakes.

Anthropogenic Inventories and Anthropogenic Sediment Burden

Inventories of anthropogenic chromium in sediment cores were calculated as follows:

Table 4. Dry deposition in the Great Lakes

Data of Cr concentration in air ($\mu g/m^3$)	Study Area	References
0.015 - 0.0191	Michigan	Michigan Dept. of Natural Resources, 1990
0.0064 - 0.0486	Michigan	Michigan Dept. of Natural Resources, 1991
0.0046	Mayville, New York state	Dutkiewicz et al., 1983
0.002	Lake Erie	Kelly et al., 1991
0.0013	Lake Superior (1977)	Eisenreich, 1982
0.0059 - 0.0151	Mean of the Great Lakes	F (dry) = 334.9 - 857.1 $\mu g/m^2$ yr

Table 5. Wet deposition in the Great Lakes

Data of Cr concentration in Precipitation ($\mu g/m^3$)	Study Area	References
158 - 192	The Great Lakes of United States region (1983-1991)	U.S.E.P.A., 1994
880	Northern Hemisphere	Galloway et al., 1982
200-900	Sudbery, Ontario, annual	Chan et al., 1982
< 1000	Dorset, Ontario, fall	Barrie, 1987
1000	Lake Erie	Barrie, 1987

Table 6. Percent atmospheric contribution to accumulation rates

Lake	Dry deposition ($\mu g/m^2$ yr)	Wet Deposition * ($\mu g/m^2$ yr)	Atmospheric Deposition ($\mu g/m^2$ yr)	Focusing corrected Accumulation rates ($\mu g/m^2$ yr)	% Atmospheric Contribution
Michigan	334.9 - 857.1	69.1 - 98.0	404.0 - 955.1	9308.1	4 - 11
Ontario	334.9 - 857.1	77.9 - 110.4	412.8 - 967.5	15319.2	2 - 7
Superior	334.9 - 857.1	66.5 - 94.2	401.4 - 951.3	6457.4	6 - 15

* Using arithmetic average concentration between 1988 and 1991 (from U.S.E.P.A., 1994).

$$Inv\ (\mu g/cm^2) = \Sigma_i\ [\ Csed \times (1-\varnothing) \times \rho \times d\ ]$$

where

Inv = the chromium inventory in the core ($\mu g/cm^2$)
Csed = background corrected chromium concentration in sediment ($\mu g/g$ dry weight)
$\varnothing$ = volumetric water fraction (porosity)
ρ = sediment dry density (2.45 g/cm^2)
i = number of depth increment
d = thickness of each increment (cm)

The inventories are corrected using the focusing factor. Table 7 and Figure 22 shows the calculated and focusing corrected chromium inventories. All of the calculations are shown in appendix D. Uncorrected inventories of chromium are different within basins and between lakes due to the variations in sediment focusing. Focusing corrected inventories of Lake Michigan collapse to similar value and perhaps also those of Lake Ontario. However, the focusing corrected inventories between Lake Michigan and Lake Ontario are different. This means that atmospheric deposition of chromium is not important source to the Great Lakes region or perhaps there is regional gradient of chromium concentration in the atmosphere of the Great Lakes.

The anthropogenic sediment burdens of chromium to the lakes are calculated as follows:

$$ASB\ (kg) = (\Sigma_j\ Invc)/j \times SA$$

Where

ASB = anthropogenic sediment burden to the lake
j = number of sites
Invc = focusing corrected inventory (kg/m^2)
SA = surface area of lake (m^2)

Table 7. Anthropogenic inventories and anthropogenic burdens of chromium in lakes Michigan and Ontario.

	Sampling sites	Inventory ($\mu g/cm^2$)	Focusing Factor	Focusing corrected inventory ($\mu g/cm^2$)	Surface Area (10^{10} m^2)	Anthropogenic sediment burden (kg)
	EPA #11	57.74	1.999	28.88		
	EPA #18	57.74	2.434	23.72		
Lake Michigan	EPA #19	38.46	1.217	31.61	57.8	1.49 E8
	LM #47s (?)	36.33	1.5	24.22		
	LM #68k	25.68	1.267	20.27		
	EPA #19	66.73	1.06	62.95	19.5	1.33 E8
Lake Ontario	EPA #40a	158.4	1.705	92.9		
	E 30	100.68	2.04	49.35		

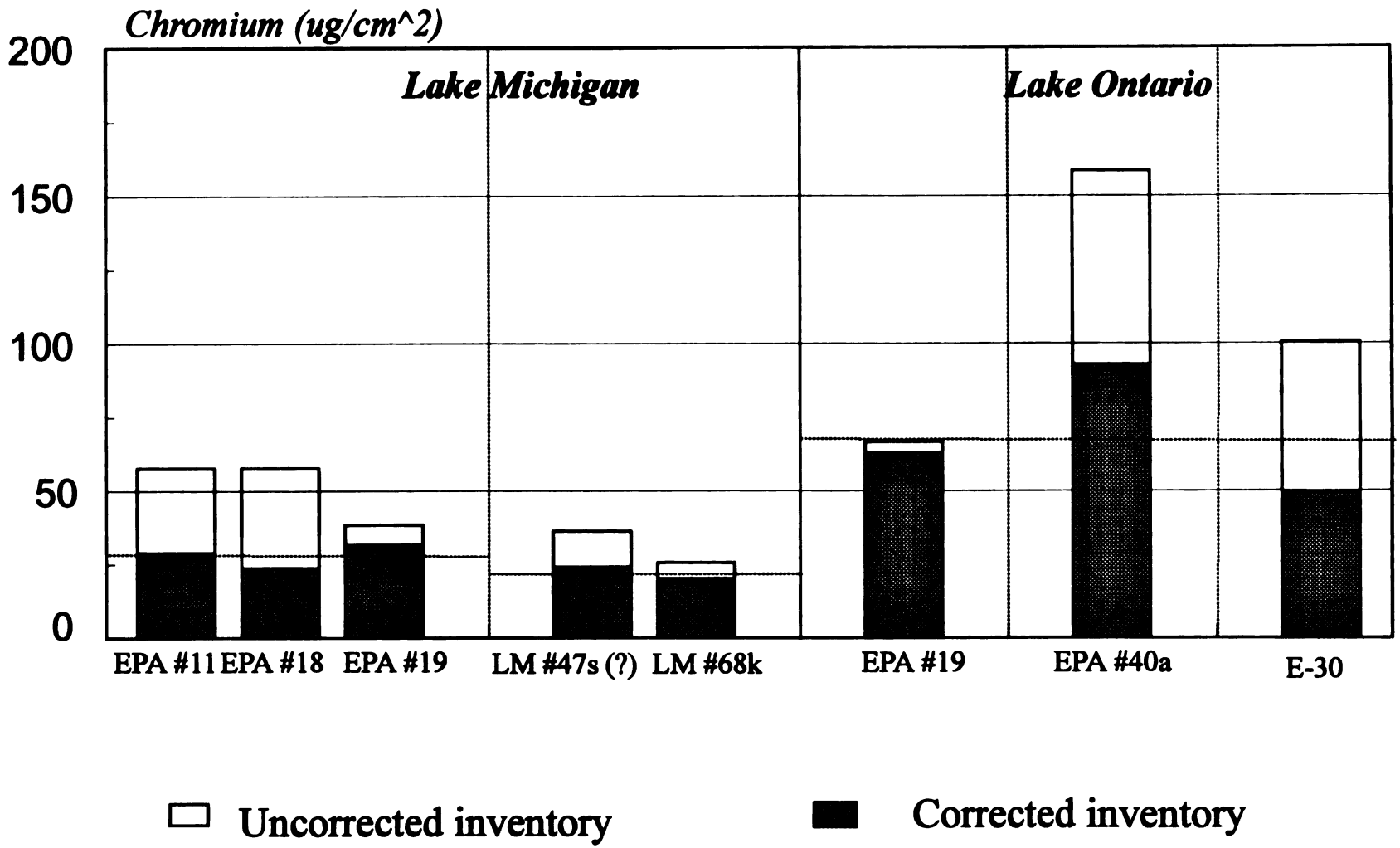

Figure 22. Chromium inventories of Lake Michigan and Lake Ontario.

Preliminary estimates of anthropogenic chromium loading into the sediments of Lake Michigan and Lake Ontario are 1.49×10^8 kg, 1.33×10^8 kg respectively (Table 7). Since the ratio of anthropogenic loading to background loading is so low, it is difficult to detect anthropogenic loading from Lake Superior sample cores.

V. Conclusions

Sediment cores were obtained from lakes Superior, Michigan, and Ontario to determine anthropogenic loading histories, chemical inventories, and recent accumulation rates of chromium. Pre-industrial concentrations of chromium, which are found to be typical for soil in the area, were determined and subtracted from the total metal concentrations to estimate anthropogenic loads. Sediment ages were determined by ^{210}Pb dating. Inventories and recent metal accumulation rates, estimated from recent sediment concentrations, were corrected for sediment focusing by ^{210}Pb inventories.

Surface concentrations in sediment cores exceed background concentrations 1-3.6 times in Lake Michigan and Lake Ontario. However, the results generally show that chromium loading rates are decreasing to the present. On the other hand, the trends in Lake Superior are not typical anthropogenic profiles and anthropogenic inventories could not be calculated. Focusing-corrected inventories are similar within basin of each lake, but are greater in Ontario than Michigan. The total amount of anthropogenic loading of chromium to the Lake Michigan is 1.49×10^8 kg and Lake Ontario is 1.33×10^8 kg. Focusing-corrected sediment accumulation rates show trends that are similar to those of chromium inventories. Accumulation rates are lowest for Superior. Atmospheric deposition rates of chromium were estimated from a variety of sources. The sediment accumulation rates of Lakes Superior, Michigan, and Ontario are contributed by atmospheric deposition as 6-15%, 4-11%, and 2-7%, respectively. These results show that the

focusing-corrected inventories are similar throughout depositional basins within each lake. Atmospheric deposition is not major source of chromium input to the Great Lakes.

Appendices

Appendix A

Table A-1

Lake Michigan EPA #11

Lat: 42° 22' 36"N, Long: 86° 59' 05"W, Depth 131 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Dark gray soupy material
2	1-2	1	Dark gray soupy material
3	2-3	1	Dark gray, less soupy
4	3-4	1	Dark gray, almost solid material
5	4-5	1	Dark gray, solid material
6	5-6	1	Upper portion dark gray, lower 0.2 cm light red color, possible worm burrows in section
7	6-7	1	Light gray, with tan mottling, some dark blebs of material (carbon)
8	7-8	1	More rigid, slightly more tan coloration and mottling--possible Fe oxides
9	8-9	1	Upper portion firm, lower portion soupy, same coloration
10	9-10	1	Sand present in this layer, same color
11	10-11	1	Higher sand content, possible Fe oxides
12	11-12	1	Light tan upper portion, Redox bands begin (tilted), yellow redox crust at base of section
13	12-12.5	1	Yellow redox crust--cements the sediment, 1 cm thick, remainder of section is light tan material, firm
14	12.5-13.5	1	More redox material, as in 13, light tan material also remainder of section
15	13.5-14.5	1	Light tan material with dark specks (carbon?), redox material at base with green material (vivianite?)
16	14.5-15	1	Redox crusts (2) each 0.1 cm thick Fe/Mn oxides, remainder is light tan material
17	15-15.5	1	Tan and gray mottling material very dry
18	15.5-16.5	1	Some redox, no sand
19	16.5-17.5	1	Redox layer near bottom of section
20	17.5-18.5	1	Thicker redox layer, pockets in middle of section, dark tan blebs 2 mm across

21	18.5-20.5	2	Mottling disappears through section
22	20.5-22.5	2	Redox layer 0.75 cm from section top, some mottling, remainder is tan
23	22.5-24.5	2	Redox layer, no mottling, tan with some gray material, *Current active redox layer* (color change)
24	24.5-26.5	2	Light gray, several black layers, much more soupy (anoxic layers)
25	26.5-28.5	2	Same as 24, slightly more black material

Table A-2

Lake Michigan EPA #18

Lat: 42° 44' 44"N, Long: 87° 00' 10"W, Depth 151 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Gray soupy material, worm burrows
2	1-2	1	Gray soupy material, worm burrows
3	2-3	1	Gray material, less soupy, worm burrows
4	3-4	1	Gray material, less soupy, worm burrows
5	4-5	1	Gray material, almost firm, worm burrows
6	5-6	1	Gray material, firm
7	6-7.5	1.5	Gray material, firm
8	7.5-8.5	1	Gray material, firm
9	8.5-9.5	1	Gray material, firm
10	9.5-10.5	1	Gray material, firm
11	10.5-11.5	1	Slightly lighter gray material, some sand
12	11.5-12.5	1	Mottled gray and tan, some zones of black material, much more sand
13	12.5-13.5	1	Same as 12
14	13.5-14.5	1	Zones of dry dark material (carbon?), some mottling, gritty
15	14.5-15.5	1	Less black material, sand content decreases
16	15.5-16.5	1	Mostly gray, black almost gone, no sand
17	16.5-17.5	1	A few dark streaks in the light gray material
18	17.5-18.5	1	Same as 17, mostly firm
19	18.5-19.5	1	No dark streaks, same as 18
20	19.5-20.5	1	Dark band at base, remainder is gray/tan material
21	20.5-21.5	1	Dark gray material, some sand
22	21.5-22.5	1	Same as 21
23	22.5-23.5	1	Dark material abundant, same as 21
24	23.5-24.5	1	Same as 23
25	24.5-25.5	1	Same as 23
26	25.5-27.5	2	Same as 23
27	27.5-29.5	2	Some slight mottling, dark bands at base
Skip	29.5-31.5	2	Material discarded, same as 27
28	31.5-33.5	2	More soupy, less dark material, mostly light gray with some mottling
29	33.5-35.5	2	Same as 28

Skip	35.5-37.5	2	Material discarded, same as 29
30	37.5-39.5	2	No dark streaks, all gray material
31	39.5-41.5	2	Mostly very dark material, remainder is light gray
Skip	41.5-43.5	2	Material discarded, same as 31
32	43.5-45.5	2	Very dark material
Skip	45.5-47.5	2	Material discarded, same as 32
33	47.5-49.5	2	Very dark material with some tan layers, bottom of core touches stopper

Table A-3

Lake Michigan EPA #19

Lat: 42° 44' 00"N, Long: 86° 35' 00"W, Depth 95 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Gray soupy material
2	1-2	1	Gray soupy material
3	2-3	1	Gray soupy material, more firm
4	3-4	1	Gray soupy material, more firm
5	4-5	1	Dark gray material, almost firm
6	5-6	1	Dark gray to tan material, almost firm
7	6-7	1	Light gray and tan material, firm
8	7-8	1	Same as 7
9	8-9	1	Same as 7 with mottling
10	9-10	1	Light tan with increasing light material, some sand present
11	10-11	1	Light tan material with sand
12	11-12	1	Tan material with rust brown spots (Fe minerals ?)
13	12-13	1	Darker and more gray, more rust spots
14	13-14	1	Same as 13, fewer rust spots, some other light mottling
15	14-15	1	Dark tan color deepens to base of sample
16	15-16	1	Redox zone: dark tan band 0.4 cm thick, dark gray band 0.2 cm thick, rust brown band 0.4 cm thick-solid crust
17	16-17	1	Dry tan crust at top, gray watery material below (0.6 cm)
18	17-18	1	Gray creamy textured material
19	18-19	1	Same as 18
20	19-20	1	Same as 18 with dark spots of organic material present
21	20-22	2	Dark gray sandy material with black streaks at base of section
22	22-24	2	Same as 21 , with a 0.3 cm band of black, rigid organic material
23	24-26	2	Lighter gray creamy texture with some dark spots
24	26-28	2	Same as 23 with sand and gravel up to 1 mm in size
25	28-30	2	Darker gray than 24, sand and gravel up to 1.5 mm in size

Table A-4

Lake Ontario EPA #19

Lat: 43° 30' 00"N, Long: 79° 25' 00"W, Depth 105 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Tan soupy material, worm burrows
2	1-2	1	Tan soupy material
3	2-3	1	Tan material, less soupy
4	3-4	1	Tan material grades into gray material, almost firm
5	4-5	1	Gray material, slightly watery
6	5-6	1	Gray color darkens to base, some sand
7	6-7	1	Gray material with dark spot, grades into tan material, slightly gritty
8	7-8	0.5	Tan material grades into gray
9	8-9	0.5	Dry redox boundary (orange)
10	9-10	1	Gray material with some redox chunks
11	10-11	1	Gray material with some black spots
12	11-12	1	Darker gray material with dry black spots
13	12-13	1	Dark gray with dark spots, shades to lighter gray with dark black spots
14	13-14	1	Same as 13, dry at base
15	14-15	1	Mostly dark material mixed with light gray material
16	15-16	1	Same as 15
17	16-17	1	Same as 16, pockets of water in light gray material
18	17-18	1	Same as 17
19	18-19	1	Same as 17
20	19-20	1	Light gray shades into dark gray material
21	20-22	1	Same as 17
22	22-24	2	Dark gray grades into watery light gray material
23	24-26	2	Same as 22
24	26-28	2	Tan to dark tan in color
25	28-30	2	Tan and dark tan material
26	30-32	2	Same as 25
27	32-34	2	Same as 25
28	34-36	2	Same as 25
29	36-38	2	Same as 25
30	38-40	2	Same as 25

Table A-5

Lake Ontario EPA #25a

Lat: 43° 30' 00"N, Long: 79° 05' 00"W, Depth 120 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Tan, very soupy material, worm burrows
2	1-2	1	Tan material, less soupy
3	2-3	1	Same as 2
4	3-4	1	Lighter tan material, almost firm
5	4-5	1	Same as 4
6	5-6	1	Very dark gray material
7	6-7	1	Same as 6, but darker color
8	7-8	1	Same as 7, with darker spots
9	8-9	1	Same as 8
10	9-10	1	Same as 8, darker color, more black material
11	10-11	1	Lighter color, more dark spots
12	11-12	1	Same as 11, but very dry
13	12-13	1	Same as 12
14	13-14	1	More dark material at base
15	14-15	1	Very dark material at base
16	15-16	1	Very dark throughout section, lots of dark gray material at base
17	16-17	1	Lighter color, with more gray material
18	17-18	1	Same as 17
19	18-19	1	Mostly light tan with some black material, very creamy
20	19-20	1	Gets darker at base of section
21	20-22	1	Light colored and firm, changes to darker colored and wet at base
22	22-24	2	Light and dark material mixed, very wet
23	24-26	2	Same as 22, darker at base
24	26-28	2	Same as 22, darker throughout section
25	28-30	2	Same as 22
26	30-32	2	Same as 22
27	32-34	2	Same as 22
28	34-36	2	Same as 22, darker color
29	36-38	2	Same as 28
30	38-40	2	Same as 28

Table A-6

Lake Ontario EPA #40a

Lat: 43° 37' 00"N, Long: 78° 05' 00"W, Depth 189 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Tan fluff, some spots of black material
2	1-2	1	Same as 1, Some gray spots
3	2-3	1	Tan with gray spots, almost firm
4	3-4	1	Greenish tan material, very soupy, black and gray spots at base of section
5	4-5	1	Gray colored material, some chunks of black material, almost firm
6	5-6	1	Same as 5, darker towards base, and black stuff gets coarser
7	6-7	1	Gray darkens, black chunks get larger
8	7-8	1	Dark gray with tan mottling, color darkens towards base with black chunks
9	8-9	1	Mostly tan with black mottling (chunks)
10	9-10	1	Very dark gray to black material
11	10-11	1	Same as 10, black chunks and gray mottling are present
12	11-12	1	Fewer black chunks, tan with black mottling at base of section
13	12-13	1	Same as 12
14	13-14	1	Dark gray color turns to light gray at base, becomes creamy texture
15	14-15	1	Lighter color tan/gray, small black chunks
16	15-16	1	Gray color with black spots increasing to the base of section
17	16-17	1	Gray/ tan material darkens towards base of section, becomes firm
18	17-18	1	Uniform black material
19	18-19	1	Same as 18, becomes lighter to base
20	19-20	1	Dark gray/ tan with black chunks within light tan patches
21	20-21	1	Medium tan becomes darker gray at base of section
22	21-22	1	Medium tan becomes lighter towards base with lighter patches
23	22-23	1	Light tan at top with black layer 0.1 mm thick, tan becomes dark to base

24	23-24	1	Light/dark tan mixture with black mottling at top, becomes light tan at base, two thick black layers in section
25	24-25	1	Light tan with a black layer, darkens to dark tan color at base
26	25-26	1	Same as 25, more black material, more wet
27	26-27	1	Same as 26
28	27-28	1	Mixture of light and dark tan material
29	28-29	1	Same as 28
Skip	29-30	1	Material discarded
30	30-31	1	Creamy light and dark tan material
Skip	31-32	1	Material discarded
31	32-33	1	Light tan changes to dark tan at base, some kind of grass like material

* Remainders of this core are not analyzed.

Table A-7

Lake Ontario EPA #64a

Lat: 43° 35' 00"N, Long: 77° 07' 00"W, Depth 168 m

Sample #	Depth (cm)	Thickness (cm)	Description
1	0-1	1	Tan soupy material
2	1-2	1	Darker tan soupy material, more firm
3	2-3	1	Same as 2
4	3-4	1	Gray material with some tan mixed in, almost firm, worm burrows
5	4-5	1	Gray darkens to base, some tan mottling, few worm burrows
6	5-6	1	Tan mottling in gray upper part, black material in darker gray at base
7	6-7	1	Gray to dark gray material with black mottling
8	7-8	1	Same as 8
9	8-9	1	Same as 8
10	9-10	1	Same as 8, more black material
11	10-11	1	Same as 10, some light gray material
12	11-12	1	Same as 11 , much drier, becomes wetter at base and color lightens
13	12-13	1	Same as 12, pockets of water and much more black material at base
14	13-14	1	Same as 13
15	14-15	1	Light gray mixed with dark gray and black spots
16	15-16	1	Same as 15
17	16-17	1	Same as 15, very light gray material also
18	17-18	1	Light and dark material mixed
19	18-19	1	Very light gray with black or dark gray spots in lower half of section
20	19-20	1	Same as 19
21	20-21	1	Same as 19, drier
22	21-21.75	0.75	Same as 21
23	21.75-22	0.25	Redox zone, orange crust with dark material mixed in
24	22-23	1	Very light gray material, wetter, not quite the same material as above redox
25	23-24	1	Same as 24, some pink material
26	24-25	1	Same as 25

27	25-26	1	Tan gray and blue gray mix, tan gray material is wetter
28	26-27	1	Same as 27
29	27-28	1	Mostly tan gray material, wet
30	28-29	1	0.25 cm black material
31	29-30	1	Same as 30
Skip	30-31	1	Material discarded
32	31-32	1	Same as 30
Skip	32-33	1	Material discarded
33	33-34	1	Turns dark at base of section, light gray and black becomes light gray
Skip	34-35	1	Material discarded
34	35-36	1	Mostly light tan with black specks
Skip	36-37	1	Material discarded
35	37-38	1	Mostly light gray with black material at base of section
Skip	38-39	1	Material discarded
36	39-40	1	Lots of black material and some pockets of water in the gray material
Skip	40-41	1	Material discarded
37	41-42	1	Upper part of section is light gray with black specks, turns black at base
Skip	42-43	1	Material discarded
38	43-44	1	Mixture of light gray and predominantly black material
Skip	44-45	1	Material discarded
39	45-46	1	Same as 38, slightly lighter color

Table A-8

Lake Ontario E 30

Lat: 43° 32' 16"N, Long: 76° 54' 03"W

Sample #	Depth (cm)	Thickness (cm)	Description
1	0.0-0.5	0.5	Tan sediment
2	0.5-1.0	0.5	Tan sediment
3	1.0-1.5	0.5	Tan sediment
4	1.5-2.0	0.5	Tan sediment
5	2.0-2.5	0.5	Sharp boundary, tan above with darker sediment below
6	2.5-3.0	0.5	Dark material and fish bones
7	3.0-3.5	0.5	Dark material and sediment
8	3.5-4.0	0.5	Dark sediment
9	4.0-4.5	0.5	Dark sediment
10	4.5-5.0	0.5	Dark sediment
11	5.0-5.5	0.5	Dark sediment
12	5.5-6.0	0.5	Dark sediment
13	6.0-6.5	0.5	Dark sediment
14	6.5-7.0	0.5	Dark sediment
15	7.0-7.5	0.5	Dark sediment
16	7.5-8.0	0.5	Dark sediment
17	8.0-8.5	0.5	Beginning of tan/ black layering
18	8.5-9.0	0.5	Tan/ black sediment layering
19	9.0-9.5	0.5	Tan/ black sediment layering
20	9.5-10	0.5	Tan/ black sediment layering
21	10-11	1	Tan/ black sediment layering
22	11-13	2	Tan/ black sediment layering
23	13-16	3	Tan/ black sediment layering
24	16-18	2	Tan/ black sediment layering

Table A-9

Lake Superior DTL

Lat: 46° 50' 50"N, Long: 91° 45' 11"W

Sample #	Depth (cm)	Thickness (cm)	Description
1	0.0-0.5	0.5	Reddish mud
2	0.5-1.0	0.5	Reddish mud
3	1.0-1.5	0.5	Reddish mud
4	1.5-2.0	0.5	Reddish mud
5	2.0-2.5	0.5	Reddish mud
6	2.5-2.75	0.25	Mud above redox zone
7	2.75-3.0	0.25	Black redox zone
8	3.0-3.1	0.1	Very thin iron redox zone
9	3.1-3.35	0.25	Red layered mud
10	3.35-3.85	0.5	Red layered mud
11	3.85-4.35	0.5	Red layered mud
12	4.35-4.85	0.5	Red layered mud
13	4.85-5.35	0.5	Mud somewhat darker
14	5.35-5.85	0.5	Darker mud
15	5.85-6.35	0.5	A lot of slag in a dark mud
16	6.35-7.35	1	Slag material in a dark mud
17	7.35-8.35	1	Slag amount decreasing
18	8.35-9.35	1	Little slag material left
19	9.35-10.35	1	Black layer (1 mm thick)
20	10.35-11.35	1	No black layers left
Skip	11.35-12.35	1	
21	12.35-13.35	1	Dark mud
Skip	13.35-14.35	1	
22	14.35-15.35	1	Dark mud
Skip	15.35-16.35	1	
23	16.35-17.35	1	Dark mud
Skip	17.35-18.35	1	
24	18.35-19.35	1	Dark mud

Table A-10

Lake Superior SJE II

Lat: 47° 02' 00"N, Long: 91° 17' 94"W

Sample #	Depth (cm)	Thickness (cm)	Description
1	0.0-0.5	0.5	Brown muddy sediment
2	0.5-1.0	0.5	Brown muddy sediment
3	1.0-1.5	0.5	Brown muddy sediment
4	1.5-2.0	0.5	Brown grading to gray colored sediment
5	2.0-2.5	0.5	Sediment darkening
6	2.5-3.0	0.5	Dark sediment
7	3.0-3.5	0.5	Dark sediment
8	3.5-4.0	0.5	Dark sediment, appears mottled
9	4.0-4.25	0.25	Mottled, Mn oxide layer, dark sediment.
10	4.25-4.4	0.15	Redox zone, 4.40 to 4.50 cm increment was thrown away
11	4.5-5.0	0.5	Slight color change to reddish.
12	5.0-5.25	0.25	Reddish colored mud
13	5.25-5.65	0.4	Better developed redox zone
14	5.65-6.05	0.4	Redox zone with interspaced material
15	6.05-6.55	0.5	Redox zone with wet mud
16	6.55-7.05	0.5	Redox zone ending, wet mud
17	7.05-7.55	0.5	Brown-red uniform mud
18	7.55-8.55	1	Brown-red uniform mud
19	8.55-9.55	1	Small (< 1 mm) black band
Skip	9.55-10.55	1	
20	10.55-11.55	1	Dark streaks in sediment
21	11.55-12.55	1	Mostly lighter sediment
22	12.55-14.55	2	Large dark band (2 mm thick)
Skip	14.55-16.55	2	
23	16.55-18.55	2	Dark material fades out
Skip	18.55-20.55	2	
24	20.55-22.55	2	Dark material fades out

Table A-11

Lake Superior #1383

Lat: 47° 39' 24" N, Long: 87° 57' 98" W

Sample #	Depth (cm)	Thickness (cm)	Description
1	0.0-1.0	1	Greenish-brown wet fluff
2	1.0-2.0	1	Greenish-brown wet fluff
3	2.0-3.0	1	Greenish-brown wet fluff, tan contact near base
4	3.0-3.5	0.5	Tan sediment, slightly drier
5	3.5-4.0	0.5	Greenish-black sticky material, possible start of redox
6	4.0-4.5	0.5	Flaky dry pale orange sediment, redox boundary
7	4.5-5.5	1	Gray, wet sticky clay
8	5.5-6.5	1	Gray, wet sticky clay
9	6.5-8.5	2	Gray, wet sticky clay
10	8.5-10.5	2	Gray, wet sticky clay
11	10.5-12.5	2	Gray, wet sticky clay
12	12.5-14.5	2	Gray, wet sticky clay
13	14.5-17.5	3	Gray, wet sticky clay
14	17.5-20.5	3	Gray, wet sticky clay
15	20.5-24.5	4	Gray, wet sticky clay
16	24.5-28.5	4	Gray, wet sticky clay
17	28.5-32.5	4	Gray, wet sticky clay
18	32.5-36.5	4	Gray, wet sticky clay

* Remainder of sediment discarded.

Table A-12

Lake Superior #1391

Lat: 46° 45' 40" N, Long: 84° 47' 09" W

Sample #	Depth (cm)	Thickness (cm)	Description
1	0.0-1.0	1	Brown fluff material
2	1.0-2.0	1	Dark brown sediment
3	2.0-3.0	1	Very dark brown/ sandy
4	3.0-3.5	0.5	Redox zone, black-red sediment
5	3.5-4.5	1	Light red sediment
6	4.5-5.5	1	Black material below redox
7	5.5-6.5	1	Light gray/ black sediment
8	6.5-8.5	2	Light gray/ black sediment
9	8.5-10.5	2	Light gray/ black sediment
10	10.5-11.5	1	End of black sediment
11	11.5-14.5	3	Gray sediment
12	14.5-16.5	2	Gray sediment
13	16.5-19.5	3	Gray sediment
14	19.5-23.5	4	Gray sediment
15	23.5-28.5	5	Gray sediment

Appendix B

Table B-1

Replicate result

Sample #	Run 1	Run 2	Run 3	Mean	Std. Dev.	RSD (%)
EPA#11-18	30.31	32.97	33.61	32.2967	1.4289	4.4242
EPA#18-18	24.96	26.73	27.79	26.4933	1.1674	4.4064
EPA#18-32	24.24	25.08	24.23	24.5167	0.3984	1.6248
EPA#47s(?)-9	55.92	57.28	60.56	57.9200	1.9476	3.3625
EPA#47s(?)-20	39.03	36.57	34.65	36.7500	1.7927	4.8780
EPA#68k-10	53.93	53.55	48.79	52.0900	2.3386	4.4895
EPA#68K-17	38.00	34.74	41.97	38.2367	2.9564	7.7318
EPA#19(LO)-23	34.79	30.55	28.86	31.4000	2.4944	7.9440
EPA#19(LO)-30	37.37	36.70	32.53	35.5333	2.1412	6.0259
E-30-4	75.70	69.26	73.83	72.9300	2.7050	3.7091
E-30-17	58.87	58.09	61.13	59.3633	1.2892	2.1717
DTL-5	37.57	35.61	35.20	36.1267	1.0342	2.8628
DTL-10	43.46	45.81	42.40	43.8900	1.4249	3.2466
SJE II-5	55.03	54.35	57.51	55.6300	1.3580	2.4412
SJE II-15	61.52	59.08	62.07	60.8900	1.2994	2.1340
#1383-8	84.77	85.27	85.81	85.2833	0.4247	0.4980
#1391-7	20.05	18.23	20.27	19.5167	0.9142	4.6844

Table B-2

Quality assurance: SRM

Sample #	Concentration(ug/g)
EPA#11	93.90
EPA#18	93.90
EPA#19(LM)	88.91
EPA#47s(?)	78.61
EPA#68k	85.92
EPA#19(LO)	93.90
EPA#40A	93.90
EPA#64A	86.82
E-30	79.87
NOAA#3	83.44
DTL	86.09
SJE II	81.57
#1390	86.22
#1391	85.19
Mean	**87.02**

Table B-3

The background concentration of chromium in the sediments of this study

Sediment sample #	Concentration(ug/g)
EPA#11	30.49
EPA#18	27.98
EPA#19(LM)	26.23
LM #47s(?)	34.20
LM #68k	33.05
EPA#19(LO)	35.70
EPA#25a	33.60
EPA #40a	37.66
EPA#64a	29.20
E-30	32.68
NOAA #3	73.00
DTL	49.45
SJE II	63.16
#1390	83.06
#1391	20.00
Mean	40.63
Range	20.00 - 83.06

Appendix C

Table C-1

EPA #11 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.50	1970.5	84.6	49.73	19.24	24.88
2	1.50	1938.0	82.4	47.92	17.43	23.97
3	2.50	1915.3	82.2	50.89	20.40	25.46
4	3.50	1895.0	79.5	50.32	19.83	25.17
5	4.50	1877.0	79.2	47.23	16.74	23.63
6	5.50	1858.0	77.8	41.59	11.10	20.81
7	6.50	1838.4	77.2	34.93	4.44	17.47
8	7.50	1817.3	73.6	33.25	2.76	16.63
9	8.50	1794.2	73.3	32.97	2.48	16.49
10	9.50	1770.1	73.0	36.01	5.52	18.01
11	10.50	1745.1	66.3	30.09		15.05
12	11.50		67.5	44.40		22.21
13	12.25		68.4	51.11		25.57
14	13.00		64.9	38.27		19.14
15	14.00		61.4	33.27		16.64
16	14.75		64.0	30.66		15.34
17	15.25		66.5	30.49		15.25
18	16.00		65.8	32.29		16.15
19	17.00		63.6	33.39		16.70
20	18.00		64.9	29.98		15.00
21	19.50		66.7	35.35		17.68
22	21.50		66.7	35.96		17.99
23	23.50		65.8	31.73		15.87
24	25.50		64.4	35.79		17.90
25	27.50		66.6	39.64		19.83

Table C-2

EPA #18 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.5	1989.7	94.2	50.81	22.83	20.88
2	1.5	1984.4	93.1	46.38	18.40	19.06
3	2.5	1977.8	91.5	48.43	20.45	19.90
4	3.5	1970.8	90.5	51.68	23.70	21.23
5	4.5	1963.4	89.8	49.93	21.95	20.51
6	5.5	1956.1	89.3	49.47	21.49	20.32
7	6.8	1945.6	89.2	45.19	17.21	18.57
8	8	1938.3	89.2	40.28	12.30	16.55
9	9	1931.0	89.1	39.10	11.12	16.06
10	10	1923.8	88.3	41.33	13.35	16.98
11	11	1916.5	87.5	33.27	5.29	13.67
12	12	1856.5	87.6	37.69	9.71	15.48
13	13	1793.1	87.3	32.43	4.45	13.32
14	14	1776.8	87.2	33.24	5.26	13.66
15	15		87.0	36.25	8.27	14.89
16	16		87.0	30.73	2.75	12.63
17	17		87.0	29.34	1.36	12.05
18	18			26.49		10.88
19	19			29.73		12.21
20	20			30.29		12.44
21	21			27.83		11.43
22	22			31.89		13.10
23	23			31.60		12.98
24	24			27.67		11.37
25	25			29.76		12.23
26	26.5			27.58		11.33
27	28.5			28.90		11.87
28	32.5			28.46		11.69
29	34.5			28.31		11.63
30	38.5			27.64		11.36
31	40.5			26.68		10.96
32	44.5			24.52		10.07
33	48.5			22.86		9.39

Table C-3

EPA #19(LM) chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.5	1989.8	94.2	67.24	41.01	55.25
2	1.5	1983.9	93.1	69.07	42.84	56.75
3	2.5	1972.2	91.5	66.06	39.83	54.28
4	3.5	1956.4	90.5	58.23	32.00	47.85
5	4.5	1939.2	89.8	50.81	24.58	41.75
6	5.5	1918.1	89.3	39.02	12.79	32.06
7	6.5	1891.7	89	26.81	0.58	22.03
8	7.5		63.8	19.59		16.10
9	8.5		61.4	18.61		15.29
10	9.5		66.4	20.88		17.16
11	10.5		63.9	18.84		15.48
12	11.5		70.3	23.64		19.42
13	12.5		73.1	26.31		21.62
14	13.5		72.1	24.76		20.35
15	14.5		71.8	27.17		22.33
16	15.5		71.6	22.76		18.70
17	16.5		71.9	30.13		24.76
18	17.5		71.2	26.72		21.96
19	18.5		73.6	29.37		24.13
20	19.5		75.1	33.84		27.81
21	21		66.7	30.27		24.87
22	23		68.2	33.90		27.86
23	25		68.2	30.90		25.39
24	27		65.6	27.17		22.33
25	29		67.8	27.30		22.43

Table C-4

EPA #47s (?) chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.25	1990.5	98.4	51.46	17.26	34.31
2	0.75	1986.5	97.3	48.63	14.43	32.42
3	1.25	1981.4	97.5	61.85	27.65	41.23
4	1.75	1975.2	97.0	57.60	23.40	38.40
5	2.25	1969.0	96.6	58.08	23.88	38.72
6	2.75	1962.8	96.7	65.78	31.58	43.85
7	3.25	1955.0	95.4	57.84	23.64	38.56
8	3.75	1945.6	95.2	63.40	29.20	42.27
9	4.50	1936.2	94.9	57.92	23.72	38.61
10	5.50	1924.6	94.1	64.79	30.59	43.19
11	6.50	1910.7	94.2	63.86	29.66	42.57
12	7.50	1896.4	92.1	57.90	23.70	38.60
13	8.50	1881.7	92.7	52.08	17.88	34.72
14	9.50	1867.0	93.1	47.79	13.59	31.86
15	10.50		91.4	46.49	12.29	30.99
16	11.50		93.4	42.13	7.93	28.09
17	12.50		92.3	38.69	4.49	25.79
18	13.50		93.2	38.71	4.51	25.81
19	14.50		93.3	37.07	2.87	24.71
20	15.50		93.6	36.75	2.55	24.50
21	16.50		93.3	35.55	1.35	23.70
22	17.50		91.6	35.38	1.18	23.59
23	18.50		90.8	34.08		22.72
24	19.50		91.2	34.37		22.91
25	23.50			34.16		22.77

Table C-5

EPA #68k chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.25	1991.4	98.0	43.91	10.86	34.66
2	0.75	1989.3	96.6	51.87	18.82	40.94
3	1.25	1986.6	95.6	54.16	21.11	42.75
4	1.75	1983.4	94.7	57.64	24.59	45.49
5	2.25	1980.1	94.0	59.29	26.24	46.80
6	2.75	1976.8	93.8	63.24	30.19	49.91
7	3.25	1973.0	94.1	61.22	28.17	48.32
8	3.75	1968.7	93.3	62.84	29.79	49.60
9	4.50	1962.3	93.5	61.22	28.17	48.32
10	5.50	1953.4	94.2	52.09	19.04	41.11
11	6.50	1944.0	93.9	47.57	14.52	37.55
12	7.50	1934.6	94.9	43.91	10.86	34.66
13	8.50	1925.2	93.6	37.07	4.02	29.26
14	9.50	1915.6	92.8	38.01	4.96	30.00
15	10.50	1905.7	93.8	39.44	6.39	31.13
16	11.50	1895.9	92.0	33.41	0.36	26.37
17	12.50	1886.0	94.0	38.24	5.19	30.18
18	13.50	1876.0	92.6	34.69	1.64	27.38
19	14.50	1866.0	92.6	33.14	0.09	26.16
20	15.50	1855.7	94.0	32.29		25.49
21	16.50	1845.1	91.6	32.74		25.84
22	17.50		93.3	36.81		29.05
23	18.50		93.9	33.18		26.19
24	19.50		91.5	36.42		28.75
25				31.88		25.16

Table C-6

EPA #19(LO) chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.5	1989.4	94.2	71.85	39.17	67.78
2	1.5	1983.8	92.2	73.91	41.23	69.73
3	2.5	1977.0	90.9	58.66	25.98	55.34
4	3.5	1969.5	90.6	84.87	52.19	80.07
5	4.5	1961.8	90.4	88.23	55.55	83.24
6	5.5	1953.0	87.9	86.76	54.08	81.85
7	6.5	1942.0	85.0	61.62	28.94	58.13
8	7.0	1920.0	83.0	39.68	7.00	37.43
9	7.5	1891.1	81.8	28.95		27.31
10	8.5	1838.1	83.6	41.97		39.59
11	9.5		84.5	39.90		37.64
12	10.5		85.1	35.03		33.05
13	11.5		84.5	36.33		34.27
14	12.5		84.3	34.08		32.15
15	13.5		84.7	34.84		32.87
16	14.5		84.0	35.87		33.84
17	15.5		84.7	37.62		35.49
18	16.5		84.3	35.61		33.59
19	17.5		84.4	33.51		31.61
20	18.5		84.5	34.67		32.71
21	19.5		84.1	33.55		31.65
22	21.5		83.9	37.36		35.25
23	23.5			31.40		29.62
24	25.5			37.74		35.60
25	27.5			36.38		34.32
26	29.5			36.22		34.17
27	31.5			34.51		32.56
28	35.5			36.61		34.54
29	37.5			37.75		35.61
30	39.5			35.53		33.52

Table C-7

EPA #25a chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.5		89.0	52.63	19.03	
2	1.5		87.0	55.13	21.53	
3	2.5		85.8	58.38	24.78	
4	3.5		84.7	66.85	33.25	
5	4.5		85.2	79.14	45.54	
6	5.5		85.0	108.42	74.82	
7	6.5		85.3	111.62	78.02	
8	7.5		83.6	86.45	52.85	
9	8.5		81.7	86.52	52.92	
10	9.5		80.2	78.86	45.26	
11	10.5		78.0	58.35	24.75	
12	11.5		79.1	51.68	18.08	
13	12.5		78.1	46.68	13.08	
14	13.5		79.3	39.93	6.33	
15	14.5		78.2	38.53	4.93	
16	15.5		78.1	36.17	2.57	
17	16.5		78.6	35.32	1.72	
18	17.5		77.8	34.22	0.62	
19	18.5		77.2	36.37	2.77	
20	19.5		78.0	35.94	2.34	
21	21.0		77.1	34.16	0.56	
22	23.0		77.7	33.31		
23	25.0		78.3	33.10		
24	27.0		77.5	34.06		
25	29.0		77.6	33.45		
26	31.0		77.6	32.79		
27	33.0		76.2	32.26		
28	35.0		77.1	32.22		
29	37.0		78.1	31.99		
30	39.0		77.1	32.93		

Table C-8

EPA #40a chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.5	1990.9	92.3	38.58	0.92	22.63
2	1.5	1988.7	89.5	54.62	16.96	32.04
3	2.5	1985.6	87.8	57.79	20.13	33.89
4	3.5	1981.7	86.9	65.31	27.65	38.30
5	4.5	1977.7	88.0	73.75	36.09	43.26
6	5.5	1974.0	88.9	81.58	43.92	47.85
7	6.5	1970.6	86.7	105.10	67.44	61.64
8	7.5	1967.1	88.3	88.41	50.75	51.85
9	8.5	1963.7	86.7	87.94	50.28	51.58
10	9.5	1959.9	86.6	82.44	44.78	48.35
11	10.5	1955.8	84.4	77.05	39.39	45.19
12	11.5	1951.4	81.9	72.12	34.46	42.30
13	12.5	1946.8	82.7	61.36	23.70	35.99
14	13.5	1937.0	98.4	53.32	15.66	31.27
15	14.5	1927.4	81.2	48.98	11.32	28.73
16	15.5	1917.6	81.3	43.08	5.42	25.27
17	16.5	1907.6	82.6	37.94	0.28	22.25
18	17.5	1897.3	81.4	36.15		21.20
19	18.5	1886.6	83.2	37.66		22.09
20	19.5	1876.1	82.3	37.81		22.18
21	20.5		81.9	38.57		22.62
22	21.5		81.7	38.95		22.84
23	22.5		82.0	43.37		25.44
24	23.5		82.7	41.25		24.19
25	24.5		82.7	39.29		23.04
26	25.5		82.4	51.67		30.30
27	26.5		81.1	40.01		23.47
28	27.5		82.6	38.81		22.76
29	28.5		83.2	37.77		22.15
30	30.5		82.3	37.79		22.16
31	32.5		81.2	41.30		24.22

Table C-9

EPA #64a chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.50		93.2	45.22	16.02	
2	1.50		90.3	51.43	22.23	
3	2.50		89.1	55.10	25.90	
4	3.50		91.1	64.74	35.54	
5	4.50		90.0	82.95	53.75	
6	5.50		89.4	99.26	70.06	
7	6.50		87.5	85.51	56.31	
8	7.50		85.9	74.32	45.12	
9	8.50		83.3	70.73	41.53	
10	9.50		84.0	60.35	31.15	
11	10.50		82.6	51.29	22.09	
12	11.50		82.1	43.63	14.43	
13	12.50		82.7	37.87	8.67	
14	13.50		80.9	33.74	4.54	
15	14.50		80.6	31.41	2.21	
16	15.50		79.8	29.92	0.72	
17	16.50		80.5	28.58		
18	17.50		81.0	29.79		
19	18.80		79.9	29.28		
20	19.50		76.2	33.83		
21	20.50		74.7	30.98		
22	21.35		76.1	31.26		
23	21.85		75.2	22.23		
24	22.50		74.7	32.76		
25	23.50		74.1	31.69		
26	24.50		73.9	32.49		
27	25.50		71.2	29.90		
28	26.50		73.7	26.67		
29	27.50		75.4	29.80		
30	28.50		75.6	31.42		
31	29.50		73.0	27.94		
32	31.50		74.1	26.00		
33	33.50		75.5	31.87		
34	35.50		74.4	27.43		
35	37.50		74.0	26.84		
36	39.50		77.3	27.84		

37	41.50	76.6	24.78
38	43.50	74.7	29.40
39	45.50	74.2	28.06

Table C-10

E 30 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.25	1989.6	93.0	33.78	1.10	16.56
2	0.75	1988.1	92.6	55.65	22.97	27.28
3	1.25	1987.4	92.2	54.26	21.58	26.60
4	1.75	1985.7	91.8	72.93	40.25	35.75
5	2.25	1984.3	91.5	81.62	48.94	40.01
6	2.75	1982.5	91.4	77.42	44.74	37.95
7	3.25	1980.8	91.3	113.04	80.36	55.41
8	3.75	1979.4	91.3	117.31	84.63	57.50
9	4.25	1978.0	91.2	114.63	81.95	56.19
10	4.75	1976.2	91.3	82.64	49.96	40.51
11	5.25	1974.8	91.5	79.50	46.82	38.97
12	5.75	1972.7	91.7	81.46	48.78	39.93
13	6.25	1971.3	91.7	77.08	44.40	37.78
14	6.75	1969.9	91.6	77.98	45.30	38.23
15	7.25	1968.5	91.5	73.44	40.76	36.00
16	7.75	1966.8	91.4	67.54	34.86	33.11
17	8.25	1965.4	91.1	59.36	26.68	29.10
18	8.75	1963.3	90.6	55.67	22.99	27.29
19	9.25	1961.9	90.5	59.08	26.40	28.96
20	9.75	1960.1	90.2	56.57	23.89	27.73
21	10.50	1957.7	89.7	51.02	18.34	25.01
22	12.00	1951.0	88.6	43.66	10.98	21.40
23	14.50	1940.6	88.1	34.11	1.43	16.72
24	17.00	1929.7	88.0	32.68		16.02

Table C-11

DTL chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.250	1989.3	83.1	30.90		20.88
2	0.750	1986.1	82.4	39.40		26.62
3	1.250	1981.4	82.6	40.53		27.39
4	1.750	1977.1	82.1	39.61		26.76
5	2.250	1973.7	81.3	36.13		24.41
6	2.625	1971.3	80.8	35.87		24.24
7	2.875	1969.7	83.3	35.69		24.11
8	3.050	1968.6	85.2	32.40		21.89
9	3.225	1967.2	81.9	36.30		24.53
10	3.600	1964.3	80.3	43.89		29.66
11	4.100	1960.5	80.9	50.93		34.41
12	4.600	1956.6	81.8	52.73		35.63
13	5.100	1952.8	81.6	49.85		33.68
14	5.600	1947.1	81.8	48.92		33.05
15	6.100	1941.3	82.2	44.81		30.28
16	6.850	1931.1	82.2	43.56		29.43
17	7.850	1916.8	81.7	51.32		34.68
18	8.850	1899.3	81.6	51.45		34.76
19	9.850	1879.6	81.5	50.73		34.28
20	10.850		82.1	49.84		33.68
21	12.850		81.9	48.92		33.05
22	14.850		82.0	50.92		34.41
23	16.850		82.5	49.11		33.18
24	18.850		82.0	49.19		33.24

Table C-12

SJE II chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.25	1988.5	95.0	32.98		26.17
2	0.75	1983.7	82.3	29.31		23.26
3	1.25	1977.9	82.5	32.71		25.96
4	1.75	1972.2	83.1	37.25		29.56
5	2.25	1965.9	83.2	55.63		44.15
6	2.75	1958.0	83.7	60.60		48.10
7	3.25	1947.9	83.9	58.75		46.63
8	3.75	1935.2	84.0	70.05		55.60
9	4.13	1926.8	84.2	70.30		55.79
10	4.28	1921.1	89.8	61.16		48.54
11	4.75	1911.4	83.4	71.66		56.87
12	5.13	1902.3	84.2	64.02		50.81
13	5.45	1892.0	85.6	45.70		36.27
14	5.85	1882.3	84.7	51.41		40.80
15	6.30	1867.4	84.4	60.89		48.33
16	6.80	1851.4	84.4	62.92		49.94
17	7.30	1835.4	84.5	56.41		44.77
18	8.05		84.2	65.38		51.89
19	9.05		83.7	64.21		50.96
20	11.05		82.5	65.68		52.13
21	12.05		83.4	68.71		54.53
22	13.05		83.2	68.49		54.36
23	17.05		83.2	61.85		49.09
24	21.05		83.3	64.83		51.45

Table C-13

NOAA#3 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.25	1988.8	95.0	64.20		56.32
2	0.75	1981.6	93.0	72.90		63.95
3	1.25	1973.3	92.0	66.74		58.54
4	1.75	1963.8	91.0	68.52		60.11
5	2.25	1953.7	91.0	69.57		61.03
6	2.75	1940.9	90.0	68.13		59.76
7	3.25	1925.1	90.0	71.13		62.39
8	3.75	1907.3	89.0	73.16		64.18
9	4.25	1891.4	88.0	74.82		65.63
10	4.75	1875.5	89.0	75.44		66.18
11	5.25	1852.3	88.0	70.17		61.55
12	5.75	1823.4	88.5	76.63		67.22
13	6.25	1800.5	88.0	54.77		48.04
14	6.75		87.0	72.09		63.24
15	7.25		88.0	76.64		67.23
16	7.75		88.0	78.27		68.66
17	8.25			78.46		68.82

Table C-14

#1383 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.50	1981.7		72.55		22.60
2	1.50	1967.5		72.13		22.47
3	2.50	1946.0		71.71		22.34
4	3.25	1929.1		78.03		24.31
5	3.75	1889.9		79.57		24.79
6	4.25	1860.7		66.75		20.79
7	5.00	1819.0		84.85		26.43
8	6.00	1698.2		85.28		26.57
9	7.50			88.01		27.42
10	9.50			100.69		31.37
11	11.50			81.58		25.41
12	13.50			83.13		25.90
13	16.00			85.14		26.52
14	19.00			86.48		26.94
15	22.50			83.74		26.09
16	26.50			84.08		26.19
17	30.50			78.34		24.40
18	34.50			81.97		25.54

Table C-15

#1391 chromium concentration and porosity data

Sample #	Depth(cm)	Age	Porosity (%)	Con(ug/g)	Adjusted by bkgd con.	Normalized by focusing factor
1	0.50	1980.7	90.0	21.63		12.08
2	1.50	1965.2	87.0	18.84		10.53
3	1.50	1944.6	81.0	25.40		14.19
4	3.25	1925.9	80.0	12.83		7.17
5	4.00	1902.2	76.0	10.60		5.92
6	5.00	1867.4	74.0	16.95		9.47
7	6.00	1794.8	74.0	19.52		10.91
8	7.00		71.0	19.68		10.99
9	8.00		72.0	13.73		7.67
10	9.00		71.0	19.90		11.12
11	10.00		72.0	24.61		13.75
12	11.00		72.0	19.47		10.88
13	12.00		71.0	19.24		10.75
14	13.00		72.0	17.14		9.58
15	14.00		72.0	25.34		14.16

Appendix D

Table D

Inventory Calculation

EPA #11 Focusing Factor =1.999

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	49.73	19.24	84.60	15.40	1.0	725.93
2	47.92	17.43	82.40	17.60	1.0	751.58
3	50.89	20.40	82.20	17.80	1.0	889.64
4	50.32	19.83	79.50	20.50	1.0	995.96
5	47.23	16.74	79.20	20.80	1.0	853.07
6	41.59	11.10	77.80	22.20	1.0	603.73
7	34.93	4.44	77.20	22.80	1.0	248.02
8	33.25	2.76	73.60	26.40	1.0	178.52
9	32.97	2.48	73.30	26.70	1.0	162.23
10	36.01	5.52	73.00	27.00	1.0	365.15
				Total inventory		57.74
				Focusing corrected inventory		28.88

EPA #18 Focusing Factor =2.434

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	50.81	22.83	94.20	5.80	1.0	324.41
2	46.38	18.40	93.10	6.90	1.0	311.05
3	48.43	20.45	91.50	8.50	1.0	425.87
4	51.68	23.70	90.50	9.50	1.0	551.62
5	49.93	21.95	89.80	10.20	1.0	548.53
6	49.47	21.49	89.30	10.70	1.0	563.36
7	45.19	17.21	89.18	10.82	1.5	684.33
8	40.28	12.30	89.16	10.84	1.0	326.66
9	39.10	11.12	89.14	10.86	1.0	295.87
10	41.33	13.35	88.31	11.69	1.0	382.35
11	33.27	5.29	87.50	12.50	1.0	162.01
12	37.69	9.71	87.64	12.36	1.0	294.04
13	32.43	4.45	87.33	12.67	1.0	138.13
14	33.24	5.26	87.19	12.81	1.0	165.08
15	36.25	8.27	87.00	13.00	1.0	263.40
16	30.73	2.75	87.00	13.00	1.0	87.59
17	29.34	1.36	87.00	13.00	1.0	43.32
18	30.39	2.41	87.00	13.00	1.0	76.76
19	29.73	1.75	87.00	13.00	1.0	55.74
20	30.29	2.31	87.00	13.00	1.0	73.57
				Total inventory		57.74
				Focusing corrected inventory		23.72

EPA #19(LM) Focusing Factor =1.217

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	67.24	41.01	94.20	5.80	1.0	582.75
2	69.07	42.84	93.10	6.90	1.0	724.21
3	66.06	39.83	91.50	8.50	1.0	829.46
4	58.23	32.00	90.50	9.50	1.0	744.80
5	50.81	24.58	89.80	10.20	1.0	614.25
6	39.02	12.79	89.30	10.70	1.0	335.29
7	26.81	0.58	89.00	11.00	1.0	15.63
				Total inventory		38.46
				Focusing corrected inventory		31.61

EPA #47s Focusing Factor =1.50

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	51.46	17.26	98.40	1.60	0.5	33.83
2	48.63	14.43	97.30	2.70	0.5	47.73
3	61.85	27.65	97.50	2.50	0.5	84.68
4	57.60	23.40	97.00	3.00	0.5	86.00
5	58.08	23.88	96.60	3.40	0.5	99.46
6	65.78	31.58	96.70	3.30	0.5	127.66
7	57.84	23.64	95.40	4.60	0.5	133.21
8	63.40	29.20	95.20	4.80	0.5	171.70
9	57.92	23.72	94.90	5.10	1.0	296.38
10	64.79	30.59	94.10	5.90	1.0	442.18
11	63.86	29.66	94.20	5.80	1.0	421.47
12	57.90	23.70	92.10	7.90	1.0	458.71
13	52.08	17.88	92.70	7.30	1.0	319.78
14	47.79	13.59	93.10	6.90	1.0	229.74
15	46.49	12.29	91.40	8.60	1.0	258.95
16	42.13	7.93	93.40	6.60	1.0	128.23
18	38.69	4.49	92.30	7.70	1.0	84.70
19	38.71	4.51	93.20	6.80	1.0	75.14
20	37.07	2.87	93.30	6.70	1.0	47.11
21	36.75	2.55	93.60	6.40	1.0	39.98
22	35.55	1.35	93.30	6.70	1.0	22.16
23	35.38	1.18	91.60	8.40	1.0	24.28
				Total inventory		36.33
				Focusing corrected inventory		24.22

EPA #68k

Focusing Factor =1.267

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	43.91	10.86	98.00	2.00	0.5	26.61
2	51.87	18.82	96.60	3.40	0.5	78.39
3	54.16	21.11	95.60	4.40	0.5	113.78
4	57.64	24.59	94.70	5.30	0.5	159.65
5	59.29	26.24	94.00	6.00	0.5	192.86
6	63.24	30.19	93.80	6.20	0.5	229.29
7	61.22	28.17	94.10	5.90	0.5	203.60
8	62.84	29.79	93.30	6.70	0.5	244.50
9	61.22	28.17	93.50	6.50	1.0	448.61
10	52.09	19.04	94.20	5.80	1.0	270.56
11	47.57	14.52	93.90	6.10	1.0	217.00
12	43.91	10.86	94.90	5.10	1.0	135.70
13	37.07	4.02	93.60	6.40	1.0	63.03
14	38.01	4.96	92.80	7.20	1.0	87.49
15	39.44	6.39	93.80	6.20	1.0	97.06

Total inventory	25.68
Focusing corrected inventory	20.27

EPA #19(LO)

Focusing Factor = 1.06

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1.00	71.85	36.15	94.20	5.80	1.0	513.69
2.00	73.91	38.21	92.20	7.80	1.0	730.19
3.00	58.66	22.96	90.90	9.10	1.0	511.89
4.00	84.87	49.17	90.60	9.40	1.0	1132.39
5.00	88.23	52.53	90.40	9.60	1.0	1235.51
6.00	86.76	51.06	87.90	12.10	1.0	1513.67
7.00	61.62	25.92	85.00	15.00	1.0	952.56
8.00	39.68	3.98	83.00	17.00	0.5	82.88

Total inventory	66.73
Focusing corrected inventory	62.95

EPA #40 a

Focusing Factor =1.705

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	38.58	0.92	92.3	7.7	1	17.36
2	54.62	16.96	89.5	10.5	1	436.30
3	57.79	20.13	87.8	12.2	1	601.69
4	65.31	27.65	86.9	13.1	1	887.43
5	73.75	36.09	88	12	1	1061.05
6	81.58	43.92	88.9	11.1	1	1194.40
7	105.10	67.44	86.7	13.3	1	2197.53
8	88.41	50.75	88.3	11.7	1	1454.75
9	87.94	50.28	86.7	13.3	1	1638.37
10	82.44	44.78	86.6	13.4	1	1470.13
11	77.05	39.39	84.4	15.6	1	1505.49
12	72.12	34.46	81.9	18.1	1	1528.13
13	61.36	23.70	82.7	17.3	1	1004.52
14	53.32	15.66	98.4	1.6	1	61.39
15	48.98	11.32	81.2	18.8	1	521.40
16	43.08	5.42	81.3	18.7	1	248.32
17	37.94	0.28	82.6	17.4	1	11.94

Total inventory	158.40
Focusing corrected inventory	92.90

E 30 Focusing Factor =2.04

Sample #	Con.(ug/g)	Corr. Con	Porosity	Dry	Thickness (cm)	Cr inventory
1	33.78	1.10	92.95	7.05	0.5	9.50
2	55.65	22.97	92.58	7.80	0.5	219.48
3	54.26	21.58	92.20	8.20	0.5	216.77
4	72.93	40.25	91.80	8.20	0.5	404.31
5	81.62	48.94	91.53	8.47	0.5	507.79
6	77.42	44.74	91.36	8.64	0.5	473.53
7	113.04	80.36	91.25	8.75	0.5	861.36
8	117.31	84.63	91.25	8.75	0.5	907.13
9	114.63	81.95	91.18	8.82	0.5	885.43
10	82.64	49.96	91.29	8.71	0.5	533.06
11	79.50	46.82	91.53	8.47	0.5	485.79
12	81.46	48.78	91.67	8.33	0.5	497.76
13	77.08	44.40	91.67	8.33	0.5	453.07
14	77.98	45.30	91.57	8.43	0.5	467.80
15	73.44	40.76	91.50	8.50	0.5	424.41
16	67.54	34.86	91.36	8.64	0.5	368.96
17	59.36	26.68	91.11	8.89	0.5	290.55
18	55.67	22.99	90.57	9.43	0.5	265.57
19	59.08	26.40	90.52	9.48	0.5	306.58
20	56.57	23.89	90.20	9.80	0.5	286.80
21	51.02	18.34	89.72	10.28	1.0	461.91
22	43.66	10.98	88.56	11.44	2.0	615.49
23	34.11	1.43	88.14	11.86	3.0	124.65
				Total inventory		100.68
				Focusing corrected inventory		49.35

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