The North American Soil Geochemical Landscapes Project — A Canadian Perspective

INTRODUCTION

"Documenting and understanding natural variability is a vexing topic in almost every environmental problem: How do we recognize and understand changes in natural systems if we don't understand the range of baseline levels?"

M.L. Zoback, GSA Today, December 2001

Soil geochemical properties are critical to the health of the environment and to the health of virtually all organisms, including humans, existing near and on the Earth's surface. Chemical elements originating in earth materials move through the biogeochemical cycle and enter the food we eat, the water we drink and the air we breathe. These elements may be essential to our health and well-being, or they may be toxic, even in trace amounts. The nature and elemental content of soils vary both in time and in space across North America. The information obtained by chemically analyzing soils and mapping the abundance and spatial distribution of elements in soils is needed to better assess risk, guide decision-making and foster more integrated regulation by human health and environmental protection agencies.

The natural concentrations of elements differ among soil constituents and vary markedly between geologically distinct terranes. At present there is no common understanding of the amount and origin of variation in soil geochemistry nor is a consistent methodology used for its determination (Jennings & Petersen 2006; Garrett *et al*. 2008a). In addition, outside the earth sciences world there is little awareness of the enormous amount of natural variability and the value of this information for evaluating risk potential and defining the limits above or below which remedial action is necessary. Already there are cases where natural concentrations are consistently higher than the action limits for soils covering large areas.

The requirement for soil geochemical data to assess spatial variability was being met in the United States by a low-density (1 sample per 6,000 km^2) soil geochemical survey conducted during the 1960s and 1970s (Shacklette & Boerngen 1984) but the utility of these data is hampered by detection limits that no longer meet today's standards and a lack of data for some elements of environmental interest. In Canada there have been 99 soil and 274 till sampling surveys undertaken by the Geological Survey of Canada (GSC) and its provincial counterparts but national coverage is incomplete and the methodology is variable (Fig. 1; Spirito *et al.* 2006). There is no national-scale set of soil geochemical data for Mexico. Hence, there is a critical need for data for a wide spectrum of elements and compounds in mineral- and organic-based soils based on up-to-date field and laboratory techniques.

The North American Soil Geochemical Landscapes Project — a tri-national initiative between United States, Canada and Mexico — was established to meet the need

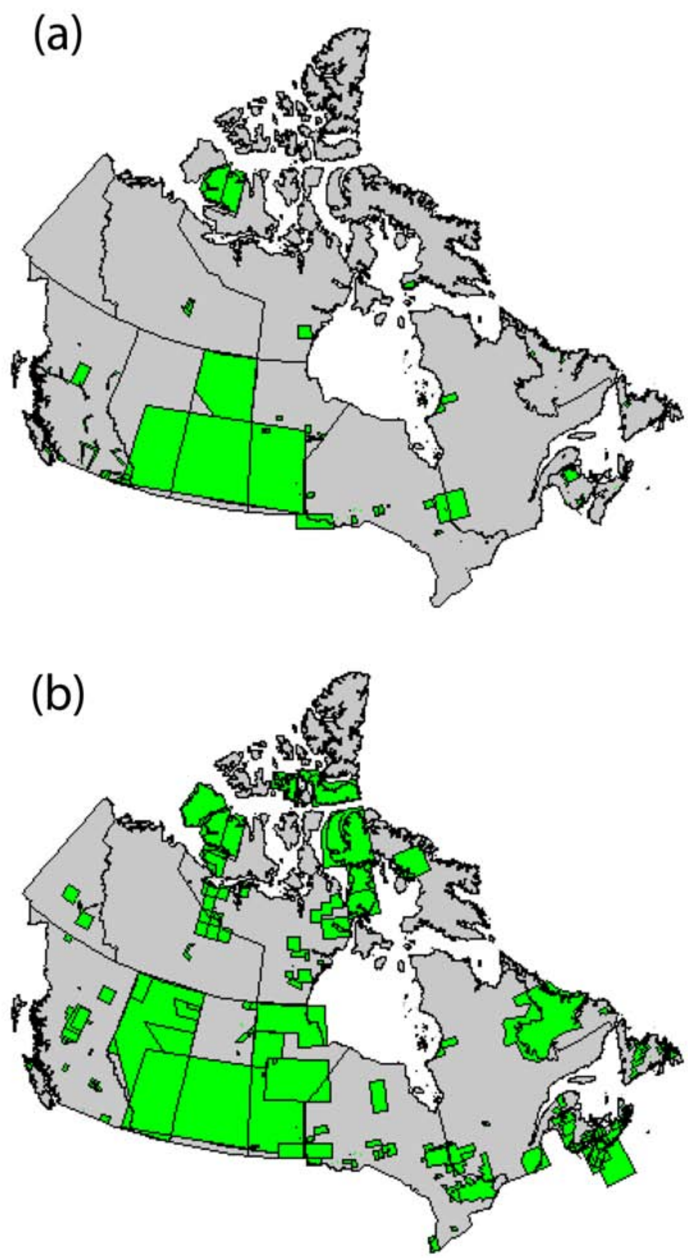

Figure 1. *Map of Canada showing areas (green polygons) covered by a) soil and b) till sampling surveys up to 2007.*

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for soil geochemical data by providing a consistent national- and continental-scale framework and database. For North America, the Tri-national project is the first multi-national multi-agency collaboration of its kind starting with common focus, understanding and protocols. Coordinated continental-scale undertakings have been started elsewhere in the world. The Forum of European Geological Surveys (FOREGS) Geochemical Baseline Programme was set up to provide high quality environmental geochemical baseline data for soils stream water, stream sediment, floodplain sediment, and humus for Europe (Salminen *et al.* 2005; De Vos *et al.* 2006). Sampling of arable and grazing land at a scale of 1 sample/ 2500 km^2 was undertaken in 2008 by 34 geological surveys in Europe (EuroGeoSurveys Geochemistry Working Group 2008).

A Canada-United States pilot study consisting of two sampling transects (E-W and N-S) was carried out in 2004 to test protocols and data applications (Fig. 2). On the basis of the methodology used for the pilot study and its

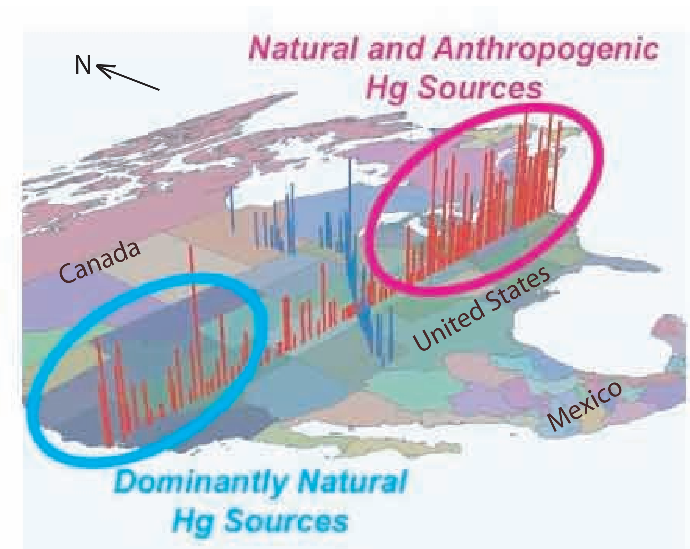

Figure 2. *Distribution of Hg in the <2 mm fraction of soil samples collected along two transects through United States and Canada. Results of this pilot study showed the following: 1) significant, systematic regional variations in soil geochemistry and microbiology; (2) regional variability that relates to natural soil-forming factors (e.g. geology, rainfall, and temperature); and (3) regional differences that signal anthropogenic sources (Smith & Reimann 2008). Mercury levels in the western United States reflect predominantly natural sources whereas those in eastern United States reflect more strongly inputs from anthropogenic as well as natural sources.*

results, a plan for the Tri-national project was formulated. At the same time consultations were solicited with the user community to ensure that the data produced would be useful. From the project outset care has been taken to develop the necessary mechanisms to have these data recognized and used by government policy makers and regulators dealing with health and environmental protection.

Briefly described, the Project is designed to show the following: (1) systematic regional variations in chemistry at a 40 km sample spacing; (2) regional natural-occurring differences, thereby defining natural regional background levels and controls; (3) regional variation from anthropogenic sources, thereby identifying human impacts on the soil landscape; and (4) a new understanding of the links between soil geochemical factors and environmental and human health. The Project will provide a continental-scale framework for generating soil geochemical and relevant biological and organic compound data, a continent-wide protocols manual for field and analytical methods and user-friendly data that are available and useful for a wide range of applications and disciplines. The Project is *not* designed to provide data for site-specific risk assessments, identify local geochemical hot spots related to natural or human factors, or directly support epidemiological research.

PROJECT DESIGN

Sampling Sites

The Project sampling is based on a spatially balanced array known as a generalized random tessellation stratified (GRTS) sampling design (Garrett 1983; Stevens & Olsen 2004) chosen for its added flexibility. With this design it is possible to locally increase the sampling density in areas of special concerns within the context of the continental sampling framework. A total of 13 212 sites representing an approximate density of 1 site per 1600 km^2 (Fig. 3, *see p.14*) have been selected with 6183 sites in Canada, 5813 in the United States, and 1216 in Mexico.

The total land surface area covered by the Tri-national survey is nearly 40 times the size of France. The collection of soil samples to generate the geochemical database is only possible through the establishment of partnerships. These include federal, provincial and state geological surveys and organizations related to agriculture and forestry. Sampling and data generation will continue for an estimated decade. Use of consistent protocols ensures that the resultant data sets will stitch together to produce a final seamless geochemical database.

Core soil analyses

The Tri-national survey is developing a set of protocols that will be the basis for field sampling and chemical

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Figure 3. Distribution of sample sites (black dots) over North America. Ecozones for North America are shown in colour (after Commission for Environmental Co-operation, 1997). Legend explained on web site listed in reference.

analysis in each of the three countries. Developing a set of protocols to ensure a consistent data set for North America is not without its challenges, some of which are noted as follows: (1) the enormous size of the continent; (2) three international and 95 state and provincial boundaries; (3) the complexity of the operation in that sampling is horizon- and depth-based and involves numerous types of analyses, all requiring field, laboratory, quality assurance, archiving, and data handling protocols; (4) the many types of mineral and organic soils and field situations (e.g. peatland, permafrost, desert, mountain, urban, and agriculture areas) that require diverse equipment and procedures; and (5) the need to anticipate and accommodate possible future requirements. From the outset of the Project, attention has been paid to developing and documenting the protocols necessary to provide a data set that serves as a common national and international standard.

At each site in areas of mineral soils, samples are collected from a depth of 0-5 cm (referred to as the “public health” layer) and from the A- and C- soil horizons (Fig. 4). The <2 mm fraction (an agricultural and environmental standard) is analyzed for a suite of more than 40 major, minor and trace elements, including most elements of environmental concern, following a near-total (4-acid) digestion. A separate sample from the 0-5-cm depth interval from each site will be analyzed for the presence of *Bacillus anthracis* (anthrax). Splits of each soil sample are archived and will be made available for future investigations.

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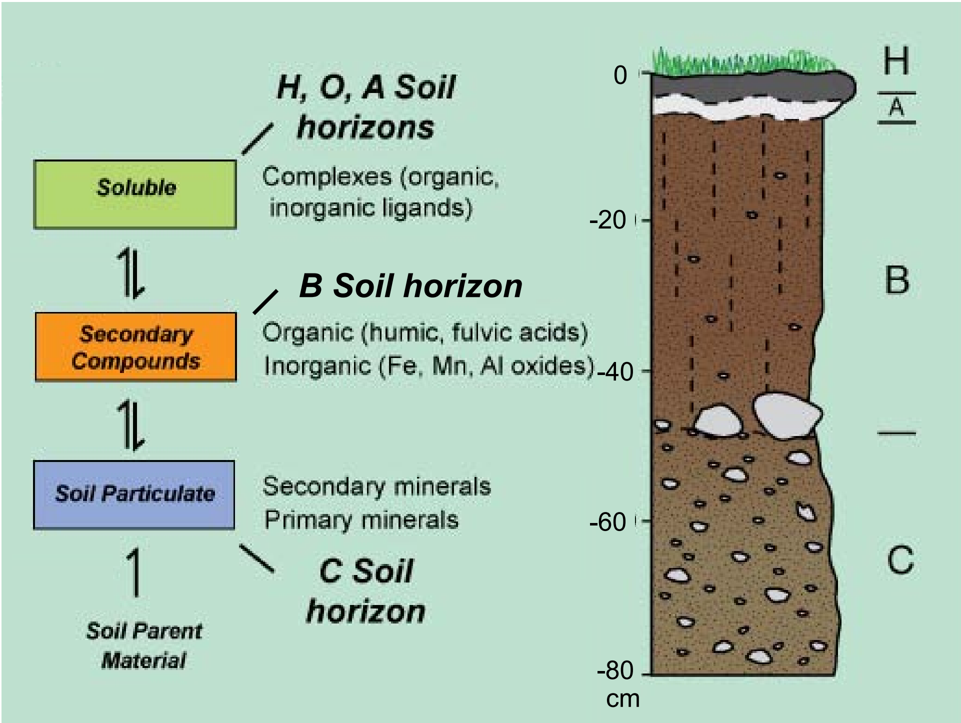

Figure 4. Schematic diagram of a profile showing horizons in a podzolic soil. Samples for the Canadian project are collected from the 0-5 cm (public health) layer, and from the A, B, and C soil horizons. Diagram shows some physical and chemical characteristics of individual soil horizons.

Additional soil analyses

Each country will carry out certain other procedures and analyses that are particular to its environmental and/or policy needs. Table 1 outlines the scheme for sampling and analyses for the Canadian project. In Canada, the extra procedures

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Table 1. Sample collection and analyses for North American Soil Geochemical Landscape Project — Canadian aspect.

Sample Horizons/Depth for Analysis
0-5 cm "public health" layer and A-, B -, C-horizons

Sample Preparation
- Air drying *
- Splitting and archiving *
- Preparing specific size fractions for analysis *
- Ball-milling
- Storing and archiving sample splits and unused sample materials *

Size Fractions for Analysis
- <2.00 mm fraction for all analyses (Note: <2.00 mm splits used for 4-acid and carbon analyses are ball-milled to <100 µm).
- <0.063 mm for selected analyses (carbon, 4-acid, and US-EPA 3050B (aqua regia variant))

"Core" Determinations On Tri-National Soil Samples
- ICP-MS/ES analysis (42 elements) after US-EPA 3050B (aqua regia variant) digestion (0-5 cm , A, B, C)
- ICP-MS/ES analysis (42 elements) after 4-acid near total digestion (0-5 cm , A, B, C) *
- ICP-MS/ES analysis after water leach (0-5 cm and C)
- Carbon – organic and inorganic content (0-5 cm , A, B, C) *
- Loss-on-ignition (0-5 cm , A, B, C)*
- Moisture content (0-5 cm, A, B, C) *
- Bulk density (0-5 cm , A, B, C) *
- Munsell colour (0-5 cm , A, B, C) *
- Particle size analysis *
- Electrical conductivity (0-5 cm , A, B, C) *
- Cation exchange capacity (A, C)

"Add-on" determinations on splits from core tri-national samples
- Selected minor elements (N, P) (0-5 cm, A, B,C)
- Biomethods for assessing soil toxicity (A and C)
- X-ray diffraction (A, B, C)
- Radiometric tests in laboratory (0-5 cm, A, B,C)
- Gastric leach (A and C)

"Add-on" determinations on additional samples or other data collected at the tri-national sites
- Soil gas radon measurements
- Radiometric tests (including measurements of U, Th, K)
- Anthrax (whole sample size fraction)
- Ecotoxicological studies and analysis for selected organic compounds on 0-30 cm sampling interval
- Collaborative sample and data collection for National Forest Inventory
- Perchlorates (A and C)

"Add-on" determinations on additional samples or other data collected outside the tri-national sites
- Stream waters and sediments analysis — sites selected within the same drainage basin and downstream from the previously sampled tri-national soil sample sites. The drainage basins have an areal extent of <100 km2, (mostly first or small second order streams).

Note: Procedures denoted with * are documented in Geological Survey of Canada Open File 4823 (available as free download at http://geopub.nrcan.gc.ca/moreinfo_e.php?id=216141). Remaining procedures are to be released as North American Soil Geochemical Landscape Project Field and Laboratory Protocols Manual (digital document, in preparation).

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include the following: collection and analysis of B-horizon samples; analyses of the <63 μm fractions of A-, B-, and C-horizon samples using total (4-acid) and partial (USA-EPA 3050B) digestions; and analysis of 0-5 cm and C-horizon samples after a water leach (Hall 2008). Another major addition to the Canadian project is the in-situ measurement of soil gas radon and natural radioactivity that are discussed later in this paper (Fig. 5).

***Figure 5**. Brad Harvey (left) and Ken Ford (right), Geological Survey of Canada, making soil gas radon measurements at a Tri-national project site near Pembroke, Ontario. (Photo: Inez Kettles, GSC)*

Use of the <63 μm (silt-plus clay-sized) fraction and partial leaches allow for a more detailed understanding of bioaccessibility. In addition, this fraction of soil and till samples is commonly analyzed in Canada for mineral exploration and geological mapping purposes and there is a large body of existing geochemical data for this size fraction for comparison. For example, the New Brunswick Ministry of Natural Resources has released geochemical data for the <63 μm fraction of more than 8150 mostly till samples. The GSC has published geochemical data for the <63 μm fraction of more than 16,800 samples (S.W. Adcock, Geological Survey of Canada, pers. comm., 2008, http://gdr.nrcan.gc.ca/geochem/index_e.php).

In United States, samples of each of the three depths/horizons at 10% of the sites are being collected for additional microbial characterization. Physiological-based extraction techniques, such as digestion with simulated human gastric and lung fluids, are conducted on a subset of the 0-5cm soils. In Mexico bioaccessibility of selected potentially toxic elements are being measured in 0-5 cm interval and A-horizon samples, as is the mobility of a broad suite of elements in C-horizon and some B-horizon soil samples.

PROJECT ACTIVITIES

Sample collection

In 2007, sampling in Canada was undertaken in Nova Scotia and New Brunswick by the provincial geological surveys and some sites were accessed in the northern Canada, through shared logistics with a Yukon territorial government program (Fig. 6, 7). In the United States,

***Figure 6**. Collection of Tri-national soil horizon samples in the boreal forest of Nova Scotia by Terry Goodwin, Nova Scotia Department of Natural Resources (Photo: Rita Mroz, Environment Canada).*

sampling covered the New Hampshire, Vermont, Massachusetts, Maine, Rhode Island, and Connecticut, New York, Nebraska, and a transect across Alaska. Samples were collected along two transects in Mexico. One transect extended from central Mexico south to the coast of Guerrero state and the other from central Mexico westward to the coast of the state of Sinaloa and then northward to Ciudad Juarez, Chihuahua. The second transect is the southern continuation of the north-south continental transect from the Project pilot study undertaken in the United States and Canada in 2004 (Fig. 2).

Sampling continued in 2008 along a trans-continental swath in Canada (Fig. 8) and in the United States including the states of Utah, Colorado, Kansas, Nevada, Wyoming, Missouri, Arkansas, Louisiana, Mississippi, West Virginia, Delaware, Maryland, New Jersey, Virginia, Pennsylvania, North Dakota, South Dakota, and Minnesota. In Mexico sampling covered the northernmost part of Sonora, Chihuahua, Coahuila and some areas of Baja California (Fig 9).

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Figure 7. *Scott Smith (Agriculture and Agri-Foods Canada) and Toon Pronk (New Brunswick Department of Natural Resources) digging a soil pit in the tundra of northern Yukon. (Photo: Martin McCurdy, GSC)*

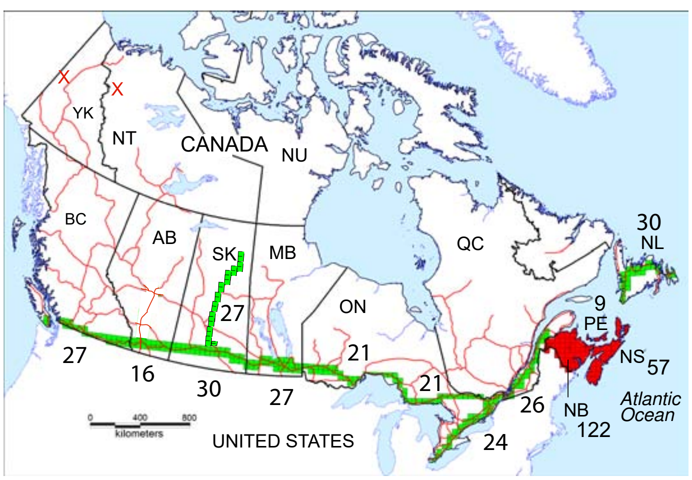

Figure 8. *Trans-Canada soil sampling swath collected in 2008. Sampling was completed in 2007 in eastern Canada (shown in red) and at some sites in the northern Yukon and northwestern Northwest Territories (red X). Numbers indicate the sample count expected to be collected along each segment of the transect in 2008. (Note: BC – British Columbia, AL – Alberta, SK – Saskatchewan, MB – Manitoba, ON - Ontario, QC – Quebec, NB – New Brunswick, NS – Nova Scotia, PE – Prince Edward Island, NL – Newfoundland, NU – Nunavut, NW – Northwest Territories, YK – Yukon).*

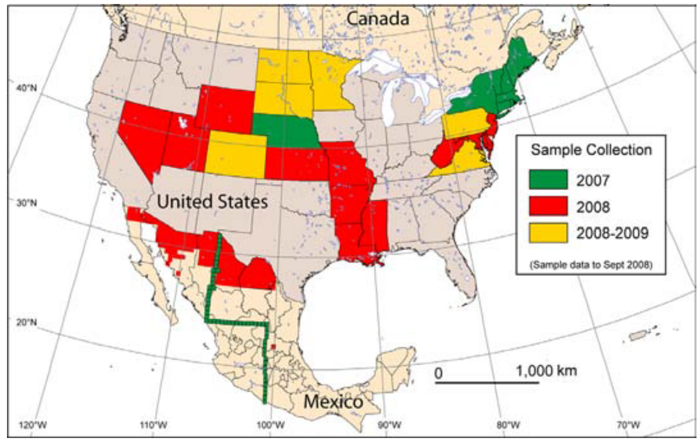

Figure 9. *Map shows completed and ongoing sampling surveys (2007-2009) in United States and Mexico.*

Protocol development

A major part of the Tri-national Project is the development and documentation of protocols for soil sample collection and analysis to ensure consistent geochemical data. The protocol manual being constructed has sufficient background information and detail to provide guidance to individuals from the user community who are seeking advice on procedures. To determine "optimal" methodology for the purpose of establishing a Tri-national protocol it is sometimes necessary to test a variety of analytical methods. One such case was the partial extraction experiment that is described below.

The study of aqua regia and its variants

Soil geochemical data are needed to satisfy the requirements for environmental assessments and regulations pertaining to land use and development and contaminated site remediation. The procedures for analyzing soil samples were decided on by various government departments in different provinces and states, and, as a result, a variety of partial extraction methods are used by environmental agencies in North America to determine element concentrations. In many cases, few details are provided on the requirement for formulation in soil quality guideline documents and websites. Before deciding on a protocol for the Tri-national survey, GSC initiated a research project to test and compare the element concentrations obtained using a variety of partial extraction formulations (Garrett *et al.* 2008b). The following five digestion protocols were tested in soil materials: Aqua regia, Lefort (reverse aqua regia), 1:1 HCl-HNO_3, 1:1:1 HCl-HNO_3-H_2O, and the HNO_3-H_2O_2 variant of US-EPA 3050B. Eight control reference materials classified as certified or recommended were analyzed, with appropriate randomization, in triplicate by the five methods. Two each of the reference materials were collected from soil, till, and stream and lake sediments. Analyses of Variance were undertaken to determine which protocols yielded similar data. The results are described below.

Data applications developed through partnerships

Researchers with the Tri-national Project at GSC

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have established partnerships with groups in other federal agencies to develop or test applications of soil geochemical data to health risk issues, mostly related to toxic metal exposure.

Studies of natural radioactivity linked to the Tri-national project

Radon is a naturally-occurring hazard and the world's second leading cause of lung cancer (World Health Organization 1978). In 2007 Health Canada lowered the threshold limit of exposure in Canadian homes and buildings above which there is a recommended need for remediation. This change has led to research on new approaches to achieve compliance with the guideline.

In 2007 GSC entered into a partnership with Health Canada - Radiation Protection Bureau to make in-situ measurements of soil gas radon radiometric, estimates of soil K, U, and Th concentrations, and, in some areas, to carry out new airborne geophysical surveys (Fig. 5). These new data will be used with Tri-national and other geological data to produce a map of radon prone areas in Canada to guide risk management. The map will be used to delineate those areas where there is increased health risk from radon and, hence, require follow-up testing.

Studies related to soil toxicity

One project at Environment Canada - Biological Methods Division (BMD) involves evaluating the use of boreal forest plant and soil invertebrate species for the development standardized soil toxicity test methods to assess soil pollutants. Researchers from BMD are teaming up with GSC scientists to select reference sites across Canada that reflect the scope of natural variability in geologic terranes. A second collaboration involves Environment Canada-Atlantic (EC-A) scientists who are developing a background soil chemistry/toxicology database for the Atlantic region. At Tri-national sites additional samples from the 0-30 cm depth interval are collected according to the EC-A protocol in order to compare and evaluate the resultant data.

Consultations with scientists from the Contaminated Sites Division (CSD) of Health Canada and Natural Resources Canada- National Forest Inventory (NFI) are also part of the project. The CSD plays a key role in both the development of soil quality guidelines and as expert support on issues related to contaminated sites on federal land. Soil data from the Tri-national Project will provide information on natural background concentrations of soil elements.

RESULTS

Soil geochemistry in eastern Canada

Surveys in Canada started in 2007 and to date only partial results are available for eastern Canada. The distribution of As and Cr in the <63 μm fraction (silt plus clay-sized material) of the C-horizon soil samples are shown in Figures 10 and 11. Arsenic levels range from a low of 2 ppm to a

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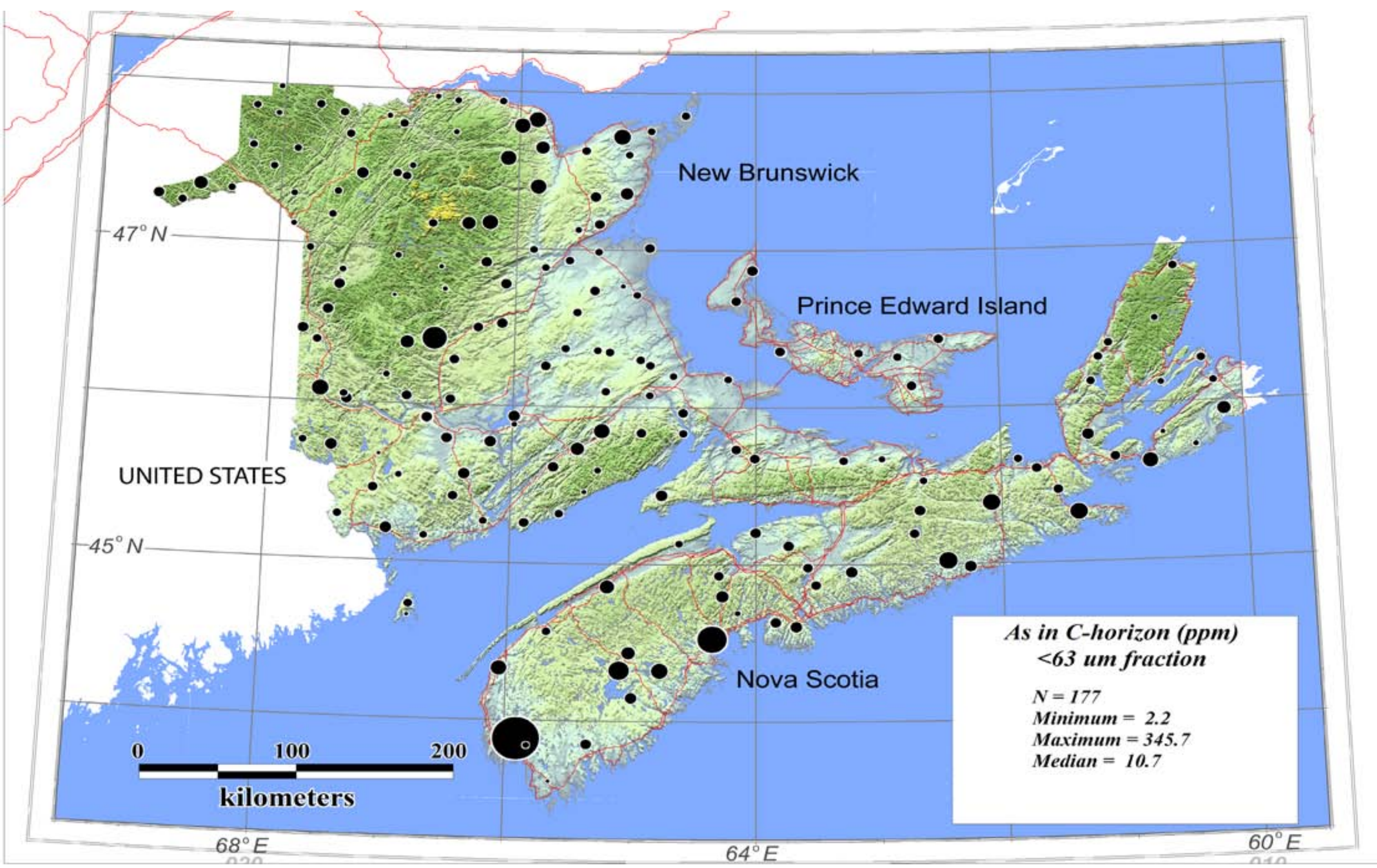

__Figure 10.__ Distribution of As in the <63 μm fraction of C-horizon soil samples in eastern Canada. Samples were analyzed using ICP-MS after a near total (4-acid) digestion.

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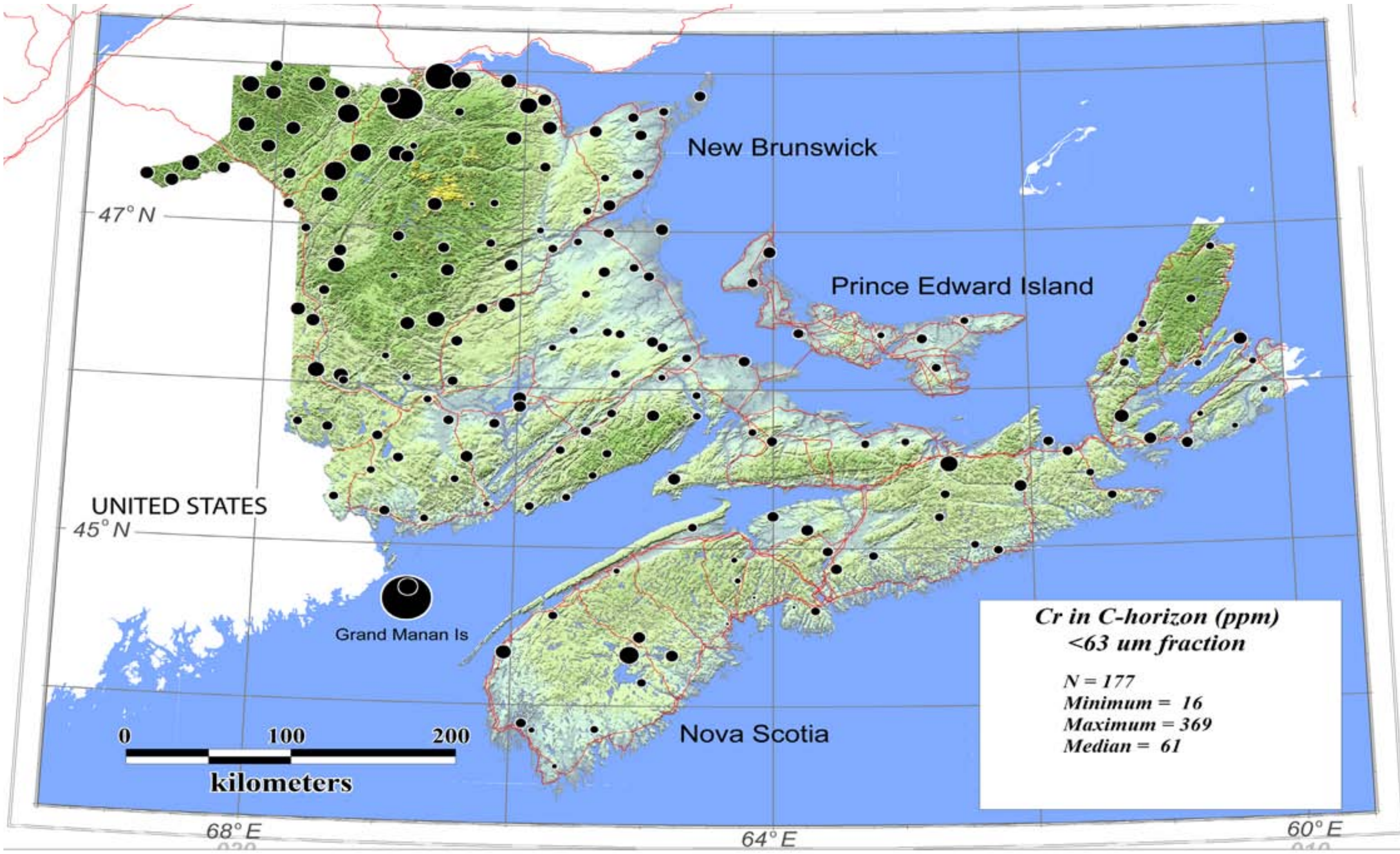

Figure 11. Distribution of Cr in the <63 µm fraction of C-horizon soil samples in eastern Canada. Samples were analyzed using ICP-MS after a near total (4-acid) digestion.

high of 346 ppm (median 10.7 ppm) and Cr concentrations from a low of 16 to a high of 369 ppm (median 41 ppm). Box and whisker plots and a table showing summary statistics indicate the range of concentrations of these 2 elements as well as others of environmental interest in the <63 µm fraction of the C-horizon samples (Fig. 12, Table 2). Box and whisker plots, also known as Tukey box plots, will be used routinely because they effectively display the range of concentrations levels plus the median level for individual elements (Grunsky & Garrett 2008).

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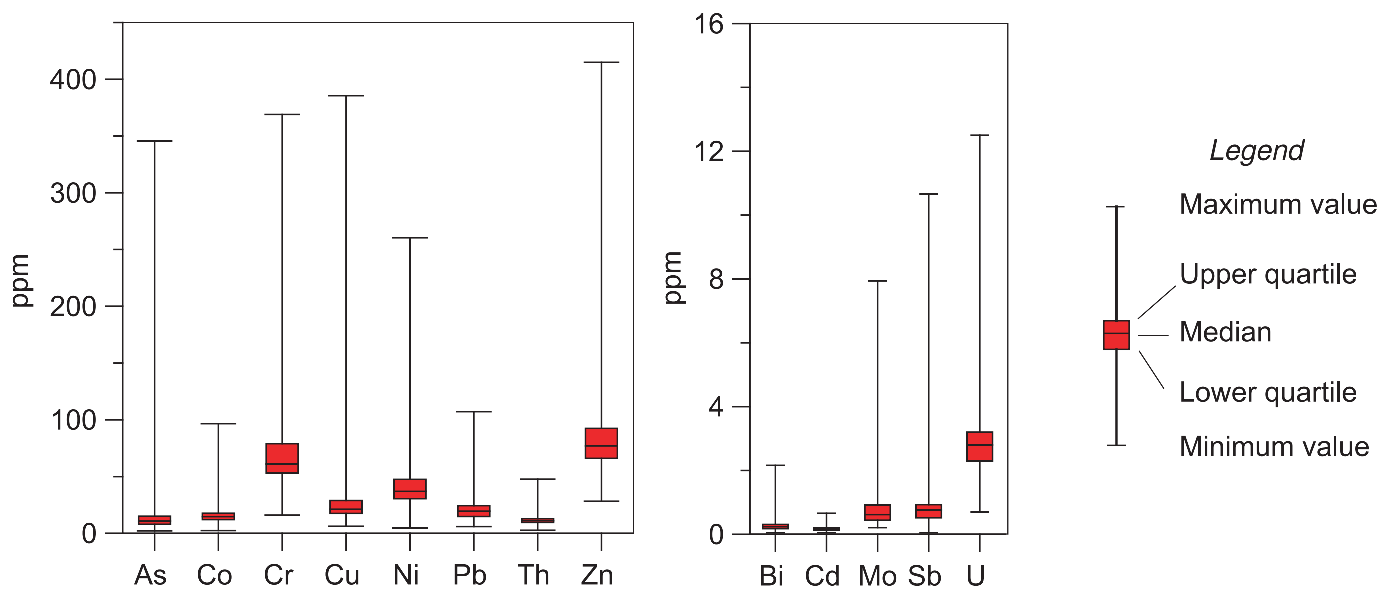

Figure 12. Box and whisker plots show the range of concentrations of selected elements in the <63 µm fraction of the C-horizon samples from New Brunswick, Nova Scotia, and Prince Edward Island.

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		As	Bi	Co	Cr	Cd	Cu	Mo	Ni	Pb	Sb	Th	U	Zn
N	Valid	177	177	177	177	177	177	177	177	177	177	177	177	177
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Mean		14.9	0.29	15.3	70	0.18	27	0.86	40.8	21.67	0.86	12.0	3.0	84.1
Median		10.7	0.24	14.7	61	0.17	21	0.62	36.9	19.46	0.76	11.1	2.8	77.0
Mode		10.0	0.24	14.1	58	0.16	14	0.41	33.7	10.50	0.81	11.5	2.7	66.2
Std. Deviation		26.7	0.24	7.8	35	0.09	30	0.92	23.3	12.11	0.98	5.1	1.4	37.5
Variance		713.9	0.06	60.9	1198	0.01	917	0.85	544.8	146.77	0.95	25.5	1.9	1406.3
Minimum		2.2	0.05	2.4	16	0.05	6	0.21	4.6	5.96	0.05	2.6	0.7	28.2
Maximum		345.7	2.16	96.6	369	0.66	386	7.94	260.4	107.20	10.66	47.6	12.5	414.9
Percentiles	5th	3.6	0.12	7.4	37	0.07	13	0.27	15.6	10.50	0.25	7.3	1.9	46.9
	10th	5.5	0.14	9.6	45	0.09	15	0.34	22.7	12.11	0.36	8.3	2.0	52.8
	25th	7.9	0.18	12.1	53	0.13	17	0.44	30.4	14.70	0.52	9.5	2.3	66.0
	50th	10.7	0.24	14.7	61	0.17	21	0.62	36.9	19.46	0.76	11.1	2.8	77.0
	75th	15.0	0.31	17.6	79	0.21	29	0.92	46.7	24.36	0.93	12.9	3.2	92.1
	90th	26.2	0.44	20.1	103	0.29	39	1.38	61.7	31.57	1.14	16.3	4.1	116.3
	95th	30.4	0.57	23.5	116	0.37	54	2.70	72.1	41.90	1.64	20.8	5.2	139.9
	98th	49.6	1.09	30.6	157	0.49	85	4.33	97.5	58.40	2.56	33.3	8.5	190.5

Table 2. Summary statistics for selected elements in the <63 µm fraction of C-horizon samples from eastern Canada (n=177). Element data were obtained using ICP-MS after a 4-acid digestion.

The proportional symbol maps and box and whisker plots (Figs 10-12) for soils show the wide range of concentrations for several elements in C-horizon samples from eastern Canada. The majority of sites with high levels of As in Nova Scotia overlie Cambro-Ordovician Meguma Terrane, a thick succession of siliciclastics (T. Goodwin, Nova Scotia Department of Natural Resources, pers. comm., 2008; Keppie 2000). Enrichment of Au and As characterize the gold deposits of the Meguma Terrane (Kontak & Smith 1993) and these elements are commonly geochemically enriched in soils and till down-ice from known gold mineralization (Coker *et al.* 1988).

In northeastern New Brunswick, sample sites with highest As concentrations are located in areas that host base metal occurrences containing arsenopyrite (M. Parkhill, New Brunswick Department of Natural Resources, pers. comm. 2008; New Brunswick Department of Natural Resources 2000). In northwestern New Brunswick, there are high levels of Cr where Ni and other base metal enrichment have been detected in lake sediments, till and bedrock (Parkhill 2005). North-central New Brunswick soils contain elevated Cr where they overlie mafic volcanic rocks that host known occurrences of base metals (New Brunswick Department of Natural Resources Mineral Occurrence Database, 2008). The highest Cr concentration measured in soils in New Brunswick is on Grand Manan Island and reflects the underlying mafic volcanic bedrock where base metal occurrences are known (A. Seaman, New Brunswick Department of Natural Resources, pers. comm. 2008).

Test Research on partial extractions (aqua regia variants)

Results showed that HNO_3-H_2O_2 variant of US-EPA 3050B generally extracts significantly less metals and metalloids, with the exception of Hf, Nb, Th and Zr, than aqua regia and similar digestions (Garrett *et al*. 2008b). For the remaining protocols, aqua regia and three HCl-HNO_3 variants, the results are similar.

At present there are large amounts of aqua regia and US-EPA aqua regia-variant digestion data for soils published in North America and internationally. Also, the aqua regia digestion yields very consistent results for most elements. As a result of testing, the Tri-national project will use the US-EPA 3050B aqua regia-variant digestion. This procedure used a 4:1 HCl-HNO_3 mix rather than the 3:1 of "classical" aqua regia. The GSC has prepared a protocol defining the

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procedures to be used for Tri-national analyses that can be obtained upon request from the authors.

SUMMARY

The Tri-national project will provide a database of geochemical data that serves as a common national and international standard applicable at all levels of government. By early 2009 data will be available for a transcontinental swath in Canada and many states in United States and Mexico that covers diverse geologic and ecoclimatic terranes. The development and detailed documentation of field, laboratory and data handling protocols are a major part of the Tri-national project. Research is also ongoing on key analytical protocols to determine "optimal" methodology for generating soil geochemical data that are useful for health risk assessment. The protocols and data generated from these research efforts may be used in risk assessments, for developing or improving soil guidelines, and for assessing bioavailability.

Since the initiation of the Project, care has been taken to learn about the environmental research or regulatory activities ongoing in other Canadian provincial and federal government departments that require or have the potential to benefit from soil geochemical data. Partnerships have been formed with other agencies to carry out sampling or to develop new applications for these data through additional value-added projects. Several field meetings and demonstrations have taken place and Project information and data have been released through annual workshops, regular newsletters, and presentations at conference and meetings. These activities and also new sample collection will be continued by Geological Survey of Canada and provincial survey scientists over the next 5 to 10 years. In future, results will be released digitally through web postings by the federal and provincial geological surveys, journal articles, and other government reports.

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Website

Canada: http://ess.nrcan.gc.ca/eh-esh/trinat/index_e.php
United States: http://minerals.cr.usgs.gov/projects/geochemical_landscapes/t1subtask1.html

Project participants

Agriculture and Agri-Food Canada; Alberta Geological Survey; British Columbia Geological Survey; Canadian Forest Service, National Forest Inventory; Environment Canada, National Guidelines and Standards Office; Environment Canada - Biological Methods Division; Natural Resources Canada - Geological Survey of Canada; Health Canada - Radiation Protection Bureau; Health Canada - Contaminated Sites Division; Manitoba Geological Survey; New Brunswick Department of Natural Resources; Northwest Territories Geoscience Office; Nova Scotia Department of Natural Resources; Ontario Geological Survey; Saskatchewan Energy and Resources - Northern Geological Survey

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