

THE NORTH AMERICAN SOIL GEOCHEMICAL LANDSCAPES PROJECT (NASGLP): FIELDWORK IN NEWFOUNDLAND IN 2009

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ABSTRACT

The Newfoundland component of the North American Soil Geochemical Landscapes Project (NASGLP) was completed in the summer of 2009, with a total of 64 sites sampled subsequent to the nine sampled in 2008. Areas inaccessible to four-wheel drive vehicles were not sampled. Soil types encountered were mostly (although not exclusively) podzolic. Samples will be analyzed for their geochemical and physical properties under the direction of the Geological Survey of Canada, and the results released in the second half of 2010.

Soil radioactivity measurements were conducted concurrently with the soil sampling. The data show that the values of potassium and thorium are highest on the Great Northern Peninsula. High uranium values are also present here and elsewhere in the sampled areas. The highest values of radon in soil gas display an association with carbonate rocks in the vicinity of the Port au Port Peninsula.

INTRODUCTION

The North American Soil Geochemical Landscapes Project (NASGLP) – a tri-national initiative between United States, Canada and Mexico (referred to colloquially as the ‘Trinational Program’) – was established to meet the need for soil geochemical data by providing a consistent national- and continental-scale framework and database. One of the products of this program will be the first ever continental-scale map of the soil geochemistry; this data will be of use to land-use planners, environmental scientists, agronomists and geoscientists.

Soil geochemistry is critical to the health of virtually all organisms (including humans), existing near, and on, the Earth’s surface. Some are of vital importance, even in trace amounts, to human health while others, in equally small quantities, may be chronically or acutely toxic. However, the natural concentrations of all elements differ among soil constituents and vary between geologically distinct terranes. At present, there is no common understanding of the amount, and origin of, variation in the chemical composition of soil, and there are no universally agreed methods for its measurement. This has led to a number of environmental issues being raised, whose seriousness cannot always be rigorously assessed. To that end, an important component of the program has been the establishment of a standard method for sample preparation and analysis (Kettles *et al.*,

2008) with all Canadian-collected samples being processed centrally under the direction of the Geological Survey of Canada (GSC).

As of the start of the 2009 field season, coverage was complete for the Canadian Maritime Provinces (all sampled in 2007) as well as the states of Nebraska, New York and the New England states (2007), and Nevada, Utah, Wyoming, Colorado, Kansas, Missouri, Arkansas, Louisiana, Mississippi, West Virginia, Delaware, Maryland and New Jersey (2008). Partial coverage has been achieved for Yukon and Northwest Territories (pilot studies in 2007) and all Canadian Provinces (including the Avalon Peninsula of Newfoundland), in 2008 (*see* Figure 1); as well as the states of North and South Dakota, Minnesota, Pennsylvania and Virginia whose coverage was expected to be completed in 2009. Sampling has also covered much of Mexico’s border regions with the USA, as well as a transnational traverse beginning at the USA border in Chihuahua State, Mexico and ending at the Pacific Ocean in Guerrero State, Mexico.

Although the main terms of reference of the project have remained constant, local priorities have prompted the addition of various ancillary projects. For example, at all Canadian sites, the soil sampling was accompanied by measurements of natural soil radioactivity, as manifested by gamma-ray spectra and radon in soil gas.

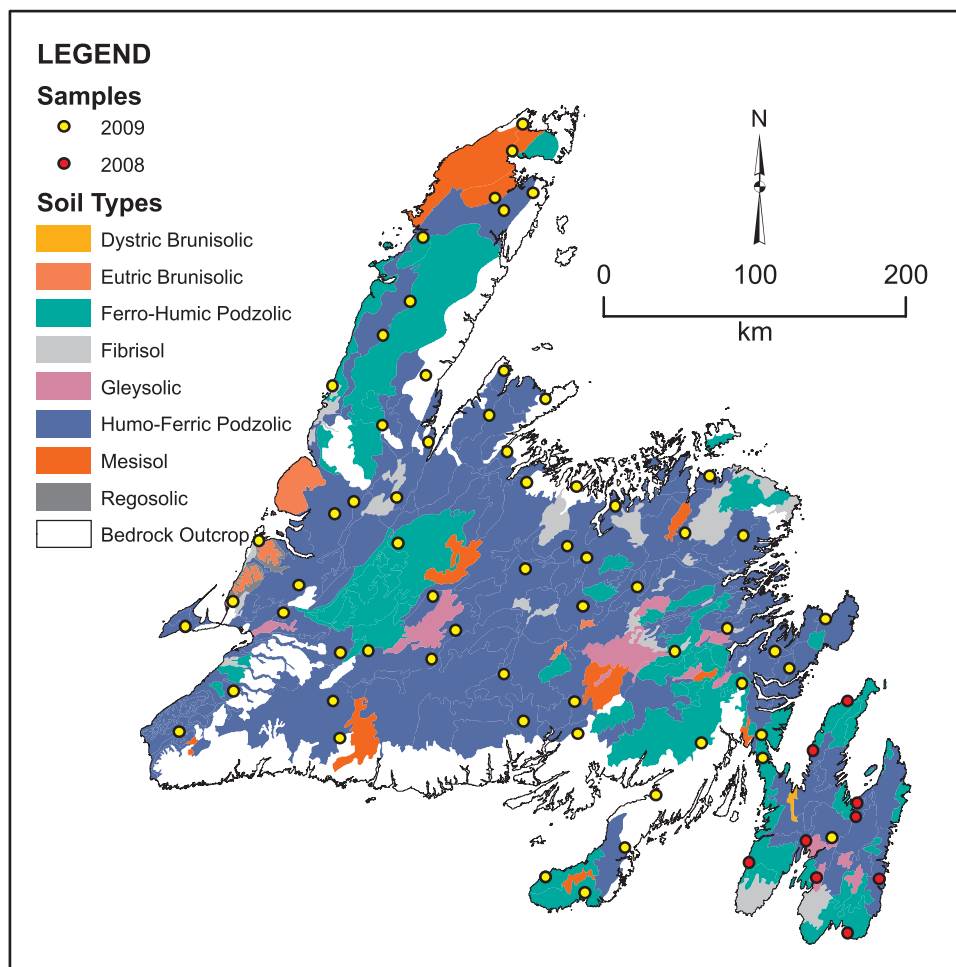


Figure 1. Location of soil samples collected in Newfoundland in 2008 (red dots) and 2009 (yellow dots). Soil map is from Hender and Woodrow (1986).

SELECTION OF SAMPLE SITES

The project sampling is based on a spatially balanced array known as a generalized random tessellation stratified (GRTS) sampling design (Garrett, 1983; Stevens and Olsen, 2004). The entire North American continent is divided into 40-km² quadrants and sample location coordinates are generated randomly at an average density of one every 25 km². A sample site is selected by dividing each quadrant into four sub-quadrants and selecting one at random. This sub-quadrant is then subdivided again into four, and one of these small quadrants is selected at random. This 10-km² quadrant will contain, on average, four of the randomly selected sites, from which one is selected based on ease of access. This policy was adhered to as closely as possible, but in practice access issues over much of the Island forced most of the GRTS-based criteria to be set aside in favour of the nearest site (or in some cases, any site within a quadrant) that could be reached by four-wheel drive vehicle.

SOIL LOGGING AND SAMPLING

Soil pits were dug to the C horizon, to bedrock, to the water table or to about 1 m, depending on which was encountered first. In logging the horizons, depths were measured from the base of the LFH (litter, fermentation, humus) layer that was scraped away prior to sampling. The median depth thus defined was 0.55 m, with a minimum of 0.25 m and maximum of 1.08 m. Bedrock was reached in ten holes and water in nine. The field observations, as described in Table 1, were recorded in a standardized form designed for the project.

Extensive use was made of the Field Manual for Describing Soils in Ontario (Denholm *et al.*, 2003), which provides useful field tests for many of these parameters. Normally, the following horizons would be expected to be present, although with the exception of the Ah horizon, any (or all) might be missing at a particular site:

Table 1. Parameters recorded in the field

Sampling Data	Site Data	Soil Profile Data	Soil Horizon Data
Horizons or intervals sampled for geochemical analysis:	GRTS Cell ID	Soil Order	Horizon Number
<ul style="list-style-type: none"> • PH Interval • A-Horizon • B-Horizon • C-Horizon • 0-30 cm • Anthrax 	Site ID	Soil Great Group	Horizon Name and Suffix
	Replicate Status	Soil Sub-Group	Depth of Upper Boundary of Interval (cm)
	NTS Sheet Number		Depth of Lower Boundary of Interval (cm)
	Latitude and Longitude (NAD83)		Horizon Base Definition
Horizons or intervals sampled for bulk density:	Elevation		Horizon Base Form
<ul style="list-style-type: none"> • PH Interval • A-Horizon • B-Horizon • C-Horizon 	Type of Surface Material		Horizon Colour (from simplified Munsell Chart)
	Mode of Deposition		Mottle Abundance
	Local Surface Expression		Mottle Shape
Type of Surface Material	Vegetation Cover		Mottle Contrast
Mode of Deposition	Rockiness		Mottle Colour
Local Surface Expression	Stoniness		Root Size
Weather	Mapped Bedrock Type		Root Quantity
Date	Slope Type		Root Location
Start Time and End Time	Slope Class		% Coarse Fragments
Air Temperature	Slope Position		Structure Grade
Name(s) of Sampler(s)	Slope Aspect		Structure Type
	Drainage		Structure Class
	Contamination		Most Consistency
	Depth to Water Table (if known)		Texture
	Depth to Bedrock (if known)		Effervescence (with 10% HCl)
Comments:			

- A_h Horizon
- A_e Horizon
- B_f Horizon
- BC Horizon, and
- C Horizon

Where present, all the above soil horizons or intervals, except A_e and BC, were sampled for subsequent analysis; in addition, the Public Health (PH) interval (base of LFH to 5 cm) and 0–30 interval (base of LFH to 30 cm, for soil toxicity studies) were sampled. The soil samples were collected in custom-made, extra-large Kraft paper bags supplied by the GSC, which hold approximately three kilograms of soil material.

Samples were also collected from the same horizons, for bulk-density and/or moisture content determination. This involved pushing a clear plastic cylindrical tube into the interval to be sampled, and recording the thickness of the material in the tube. The volume of the sample is calculated as the radius of the tube is known. The sampled material was then transferred to a steel can, which was closed and sealed with electrical tape. The sampling tube was designed for use in soils common to western Canada and some difficulty was experienced in getting it to penetrate the root-clogged upper soils that are typical of much of Newfoundland.

Finally, a sample of surface soil (the uppermost 2–3 cm) was collected in a plastic vial for the counting of anthrax (*Bacillus anthracis*) spores. The complete sample collection from one sample pit (see Plate 1) typically filled a 5-gallon pail.



Plate 1. Samples collected from a single pit. The metal cans are used to collect samples for bulk-density and moisture-content determinations. The sample collected for *Bacillus anthracis* (anthrax) determination can be seen (in a clear plastic tube, with blue cap) between the second and third can.

Duplicate sampling pits were dug at a frequency of one in 20, with the duplicate sites separated by a distance of 10 to 30 m.

SOIL TYPES

Table 2 summarizes the frequency of the soil types observed at the survey sites. Some typical soil profiles (and one atypical one) are shown in Plates 2A-2F; preliminary soil classifications are provided in the Plate 2 captions.

Table 2. Frequency of occurrence of soil types

Soil Type	Frequency of Occurrence
Regosol or peat	14
Gleysol	10
Ferrohumic podzol (Variant 1)	24
Ferrohumic podzol (Variant 2)	10
Eutric or distric brunisol	5
Unknowns	4

SAMPLE COVERAGE

A total of 64 sites were sampled in 2009. Duplicate samples were collected at three of these sites. The GSC had previously sampled nine sites on the Avalon Peninsula in 2008. At some of the quadrants, mainly in the Burin Peninsula, there was no topsoil, or the sites were so rocky that it was not possible to collect a suitable sample. Furthermore, several quadrants in south-central Newfoundland were not accessible. However, within the terms of reference of the project, coverage of Newfoundland is complete.

An additional site was sampled at the request of the Biological Methods Section of Environment Canada, who are deriving new test methods using ecologically relevant species and soil from the boreal forest eco-zones of Canada. For this purpose, two pails of LFH material, two pails of A_h, two pails of B_f and one of A_e were sampled. Additionally, live samples of forest litter were gathered and air-couriered, in a cooler, directly to Ottawa. The sampling site (48.17527°W, 54.06223°N) is located approximately 5 km west of Clarenville. The site is easily accessible and has a typical, relatively rock-free soil profile developed over till, and a coniferous overstory,

Locations of the sample sites, with the boundaries of the GRTS quadrants, superimposed on a soil map of the Island are shown in Figure 1.

ANALYSIS

The samples will be processed and analyzed in Ottawa. Analytical procedures will include 42-element determina-



Plate 2. A) Regosol or peat. Humus-rich material lying directly on rocky till and bedrock; Latitude 47.21905°N Longitude 55.14136°W (Burin Peninsula, north of Marystown). B) Gleysol. Latitude 48.3567°N, Longitude 56.82793°W (northwest of Meelpaeg Reservoir). C) Ferrohumic podzol (Variant 1). Latitude 51.02452°N, Longitude 56.13165°W (Northern Peninsula, south of Main Brook). D) Ferrohumic podzol (Variant 2). Latitude 48.94727°N, Longitude 55.42124°W (East of Grand Falls-Windsor). E) Possible eutric or dystic brunisol. Latitude 48.15623°N, Longitude 58.59311°W (near Crabbs River, SW Newfoundland). F) Unusual double soil profile showing podzolic or gleyed profile developed over older podzolic profile. Latitude 48.09526°N, Longitude 55.55742°W (north of Head of Baie D'Espoir).

tion after three different leaches, determination of organic and inorganic carbon content, loss-on-ignition, moisture content, bulk density, particle-size analysis, electrical conductivity and cation exchange capacity (Kettles *et al.*, 2008). It is expected that results will be released in the second half of 2010.

RADIOACTIVITY MEASUREMENTS

Measurement of gamma-ray spectra for potassium, uranium and thorium, and of radon in soil gas, was carried out at every sample site, including field duplicate sites. Both sets of measurements were conducted at five subsites, and



Plate 3. A) RS-230 spectrometer placed in soil-sampling pit for in-situ measurement. B) Insertion of soil-gas sampling probe. C) Measurement of radion ionizations with ERM2 electrometer.

disposed where possible around the soil-sampling pit. In addition, spectrometric measurements were made on the floor of the sample pit, and the soil pile extracted from the pit (Plate 3A); the spectrometer was hung from a photographic tripod for measurements at the five peripheral sites.

The gamma-ray spectra were measured using an RS-230 spectrometer, from which data were recorded manually and stored in the instrument before being downloaded after fieldwork was complete.

For radon measurements, a hollow steel probe was hammered into the ground at each of the five sites. The target penetration depth was 60 cm, although this was not always possible. A ‘lost tip’ was inserted into the lower end of each probe prior to hammering; once the probe was in position, the tip was pushed farther into the ground by inserting a punch wire into the probe and hammering it down, thereby creating an opening at the base of the probe through which soil gas was drawn into a syringe and subsequently transferred to an evacuated stainless-steel chamber for ionization measurement by an ERM2 electrometer (Plate 3B and C).

Preliminary results of the surveys are displayed in Figure 2A–D and summarized in Table 3. In Figure 3A–D, the cumulative frequency distributions of the four elements, as measured in Newfoundland in 2009, are compared with those for the Maritime Provinces as measured in 2007 (K. Ford, personal communication, December 2009). These show that potassium is generally higher in Newfoundland, thorium and radon are higher in the Maritimes, and there is no significant difference between the two regions in uranium.

Potassium displays a conspicuous concentration of values greater than 1.3% K, the 80-percentile of the 2009 dataset, on the Great Northern Peninsula, over Paleo- to Mesoproterozoic granitoid rocks, gneisses and mafic–anorthositic intrusions (Colman-Sadd *et al.*, 1990). However, other high-potassium sites in the same region were located over the flanking late Precambrian–Early Cambrian siliciclastic sediments and volcanic rocks, Cambrian carbonate rocks, and Cambrian to Ordovician and Ordovician siliciclastic and carbonate rocks. In the Baie Verte Peninsula, potassium values exceeding the 80-percentile are also reported over the Cambrian to Ordovician carbonate rocks, and over Silurian volcanic rocks. In eastern Newfoundland, similarly high potassium values are reported from sites near the contact with Neoproterozoic subaerial mafic and felsic volcanic rocks, although no site was located directly over this lithology.

Thorium also displays high counts (greater than 5.4 ppm equivalent Th, also the 80-percentile of the 2009 dataset) over the plutonic rocks of the Great Northern Peninsula, although with lower values in the supracrustal rocks to the north and west. Similarly high Th values are reported

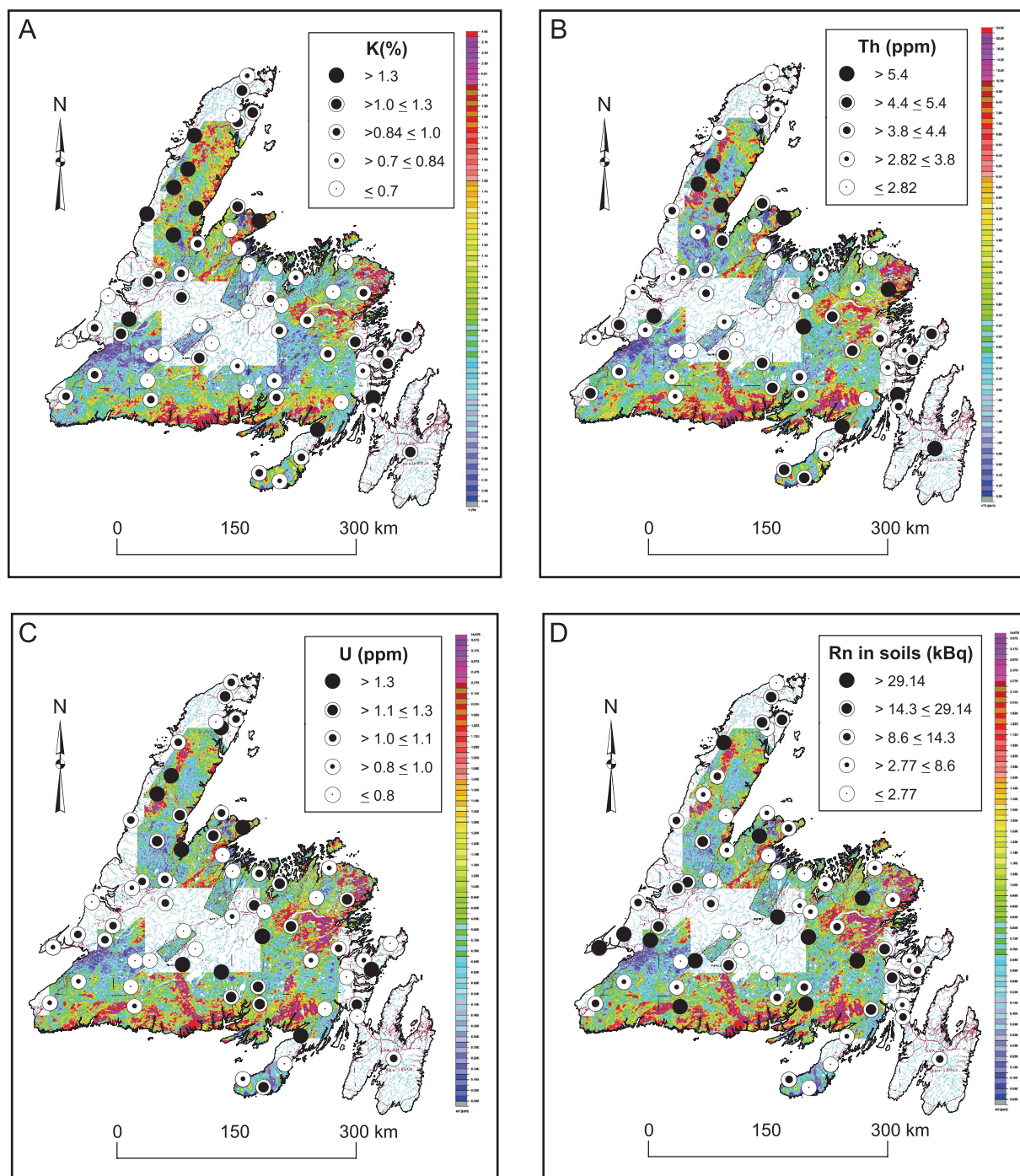


Figure 2. A) Estimated spectrometric K (%). Plotted value is the median of the measurement at 5 stations, not including sample pit or pile. Symbols are superimposed over airborne gamma-ray spectrometric K. B) Estimated spectrometric Th (ppm). Plotted value is the median of the measurement at 5 stations, not including sample pit or pile. Symbols are superimposed over airborne gamma-ray spectrometric Th. C) Estimated spectrometric U (ppm). Plotted value is the median of the measurement at 5 stations, not including sample pit or pile. Symbols are superimposed over airborne gamma-ray spectrometric U. D) Radon in soils (kBq). Plotted value is the median of the measurement at 5 stations, not including sample pit or pile. Symbols are superimposed over airborne gamma-ray spectrometric U. Airborne gamma-ray spectrometric maps are from Carson et al., 2003.

Table 3. Summary statistics of soil radioactivity survey; figures in parentheses indicate equivalent values for 2007 Tri-National Survey Maritime Provinces data set (K. Ford, personal communication, December 2009)

Element	Minimum (site median excluding sample pit)	Minimum (individual reading excluding sample pit)	Maximum (site median excluding sample pit)	Maximum (individual reading excluding sample pit)
Potassium (%)	0.3	0.2	2.8 ¹ (1.9)	3.0 ¹ (2.2)
Thorium (ppm)	1.0	0.6	14.5 ² (11.1)	18.0 ² (14.0)
Uranium (ppm)	0.4	0.2	2.9 ³ (3.2)	9.9 ⁴ (3.8)
Radon (kBqm ⁻³)	0.15	0.0	62.6 ⁵ (109)	95.7 ⁶ (246)

¹ 50.4882°N, 57.02221°W (Northern Peninsula, southeast of Hawkes Bay)

² 50.28265°N, 57.26757°W (Northern Peninsula, east of Daniel's Harbour)

³ 47.52806°N, 54.85969°W (Burin Peninsula, east of Bay L'Argent)

⁴ 48.68828°N, 58.6134°W (on Fox Island River, north of Stephenville)

⁵ 48.53275°N, 59.03124°W (on Port au Port Peninsula)

⁶ 49.0818°N, 54.5267°W (North of Gander)

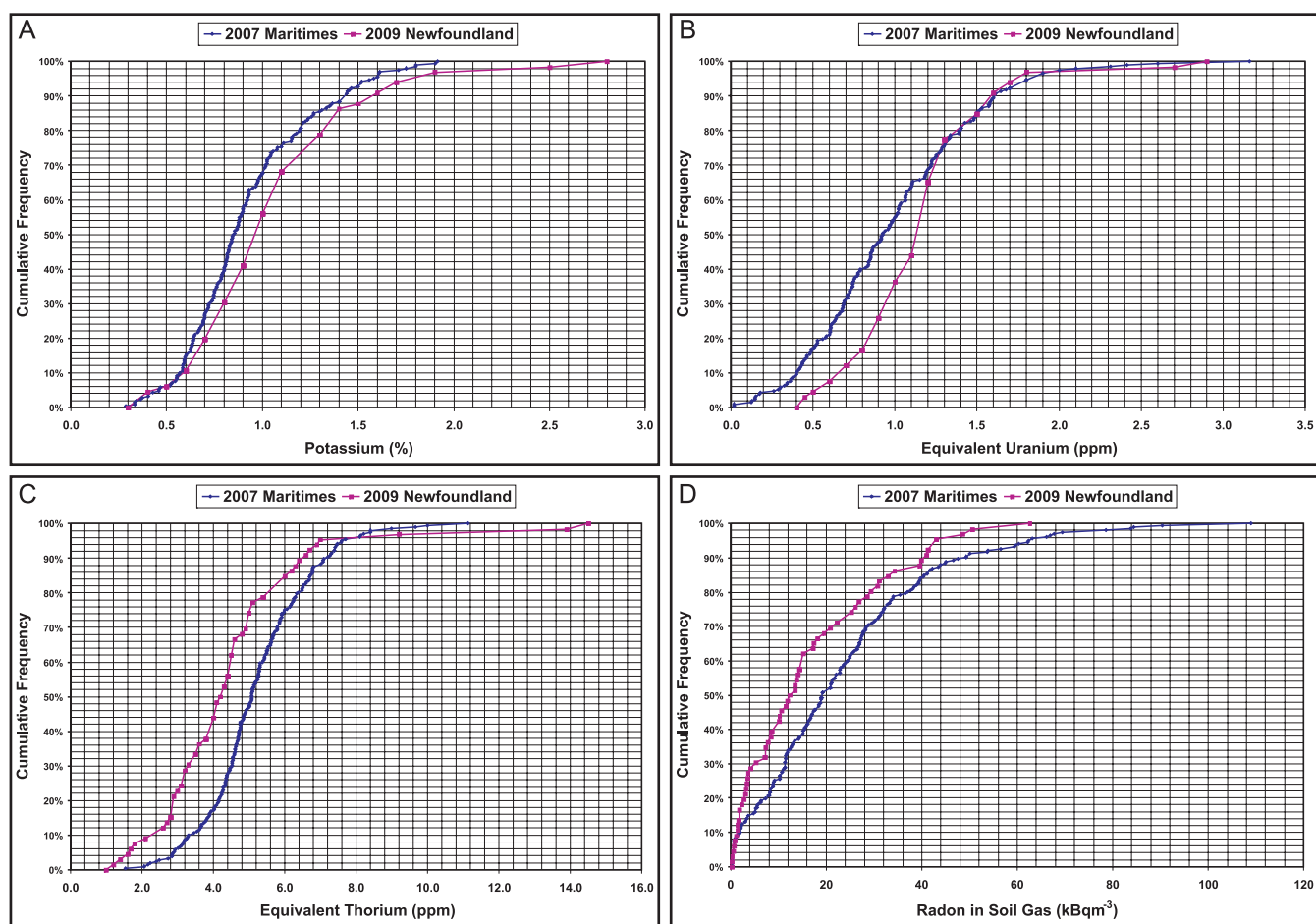


Figure 3. A) Cumulative frequencies of potassium spectrometric measurements in Newfoundland (2009) and the Maritime Provinces (2007). B) Cumulative frequencies of equivalent uranium spectrometric measurements in Newfoundland (2009) and the Maritime provinces (2007). C) Cumulative frequencies of equivalent thorium spectrometric measurements in Newfoundland (2009) and the Maritime provinces (2007). D) Cumulative frequencies of equivalent measurements of radon in soil gas in Newfoundland (2009) and the Maritime provinces (2007).

from Silurian volcanic rocks in the northeastern Baie Verte Peninsula and west of White Bay. Spatial concentrations of values exceeding the 80-percentile elsewhere on the Island are not conspicuous, although there is a tenuous association with granitic contacts.

The highest values of equivalent uranium (greater than the 80-percentile of 1.3 ppm U) show more spatial coincidence with those of potassium than with thorium, occurring over both the Proterozoic plutonic rocks of the Great Northern Peninsula and the adjacent supracrustal rocks. Values exceeding the 80-percentile were also reported from sites on the Baie Verte Peninsula, including the two sites that were high in potassium and thorium. Similarly high values are present elsewhere on the Island but they do not display pronounced spatial or lithological association.

The most conspicuous concentration (three sites) of counts of radon in soil gas, that exceed the 2009 80-percentile of 29 kBqm⁻³ (kilobecquerels per cubic metre), occurs on the Port au Port Peninsula and its immediate hinterland. Associated rock types are Cambrian and Ordovician carbonate rocks and Ordovician turbidites and carbonate breccia. Near one site, the Cambrian carbonate rocks are in contact with Proterozoic granitoids. Uranium values in the same area fall between the 60- and 80-percentiles, so there is a tenuous relationship between the two elements in this area. Elsewhere on the Island the high values do not show a pronounced spatial association, either with a particular lithology or with each other.

CONCLUSION

Soil sampling and radioactivity measurements for the Island of Newfoundland component of the North American Soils Geochemical Landscapes Project are complete. Some areas that are not easily accessible remain unsampled. A total of 64 sites were sampled in 2009, and a further nine in 2008. Of the 2009 sites, the most common soil type is humo-ferric podzol, which was encountered in more than half of the sample pits; other types are gleysol, listric or eutric brunisol, and peaty regosol.

Of the 2009 radioactivity measurements, thorium and potassium both display the highest soil content, as measured by gamma-ray spectrometry, in the Great Northern Peninsula. The behaviour of uranium (measured by gamma-ray spectrometry) and radon in soil gas is less consistent. However, both elements show some enrichment in the Port au Port Peninsula and its hinterland.

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REFERENCES

- Carson, J.M., Holman, P.B., Ford, K.L., Grant, J.A. and Shives, R.B.K.
2003: Island of Newfoundland Airborne Gamma Ray Spectrometry Compilation, 1: 1,000,000 scale. Geological Survey of Canada, Open File 4463, 8 maps.
- Colman-Sadd, S.P., Hayes, J.P. and Knight, I.
1990: Geology of the Island of Newfoundland, scale: 1:1,000,000. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch. Open File GS# NFLD/2192
- Denholm, K.A., Schut, L.W. and Irvine, D.E.
2003: Field Manual for Describing Soils in Ontario, 4th Ed. Land Resource Science, University of Guelph, 62 pages.
- Garrett, R.G.
1983: Chapter 4: Sampling Methodology. *In Statistics and Data Analysis in Geochemical Prospecting (Handbook of Exploration Geochemistry, Volume 2)*. Edited by R.J. Howarth. Elsevier, pages 83-110.
- Hender, F. and Woodrow, E.
1986: Soil Landscapes of Canada – Newfoundland-South. 1:1,000,000 map. Agriculture Canada.
- Kettles, I.M., Rencz, A.N. and Friske, P.W.B.
2008: The North American Soil Geochemical Landscapes Project – A Canadian Perspective. *EXPLORE*, Volume 141, pages 12-22.
- Stevens, D.L. and Olsen, R.
2004: Spatially balanced sampling of natural resources. *Journal of the American Statistical Association*, Volume 99, No. 465, pages 262-278.

