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Minor Elements in Canadian Soils

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INTRODUCTION

In 1971 the Soil Research Institute[1] initiated a project to study background levels of minor elements in Canadian soils. This research was undertaken for several reasons.

Livestock diseases attributable to excesses or deficiencies of minor elements in feed are increasing, and an understanding of the relationships between the concentration of elements in soils and that in crops is necessary for their control.

Minor elements in waste products from industries, sewage, and automobiles are contaminating the soils and hence the vegetation. To assess the extent of contamination, *we* need to know the background levels at which minor elements exist in the parent materials of soils and how much these elements are redistributed during soil genesis.

An inventory of the soil resources of Canada should include information on the concentration of minor elements in soils derived from major surficial materials.

Atomic absorption spectrophotometry makes it feasible to determine the levels of several minor elements in soils at reasonable cost compared with costs of these analyses by older methods. The capability to determine efficiently a wide range of minor elements is considered an asset that the Institute should develop.

Because information on background levels of minor elements in soils of Canada in 1971 was limited to only a few localities, research in this area seemed necessary.

Several steps in the minor element project were taken initially. Allen St. James, a student under the direction of A. J. MacLean, compiled references on the minor element content of soils and rocks in Canada. Some of these appear in the list of references following this report. Available soil samples thought to be representative of important soils and soil materials in several regions of Canada were selected for analysis. Rock samples from the United States Geological Survey (USGS) were used as standards to test several acid digestion procedures for their ability to dissolve samples and recover minor elements completely. Preliminary tests of techniques for concentrating some elements in soil digests by complexing and solvent extraction yielded mediocre results.

In 1972, J. G. Desjardins assumed technical responsibility for the minor element laboratory. He developed an acid dissolution procedure that achieved complete solution of soil and rock samples. Further work was done to improve the measurements of elements at concentrations near the limit of detection. Analyses for 15 elements in the 170 soil samples selected previously were started. When the 28 reference soil samples of the Canada Soil Survey Committee (CSSC) became

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[1] When the Research Branch was reorganized in 1978 the Soil Research Institute was replaced by the Land Resource Research Institute, which continued the minor element project.

available in 1973 and 1974, they were analyzed in quadruplicate to determine the precision of results of minor element analysis (McKeague et al. 1978). Coefficients of variation were generally less than 10% except for samples having low concentrations of the elements.

Work on the minor element project was superseded throughout most of 1975 and 1976 by total elemental analyses of soils and sediments for the International Joint Commission program on possible pollution of the Great Lakes from agricultural sources. Analysis of the soil samples selected initially was completed after the work for the International Joint Commission was done.

The purpose of this publication is to assemble all the data from the elemental analyses performed in the laboratory that are pertinent to the evaluation of background levels of minor elements in mineral soils of Canada. These data include information published previously on Hg (McKeague and Kloosterman 1974) and on soils studied in the International Joint Commission project (Whitby et al. 1978a, 1978b). The data are compared with other published data on minor elements in soil in this country. Many relevant reports have been published in the past decade. When possible, the relationships between geological material and minor element content of the soils are broadly identified. Evidence of redistribution of minor elements during pedogenesis is noted, and relationships between contents of specific minor elements and other soil properties are evaluated statistically. The current state of knowledge of background levels of minor elements in Canadian soils is summarized, and the most serious gaps in present information are pointed out. Data on the minor element content of Organic soils (Mathur and Sanderson 1978, Mathur and Lévesque 1979) are not included here.

MATERIALS AND METHODS

SOILS

Samples from three general sources were analyzed:

- samples taken for research related to soil classification, genesis, and mineralogy studies at the Institute;
- samples taken in watersheds of the Great Lakes for the International Joint Commission studies of pollution of the Lakes (Whitby et al. 1978b);
- samples provided by the Canada Soil Survey Committee as references, 28 in all.

In all cases the soils were sampled by horizon, and usually samples of A, B, and C horizons were analyzed. Definitions of the subdivisions of the A, B, and C horizons are found in the Canadian system of soil classification (Canada Soil Survey Committee 1978). Sample locations, horizons, depths, and other variables are given in Tables 1, 3, 5, 7, and 9; general locations are shown in Fig. 1.

DISSOLUTION OF SAMPLES

Initially, three methods of acid dissolution were tested on three USGS rock standards (G2, BCR, and W1) and two soil samples. In the Shapiro and Brannock (1956) method, the sample is digested in H_2SO_4-HF-HNO_3, after which a few drops of HNO_3-$HClO_4$ are added. In Olson's (1965) method, the sample is digested with HF-$HClO_4$. To take up the residue we substituted HNO_3 for the H_2SO_4 specified in the procedure. In the HF-HNO_3 method, the samples are digested in HF-HNO_3 and the residue is taken up in HNO_3.

With H_2SO_4 present, a white precipitate developed in some of the solutions. It was assumed to be calcium sulfate. A residue remained after HF-HNO_3 treatment in samples containing several percent organic matter. A mixture of HNO_3-HF-$HClO_4$ seemed most promising and it was tested further. Grinding samples to less than 300 mesh (47 pm) helped to achieve complete dissolution and reduced the digestion time.

The final procedure for acid dissolution developed and used by Desjardins is outlined in a methods manual (McKeague 1978). The finely ground sample is treated with HNO_3 and subsequently with HF and $HClO_4$. The digest is treated with H_2O_2 to ensure reduction of Cr(VI) to Cr(III) (Green 1975), and the excess H_2O_2 is boiled off. The residue from a 1.000 g soil sample is taken up in 25 ml of 1 N HNO_3 and made up to a volume of 50 ml.

ANALYSIS BY ATOMIC ABSORPTION

Solutions prepared as described in the previous paragraph were analyzed by atomic absorption for the following elements: Fe, Al, Ca, Mg, K, Na, Mn, Zn, Cu, Pb, Ni, Co, Cr, Sr, and Cd. In general, directions in the Techtron manuals were followed. Corrections for nonatomic absorption using a nonabsorbing line for the element concerned were made for Ni, Pb, and Cd. Concentrations of some minor elements were close to the limit of detection, and Cd was not detectable in most of the samples.

Determination of Se

Selenium was determined by the method of Lévesque and Vendette (1971), which involves an HNO_3-$HClO_4$ digestion of the samples and determination of Se by a fluorometric method.

Determination of Hg

Mercury was determined by flameless atomic absorption according to the procedure described by Stone and Dowser (McKeague 1978).

Determination of As

Arsenic was determined by flameless atomic absorption after arsine generation in the samples from the International Joint Commission Great Lakes study (Whitby et al. 1978b). F. C. Darcel of the Ontario Ministry of Environment performed the tests.

OTHER ANALYSES

Organic carbon, clay, and pH were determined by established methods (McKeague 1978) as follows:

- organic C: induction furnace (method 3.611) or wet oxidation (method 3.613);
- clay: pipet (method 2.111 or 2.112);
- pH: in 0.01 M $CaCl_2$ (method 3.11).

RESULTS AND COMPARISONS WITH LITERATURE

BASIC DATA

The elemental analysis data are tabulated by physiographic regions (Tables 2, 4, 6, 8, and 10). Clay, pH, and organic C are reported for each sample to help identify relationships between these variables and the contents of some elements. As shown by the locations indicated in Fig. 1, the sample sites tend to be clustered and some regions are inadequately represented by only a few samples; therefore the data reported may not represent the range of values likely to be found within each physiographic region. For example, nearly all the samples for the Cordilleran region were from Vancouver Island. Values for Cd are not indicated because most of the Cd levels were less than 0.3 ppm, the limit of detection by the method used.

A summary of means and ranges of concentrations of the elements determined (Table 11) indicates some apparent differences among physiographic regions. However, the significance of these differences is uncertain because of scanty sampling from the Canadian Shield and the Cordilleran region and uneven distribution of sample sites within each region. Nevertheless, the following differences are evident. Contents of Fe, Mn, Cu, Co, Ni, and Cr tend to be highest in the samples from the Cordilleran region (Vancouver Island mainly). The mean Ca and Sr contents are markedly lowest in samples from the Appalachian region. Mean Hg values tend to be highest in the Canadian Shield and Appalachian regions. The mean Hg value for the Interior Plains region is substantially distorted by two high values (770 and 480 ppb) for samples from the Northwest Territories. Without these values, the mean is 46 ppb.

Mean concentrations of Zn, Pb, and Se in the five regions are similar.

Tabulating mean elemental contents in samples from major horizons in different physiographic regions brings out some differences that might be associated with pedogenesis (Table 12). Data for the Canadian Shield and the Cordilleran regions are not shown because few samples were analyzed.

The A horizon samples from the Appalachian region have markedly lower mean contents of Fe, Ca, Mg, Mn, Cu, Pb, Co, and Ni than the C horizon samples from the same region. The A horizon samples also have somewhat lower mean contents of Al, Zn, Cr, and Sr than C horizon samples. The A horizon samples are enriched in Hg, and mean contents of Ti and Se are similar in the A and C horizon samples. The B horizon samples appear to be impoverished in Ca and enriched in Se and Hg compared with the C horizon samples. However, the mean values for Se and Hg are raised mainly by the data for two Podzolic soils, St. Stephen and Holmesville (Table 2).

Differences in elemental contents of samples from A, B, and C horizons of the St. Lawrence Lowlands were small relative to those from the Appalachian region. However, the A horizons are lower in Ca and Mg (dissolution of carbonates) and much higher in Se and Hg than the C horizons of this region.

Mean values for soils from the A, B, and C horizons of the Interior Plains region show that contents of Fe, Ca, Mg, Ni, and Hg are lower in the A horizon than in the C horizon. No marked enrichment of any element in either the A or B horizon is evident.

Correlations

Correlation coefficients (**r**) for all the data and for the data partitioned according to region and horizon are shown in Tables 13-20. Data were deleted for the four organic surface horizons (L, F, H, and O); a few very high values (>1000 ppb) for Hg and one very high value (>4000 ppm) for Mn were also omitted. Only correlation coefficients equal to or greater than 0.3 are reported. If the data collected had represented random samples from normal distributions, this level would be significant at the 5% level when there are more than 40 observations, and at the 1% level when there are more than 70. Correlation coefficients are not given separately for the Canadian Shield because there were only 13 samples.

For all samples (Table 13), correlation coefficients for many pairs of variables exceeded 0.3, but Hg was correlated this highly only with organic C. The dominantly positive correlations probably occur because the inorganic fraction of Canadian soils is composed mainly of silicates and quartz (SiO_2). Samples containing low amounts of quartz have higher concentrations than quartziferous soils of all elements except Si and O. The positive correlations of most of the elements with clay occur for the same reason; clay (<0.002 mm) contains a much lower proportion of quartz than do the silt (0.002-0.05 mm) and sand (0.05-2 mm) fractions of soil. In addition, the clay fraction is the most active in sorbing elements released by weathering (Shilts 1975).

Many of the relatively high correlation coefficients were predictable from general geochemical information (Goldschmidt 1954); among these were the correlations of Fe with Co, Ni, and Cr. Others, such as the correlation of Cu with clay (r = 0.66), were not anticipated. Similar relationships between pairs of variables tend to hold for all the group of samples (Tables 13-20). For example, except in the Cordilleran region (Table 17), Se was highly correlated with organic C; and

Co, Ni, and Cr were usually highly correlated with Fe and with each other. Because of the high correlations, some sets of variables are further analyzed later in this report.

Comparisons with other data for Canadian soils

The ranges and mean levels of minor elements reported in this study are compared with results reported by others. In this comparison, no reference is made to the papers of McKeague and Kloosterman (1974) or of Whitby et al. (1978a, 1978b) because the data reported in those publications are included herein. The comparisons are restricted to publications on Canadian soils (Table 21), with the exception of generalized data for soils.

Manganese. Manganese concentration of the samples ranged from 69 ppm in the Ae horizon of a Placic Ferro-Humic Podzol from Newfoundland to 4295 ppm for an Ap horizon of a Gleyed Gray Brown Luvisol from Lincoln County, Ont. This range includes most of the values reported by others for Canadian soils (Table 22).

The data from other reports are based on many methods of analysis, some of which are not intended to yield total values. However, extraction with hot HNO_3 or H_2SO4-HF should yield data approximating total values, and the data of Dudas and Pawluk (1977) for Mn can be corrected approximately to total values by multiplying by 1.5. Most of the sets of data yield mean Mn values of 300-700 ppm. Exceptions are the data of Reid and Webster (1969), which seem uncommonly high, and those of Hutchinson and Whitby (1974), which are uncommonly low.

Extremely high Mn concentrations occur in specific horizons of some soils. For example, McKeague et al. (1968) reported a Mn content of 15% (150 000 ppm) in a thin (2 mm) band of a placic horizon; several other "Fe-Mn pans" from Newfoundland contained more than 1% Mn, as did one from British Columbia (Lavkulich et al. 1971). Similarly, some nodules and concretions in soils contain a high concentration of Mn.

The mean Mn concentration (544 ppm) of our samples is similar to that reported (560 ppm) by Shacklette et al. (197la) for subsurface soil samples from the United States. Norrish (1975) cited a general level for soil of 1000 ppm. Some other average Mn values cited by Warren (1975) are: World soils, 850 ppm; soils from the United Kingdom and British Columbia, 800 ppm; and New Mexico soils, 400 ppm.

The influence of pedogenesis on the concentration of Mn in various horizons has been considered by several authors. Wright et al. (1955) found an irregular distribution of Mn in profiles of several classes of soil. Surface horizons were depleted in some and relatively enriched in others. Michalyna's (1971) data show an increase of Mn with depth in Humic Luvic Gleysols, an irregular decrease with depth in an Orthic Gray Luvisol, and an irregular distribution in Gleyed Gray Luvisols. For some Gleysolic soils in our study, the maximum Mn concentration occurred in the A horizon; in others, the maximum was in the C.

Distribution of Mn in poorly drained soils is probably controlled mainly by fluctuations in redox conditions as the water table rises and falls. Soils in areas where groundwater discharges tend to have Mn maxima near the soil surface, and those where it recharges are likely to have maxima in the C horizon.

Manganese generally occurs in Canadian soils at 100-1200 ppm. However, considerably higher concentrations may occur in uncontaminated soils, and some horizons of leached soils have concentrations below 100 ppm. Determining the levels of Mn available for plant nourishment in leached soils, particularly in some A horizon samples from the Appalachian region, might make an interesting study.

Zinc. Zinc concentrations ranged from 5 ppm for three Ae horizon samples of soils from Nova Scotia (Tables 1 and 2) to 300 ppm for the Aeg horizon of Margate, a Fera Luvic Gleysol from Prince Edward Island. These values encompass all but a few of those reported by others for Canadian soils (Table 22). Apart from the values of Smeltzer et al. (1962, which are unusually high, and those for samples from mineralized zones[2] (Presant 1966, Warren et al. 1966), nearly all the tabulated data show Zn levels of less than 200 ppm in soils of Canada.

The influence of pedogenesis and texture on Zn levels in various horizons of a pedon was considered by several authors. For example, both Wright et al. (1955) and Presant (1966) showed that Zn levels were lowest in the Ae horizons of Podzolic soils. Our data for Podzolic and other acid soils of the Appalachian region are consistent with their findings, but the values for two Podzolic soils from the Canadian Shield are not. Mills and Zwarich (1975) working with soils from Manitoba and John (1974) with soils from British Columbia showed that the A horizon usually contained higher levels of Zn than the associated C horizon. Our data show the opposite trend. Mills and Zwarich (1975), Frank et al. (1976), and Kalbasi and Racz (1978) found that Zn levels tended to increase with increasing clay content. Our correlations between Zn and clay are high for several groups of samples (Tables 13, 15, 16, and 17).

The overall mean Zn concentration (77 ppm) of our samples is somewhat higher than that reported (54 ppm) by Shacklette et al. (197la) for subsurface soil samples of the United States. Norrish (1975) cited a general value for soil of 60 ppm. Other average Zn values cited by Warren (1975) are: World soils, 50 ppm; soils of the United Kingdom and British Columbia, 90 ppm; and New Mexico soils, 90 ppm.

Zinc generally occurs in Canadian soils at 10-200 ppm. However, lower concentrations and higher concentrations (up to about 400 ppm) occur in apparently normal soils. Much higher levels may occur in soils within and close to mineralized zones (Presant 1966, Warren et al. 1966). The low level of Zn in the Ae horizons of some soils of the Appalachian region suggests that Zn deficiencies are a possibility there.

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[2] Areas of the earth's crust that have a high content of one or more mineral elements such as Fe, Cu, Pb, and Co.

Copper. Copper concentrations of the samples in this study ranged from 1 ppm for the B and C horizon samples of a Pinesands soil from Saskatchewan (Table 8), to 78 ppm for the Cg horizon of a Cowichan soil from Vancouver Island (Table 10). This range includes most of the Cu values reported by others for Canadian soil with the exception of contaminated samples or samples from mineralized zones (Tables 21 and 22).

The influence of pedogenesis and texture on Cu levels in various horizons of a pedon was noted by some authors. Wright et al. (1955) showed the lowest levels of Cu to occur in the Ae horizons of Podzols and Gray Brown Luvisols, and Presant (1966) showed the same trend for Podzols he studied. With a few exceptions such as the Holmesville soil from New Brunswick (Table 2), this generalization holds for our samples. Indeed, A horizons generally contain somewhat lower levels of Cu than B and C horizons (Table 12). Haluschak and Russell (1971) and Mills and Zwarich (1975) found that Cu levels were positively correlated with clay. Our data for most groups of samples support this relationship (Tables 13-20).

The overall mean of 22 ppm for our samples is very close to that (25 ppm) reported by Shacklette et al. (197la) for 863 subsurface soil samples from the United States. Norrish (1975) cited a general range of values for soils of 2-50 ppm. Other average Cu values cited by Warren (1975) are: World soils, 20 ppm; soils of the United Kingdom and British Columbia, 30 ppm; and Maryland soils, 65 ppm.

Copper probably occurs in Canadian soils typically at 5-50 ppm. Considerably higher levels occur in soils close to Cu-rich ore bodies and in contaminated soils. Lower levels occur in some siliceous sands, in peats, and in some Ae horizons.

Lead. Lead concentrations of the samples ranged from 5 ppm in the Ae horizon of two Podzolic soils from the Appalachian region (Table 2) to 71 ppm for the Ah horizon of Guelph loam, a Gray Brown Luvisol from Ontario (Table 6). This range includes most of the Pb values reported by others for uncontaminated soils, with the exception of those for soils near Pb-bearing ore bodies (Tables 21 and 22).

The influences of pedogenesis and texture on Pb levels of various soil horizons were noted by some authors. For example, Wright et al. (1955) noted the tendency for Pb accumulation in organic-rich surface horizons. Mills and Zwarich (1975) showed that Pb tended to increase with increases in clay content. Our data indicate generally low correlations between Pb and organic C, and between Pb and clay (Tables 13-20). However, the four organic surface horizons were excluded from the correlation analysis. Lead contents of the Ae horizons of soils from the Appalachian region were generally lower than those of the associated B and C horizons (Tables 2 and 12).

The overall mean Pb level (22 ppm) for our samples is close to that (20 ppm) of Shacklette et al. (1971a) for subsurface soil samples from the United States. Norrish (1975) cited a general level for soils of 12 ppm. Other average Pb values cited by Warren (1975) are: World soils, 10 ppm; soils of the United Kingdom and British Columbia, 20 ppm; New Mexico soils, 18 ppm; and Maryland soils, 25 ppm.

Lead generally occurs in Canadian soils typically at 5-50 ppm. However, lower levels occur particularly in quartziferous sandy materials, and higher natural levels are common in mineralized areas. Contamination from automobiles and other sources commonly results in high Pb levels in surface soil.

Cobalt. Cobalt concentrations ranged from 5 ppm for the Ae horizon of an Ortstein Humic Podzol from Nova Scotia (Table 2) to 60 ppm for the Ckg horizon of Lincoln soil, a Fera Humic Gleysol from Ontario (Table 6). This range includes most of the values reported by others for Canadian soils that are neither contaminated nor from mining areas. However, several values reported in early work are below this range (Tables 21 and 22).

Several authors reported relationships between Co levels and pedogenesis or between Co and soil properties such as clay content. For example, Wright et al. (1955) found that the Ae horizons of Podzolic soils were depleted of Co. Rana and Ouellette (1967) reported a positive correlation between Co and clay in Quebec soils. Our data show Co to be generally somewhat depleted in A horizons, especially in the Appalachian region (Table 12), and highly correlated with clay, Fe, Al, and several other elements for most groups of samples (Tables 13-20).

The mean Co concentration (21 ppm) of our samples is considerably higher than that (10 ppm) reported by Shacklette et al. (1971a) for subsurface soil samples from the United States. It is also much higher than the general value of 3 ppm quoted by Norrish (1975) from several sources. However, the range of our values is similar to that given (less than 2 to 80 ppm) by Mitchell (1964) for surface samples of Scottish soils.

Cobalt generally occurs in mineral soil in Canada at 5-50 ppm; the level in Organic soils is probably lower. Some doubt remains about the lower limit of the range stated, because values below 5 ppm are common in the literature. However, many of the values reported in the literature are not total Co values because several of the acid digestion methods used do not dissolve the samples completely. Cobalt values obtained by Desjardins for the four CCRMP[3] reference soil samples are close to the certified values (G. H. Faye, personal commun. 1978). Therefore we favor the estimate of 5 ppm as the general lower level for Co, as determined from the data in this publication. Undoubtedly some mineral soil samples have Co levels below 5 ppm and samples in mineralized zones may have levels far above 50 ppm.

Nickel. Nickel concentrations ranged from 1 ppm in the Ae horizon of Holmesville, a Humo-Ferric Podzol from New Brunswick (Table 2), to 67 ppm for the Bg2 horizon of a Humic Gleysol from Ontario (Table 6). This range includes most of the data reported previously for Ni levels of uncontaminated Canadian soils, except for some samples taken near mines (Tables 21 and 22).

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[3] Canada certified reference materials project.

Our data show that Ni is depleted from A horizons to about the same. extent as Co (Tables 2 and 12) and that Ni and Co are similarly correlated with clay, Fe, and other elements (Tables 13-20), with the exception of data for the Cordilleran region (Table 17).

The mean Ni level for our samples (22 ppm) is similar to that (20 ppm) reported by Shacklette et al. (197la) for subsurface soil samples from the United States. Norrish (1975) gave a general value for soils of 40 ppm. Other mean Ni values cited by Warren (1975) are: World soils, 40 ppm; soils of the United Kingdom and British Columbia, 30 ppm; and New Mexico soils, 10 ppm.

Nickel generally occurs in mineral soils in Canada at 5-50 ppm. Soils in mineralized zones and in contaminated areas may have much higher levels of Ni, and some strongly leached sandy soils may contain only 1 or 2 ppm.

Chromium. Chromium concentrations ranged from 2 ppm for the Ae horizon of an Ortstein Humic Podzol from Nova Scotia (Table 2) to 141 ppm for the Cgl horizon of Laplaine soil, a Rego Gleysol from Ontario (Table 6). This range includes nearly all the data on Cr levels that appear in the few publications available on Cr in Canadian soils (Tables 21 and 23).

The mean Cr level for our samples (45 ppm) is similar to that (53 ppm) reported by Shacklette et al. (197la) for subsurface soil samples of the United States, but it is far below the general value for soils of 200 ppm cited by Norrish (1975).

Chromium generally occurs in most Canadian soils at 10-100 ppm. Some quartziferous sands and strongly leached Ae horizons of Podzolic soils are likely to have Cr levels below 10 ppm, and some soils derived from basic rocks may have levels well above 100 ppm.

Strontium. Strontium concentrations ranged from 20 ppm in the Ae horizon of an Ortstein Humic Podzol from Nova Scotia (Table 2) to 605 ppm in the C horizon of Ste. Agathe soil, a Ferro-Humic Podzol from Labelle County, Que. (Table 4). Few other published data on total Sr levels in Canadian soils are available.

The mean Sr level (207 ppm) is similar to that (240 ppm) reported by Shacklette et al. (197la) for subsurface samples of soils of the United States.

Selenium. Selenium levels range from 0.02 ppm for the C horizon of a Humo-Ferric Podzol from Nova Scotia (Table 2) to 3.7 ppm for the H horizon of Laplaine soil, a Rego Gleysol from Ontario (Table 6). This range includes most of the values reported by others on Se in Canadian soils (Tables 21 and 23), with the exception of data for seleniferous soils (Byers and Lakin 1939, Fletcher et al. 1973).

Lévesque (1974a) showed that Se was significantly correlated with organic C and that the Se content of A and B horizons was related to the Se content of the parent material. Similar relationships held for our samples, which included many of those reported on by Lévesque.

The mean Se level of our samples (0.30 ppm) is somewhat lower than that (0.45 ppm) reported by Shacklette et al. (1974) for subsurface soil samples of the United States. It is far higher than the general values for soils (0.01 ppm) cited by Norrish (1975).

Selenium generally occurs in mineral soil samples in Canada at 0.03 ppm to approximately 2 ppm. Considerably higher levels occur in soils derived from Se-rich materials and in some organic soil materials.

Arsenic. All the arsenic data reported herein were summarized by Whitby et al. (1978a, 1978b). Therefore, only a brief review is presented. Arsenic occurs in southern Ontario soils at 1-20 ppm (mean 5.2 ppm). A similar mean (7.4 ppm) was reported by Shacklette et al. (1974) for subsurface samples of soils of the United States. However, their range of values for 910 samples was from 1 to 97 ppm. Norrish (1975) gave a general value of 1.l ppm for the As level of soils. No normal range is suggested for As levels in Canadian soils because the data are all for soils from southern Ontario.

Other As data for Canadian soils range from 0 to 70 ppm (Tables 21 and 23), with the exception of samples from sulfide zones.

Mercury. Mercury levels of the samples in this study ranged from about 1 part per billion (ppb) to about 14 000 ppb for a C horizon sample of Liard, a Regosol from the Mackenzie Valley, N.W.T. Only one other value (1700 ppb) exceeded l000 ppb; these two high values were excluded from the analysis. Most of the Hg data reported here were published by McKeague and Kloosterman (1974) or by Whitby et al. (1978b). The range of Hg values for these soils includes most of the Hg values reported by others for Canadian soils (Tables 21 and 23).

The mean Hg level (54 ppb, with two high values excluded) of our samples is similar to that (71 ppb) for some 900 subsurface soil samples from the United States (Shacklette et al. 197lb), and to the general average value (70 ppb) given by Jonasson and Boyle (1971) for normal soils.

Mercury generally occurs in most Canadian soils at 5-100 ppb, but some apparently contaminated samples contain Hg at several parts per million. Jonasson and Boyle (1971) outlined general mercuriferous belts where high Hg levels might be expected.

Cadmium. Cadmium levels in most of our samples were below or near the limit of detection, 0.3 ppm. Therefore mean levels could not be determined. Whitby et al. (1978b) reported a maximum Cd level of 1.7 ppm in some of the same samples. Other data for Canadian soils indicate Cd levels of 1 ppm or less (Tables 21 and 23). Allaway (1968) suggested a mean soil Cd level of 0.06 ppm and a range of 0.01-7 ppm.

Comparisons with selected geochemical data

Geochemical exploration has produced a vast body of data on the content of certain minor elements in surficial materials in Canada. Some of this information is not pertinent to background levels in soils because geochemical sampling is concentrated in mineralized zones. However, much geochemical exploration extends to sampling and analyzing of normal surficial deposits. The work of Shilts and co-workers (Shilts 1973a, 1973b, 1975, 1977, 1978; Ridler and Shilts 1974; Grant and Tucker 1976; Di Labio and Shilts 1977, 1978; Podolak and Shilts 1978) is particularly relevant to this study because it includes analytical data for thousands of samples of till from eastern and northern Canada. The tills analyzed are the parent materials of vast areas of soils in the regions. Data for these till samples are not summarized with the soil data because only the fine fraction (<2, <4, <37, or <63 pm) was analyzed. The minor element content of a fine fraction, especially the <2 pm fraction in weathered material, is commonly much higher than that of the soil, <2 mm (Shilts 1973a, 1975). Selected geochemical data are summarized in Table 24. Further data of this kind will be published by Shilts and associates as analysis of till samples taken along possible pipeline routes from the north and elsewhere progresses.

Generally, the geochemical data for clay and for clay plus silt fractions (Table 24) indicate levels of minor elements within or somewhat above the range of those reported in this study for soils (Table 11). The higher average values for the fine fractions were predictable for the reasons stated previously (Shilts 1973a).

LINEAR REGRESSION ANALYSES

The possibility of estimating levels of some of the minor elements from other available soil data is appealing. Minor elements that are highly correlated with properties such as clay and Fe were used as dependent variables in linear regression analyses. In the stepwise regression analyses described subsequently, four or five soil properties that are highly correlated with each minor element were used as independent variables in each analysis. Major elements (Al, Fe, Ca, Mg), organic C, and clay were given priority over minor elements in the selection of independent variables. The variable introduced in the regression equation at each step was that which accounted for the highest percentage of the residual variation.

Regression equations that account for 50% or more of the variability of each minor element are given in Table 25. In those equations, only independent variables that account for more than an additional 2% of the variability are included. Results of stepwise linear regression analysis for each minor element are discussed briefly.

Manganese

Stepwise regression analysis for various groups of samples with Mg, Fe, organic C, Al, and clay as independent variables showed that usually less than half of the variability of Mn was accounted for. The only exception was A horizons (Table 25).

For samples from the Interior Plains, the regression equation with five independent variables accounted for only 5% of the variability of Mn. The feasibility of estimating the level of Mn from data on elemental composition of the sample is limited.

Zinc

With clay, Fe, Al, Mg, and Ti as independent variables regression equations accounted for less than half of the variability of Zn for all groups of samples. The highest proportion of the variability of Zn (43%) was accounted for in samples from the Interior Plains.

Copper

Fifty percent or more of the variability of Cu was accounted for in several groups of samples (Table 25). Clay accounted for more of the variability than Al, Fe, Co, and Mg for most groups of samples, but Mg was the first variable in the stepwise regression equations for samples from the Appalachian region and the St. Lawrence Lowlands. Samples having high Ca and Mg content because of a high carbonate content were excluded from the regression analysis but not from the correlation analysis reported in Tables 13-20. The ionic radii of Mg(II) and Cu(II) are similar (0.66 and 0.72); therefore Cu may proxy for Mg in minerals such as pyroxenes, amphiboles, biotites, and chlorites.

Lead

Linear regression equations with Pb as a function of organic C, Fe, Al, and Mg accounted for less than 30% of the variability for most groups of samples; accountability for 50% was found only in the case of Interior Plains samples (Table 25).

Cobalt

Cobalt was highly correlated with Fe, Al, and clay for several groups of samples, as well as with minor elements such as Mn, Cu, Ni, and Cr. Because Cu, Ni, and Cr were all highly correlated, Ni was chosen as the independent variable to represent this group of elements. Magnesium was not included as an independent variable although Co and Mg were highly correlated (0.89) in the Appalachian region. With all the groups of samples tested, the stepwise regression equations accounted for more than 50% of the variation in Co (Table 25).

Although the general positive correlation between Co and Fe is well documented (Goldschmidt 1954), Fe accounted for the highest proportion of the variation in only three of the seven groupings of samples. The fact that Fe was the first independent variable selected for A and C horizons but not for B horizons might be because organic-iron complexes accumulate in some B horizons. Cobalt may be associated more closely with Fe in silicate structures than with secondary forms of Fe in soils.

The linear regression lines for Co on Fe were also calculated for three regions; Fe accounted for 67% of the variation in the Appalachian region, 37% in the St. Lawrence Lowland, and 43% in the Interior Plains; these percentages were only slightly below those accounted for by the first variable indicated in Table 25. The high correlation for soils from the Appalachian region may be because these soils are more acid and weathered than soils of the other two regions. Minerals resistant to weathering are enriched in soils of the Appalachian region, and these minerals may contain relatively constant proportions of Co and Fe.

Slopes of regression lines for Co on Fe vary within a fairly narrow range (4.4-5.5, mean 4.8) for the seven groups of samples tested. Therefore an increase of l% in the Fe content of a soil is likely to be associated with an increase of 5 ppm in the content of Co. A plot of Co against Fe (Fig. 2), however, demonstrates that a precise relationship between Co and Fe is lacking, especially for Fe values above 3%.

Nickel

Nickel was highly correlated with several of the same variables as Co. Stepwise regression analysis with Fe, clay, Al, Mg, and Mn as independent variables accounted for a wide range of variability of Ni for various groups of samples. With samples from the Appalachian region Mg accounted for 81% of the variability of Ni (Table 25). A plot of Ni against Mg (Fig. 3) shows the relatively close fit of the data for the Appalachian region to the equation from the first step of the regression analysis (Ni (ppm) = 1.83 + 34.3 Mg (%)). On the other hand, less than 12% of the variability of Ni in C horizon samples was accounted for by the five variables. This low accountability might be because high Mg values are not associated with Ni in some dolomitic C horizons.

Chromium

Stepwise linear regression equations with Cr as a function of clay, Al, Fe, Mg, and Ti accounted for more than 50% of the variability of Cr for several groups of samples (Table 25).

Strontium

Linear regression equations with Sr as a function of Ca, Mg, Al, Fe, and clay accounted for more than 50% of the variability of Sr for all groups of samples tested (Table 25). Samples having high carbonate content were deleted by excluding values of Ca above 6% and Mg values above 2.5%.

Useful predictions of Sr levels may possibly be made from data on Ca, Al, and clay for several groups of samples. Some predictability of Sr levels from Ca data is indicated by a plot of data for all samples except those having more than 6% Ca or 2.5% Mg (Fig. 4).

Selenium

Linear regression equations of Se on organic C, Fe, and clay accounted for more than 50% of the variability for several groups of samples. The best fit was for samples from the Interior Plains.

Mercury

Less than 30% of the variability of Hg was accounted for in any group of samples tested by linear regression equations with organic C, clay, and Fe as independent variables. Mercury values above 1000 ppb were excluded in this analysis.

Summary

Linear regression analysis for predicting concentrations of several minor elements from data on other properties such as clay, organic C, and Fe showed some promise, especially for Sr and Co in most groups of samples and for Ni and Cr in some groups of samples. However, the regression equations accounted for less than half the variability of Zn, Mn, Pb, and Hg for most groups of samples.

Relationships between levels of elements in the C horizon and in the associated A and B horizons

Levels of a given minor element in various horizons of the same soil were commonly highly correlated (Table 26). Generally, the correlation coefficient relating the A to the C horizon (A/C) was lower than that relating the B to the C horizon (B/C), Some of the relationships are difficult to explain; for example, the Hg level of a given horizon was generally highly correlated with the level in adjacent horizons, but this relationship did not hold for samples from the St. Lawrence Lowlands.

The correlations shown in Table 26 indicate that if a given element in the C horizon were introduced as an independent variable in some of the linear regression analyses discussed in the previous section, the residual variations might be reduced. This aspect was examined for Zn, Mn, and Co. The procedure involved two steps. First, the level of a given element in an A (or B) horizon was estimated as a linear function of the level of that element in the associated C horizon and of properties such as the level of clay or organic C in the A (or B) horizon. Second, all the independent variables were taken from the C horizon.

The results for Zn, Mn, and Co showed that inclusion of data from the C horizon for that element as an independent variable contributed little to the reduction of the residual variation in the linear regression equations obtained without that term (Table 25). However, for Se, Lévesque's work (1974a) indicates that the Se level of the C horizon accounts for a high percentage of the Se variability of some B horizons. The data in Table 26 indicate that the Se level of the C horizon would account for about 54% of the variability of Se in A horizons for all samples, and about 81% for A and B horizon samples from the Interior Plains. Predictability of Hg would probably be improved somewhat by including Hg content of the C horizon as a variable in the regression equation, especially for the Interior Plains and the Appalachian region (Table 26).

DISCUSSION AND CONCLUSIONS

The results reported herein, including data summarized from the literature, provide a state-of-the-art picture of information on background levels of several minor elements in Canadian soils. Such information has increased markedly since 1971 when this project was started. The similarities of means and ranges of minor element levels in normal soils of Canada, the United States, and elsewhere suggest that further general study of background levels of the commonly determined minor elements is not work of high priority.

Based on the data summarized here with some judgments about spurious values, approximate common background levels of some minor elements in uncontaminated soils from nonmineralized areas of Canada are: Mn, 100-1200 ppm; Zn, 10-200 ppm; Cu, Pb, Co, and Ni, 5-50 ppm; Cr, 10-100 ppm; Sr, 30-500 ppm; Se, 30-2000 ppb; Hg, 5-100 ppb; and Cd, less than 1 ppm. Soils having levels of these elements outside the common ranges are not unusual, but levels that exceed the high end of the range by a factor of 5 or more are unusual.

The data indicate some differences in levels of certain minor elements associated with both pedogenesis and physiographic region. For example, depletion of most of the minor elements determined in the Ae horizon of soils from the Appalachian region is more marked than that in Ae horizons of soils from other regions. Levels of minor elements in soils of the St. Lawrence Lowlands seem to be the least affected, in general, by pedogenesis. This apparent stability might be because most of the samples from that region were taken from cultivated soils in southern Ontario.

Attempts to estimate the levels of the minor elements studied by linear regression analysis using other soil properties as independent variables yielded some promising results. For various groups of samples without high carbonate contents, from 67 to 88% of the variability of Sr was accounted for by Ca (Table 25). For some groups of samples, more than 70% of the variability of Co, Ni, and Cr were accounted for by regression equations. However, the regression analysis accounted for much less than 50% of the variability of Mn, Zn, Cu, Pb, Se, and Hg for most groups of samples.

Studies on minor elements continues to be an important aspect of soil research in Canada. The focus of such work in the Land Resource Research Institute requires careful consideration. Some possible lines of work are discussed here.

The capacity to determine efficiently a wide range of minor elements in soil could be improved. Some elements of environmental significance that were not determined in this study are Mo, B, As, and F. The determination of Cd was not satisfactory because most Cd levels were at the limit of detection by the method used. Complexing and solvent extraction to concentrate elements such as Cd is one possible solution (Dudas and Pawluk 1977). New analytical techniques may increase efficiency of analysis greatly; in the meantime, atomic absorption is suitable for many elements.

Land areas where deficiencies or excesses of certain minor elements present a problem or are likely to become a problem could be identified. Appropriate sampling of the soils of such areas and determinations of total and extractable elements of concern would follow. Such problems are likely to develop frequently because of additions of minor elements from industrial, mining, and sewage sludge disposal operations and depletion of minor elements by intensive cropping. Close liaison with soil correlators and with plant and animal scientists would be required to identify such areas. Cooperative studies with soil chemists would be useful for determining the chemical forms of minor elements in soils.

An up-to-date overview of the knowledge concerning minor elements in Canadian soils could be maintained. An important aspect of this work would be to keep abreast of and to interpret the vast body of data emerging from studies by the Geological Survey of Canada.

Cooperative work with soil survey units and with other agencies concerned with land inventory and productivity or with environmental protection could be undertaken. Personnel of such agencies are likely to be aware of areas where minor element imbalances are probable but some lack laboratories to carry out the required analysis. The Institute could provide an analytical service to some of these clients.

Minor element analysis could be used to aid soil surveyors in differentiating parent materials of soils.

Finally, reasons for the high correlation between certain pairs of elements in some groups of soil samples could be investigated.

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Table 1. Soil Identification and Characterization Data - Appalachian Region

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
St.Stephen	Avalon Pen.,	McKeague	6576	Ae	0 - 4	6.4	28	3.4
P.FHP	Nfld.	et al.	6578	Bhf	8 - 22	8.7	27	4.0
g till	46º46'N	1967	6551	Bhfc	22- 22.5	8.7		
	53º35'W		6582	C	58- 68	0.3	2.6	4.6
Holmesville	Victoria Co.,	Brydon	SMC56	Ae	0 - 5	1.5	15.2	3.8
O.HFP	N.B.	1965	SMC58	Bf	8 - 15	5.1	19.7	4.6
s till	46º58'N		SMC60	BC	28- 48	1.0	12.1	5.0
	67º43'W		SMC64	C3	157	0.1	18.5	5.0
Pugwash	Cumberland	McKeague	66246	Ae	0 - 7	1.0	4.6	3.5
0.HFP	Co.,N.S.	et al.	66248	Bf	12- 28	1.1	8.2	4.3
sl till	45º45'N	1969	66250	BC	37- 50	0.1	7.8	3.8
	63º42'W		66252	Cx	65- 83	0.1	9.8	3.8
-	Colchester	Wang	7536	Ae	0 - 17	0.2	1	3.0
0T.HFP	Co.,N.S.	et al.	7540	Bfl	5 - 15	2.0	8	4.4
s alluvium	45º25'N	1978	7543	Bfc	40- 50	0,7	5	4.6
	63º25'W		7549	C	50- 65	0.1	3	4.4
-	Colchester	Wang	7554	Aeg	0 - 35	0.2	1	3.2
0T.HP	Co.,N.S.	et al.	7555	Bhg	35-41	2.1	5	3.5
s alluvium	45º25N	1978	7556	Bhgcl	41- 46	2.6	5	3.7
	63º25'W		7557	Bhgc2	46- 53	1.4		3.8
			7560	Bfc	68- 70	0.7		4.3
Tignish	P.E.I.	McKeague	7134	Aeg	0 - 35	0.2	1	4.0
LU.HFP	46º10'N	et al.	7136	Ae	19 - 28	0.4	10	4.0
sl till	62º55'W	1973	7137	Bf	28 - 38	1.3	16	4.3
			7138	Btl	38 - 51	0.2	16	4.3
			7141	BC	92-120	0.1		

(Continued)

Table 1 (cont.). Soil Identification and Characterization Data - Appalachian Region

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Joggins	Cumberland	McKeague	6837	Aeg	0-9	1.l	15	3.3
0.LG	Co.,N.S.	et al.	6839	Btg	19- 25	0.2	23	4.0
shaly till	45°42'N	1971	6842	IICg	55- 70	0.6	38	5.2
	64°25'W							
Kingsville	Colchester	McKeague	66228	Aeg	0-8	l.6	28	3.1
FE.LG	Co.,N.S.	et al.	66229	Bgf	8- 19	0.7	23	3.3
cl till	45°14'N	1969	66230	Btg	18- 28	0.2	29	3.8
	63°16'W		66234	Ck	150-165	0.l	30	7
Margate	P.E.I.	McKeague	7115	Ae	0-5	0.6	8.6	3.9
FE.LG	46°44'N	et al.	7116	Aeg	5- 10	0.4	16	3.8
si till	64°16'W	1973	7118	Btgf	16- 22	0.4	20	4.0
			7119	Btg	22--42	0.1	17	4.0
			7120	Bt	42- 60	0.05		4.3
			7123	C	100-120	0.03	19	6.0
Kingsville	Hants	McKeague	6824	LH	10-0	36.8		
FE.LG	Co.,N.S.	et al.	6825	Aeg	0- 11	0.6	10	3.6
1 till	45°10'N	1971	6827	Btgf	17- 25	0.3	22	3.8
	63°52'W		6830	BC	38- 59	0.1	16	6.1
			6834	C	147-155	0.1	18	6.5
Rob	Westmorland	McKeague	CSSC22	Aeg	0- 15	0.8	10	3.7
0.LG	Co.,N.B.	et al.	CSSC23	Btg	15- 52	0.2	27	3.8
1 till	45°48'N	1978	CSSC24	Cg	68-110	0.l	22	4.0
	65°03'W							
-	Cumberland	McKeague	CSSC25	Ae	11- 24	0.1	6	5.0
GLBR.GL	Co.,N.S.	et al.	CSSC26	Bt	40- 53	0.05	16	5.3
sl till	45°48'N	1978	CSSC27	C	65-100	0.05	17	6.1
	63°37'W							

(Continued)

Table 1 (concl.). Soil Identification and Characterization Data - Appalachian Region

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Queens	Colchester	McKeague	66201	Ae	0-4	2.9	18	3.6
BR.GBL	Co.,N.S.	et al.	66203	AB	20- 25	0.4	11	3.6
cl till	45º14'N	1969	66206	Bt	42- 65	0.2	24	3.7
	63º16'W		66210	Ck	160-180	0.1	29	7

Table 2. Total Elemental Analysis of Soils - Appalachian Region

Sample No.	Horizon	%					ppm									ppb
		Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	Hg
6576	Ae	6.2	0.7	0.48	0.16	0.28	69	36	6	14	13	11	16	125	0.16	120
6578	Bhf	7.0	3.0	0.61	0.15	0.48	230	69	13	36	14	17	30	95	l.7	200
6551	Bhfc	5.4	12.2	0.41	0.20	0.45	370	54	9	32	19	8	25	80	2.2	230
6582	C	8.4	2.8	0.46	0.41	0.85	855	95	22	28	26	20	13	135	0.17	44
SMC56	Ae	3.5	0.4	0.18	0.09	0.16	80	22	28	5	12	1	58	40	0.03	660
SMC58	Bf	6.8	4.0	0.33	0.09	0.65	215	60	18	13	16	28	100	50	0.44	566
SMC60	BC	7.0	3.6	0.40	0.09	0.95	240	70	24	23	19	44	100	60	0.28	162
SMC64	C3	7.3	4.2	0.47	0.16	l.15	560	75	41	18	24	41	55	70	0.14	134
66246	Ae	5.5	1.6	0.35	0.22	0.20	270	38	3	18	8	4	14	30	0.09	36
66248	Bf	4.8	1.4	0.30	0.03	0.25	200	120	10	51	12	14	18	35	0.43	52
66250	BC	5.2	2.2	0.51	0.04	0.33	355	100	24	37	16	18	26	55	0.08	
66252	Cx	6.l	2.5	0.58	0.05	0.43	510	100	30	34	14	24	30	65	0.02	60
7536	Ae	1.1	0.4	0.31	0.08	0.03	215	5	6	8	6	5	6	25		
7540	Bfl	4.4	1.6	0.28	0.10	0.20	300	40	11	32	16	9	35	50		
7543	Bfc	3.2	0.9	0.29	0.10	0.23	450	35	11	16	14	10	10	50		
7549	C	3.0	0.4	0.30	0.10	0.20	475	25	10	14	12	8	8	55		
7554	Aeg	1.1	0.1	0.28	0.08	0.03	150	5	5	5	5	5	2	20		
7555	Bhg	2.8	0.3	0.33	0.08	0.10	210	10	8	12	6	2	10	45		
7556	Bhgcl	3.5	0.6	0.32	0.10	0.21	375	20	10	12	10	10	11	50		
7557	Bhgc2	3.8	0.9	0.32	0.12	0.18	300	30	12	15	11	10	14	60		
7560	Bfc	3.8	2.0	0.31	0.12	0.28	400	40	12	15	15	12	16	55		
7134	Ahe	4.4	l.3	0.59	0.07	0.21	500	175	10	19	12	7	37	65	0.18	
7136	Ae	5.0	1.1	0.63	0.04	0.23	380	175	9	12	12	6	15	70	0.05	41
7137	Bf	6.8	3.1	0.58	0.04	0.70	750	250	19	22	28	20	32	75	0.27	50
7138	Btl	7.3	3.1	0.56	0.04	0.90	685	115	24	20	30	30	36	80	0.07	
7141	BC														0.05	20

(continued)

Table 2 (concl.). Total Elemental Analysis of Soils - Appalachian Region

Sample No.	Horizon	%					ppm									ppb
		A1	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	Hg
6837	Aeg	3.8	0.4	0.54		0.16	500	52	4	12	6	4	28	54	0.10	30
6839	Btg	5.8	3.4	0.48	0.05	0.56	510	83	22	27	20	20	39	62	0.19	24
6842	IICg	8.3	4.2	0.65	0.33	0.97	680	145	48	51	31	38	48	96	0.09	16
66228	Aeg	5.8	0.8	0.75	0.05	0.28	150		17		16	13	44	100	0.10	22
66229	Bgf	5.8	3.3	0.65	0.08	0.50	250		12		16	15	42	88	0.24	28
66230	Btg	7.6	3.2	0.53	0.11	0.65	820	70	17	20	29	24	36	105	0.20	14
66234	Ck	7.6	3.1	0.53	2.48	0.87	830	70	17	20	24	30	40	145	0.18	8
7115	Ae	3.8	0.5	0.62	0.03	0.20	118	170	11	10	8	4	19	47	0.21	
7116	Aeg	5.3	0.8	0.65	0.03	0.38	135	300	20	12	12	8	20	55	0.15	18
7118	Btgf	6.8	4.0	0.57	0.03	0.98	470	250	33	36	33	28	28	60	0.24	24
7119	Btg	6.9	3.1	0.60	0.07	1.00	670	85	31	34	33	28	36	65	0.17	
7120	Bt	6.5	3.1	0.58	0.13	0.98	1010	110	33	23	33	28	28	65	0.11	2
7123	C	7.2	3.1	0.61	0.23	1.08	710	175	34	21	36	32	32	75	0.03	12
6824	LH	0.1	0.6	0.10	0.16	0.14	125	252	18	27	8	6	16	37	0.40	220
6825	Aeg	4.0	0.4	0.62	0.04	0.10	85	9	8	9	10	6	18	75	0.02	30
6827	Btgf	6.8	4.0	0.62	0.05	0.45	160	48	10	14	24	23	55	99	0.52	30
6830	BC	6.8	2.8	0.60	0.14	0.58	134	60	20	15	29	35	44	114	0.07	
6834	C	8.4	3.5	0.58	0.18	0.69	125	74	20	16	34	41	68	129	0.03	20
CSSC22	Aeg	3.7	0.4	0.45	0.08	0.14	70	11	8	6	7	4	20	34	0.02	13
CSSC23	Btg	7.6	3.5	0.46	0.10	0.66	279	69	25	22	22	26	36	55	0.10	28
CSSC24	Cg	6.9	3.4	0.44	0.18	0.61	462	74	24	25	27	26	33	57	0.08	32
CSSC25	Ae	5.3	2.1	0.39	0.18	0.46	684	5	15	20	18	19	20	84	0.04	16
CSSC26	Bt	7.4	3.4	0.40	0.18	0.75	912	90	20	26	25	30	32	102	0.03	14
CSSC27	C	7.8	3.4	0.42	0.25	0.82	891	103	21	26	30	34	49	112	0.03	41
66201	Ae	5.2	2.3	0.60	0.07	0.25	345	65	12	19	12	10	26	50	0.26	44
66203	AB	4.2	1.6	0.60	0.15	0.18	345	39	9	14	9	6	19	70	0.15	
66206	Bt	7.2	3.0	0.54	0.10	0.53	490	95	16	20	20	20	32	95	0.28	22
66210	Ck	7.1	2.9	0.53	1.68	0.63	865	70	20	22	24	25	30	115	0.04	14

Table 3. Soil Identification and Characterization Data - Canadian Shield

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org. C %	Clay %	pH $CaCl_2$
Ste.-Agathe	Labelle Co.,	McKeague	SSD256	Ae	0-5	1.0	4.2	4.7
0.FHP	Que.	1973	SSD257	Bf	5- 31	4.3	2.9	4.7
sl	45°57'N		SSD258	Bf	31- 46	1.8	4.2	4.8
	74°27'W		SSD259	C	61+	0.2	3.9	5.2
Laurentides	Montmorency	McKeague	CSSC18	Ae	0-5	1.4	3	3.4
0.FHP	Co.,Que,	et al.	CSSC19	Bhf	5-17	12.0	11	3.5
ls till	47°20'N	1978	CSSC20	Bf	20-40	3.0	7	4.4
	71°09'W		CSSC21	C	60-80	0.3	4	4.7
McConnell R.	Hudson Bay	McKeague	SSK75	Cgl	0-17	1.4		5.8
R.G sand	60°50'N 94°25'W	et al. 1972a	SSK76	Cg2	17-42	1.5		5.6
McConnell R.	Hudson Bay	McKeague	SSK83	Ah	0-10	3.1		3.7
0.SB	60°50'N	et al.	SSK84	Bm	10-26	0.2		4.3
sand	94°25'W	1972a	SSK86	C	60+	0.1		4.6

Table 4. Total Elemental Analysis of Soils - Canadian Shield

Sample		%					ppm									ppb
No.	Horizon	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	Hg
SSD256	Ae	7.0	1.7	0.55	2.28	0.80	485	8	8	28	16	26	41	515	0.10	244
SSD257	Bf	7.0	3.2	0.38	2.20	0.73	540	8	8	28	22	23	27	505	0.22	396
SSD258	Bf	7.2	2.0	0.29	2.05	0.60	365	12	12	25	22	23	28			196
SSD259	C	7.1	1.7	0.27	2.32	0.65	350	14	14	22	21	20	26	605	0.08	190
CSSC18	Ae	6.6		1.3	1.6	0.44	732	99	6	18	16	2	11	426	0.06	12
CSSC19	Bhf	6.6	6.1	1.8	1.5	0.42	518	89	7	26	18	4	16	300	0.71	166
CSSC20	Bf	8.4	5.2	0.92	2.1	0.59	696	135	8	20	23	6	13	394	0.32	74
CSSC21	C	8.1	5.2	1.1	2.5	0.70	810	146	7	19	23	5	12	447	0.08	7
SSK75	Cgl	5.8	1.4	0.22		0.53	275	90	15	16	19	13	34	325	0.21	24
SSK76	Cg2	5.7	1.2	0.20		0.50	255	85	20	12	19	12	19	325	0.15	20
SSK83	Ah	5.7	0.8	0.12	0.92	0.25	127	16	16	16	16	7	10	340	0.08	36
SSK84	Bm	6.1	0.7	0.13	1.05	0.32	134	18	16	16	15	9	8	363	0.06	14
SSK86	C	6.2	0.7	0.12	1.02	0.32	128	17	16	18	18	9	7	368	0.07	14

Table 5. Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Guelph	Wellington	McKeague	6616	Ah	0- 5	4.6	16	6.5
0.GBL	Co.,Ont.	and Day	6618	Ahe	10- 15	3.2	15	6.3
1 till	43º41'N	1966	6620	AB	20- 25	l.8	23	6.2
	80º15'W		6623	Bt	35- 40	0.5	24	6.2
			6627	BC	55- 60	0.5	16	6.9
			6631	Ck	90-100	0.l	14	7
Guelph	near	McKeague	CSSCl5	Ah	0- 15	5.7	18	6.8
0.GBL	Guelph	et al.	CSSC16	Bt	25- 50	l.2	22	7.2
1 till	43º26'N	1978	CSSC17	Ck	100-130	0.l	12	7.5
	78˚50'W							
Oneida	Halton	McKeague	661	Ah1	0- 5	4.5	21	5.l
0.GBL	Co.,Ont.	et al.	662	Ah2	5- 10	3.3		4.9
c till	43º26'N	1972b	663	Ae	10- 15	l.0	21	3.9
	79º50'W		667	Bt	30- 35	0.6	40	4.0
			6611	BCk	50- 55	0.3	37	7
			6615	Ck	90- 95	0.3	16	7
Uplands	Carleton	McKeague	6246	Ae	0- 5	0.8	2.9	3.8
0.HFP	Co.,Ont.	1965a	6247	Bf	5- 20	l.8	6.4	5.0
sand	45º25'N		6251	C	102-127	0.1	1.5	5.2
	75˚35'W							
Grenville	Carleton	McKeague	701	Ah	0- 13	2.5	14	5.3
0.MB	Co.,Ont.	and Day	702	Bm	13- 25	l.0	13	5.2
1 till	45º25'N	1966	704	BCgj	43- 73	0.3	14	5.9
	75º36'W		706	Ckgj	86-102	0.l	11	7
Carp	Carleton	McKeague	7026	Ap	0- 8	3.0	16	7.0
GL.MB	Co.,Ont.	(unpubl.)	7028	Bm	23- 39	0.3	16	6.9
1 alluvium	45º20'N		7031	BCgj	96-122	0.l	15	6.9
	76º01'W		7034	Cg	180-220	0.2	15	7.2

(continued)

Table 5 (cont.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Harkaway	Grey Co.,	McKeague	SSD1	Ah	0- 9	8.6	14	6.5
0.MB	Ont.	and Day	SSD2	Bm	9- 22	1.6	17	6.6
1 till	44°40'N	1966	SSD4	Ck	34- 41	0.1		7.1
	81°05'W							
Brookston	Huron Co.,	McKeague	SSD29	Ah	0- 13	5.8	33	6.3
0.HG	Ont.	and Day	SSD30	Bg	13- 28	0.7	44	6.0
clay	43°57'N	1966	SSD32	Ckg	46- 63	0.2	41	7.2
	81°36'W							
Lincoln	Lincoln	McKeague	SSD211	Ap	0- 15	4.2	56	4.8
FE.HG	Co.,Ont.	and Day	SSD212	Bfg	15- 23	0.9	54	4.8
clay	43°11'N	1966	SSD213	Bgf	23- 33	0.6	61	4.1
	79°35'W		SSD215	Ckg	51	0.5	65	7
Bearbrook	Carleton	McKeague	6218	H	10-0	1.8		4.4
FE.G	Co.,Ont.	1965b	6219	Aeg	0-4	3.5	39	4.5
clay	45°27'N		6221	Bgf	5- 18	0.6	49	5.3
	75°27'W		6223	Cgl	48- 56	0.2	76	6.7
			6226	Cg4	105-115	0.1	82	7.3
Laplaine	Carleton	McKeague	6211	H	18- 0	4.2		6.0
R.G	Co.,Ont.	1965b	6212	Cgl	0- 10	0.8	75	6.5
clay	45°29'N		6216	Cg4	78- 86	0.1	72	7.0
	75°27'W							
Castor	Carleton	McKeague	684	Ah	0- 9	5.3	6.9	5.2
FE.HG	Co.,Ont.	et al.	685	Aeg	9- 20	0.9	3.7	4.8
sl	45°18'N	1971	686	Bgf	20- 35	0.3	7.6	5.0
	75°32'W		688	BCg	48- 70	0.1	4	7.1
			6811	Ckg	110-122	0.2	3.9	7.0

(continued)

Table 5 (cont.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
St.Samuel	Carleton	McKeague	6228	Ah	0- 8	4.7	8.7	4.0
FE.G	Co.,Ont.	1965a	6229	Aeg	8- 25	0.2	3.8	5.0
sand	45º35'N		6231	Bgf	46- 53	0.1	9.0	5.l
	75º35'W		6232	Cgl	53- 61	0.1	12.0	5.1
			6234	Cg3	102-127	0.1	2.1	5.0
W1,S1(176)*	Essex Co.,	Whitby		Ap	0- 16	2.2	39	6.2
0.HG	Ont.	et al.		Bgl	16- 45	0.6	58	6.7
	42º05'N	1978b		Bg2	45-116	0.3	52	7.5
	82º30'W			Ckg	116	0.4	47	7.5
W1,S2(176v)*	Essex Co.,	Whitby		Ap	0- 30	2.8	25	7.2
0.HG	Ont.	et al.		Bgl	30- 45	0.3	25	7.3
	42º05'N	1978b		Bg2	45- 60	0.4	45	7.5
	82º30'W			Ckg	60-	0.5	40	7.6
W1,S3(165)*	Essex Co.,	Whitby		Ap	0- 28	1.9	6	5.4
GL.GBL	Ont.	et al.		Aegj	28- 36	0.1	2	5.6
	42º05'N	1978b		Btgj	36- 60	0.1	13	7.0
	82º30'W			IICkg	60	0.4	42	7.5
W1,S4(176s)*	Essex Co.,	Whitby		Ap	0- 22	2.1	13	6.0
0.HG	Ont.	et al.		Bg	22- 47	1.0	15	6.4
	42º05'N	1978b		IIBg	47- 95	0.8	38	7.4
W1,S5(175g)*	Essex Co.,	Whitby		Ap	0- 20	4.1	16	6.6
GL.GBL	Ont.	et al.		Aegj	20- 28	1.1	14	6.4
	42º05'N	1978b		Btgj	28- 54	0.4	33	7.0
	82º30'W			IICkg	54	0.3	38	7.5
W1,S6(176)*	Essex Co.,	Whitby		Ap	0- 25	2.8	34	6.5
0.HG	Ont.	et al.		Bgl	25- 75	0.3	52	7.1
	42º05'N	1978b		Bg2	75-100	0.3	40	7.4
	82º30'W			Ckg	100	0.6	38	7.7

(continued)

Table 5 (cont.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
W1,S7(175)*	Essex Co.,	Whitby	Ap	0- 20	2.4	21	6.0
0.LG	Ont.	et al.	Bgl	20- 50	0.4	47	7.1
	42º05'N	1978b	Ckg	50	0.3	40	7.7
	82º30'W						
W3,S2(235)*	Huron Co.,	Whitby	Ap	0- 26	3.7	35	7.2
GL.GBL	Ont.	et al.	Btgj	37- 52	0.6	36	7.6
	43º36'N	1978b	Ckgj	52	0.2	34	7.6
	81º31'W						
W3,S3(234)*	Huron Co.,	Whitby	Ap	0- 24	3.2	29	7.3
0.GBL	Ont.	et al.	Bt	30- 50	0.6	56	7.5
	43º36'N	1978b	Ckgj	50	0.4	36	7.6
	81º30'W						
W3,S5(206)*	Huron Co.,	Whitby	Apk	0- 25	5.5	20	7.3
0.HG	Ont.	et al.	Bgkl	25- 40	0.0	14	7.5
	43º36'N	1978b	Bgk2	45- 75	0.1	14	7.5
	81º30'W		Ckg	75	0.2	18	7.6
W3,S7(216)*	Huron Co.,	Whitby	Ap	0- 20	1.8	38	7.6
0.HG	Ont.	et al.	Bg	20- 50	0.3	42	7.5
	43º36'N	1978b	Ckg	50	0.2	26	8.0
	81º31'W						
W4,S1(026)*	Wellington	Whitby	Ap	0- 20	3.3	35	6.7
0.HG	Co.,Ont.	et al.	Bg2	55- 95	0.2	38	7.1
	43º42'N	1978b	Ckg	95	0.2	26	7.5
	80º30'W						
W4,S2(025)*	Wellington	Whitby	Ap	0- 30	2.4	19	7.3
GL.GBL	Co.,Ont.	et al.	Btgj	36- 48	1.2	29	6.7
	43º42'N	1978b	Ckg	48	0.1	28	7.1
	80º30'W						

(continued)

Table 5 (cont.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Rubicon	Carleton	McKeague	6237	Ae	0- 8	0.9	3.0	3.6
G.HFP	Co.,Ont.	1965a	6238	Bhf	8- 10	6.5	6.9	4.2
sand	45°25'N		6240	BCg	20- 41	0.9	2.2	4.8
	74°35'W		6242	Cg	63-102	0.1	2.4	5.9
W4,S3(024)*	Wellington	Whitby		Ap	0- 20	2.4	26	7.2
GL.GBL	Co.,Ont.	et al.		Btgj	25- 60	0.4	48	7.1
	43°42'N	1978b		Ckgj	60	0.1	36	7.6
	80°30'W							
W4,S4(013)*	Wellington	Whitby		Ap	0- 25	l.9	18	7.1
0.GBL	Co.,Ont.	et al.		Ae,	25- 30	0.2	14	7.2
	43°42'N	1978b		Bt	35- 70	0.2	27	7.2
	80°30'W			Ck	70	0.l	17	7.5
W5,S1(046)*	Oxford Co.,	Whitby		Ap	0- 30	3.0	25	7.0
0.HG	Ont.	et al.		Aejg	30- 50	1.0	21	7.0
	43°08'N	1978b		Btjgl	50- 70	0.8	23	7.0
	80°16'W			Btjg2	70- 90	0.2	24	7.1
				Ckg	90	0.1	18	7.5
W5,S2(043T)*	Oxford Co.,	Whitby		Ap	0- 22	2.4	18	7.0
0.MB	Ont.	et al.		Btj	27- 55	0.7	20	7.1
	43°08'N	1978b		Ck	55	0.1	9	7.5
	80°16'W							
W5,S3(045)*	Oxford Co.,	Whitby		Ap	0- 25	2.5	19	7.0
	Ont.	et al.		Aegj	25- 30	0.3	14	7.2
	43°08'N	1978b		Btgj	30- 48	0.2	19	7.3
	80°16'W			Ckgj	48	0.1	12	7.6
W5,S4(045)*	Oxford Co.,	Whitby		Ap	0- 18	1.8	19	6.2
GL.GBL	Ont.	et al.		Btgjl	18- 35	0.5	19	6.5
	43°08'N	1978b		Btgj2	35- 60	0.3	20	7.2
	80°16'W			Ckgj	60	0	12	7.5

(continued)

Table 5 (cont.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
W5,S5(053)'*	Oxford Co.,	Whitby	Ap	0- 25	2.0	15	6.1
0.GBL	0nt.	et al.	Ae	25- 30	0.4	11	6.0
	43º08'N	1978b	Bt	30- 60	0.3	25	7.2
	80º16'W		Ck	65	0.2	5	7.3
W5,S6(043)*	Oxford Co.,	Whitby	Ap	0- 28	2.1	14	6.8
0.GBL	Ont.	et al.	Ae	28- 50	0.7	10	5.9
	43º08'N	1978b	Bt	50-100	0.2	18	5.1
	80º16'W		Ck	100-120	0.1	8	7.3
			IICk	120	0.1	2	7.4
W10,S1(266)*	Lincoln Co.,	Whitby	Ap	0- 15	2.8	38	6.9
0.HG	Ont.	et al.	Bg	15- 40	1.1	38	6.7
	43º08'N	1978b	Ckg	40	0.0	57	7.7
	79º30'W						
W10,S2(265)*	Lincoln Co.,	Whitby	Ap	0- 17	3.6	35	5.7
GL.GBL	Ont.	et al.	Btgj	22- 53	0.5	58	7.0
	43º08'N	1978b	Ckg	53	0.2	57	7.7
	79º30'W						
W13,S1(115S)*	Essex Co.,	Whitby	Ap	0- 30	1.7	8	6.4
GL.GBL	Ont.	et al.	Aegj	30- 45	0.4	11	6.4
	42º08'N	1978b	IIBtgj	45- 65	0.3	20	6.7
	82º30'W		IICkgj	65	0.2	10	7.5
W13,S2(105)*	Essex Co.,	Whitby	Ap	0- 25	l.0	5	5.2
GL.MB	Ont.	et al.	Bull	25- 40	0.3	2	5.8
	42º08'N	1978b	Bm2	40- 55	0.2	2	6.1
	82º30'W		Bg	55- 95	0.1	3	6.6
			Ckg	95	0.2	5	7.5

(continued)

Table 5 (concl.). Soil Identification and Characterization Data - St. Lawrence Lowlands

Soil	Location	Reference	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
W13,S3(115)*	Essex Co.,	Whitby	Ap	0- 21	1.2	10	6.4
GL.GBL	Ont.	et al.	Aegj	21-53	0.2	7	6.4
	42º08`N	1978b	IIBtgjl	53-63	0.3	23	6.8
	82º30'W		IIBtgj2	63-86	0.2	19	6.7
			IICkgj	86	0.2	39	7.5

*W refers to the watershed number and S to the site number of the soils studied by Whitby et al. (1978b). The number in parentheses is the map unit number.

Table 6. Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample No.	Horizon	%					ppm									ppb
		Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	Hg
6616	Ah	6.1	2.4	0.48	1.76	0.70	790	110	18	25	20	12	48	246	0.40	65
6618	Ahe	6.4	2.5	0.49	1.50	0.68	730	98	14	20	20	16	50	240	0.36	
6620	AB	7.1	2.8	0.48	1.51	0.78	1020	86	16	19	24	20	57	265	0.32	
6623	Bt	7.5	3.3	0.50	1.56	0.87	915	91	22	20	24	22	62	25'5	0.26	70
6627	BC	7.0	3.0	0.50	1.64	0.91	1065	88	21	22	24	21	57	260	0.11	34
6631	Ck	3.7	1.6	0.40	11.0	3.68	540	78	22	12	21	16	20	280	0.02	6
CSSC15	Ah	5.4	2.3	0.42	2.4	0.89	1010	144	17	71	16	14	49	207	0.38	18
CSSC16	Bt	7.0	3.7	0.46	2.4	1.4	996	270	27	51	21	23	58	254	0.13	83
CSSC17	Ck	3.6	1.6	0.29	13.1	4.5	552	71	21	16	19	12	16	264	0.07	13
661	Ah1	5.3	3.4	0.66	0.76	0.66	430	138	14	35	26	18	41	155	0.33	48
662	Ah2	5.6	2.3	0.52	0.70	0.66	430	134	13	35	28	18	47	155	0.28	
663	Ae	5.8	2.4	0.70	0.48	0.65	330	111	18	29	26	19	50	145	0.22	22
667	Bt	8.2	2.6	0.60	0.57	1.15	682	111	40	38	46	38	76	130	0.30	32
6611	BCk	8.0	3.9	0.60	2.44	1.22	1010	120	54	30	26	37	76	170	0.10	
6615	Ck	5.8	3.9	0.48	9.25	1.13	715	94	30	32	35	26	57	280	0.08	22
6246	Ae	6.5	1.6	0.36	1.50	0.30	415	50	8	20	12	6	25	355	0.09	8
6247	Bf	9.1	2.6	0.32	1.98	0.70	550	55	8	20		10	39	392	0.32	66
6251	C	8.4	4.5	0.40	2.50	0.92	680	42	18	14	21	8	41	392	0.04	1
6237	Ae	6.8	0.8	0.34	1.30	0.25	275	21	9	24	13	7	17	340	0.05	12
6238	Bhf	8.2	2.7	0.32	1.68	0.53	325	44	18	22	20	8	40	318	0.38	44
6240	BCg	8.4	2.4	0.32	2.28	0.73	435	46	11	22	22	8	35	355	0.14	2
6242	BC	8.1	1.8	0.24	2.30	0.70	400	45	20	20	20	9	26	370	0.05	4
701	Ah	6.8	3.4	0.22	1.88	1.10	760	77	10	23	21	22		348	0.35	52
702	Bm	6.2	3.0	0.58	1.50	1.04	750	63	11	20	22	23		360	0.28	47
704	BCgj	7.0	3.1	0.48	1.75	1.28	725	46	28	24	22	23		418	0.15	
706	Ckgj	6.1	2.5	0.40	4.00	2.01	540	42	24	20	22	19		472	0.11	16

(continued)

Table 6 (cont.). Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample		%					ppm									ppb
No.	Horizon	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	Hg
7026	Ap	7.1	2.6	0.45	2.45	0.90	810	100	22	19	26	18	37	390	0.37	44
7028	Bm	7.3	2.7	0.50	2.30	0.98	810	100	15	19	26	17	26	370	0.26	20
7031	BCgj	7.4	2.5	0.43	2.28	0.95	600	75	20	19	26	17	25	415	0.06	12
7034	Cg	7.2	2.5	0.43	2.80	1.13	600	65	24	19	26	16	25	415	0.09	18
SSD1	Ah														0.83	
SSD2	Bm	6.6	2.9	0.27	1.2	0.74	1130	26	26	28	21	30	36	200	0.34	
SSD4	Ck	4.0	1.6	0.27	9.0	3.70	600	18	30	26	16	20	29	220	0.06	
SSD29	Ah														0.40	
SSD30	Bg	7.3	3.0	0.23	0.74	1.10	675	18	18	32	28	42		135	0.30	
SSD32	Cg	5.7	2.3	0.32	6.13	3.88	435	26	26	28	22	40	45	135	0.10	
SSD211	Ap	8.2	2.4	0.57	0.38	0.88	285	102	26	32	21	27	72	130	0.48	30
SSD212	Bgf	8.2	5.2	0.62	0.33	1.03	960	94	20	32	36	31	62	130	0.40	70
SSD213	Bgf	9.4	4.2	0.46	0.35	1.23	1600	94	26	34	60	58	56	130	0.36	28
SSD215	Ckg														0.17	16
6218	H	8.1	1.7	0.50	0.60	0.43	140		24	25		11			0.92	124
6219	Aeg	10.2	2.2	0.38	1.38	0.85	320	85	10	15	10	10	92	300	0.27	22
6221	Bgf	10.2	4.7	0.42	1.49	1.15	450	110	14	17	15	12	72	290	0.26	18
6223	Cgl	11.5	5.3	0.48	1.48	1.94	1000	110	51	14	28	16	100	260	0.13	26
6226	Cg4	11.2	5.6	0.59	2.12	2.45	820	150	65	12	36	16	115	325	0.08	52
6211	H	2.9	1.1	0.19	4.40	0.42	160	100	59	24		12	41	168	3.7	
6212	Cgl	11.1	5.7	0.53	2.13	2.06	830	160	36	18	48	15	141	310	0.26	16
6216	Cg4	11.2	5.7	0.65	2.53	2.32	1020	145	56	16	46	18	108	348	0.04	8
684	Ah	6.3	1.8	0.50	2.00	0.65	480	58	6	24	18	13	57	422	0.26	100
685	Aeg	7.1	2.2	0.55	2.38	0.77	550	55	4	17	17	14	53	457	0.09	
686	Bgf	7.3	4.0	0.65	2.50	0.92	700		13	18	24	24	73	376	0.14	30
688	BCg	6.6	3.0	0.59	2.75	1.24	770	46	15	17	22	20	34	466	0.04	
6811	Ckg	6.4	2.6	0.40	4.25	1.58	650	70	16	17	20	20	34	468	0.05	8

(continued)

Table 6 (cont.). Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample		%					ppm										ppb
No.		A1	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	**Sr**	Se	As	Hg
6228	Ah	7.4	1.5	0.23	l.65	0.50	410	46	11	33	20	8	46	312	0.30		50
6229	Aeg	8.0	1.8	0.22	2.12	0.65	350	38	12	24	22	10	25	348	0.10		16
6231	Bgf	8.2	3.2	0.27	2.10	0.80	530	44	22	24	25	10	36	335	0.14		4
6232	Cgl	7.6	2.8	0.33	2.15	0.75	370	52	22	24	28	10	49	332	0.10		1
6234	Cg3	8.8	2.0	0.34	2.25	0.80	450	36	12	23	21	8	29	385	0.06		10
W1,S1	Ap	6.7	2.8				325	124	24	24		32	67			8	39
	Bgl	8.5	3.9				490	134	31	20		46	67			12	59
	Bg2	8.4	4.4				745	134	36	20		59	82				40
	Ckg	7.3	3.7				718	102	33	17		50	95			6	26
W1,S2	Ap	5.4	2.2				302	119	20	26		22	51			8	40
	Bgl	5.7	2.7				382	71	17	18		26	46			12	34
	Bg2	8.0	3.8				670	102	34	20		54	82				40
	Ckg	6.3	3.0				490	87	32	16		42	70			12	30
W1,S3	Ap	3.3	0.8				102	40	5	14		10	18			4	
	Aegj	5.2	l.4				188	25	10	10		12	10			3	
	Btgj	4.1	1.5				210	46	15	10		22	10			6	38
	IICkg	6.9	3.2				625	110	28	14		48	60			10	26
W1,S4	Ap	4.4	l.2				120	60	8	16		14	35			3	46
	Bg	4.8	1.5				188	50	8	13		20	18			4	36
	IIBg	7.1	3.8				562	115	30	19		52	70			19	26
W1,S5	Ap	5.2	2.0				254	92	17	27		18	66			8	
	Aegj	5.6	2.7				403	70	17	21		28	79			13	38
	Btgj	7.5	4.1				625	105	41	23		47	84			20	66
	IICkg	6.6	3.4				435	100	30	19		40	93				32
W1,S6	Ap	7.7	3.4				222	140	35	26		38	80			2	50
	Bgl	8.1	4.1				490	140	35	25		50	81			1	36
	Bg2	8.6	4.4				725	138	40	22		67	85			4	32
	Ckg	7.2	3.8				362	122	35	19		42	75			3	30

(continued)

Table 6 (cont.). Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample No.	Horizon	%					ppm										ppb
		A1	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	**Sr**	Se	As	Hg
W1,S7	Ap	6.2	2.8				200	100	20	26		23	70			2	36
	Btg	8.4	4.4				500	135	35	23		58	85			3	50
	Ckg	7.3	3.7				350	128	35	19		42	81			3	26
W3,S2	Ap	6.9	3.3				1085	110	25	23		33	72			5	95
	Btgj	7.5	3.5				745	85	25	20		37	68			5	23
	Ckgj	4.3	2.4				522	58	21	14		22	63			4	94
W3,S3	Ap	6.2	2.9				810	95	22	23		27	88			4	62
	Bt	6.6	3.5				720	81	29	17		38	78			6	30
	Ckgj	4.2	2.1				452	52	22	14		20	50			3	12
W3,S5	Apk	5.3	2.4				290	94	43	20		28	65			3	100
	Bgkl	3.7	1.6				335	49	16	14		34	45				12
	Bgk2	3.9	1.5				462	51	21	11		31	45				6
	Ckg	3.8	1.5				562	56	22	12		36	40			1	6
W3,S7	Ap	7.7	2.8				340	92	28	30		29	84			4	81
	Bg	7.3	3.1				362	89	28	28		38	57			4	46
	Ckg	5.0	2.4				527	60	21	21		16	57			3	12
W4,S1	Ap	6.6	3.3				1005	98	26	28		22	53			4	57
	Bg2	7.3	4.1				875	100	22	23		32	44			6	56
	Ckg	6.9	3.0				595	66	16	19		18	48			5	20
W4,S2	Ap	5.8	2.6				940	70	17	20		19	60			4	57
	Btgj	4.4	2.2				550	44	19	13		19	41			4	56
	Ckg	6.9	3.4				795	70	24	16		22	41			3	20
W4,S3	Ap	6.2	3.0				905	79	18	22		20	50			4	51
	Btgj	8.0	4.3				945	94	30	21		32	60			4	45
	Ckgj	4.7	2.4				555	50	21	12		20	32			4	5

(continued)

Table 6 (cont.). Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample No.	Horizon	%					ppm										ppb
		A1	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As	Hg
W4,S4	Ap	6.0	2.7				812	90	18	24		14	40			5	42
	Ae	6.0	2.5				808	80	16	22		17	32			4	42
	Bt	6.9	3.2				948	100	25	24		25	47			5	58
	Ck	4.8	2.3				598	62	19	22		14	24			3	24
W5,S1	Ap	6.6	2.7				515	106	14	21		18	60			2	50
	Aejg	6.7	3.1				665	100	10	19		19	59			2	50
	Btjgl	6.8	2.5				458	97	10	18		20	62			6	68
	Btjg2	6.9	3.9				560	70	20	18		25	74			5	26
	Ckg	4.8	2.2				542	48	17	16		15	42			4	10
W5,S2	Ap	6.0	2.6				990	78	19	21		18	54			7	50
	Btj	6.6	3.0				950	73	22	21		24	41			5	61
	Ck	4.6	1.9				542	41	15	12		14	18			3	10
W5,S3	Ap	5.8	2.4				645	74	16	21		15	50			5	43
	Aegj	6.0	2.7				610	61	16	18		18	30			5	40
	Btgj	6.2	2.8				715	59	21	15		20	26			5	30
	Ckgj	4.2	1.8				595	40	16	11		13	18			3	10
W5,S4	Ap	5.4	2.6				850	82	20	24		16	42			5	64
	Btgjl	5.7	2.8				715	72	19	19		20	46			5	42
	Btgj2	6.2	3.0				745	75	24	19		23	35			5	36
	Ckgj	3.7	1.6				522	48	18	13		13	26			3	7
W5,S5	Ap	5.2	2.5				1035	70	13	22		17	30			4	49
	Ae	5.6	2.6				722	60	14	20		17	33			4	34
	Bt	5.5	3.5				910	78	30	22		27	34				44
	Ck	4.0	2.8				682	50	14	14		11	33			2	4
W5,S6	Ap	5.4	2.6				1045	78	14	24		16	42			4	46
	Ae	7.5	2.6				1100	75	14	18		16	30			4	52
	Bt	6.3	2.9				758	75	29	19		24	43			5	30
	Ck	4.2	2.0				592	44	15	14		12	15			2	8
	IICk	3.0	1.0				375	30	13	12		8	15			1	1

(continued)

Table 6 (concl.). Total Elemental Analysis of Soils - St. Lawrence Lowlands

Sample No.	Horizon	%					ppm										ppb
		Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As	Hg
W10,S1	Ap	6.8	3.5				385	80	15	24		20	60			5	36
	Bg	8.0	4.1				575	98	25	22		37	78			5	34
	Ckg	7.5	3.9				505	92	30	18		28	92			5	24
W10,S2	Ap	7.4	6.3				4295	162	18	33		24	65			8	50
	Btgj	7.0	4.8				575	130	38	24		47	88			8	31
	Ckg	6.8	3.6				570	90	30	19		32	52			6	14
W13,S1	Ap	4.4	1.4				255	58	14	23		10	20			6	36
	Aegj	4.8	2.0				608	60	11	12		13	34			3	20
	IIBtgj	5.8	2.9				838	77	30	22		26	26			9	39
	IICkgj	5.4	2.3				342	70	25	16		22	47			8	39
W13,S2	Ap	3.9	1.3				175	50	10	22		9	27			4	30
	Bm1	4.5	1.6				245	32	9	10		12	31			3	12
	Bm2	3.9	1.1				382	24	9	10		9	17			4	12
	Bg	4.4	1.7				398	35	14	10		12	17			3	3
	Ckg	3.6	1.7				356	50	17	11		14	18			4	3
W13,S3	Ap	4.4	1.6				468	50	14	18		9	36			4	18
	Aegj	4.4	1.4				235	34	8	11		10	16			3	12
	IIBtgjl	5.9	2.9				498	65	31	18		26	54			10	53
	IIBtgj2	5.8	3.0				648	67	31	11		26	34				24
	IICkgj	6.4	2.9				600	67	31	11		26	35			9	12

Table 7. Soil Identification and Characterization Data - Interior Plains

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org. C	Clay %	pH $CaCl_2$
Breton	Alberta	McKeague	SSD291	Ae	0- 20	0.6	10	5.8
0.GL	53°05'N	and Day	SSD292	Bt1	20- 66	0.6	29	4.7
1 ti11	114°35'W	1966	SSD293	Bt2	66-137	0.4	27	4.8
			SSD294	Ck	162-178	0.3	23	7
Cooking	Alberta	McKeague	6634	Ahe	3- 8	0.9	12	5.8
Lake	53°22'N	et al.	6636	Ae	13- 18	0.4	22	5.1
0.GL	113°10'W	1972b	6640	Bt	33- 38	0.6	36	4.2
c till			6646	Bt	63- 68	0.5	33	5.0
			6652	Ck	105-119	0.6	29	5.8
Uncas	Alberta	McKeague	6655	Ahe	4- 9	3.1	17	4.4
D.GL	53°00'N	et al.	6658	Ae	19- 24	0.4	17	4.2
c ti11	113°51'W	1972b	6662	Bt	39- 44	0.5	28	4.2
			6666	Bt	59- 64	0.4	29	6.4
			6671	Ck	87- 92	0.4	27	7
Maleb	southern	Brydon	SMC38	Bca	23- 51	0.7		8.3
0.B	Alberta	(unpubl.)	SMC39	Cca	51-102	0.4		8.4
			SMC40	Csa	102-127	0.3		7.6
Carvel	near	McKeague	66103	Ahe	4- 9	1.6	14	4.8
0.DG	Edmonton,	(unpubl.)	66106	Ae	19- 24	0.7	13	4.8
			66113	Bt	59- 60	0.2	23	4.9
			66114	BC	60- 83	0.4	15	4.9
			66118	CB	100-115	0.4	16	5.2
Weyburn	Saskatchewan	McKeague	CSSC10	Ah	0- 10	2.1	15	7.3
0.DB	52°10'N	et al.	CSSC11	Bm	15- 33	0.8	12	7.2
	106°27'W	1978	CSSC12	Ck	33- 51	0.2	12	7.9

(continued)

Table 7 (cont.). Soil Identification and Characterization Data - Interior Plains

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org. C %	Clay %	pH $CaCl_2$
Pinesands	Loon Lake,	Day	SSJ16	Ae	2- 12	0.3		4.8
E.DYB	Saskatchewan	(unpubl.)	SSJ17	Bm	12- 63	0.2		4.9
sand			SSJ18	C	63	0.1		5.1
Hemaruka	Youngstown,	McKeague	CSSC7	Ah	0- 10	3.4	14	4.5
B.SZ	Alberta	et al.	CSSC8	Bm	15- 33	0.9	23	7.4
1 till	51º28'N	1978	CSSC9	Ck	33- 51	0.2	23	8.0
	110º15'W							
Porter	N.W.T.	Beckel	SSK40	Ae	0- 5	0.6		3.5
0.HFP	61º48'N	1975	SSK41	Bf	5- 14	1.0		4.5
sand	108º00'W		SSK43	C	46-100	0.1		4.4
Reindeer	Caribou	Day and	SSA8	Hz	10- 0			
Depot	Hills, N.W.T.	Rice	SSA12	Cz	58- 74	18	57	5.2
R.TC	68º22'N	1964						
c till	134º05'W							

(Continued)

Table 7 (concl.). Soil Identification and Characterization Data - Interior Plains

Soil	Location	Reference	Sample No.	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
-	Norman Wells,	Day and	SSA42	Ahk	0- 25	9.5		7
R.HG	N.W.T.	Rice	SSA43	IICk	25- 96	0.7		7
loam	65°25'N	1964						
	126°45'W							
-	Allan	McKeague	692	Ah	0- 17	4.9	26	5.2
HU.LG	Hills,	(unpubl.)	693	Aheg	17- 30	2.2	26	5.2
c till	Saskatchewan		694	Btg	40-100	0.6	38	5.9
			696	IICkg	300	0.3	21	7
Liard	N.W.T.	Day	SSB41	C	0- 10	5.0		6.2
CU.R	61°42'N	1966	SSB42	Ck	10- 60	3.4		7
sl alluvium	121°17'W							
Providence	Mackenzie R.,	Day	SSC42	Bm	2- 25	0.9		6.0
0.EB	N.W.T.	1968	SSC43	Ck	25- 41	1.2		7
c lacustrine	61°22'N							
	117°29'W							
Mackenzie	Mackenzie R.,	Day	SSC83	Bm	1- 25	0.8		6.1
0.EB	N.W.T.	1968	SSC85	Ck	43- 91	0.6		7
1 alluvium	61°20'N							
	118°34'W							
-	Norman Wells,	Day and	SSA39	Bm	0- 18	2.2		7.2
0.EB	N.W.T.	Rice	SSA40	IICk	18- 61	2.2		7
	65°25'N	1964						
	126°45'W							
Laferte	N.W.T.	Beckel	SSK4	Bm	2- 13	0.6		4.2
0.DYB	61°59'N	1975	SSK5	BC	13- 18	0.6		4.9
c till	119°22'W		SSK6	Ck	18	0.4		7

Table 8. Total Elemental Analysis of Soils - Interior Plains

Sample		%					ppm										ppb
No.	Horizon	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As	Hg
SSD291	Ae	4.8	l.5	0.34	0.50	0.35	165	46	10	16	8	15	18	170	0.12		14
SSD292	Bt1	7.2	2.8	0.43	0.65	0.75	252	62	24	22	16	30	58	155	0.40		28
SSD293	Bt2														0.24		200
SSD294	Ck	6.3	2.5	0.36	3.50	0.85	470	60	28	24	18	34	36	215	0.12		44
6634	Ahe	4.6	1.2	0.43	0.53	0.36	475	25	20	12	16	10	40	155	0.08		
6636	Ae		1.2	0.43				44	10	12	16	7	42	150	0.15		6
6640	Bt			0.45				80	40	12	20	26	64	140	0.42		44
6646	Bt	7.0	2.7	0.43	0.68	0.67	415	68	45	14	22	26	74	150	0.26		
6652	Ck	5.5	2.0	0.34	2.00	0.76	435	42	24	12	20	26	46	150	0.20		34
6655	Ahe	5.0	1.5	0.40	0.51	0.33	1120	43	19	15	20	16	47	145	0.38		
6658	Ae	5.0	1.4	0.45	0.42	0.45	210	30	18	12	16	16	37	150	0.28		17
6662	Bt			0.45				58	28	16	18	21	73	155	0.46		55
6666	Bt	7.2	2.9	0.48	0.71	0.71	250	48	40	14	21	24	76	185	0.49		
6671	Ck	6.2	2.4	0.43	0.83	0.60	400	42	29	10	20	36	36	185	0.14		60
SMC38	Bca	6.2	1.9	0.27	4.0	0.95	270	55	18	14	16	23	59	330	0.42		68
SMC39	Cca	6.3	2.0	0.27	1.8	0.83	330	55	14	13	15	22	26	260	0.32		66
SMC40	Csa	5.1	1.8	0.19	2.2	0.75	250	45	15	12	14	19	49	200	0.52		54
66103	Ahe	4.9	l.5	0.45	0.70	0.32	515	72	19	13	10	15	19	149	0.28		
66106	Ae	5.3	1.4	0.43	0.60	0.30	440	59	18	20	15	16	22	190	0.20		36
66109	Bt	5.7	1.6	0.41	0.66	0.30	410	115	16	15	16	18	22	195	0.16		
66113	Bt	5.9	2.l	0.43	0.66	0.33	395	60	22	18	18	24	26	195	0.20		165
66114	BC	5.8	1.7	0.40	0.65	0.30	400	65	18	15	16	20	24	215	0.12		
66118	CB	5.6	1.6	0.39	0.69	0.30	570		21	15	17	29	20	215	0.11		52
CSSC10	Ah	4.9	1.7	0.27	1.8	0.55	460	56	13	18	14	15	47	181	0.21		18
CSSC11	Bm	5.3	l.7	0.25	1.0	0.53	376	47	10	18	14	15	51	196	0.12		20
CSSCl2	Ck	4.5	1.7	0.20	4.2	l.80	377	37	12	18	15	17	27	202	0.05		16
SSA42	Ahk	5.1	2.4	0.28	2.75	0.93	515	75	26	16	16	28	62	195	2.2		150
SSA43	IICk	7.0	4.0	0.36		1.73	550	140	36	38	24	42	41	185	0.53		82

(continued)

Table 8 (concl.). Total Elemental Analysis of Soils - Interior Plains

Sample		%					ppm										ppb
No.	Horizon	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As	Hg
692	Ah	4.8	l.2	0.38	0.70	0.35	165	78	25	17	10	10	48	142	0.80		30
693	Aheg	5.2	1.9	0.38	0.63	0.35	300	71	32	18	12	11	24	152	0.60		18
694	Btg	6.6	2.8	0.42	0.68	0.64	740	130	30	20	22	26	34	148	0.28		34
696	IICkg														0.12		30
SSB41	C	5.0	2.0	0.27	1.65	0.90	230	80	22	12	14	23	61	110	0.68		14 000
SSB42	Ck	4.5	2.0	0.25	3.75	1.30	225	90	46	13	16	25	50	155	0.70		770
SSC42	Bm	3.8	2.0	0.29	4.6	1.33	280	120	26	14	23	22	55	130	0.27		55
SSC43	Ck	6.6	3.7	0.43	4.7	1.85	620	140	36	30	28	39	55	145	0.22		55
SSC83	Bm	8.2	3.5	0.37	0.33	0.90	440	65	34	20	20	37	42	154	0.59		30
SSC85	Ck	7.8	3.1	0.37	2.38	l.95	420	75	38	22	20	36	55	205	0.23		44
SSA39	Bm	5.8	4.2	0.34	0.68	0.55	490	130	25	20	19	38	75	115	1.3		55
SSA40	IICk	5.1	3.8	0.30	3.25	1.50	540		34	19	20	41	31	150	1.2		110
SSK4	Bm	5.9	2.4	0.28	0.45	0.60	330	110	25	18	24	24	31	140	0.19		20
SSK5	BC	7.2	3.1	0.37	0.63	0.75	455	58	45	20	25	36	75	160	0.24		54
SSK6	Ck	5.5	2.2	0.30	1.00	1.50	490	52	40	18	25	28	24	165	0.13		26
SSJ16	Ae	4.0	0.8	0.17	0.60	0.13	270	45	11	12	10	4	10	255	0.06		14
SSJ17	Bm	3.l	0.6	0.09	0.40	0.10	120	19	1	9	8	4	6	175	0.05		14
SSJ18	C	3.6	0.8	0.11	0.53	0.13	190	90	1	12	9	5	10	215	0.05		14
CSSC7	Ah	4.7	1.2	0.28	0.40		480	70	15	13	13	10	42	170	0.39		38
CSSC8	Bm	5.4	1.8	0.29	0.34		419	68	14	17	17	19	48	188	0.50		36
CSSC9	Ck	5.4	1.8	0.28	2.2		337	63	15	17	17	23	30	262	0.24		36
SSK40	Ae	2.9	0.5	0.08	0.53	0.08	95	10	12	12	6	2	5	165	0.05		22
SSK41	Bf	3.9	l.1	0.13	0.63	0.11	155	20	15	11	10	4	10	205	0.42		24
SSK43	C	4.0	1.2	0.14	0.85	0.17	230	95	15	12	11	4	8	310	0.10		20
SSA8	Hz	0.9	1.2	0.04	1.48	0.08	155	30	25		7	30	50	55	l.8		480
SSA12	Cz														1.0		1700

Table 9. Soil Identification and Characterization Data - Cordilleran Region

Soil	Location	Reference	Sample	Horizon	Depth cm	Org.C %	Clay %	pH $CaCl_2$
Sandwick	Vancouver Is. ,	Day	SSJ47	Ah	0- 30	7.8		4.6
SM.FHP	B.C.	et al.	SSJ48	Bf	30- 60	5.0		4.2
sl till	49°40'N	1959	SSJ50	Cg	85-100	0.5		4.4
	124°59'W							
Cadboro	Vancouver Is. ,	McKeague	SSD318	Ah	0- 25	11		5.4
SM.FHP	B.C.	and Day	SSD319	Bfh	25- 41	5.0		4.9
sl till	48°28'N	1966	SSD321	C	50	0.7		4.5
	123°22'W							
Langford	Vancouver Is. ,	McKeague	CSSC1	Ah	0- 15	11.0	17	5.1
SM.FHP	B.C.	et al.	CSSC2	Bhf	15- 25	5.5	11	4.7
marine	48°29'N	1978	CSSC3	C	100-125	0.3	6	5.0
	123°22'W							
Whatcom	Fraser	McKeague	CSSC4	Bf	18- 76	2.2	10	5.0
LU.HFP	Va11ey, B.C.	et al.	CSSC5	Bt	100-140	0.1	30	5.5
eolian/	49°15'N	1978	CSSC6	C	175-225	0.1	31	6.0
lacustrine	122°31'W							
Fairbridge	Vancouver Is. ,	McKeague	SSD330	Bull	1- 30	1.5		4.9
0.DYB	B.C.	and Day	SSD331	Bm2	30- 48	1.1		4.6
clay	48°43'N	1966	SSD334	C	91	0.2		5.4
	123°38'W							
Shawnigan	Vancouver Is.,	McKeague	SSD374	Bm	0- 23	1.5		5.1
0.DYB	B.C.	and Day	SSD376	C	48- 76	0.6		5.2
sl till	48°37'N	1966						
	123°33'W							
Cowichan	Vancouver Is.,	McKeague	SSD322	Ah	0- 15	2.0		5.3
0.HG	B.C.	and Day	SSD323	Aeg	15- 20	1.7		5.6
clay	48°48'N	1966	SSD325	Cg	41	0.4		5.9
	123°38'W							

Table 10. Total Elemental Analysis of Soils - Cordilleran Region

Sample No.	Horizon	%					ppm										ppb
		Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As	Hg
SSJ47	Ah	6.5	4.4	0.53	2.10	1.05	1070	90	50	14	32	28	76	275	0.35		34
SSJ48	Bf	7.6	4.0	0.58	2.03	1.18	700	100	50	6	32	31	78	505	0.56		28
SSJ50	Cg	8.4	4.3	0.55	1.83	0.83	570	55	70	8	33	27	49	275	0.24		28
SSD318	Ah	6.9	3.2	0.46	2.54	1.20	1180	86	28	26	33	31	57	269			54
SSD319	Bf	8.2	3.6	0.48	2.21	1.33	900	78	38	20	46	51	82	251	0.78		190
SSD321	C	8.6	3.6	0.60	1.26	0.95	630	54	43	23	44	37	74	164	0.40		50
CSSC1	Ah	6.1	2.8	0.34	2.2	0.83	1403	91	42	24	21	29	60	296	0.18		76
CSSC2	Bhf	7.7	3.6	0.38	1.9	0.95	874	75	43	12	24	35	86	277	0.31		31
CSSC3	C	7.8	3.0	0.40	2.2	0.95	615	49	33	11	23	28	41	347	0.12		35
CSSC4	Bf	8.2	4.6	0.64	1.4	1.0	641	107	23	14	30	46	106	236	0.42		111
CSSC5	Bt	8.6	4.8	0.53	2.4	1.6	918	93	46	14	33	60	75	358	0.07		54
CSSC6	C	8.6	4.6	0.54	2.5	1.7	869	96	46	14	31	59	78	378	0.07		46
SSD330	Bm1	8.8	4.9	0.73	1.40	1.56	915	54	54	19	32	48	86	240	0.34		55
SSD331	Bm2	9.0	4.6	0.64	1.50	1.53	920	54	54	20	38	65	89	250	0.35		
SSD334	C														0.17		52
SSD374	Bm	7.8	3.5	0.68	1.95	1.08	598	66	34	15	36	32	86	220	0.24		34
SSD376	C	7.6	3.5	0.59	2.30	1.05	635	54	50	19	38	30	81	280	0.30		46
SSD322	Ah	7.8	3.0	0.65	1.80	1.00	475	48	44	16	36	32	86	245	0.32		34
SSD323	Aeg	9.0	2.9	0.71	1.86	0.98	410	48	40	16	38	31	89	210	0.30		40
SSD325	Cg	4.5	4.4	0.71	1.56	1.30	630	90	78	19	52	54	100	235	0.17		58

Table 11. Minimum, maximum, and mean values for a11 samples and for samples of each region[1]

Variable	All regions				Appalachian region				Canadian Shield			
	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean
Org.C	293	0.03	36.8	1.5	54	0.03	36.8	1.8	13	0.1	12.0	2.3
Clay	243	1.0	82.0	21.8	47	1.0	38	15.7	8	2.9	11	5.0
pH	292	3.0	8.4	5.8	51	3.0	7.0	4.3	13	3.4	5.8	4.5
Al	285	0.1	11.5	6.2	53	0.1	8.4	5.5	13	5.7	8.4	6.7
Fe	285	0.1	12.2	2.6	53	0.1	12.2	2.4	12	0.7	6.1	2.5
Ti	191	0.04	1.8	0.44	53	0.1	0.75	0.48	13	0.12	1.8	0.57
Ca	184	0.03	13.1	1.5	52	0.03	2.5	0.19	11	0.92	2.5	1.8
Mg	185	0.03	4.5	0.82	53	0.03	1.2	0.48	13	0.25	0.80	0.53
Mn	285	69	4295	544	53	69	1010	415	13	127	810	417
Zn	282	5	300	77	51	5	300	85	13	8	146	57
Cu	288	1	78	22	53	3	48	17	13	6	20	12
Pb	285	5	71	20	51	5	51	21	13	12	28	20
Co	188	5	60	21	53	5	36	18	13	15	23	19
Ni	288	1	67	22	53	1	44	18	13	2	26	12
Cr	282	2	141	45	53	2	100	31	13	7	41	19
Sr	189	20	605	207	53	20	145	71	12	300	605	409
Se	188	0.02	3.7	0.30	45	0.02	2.2	0.23	12	0.06	0.71	0.18
As	90	1	20	5.2								
Hg[2]	253	1	770	54	38	2	660	82	13	7	396	107

	St. Lawrence Lowlands				Interior Plains				Cordilleran region			
Variable	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean
Org.C	153	0.1	8.6	1.2	53	0.1	18.0	1.5	20	0.1	11.0	2.9
Clay	151	1.5	82	24.6	31	10	57	22.7	6	6.0	31	17.5
pH	155	3.6	8.0	6.6	53	3.5	8.4	5.9	20	4.2	6.0	5.1
Al	152	2.9	11.5	6.4	48	0.9	8.2	5.3	19	4.5	9.0	7.8
Fe	152	0.8	6.3	2.8	49	0.5	4.2	2.0	19	2.8	4.9	3.9
Ti	55	0.19	0.7	0.44	51	0.04	0.48	0.32	19	0.34	0.73	0.56
Ca	55	0.33	13.1	2.8	47	0.33	4.7	1.4	19	1.3	2.5	1.9
Mg	55	0.25	4.5	1.2	45	0.08	2.0	0.69	19	0.83	1.7	1.2
Mn	152	102	4295	622	48	95	1120	378	19	410	1403	787
Zn	150	18	270	80	49	10	140	66	19	48	107	73
Cu	152	4	65	22	51	1	46	23	19	23	78	46
Pb	152	10	71	21	50	9	38	16	19	6	26	16
Co	52	10	60	25	51	6	28	16	19	21	52	34
Ni	152	6	67	23	51	2	42	21	19	27	65	40
Cr	146	10	141	50	51	5	76	40	19	41	106	78
Sr	54	130	472	296	51	55	330	178	19	164	505	280
Se	58	0.02	3.7	0.28	54	0.05	2.2	0.40	19	0.07	0.78	0.30
As	90	1	20	5.2								
Hg[2]	138	1	124	34	45	6	770	72	19	28	190	56

[1] Values for organic C, clay, Al, Fe, Ti, Ca, and Mg are percentages; those for Mn, Zn, Cu, Pb, Co, Ni, Cr, Sr, Se, and As are in parts per million and those for Hg are in parts per billion.

[2] Values exceeding 1000 ppb are excluded from this summary. There were two such values, 1700 and 14,000 ppb, both from a soil in the Mackenzie River Valley, N.W.T.

Table 12. Mean contents of elements in A, B, and C horizons of samples from each of three regions

	Hor.	No.[1]	%					ppm										ppb
			Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se[1]	As[1]	Hg
Appala-	A	16	4.2	0.9	0.50	0.09	0.21	256	74	11	12	10	7	23	59	0.11		94
chian	B	25	5.9	3.0	0.46	0.09	0.54	431	82	18	24	20	20	35	70	0.38		92
region	C	11	7.1	3.0	0.51	0.55	0.76	633	91	26	25	26	29	37	96	0.08		38
St.	A	52	6.1	2.4	0.44	1.5	0.70	636	41	16	23	20	18	48	283	0.31	4.7	45
Lawrence	B	56	6.9	3.2	0.46	2.0	1.0	663	52	24	21	27	29	52	288	0.22	6.4	37
Lowlands	C	42	6.2	2.9	0.41	4.8	2.1	572	70	26	17	27	22	51	328	0.09	4.4	18
Interior	A	14	4.7	1.4	0.34	0.82	0.38	401	52	18	15	13	12	33	169	0.41		33
Plains	B	18	5.9	2.3	0.35	1.0	0.60	365	73	25	16	18	23	48	175	0.36		56
	C	17	5.5	2.3	0.29	2.2	1.1	386	74	25	17	18	26	36	196	0.35		89

[1] Numbers of samples from the St. Lawrence Lowlands analyzed for Se were 19, 20, and 17 for the A, B, and C, respectively; and for As 35, 30, and 20.

Table 13. Correlation coefficients for samples from all regions[1]

	Org C	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As
Org C																		
Clay																		
pH		.34																
Al		.54																
Fe		.59		.67														
Ti				.33	.47													
Ca			.55															
Mg		.40	.58	.31	.35		.78											
Mn				.43	.49			.38										
Zn		.43		.36	.42	.38												
Cu		.66		.48	.50			.47	.35	.31								
Pb				.30	.32					.38								
Co		.53		.67	.62	.34		.45	.61	.30	.66							
Ni		.57	.35	.48	.53			.42	.34	.30	.67		.67					
Cr		.71		.61	.58			.40	.30	.35	.63		.61	.64				
Sr				.41			.45											
Se	.62				.37													
As					.32	n	n	n			.33		n	.39		n		
Hg	.32																	

[1] Data for the fo11owing samples are not included: LFH and H horizons, samples having Hg > 1000 ppb, or Mn > 4000 ppm. Numbers of pairs of data points are: 0 for As with Ti, Ca, Mg, Sr, and Co; 90 for As with other variables. For other pairs, from a low of 134 for clay-Mg to a high of 280 for Ni-Cu. The n's indicate no data.

Table 14. Correlation coefficients for soils from the Appalachian region[1]

	Org.C	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se
Org. C																	
Clay																	
pH																	
Al		.68	.54														
Fe	.31	.59	.49	.57													
Ti		.53		.43													
Ca		.34	.63														
Mg		.51	.58	.84	.57	.32											
Mn			.47	.48	.31		.39	.63									
Zn				.38		.56		.41									
Cu		.45	.40	.61	.36			.81	.46	.41							
Pb				.49	.47			.46	.37	.33	.48						
Co		.52	.60	.82	.56	.35		.89	.61	.38	.73	.44					
Ni		.50	.67	.82	.50			.90	.46		.74	.43	.84				
Cr		.45	.37	.55	.39			.52			.44		.42	.64			
Sr		.56	.58	.71	.35	.45	.49	.49	.40				.57	.52			
Se	.80				.66												
Hg	.48					-.57			-.34						.51		

[1] The LH sample was excluded.
Numbers of pairs of data points range from 34 for Hg-clay, 40 for Se-clay, to 52 for most others.

Table 15. Correlation coefficients for samples from the St. Lawrence Lowlands[1]

	Org.C	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As
Org.																		
Clay																		
pH																		
Al		.59																
Fe		.74		.73														
Ti		.39	.51		.46													
Ca			.58	-.52														
Mg	-.37	.35					.78											
Mn				.32	.49													
Zn		.61		.47	.66	.58												
Cu		.73	.38	.47	.64	.32		.44		.52								
Pb	.47									.47								
Co		.62		.42	.61	.39			.54	.35	.56							
Ni		.62	.33		.51					.45	.59		.57					
Cr		.79		.65	.73	.53				.67	.64		.50	.55				
Sr		-.50								.31		-.53	-.30	-.57				
Se	.79						-.48	-.38				.38				.47		
As					.32	n	n	n			.33		n	.39		n		
Hg	.50									.39		.32			.30		.55	

[1] The value for Mn in W10,S_2 (265) was excluded. The n's indicate no data. Numbers of pairs of data points range from 0 for As with Ti, Ca, Mg, Co, Sr; 42 for Hg with Ti, Ca, Mg, Co; to 150 for Cu with Pb.

Table 16. Correlation coefficients for samples from the Interior Plains[1]

	Org.C	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se
Org. C																	
Clay																	
pH																	
Al		.74	.32														
Fe		.75	.47	.77													
Ti		.40		.67	.44												
Ca			.64		.30												
Mg			.70	.42	.65		.77										
Mn				.36	.39	.48											
Zn		.41			.58			.37									
Cu		.79		.64	.73	.51		.57		.36							
Pb			.34	.56	.70		.30	.57	.39	.55	.40						
Co		.63		.68	.76	.52	.30	.63	.54	.47	.72	.52					
Ni		.53	.50	.77	.92	.46	.37	.68	.43	.47	.71	.62	.79				
Cr		.56		.56	.60	.46		.43			.57		.55	.53			
Sr		.33				-.38					-.36				-.35		
Se	.80	.45												.34	.43		
Hg	.31						.34				.41						

[1] The data for SSA8 and 12 (Hz and Cz), and the Hg values exceeding 1000 ppb were excluded. Numbers of pairs of data points range from 42 to 52.

Table 17. Correlation coefficients for samples from the Cordilleran region[1]

	Org.	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se
Org. C																	
Clay																	
pH		.88															
Al	-.43	.39															
Fe	-.37	.60															
Ti	.36	.30			.37												
Ca		.68	.34			-.59											
Mg		.89	.36		.65												
Mn	.75	.33				-.58	.39										
Zn	.41	.51		-.41	.36		.30		.47								
Cu	-.32	.71			.42	.30											
Pb	.36								.46								
Co	.36	.66				.60	-.32		.38		.40						
Ni	-.39	.83	.33		.67			.85									
Cr					.36	.64	-.49						.46	.47			
Sr		.64				-.35	.54			.45		-.56	-.42		-.30		
Se	.33	-.63	-.55										.34				
Hg												.37	.30	.43			.59

[1] Numbers of pairs of data points, 18 or 19.

Table 18. Correlation coefficients for A horizons from all regions[1]

	Org.	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As
Org. C																		
Clay	.40																	
pH		.34																
Al		.51	.30															
Fe	.37	.53	.59	.64														
Ti																		
Ca	.51		.64	.59	.64													
Mg	.57	.35	.65	.73	.88		.80											
Mn	.38		.43	.34	.63		.63	.63										
Zn		.43			.39	.41												
Cu	.49	.56	.32	.34	.48		.31	.52	.34									
Pb	.36	.33	.37	.41	.51		.44	.49	.53	.37								
Co	.41		.44	.63	.79		.56	.80	.41		.63	.37						
Ni	.44	.60	.58	.56	.76		.57	.84	.31		.68	.40	.79					
Cr	.45	.71	.50	.63	.67		.53	.80	.41	.30	.62	.37	.68	.76				
Sr			.34	.64	.45		.81	.57				.32	.41	.33				
Se	.60	.47	.55		.33		.36	.40			.33			.42	.36			
As						n	n	n				.33	n			n		
Hg																		

[1] The value for Mn in W10,S_2 (265) was excluded. The n's indicate no data. Numbers of pairs of data points range from: 0 for As with Ti, Ca, Mg, Co, Sr; 35 for As with other variables; 41 for Hg with Ca, Mg, Ti, Co; to 90 for Cu - organic C.

Table 19. Correlation coefficients for B horizons from all regions[1]

	Org.C	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As
Org. C																		
Clay																		
pH	-.33	.31																
Al		.51																
Fe	.39	.55		.56														
Ti	.40			.34	.48													
Ca			.52															
Mg		.42	.39	.68	.39		.54											
Mn		.33		.49	.36			.65										
Zn		.38		.36	.35	.31		.32	.33									
Cu		.58		.50	.32			.65	.44	.34								
Pb					.30					.43								
Co		.50		.66	.37	.31		.70	.69	.30	.54							
Ni		.69	.33	.55	.38			.71	.43	.34	.73		.73					
Cr		.59		.60	.45			.67			.66		.44	.75				
Sr			.36	.42			.76	.39										
Se	.68				.59													
As						n	n	n			.34		n	.30		n		
Hg	.54																.34	

[1] Numbers of pairs of data points are: 0 for As with Ti, Ca, Mg, Co, Sr; 30 for As with other variables; 54 for Se-Mg; to 112 for Cu-Pb. The n's indicate no data.

Table 20. Correlation coefficients for C horizons from all regions[1]

	Org.	Clay	pH	Al	Fe	Ti	Ca	Mg	Mn	Zn	Cu	Pb	Co	Ni	Cr	Sr	Se	As
Org. C																		
Clay	.40																	
pH																		
Al		.54																
Fe		.65		.78														
Ti				.54	.76													
Ca			.46															
Mg			.53				.78											
Mn				.50	.64	.67												
Zn		.57		.50	.66	.53												
Cu		.75		.48	.66	.45				.43								
Pb																		
Co		.65		.61	.75	.66			.57	.46	.69							
Ni					.43						.55		.40					
Cr		.84		.60	.74	.43				.50	.67		.76	.48				
Sr														-.41				
Se	.72																	
As	.45	.49		.53	.42	n	n	n		.44	.55		n	.52		n		
Hg	.73																.48	

[1] Data for the Cz horizon (SSA12) and Hg values exceeding 1000 ppb are excluded. Numbers of pairs of data points are: 0 for As with Ti, Ca, Mg, Co, Sr; 25 for As with other variables; 36 for clay with Ti, Mg, Ca, Co, Sr; to 81 for Ni with Fe, Mn, Cu, etc. The n's indicate no data.

Table 21. Sources of data on minor element content of Canadian soils

Reference	Samples analyzed	Sample location
Byers and Lakin 1939	seleniferous soils	Interior Plains
Walker et al.1941	27 surface samples	Alberta
Hill 1949	surface samples	Cape Breton, N.S.
Atkinson et al. 1953	surface, 10 soils	Carleton and Grenville Cos., Ont.
Chisholm and McEachern 1954	surface, 14 soils	Nova Scotia
Wright and Lawton 1954	surface, 14 soils	Nova Scotia
Wright et al. 1955	horizons, 8 soils	Eastern Canada
Bishop and Chisholm 1961	surface samples	Annapolis Valley, N.S.
Smeltzer et al.1962	surface, 4 soils	Nova Scotia
Presant 1966	soils near sulfide zones	Bathurst area, N.B.
Warren et al. 1966	horizons and surface	mining areas of British Columbia
Rana and Ouellette 1967	0-20 cm and 20-40 cm	Quebec soils
Reid and Webster 1969	horizons, 5 soils	Alberta
Pawluk and Bayrock 1969	glacial till, 475 samples	Alberta
Wright 1969	horizons, 6 soils	Interior Plains
Baraskso and Tarnocai 1970	horizon samples	mineralized zones, Hope-Princeton, B.C.
Warren et al. 1970	horizons, 62 soils	British Columbia
Haluschak and Russell 1971	A and C horizons, 19 soils	Portage area, Man.
John 1971	surface soils	British Columbia
Michalyna 1971	horizons, 7 soils	westcentral Manitoba
Pawluk 1971	horizons, 2 soils	northwestern Alberta
Presant 1971	horizon and surface samples	Bathurst area, N.B.
Stewart and Tahir 1971	0-15 and 15-30 cm, 24 sites	Interior Plains
John 1972	surface, 86 samples	British Columbia
John et al.1972	surface, 33 samples	Fraser River Valley, B.C.
Bishop and MacEachern 1973	surface, 69 samples	Nova Scotia
Fletcher et al.1973	seleniferous soils	eastern Yukon
MacLean et al. 1973	profile samples, golf courses	Ottawa area, Ont.
Hutchinson and Whitby 1974	0,5, and 10 cm, 30 soils	Sudbury area, Ont.
Gracey and Stewart 1974	horizons, 27 soils	Saskatchewan
John 1974	horizons, 7 soils	Fraser River Valley, B.C.
Lahti 1974	horizons, 21 soils	St.Stephen area, N.B.
Lévesque 1974a	horizons, 54 soils	Canada
Lévesque 1974b	horizons, 10 soils	Quebec, Ontario
MacLean 1974a	surface, 3 soils and additives, 10 samples	eastern Ontario
MacLean 1974b	6 mineral soil samples	Ottawa
Gupta and Winters 1975	surface, 66 samples	Prince Edward Island
John et al.1975	horizons, 8 soils, Hg mine area	Pinchi Lake, B.C.
Mills and Zwarich 1975	A and C horizons, 28 soils	Manitoba
Warren 1975	unspecified soil samples	Ontario, Saskatchewan, British Columbia
Dudas and Pawluk 1976	horizons, 14 soils	Alberta
Frank et al. 1976	cultivated surface, 296 samples	Ontario
Karamanos et al. 1976	Ap horizons, 3 soils	Saskatchewan
MacLean 1976	surface and subsurface, 6 samples	eastern Ontario
Dudas and Pawluk 1977	cultivated surface, 54 samples	Alberta
Kalbasi and Racz 1978	horizons, 8 soils	Manitoba
Singh, Personal commun.1978	surface, 10 samples	southern Ontario

Table 22. Summary of data from the literature on total Mn, Zn, Cu, Pb, Co, and Ni in Canadian soils[1]

Reference	Mn	Zn	Cu	Pb	Co	Ni
Hill 1949					2.7,8.9 [2]	
Atkinson et al. 1953	255-1196		4-24		3-16	
Chisholm and MacEachern 1954		23-86				
Wright and Lawton 1954					4-21	
Wright et al. 1955	250-1380	10-150	4-23	5 - 33	l-18	
Smeltzer et al. 1962	354-1802	247-593	17-22		4-9	
Presant 1966		60-100 [3]	7-22 [3]	15-75 [3]		
Warren et al. 1966	80-1440	<200 [4]	3-2030	1-600		4-100
Rana and Ouellette 1967					1-36	
Reid and Webster 1969	1985-2855					
Pawluk and Bayrock 1969	80-550	20-120	5-40		2-11	
Wright 1969	250-650	30-70	7-24	6 - 17	4-10	
Warren et al. 1970		31-151	3-91			
Haluschak and Russell 1971	55-950	41-127	2-43		3-25	
John 1971				41 - 61 [5]		
Michalyna 1971	75-975					
Pawluk 1971	67-650					
Presant 1971	<100-5740	10-5100	5-2200	0-55000		
Stewart and Tahir 1971		122				
John 1972		105 ±54 [6]				
Bishop and MacEachern 1973		14-108				
Hutchinson and Whitby 1974	122-360	50-100	3-2071	9 - 78	6-154	35-5104 [7]
John 1974		52-221				
Lahti 1974	100-900		16-472		1-89	41-440
MacLean 1974a		51-106				
Mills and Zwarich 1975		24-350	7-61	7-23 [8]		18-145
Warren 1975		33-160				
Frank et al. 1976	90-3000	5-162	2-144 [9]	2-888 [9]	l-66	1-119
Karamanos et al. 1976				6 - 9		
MacLean 197		57-92				
Dudas and Pawluk 1977	180-460 [10]			5 - 8 [10]		
Kalbasi and Racz 1978	54-1420	8-137				
Singh, Personal commun.1978		51-195	8-31			10-34

[1] Most data are ranges of values (ppm); mean values are underlined. See Table 21 for information on samples.

[2] Mean values for soils producing forages deficient and non-deficient, respectively, in Co.

[3] Values for 'normal' soils. Above sulfide zones, values were higher (see Presant 1971). [4] Values for 'normal' soils. In mineralized sites Zn ranged up to 13000 ppm.

[5] Values for uncontaminated soils. [6] Mean value ± standard deviation. [7] The highest values were for surface samples near the smelter.

[8] Pb concentrations were higher (up to 64 ppm) near highways and in Winnipeg (up to 43 ppm).

[9] Contamination by pesticides resulted in high values; mean values were 25 ppm for Cu and 14 ppm for Pb.

[10] These 1 N HCl-extractable values were about half the total values for Pb and about two-thirds for Mn.

Table 23. Summary of data from the literature on total Cr, Se, As, Hg, and Cd in Canadian soils[1]

Reference	Cr	Se	As	Hg	Cd
Byers and Lakin 1939		0.1 - 6			
Walker et al.1941		<0.1 - 1			
Bishop and Chisholm 1961			3.7 - 7.9		
Presant and Tupper 1966			0 - 70 [2]		
Baraskso and Tarnocai 1970				50 - 400	
Presant 1971					<u>0.9</u>[3]
John et al.1972					<3 [4]
Fletcher et al.1973		0.5 - 15			
MacLean et al.1973				50	
Gracey and Stewart 1974				5 - 60	
Lévesque 1974a		<u>0.07 - 2.1</u>			
Lévesque 1974b		0.20 - 0.74			
MacLean 1974b				20 - 114	
Gupta and Winter 1975		0.09 - 0.60			
John et al.1975				10 - 310[5]	
Mills and Zwarich 1975	10 - 33				
Dudas and Pawluk 1976				12 - 146 [6]	
Frank et al.1976	10 - 46		1.1-16.7	10 - 1140	
MacLean 1976					0.3 - 0.65
Dudas and Pawluk 1977				<u>16 - 41</u>	
Singh, Personal commun.1978					0.2 - 1.0

[1] Most data are ranges of values (ppb for Hg and ppm for others); mean values are underlined. See Table 21 for information on samples.
[2] Values for 'normal' soils; above sulfide zone As reached a level of 3500 ppm.
[3] Nitric acid soluble Cd; Cd levels in contaminated soil near a battery smelter were up to 95 ppm.
[4] Above sulfide zones, Cd levels up to 23 ppm were found.
[5] Values for normal soils; near the mine Hg reached a level of 2320 ppb.
[6] The high Hg values were thought to be due to contamination from insecticides.

Table 24. Range of minor element levels (ppm) in fine fractions of till samples

Reference	Sample location	Samples analyzed	Mn	Zn	Cu	Pb	Co	Ni	Cr
Shilts 1973a	Lac Megantic area, southeastern Quebec	glacial till, >2 m depth <63 µm fraction 29 samples		53-89	17-75	17-27		20-110	60-260
		till with ultrabasic rock component						90-180	130-280
		normal Lennoxville till						20-39	56-90
Shilts 1973b	Thetford mines area of southeastern Quebec	till exposures, <63 µm fraction		60-90	18-50	15-25			
		ultrabasic train					21-64	70-950	50-260
		average range outside train					11-25	30-50	18-50
May and Dreimanis 1973	southern Ontario	till, 1-2 m depth, <37 µm fraction, 109 samples		62±14[1]	23 ± 6[1]			28 ± 8[1]	51 ± 15[1]
Ridler and Shilts 1974	Rankin Inlet, Ennadai Belt, N.W.T.	surface till, <2 µm		<120	<80				
Grant and Tucker 1976	Red Indian and Gander Lake areas, Nfld.	glacial till, <75 µm fraction		10-200	5-200	5-185		5-160	
		approximate mean normal till		60	40	20		20	
Shilts 1977	Keewatin, N.W.T.	clay (<2 µm) from till, 1000 'normal' samples		<100	<100			<80	
Di Labio and Shilts 1977	Rankin Inlet area, N.W.T.	till from mudboils, <2 µm fraction	440-1120	96-186	108-580	12-50	33-112	94-1840	108-351
Di Labio and Shilts 1978	Bylot Is.,N.W.T.	moraines from five glaciers, <4 pm fraction	500-1500	140-370	30-170			30-170	30-250
		debris in transport, <4 µm fraction	350-600	100-260	25-105	5-60	15-60	30-135	50-280
Podolak and Shilts 1978	southeastern Nova Scotia	glacial till, <2 µm fraction, normal range	1000-3000	120-170	40-60	20-40	20-40	33-69	

[1] Mean and standard deviation

Table 25. Linear regression equations relating levels of Mn, Cu, Pb, Co, Ni, Cr, Sr, and Se to other variables

Element	Grouping	Percentage of variance explained	Equation [1]	
Mn	A horizons	56	Mn	(ppm) = 123.4 + 207.9 Fe (%) + 53.8 organic C (%) - 9.6 clay (%)
Cu[2]	All samples	50	Cu	(ppm) = 7.1 + 0.30 clay (%) + 10.3 Mg (%)
	Appalachian region	63	Cu	(ppm) = 5.4 + 24.9 Mg (%)
	St. Lawrence Lowlands	66	Cu	(ppm) = 2.4 + 13.1 Mg (%) + 0.24 clay (%)
	Interior Plains	71	Cu	(ppm) = -6.6 + 0.74 clay (%) + 2.5 Al (%)
Pb	Interior Plains	50	Pb	(ppm) = 8.1 + 3.3 Fe (%) + 2.2 Mg (%)
Co	All samples	69	Co	(ppm) = -0.9 + 1.2 Fe (%) + 0.22 Ni (ppm) + 1.6 Al (%) + 0.007 Mn (ppm)
	A horizons	62	Co	(ppm) = 5.6 + 3.6 Fe (%) + 0.28 Ni (ppm)
	B horizons	67	Co	(ppm) = -1.9 + 0.28 Ni (ppm) + 0.01 Mn (ppm) + 1.8 Al (%)
	C horizons	63	Co	(ppm) = 11.7 + 3.6 Fe (%) + 0.1 clay (%)
	Appalachian region	80	Co	(ppm) = -0.2 + 0.35 Ni (ppm) + 1.6 Al (%) + 0.007 Mn (ppm)
	St. Lawrence Lowlands	56	Co	(ppm) = 7.7 + 0.08 clay (%) + 0.34 Ni (ppm) + 2.9 Fe (%)
	Interior Plains	70	Co	(ppm) = 1.4 Al (%) + 0.008 Mn (ppm) + 0.13 Ni (ppm) + 0.12 clay (%)
Ni[2]	A horizons	64	Ni	(ppm) = 2.2 + 12.7 Mg (%) + 0.006 Mn (ppm) + 0.1 clay (%)
	Appalachian region	86	Ni	(ppm) = 1.4 + 25.9 Mg (%) + 3.1 Fe (%) - 0.006 Mn (ppm)
	St. Lawrence Lowlands	57	Ni	(ppm) = 25.1 + 0.02 Mn (ppm) + 0.30 clay (%) - 2.8 Al (%) - 1.8 Fe (%)
	Interior Plains	62	Ni	(ppm) = -22.1 + 6.7 Al (%) + 4.7 Mg (%) + 0.006 Mn (ppm)
Cr[2]	All samples	56	Cr	(ppm) = 12.8 + 24.7 Mg (%) + 0.63 clay (%)
	A horizons	66	Cr	(ppm) = 6.1 + 43.7 Mg (%) + 0.66 clay (%)
	C horizons	84	Cr	(ppm) = -15.3 + 0.91 clay (%) + 5.3 Al (%)
	St. Lawrence Lowlands	74	Cr	(ppm) = 23.2 + 0.79 clay (%) + 12.1 Mg (%)
Sr[2]	All samples	78	Sr	(ppm) = -35.9 + 89.9 Ca (%) + 28.4 Al(%) - 2.5 clay (%)
	A horizons	88	Sr	(ppm) = -40.4 + 98.4 Ca (%) + 32.4 Al (%) - 2.8 clay (%)
	B horizons	84	Sr	(ppm) = 68.4 + 132 Ca (%)
	C horizons	69	Sr	(ppm) = -165.3 + 82.6 Ca (%) + 44.7 Al (%) - 2.9 clay (%)
	Appalachian region	67	Sr	(ppm) = -6.5 + 17.7 Al (%) + 21.5 Ca (%) - 11.8 Fe (%)
	St. Lawrence Lowlands	74	Sr	(ppm) = 23.1 + 75.4 Ca (%) + 2.5 clay (%) + 26.1 Al (%)
	Interior Plains	67	Sr	(ppm) = 72.6 + 21.8 Ca (%) - 3.0 clay (%) + 28.5 Al (%)
Se	B horizons	57	Se	(ppm) = 0.21 + 0.09 organic C (%) + 0.007 clay (%) - 0.06 Fe (%)
	Appalachian region	60	Se	(ppm) = -0.08 + 0.12 organic C (%) + 0.06 Fe (%)
	St. Lawrence Lowlands	56	Se	(ppm) = 0.10 + 0.05 organic C (%) + 0.002 clay (%)
	Interior Plains	70	Se	(ppm) = -0.08 + 0.11 organic C (%) + 0.01 clay (%)

[1] Only those independent variables are included that account for more than 2% of the residual variability.

[2] Samples having high carbonate contents (Ca above 6% or Mg above 2.5%) are excluded.

Table 26. Correlations of levels of elements in A to B, A to C, and B to C horizons

Element	Horizons compared	Data set							
		All		Appalachian		St. Lawrence		Interior	
		r[1]	no.	r[1]	no.	r[1]	no.	r[1]	no.
Mn	A/B	.38**	61	.70**	12	.21	37	.24	6
	A/C	.14	61	.44	11	.10	35	.46	8
	B/C	.40**	66	.69**	11	-.09	37	.62*	10
Zn	A/B	.70**	61	.79**	11	.73**	36	.69*	8
	A/C	.39**	60	.76**	10	.39*	35	.23	8
	B/C	.53**	64	.80**	10	.52**	36	.26	10
Cu	A/B	.58**	63	.36	12	.32*	37	.53	8
	A/C	.51**	62	.19	11	.06	35	.66*	9
	B/C	.60**	68	.59'*	11	.26	37	.81**	12
Pb	A/B	.58**	62	.62*	11	.89**	37	.81**	8
	A/C	.00	61	.36	10	.31	35	.54	9
	B/C	.57**	67	.47	10	.56**	37	.43	12
Co	A/B	.69**	36	.41	12	.57	10	.64*	8
	A/C	.60**	37	.25	11	.29	10	.70*	9
	B/C	.84**	42	.84**	11	.38	10	.96**	12
Ni	A/B	.75**	63	.02	12	.81**	37	.66*	8
	A/C	.41**	62	-.04	11	.53**	35	.86**	9
	B/C	.73**	68	.83**	11	.75**	37	.86**	12
Cr	A/B	.81**	62	.86**	12	.77*	36	.88**	8
	A/C	.66**	61	.51	11	.59**	34	.76**	9
	B/C	.68**	66	.61*	11	.64**	35	.64*	12
Sr	A/B	.93**	36	.80**	12	.98**	11	.21	8
	A/C	.85**	37	.91**	11	.86**	10	.03	9
	B/C	.88*	42	.90**	11	.93**	12	.56*	12
Se	A/B	.05	37	.34	11	.36	13	.21	9
	A/C	.74**	39	.02	10	.28	13	.90**	10
	B/C	.57**	45	.54	10	.37	13	.91**	14
Hg	A/B	.78**	49	.92**	6	-.21	31	.91**	6
	A/C	.68**	53	.92**	8	.29	31	.90**	7
	B/C	.69**	59	.90**	7	-.06	33	.47	11
As	A/B					.67**	21		
	A/C					.37	24		
	B/C					.60**	19		

[1] In cases of more than one A, B, or C horizon value at a site, the data for each horizon are averaged for calculation of **r** values. If the data were norma11y distributed, those values indicated by * would be significantly different from zero at the 5% level, and those values indicated by ** at the 1% level.

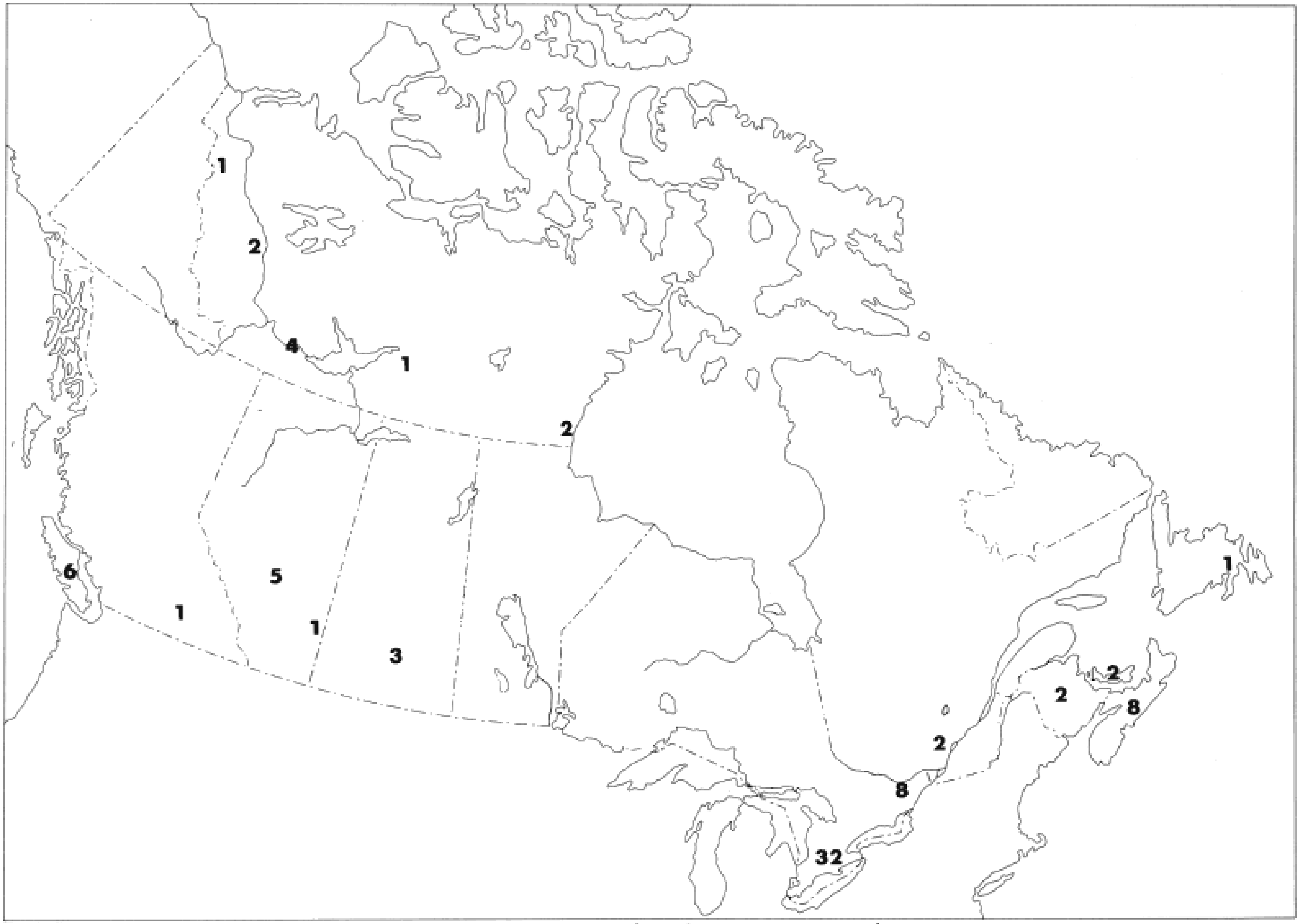

Fig.1 Location of sampling sites. The numbers indicate the number of sites in the general area.

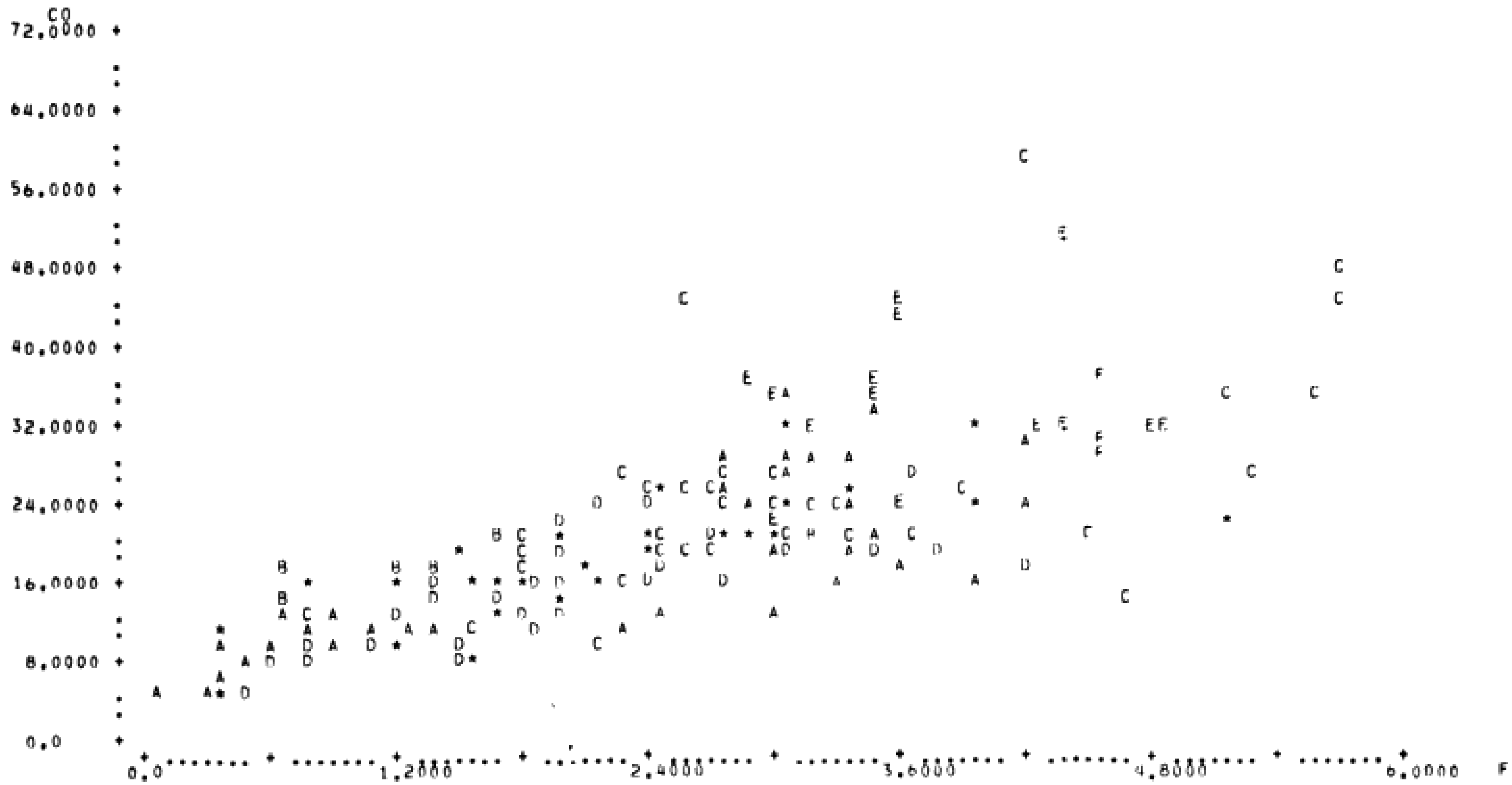

Fig. 2. Plot of Co (ppm) against Fe (%). Samples having more than 6% Fe are excluded. Regions are indicated as fo11ows: A, Appalachian; B, Canadian Shield; C, St. Lawrence Lowlands; D, Interior Plains; E, Cordi11eras. The stars indicate two or more coincident points.

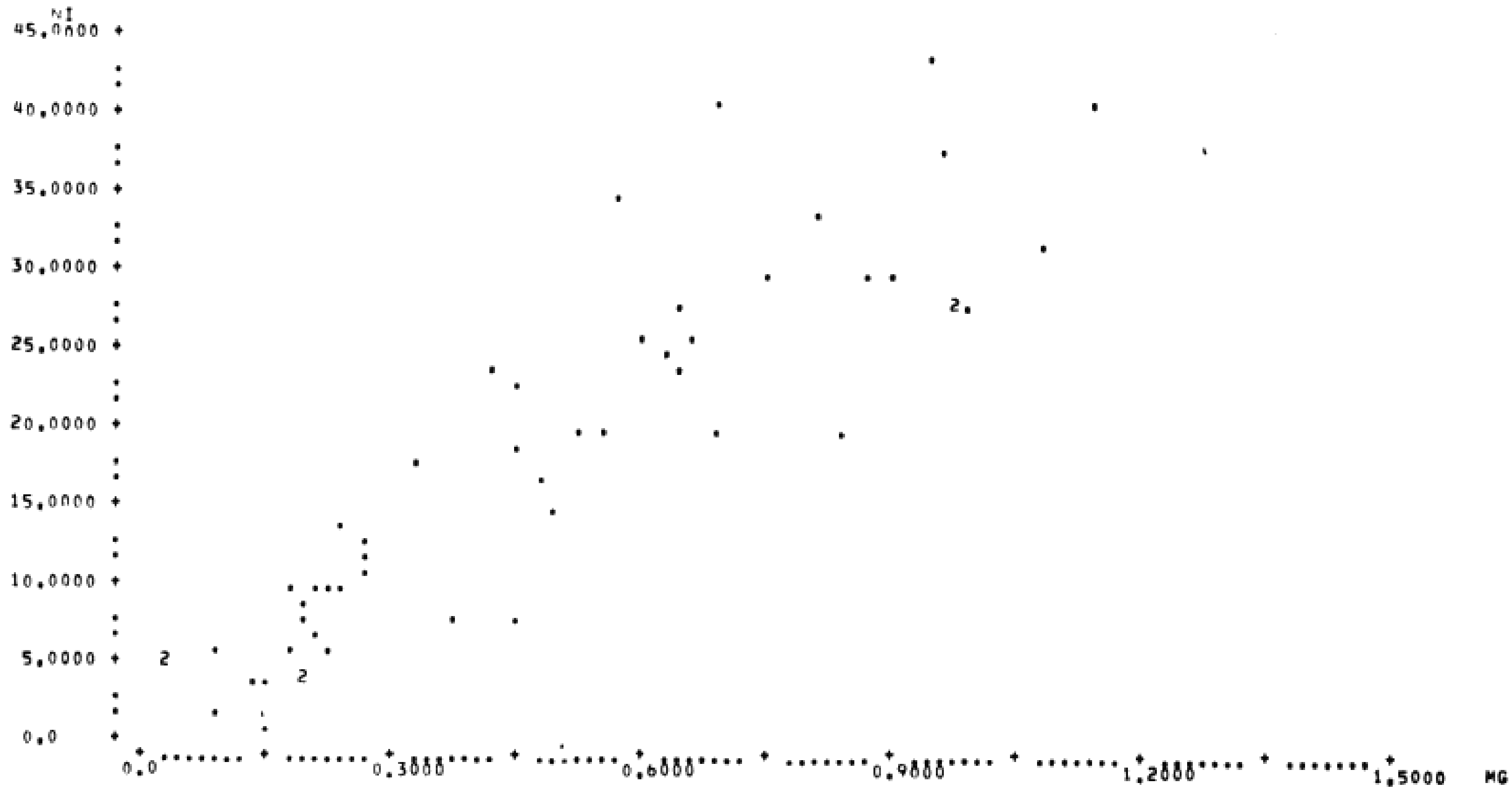

Fig. 3. Plot of Ni (ppm) against Mg (%) for samples from the Appalachian region. The '2's indicate two coincident points.

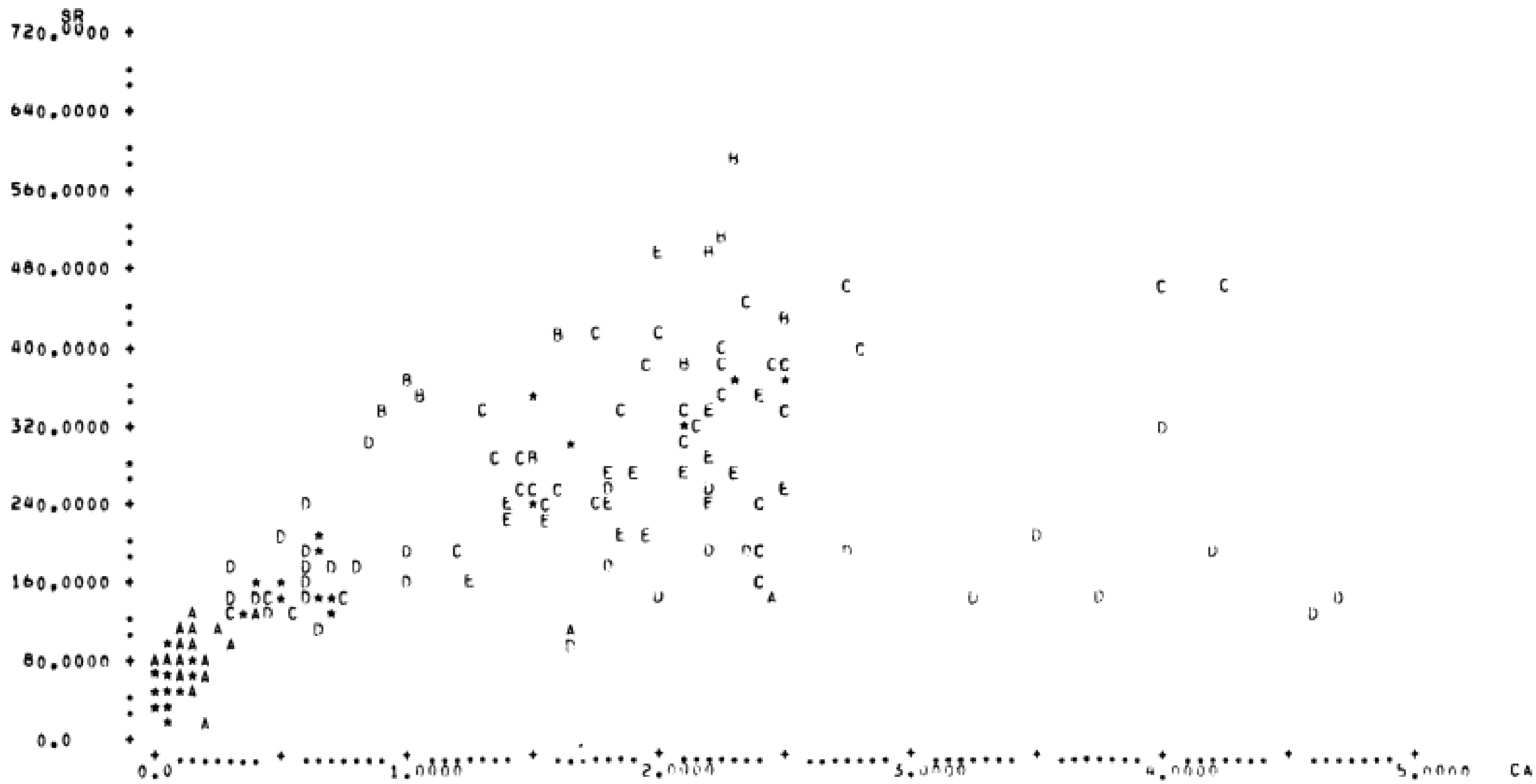

Fig. 4. Plot of Sr (ppm) against Ca (%). Samples having more than 5% Ca are excluded. Regions are indicated as fo11ows: A, Appalachian; B, Canadian Shield; C, St. Lawrence Lowlands; D, Interior Plains; E, Cordi11eran. The stars indicate two or more coincident points.