GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6282

North American Soil Geochemical Landscapes Project: Canadian Field Protocols For Collecting Mineral Soils And Measuring Soil Gas Radon And Natural Radioactivity

P.W.B. Friske, K.L. Ford, I.M. Kettles, M.W. McCurdy, R.J. McNeil
and B.A. Harvey

2010

Natural Resources Canada Ressources naturelles Canada

Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6282

North American Soil Geochemical Landscapes Project: Canadian Field Protocols For Collecting Mineral Soils And Measuring Soil Gas Radon And Natural Radioactivity

P.W.B. Friske, K.L. Ford, I.M. Kettles, M.W. McCurdy, R.J. McNeil and B.A. Harvey

2010

Friske, P.W.B., Ford, K.L., Kettles, I.M., McCurdy, M.W., McNeil, R.J. and Harvey, B.A. 2010. North American Soil Geochemical Landscapes Project: Canadian field protocols for collecting mineral soils and measuring soil gas radon and natural radioactivity; Geological Survey of Canada, Open File 6282, 175 p.

Foreword

Chemical elements in soil support and affect human, animal and plant life. Naturally-occurring levels of elements may vary by several orders of magnitude. Understanding the amount and causes of natural variability is vital for the assessment and management of risks to human health and the environment. At present there is no systematic continent-wide data on background variations in soil composition. 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.

This project was established to produce the needed soil data and to develop the necessary mechanisms to have these data recognized and used by policy makers and regulators dealing with natural resource development and health and environmental protection. It is being undertaken jointly by Natural Resources Canada-Geological Survey of Canada, the United States Geological Survey and the Servicio Geologico Mexicano.

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. Use of consistent protocols ensures that the resultant data sets will stitch together to produce a final seamless geochemical database. 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.

Front cover - Collecting soil samples and soil gas radon data in Prince Edward Island. (Photo by R.J. McNeil)

Above - Elements in soil support and affect all human, animal and plant life. (Photo by I. Kettles)

Collecting NASGLP soil samples in southern Saskatchewan in 2008. (Photo by J. Campbell)

TABLE OF CONTENTS

PART 1

INTRODUCTION TO THE NORTH AMERICAN SOIL GEOCHEMICAL LANDSCAPE PROJECT

Field meeting to demonstrate sample collection protocols was held in the Fredericton area, New Brunswick, in June 2007. It was attended by Project participants from Geological Survey of Canada, provincial surveys, and United States Geological Survey. (Photo by A. Rencz)

Field meeting to co-ordinate sample collection protocols was held in the Sonora area, Mexico, in November 2007. It was attended by Project participants from Geological Survey of Canada, United States Geological Survey, Servicio Geologico Mexicano, and University of San Luis Potosi. (Photo by A. Rencz)

NORTH AMERICAN SOIL GEOCHEMICAL LANDSCAPES PROJECT – OVERVIEW FROM THE CANADIAN PERSPECTIVE

Introduction

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. The natural concentrations of elements differ among soil constituents and vary markedly between geologically distinct terranes. Currently there is no common understanding of the amount and origin of variation in soil geochemistry within Canada and North America nor is there a consistent methodology used for its determination.

The North American Soil Geochemical Landscapes Project (NASGLP) is a tri-national initiative between the Canada, United States, and Mexico and is the first multi-national, multi-agency collaboration of its kind for this continent. It was established to develop a useful set of geochemical data for North America that is being generated using consistent protocols. The Project is supplying soil geochemical data for the different geological terranes and will provide a broader context to fit data from site specific studies. The aim is to provide data and protocols that are useful to a wide range of users in the fields of sustainable resource development and environment and health.

Figure 1-1

Collection of samples from a podzolic soil in Nova Scotia for the NASGLP Project in June 2006. (Photo by R. Mroz)

What will the project provide?

- A soil geochemistry database with a broad spectrum of inorganic elements and selected biological and organic compounds; it is based on low-density sampling (1 sample per 1600 km^2) for Canada, United States and Mexico.
- A set of field and analytical protocols and a framework for accommodating geochemical and related data.
- A coordinated common approach for environmental assessments related to sustainable development of natural resources and human health protection that is founded on sound scientific principles.
- Geochemical and related data that provide a stable predictive environmental framework for decision-makers; these data are uniformly applicable by provincial, federal, and international levels of government.
- Data that are web-enabled, user-friendly and valuable for a wide range of applications.

The project nuts and bolts

- The project is based on low density sampling (within a 40 km x 40 km grid). There are 6,018 sites in Canada and a total of 13,487 sites across North America (Figure 1-2).
- The NASGLP survey has a core protocol that is used in each of the three countries. At each site, soil samples are collected from a depth of 0-5 cm and from the A- and C- soil horizons. The <2 mm fraction (an agricultural and environmental standard) is analyzed for a suite of approximately 50 elements, following a near-total (4-acid) digestion. A sample of 0-5-cm material from each site will be analyzed for the presence of *Bacillus anthracis* (anthrax).
- In addition to the core protocol, each country may add certain procedures and analyses that are particular to its environmental and/or policy needs.
- Field and laboratory data are stored using set protocols and sample splits are preserved for purposes of quality control and future work.
- The methodology and protocols were planned to provide a framework that will support future work, including more detailed sampling and different types of analyses.

Meeting the project goals in Canada

In addition to the core protocols outlined above, extra procedures 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.

Also, a major addition to the Canadian project is the in-situ measurement of soil gas radon and the radiometric estimates of soil K, U and Th concentrations. These data will be integrated with NASGLP soil data to support development of a map showing radon-prone areas in Canada.

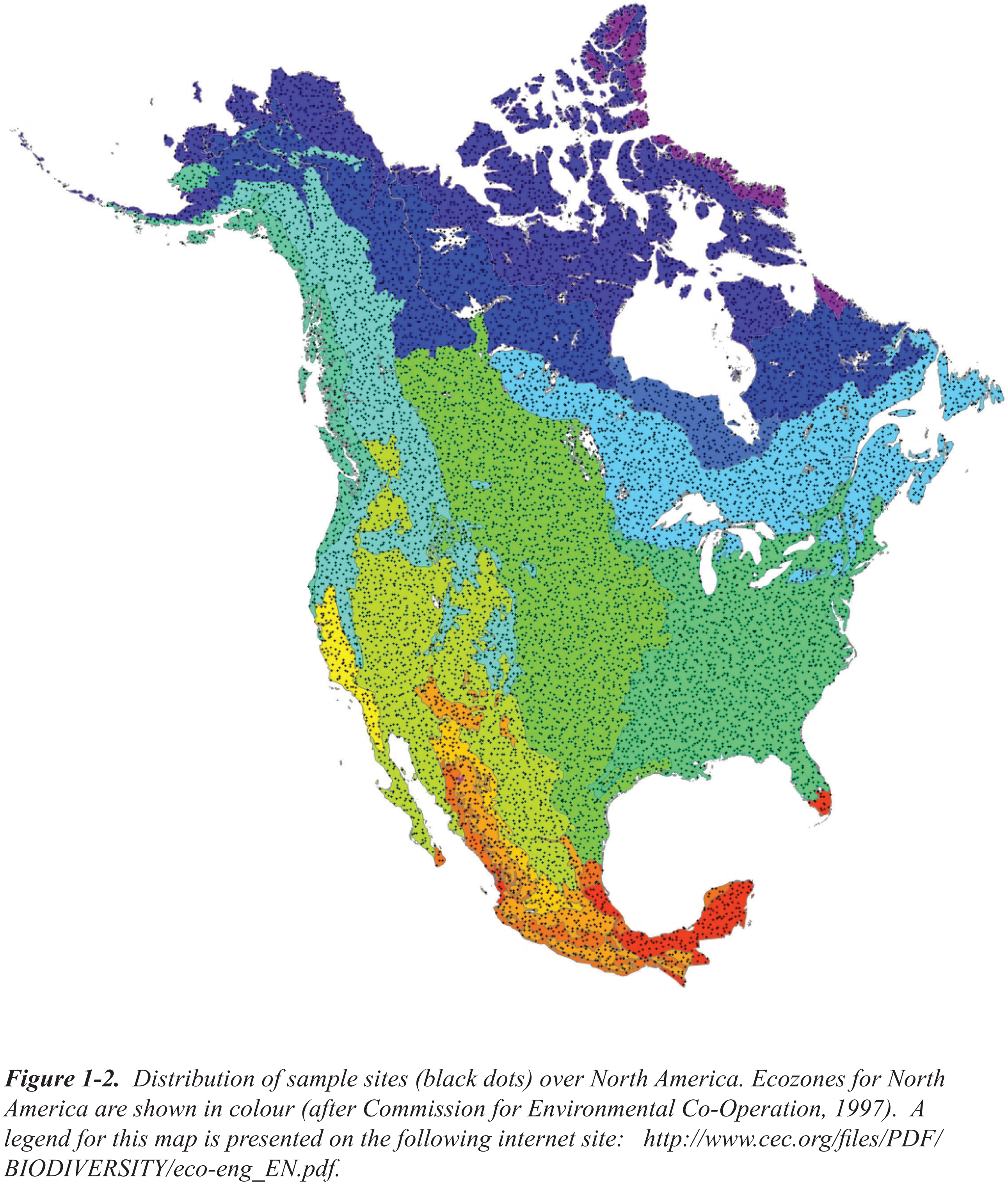


***Figure 1-2.** Distribution of sample sites (black dots) over North America. Ecozones for North America are shown in colour (after Commission for Environmental Co-Operation, 1997). A legend for this map is presented on the following internet site: http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf.*

OVERVIEW OF THE NASGLP PROTOCOLS MANUAL FOR COLLECTION AND ANALYSIS OF SOIL SAMPLES

A major objective of the NASGLP is the development of a set of protocols for field sampling and laboratory analysis of soils. 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 numerous state and provincial boundaries; (3) the complexity of the operation; (4) the many types of mineral and organic soils and field situations (e.g. permafrost areas) that require diverse equipment and procedures; and (5) the need to anticipate and accommodate possible future requirements. The sampling is horizon- and depth-based and involves many types of analyses, all requiring field, laboratory, quality assurance, archiving, and data handling protocols.

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 applicable at all levels of government. Samples will be collected and data will be generated by many organizations in many geographic areas over a long time period. Use of consistent protocols ensures that the resultant data sets will stitch together to produce a final seamless geochemical database.

The protocol manual for the NASGLP is being developed as a series of modules to facilitate its release and management. This modular format will allow the user to print only those parts of the manual that are of interest.

An outline of the final master document that will be required to cover all aspects of the Canadian project is shown below. The text for the parts of the master document covered in this release is shown in italic.

Master outline of field, laboratory, and data-handling protocols required for the NASGLP in Canada

Introduction

- *North American Soil Geochemical Landscapes Project - Overview from the Canadian perspective*
- *Overview of the NASGLP protocols manual for collection and analysis of soil sampling*
- *Master outline of field, laboratory, and data-handling protocols required for NASGLP for Canada*

Field sampling design

- *Background information, including history and references*
- *Site selection*
    - *Office preparation*
    - *Field implementation*
- *Field controls, duplicates, blind samples*

Field sampling protocols

- *Mineral soils*
  - *(1) Permafrost-free terrain*
    - *Checklist of required field equipment for site location, sample collection, sample storage and data recording*
    - *Steps for on-site sample collection for geochemical and physical analyses*
    - *Steps for on-site measurements of soil gas radon and natural radioactivity*
    - *Using the field card*
  - (2) Adjustments for permafrost-affected (cryosols) or disturbed terrains, including agriculture, urban, and mining or other contaminated areas
    - Checklist of required field equipment for site location, sample collection, sample storage and data recording
    - Steps for on-site sample collection for geochemical, geophysical and physical analyses
    - Steps for on-site measurements of soil gas radon and natural radioactivity
    - Using the field card

- Organic soils
  - (1) Permafrost-free terrain
    - Checklist of required field equipment for site location, sample collection, sample storage and data recording
    - Steps for on-site sample collection for geochemical, geophysical and physical analyses
    - Using the field card
  - (2) Adjustments for permafrost-affected (cryosols) or disturbed terrains, including agriculture, urban, and mining or other contaminated areas
    - Checklist of required field equipment for site location, sample collection, sample storage and data recording
    - Steps for on-site sample collection for geochemical, geophysical and physical analyses
    - Using the field card

Laboratory Protocols

- Background rationale

- Sample preparation (core and value-added activities)
  - (1) Air drying
  - (2) Preparing specific size fractions for analysis
  - (3) Ball-milling procedures
  - (4) Storing and archiving sample splits and unused sample materials

- Sample analysis – Core Canadian procedures
  - (1) Geochemical tests
    - Rationale behind the selection of dissolution techniques and required formulations (4-acid, aqua regia, water leach)
    - Rationale behind selection of analytical techniques for chemical elements and explanations of the techniques (ICP-MS/ES, INAA and others, as needed

        - Carbon content – organic and inorganic content
        - pH measurements
        - Cation exchange capacity (CEC)

    (2) Physical tests
        - Munsell colour coding
        - Particle size analysis
        - Loss on ignition (LOI)
        - Moisture content
        - Bulk density
        - Electrical conductivity

- Sample Analysis – Value-added determinations on splits of core NASGLP samples from selected soil horizons and the rationale for the inclusion of these analyses
    (1) Selected minor elements (N, P)
    (2) Bioaccessibility
    (3) Perchlorate
    (4) Biomethods for assessing soil toxicity
    (5) X-ray mineralogy
    (6) Radiometric tests
    (7) Gastric leach

- Sample Analysis – Value-added determinations on additional samples collected at or associated with NASGLP sites and the rationale for the inclusion of these analyses
    (1) Radon analysis
    (2) Radiometric tests
    (3) Anthrax study
    (4) Studies on the 0-30 cm interval
    (5) Stream waters and sediments collection and analysis
    (6) Studies of hydrocarbons in soils

QA/QC and Data Management

- Database structure with rationale
- QA/QC – how quality is controlled from sample collection to data in database
- Data reporting – field, laboratory, QA/QC, Summary statistics, digital formats
- Summary statistics

Background Information

- *Bedrock geology of Canada*
- *Surficial geology of Canada*
- *Comments on till and associated glacial and postglacial sediments; postglacial modification of glacial sediments and soil formation*
- *Soil distribution and characteristics in Canada*
- *Permafrost distribution in Canada*

EXPLANATION OF THIS GEOLOGICAL SURVEY OF CANADA OPEN FILE

The protocols for the field sampling of mineral soils (non-cryogenic) are presented in this Open File. Sampling of mineral soils was undertaken in the eastern provinces and in some areas in Nunavut in 2007, as well as along a transect that stretched roughly parallel to part of the Trans-Canada highway in 2008. In this two year period the field sampling protocols were developed and refined, based on field experience.

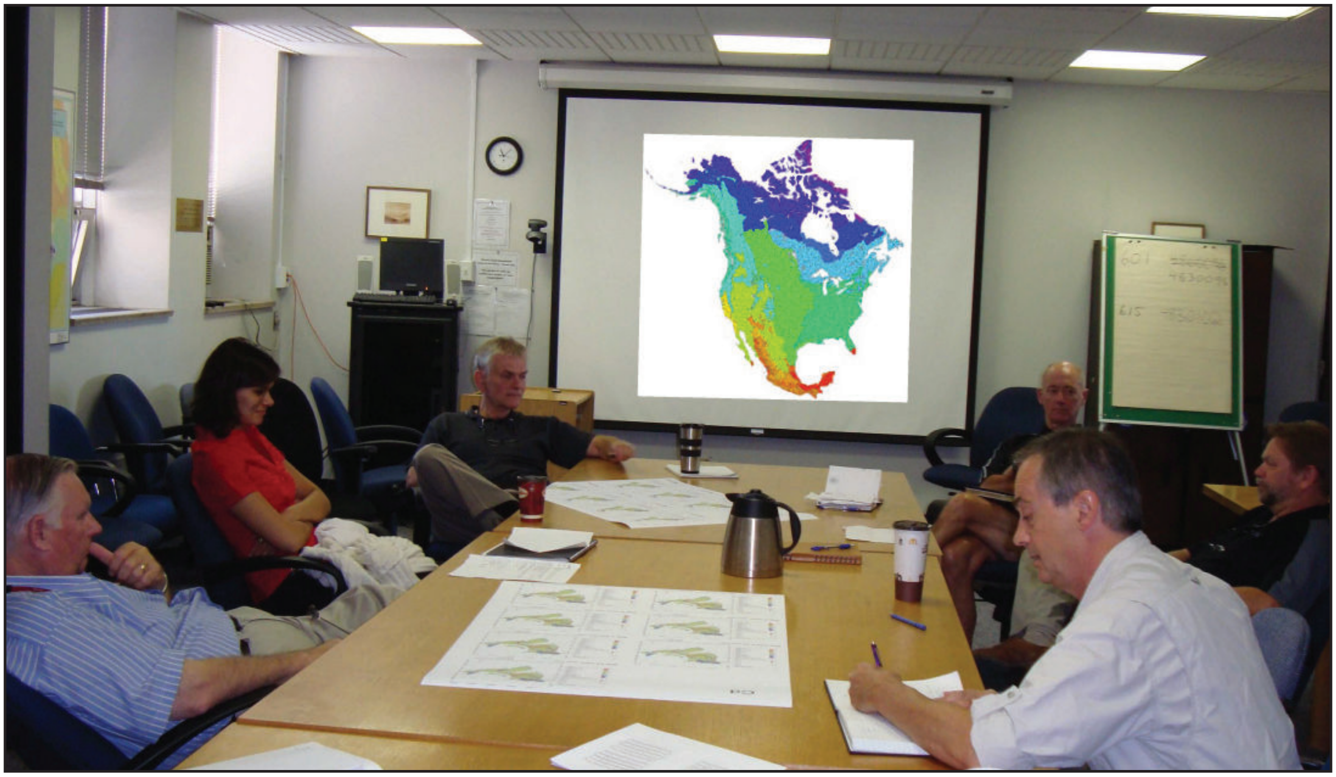
The measurement of soil gas radon and natural radioactivity using gamma ray spectrometry is an important value-added activity in Canada. This work was undertaken at the NASGLP sites at the same time as the soil sampling. Because the two activities are so closely linked, the protocols for taking soil gas radon and gamma ray spectrometry measurements are included in this Open File.

ACKNOWLEDGMENTS

The authors wish to thank Andy Rencz, for his leadership on the Canadian part of the North American Soil Geochemical Landscapes Project; Robert Garrett for his helpful advice and contribution to the sample site selection procedures; Dave Smith (USGS) and Laurel Woodruff (USGS) for their input into NASGLP field protocol development; Dave Kroetsch for help on soil identification and classification; Wendy Spirito for a helpful review of this manual; the scientists from the provincial surveys and other agencies, including Terry Goodwin (Nova Scotia), Toon Pronk (New Brunswick), Mike Parkhill (New Brunswick), Janet Campbell (Saskatchewan), Gaywood Matile (Manitoba) and Heather Groom (Manitoba) for the field testing of protocols documented in earlier versions of this manual; and summer students at the GSC and the provincial surveys for their field and laboratory assistance.

PART 2

OFFICE PREPARATION FOR SAMPLE SITE SELECTION



Office preparation by NASGLP participants at Geological Survey of Canada, Ottawa. (Photo by I. Kettles)

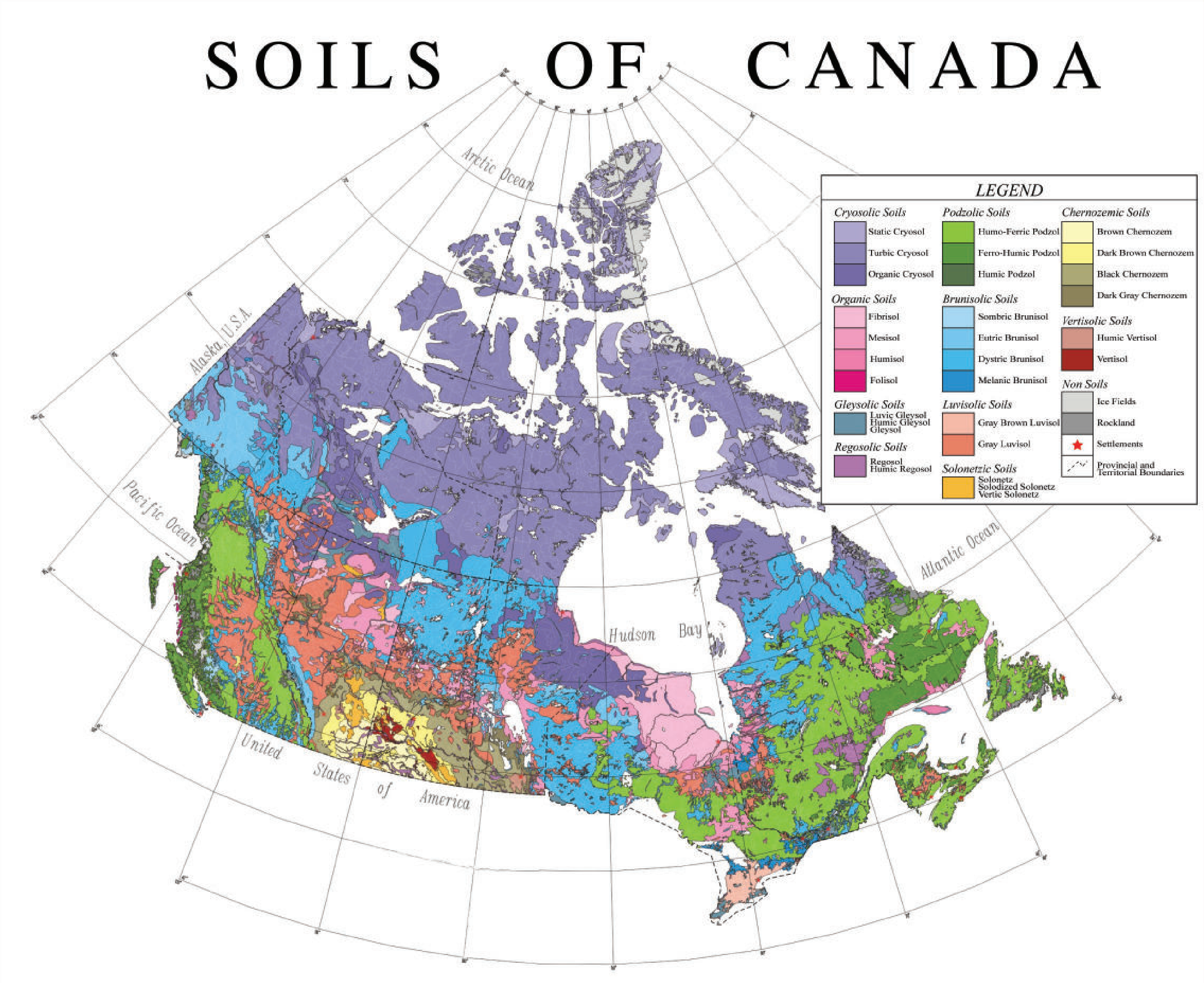


Figure 2-1. Generalized map showing the distribution of soils in Canada, based on the Soil Classification Working Group (2000).

BACKGROUND INFORMATION ON SITE SELECTION PROCEDURES

The history of the development of methodology for site selection is documented in Open File 6300 (Garrett and Kettles, 2009) and is also posted on-line at the following ftp site: ftp://nrn1.nrcan.gc.ca/gsc/NAmSGLs. In this section some details of the procedure are presented. Most of the text in this section is taken directly from the Open File and the ftp site.

In 2006, a panel was convened at the United States Geological Survey in Denver to finalize the sampling scheme for continental coverage. Thirteen attendees were present, representing the United States Environmental Protection Agency (Corvallis), Center for Disease Control (Atlanta), Savannah River Environmental Laboratory (GA), United States Department of Agriculture-National Resources Conservation Service, the Minnesota Geological Survey, Agriculture and Agri-Food Canada, Environment Canada, the United States Geological Survey and the Geological Survey of Canada. The choice of a geographically-based stratified random sampling plan was confirmed. The consensus was to implement the US-EPA Generalized Random Tessellated Stratified (GRTS) design procedure (Stevens and Olsen, 2004) to determine the locations of potential sample sites.

Software to implement the GRTS design procedure was available through R (The R Project, 2009), an open source software environment for statistical computing and graphics. It is available from the Comprehensive R Archival Network (CRAN, 2009) as package ‘spsurvey’ (Kincaid and Olsen, 2009) posted on-line at http://www.r-project.org/.

When a sample density of 1 sample per 40 x 40 km cell is selected using the GRTS procedure, it generates a sample set that has the selected average sample density, but each cell is not necessarily populated with a site. Some cells will have none, and others multiple sites. To ensure that each 40 x 40 km cell has a sample site, the selected sample density using the GRTS procedure was increased to one site per 5 x 5 km cell, i.e., by a factor of 64. The origin of the grid of 5x 5 km cells, and therefore 8 x 8 blocks of these comprising the desired 40 x 40 km cells, was 45º N and 100º W, and when this was coupled with the coastline of North America a total of 845,763 potential sites were generated.

The coordinates of the 845,763 potential sites are available in an MS Access® database, on the ftp site as GRTS64_rgg.mdb, and as a file in GSC Open File 6300. The table ‘NAsites’ is the output from the R run of package ‘spsurvey’, and includes a variety of details including the country and province/state of the sites. The coordinates are in Lambert projection meters from the 45º N and 100º W grid origin, and each site is identified by a unique ‘siteID’ allocated by package ‘spsurvey’. Two additional tables are included. Firstly, ‘All_Locations’ which contains the unique ‘siteID’ and the Lambert coordinates and WGS84 spheroid latitudes and longitudes for each site; and secondly, ‘GRTS64_Celled’ which contains the unique ‘siteID’, the Lambert coordinates, and the ‘cellID’, down to the 10 x 10 km unit, that the site falls within.

The ‘cellID’ is constructed as follows. The first two characters identify the quadrant the site falls into relative to the 45º N and 100º W grid origin. These characters are followed by a ‘-’ and two numbers separated by a ‘.’. The first of these indicates the identification number of the 40 x 40 km cell east or west of the grid origin meridian, 100º W, and the second indicates the identification number of the 40 x 40 km cell located north or south of the grid origin parallel, 45º N. This construct is followed by a further ‘-‘, and then two numbers that indicate the 20 x 20 km cell, and within it the 10 x 10 km cell the site falls within.

In each instance the cells are numbered 1 to 4, in south-north order west-east from the SW quadrant, such that 1 is the SW, 2 is the NW, 3 is the SE, and 4 is the NE quadrant. Thus the first record 'siteID', NE-29.10-2-1, indicates the NE quadrant, and 29 40 x 40 km cells east and 10 40 x 40 km cells north of the origin. Within that cell the site lies in the NW 20 x 20 km cell, and within that in the SW 10 x 10 km cell. The steps for accomplishing site selection as described above are shown in Figures 2-1 and 2-2, using an area of central Alberta as an example.

Several queries are included in the database. Firstly, 'IDs_&_Locations' which lists the 'siteID', Lambert coordinates, WGS84 geographic coordinates and 'cellID' for each of the 845,763 potential sites. This query was used to generate the two files, 'IDs _&_Locations.dbf' and 'IDs_&_Locations.txt' on the ftp site. The former is in dBaseIV® format, and the latter is a comma delimited 'csv' file; these are provided for user input into other software packages. Secondly, the query 'Cells' provides the unique 'siteID', 'cellID' as 'cell10', and 'cell40' and 'cell20' that identify the 10 x 10 km, 40 x 40 km and 20 x 20 km cells that the site location falls within, respectively. This query is available as the file, 'grts64_celled.txt' on the ftp site.

The presence of multiple potential sites for each 40 x 40 km cell permits the selection of alternate sites if, for example, the first site selected falls within a lake or on 'forbidden land', such as a penitentiary, military or other reservation. For each field activity, potential site coordinates need to be retrieved on some geographic basis, such as province or state, or any latitude and longitude bounded block. As an example, the database query 'NB_&_NS' was used to retrieve the coordinates for the 2007 field campaign in New Brunswick and Nova Scotia. The query retrieves the unique GRTS 'siteID', both Lambert and

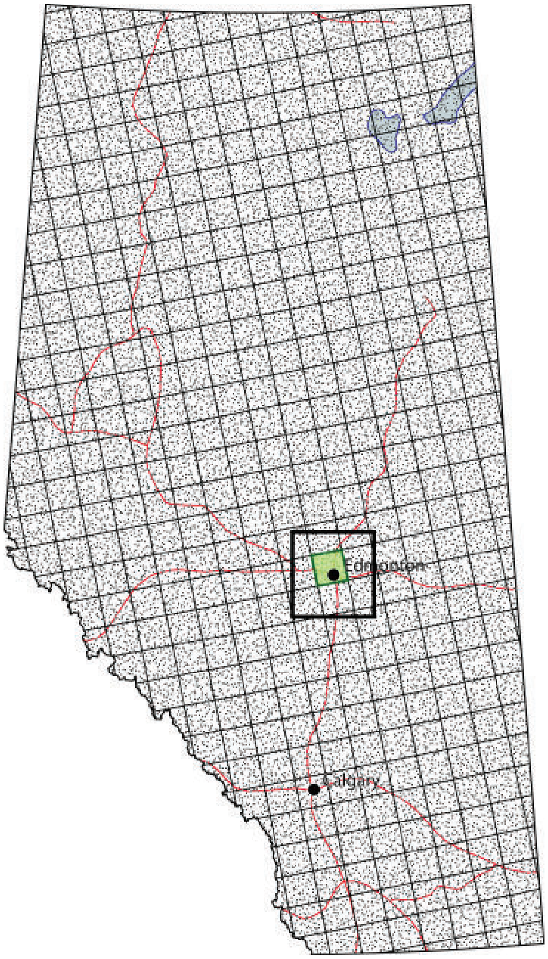
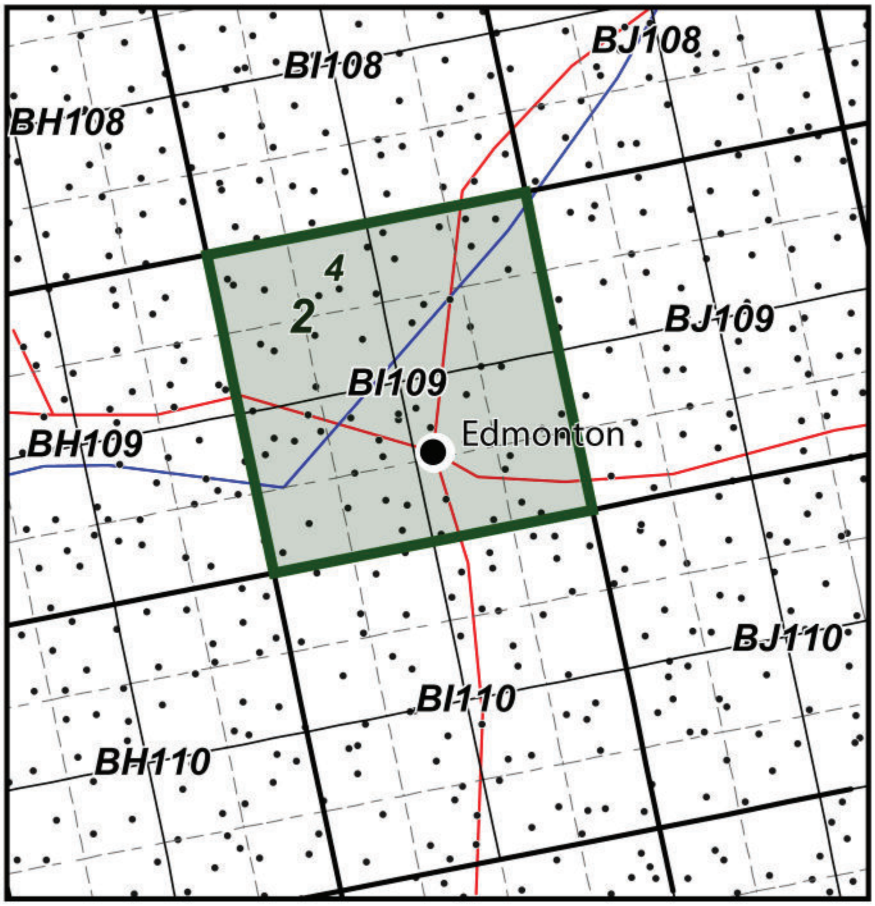


Figure 2-1. Distribution of potential sample points in Alberta. The area outlined in black is the map area shown in Figure 2-2.



A. Part of the table of random numbers for site selection used in 2008. The two number sequence outlined in red is used to select the target sample site as explained in `B` and `C`.

2	4	4	4	3	1
1	4	1	1	3	3
4	4	3	2	4	4

B. By definition, the following numbers are associated with the four 20 km X 20 km quadrants in the 40 km X 40km cell.

2 NW	4 NE
1 SW	3 SE

C. The first random number defines a 20 km X 20 km quadrant and the second a 10 km X 10 km quadrant within the 20 km X 20 km cell. Within the 10 km X 10 km cell, the target site is the one with the highest GRTS number. The GRTS numbers for sites in a 40 km X 40 km cell are obtained by clicking on an individual site on the GIS plot, based on the desired area subset from the MS Access® database. If the site with the highest number is unsuitable, such as being located in a lake, the new target is the next lower number.

Figure 2-2. Map showing potential sample sites for a region in central Alberta. The area is covered by four 40 x 40 km grid cells and parts of 8 others. Also explained is the procedure for selecting the targeted sample site within a grid cell.

geographic coordinates, the ‘cellID’ and the ‘stateabb’ field from the ‘spsurvey’ output, upon which the query selection was based. This query can be used as a model for potential site coordinate retrievals. Importantly, the query output is sorted in increasing ‘cellID’ order to facilitate sample site selection. The detailed procedure for site selection is provided on the ftp site and in GSC Open File 6300.

NASGLP site selection

Site selection involves considerable work at the office before field work begins to determine target and alternative sites. It is necessary to prepare a binder that contains the pertinent information for the predetermined sites for use as a guide in the field. At the office, the final selection of a site in each 40 km by 40 km cell of the sampling grid involves obtaining and considering possible sites based on the GRTS design.

The co-ordinates of potential sample sites for the desired field region are found in the MS Access® database on the ftp site or in GSC Open File 6300. More explanations of the sites and database were provided above. During standard NASGLP sampling the objective is to collect, from each 40 km x 40 km cell, one random sample from the 64 possible sites. The steps for accomplishing this are described above and shown in Figures 2-1 and 2-2, using an area in central Alberta as an example. A table of random numbers of integers between 1 and 4, found in Appendix 2-A, is used to define a 10 x 10 quadrant within which the NASGLP site is selected.

Generally within the target 10 x 10 km quadrant there are 3 to 5 GRTS sites. All else being equal, the site with the highest GRTS site number is selected as the sample site. If, however, the site with the highest number is not suitable, the remaining sites within the target quadrant are evaluated (in order from highest to lowest GRTS site number) until a site is selected.

QUALITY ASSURANCE AND QUALITY CONTROL

Block of 20 collection system

For every block of 20 consecutive field numbers there will be 17 routine field samples (Replicate Status (RS) = 0), one control reference sample (RS = 9), one blind (analytical) duplicate sample (RS = 8) and one pair of field duplicate samples (RS = 1 and 2).

At the duplicate sample site, two immediately adjacent separate samples are collected to provide a site duplicate. Their numbers would be, for example, 1048 with the RS code “1” and 1049 with the RS code “2” on the field card. The choice of which of the 17 sites in a block of 20 to duplicate is random and left to the judgement of the traverse planner and/or the sampling team.

A field sample number in each block (e.g., 1043) must be reserved for the control reference sample. A randomly generated list of reserved field numbers, one field number for each block of 20 field sample numbers will be generated in advance of field work . The corresponding field card for the control reference sample contains only the field sample number and the RS code “9”.

A field sample number in each block of twenty (e.g., 1001 to 1020, 1021 to 1040 etc.) must be reserved for the second member of a blind duplicate pair. This reserved number is always the first sample number in the block (i.e., 1001, 1021, 1041, etc.). An empty sample bag and bottle are numbered with the first field sample number of each block. The corresponding field card is filled out with the sample number and the RS code "8". The sample preparation laboratory will select a sample in the block to duplicate in this reserved slot, generally the first sample of the field duplicate pair.

If a site is resampled for quality control, cross checking or any other reason, the RS is recorded as "5" and the original sample number is noted in the comments field.

Appendix 2-A

Table of Random Numbers for Final Site Selection

Frequency of occurrence of random numbers, 1 to 4 (expected = 1250): 1262 1275 1228 1235

```
1       3 1 1 2 2 4 4 4 1 4 1 2 2 1 2 4 1 1 2 1 1 1 2 4 1 4 1 2 4 2 2 3 4 3 1 2 1 1 3 1 4 3 1 1 1 3 3 2 2 4
2       3 3 3 1 2 2 3 2 4 3 3 3 3 1 1 1 4 3 3 3 3 3 3 2 4 1 3 3 3 2 2 1 2 1 2 2 4 1 4 4 1 3 4 3 2 4 4 3 4 3
3       3 2 1 1 2 3 4 3 4 1 2 1 4 4 1 3 1 4 4 3 4 1 3 1 1 4 3 4 1 4 4 2 3 3 4 3 2 3 3 3 4 2 2 4 4 1 4 1 2 2
4       2 4 1 3 2 3 1 4 3 3 4 1 1 3 1 3 3 2 4 3 4 4 2 2 1 3 2 4 1 1 1 3 3 1 3 3 2 1 2 1 4 3 3 1 4 4 4 2 3 3
5       1 2 1 3 4 3 4 2 3 4 2 3 3 1 3 1 1 1 3 2 3 3 2 3 1 2 2 1 4 3 2 2 2 4 4 4 4 1 1 1 2 1 3 4 3 3 4 1 3 3
6       4 1 4 4 1 3 3 3 3 2 1 2 3 1 3 3 1 2 4 2 2 3 3 1 2 2 1 2 2 2 2 4 4 3 2 1 2 2 3 2 1 2 2 1 1 3 3 2 3 2
7       3 2 3 4 1 1 4 1 1 2 2 4 2 4 1 2 3 2 1 2 3 1 4 1 2 1 2 2 1 2 2 3 3 2 4 1 3 2 2 1 1 3 1 1 4 1 4 1 3 4
8       2 2 2 1 2 1 3 3 4 1 2 3 2 3 4 4 3 1 4 2 1 4 1 2 4 2 4 1 4 3 4 3 3 4 2 3 3 3 3 3 4 1 2 2 3 3 1 2 3 4
9       1 2 2 4 3 2 3 2 1 3 2 1 1 3 4 3 4 2 1 4 3 2 2 1 3 1 3 3 3 2 2 3 4 2 3 1 1 3 4 1 4 3 3 3 2 4 1 1 4 4
10      4 4 1 3 2 3 3 4 4 3 3 3 2 3 1 2 4 3 1 2 4 1 2 4 4 3 2 4 3 3 2 1 2 2 2 2 1 2 4 1 1 3 2 1 4 2 3 1 4 2
11      2 2 2 4 1 1 1 3 4 2 1 2 3 2 1 3 1 1 2 1 1 4 1 1 2 1 3 1 2 1 3 1 3 2 4 1 3 4 3 1 4 1 2 4 3 1 4 4 2 3
12      2 4 1 1 3 1 3 2 3 1 1 3 3 3 2 3 1 4 3 2 3 2 2 2 3 3 1 2 3 3 1 1 4 3 4 1 3 4 2 4 4 4 1 4 4 3 1 4 3 4
13      1 3 1 1 3 3 3 4 2 3 1 3 2 2 3 2 4 4 1 1 1 3 2 1 2 3 1 4 3 2 1 3 4 1 1 4 3 4 3 4 2 1 2 2 3 2 4 1 4 1
14      1 1 4 3 4 4 2 1 3 4 2 3 2 2 1 1 4 1 1 3 2 3 2 1 3 4 3 4 4 1 4 3 1 1 3 4 4 2 2 4 3 1 3 4 1 1 1 4 2 3
15      2 2 1 1 1 2 2 4 3 1 1 4 1 4 3 2 2 4 4 3 2 1 2 2 3 2 1 1 1 1 1 3 1 3 3 1 4 4 4 1 1 4 4 3 1 4 2 4 2 4
16      2 3 4 4 1 1 2 4 4 2 1 3 1 1 2 3 3 3 3 2 3 1 1 1 2 3 4 1 4 1 2 3 2 2 2 3 1 1 1 4 2 4 4 1 1 2 1 4 1 2
17      2 1 1 2 4 4 1 2 3 1 3 3 2 3 4 3 1 3 2 2 1 2 2 4 3 2 3 2 4 1 4 3 3 1 3 4 3 1 4 2 2 2 1 4 2 2 3 2 3 3
18      3 2 3 4 1 4 1 2 4 3 4 4 4 2 3 4 4 4 3 2 1 2 1 1 1 1 3 4 3 1 2 3 1 1 3 3 1 3 4 3 2 4 3 2 1 1 1 4 3 3
19      4 1 4 1 2 4 2 1 3 1 1 3 1 1 2 2 3 4 2 3 1 1 3 4 2 1 2 3 3 3 1 1 3 2 3 1 3 4 2 3 4 1 3 1 3 2 4 1 3 1
20      2 4 4 1 2 1 1 3 1 3 3 2 3 4 2 4 4 3 2 4 2 2 1 1 3 4 4 1 1 4 2 1 2 3 1 2 2 2 4 1 4 1 1 4 2 3 3 4 1 3
21      4 2 2 2 1 3 4 1 4 4 2 4 2 1 2 2 3 3 1 4 2 4 4 2 4 1 4 2 3 2 2 1 4 1 3 1 3 3 3 3 2 4 2 2 3 1 4 2 1 3
22      2 3 4 2 1 3 1 1 2 3 1 2 3 4 1 4 2 3 3 3 4 4 3 3 1 4 4 4 1 2 3 2 2 1 2 2 4 3 4 3 4 2 1 2 1 3 3 1 2 4
23      4 1 3 2 2 3 1 4 4 3 1 4 4 3 1 4 3 1 1 1 4 3 1 3 2 3 2 4 2 2 2 1 1 3 4 4 3 1 1 2 4 2 1 3 3 1 2 2 2 4
24      1 2 3 2 4 2 4 2 2 4 3 4 1 2 1 4 4 2 1 2 2 1 3 2 1 3 3 4 4 3 3 4 4 4 2 2 1 3 3 1 1 1 4 1 1 4 3 2 3 1
25      1 2 1 2 2 1 2 1 2 4 3 2 4 4 4 3 4 2 2 3 3 3 2 3 3 1 3 2 3 4 3 3 4 3 4 4 1 3 4 4 4 4 1 4 1 1 4 4 4 2
26      3 1 2 2 2 4 1 4 3 3 1 1 4 3 1 4 2 2 2 2 2 1 3 3 2 3 2 2 1 1 2 3 3 1 2 4 4 3 3 1 4 3 2 4 4 3 4 2 1 1
27      2 2 3 4 4 4 1 2 4 1 2 1 1 2 3 3 3 4 3 4 4 1 1 3 4 2 2 1 1 1 3 1 4 4 3 3 3 1 4 1 2 1 3 4 4 1 2 1 4 3
28      4 3 4 2 3 2 3 3 4 2 4 3 1 1 3 3 4 3 1 4 4 2 1 2 3 4 4 2 1 3 1 4 2 2 4 3 3 2 4 4 4 3 4 4 2 2 1 3 4 1
29      3 1 4 3 2 3 2 3 3 3 1 4 2 3 2 2 1 4 4 4 3 2 3 2 3 3 2 4 4 4 4 1 3 3 2 1 2 4 4 1 4 1 2 2 2 1 4 3 4 4
30      3 3 1 2 3 4 2 2 1 2 2 4 1 3 2 3 2 2 1 2 1 4 1 2 2 4 1 1 3 1 3 4 2 1 2 1 2 2 4 4 3 3 4 2 2 4 1 4 1 3
31      2 3 4 4 3 2 1 1 4 1 3 1 2 2 1 1 2 3 3 3 1 1 3 1 3 4 4 2 1 1 3 4 4 1 2 1 2 2 3 2 1 3 1 2 4 1 1 1 4 1
32      2 2 4 1 1 3 1 4 4 3 4 1 2 2 1 1 1 1 4 4 4 3 2 2 3 3 3 2 4 2 1 1 3 4 2 4 4 2 2 3 3 4 3 4 1 4 1 2 2 3
33      1 2 2 4 1 1 3 1 2 2 1 4 4 4 2 2 2 2 3 1 3 2 2 1 4 3 1 2 1 4 3 1 3 2 3 1 1 2 2 3 3 2 1 2 3 3 1 3 4 4
34      1 1 1 4 2 4 2 4 2 2 4 4 1 2 1 2 3 1 3 4 3 2 1 1 1 3 3 2 4 4 4 1 4 4 1 1 1 3 2 1 2 3 3 3 1 3 2 4 3 4
35      1 2 2 3 2 3 1 2 1 4 2 3 1 1 1 3 3 1 4 3 3 4 2 4 1 3 2 3 1 1 2 1 4 4 3 4 2 2 1 1 3 1 1 1 1 2 2 2 2 4
36      2 3 3 2 3 2 1 1 3 2 4 1 2 2 4 1 3 1 3 2 1 1 3 3 1 4 2 3 3 1 3 2 3 3 3 3 3 3 1 2 1 1 4 1 1 3 1 4 1 2
37      1 3 2 1 4 2 1 1 2 3 4 2 2 1 2 1 1 1 4 4 1 1 2 4 3 4 3 3 1 1 3 1 1 1 1 1 4 3 1 3 3 2 4 4 1 2 4 3 3 4
38      2 1 2 3 4 4 3 2 2 2 4 2 1 1 2 3 4 3 4 4 3 3 1 1 3 3 2 1 4 4 2 2 4 1 3 3 4 2 1 1 1 4 4 2 4 4 2 1 1 4
39      1 4 3 4 3 3 4 3 3 4 2 4 4 3 4 3 4 3 2 1 3 1 3 4 1 1 4 1 1 4 2 2 3 4 4 1 2 3 1 3 4 1 1 3 3 2 2 1 2 3
40      3 4 2 4 1 4 3 4 4 1 1 4 4 2 4 4 4 4 1 3 2 4 4 3 4 3 1 2 2 2 2 4 2 3 4 4 3 4 3 1 1 3 2 3 4 2 3 4 4 4
41      2 1 4 3 4 2 2 2 4 1 2 1 3 2 1 4 1 2 1 4 1 1 2 1 2 4 1 3 2 3 2 1 4 3 3 4 1 2 1 4 2 2 3 3 4 3 1 1 4 4
42      4 1 4 3 3 2 4 2 3 4 3 4 1 4 3 1 2 1 1 4 4 4 4 1 1 4 3 1 2 4 2 1 1 2 2 3 1 2 1 4 3 2 2 3 1 1 2 4 3 1
43      3 2 2 2 1 3 4 4 1 4 1 1 4 3 4 3 1 1 1 2 2 4 3 4 4 2 1 4 3 2 1 3 3 3 1 2 1 2 3 4 4 2 4 4 4 2 4 3 4 1
44      4 1 3 1 3 2 3 1 3 2 1 3 1 2 3 4 2 4 4 1 2 2 2 4 4 1 1 2 3 2 3 3 4 4 2 2 3 4 1 1 2 4 1 4 2 1 3 3 4 2
45      4 4 1 4 4 3 2 2 1 1 2 4 3 3 3 3 1 4 1 3 1 4 2 3 3 2 2 3 2 1 1 2 1 4 3 1 4 1 1 3 2 3 4 4 4 3 3 3 4 2
46      4 4 4 1 3 1 3 4 2 1 3 2 2 2 2 3 1 1 3 4 2 4 3 4 2 1 4 1 4 4 4 1 3 4 2 2 3 4 1 1 1 1 3 4 2 3 4 1 1 3
47      2 4 2 3 1 1 1 2 3 1 3 4 3 4 3 4 3 3 3 2 2 1 4 2 2 1 1 3 2 2 3 1 2 2 2 3 3 1 4 3 4 4 3 2 1 1 4 3 4 2
48      1 1 4 3 3 1 1 4 4 4 1 4 2 4 2 2 3 4 1 1 3 2 1 3 3 2 3 1 1 3 4 1 1 1 1 4 2 3 1 2 2 1 3 1 4 4 3 3 2 4
```

49 4 1 4 2 3 2 3 4 4 3 1 4 1 1 2 2 2 1 1 3 3 2 1 1 1 3 1 1 1 3 1 3 3 2 3 1 2 4 3 4 4 4 2 4 2 3 1 1 3 2
50 4 2 2 2 2 4 4 2 3 2 2 3 2 1 4 3 3 3 3 4 1 2 4 4 4 2 3 3 2 1 4 2 2 4 2 1 4 4 2 3 4 2 1 1 3 1 1 1 2 2
51 4 2 3 2 3 1 2 4 1 1 2 4 2 2 2 3 2 2 4 1 1 3 2 4 3 3 4 3 2 2 1 2 2 4 4 1 4 1 1 3 1 1 3 3 1 4 1 4 3 3
52 4 4 3 3 2 1 2 2 1 2 2 1 1 4 4 3 2 4 4 1 1 1 4 2 3 3 3 4 1 2 4 4 2 4 4 2 4 4 3 2 1 4 4 4 2 3 3 4 3 2
53 4 2 1 3 1 1 4 2 2 2 4 2 1 3 2 2 1 2 1 1 4 3 2 1 1 1 1 1 4 4 3 4 4 3 3 2 1 3 3 4 3 4 2 3 3 2 4 3 3 1
54 2 2 2 2 4 2 2 2 4 4 3 4 3 3 4 1 4 4 3 2 1 3 4 3 1 2 2 3 1 2 4 1 4 1 3 1 2 1 3 4 1 3 2 3 1 4 4 3 1 3
55 4 1 4 3 1 3 1 3 2 2 4 3 3 4 3 2 3 3 3 2 3 2 2 3 4 3 2 2 2 4 2 2 2 4 2 4 4 1 4 4 3 4 1 3 3 1 4 2 3 4
56 2 3 1 4 4 2 1 1 3 2 2 1 1 2 1 4 2 2 4 4 1 2 2 4 3 3 1 3 4 3 1 3 4 4 2 2 4 1 1 2 4 2 1 3 2 3 3 1 2 3
57 3 4 1 4 3 3 4 1 3 3 4 1 3 2 3 1 2 1 4 3 3 2 1 4 4 1 1 1 4 4 1 2 4 4 1 1 3 2 2 4 2 1 1 4 2 3 4 1 4 1
58 2 3 3 3 3 4 1 4 1 2 2 1 2 4 4 3 3 3 3 3 3 4 4 1 4 4 2 2 2 3 1 4 2 2 1 2 2 2 1 3 2 3 3 1 1 4 1 2 4 1
59 4 3 1 3 2 4 3 4 4 4 2 1 3 2 4 2 4 4 4 3 3 4 4 4 3 3 2 4 2 1 2 4 2 2 2 1 1 1 3 1 3 3 2 3 4 1 2 1 2 1
60 2 3 4 1 2 1 4 3 3 2 2 1 1 1 1 2 3 2 3 4 4 2 4 1 2 2 1 2 1 4 4 3 2 4 1 4 3 4 1 2 1 4 1 3 4 4 1 4 4 2
61 4 2 4 4 4 4 1 1 1 2 3 3 4 4 2 3 1 3 4 1 2 3 2 2 3 2 4 3 3 2 2 4 2 1 4 2 3 4 3 2 1 1 1 1 3 1 4 3 4 4
62 4 2 2 2 2 3 1 3 4 4 2 1 2 2 1 1 3 3 2 3 1 4 3 4 1 4 1 3 1 4 3 1 1 2 4 1 4 1 2 4 4 1 3 3 2 3 2 2 4 2
63 1 4 2 1 2 1 2 3 1 4 4 1 3 3 2 2 3 3 3 4 2 2 3 1 4 4 1 4 2 2 3 3 1 2 4 3 2 4 1 1 2 3 1 4 3 2 1 1 1 4
64 4 3 1 4 2 1 1 4 3 1 2 4 1 2 3 4 3 2 4 4 2 4 4 1 4 4 2 4 1 3 3 4 1 1 4 3 2 4 4 3 1 3 4 2 1 4 3 4 4 2
65 4 2 4 3 2 4 4 3 4 2 2 2 2 1 1 1 1 4 2 4 4 1 1 1 1 3 2 1 1 4 1 4 2 3 4 3 1 3 3 3 3 4 1 1 1 2 3 3 4 1
66 2 2 4 2 4 3 3 1 2 4 1 4 1 4 4 4 2 2 2 1 3 3 2 4 2 4 4 4 4 3 3 3 1 4 4 3 1 2 4 1 3 4 2 1 2 4 3 4 3 3
67 3 4 3 4 4 2 3 3 1 4 2 2 1 4 2 2 4 3 1 2 4 2 3 4 3 2 1 3 2 3 1 3 3 2 4 1 2 4 2 2 4 1 4 3 2 3 3 3 3 4
68 2 3 1 2 2 2 3 3 2 4 3 2 3 1 2 1 4 4 2 2 3 2 1 2 2 4 3 2 4 1 2 3 1 2 3 3 1 3 1 3 2 2 4 4 4 4 1 4 2 4
69 1 4 4 3 2 1 1 3 3 1 3 1 1 1 1 1 4 1 4 1 2 4 4 4 1 3 2 2 3 4 3 3 4 3 3 4 3 4 1 4 2 1 4 3 2 2 4 3 3 2
70 2 1 1 3 2 4 1 4 4 1 1 2 1 4 1 1 4 2 4 2 4 4 4 1 3 2 3 4 4 4 2 3 2 1 4 1 2 1 4 3 2 4 2 1 4 3 3 2 4 3
71 4 1 2 2 4 2 4 1 3 3 2 1 1 2 1 4 4 3 2 3 3 1 3 3 4 3 2 4 1 4 3 4 4 1 4 1 3 4 4 3 1 4 4 3 3 4 4 2 1 3
72 4 2 4 3 3 3 3 2 3 2 1 2 1 1 2 2 2 2 2 1 2 1 4 2 1 4 4 2 2 4 1 3 4 1 3 4 4 1 1 2 4 1 1 3 4 2 2 4 1 2
73 4 1 3 2 4 2 2 1 4 1 1 2 1 2 4 3 4 3 1 2 4 2 2 4 2 4 3 1 4 2 1 1 4 3 4 3 1 3 4 1 2 2 2 2 4 1 1 4 3 1
74 3 4 2 3 2 1 2 1 2 2 3 4 1 1 3 3 2 2 4 4 4 4 3 1 1 4 3 1 2 2 4 3 1 1 1 1 1 4 2 2 2 3 1 2 1 3 3 2 4 1
75 1 2 3 1 1 4 3 1 1 4 4 1 1 2 3 1 2 2 4 1 3 4 2 2 4 2 1 1 4 2 3 3 2 2 3 3 3 2 2 1 2 1 3 3 4 4 1 1 4 2
76 2 2 2 4 1 4 3 4 1 3 2 2 3 3 2 3 2 1 2 2 1 1 2 4 2 4 4 2 1 3 4 1 3 4 2 3 4 1 2 4 1 2 3 2 3 3 2 3 1 2
77 1 2 4 1 2 3 3 3 1 4 2 3 3 2 2 2 4 3 4 4 1 2 4 4 3 3 1 2 2 4 3 3 3 4 1 2 3 4 3 1 4 1 2 3 4 2 1 4 2 2
78 2 4 3 4 1 3 1 3 1 4 3 1 1 4 4 4 4 1 1 3 2 4 1 3 1 3 3 4 3 3 3 3 2 3 3 3 4 2 4 3 3 2 4 1 1 2 4 1 4 4
79 2 1 2 2 3 3 4 4 3 2 2 1 1 2 2 3 2 1 3 1 1 3 1 1 3 2 2 1 3 3 1 2 1 1 4 3 2 4 3 2 3 3 3 2 2 3 3 4 3 2
80 2 1 1 4 4 2 3 1 4 4 4 1 2 4 2 2 1 2 2 2 3 3 1 3 3 4 4 4 2 4 1 4 4 1 1 4 2 2 4 3 2 3 3 1 4 3 3 1 1 3
81 2 3 3 1 3 3 1 3 2 2 3 1 3 4 2 1 1 2 2 1 2 4 3 4 3 4 2 2 1 3 1 1 1 3 4 3 1 1 4 2 1 3 3 1 3 3 3 4 3 4
82 1 1 4 1 4 1 4 4 3 3 3 2 4 4 1 3 3 2 2 1 4 2 1 2 1 4 4 2 4 1 1 1 4 2 3 3 4 1 4 3 4 1 3 1 1 2 4 4 4 3
83 2 1 1 1 1 4 2 1 4 1 2 4 1 2 4 3 1 4 3 4 2 4 2 2 3 3 4 3 2 2 3 2 1 2 1 3 4 3 3 2 3 2 1 2 3 4 1 1 2 4
84 3 2 2 4 1 4 3 3 3 2 1 1 3 4 4 1 1 2 3 1 4 1 3 4 1 4 1 2 4 3 1 1 3 4 4 3 2 3 4 3 2 2 4 2 1 1 1 1 2 4
85 2 3 3 1 2 4 3 3 2 3 1 4 3 2 1 2 4 1 1 2 2 4 3 4 2 3 4 4 1 3 3 3 1 2 2 1 1 4 1 1 3 1 3 2 3 1 1 4 3 4
86 1 4 3 2 4 4 4 1 2 3 3 2 3 4 4 4 4 3 2 1 3 4 4 4 2 1 3 3 4 2 4 2 4 2 2 2 4 3 2 3 3 3 3 3 2 3 3 2 3 4
87 2 2 1 1 4 2 1 3 4 3 2 2 3 1 2 4 1 4 3 2 3 2 1 4 2 3 1 4 3 2 3 2 4 1 4 1 2 2 4 3 3 2 1 4 2 1 2 4 3 1
88 3 2 1 2 3 2 2 2 1 1 2 3 3 3 3 1 4 3 4 2 2 4 4 3 4 2 1 2 1 2 2 1 3 2 4 1 2 3 2 3 4 1 4 1 4 2 2 2 3 4
89 4 3 1 3 4 4 2 2 2 4 3 4 1 3 4 1 4 4 2 3 3 3 1 2 1 2 3 1 4 1 4 1 1 1 2 1 2 3 4 4 3 1 2 1 1 4 1 1 1 3
90 3 4 2 1 3 2 2 3 3 1 2 3 2 2 2 2 2 3 4 2 1 3 1 3 4 1 1 4 4 1 1 2 2 3 3 2 4 3 1 2 2 4 2 1 4 1 2 4 2 4
91 3 1 3 3 1 4 3 2 2 2 2 2 2 2 2 2 3 4 1 1 1 4 1 2 2 2 3 3 4 1 3 1 1 4 2 3 1 3 3 2 1 4 2 4 2 1 3 2 2 4
92 2 3 1 4 1 2 3 4 1 1 1 2 1 3 2 3 3 1 2 4 4 1 2 4 2 1 1 2 3 2 2 2 2 4 2 1 3 1 2 1 4 2 2 4 4 4 3 2 2 1
93 2 4 4 3 2 4 4 4 2 2 4 1 1 1 2 2 3 2 1 1 4 3 3 4 4 1 1 3 4 2 3 3 2 3 3 4 4 3 1 3 3 4 1 4 4 3 3 4 3 2
94 3 2 3 1 4 3 2 2 4 2 2 1 2 4 4 4 4 4 2 3 3 4 2 3 3 2 1 1 4 4 2 2 4 4 2 1 4 1 3 4 2 4 2 1 3 2 1 4 4 3
95 2 2 1 3 2 3 3 3 2 3 2 2 1 2 3 2 1 4 2 4 2 2 4 2 3 3 4 1 1 2 2 1 3 1 3 3 3 2 1 3 2 4 2 2 2 4 3 1 4 2
96 4 2 1 1 2 4 4 4 3 2 1 1 2 4 1 2 3 2 1 1 4 3 2 3 2 2 1 1 2 2 1 3 4 2 1 3 1 1 3 2 2 3 1 2 3 4 4 4 2 1
97 1 1 4 1 1 3 4 3 3 1 4 4 3 1 2 4 4 4 1 1 1 2 1 1 1 2 2 2 4 4 4 1 2 3 2 1 2 4 4 2 4 3 1 2 2 4 2 2 2 3
98 1 3 1 3 4 2 4 4 4 3 1 2 2 3 1 3 1 2 4 3 1 2 2 4 2 1 4 1 2 1 2 4 1 2 4 3 1 1 3 3 2 4 1 4 2 4 2 4 1 1
99 4 2 2 1 3 3 3 2 1 2 2 3 3 4 4 1 4 2 4 1 4 2 3 2 3 2 2 3 4 2 3 2 4 1 4 4 3 2 1 4 3 1 3 1 2 3 3 4 4 2
100 1 2 1 4 4 3 2 2 4 1 4 2 4 4 1 4 2 1 4 2 4 1 2 4 3 3 2 2 2 1 1 4 1 3 2 1 2 3 2 3 3 3 1 2 3 2 2 4 1 2

PART 3

CANADIAN PROJECT - INSTRUCTIONS FOR COLLECTING MINERAL SOIL SAMPLES

Collecting NASGLP soil samples in Yukon Territory, summer 2007.
(Photo by M. McCurdy)

FIELD COLLECTION OF SOIL SAMPLES

In the field, the final location of the sample site is based on the information obtained from office preparation and on the field conditions encountered by the sampling crew. The objective is to get within 500 m of the pre-selected site and for the final site to have the same soil landscape characteristics as the 1 km^2 target area. For example, a target site was identified in the office as being in an upland area associated with podzolic soils. Once in the field, however, its actual location was determined to be in a low-lying area with gleysol soils but surrounded by upland areas with podzolic soils. In this case, the site would be moved to a point within 500 m of the original site in one of the surrounding upland areas.

Other factors that affect final site selection include the *avoidance of sample sites* as follows:
1) Closer than 200 meters from major highways;
2) Closer than 100 meters from rural roads;
3) Closer than 100 meters from buildings;
4) Closer than 50 meters from end rows in agricultural fields or in areas where large quantities of fertilizer have been deposited; and
5) Closer than 5 km downwind from an active major industrial activity, such as a power plant or smelter.

All sampling equipment that comes into contact with the geochemical samples must be either polyethylene or simple steel in composition. Some steel implements, e.g., shovels, are coated with various types of paint which may peel off and get into the sample. Use of these is unacceptable unless all paint has been removed prior to sampling. An exception to this rule is the use of stainless steel equipment for the collection of samples for analysis of organic compounds.

Particular care must be taken to ensure that all devices used to collect samples for chemical analysis are cleaned prior to every use to avoid cross contamination. Once the pieces of equipment have been cleaned, they must be protected from possible contamination by placing them in plastic bags.

At an ideal mineral soil site the following will be collected: a sample, referred to as the “public health” layer (PH), collected from the top of the H horizon to 5 cm below the top; an A-horizon sample; a B-horizon sample; a C-horizon sample; and separate samples from each of the above horizons and the PH layer for later determinations of bulk density and moisture content.

FIELD EQUIPMENT CHECKLIST

General

GPS unit set to decimal degrees and NAD83/WGS84 Datum
Maps
Clipboard
Field cards
Digital camera
Tape measure (metric) and 15 cm ruler
Munsell soil colour chart
Permanent black markers
Dry eraser board for sample labels for photos
Compass (with inclinometer)
Core box to lay out soil samples for photos and identification
Squeeze or medicine bottle with 10% HCl
Misting bottle
Plastic tarpaulin or sheet
Extra batteries for GPS and camera

Collection Tools

Steel heavy weight shovel (round point firefighter)
Shovel (Montana sharpshooter)
Soil dutch auger, with one extension
Polyethylene garden trowel
Margin mason trowel (5” x 2”)
Pointing mason trowel (7” x 3”)
Folding pruning saw (7” blade) for cutting roots and into the A-horizon
Mallet and wood block
Acrylic/lexan coring tube and extruding foam plug/saran wrap
Cleaning brushes and cloths

Equipment for Sample Storage

Large Kraft paper bags (12” x 6” x 2”)
Plastic sleeves to protect samples during transport
Plastic pails (5 gallon) with lids for sample shipping
Centrifuge tubes (50 ml)
Metal tins for collection of samples for bulk density/moisture content analysis
Electrical tape for sealing plastic bags and metal tins
Plastic garbage bags to be used for lining 5 gallon plastic pails

AT THE SITE - STEP-BY-STEP PROCEDURES FOR SOIL SAMPLING

Preparations for sampling

1. Proceed to the pre-selected site noting vegetation cover, types of exposed bedrock and surficial deposits, and possible sources of contamination in the vicinity of the site. Ideally the collection of samples will take place at the designated site. However, if the site is unsuitable, e.g., backyard of home or grounds of a smelter, select an alternate site within 500 m of the pre-selected site following the guidelines listed in the previous section - Part 2 - Office Preparation for Sample Selection.

2. Ensure that all tools used for sampling have been properly cleaned to avoid contaminating the samples.

3. At a potential site, core samples are collected with an auger to obtain information on the soil profile. To do this, bore into the ground to the depth of the top of the auger bit (about 25 cm). Remove the bit from the hole with the soil core in place and place this core segment into a core box. Re-insert the auger into the hole, bore down another 25 cm and remove the auger from the hole. Discard the top few centimetres of soil from the core and place the second segment in the core box in line with the previous core. Repeat this process, each time noting the auger depth just before removing it from the hole. This is accomplished by (1) placing a finger on the auger shaft level with the ground surface and (2) lining up the shaft with the top of the core box which corresponds to the ground surface. Next, carefully remove the soil from the auger bit. The goal is to examine the uppermost 75 to 100 cm of the soil profile in order to establish the soil type. Figure 3-1 shows an idealized soil profile.

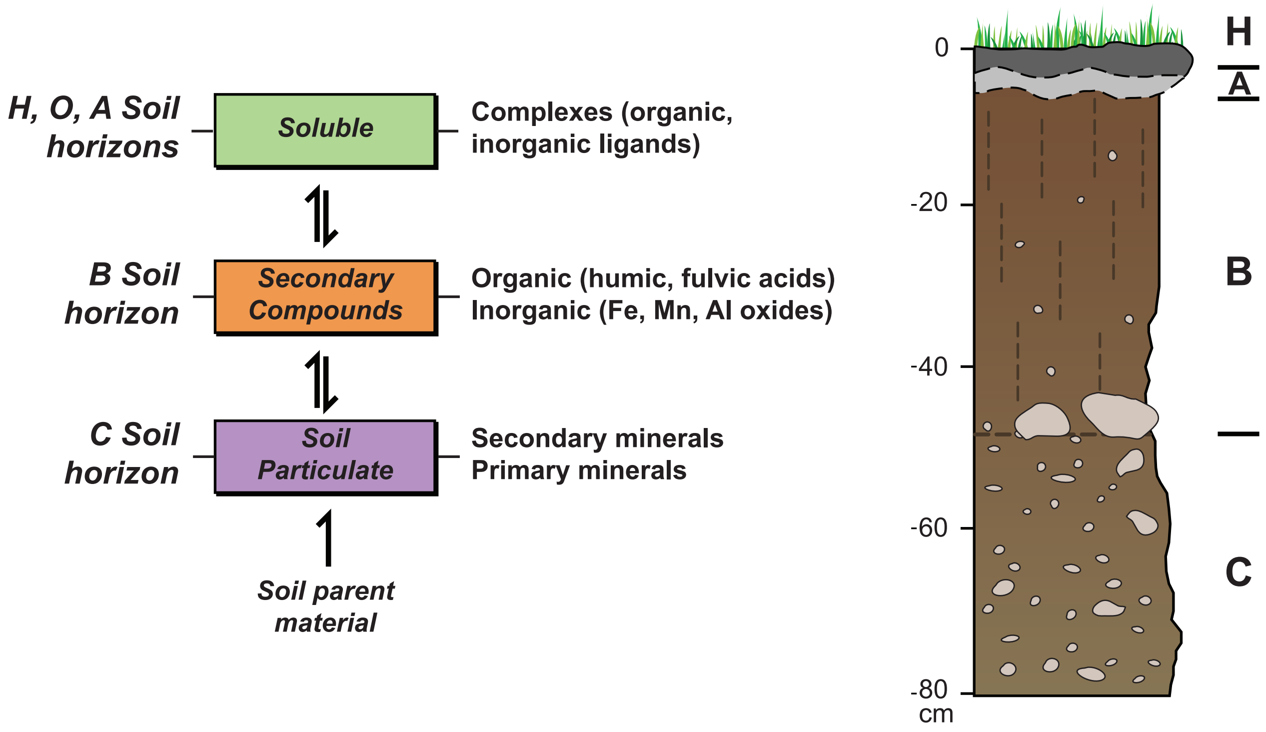


***Figure 3-1**. Diagram shows an idealized soil profile (right side) and descriptions of the soil materials and phases.*

4. Take a photograph of the complete core and then squeeze a stream of 10% HCl along the length of the core to test for effervescence.

5. Once the soil type at the site is identified as being either a primary or secondary soil according to the Soil Landscapes of Canada (SLC) guidelines, begin digging the soil pit for sampling.

Digging the soil pit for sampling

6. A suitable sample pit is a rectangular hole, at least 60 cm wide and 70 cm long, that is free of roots and loose material (see photo at right). The depth of the pit depends on the distance to the top of the C-horizon layer, but should be at least be 60 cm. Where possible, align the long axis of the pit such that one face will be exposed to the direction of maximum light to enhance photography. One side of the long axis of the pit will be used for the collection of A-horizon and B-horizon samples, including those collected for bulk density. Avoid any disturbance or compaction of the area around the face used for sampling. Do not walk on it. Pile the spoil material well away from the pit to prevent it from being knocked back into the hole. Ensure that the pit faces are clean and the soil profile is easily observed. Trim the roots flush with the surfaces of the pit faces.

Step 6. Digging the sample pit.

7. A good technique to expose the soil profile on the selected face is to gently flick small portions of the soil away from the pit face using a trowel (scraping tends to smear the horizons). Clean all loose materials from the pit. Take a photograph of the pit showing the exposed soil profile.

Collecting C-horizon samples

8. Collect a sample of C-horizon for bulk density and moisture content determinations from the bottom of the sample pit. To do this, push and/or tap the corer with a mallet and wooden block down from the bottom of the pit. Remove the corer, supporting its underside by a trowel if necessary. Trim the soil flush with the end of the core cylinder. If the top of the sample is not at right angles to the cylinder take at least two measurements of length and average the two. Additional information on how to collect the bulk density and moisture content samples is found in Appendix 3-D.

9. The second sample collected from the C-horizon is for inorganic chemical element analysis. If possible, this sample is collected from a depth greater than 75 cm by boring into the bottom of the pit using a dutch auger. After each bore into the same hole, discard the top few centimetres of material from the augur bit before putting the remainder into sample bags. Two pre-labelled Kraft paper bags are filled about ¾ full. Fill to just below the set of four holes at the top of the bag (approximately (3-4 litres).

Collecting samples from the "public health" (PH) layer

10. Bulk density samples from the 0-5 cm depth interval or public health (PH) layer, and samples for inorganic analyses from the A- and B-horizons are collected from the undisturbed side of the pit. This is accomplished by systematically exposing layers and collecting samples from a cut made into the undisturbed wall of the pit.

11. The next part of the sampling procedure involves collection of samples from the 0-5 cm (PH) interval. Regardless of the mixture of horizons or soil materials, a composite of all soil materials present (mineral and/or organic) are collected between 0 and 5 cm, with 0 cm referring to the upper soil surface. The upper soil surface is considered to be the top boundary of the first soil layer that can support plant/root growth. This equates to: (a) for bare mineral soils: the air/earth interface; (b) for vegetated mineral soils: the upper boundary of the first layer that supports root growth - the top of the H-horizon if it is present; and (c) for organic soils (not covered in this manual): the upper boundary of the first layer that supports root growth, excluding freshly fallen plant litter, but including litter that has compacted and begun to decompose. These samples may be in part duplicative of other samples such as the O or A horizons, but are valuable for providing information on that portion of the soil to which humans are most often exposed.

Collect the PH sample for bulk density analysis. At the undisturbed edge of the sample pit clear away the L- and F-horizon materials to expose the H-horizon material or upper mineral soil (usually the A-horizon). At a depth of 5 cm below the exposed surface (the 0 cm level), slide a flat trowel into the pit face. Push the coring device down until it meets the surface of the trowel. Lift out the core keeping the trowel on its underside for support. The sample should fill the coring device to a depth of 5 cm and be flush with the base of the coring device.

11A. Using foam plugs wrapped in Saran, extrude the material into a metal container labelled with the sample number and volume of sample (length of core tube x diameter). Use electrical tape to seal any gaps between the lid and the container. Insert the metal container into a Ziploc bag and seal.

12. Collect a PH sample for analysis of inorganic components. Use the pruning saw to cut out a block of soil materials adjacent to the core hole remaining from the bulk density sample. A block of about 25 x 25 x 5 cm is needed to fill two previously labelled Kraft paper bags. Slice the block down the middle and use a trowel to lift each section into the Kraft bag.

Collecting samples from the A-horizon

13. Collect a bulk density sample of the A-horizon from an undisturbed side of the pit. One potential spot to collect this sample is located adjacent to the gap in the surface where the PH sample was removed for inorganic analysis. Clear an area to expose the top of the A horizon. Insert a flat trowel into A-horizon layer (above the Ae horizon, if present) and push the corer down from the surface to the trowel. Remove the coring device and continue as in Step 11A.

14. Collect a sample of A-horizon material for inorganic element analysis. Label two Kraft paper bags. Collect 3-4 litres of A-horizon material (excluding Ae material) near the area from which the A-horizon bulk density sample was collected. (Note: The coring device must be made of plastic.) After sufficient material is collected, continue clearing the cut downwards on the side of the pit until the top of the B-horizon is exposed.

Collecting B-horizon samples

15. Collect a sample for bulk density analysis from the B-horizon layer. Push and/or tap the corer with a mallet and wooden block down from the B-horizon surface until the bottom of the B-horizon is reached or as far as it is possible to go without compressing the sample. Remove the corer, supporting its underside by a trowel if necessary. Trim the soil flush with the end of the core cylinder. If the top of the sample is not at right angles to the cylinder take at least two measurements of length and average the two. Proceed as in Step 11A.

16. Collect a B-horizon sample for inorganic element analysis. Prior to sampling, label two Kraft paper bags. Collect approximately 3-4 litres of B-horizon material from the area near where the B-horizon bulk density sample was collected. Collect from the upper zone of enrichment (illuviated zone) on the pit face.

Collecting a sample from the "public health" (PH) layer for anthrax analysis

17. The sample from the PH interval is collected in a 50 ml centrifuge tube. Insert the trowel at 5 cm depth. Push the tube until the trowel is reached 2 or 3 times in order to fill the tube.

Collecting additional samples for value-added activities related to the Canadian project

18. In many cases there will be additional sampling undertaken to support the value added activities related to the Canadian Project. For example, in 2007, samples were collected using the following methodologies:

a) For the purpose of comparing National Forest Inventory and NASGLP sampling methodology - Collection of interval-based samples at 3 depths from the undisturbed pit wall: 0 - 15 cm; 15 - 35 cm and 35 - 55 cm. Use a set of bench cuts to collect the samples in sequence. Fill one Kraft bag for each sample. Label the bags with the site and interval information, e.g., NB071006 15 to 35.

b) For the purpose of comparing results for soil toxicity studies undertaken by Health Canada with those of the NASGLP - Collection of composite samples from the 0 - 5 cm and/or 0 - 30 cm depth intervals. Collect samples for the analysis of organic compounds using a stainless steel probe. These samples have been collected at a percentage of the NASGLP sites.

Completing the documentation and photography

19. Complete the documentation of field observations on the the field sheet. Take a series of photographs, at least one from each of the four points of the compass.

Filling and marking the hole

20. Begin filling in the pit. When the fill material is about 10 cm below the surface drop a sealed Ziploc bag containing a horseshoe and a Tyvex tag with the site ID into the hole. Continue filling in the pit.

21. Flag the site and note the end time. Go to the next site or finish for the day.

FILLING IN THE FIELD CARD

The components of the NASGLP field card for inorganic mineral soils are shown in Appendix 3-A. An associated document, referred to as a field guide, has the explanations and further information needed to complete the various fields and terms. It is presented in Appendix 3-B. The field card is appropriate for mineral soils in non-permafrost areas and, with some modification, in permafrost areas.

The field card is detailed enough to provide the necessary and other useful information about the samples and sites. However, it was designed to be user-friendly for field personnel who are not soil scientists.

Sampling at each site requires the completion of a paper field form. The paper field forms are later scanned and the data included in a database. Hence, legibility is an important requirement.

A customized Excel spreadsheet will be provided for the entry of the field data. It is recommended that the data be entered on a daily basis so that errors or omissions will be detected and corrected while memories are still fresh.

There is no panacea in terms of a feature list, e.g., the landform list. Because the NASGLP data may be integrated with Agriculture and Agri-Food Canada National Land and Water Information Service (NLWIS) database, feature lists are taken from the NLWIS (2007), wherever possible.

AN EXAMPLE OF REGIONAL SOIL TYPE DISTRIBUTION

To provide an example of the distribution of different types of soils on a regional basis, we refer to the eastern provinces of Canada sampled in 2007. Table 3-1 provides a summary and estimates of the areas in New Brunswick, Nova Scotia, and Prince Edward Island covered by soils belonging to specific Orders and Great Groups. The areal extents were calculated, based on the Soils Landscape of Canada digital map (SLC version 2.2). Field crews sampling in the 3 eastern provinces of Canada were required to familiarize themselves with the characteristics of the three main soil orders (Podzols, Luvisols and Gleysols) and the associated great groups. To this end, a supplementary document (Appendix 3-C) was compiled that provided the information pertinent to these soil types. It included lists and explanations of the lower case suffixes commonly added to further describe soil horizons. The construction of similar supplementary documents is recommended for sampling in other parts of Canada.

Table 3-1. Estimated areas in New Brunswick (NB), Nova Scotia (NS) and Prince Edward Island (PEI) covered by soils belonging to specific Orders and Great Groups (Soil Classification Working Group, 1998).

ORDER	GREAT GROUP	NB	NS	PEI
ORGANIC		4%	7%	
REGOSOLIC	Humic Regosol			
	Regosol	<1%	3%	1%
BRUNISOLIC	Sombric Brunisol	<1%		
	Eutric Brunisol	<1%		
	Dystric Brunisol	<1%		
PODZOLIC	Humic Podzol		2%	
	Humo - Ferric Podzol	56%	62%	82%
	Ferro-Humic Podzol	12%	5%	
LUVISOLIC	Gray Brown Luvisol			
	Gray Luvisol	15%	5%	5%
GLEYSOLIC	Luvic Gleysol			
	Humic Gleysol			
	Gleysol	11%	9%	12%
Not Applicable		<1%	8%	
Total: Podzolic + Luvisolic + Gleysolic		94%	83%	99%

Appendix 3-A

Field Cards for Sampling Mineral Soils

Collecting soil samples from the "public health" layer and A-, B- and C-horizons near Pembroke, Ontario, in summer 2008. (Photo by I. Kettles)

Tri-National Mineral Soil Sampling Field Data

Site Sample
GRTS Site ☐
NFI Site ☐

Cell ID

Site ID

RepStat

Resampled Site
No x Yes x ➡
Previous Site ID

NFI Network Label

Samples Collected

PH interval
for inorg. analysis ☐
for org. analysis ☐

A - horizon ☐
B - horizon ☐
C - horizon ☐

Anthrax ☐
NFI (0-15cm) ☐
Other: ______

	Moisture Only	Bulk Density	Sample depth interval Top	Bottom
PH	☐	☐ —	______cm	______cm
A-horizon (% of A and H material collected when A material is insufficient)	☐	☐ —	______cm A ______%	______cm H ______%
B-horizon	☐	☐ —	______cm	______cm
C-horizon	☐	☐ —	______cm	______cm

NTS

Latitude NAD83
.
Decimal Degrees

Longitude NAD83
.
Decimal Degrees

Elevation
m

Weather
Sunny/Clear ☐
Partly cloudy ☐
Overcast ☐
Rain ☐
Sleet ☐
Snow ☐

Date
D D M M Y Y

Time
START :
FINISH :

Air Temp.
∞C

Name of Samplers

❶ **Type of Surface Material**

Mineral Soil ☐
Organic Soil ☐
Non-Soil ☐
Urban ☐

❷ **Mode of Deposition**

Anthropogenic ☐
Colluvial ☐
Eolian ☐
Fluvial ☐
Glaciofluvial ☐
Glaciolacustrine ☐
Glaciomarine ☐
Lacustrine ☐
Marine ☐
Residual ☐
Saprolite ☐
Till (Morainal) ☐
Undifferentiated Mineral ☐
Volcanic ☐

❸ **Local Surface Expression**

Mineral Surface Form
Blanket ☐
Dissected ☐
Fan ☐
Hummocky ☐
Inclined ☐
Pitted ☐
Level ☐
Rolling ☐
Ridged ☐
Steep ☐
Terrace ☐
Undulating ☐
Veneer ☐

❹ **Vegetation Cover**

Agricultural Crops ☐
Coniferous Forest ☐
Deciduous Forest ☐
Grassland ☐
Arctic Desert ☐
Lichen ☐
Mixed Forest ☐
Parkland ☐
Shrubland ☐
Tundra
- *Alpine* ☐
- *High Shrub* ☐
- *Medium Shrub* ☐
- *Low Shrub* ☐
- *Broken Herb - Low Shrub* ☐

Unvegetated Surface ☐
Meadow, Wet ☐

❺ **Rockiness**

Nonrocky (<2%) ☐
Slightly rocky (2-10%) ☐
Moderately rocky (10-25%) ☐
Very rocky (25-50%) ☐
Exceedingly rocky (50-90%) ☐
Excessively rocky (>90%) ☐

❻ **Stoniness**

Nonstony (<0.01%) ☐
Slightly stony (0.01 - 0.1%) ☐
Moderately stony (0.1 - 3%) ☐
Very stony (3 -15%) ☐
Exceedingly stony (15 - 50%) ☐
Excessively stony (>50%) ☐

❼ **Bedrock Type**

Igneous, (Intrusive) ☐
Igneous, (Extrusive) ☐
Igneous, (Pyroclastic) ☐
Metamorphic ☐
Sedimentary ☐
Evaporites, Organics, Precipitates... ☐
Other ☐

❽ **Slope**

Slope Type
Simple ☐
Complex ☐

Slope Gradient

% Slope	Class	
0 to 3	1	☐
4 to 9	2	☐
10 to 15	3	☐
16 to 30	4	☐
31 to 60	5	☐
>60	6	☐

Sample Site Position on Slope
Crest ☐
Upper Slope ☐
Middle ☐
Lower Slope ☐
Toe ☐
Depression ☐

Slope Aspect ∞

❾ **Drainage**

Very rapidly drained ☐
Rapidly drained ☐
Well drained ☐
Moderately well drained ☐
Imperfectly drained ☐
Poorly drained ☐
Very poorly drained ☐

⓬ **Contamination**

- None ☐
- Possible ☐
- Probable ☐
- Definite ☐
  - Farming ☐
  - Housing ☐
  - Industry ☐
  - Logging ☐
  - Mining ☐
  - Road ☐
  - Garbage ☐
  - Other ______

Revised May 12th, 2008

Soil Horizon Description

Site ID

	1 Horizons				2 Depth		3 HB		4 Colour	5 Mottles				6 Roots			7 CF	8 Structure			9 MC	10 Texture	11 Eff
#	D	Ma	Suffix	M	Up	Low	D	F		A	S	C	Colour	S	Q	L	%	G	T	C			
1																							
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							

Soil Profile Diagram

Depth of thaw ______ cm
Not Applicable ☐
Unknown ☐

Estimated max thaw depth ______ cm
Not applicable ☐
Unknown ☐

Depth to bedrock ______ cm
Not applicable ☐
Unknown ☐

Depth to watertable ______ cm
Unknown ☐

Depth to impermeable layer ______ cm
Unknown ☐

Soil Classification (Section 3)

Order	Great Group	Sub-Group

Comments:

SITE PHOTOS!

Codes for Horizon Description

	1 Horizons				2 Depth		3 HB		4 Colour	5 Mottles				6 Roots			7 CF	8 Structure			9 MC	10 Texture	11 Eff
#	D	Ma	Suffix	M	Up	Low	D	F		A	S	C	Colour	S	Q	L	%	G	T	C			
1	-	B	f	-	22	34	G	S	Reddish Brown	C	F	D	Red Brown	F	P	T	30	M	B	F	VF	Sandy Loam	S

1 **Horizons**
D: Lithological discontinuity
Ma: Master horizons (O, A, B, C)
Suffix: Suffixes
M: Modifier (B1, B2, B3)

3

Horizon Boundary	
Distinctness (Vertical Change)	**F**orm
A: Abrupt (<2cm)	**S:** Smooth
C: Clear (2-5 cm)	**W:** Wavy
G: Gradual (5-15cm)	**I:** Irregular
D: Diffuse (>15cm)	**B:** Broken

Table 1. Correlation of Munsell colours with descriptive colours (AG Boden, 1994)

4

Colour hue and value 5	Chroma					
	/1	/2	/3	/4	/6	/8
7.5R 5/	Reddish Gray		Red Gray	Gray Red	Red	
10R 5/					Gray Red	
2.5YR 5/					Red Brown	
5YR 5/	Brownish Gray		Brown Gray	Gray Brown	Reddish Brown	
7.5YR 5/		Brown Gray			Brown	
10YR 5/	Gray				Yellowish Brown	
2.5Y 5/		Yellowish Gray	Yellow Gray		Yellow Brown	
5Y 5/	Greenish Gray		Green Gray	Gray Green	Olive Green	
5G 5/						
5B 5/	Blue Gray					
5BG 5/						

5

Mottles		
Abundance	**S**ize (mm)	**C**ontrast
F: Few (<2mm)	**F:** Fine (<5)	**F:** Faint
C: Common (2-20)	**M:** Medium (5-15)	**D:** Distinct
M: Many (>20)	**C:** Coarse (>15)	**P:** Prominent

6

Roots			
Size / Quantity	**F:** Fine (<2mm)	**M:** Medium (2-5mm)	**C:** Coarse (>5mm)
F: Few	10	1	1
P: Plentiful	10-100	1-10	1-5
A: Abundant	>100	>10	>5

Location
T: Throughout
M: Matted on top of horizons
C: in cracks

7 **Coarse Fragments (CF)**
Estimated value in % (>0.2 cm)

8 **Structure (Page 23-24)**
Grade
- **W**: Weak
- **M**: Moderate
- **S**: Strong

Type
- **S**: Structureless
- **B:** Blocklike
- **P:** Platelike
- **R:** Prismlike

Class
- **VF**: Very fine
- **F**: Fine
- **M**: Medium
- **C**: Coarse

9 **Moist consistency**
L: Loose
VF: Very friable
F: Friable
M: Firm
VM: Very firm

10 **Field Texture**
Clay, Sandy Clay, Sandy Clay Loam
Silt, Silty Sand, Silt Loam, Silty Clay Loam
Loam, Sandy Loam, Loamy Sand
Sand, Very Fine Sand, Fine Sand, Medium Sand, Coarse Sand, Very Coarse Sand

11 **Effervescence**

N: Noncalcareous
W: Weakly
S: Strongly
E: Extremely

Appendix 3-B

Guide for Completion of the Mineral Soil Field Card

Collecting samples in the Gaspé area of Quebec in summer 2008. (Photo by R. McNeil)

PAGE 1 - SITE INFORMATION (TOP GREY AREA)

As noted in this previous section, the feature lists follow the feature lists in National Land and Water Information Service (NLWIS), 2007. In most cases the information in the sections that follow has been taken directly from this source. The NLWIS document can be downloaded from http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1227209183756&lang=eng

Site sample - Indicate whether the sample site is a primary or secondary NASGLP GRTS site or a National Forest Inventory (NFI) site.

Samples collected - Check off the routine samples collected at the site (PH and A-, B-, and C-horizon for the Canadian project) as well as "Other" for any types of samples that are not standard procedure, e.g., the sample from the 0-30 cm depth interval collected for soil toxicity studies. This data field is useful for cross checking samples and cataloging the roster of collected materials. Refer to Part 3 - Instructions for Collecting Mineral Soil Samples - for the description of the various types of samples.

Cell identification - A five-character 'Cell ID' identifies each 40 x 40 km^2 grid cell for North America generated for the NASGLP. The Cell ID consists of two letters and three numbers: for example, the city of Fredericton, New Brunswick, is located in grid cell EP119.

Site identification - The first two characters in the Site ID field indicate the province or territory where the sample site is located, using the same characters used by Canada Post, e.g., NL - Newfoundland and Labrador and ON - Ontario. The next two characters are numbers that indicate the year of collection, followed by a single digit (from 1 to 9) which is assigned to the crew collecting the sample. The last three characters form a number that identifies each site, beginning with the number 001. The soil samples collected at each site will be designated by writing the Site ID on the sample bag, followed by the soil sample name, such as PH (0-5 cm), A, B, C, etc. For example, AL-07-3035A would identify the A-horizon soil collected from sample site 035 by crew 3 in Alberta, Canada. Field duplicate sites are numbered in sequence with regular sites but are identified as field duplicate pairs on the field card by a "10" and "20" in the Rep Stat (replicate status) field.

Rep stat - 'Rep Stat' is an abbreviation of Replicate Status and is a two-digit number, i.e. 00, 10, 20, 30, 70, 80 or 90, indicating the relationship of the sample to others in the survey. Note that sample crews will NOT be using 80 and 90 designations in the field.

00 - routine site
10 - first sample in a field duplicate pair
20 - second sample in a field duplicate pair
30 - resample of a previously sampled site
70 - cell duplicate
80 - blind duplicate number (empty bag) to be used at a later time for a blind duplicate split from one routine sample within a block of 20 samples
90 - control reference sample for insertion of standard reference material

Resampled site - In some cases it may be necessary to revisit a site at a later date. Some reasons for resampling are as follows: as a duplicate to cross-check results from a previous year; for follow-up work; or for QA/QC considerations. A new Site ID is required, but the original Site ID will also be recorded in this data field on the field card.

NFI Network Label - The National Forest Inventory Network Label identifies the point on the network associated with the plot of NFI sample sites. Permitted values range from 1 to 2399999.

NTS - National Topographic System, 1:250,000 index reference, consisting of up to three numbers, including leading zeros, and one letter (A to P), e.g., 085E, occupying the first four positions. The last two boxes are used for the 1:50,000 NTS map sheet identification number (1 to 16), if applicable.

Latitude NAD83 – A record of the geographical latitude of the site in decimal degrees to five decimal places, e.g., 59.56789. All measurements will be derived using a reference datum of NAD 1983 (North American Datum, 1983).

Longitude NAD83 – A record the geographical longitude of the site in decimal degrees to five decimal places, e.g., -120.56789). Note that values in North America are negative. All measurements will be derived using a reference datum of NAD 1983 (North American Datum, 1983).

Elevation – A record of the height with respect to mean sea level (MSL) at the site location, measured in meters (m).

Date - DAY/MONTH/YEAR – A record of the date of the observations. Use numeric notation DD, MM, YY, e.g., 19/08/07 for August 19, 2007

Time - The time of arrival at the site and the time at the end of collecting the samples and site data. Use local time.

Weather and air temperature – A record of prevailing weather conditions at the time of sample collection. Record the dominant weather conditions and air temperature, e.g. Rain, 21°C

Name of samplers - Record the names or initials of the sampling crew and any other individuals present who were involved with collecting the samples or making site observations.

PAGE 1 - SITE DESCRIPTION (BOTTOM WHITE AREA)

Type of surface material

Record the type of surface material according to the following categories.

The information in this section was taken from Chapter 2 of Canadian System of Soil Classification, 3rd Edition. The chapter can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt2.html.

Soil - Soil is defined herein as the naturally occurring, unconsolidated mineral or organic material at least 10 cm thick that occurs at the earth's surface and is capable of supporting plant growth. In this definition "naturally occurring" includes disturbance of the surface by activities of man such as cultivation and logging but not displaced materials such as gravel dumps and mine spoils. Unconsolidated material includes material compacted or cemented by soil-forming processes.

Mineral Soil – Mineral horizons contain 17% or less organic carbon (about 30% organic matter) by weight. Considered here are the A, B and C mineral horizons.

Organic Soil – Organic horizons occur in Organic soils and commonly at the surface of mineral soils .They contain more than 17% organic C (about 30% or more organic matter) by weight. Although two groups of these horizons are recognized, the O horizons (peat materials) are not considered here. ‘Organic soil’ refers to folic materials (L, F and H horizons) only.

Non-Soil - Non-soil is the aggregate of surficial materials that do not meet the preceding definition of soil. It includes soil materials displaced by unnatural processes such as dumps of earth fill, unconsolidated mineral or organic material thinner than 10 cm overlying bedrock, exposed bedrock, and unconsolidated material covered by more than 60 cm of water throughout the year. Nonsoil also includes organic material thinner than 40 cm overlying water.

Urban – Soil material having a non-agricultural, man-made surface layer more than 50 cm thick that has been produced by mixing, filling, or by contamination of the land surface in urban and suburban areas. Examples of fill material in urban soils include natural soil materials that have been moved around by humans, construction debris, materials dredged from waterways, coal ash, municipal solid waste and combinations of any of the above.

Mode of Deposition

Record the mode of deposition of the sediments upon which soil is developed and/or the sample is being taken.

Some background information on surficial materials for Canada is included in Part 5 of this manual. Study of reports and maps relating to the soils and surficial and bedrock geology of the region being sampled is needed. This will provide the members of the sampling crew with an understanding, within a regional context, of the types of sediments and soils they are likely to encounter in the areas being sampled. These publications are available through the Geological Survey of Canada and the provincial and territorial surveys and also from Agriculture and Agri-Food Canada.

The following information on mode of surficial sediment deposition was taken mostly from Chapter 18 of the Canadian System of Soil Classification (3rd Edition). It can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt18.html.

Anthropogenic – Man-made or man-modified materials, including those associated with mineral exploitation and waste disposal. They include materials constructed by man or geological materials modified by man so that their physical properties (structure, cohesion and compaction) have been drastically altered.

Colluvial – Massive to moderately well-stratified, non-sorted to poorly sorted sediments with any range of particle sizes from clay to boulders and blocks that have reached their present position by direct, gravity-induced movement. They are restricted to products of mass-wasting whereby the debris is not carried by wind, water or ice (except snow avalanches).

Aeolian – These materials have been transported and deposited by wind action. They consist of medium to fine sand and coarse silt particle sizes, that is well-sorted, poorly compacted and may show internal structures such as cross-bedding or ripple laminae, or may be massive.

Fluvial – These materials have been transported and deposited by streams and rivers. They generally consist of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well-sorted and display stratification, but massive, non-sorted fluvial gravels do occur. They take the form of channel deposits, overbank deposits, terraces, alluvial fans and deltas.

Glaciofluvial - These materials have been transported by meltwater streams flowing from wasting glacier ice. They are composed of complexly bedded and faulted, coarse bouldery to cobbly gravel interbedded with sand, gravel, and, in some places, bedded fine sand and silt. They take the form of eskers, kames, kame terraces, subaqueous fan deposits and outwash plains.

Glaciolacustrine - These materials were deposited in a glacial lake during deglaciation and subsequent lake drainage or laid down under alternating or overlapping lacustrine and fluviatile conditions. Some glacial lakes were local and small while others existed at the scale of the present day Great Lakes. These deposits are composed of rhythmically bedded clay and silt to fine sand or stratified gravel.

Glaciomarine - These materials were deposited from meltwater and floating ice, in marine waters, during deglaciation and subsequent regression. They are composed of stratified to massive, clay to gravel.

Lacustrine – Sediment generally consisting of stratified fine sand, silt and clay deposited on the lake bed; or moderately well-sorted and stratified sand and coarser materials that are beach and other near-shore sediments transported and deposited by wave action. These are materials that either have settled from suspension in bodies of standing fresh water or have accumulated at their margins through wave action.

Marine - Unconsolidated deposits of clay, silt, sand or gravel that are well to moderately well-sorted and well-stratified to moderately stratified (in some places containing shells). They have settled from suspension in salt or brackish water bodies or have accumulated at their margins through shoreline processes such as wave action and longshore drift.

Residual – A residual soil is formed above in-situ parent rock after all soluble elements have dissolved away by mechanical and chemical weathering.

Saprolite – Rock containing a high proportion of residual silts and clays formed by alteration, chiefly by chemical weathering. The rock remains in a coherent state, interstitial grain relationships are undisturbed, and no downhill movement due to gravity has occurred.

Till (Morainal) – Sediment generally consisting of well-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often in a mixture of sand, silt and clay that has been transported beneath, beside, on, within and in front of a glacier and not modified by any intermediate agent. Examples are basal till (ground moraine), lateral and terminal moraines, rubbly moraines of cirque glaciers, hummocky ice-disintegration moraines and pre-existing, unconsolidated sediments reworked by a glacier so that their original character is largely or completely destroyed.

Undifferentiated mineral – A layered sequence of more than three types of genetic material outcropping on a steep erosional escarpment. This complex class is to be used where units relating to individual genetic materials cannot be delimited separately at the scale of mapping. It may include colluvium derived from the various genetic materials and resting upon the scarp slope.

Volcanic – These deposits consist of unconsolidated pyroclastic sediments. Examples are volcanic dust, ash, cinders and pumice.

Local surface expression – Mineral surface form

Most of the information in this section was taken from Chapter 18 of Canadian System of Soil Classification, 3rd Edition and from the Component Table of Soil Landscapes of Canada, v. 2.0. The chapter can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt18.html and http://sis.agr.gc.ca/cansis/nsdb/slc/v2.0/component/locsf.html, respectively.

The surface expression of genetic materials is their form (assemblage of slopes) and pattern of forms. Form as applied to unconsolidated deposits refers specifically to the product of the initial mode of origin of the materials. When applied to consolidated materials, form refers to the product of their modification by geological processes. Surface expression also indicates how unconsolidated genetic materials relate to the underlying unit.

Blanket - A mantle of unconsolidated materials thick enough to mask minor irregularities in the underlying unit but still conforming to the general underlying topography. Examples are a till plain and lacustrine blanket overlying hummocky moraine

Dissected - A dissected (or gullied) pattern providing external drainage for an area.

Fan - A fan-shaped form similar to the segment of a cone and having a perceptible gradient from the apex to the toe. Examples are alluvial fans, talus cones, and some deltas.

Hummocky (or irregular) - A very complex sequence of slopes extending from somewhat rounded concavities (or swales) of various sizes to irregular conical knolls (or knobs) and short discontinuous ridges; there is a general lack of concordance between knolls and swales. Slopes are generally 9-70%. Examples are hummocky moraines and hummocky fluvioglacial landforms.

Inclined - A sloping, unidirectional surface with a generally constant slope unbroken by marked irregularity or gullies; a weakly developed dissected pattern provides external drainage for the local area. Slopes are 2-70%. The form of inclined slopes is not related to the initial mode of origin of the underlying material. Examples are: terrace scarps, river banks.

Pitted (knoll and kettle) - A chaotic sequence of knolls and kettles (or sloughs), which occupies 15-20% of an area and has no external drainage. Slopes are generally >3%. Examples are morainal plains and hill lands.

Level - A flat or very gently sloping, unidirectional surface with a generally constant slope unbroken by marked elevations and depressions. Slopes are generally <2%. Examples are floodplains and lake plains.

Rolling - A very regular sequence of moderate slopes extending from rounded and, in some places, confined concave depressions to broad, rounded convexities producing a wavelike pattern of moderate relief. Slope gradients are generally >5% but may be less. This surface form is usually controlled by the underlying bedrock.

Ridged - A long, narrow elevation of the surface, usually sharp crested with steep sides. The ridges may be parallel, subparallel, or intersecting. Examples are eskers, crevasse fillings, washboard moraines and some drumlins.

Steep - Erosional slopes of >70%, present on both consolidated and unconsolidated materials. An example is an escarpment.

Terraced - Scarp face and the horizontal or gently inclined surface (or tread) above it. An example is an alluvial terrace.

Undulating - A very regular sequence of gentle slopes that extends from rounded and, in some places, confined concavities to broad, rounded convexities producing a wavelike pattern of low local relief. Slope length is generally <0.8 km and the dominant gradient of slopes is usually 2-5%. The terrain lacks an external drainage pattern. Examples are some ground moraines and lacustrine material of varying textures.

Veneer – Unconsolidated materials too thin to mask the minor irregularities of the underlying unit surface. A veneer ranges from 10-100 cm in thickness and possesses no form typical of the material's genesis, e.g., shallow lacustrine deposits overlying till.

Vegetation Cover

Record the vegetation cover or land use, or both.

The information in this section was obtained from Soil Landscapes of Canada, v. 2 (Soil Landscapes of Canada Working Group, 1996). It can be downloaded from the http://sis.agr.gc.ca/cansis/nsdb/slc/v2.0/component/veget.html. The original information was derived from documents released by Permafrost Subcommittee (1988) and National Wetlands Working Group (1987).

Agricultural Crops - Cultivated field crops.

Coniferous Forest - Dominated by needle-leaved, cone-bearing species. In the Subarctic Ecoclimatic Regions this refers to an open lichen coniferous forest; in the Boreal Ecoclimatic Regions this refers to a closed canopy coniferous forest.

Deciduous Forest - Dominated by broadleaf species.

Grassland - Perennial native grassland or improved pasture.

Arctic Desert - Unvegetated areas in the High Arctic; may be caused by either climatic (too cold or too dry) or edaphic (low soil nutrients or toxic substrates such as salt) factors, or a combination of both.

Lichen - Dominated by lichens with significant amounts of mosses and usually including low to medium ericaceous shrubs.

Mixed Forest - Composed of both coniferous and deciduous tree species.

Parkland - A forest - grassland transition consisting of a mosaic of trembling aspen stands interspersed with patches of cropland, grassland, and meadow.

Shrubland - Dominated by shrub species.

Tundra, alpine - Treeless terrain occurring at high altitudes, immediately above the forest zone and the upper altitudinal timberline. Vegetation consists of lichens, mosses, sedges, grasses, forbs, and low shrubs (<20 cm) such as heath, dwarf willows, and birches.

Tundra, high shrub - Dominated by 20-60 cm high shrubs occurring in the Low Arctic Ecoclimatic Region.

Tundra, medium shrub - Dominated by 10 - 20 cm high shrubs occurring in the Mid-Arctic Ecoclimatic Region.

Tundra, low shrub - Dominated by <10 cm high shrubs occurring in the High Arctic Ecoclimatic Region.

Tundra, broken herb-low shrub - Dwarf shrubs, Dryas and willows are important components of the vegetation. Other vascular plants are present but have low total coverage. Crustose lichens are common on the ground surface. Ground cover ranges from 10-20%.

Unvegetated Surface – No vegetation observed.

Meadow, Wet - Dominated by sedges and cotton grass, with “wet” mosses (e.g., Mnium spp., Sphagnum spp.) and occasional herbs.

Rockiness

Record the estimated area of rock outcropping in the vicinity of the sample site.

The information in this section was taken from Chapter 15 of the Canadian System of Soil Classification (3rd Edition). It can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt15.html.

Nonrocky - Bedrock exposures cover less than 2% of the surface and are more than 100 m apart. There is some interference with tillage, but to a small extent.

Slightly rocky - Sufficient bedrock exposures are present to interfere with tillage but not to make intertilled crops impracticable. Depending upon how the pattern affects tillage, rock exposures are roughly 35-100 m apart and cover 2-10% of the surface.

Moderately rocky - Sufficient bedrock exposures make tillage of intertilled crops impracticable, but soil can be worked for hay crops or improved pasture if other soil characteristics are favourable. Rock exposures are roughly 10 - 35 m apart and cover 10-25% of the surface, depending upon the pattern.

Very rocky - Sufficient rock outcrop is present to make use of machinery impracticable, except for light machinery where other soil characteristics are especially favourable for improved pasture. The land may have some use for wild pasture or forests, depending on other soil characteristics. Rock exposures, or patches of soil too thin over rock for use, are roughly 3.5 - 10 m apart and cover 25 - 50% of the surface, depending on the pattern.

Exceedingly rocky - Sufficient rock outcrops (or very thin soil over rock) are present to make all use of machinery impracticable. The land may have some value for poor pasture or for forestry. Rock outcrops are 3.5 m or less apart and cover 50 - 90% of the area.

Excessively rocky – More than 90% of the land surface is exposed bedrock (rock outcrop).

Stoniness

Record how stony is the land surface at the sample site.

The following information was taken from Chapter 15 of the Canadian System of Soil Classification (3rd Edition). It can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt15.html.

Three phases of stoniness are defined on the basis of the percentage of the land surface occupied by fragments coarser than 15 cm in diameter. The limitations they impose are related to their number, size, and spacing at the surface.

Stones, as a surface condition, are different than “Coarse Fragments” within particular soil layers. For example, there can be very stony soils with no coarse fragments lying in the underlying soil materials. The class limits that follow are defined in terms of the approximate amount of stones (25 to 60 cm in diameter or, if flat, 38 to 60 cm long) and of boulders (more than 60 cm in diameter or, if flat, more than 60 cm long) and of their spacing.

Class	**Percentage of Surface Covered**	**Distance (meters) between stones or boulders if their diameter is…**		
		25 cm	***60 cm***	***120 cm***
None	<0.01	>25	>60	>120
Slight	0.01 -3	1 - 25	3 - 60	6 -120
Very stony	3 - >50	<0.1 - 1	<0.2 - 3	<0.5 - 6

Bedrock Type

Describe the type of bedrock underlying the soil or in the vicinity of the sample site. Local- to regional-scale bedrock maps available for the sampling region will assist the sampler in defining this field. The following chart lists some of the common bedrock types.

Igneous *(intrusive)*

- Anorthosite
- Diabase
- Diorite
- Gabbro
- Granite
- Granodiorite
- Monzonite
- Peridotite
- Pyroxenite
- Syenite
- Tachylite
- Tonalite
- Ultramafic rock

Igneous *(Extrusive)*

- A'a lava
- Andesite
- Basalt
- Block lava
- Dacite
- Latile
- Obsidian
- Pahoehoe lava
- Pillow lava
- Pumice (flow, coherent)
- Scoria (coherent mass)
- Trachyte

Igneous *(Pyroclastic)*

- Ignimbrite
- Pyroclastics (unconsolidated)
- Pyroclastics flow
- Pyroclastic surge
- Tuff
- Volcanic breccia
- Volcanic sandstone

Metamorphic

- Amphibolite
- Gneiss
- Granofels
- Granulite
- Greenstone
- Hornfels
- Marble
- Metaconglomerate
- Metaquartzite
- Metasedimentary rocks
- Metavolcanics
- Mica schist
- Migmatite
- Mylonite
- Phyllite
- Schist
- Serpentine
- Slate
- Soapstone (talc)

Sedimentary - *Clastics*

- Arenite
- Argillite
- Arkose
- Breccia (non-volcanic)
- Claystone
- Conglomerate
- Glauconitic sandstone
- Greywacke
- Mudstone
- Orthoquartzite
- Sandstone
- Shale
- Siltstone

Evaporite, Organics and Precipitates

- Chalk
- Chert
- Coal
- Dolomite
- Gypsum
- Limestone
- Travertine
- Tufa

Slope

Record the slope according to the aspects listed below.

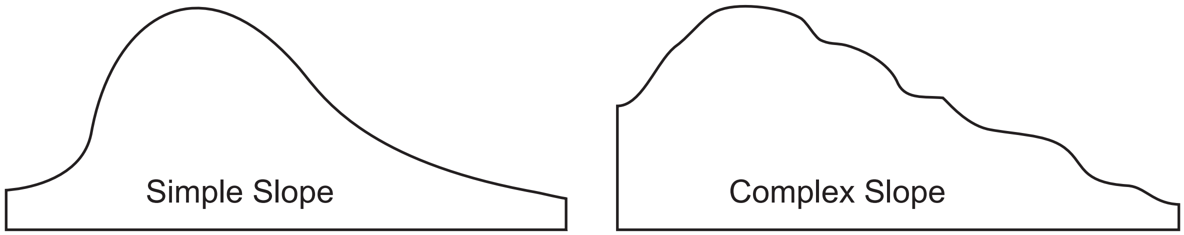
The following information was taken from Chapter 15 of the Canadian System of Soil Classification (3rd Edition). It can be downloaded from http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt15.html

Slope Type - Describe the relative uniformity or irregularity of the ground surface. A smooth linear or curvilinear surface is described as *simple* and irregular one as *complex*. See diagrams below.

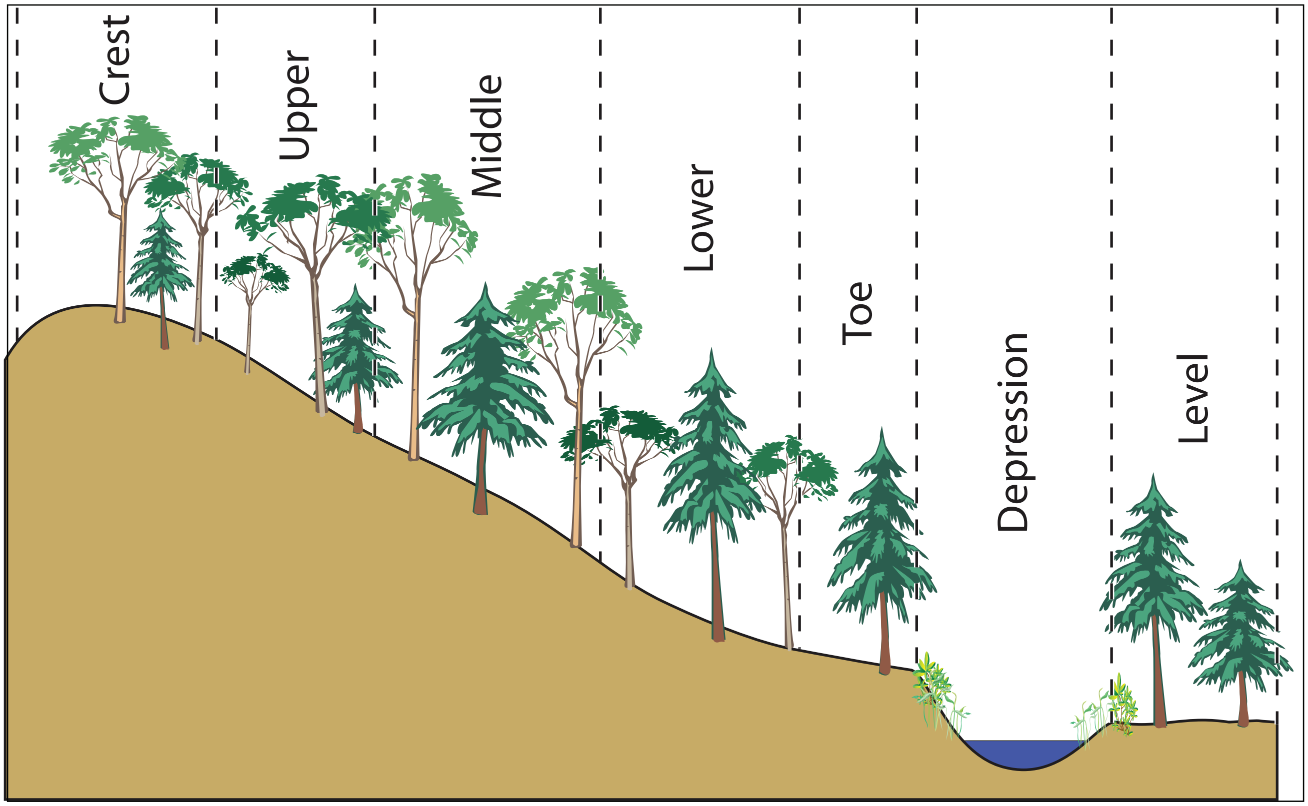
Slope Gradient - Record the angle of the ground surface (in percent) through the site and in the direction that overland water would flow; commonly called 'slope'.

Sample Site Position on Slope - Note the position of the sample site on a slope using the diagram below.

Slope Aspect - the compass direction (in degrees) that a slope faces, facing down slope.



Diagrams of simple and complex slope (above) and sample site position on slope (below).



Drainage

Record an estimate of the prevailing wetness conditions at the soil site.

The following information was taken from AAFC's Canadian Information Systems (CanSIS) - National Soil DataBase (NSDB) - Soil Name Table. It can be downloaded from http://sis.agr.gc.ca/cansis/nsdb/detailed/name/drainage.html or from http://sis.agr.gc.ca/cansis/nsdb/slc/v1/slc-v1_report.pdf.

Very rapidly drained
Water is removed from the soil very rapidly in relation to supply. Excess water flows downward very rapidly if underlying material is pervious. There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient. Soils have very low available water storage capacity (usually less than 2.5 cm) within the control section and are usually coarse textured, or shallow, or both. The water source is precipitation.

Rapidly drained
Water is removed from the soil rapidly in relation to supply. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Soils have low available water storage capacity (2.5-4 cm) within the control section, and are usually coarse textured, or shallow, or both. The water source is precipitation.

Well drained
Water is removed from the soil readily but not rapidly. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. Soils have intermediate available water storage capacity (4-5 cm) within the control section, and are generally intermediate in texture and depth. The water source is precipitation. On slopes, subsurface flow may occur for short durations, but additions are equalled by losses.

Moderately well drained
Water is removed from the soil somewhat slowly in relation to supply. Excess water is removed somewhat slowly due to low perviousness, shallow water table, lack of gradient, or some combination of these. Soils have intermediate to high water storage capacity (5-6 cm) within the control section and are usually medium to fine textured. Precipitation is the dominant water source in medium to fine textured soils; precipitation and significant additions by subsurface flow are necessary in coarse textured soils.

Imperfectly drained
Water is removed from the soil sufficiently slowly in relation to supply, to keep the soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major supply. If subsurface water or groundwater, or both, is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season. Precipitation is the main source if available water storage capacity is high; contribution by subsurface flow or groundwater flow, or both, increases as available water storage capacity decreases. Soils have a wide range in available water supply, texture, and depth, and are gleyed phases of well drained subgroups.

Poorly drained
Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Excess water is evident in the soil for a large part of the time. Subsurface

flow or groundwater flow, or both, in addition to precipitation are the main water sources; there may also be a perched water table, with precipitation exceeding evapotranspiration. Soils have a wide range in available water storage capacity, texture, and depth, and are gleyed subgroups, Gleysols, and Organic soils.

Very poorly drained
Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Excess water is present in the soil for the greater part of the time. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important, except where there is a perched water table with precipitation exceeding evapotranspiration. Soils have a wide range in available water storage capacity, texture, and depth, and are either Gleysolic or Organic.

Contamination

Record the absence or presence (Possible/Probable/Definite) of any contamination resulting from human activity. Identify the activity. Examples of sources of contamination include mine settling ponds and spoils heaps, industrial pollution, farms, garbage dumps, forestry activity and roads.

PAGE 2 - FIELD CARD - SOIL HORIZON DESCRIPTION
PAGE 3 - FIELD CARD - CODES FOR HORIZON DESCRIPTION

Page 2 of the Field Card is used to record the observations required to characterize the physical attributes of the materials in each soil horizon. Page 3 provides the codes needed to supply the required information for fields 1 to 11 on Page 2. The codes for soil horizons and other criteria on Page 2 are based on information obtained from Chapters 2 and 17 of Soil Classification Working Group (1998), available for downloading from http://www.pedosphere.com/resources/cssc3rd/ . In turn, much of the the information presented in that document was released previously in Agriculture Canada Expert Committee on Soil Survey (1983) available for downloading from http://sis.agr.gc.ca/cansis/publications/manuals/describing_soils.html.

Field 1 - Horizons

View the soil profile and record the horizons present.

D: Lithological discontinuity

If the soil shows a lithological discontinuity over or within the argic horizon (a subsurface horizon which has a distinctly higher clay content than the overlying horizon), or if the surface horizon has been removed by erosion, or if only a plough layer overlies the argic horizon, the illuvial nature must be clearly noted.

Ma: Master Horizons

Organic Horizons
Organic horizons are found in Organic soils and, commonly, at the surface of mineral soils. They may occur at any depth beneath the surface in buried soils or overlying geologic deposits. They contain more than 17% organic carbon (approximately 30% organic matter) by weight. Two groups of these horizons are recognized, the O horizons and the L, F and H horizons.

O – This is an organic horizon developed mainly from mosses, rushes and woody materials.

L, F and H – These are organic horizons that developed primarily from the accumulation of leaves, twigs and woody materials with or without a minor component of mosses. Usually they are not saturated with water for prolonged periods.

> L – This is an organic horizon that is characterized by an accumulation of organic matter derived mainly from leaves, twigs and woody materials in which the original structures are easily discernible.
>
> F –This is an organic horizon that is characterized by an accumulation of partly decomposed organic matter derived mainly from leaves, twigs and woody materials. Some of the original structures are difficult to recognize.
>
> H – This is an organic horizon that is characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible. This horizon differs from the F by having greater humification due chiefly to the action of organisms. It is frequently intermixed with mineral grains, especially near the junction with the mineral horizon.

Mineral Horizons

Mineral horizons contain 17% or less organic carbon (about 30% organic matter) by weight.

A – This mineral horizon formed at or near the surface in the zone of leaching or eluviation of materials in solution or suspension, or of maximum in-situ accumulation of organic matter or both. The accumulation of organic matter is usually expressed morphologically by a darkening of the surface soil (Ah). Conversely, the removal of organic matter is usually expressed by a lightening of the soil colour usually in the upper part of the solum (Ae).

B – This mineral horizon is characterized by enrichment in organic matter, sesquioxides or clay; or by the development of soil structure; or by a change of colour denoting hydrolysis, reduction or oxidation. The accumulation of organic matter (Bh) in B horizons is evidenced usually by dark colours relative to the C horizon. Clay accumulation is indicated by finer soil textures and by clay cutans coating peds and lining pores (Bt). Colour changes include relatively uniform browning due to oxidation of iron (Bm), and mottling and gleying of structurally altered material associated with periodic reduction (Bg).

C – This mineral horizon is comparatively unaffected by the pedogenic processes operating in A and B, except the process of gleying (Cg), and the accumulation of calcium and magnesium carbonate (Cca) and more soluble salts (Cs, Csa). Diatomaceous earth, marl and rock no harder than 3 on Mohs' scale are considered to be C horizons.

R – This consolidated bedrock layer is too hard to break with the hands (<3 on Mohs' scale) or to dig with a spade when moist and does not meet the requirements of a C horizon. The boundary between the R layer and any overlying unconsolidated material is called a lithic contact.

W – This layer of water may occur in Gleysolic, Organic or Cryosolic soils. Hydric layers in Organic soils are a kind of W layer.

Suffix: Suffixes

For a detailed description of commonly used suffixes refer to Appendix 3-C in this document. Information in Appendix 3-C was obtained from Chapter 2 of Soil Classification Working Group (1998).

The major mineral horizons are A, B, and C. The major organic horizons are L, F and H, which are mainly forest litter at various stages of decomposition, and O, which is derived mainly from bog, fen, marsh or swamp vegetation. Subdivisions of horizons are labelled by adding lower case suffixes to some of the major horizon symbols as with Ah or Ae. Well-developed horizons are readily identified in the field. However, in cases of weak expression or of borderline properties, as between Ah and H, laboratory determinations are necessary before horizons can be designated positively.

M: Modifier

All horizons except A and B may be vertically subdivided by consecutive numeral suffixes. The uppermost subdivision is indicated by the numeral 1; each successive subdivision with depth is indicated by the next numeral. This convention followed regardless of whether or not the horizon subdivisions are interrupted by a horizon of a different character. For example, an acceptable subdivision of horizons would be: Ae1, Bf, Ae2, Bt1, Bt2, C1, C2. In some instances it may be useful for sampling purposes to subdivide a single horizon, for example, Bm1-1, Bm1-2, Bm1-3.

Field 2 - Depth

Record the depth in centimetres at the top and at the bottom of the horizon or interval. The top of the A-horizon or first mineral horizon is considered the zero point. Depths of material above that position are indicated with a positive value and those below with a negative value.

Field 3 - HB - Horizon boundary

D: Distinctiveness

Record the distinctiveness of the horizon boundary (abrupt, clear, gradual, or diffuse) as described on Page 3 of the field card.

F: Form

Record the form of the lower boundary.
Smooth – nearly a plane
Wavy – pockets wider than deep
Irregular – pockets deeper than wide
Broken – some parts are unconnected

Field 4 - Colour

Describe the colour of each layer using the colour descriptors as outlined on Page 3 of the field card. Colours are classified using the Munsell Soil Colour Charts later in the laboratory.

Field 5- Mottles

Record mottle abundance, colour and contrast with the matrix. Refer to Page 3 of the field card for details. Mottles are localized zones that have enhanced or decreased pigmentation compared to the adjacent matrix. In the case of enhanced pigmentation it may be caused by the accumulation or phase change of Fe-Mn minerals and take the form of masses or nodules or concretions. Where pigmentation is decreased it is generally caused by the loss of Fe and/or Mn or clay.

Field 6 - Roots

Where present, record the location (L) and quantity and size (Q and S) of the roots within each layer. Refer to Page 3 of the field card for more details.

Field 7 - CF - Coarse fragments

Record an estimate, as percent of the total volume, of the amount of rounded, subrounded, flat, angular or irregular rock fragments greater than 2 cm to 60 cm in size.

Field 8 - Structure

Record the structure of the soil according to the following criteria. Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles, when assembled, appear as larger particles, referred to as aggregates.

Some information in this section was obtained from the Food and Agriculture Organization of the United Nations website: ftp://ftp.fao.org/FI/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e07.htm.

Grade (G)

Grade refers to the degree of aggregation of the soil.

Structureless has no observable aggregation or no definite orderly arrangement of natural lines of weakness.

Weak structure is poorly formed from indistinct aggregates that can barely be observed in place. When removed from the profile, the soil material breaks down into a mixture of very few entire aggregates, many broken aggregates and much non-aggregated material.

Moderate structure is well formed from distinct aggregates that are moderately durable and evident but not distinct in undisturbed soil. When removed from the profile, the soil material breaks down into a mixture of many distinct entire aggregates, some broken aggregates and little non-aggregated material.

Strong structure is well formed from distinct aggregates that are durable and quite evident in undisturbed soil. When removed from the profile, the soil material consists very largely of entire aggregates and includes few broken ones and little or no non-aggregated material.

Type (T)

Type refers to the form of the aggregates.

Granular - Structures are individual particles of sand, silt and clay grouped together in small, nearly spherical grains. This structure is common in the A-horizon.

Blocky and subangular blocky - Structures are soil particles that cling together in nearly square or angular blocks having more or less sharp edges. This structure is common in the B-horizon where clay has accumulated.

Platy - Structure is made up of soil particles aggregated in thin plates or sheets piled horizontally on one another. It is commonly found in forest soils, in part of the A- horizon, and in claypan soils.

Prismatic and columnar - Structures are soil particles which have formed into vertical columns or pillars separated by miniature, but definite, vertical cracks. They are common in the B-horizon where clay has accumulated.

Class (C)

Class refers to the average size of the aggregates.

Class of structure describes the average size of individual aggregates as follows:
VF - Very fine
F - Fine
M - Medium
C - Coarse

Table 10 below from Chapter 17 of Canadian System of Soil Classification (third edition) provides more information on the types, classes and sizes related to soil structure.

Canadian System of Soil Classification (third edition), Table 10, Types and classes of soil structure

Type	Kind	Class	Size (mm)
Structureless: no observable aggregation or no definite orderly arrangement around natural lines of weaknesses	Single grain structure: loose, incoherent mass of individual particles as in sands		
	Amorphous (massive) structure: a coherent mass showing no evidence of any distinct arrangement of soil particles		
Blocklike: soil particles are arranged around a point and bounded by flat or rounded surfaces	Blocky (angular blocky): faces rectangular and flattened, vertices sharply angular	Fine blocky Medium blocky Coarse blocky Very coarse blocky	<10 10 - 20 20 - 50 >50
	Subangular blocky: faces subrectangular, vertices mostly oblique or subrounded	Fine subangular blocky Medium subangular blocky Coarse subangular blocky Very coarse subangular blocky	<10 10 - 20 20 - 50 >50
	Granular: spheroidal and characterized by rounded vertices	Fine granular Medium granular Coarse granular	<2 2 - 5 5 - 10
Platelike: soil particles are arranged around a horizontal plane and generally bounded by relatively flat horizontal surfaces	Platy structure: horizontal planes more or less developed	Fine platy Medium platy Coarse platy	<2 2 - 5 5 - 10
Prismlike: soil particles are arranged around a vertical axis and bounded by relatively flat vertical surfaces	Prismatic structure: vertical faces well defined and edges sharp	Fine prismatic Medium prismatic Coarse prismatic Very coarse prismatic	<20 20 - 50 50 - 100 >100
	Columnar structure: vertical edges near top of columns not sharp; columns flat-topped, round-topped or irregular	Fine columnar Medium columnar Coarse columnar Very coarse columnar	<20 20 - 50 50 - 100 >100

Field 9 - MC - Moisture consistency

Much of the information that follows was obtained from the Food and Agriculture Organization of the United Nations website: Source; ftp://ftp.fao.org/FI/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e07.htm

Soil consistency is the strength with which soil materials are held together or the resistance of soils to deformation and rupture. In this case it is a field test for moisture consistency. It is done when the soil is moist but not wet, as, for example, 24 hours after a good rainfall.

Crush a small amount of moist soil by pressing it between your thumb and forefinger or by squeezing it in the palm of your hand. Rate the moist soil consistency as follows:
Loose, if the soil is non-coherent (single-grain structure);
Very friable, if the soil crushes easily under very gentle pressure but will stick together if pressed again;
Friable, if the soil crushes easily under gentle to moderate pressure;
Firm, if the soil crushes under moderate pressure but resistance is noticeable; and
Very firm, if the soil crushes under strong pressure, but this is difficult to impossible to do between the thumb and forefinger.

Field 10 - Field texture

Soil texture describes the proportions of sand, silt and clay particles in the soil. The terms sand, silt and clay refer to different size fractions of the soil's mineral content. See the soil texture diagram below from United States Department of Agriculture (2002). Other information on soil texture is available in Chapter 17 of The Canadian System of Soil Classification; Agriculture and Agri-Food Canada Publication 1646 (Third Edition).

Texture is recorded using terms such as loam, sandy clay loam or silty clay derived from the 'Texture Triangle' below and using the simple tests outlined below. The tests were obtained from Burnham (1980).

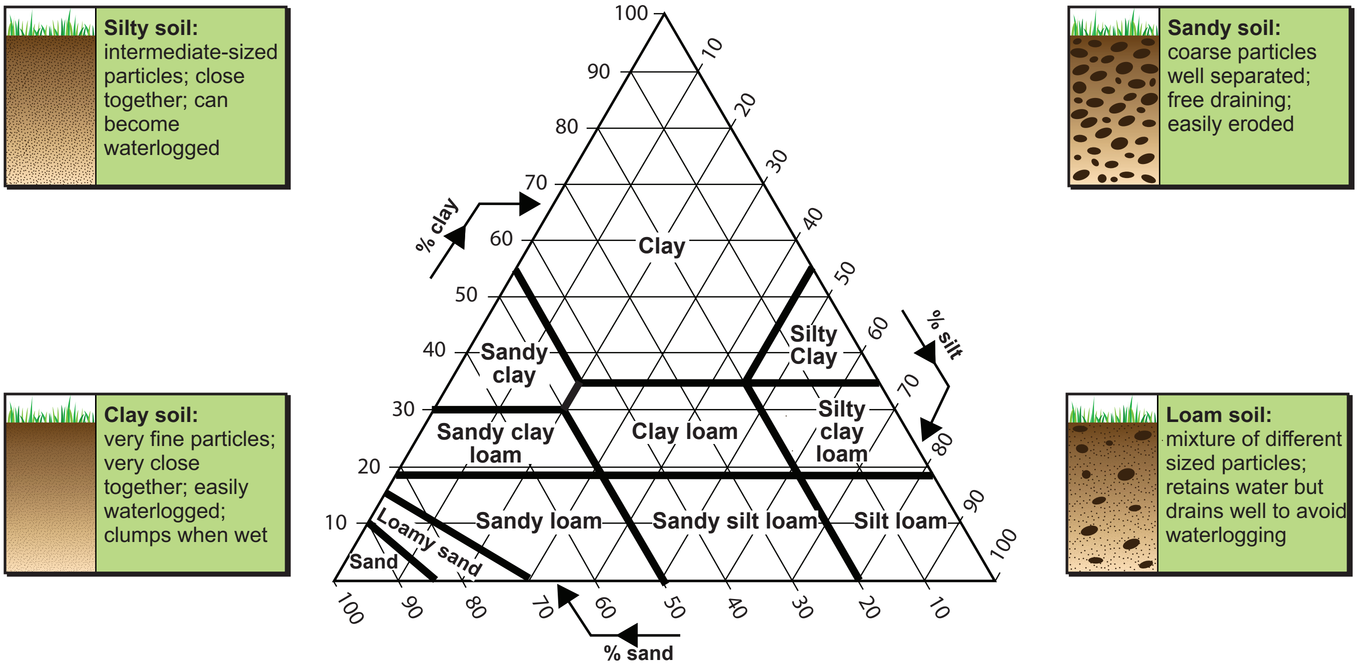
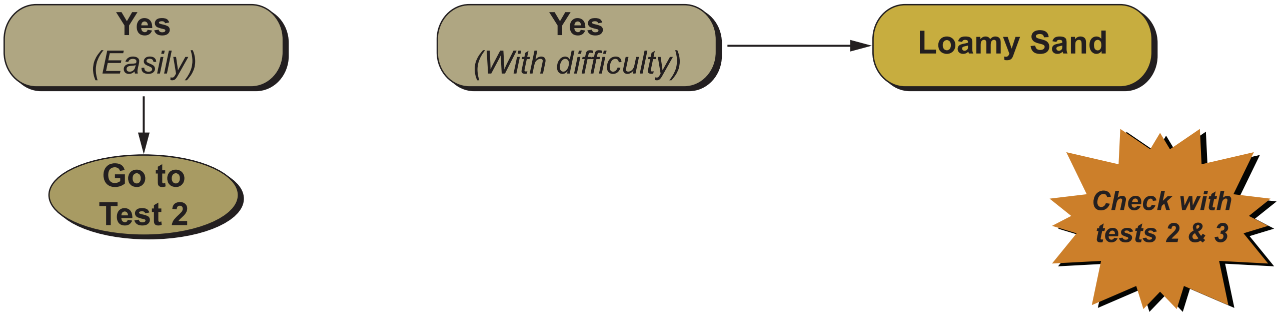


Diagram showing the textural composition related to soil textures (USDA, 2002)

Tests for Determing Soil Texture

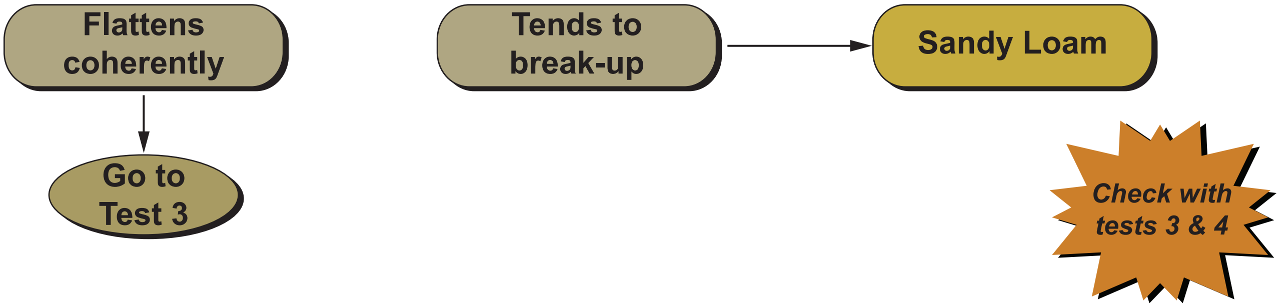
Test 1

Does the moist soil from a coherent ball?



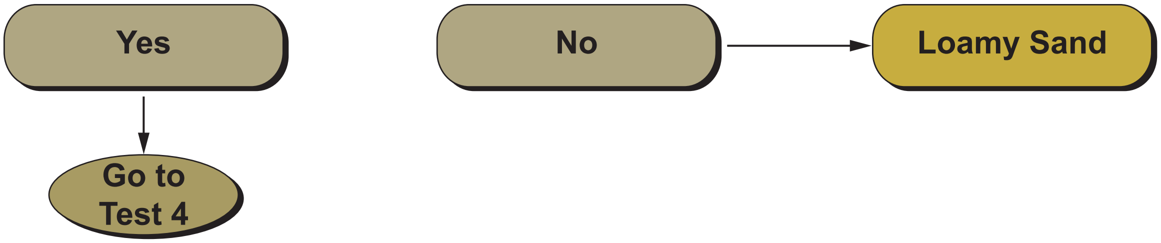
Test 2

What happens when the ball is pressed between thumb and forefinger?



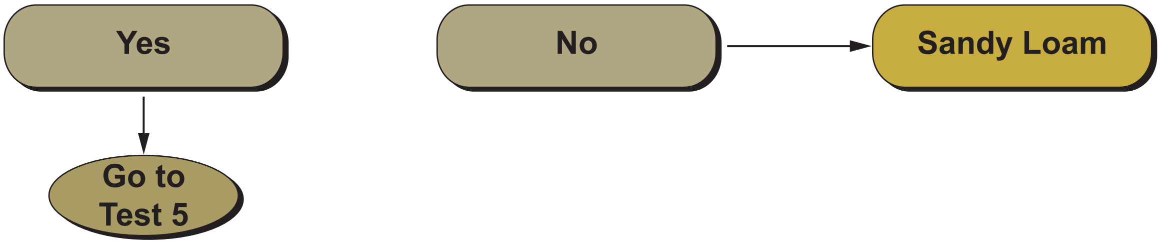
Test 3

With further moistening can the ball be rolled into a thick cylinder (approx. 5mm thick)?



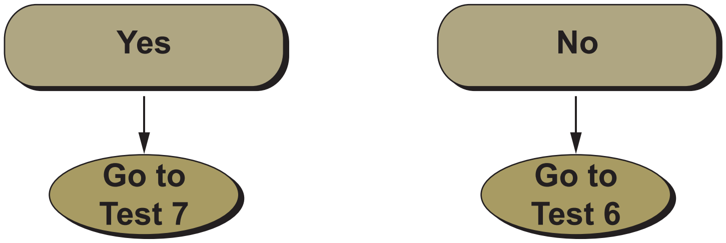
Test 4

With further moistening can the ball be rolled into a thin thread (approx. 2mm thick)?



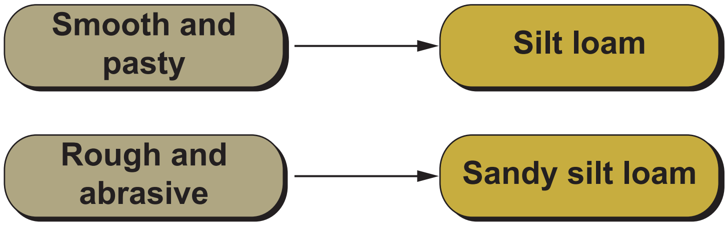
Test 5

Can the thread be bent into a horseshoe (e.g. around the side of the hand) without the soil cracking?



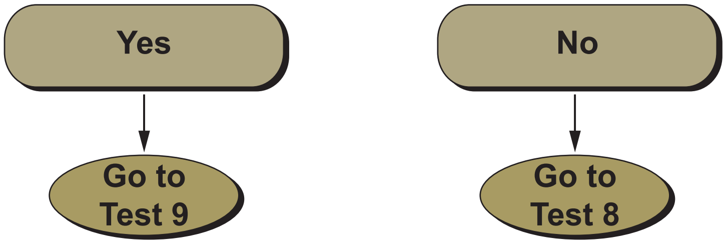
Test 6

On remoulding with further moisture what does the soil generally `feel` like?



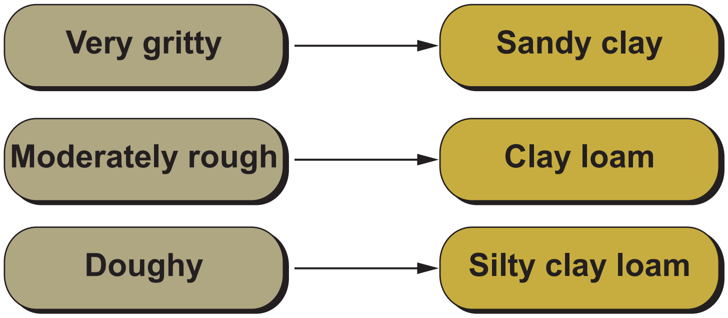
Test 7

Can the two ends of the thread be joined to form a ring (approx. 25mm in diameter), without the soil cracking



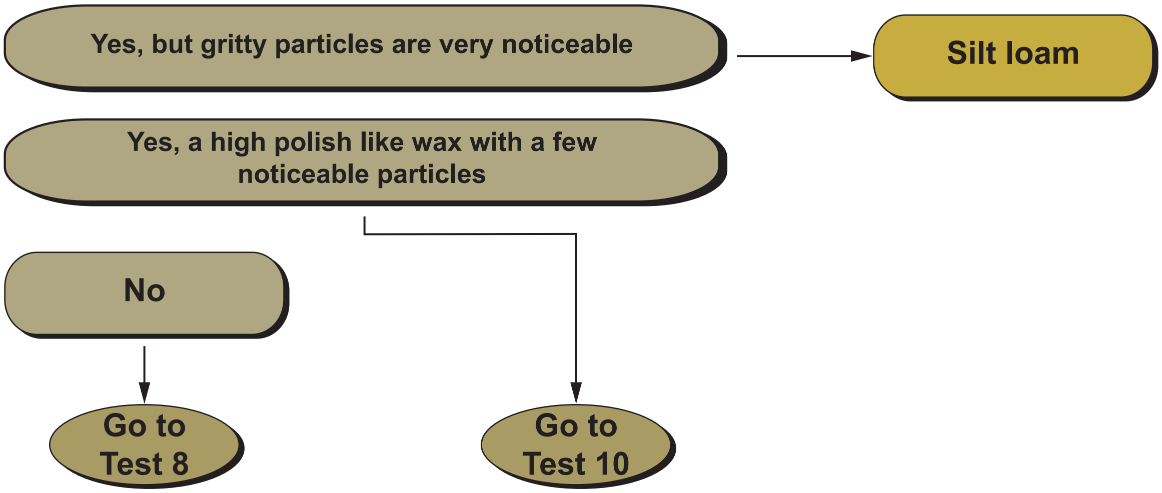
Test 8

On remoulding with further moisture what is the general `feel`of the soil?



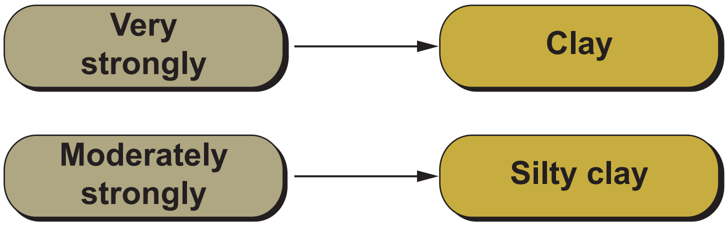
Test 9

On remoulding without rewetting can the surface be polished with the thumb?



Test 10

On wetting thoroughly, how strongly does the soil stick one`s fingers together?



Field 11 - Effervescence

Record the gaseous response of soil when 10% HCl is applied. An effervescent response is seen as bubbles. Apply the acid solution to the soil matrix and not to carbonate masses.

The following information was taken from Agriculture and Agri-food Canada - CanSIS - National Soil DataBase (NSDB) - Soil Landscapes of Canada (v. 2.0) - Component Table. It is found at http://sis.agr.gc.ca/cansis/nsdb/slc/v2.0/component/calc.html.

Noncalcareous - No $CaCO_3$ detectable with dilute HCl.

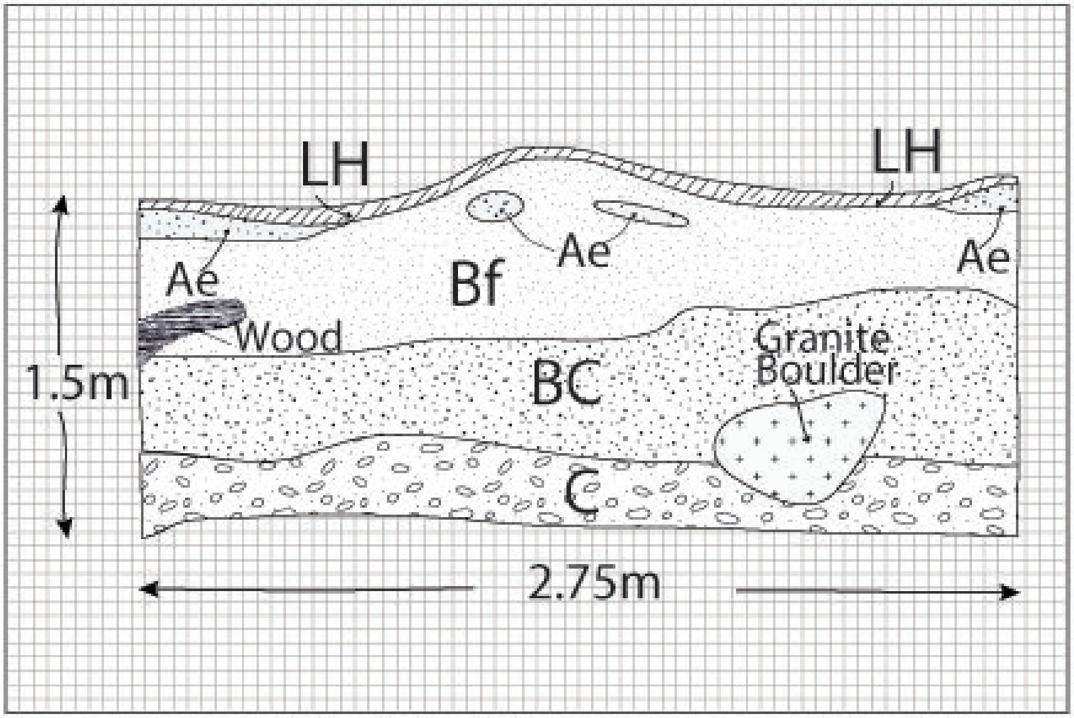
Weakly calcareous - 1-5% $CaCO_3$ equivalents (weak effervescence with dilute HCl)

Strongly calcareous - 6-40% $CaCO_3$ equivalents (moderate to strong effervescence with dilute HCl)

Extremely calcareous - >40% $CaCO_3$ equivalents (very strong effervescence with dilute HCl)

Soil Profile Diagram

Sketch a cross-sectional profile diagram of the horizon, indicating depths to recorded features (soil horizons, lithic contact, etc.) and noting other significant observations such as relative coarse fragment distribution, wood fragments.



Soil Classification

Classify the soil at the sample site according to Order, Great Great Group, and Sub-group.

The information in this section was taken from Chapter 3 of Canadian System of Soil Classification (third edition). The chapter can be downloaded from the following internet site: http://sis.agr.gc.ca/cansis/taxa/cssc3/chpt3.html.

Order-Great Group-Sub-group

The pedon is the basic unit of soil in the Canadian classification system. It is the smallest, three-dimensional unit at the surface of the earth that is considered as a soil.

The Canadian System of Soil Classification differentiates soil types on the basis of measured properties of the profile and uses a hierarchical scheme to classify soils from general to specific. The most recent version of the classification system has five categories in its hierarchical structure. From general to specific, the major categories in this system are: orders, great groups, subgroups, families, and series.

At its most general level, the Canadian System of Soil Classification recognizes nine different soil orders. These are listed in Pidwirny (2006) as well as the orders associated with the system of soil classification used in the United States.

(1) Brunisol - is a normally immature soil commonly found under forested ecosystems. The most identifying trait of these soils is the presence of a B horizon that is brownish in color. The soils under the dry pine forests of south-central British Columbia are typically brunisols.

(2) Chernozem - is a soil common to grassland ecosystems. This soil is dark in color (brown to black) and has an A horizon that is rich in organic matter. Chernozems are common in the Canadian prairies.

(3) Cryosol - is a high latitudes soil common in the tundra. This soil has a layer of permafrost within one meter of the soil surface.

(4) Gleysol - is a soil found in an ecosystem that is frequently flooded or permanently waterlogged. Its soil horizons show the chemical signs of oxidation and reduction.

(5) Luvisol - is another type of soil that develops under forested conditions. This soil, however, has a calcareous parent material which results in a high pH and strong eluviation of clay from the A horizon.

(6) Organic - this soil is mainly composed of organic matter in various stages of decomposition. Organic soils are common in fens and bogs. The profiles of these soils have an obvious absence of mineral soil particles.

(7) Podzol - is a soil commonly found under coniferous forests. Its main identifying traits are a poorly decomposed organic layer, an eluviated A horizon, and a B horizon with illuviated organic matter, aluminum, and iron. Podzols are common in the forested regions of Southern Ontario.

(8) Regosol - is any young underdeveloped soil. Immature soils are common in geomorphologically dynamic environments. Many mountain river valleys in British Columbia have floodplains with surface deposits that are less than 3000 years old. The soils in these environments tend to be regosols.

(9) Solonetzic - is a grassland soil where high levels of evapotranspiration cause the deposition of salts at or near the soil surface. Solonetzic soils are common in the dry regions of the prairies where evapotranspiration greatly exceeds precipitation input. The movement of water to the earth's surface because of capillary action, transpiration, and evaporation causes the deposition of salts when the water evaporates into the atmosphere.

The chart that follows obtained from the Canadian System of Soil Classification document provides the Great Groups and Sub-groups associated with the 9 soil orders. Prior to collecting samples, the field crew is advised to determine soil types in the field area by studying the on-line map of soil distribution in Canada supplied by Agriculture and Agri-Food Canada. There is information on the Great Groups and Sub-groups in Chapters 3 to 14 of the Canadian System of Soil Classification (3rd Edition) available on-line at http://www.pedosphere.com/resources/cssc3rd/.

Outline of the System

The Canadian system of soil classification at the order, great group, and subgroup levels is tabulated alphabetically according to the names of the orders. For each subgroup the abbreviation of the name is appended.

Order	*Great Group*	*Subgroup*	*Abbrev*
Brunisolic	Melanic Brunisol	Orthic Melanic Brunisol	O.MB
		Eluviated Melanic Brunisol	E.MB
		Gleyed Melanic Brunisol	GL.MB
		Gleyed Eluviated Melanic Brunisol	GLE.MB
	Eutric Brunisol	Orthic Eutric Brunisol	O.EB
		Eluviated Eutric Brunisol	E.EB
		Gleyed Eutric Brunisol	GL.EB
		Gleyed Eluviated Eutric Brunisol	GLE.EB
	Sombric Brunisol	Orthic Sombric Brunisol	O.SB
		Eluviated Sombric Brunisol	E.SB
		Duric Sombric Brunisol	DU.SB
		Gleyed Sombric Brunisol	GL.SB
		Gleyed Eluviated Sombric Brunisol	GLE.SB
	Dystric Brunisol	Orthic Dystric Brunisol	O.DYB
		Eluviated Dystric Brunisol	E.DYB
		Duric Dystric Brunisol	DU.DYB
		Gleyed Dystric Brunisol	GL.DYB
		Gleyed Eluviated Dystric Brunisol	GLE.DYB
Chernozemic	Brown Chernozem	Orthic Brown Chernozem	O.BC
		Rego Brown Chernozem	R.BC
		Calcareous Brown Chernozem	CA.BC
		Eluviated Brown Chernozem	E.BC
		Solonetzic Brown Chernozem	SZ.BC
		Vertic Brown Chernozem	V.BC
		Gleyed Brown Chernozem	GL.BC
		Gleyed Rego Brown Chernozem	GLR.BC
		Gleyed Calcareous Brown Chernozem	GLCA.BC
		Gleyed Eluviated Brown Chernozem	GLE.BC
		Gleyed Solonetzic Brown Chernozem	GLSZ.BC
		Gleyed Vertic Brown Chernozem	GLV.BC
	Dark Brown Chernozem	Orthic Dark Brown Chernozem	O.DBC
		Rego Dark Brown Chernozem	R.DBC
		Calcareous Dark Brown Chernozem	CA.DBC
		Eluviated Dark Brown Chernozem	E.DBC
		Solonetzic Dark Brown Chernozem	SZ.DBC
		Vertic Dark Brown Chernozem	V.DBC
		Gleyed Dark Brown Chernozem	GL.DBC
		Gleyed Rego Dark Brown Chernozem	GLR.DBC
		Gleyed Calcareous Dark Brown Chernozem	GLCA.DBC
		Gleyed Eluviated Dark Brown Chernozem	GLE.DBC
		Gleyed Solonetzic Dark Brown Chernozem	GLSZ.DBC
		Gleyed Vertic Dark Brown Chernozem	GLV.DBC
	Black Chernozem	Orthic Black Chernozem	O.BLC
		Rego Black Chernozem	R.BLC
		Calcareous Black Chernozem	CA.BLC
		Eluviated Black Chernozem	E.BLC
		Solonetzic Black Chernozem	SZ.BLC
		Vertic Black Chernozem	V.BLC
		Gleyed Black Chernozem	GL.BLC
		Gleyed Rego Black Chernozem	GLR.BLC
		Gleyed Calcareous Black Chernozem	GLCA.BLC
		Gleyed Eluviated Black Chernozem	GLE.BLC
		Gleyed Solonetzic Black Chernozem	GLSZ.BLC
		Gleyed Vertic Black Chernozem	GLV.BLC
	Dark Gray Chernozem	Orthic Dark Gray Chernozem	O.DGC
		Rego Dark Gray Chernozem	R.DGC
		Calcareous Dark Gray Chernozem	CA.DGC
		Solonetzic Dark Gray Chernozem	SZ.DGC
		Vertic Dark Gray Chernozem	V.DGC
		Gleyed Dark Gray Chernozem	GL.DGC
		Gleyed Rego Dark Gray Chernozem	GLR.DGC
		Gleyed Calcareous Dark Gray Chernozem	GLCA.DGC
		Gleyed Solonetzic Dark Gray Chernozem	GLSZ.DGC
		Gleyed Vertic Dark Gray Chernozem	GLV.DGC

Cryosolic	Turbic Cryosol	Orthic Eutric Turbic Cryosol	OE.TC
		Orthic Dystric Turbic Cryosol	OD.TC
		Brunisolic Eutric Turbic Cryosol	BRE.TC
		Brunisolic Dystric Turbic Cryosol	BRD.TC
		Gleysolic Turbic Cryosol	GL.TC
		Regosolic Turbic Cryosol	R.TC
		Histic Eutric Turbic Cryosol	HE.TC
		Histic Dystric Turbic Cryosol	HD.TC
		Histic Regosolic Turbic Cryosol	HR.TC
	Static Cryosol	Orthic Eutric Static Cryosol	OE.SC
		Orthic Dystric Static Cryosol	OD.SC
		Brunisolic Eutric Static Cryosol	BRE.SC
		Brunisolic Dystric Static Cryosol	BRD.SC
		Luvisolic Static Cryosol	L.SC
		Gleysolic Static Cryosol	GL.SC
		Regosolic Static Cryosol	R.SC
		Histic Eutric Static Cryosol	HE.SC
		Histic Dystric Static Cryosol	HD.SC
		Histic Regosolic Static Cryosol	HR.SC
	Organic Cryosol	Fibric Organic Cryosol	FI.OC
		Mesic Organic Cryosol	ME.OC
		Humic Organic Cryosol	HU.OC
		Terric Fibric Organic Cryosol	TFI.OC
		Terric Mesic Organic Cryosol	TME.OC
		Terric Humic Organic Cryosol	THU.OC
		Glacic Organic Cryosol	GC.OC
Gleysolic	Luvic Gleysol	Solonetzic Luvic Gleysol	SZ.LG
		Fragic Luvic Gleysol	FR.LG
		Humic Luvic Gleysol	HU.LG
		Fera Luvic Gleysol	FE.LG
		Orthic Luvic Gleysol	O.LG
		Vertic Luvic Gleysol	V.LG
	Humic Gleysol	Solonetzic Humic Gleysol	SZ.HG
		Fera Humic Gleysol	FE.HG
		Orthic Humic Gleysol	O.HG
		Rego Humic Gleysol	R.HG
		Vertic Humic Gleysol	V.HG
	Gleysol	Solonetzic Gleysol	SZ.G
		Fera Gleysol	FE.G
		Orthic Gleysol	O.G
		Rego Gleysol	R.G
		Vertic Gleysol	V.G
Luvisolic	Gray Brown Luvisol	Orthic Gray Brown Luvisol	O.GBL
		Brunisolic Gray Brown Luvisol	BR.GBL
		Podzolic Gray Brown Luvisol	PZ.GBL
		Vertic Gray Brown Luvisol	V.GBL
		Gleyed Gray Brown Luvisol	GL.GBL
		Gleyed Brunisolic Gray Brown Luvisol	GLBR.GBL
		Gleyed Podzolic Gray Brown Luvisol	GLPZ.GBL
		Gleyed Vertic Gray Brown Luvisol	GLV.GBL
	Gray Luvisol	Orthic Gray Luvisol	O.GL
		Dark Gray Luvisol	D.GL
		Brunisolic Gray Luvisol	BR.GL
		Podzolic Gray Luvisol	PZ.GL
		Solonetzic Gray Luvisol	SZ.GL
		Fragic Gray Luvisol	FR.GL
		Vertic Gray Luvisol	V.GL
		Gleyed Gray Luvisol	GL.GL
		Gleyed Dark Gray Luvisol	GLD.GL
		Gleyed Brunisolic Gray Luvisol	GLBR.GL
		Gleyed Podzolic Gray Luvisol	GLPZ.GL
		Gleyed Solonetzic Gray Luvisol	GLSZ.GL
		Gleyed Fragic Gray Luvisol	GLFR.GL
		Gleyed Vertic Gray Luvisol	GLV.GL

Organic	Fibrisol	Typic Fibrisol	TY.F
		Mesic Fibrisol	ME.F
		Humic Fibrisol	HU.F
		Limnic Fibrisol	LM.F
		Cumulic Fibrisol	CU.F
		Terric Fibrisol	T.F
		Terric Mesic Fibrisol	TME.F
		Terric Humic Fibrisol	THU.F
		Hydric Fibrisol	HY.F
	Mesisol	Typic Mesisol	TY.M
		Fibric Mesisol	FI.M
		Humic Mesisol	HU.M
		Limnic Mesisol	LM.M
		Cumulic Mesisol	CU.M
		Terric Mesisol	T.M
		Terric Fibric Mesisol	TFI.M
		Terric Humic Mesisol	THU.M
		Hydric Mesisol	HY.M
	Humisol	Typic Humisol	TY.H
		Fibric Humisol	FI.H
		Mesic Humisol	ME.H
		Limnic Humisol	LM.H
		Cumulic Humisol	CU.H
		Terric Humisol	T.H
		Terric Fibric Humisol	TFI.H
		Terric Mesic Humisol	TME.H
		Hydric Humisol	HY.H
	Folisol	Hemic Folisol	HE.FO
		Humic Folisol	HU.FO
		Lignic Folisol	LI.FO
		Histic Folisol	HI.FO
Podzolic	Humic Podzol	Orthic Humic Podzol	O.HP
		Ortstein Humic Podzol	OT.HP
		Placic Humic Podzol	P.HP
		Duric Humic Podzol	DU.HP
		Fragic Humic Podzol	FR.HP
	Ferro-Humic Podzol	Orthic Ferro-Humic Podzol	O.FHP
		Ortstein Ferro-Humic Podzol	OT.FHP
		Placic Ferro-Humic Podzol	P.FHP
		Duric Ferro-Humic Podzol	DU.FHP
		Fragic Ferro-Humic Podzol	FR.FHP
		Luvisolic Ferro-Humic Podzol	LU.FHP
		Sombric Ferro-Humic Podzol	SM.FHP
		Gleyed Ferro-Humic Podzol	GL.FHP
		Gleyed Ortstein Ferro-Humic Podzol	GLOT.FHP
		Gleyed Sombric Ferro-Humic Podzol	GLSM.FHP
	Humo-Ferric Podzol	Orthic Humo-Ferric Podzol	O.HFP
		Ortstein Humo-Ferric Podzol	OT.HFP
		Placic Humo-Ferric Podzol	P.HFP
		Duric Humo-Ferric Podzol	DU.HFP
		Fragic Humo-Ferric Podzol	FR.HFP
		Luvisolic Humo-Ferric Podzol	LU.HFP
		Sombric Humo-Ferric Podzol	SM.HFP
		Gleyed Humo-Ferric Podzol	GL.HFP
		Gleyed Ortstein Humo-Ferric Podzol	GLOT.HFP
		Gleyed Sombric Humo-Ferric Podzol	GLSM.HFP
Regosolic	Regosol	Orthic Regosol	O.R
		Cumulic Regosol	CU.R
		Gleyed Regosol	GL.R
		Gleyed Cumulic Regosol	GLCU.R
	Humic Regosol	Orthic Humic Regosol	O.HR
		Cumulic Humic Regosol	CU.HR
		Gleyed Humic Regosol	GL.HR
		Gleyed Cumulic Humic Regosol	GLCU.HR

Solonetzic	Solonetz	Brown Solonetz	B.SZ
		Dark Brown Solonetz	DB.SZ
		Black Solonetz	BL.SZ
		Alkaline Solonetz	A.SZ
		Gleyed Brown Solonetz	GLB.SZ
		Gleyed Dark Brown Solonetz	GLDB.SZ
		Gleyed Black Solonetz	GLBL.SZ
	Solodized Solonetz	Brown Solodized Solonetz	B.SS
		Dark Brown Solodized Solonetz	DB.SS
		Black Solodized Solonetz	BL.SS
		Dark Gray Solodized Solonetz	DG.SS
		Gray Solodized Solonetz	G.SS
		Gleyed Brown Solodized Solonetz	GLB.SS
		Gleyed Dark Brown Solodized Solonetz	GLDB.SS
		Gleyed Black Solodized Solonetz	GLBL.SS
		Gleyed Dark Gray Solodized Solonetz	GLDG.SS
		Gleyed Gray Solodized Solonetz	GLG.SS
	Solod	Brown Solod	B.SO
		Dark Brown Solod	DB.SO
		Black Solod	BL.SO
		Dark Gray Solod	DG.SO
		Gray Solod	G.SO
		Gleyed Brown Solod	GLB.SO
		Gleyed Dark Brown Solod	GLDB.SO
		Gleyed Black Solod	GLBL.SO
		Gleyed Dark Gray Solod	GLDG.SO
		Gleyed Gray Solod	GLG.SO
	Vertic Solonetz	Brown Vertic Solonetz	BV.SZ
		Dark Brown Vertic Solonetz	DBV.SZ
		Black Vertic Solonetz	BLV.SZ
		Gleyed Brown Vertic Solonetz	GLBV.SZ
		Gleyed Dark Brown Vertic Solonetz	GLDBV.SZ
		Gleyed Black Vertic Solonetz	GLBLV.SZ
Vertisolic	Vertisol	Orthic Vertisol	O.V
		Gleyed Vertisol	GL.V
		Gleysolic Vertisol	GLC.V
	Humic Vertisol	Orthic Humic Vertisol	O.HV
		Gleyed Humic Vertisol	GL.HV
		Gleysolic Humic Vertisol	GLC.HV

Appendix 3-C

Example of a Region-Specific Field Guide for Soil Classification Prepared Prior to Field Work

Profile in a podzolic soil in New Brunswick. (Photo by P. Friske)

Soil Type distribution in the Maritime provinces						
Order Description	**Order**	**Great Group Description**	**Great Group**	**NB**	**NS**	**PE**
Soils mainly composed of organic peat materials or upland organic forest materials with L, F or H >40 cm thick	**Organic**	Refer to organic soil sampling protocol		**4%**	**7%**	**-**
Soils with a Bm, Btj or Bfj horizon <5 cm thick and no Bg horizon	**Regosolic**	Ah horizon >10 cm thick	Humic Regosol	**-**	**-**	**-**
		Other soils	Regosol	**1%**	**3%**	**1%**
Soils with either a Bm, Btj or Bfj horizon <5 cm thick and no Bg horizon	**Brunisolic**	Ah horizon >10 cm thick and pH >5.5 cm in B	Melanic Brunisol	**-**	**-**	**-**
		Other soils with an Ah >10 cm thick	Sombric Brunisol	**1%**	**-**	**-**
		Other soils with a pH >5.5 in the B horizon	Eutric Brunisol	**1%**	**-**	**-**
		Other soils	Dystric Brunisol	**1%**	**-**	**-**
Soils with a podzolic B horizon and no Bt horizon within 50 cm of the mineral surface	**Podzolic**	Soils with a Bh horizon >10 cm thick	Humic Podzol	**-**	**2%**	**-**
		Other soils with a Bf horizon or a thin Bhf + Bf horizon >10 cm thick	Humo-Ferric Podzol	**56%**	**62%**	**82%**
		Other soils with a Bhf horizon >10 cm thick	Ferro-Humic Podzol	**12%**	**5%**	**-**
Soils with a Bt horizon and no Bg horizon or podzolic B horizon if Bt is >50 cm below mineral surface	**Luvisolic**	Soils with an Ah horizon and mean annual soil temperature >8° C	Gray-Brown Luvisol	**-**	**-**	**-**
		Other soils	Gray Luvisol	**15%**	**5%**	**5%**
		Soils with a Btg horizon	Luvic Gleysol	**-**	**-**	**-**
Soils with a g horizon within 50 cm of the mineral surface	**Gleysolic**	Other soils with an Ah horizon >10 cm thick	Humic Gleysol	**-**	**-**	**-**
		Other soils	Gleysol	**11%**	**9%**	**12%**
	Not applicable	Ice, water, rock etc		**<1%**	**8%**	**-**

Soil Horizons

L, F, H - Organic horizons commonly found at the surface of mineral soils and developed mainly from leaves, needles and twigs. **L** - organic matter in which the original structures are easily discernible; **F** - accumulation of partly decomposed organic matter, some of the original structures are difficult to recognize; **H** - accumulation of decomposed organic matter in which the original structures are indiscernible.

A - Mineral horizon at or near the surface in the zone of leaching or eluviation. Accumulated organic matter is usually expressed morphologically by a darkening of the surface soil (Ah). Conversely, the removal of organic matter is usually expressed by a lightening of the soil (Ae).

B - Mineral horizon characterized by enrichment in organic matter, sesquioxides, or clay; or by the development of soil structure; or by a change of color denoting hydrolysis, reduction, or oxidation. In B horizons, accumulated organic matter (Bh) is evidenced usually by dark colors relative to the C horizon. Clay accumulation is indicated by finer soil textures and by clay cutans coating peas and lining pores (Bt). Color changes include relatively uniform browning due to oxidation of iron (Bm), and mottling and gleying of structurally altered material associated with periodic reduction (Bg).

C - This mineral horizon is comparatively unaffected by the pedogenic processes operating in A and B horizons.

R - Bedrock layer.

Commonly used lowercase suffixes

f - A horizon enriched with amorphous material, principally Al and Fe combined with organic matter. It must have a color as defined under Podzolic B horizon. lt is used with B alone (Bf), with B and h (Bhf), with B and g (Bfg), and with other suffixes. By definition: Bf 0.5-5% organic C; Bhf - more than 5% organic C. No minimum thickness is specified for a Bf or a Bhf horizon. Thin (<10cm) Bf and Bhf horizons do not qualify as podzolic B horizons. Some Ah and Ap horizons contain sufficient extractable Al + Fe to satisfy criteria of f but are designated Ah or Ap.

g - A horizon characterized by gray colors, or prominent mottling, or both, indicative of permanent or periodic intense reduction.

j - A modifier of suffixes e, f, g, n, t, and v. It is used to denote an expression of, but failure to meet, the specified limits of the suffix it modifies. It must be placed to the right and adjacent to the suffix it modifies. For example, Bfgj means a Bf horizon with a weak expression of gleying; Bfjgj means a B horizon with weak expression of both f and g features.

k - Denotes the presence of carbonate as indicated by visible effervescence when dilute HCI is added. It is used mostly with B and m (Bmk) or C (Ck).

m - A horizon slightly altered by hydrolysis, oxidation, or solution, or a11 three to give a change in color or structure or both. Bm is a brownish subsurface horizon with only slight addition of iron, aluminum or clay. Illuviation too slight to meet requirements of a Bt or a podzolic B. Suffix can be used as Bm, Bmgj, Bmk, and Bms.

p - A horizon disturbed by man’s activities such as cultivation, logging, and habitation. It is used with A and O.

t - An illuvial horizon enriched with silicate clay. It is used with B alone (Bt), with B and g (Btg), with B and n (Bnt), etc.; Bt horizon must be at least 5 cm thick.

Definitions

Gleying *(also gleization)*, is the process whereby a soil changes colour from an earthy reddish/yellow to a bluish/grey, due to waterlogging, and the resultant loss of iron compounds and oxygen. Tundra, meadow, and podsol soils are often affected by gleying, leaving a mottled appearance, because of the lack of drainage. Soil so affected may be called gleysol. If the soil is grey, there is no iron present, if the soil is bluish-green, there still remains some iron in the soil. On exposure to the air, gley colors are transformed to a mottled pattern of reddish, yellow or orange patches.

Podzolic B horizon is at least 10 cm thick and has moist, crushed colors as follows: a) color is black or the hue is either 7.5YR or redder or 10YR near the Upper boundary and becomes yellower with depth; b) chroma is higher than 3 or the value is 3 or less.

Appendix 3-D

Additional Information on Collection of Bulk Density and Moisture Content Samples

Bulk density sample collected from the "public health" layer (0-5 cm) in Gaspé, Québec. (Photo by R. McNeil)

BULK DENSITY/MOISTURE CONTENT - SAMPLE COLLECTION PROCEDURES

For sample collection in 2007, the sampler used was a clear lexan cylinder that had a bevelled cutting edge, 7.5 cm in diameter and 25 cm in length.

Step-by-step procedures for sampling

1) Prepare a smooth undisturbed vertical or horizontal surface at the depth to be sampled.
-For the Public Health (PH) sample, this is the "upper soil surface" as defined in Part 3 of this manual.
-For the A-horizon sample this is the upper surface of the A-horizon if the A-horizon is <=10 cm in thickness or the centre of the A-horizon, from the vertical face of the soil pit, if its thickness is >10 cm.
-For the B-horizon sample this is a vertical face in the soil pit at the depth where the B-horizon sample is to be taken.
-For the C-horizon sample this is a vertical face in the soil pit as deep down as possible from the bottom of the sample pit.

2) Press the sampler into the soil the required distance.
-For the PH sample this is 5 cm.
-For the A-horizon sample this is the thickness of the horizon (if less than 10 cm) or as far as possible without compressing the soil if from the pit wall (horizon thickness greater than 10 cm).
-For the B-horizon sample this is as far as possible without compressing the sample.
-For the C-horizon sample this is as far as possible without compressing the sample.

3) Carefully remove the sampler making sure to preserve the sample. If the sample does not stay in the cylinder, dig around the cylinder with a trowel and hold it in place with the utensil.

4) Carefully trim the soil flush with the end of the cylinder and measure and record the length of the sample in the cylinder. If the top of the sample is not at right angles to the cylinder, take at least two measurements of length and average the two values.

5) Extrude the sample into an appropriately labelled tin container. Seal the container with electrical tape, and place it in a Ziplock bag. The label consists of the siteID and the sample type, e.g., NB071004-B. It also includes the diameter (D) of the cylinder, length (L) of the sample segment, and the interval or depth (all in cm) from which the sample was collected,

Step 2 - Press the sampler into the soil.

Step 3 - Remove the sampler using the trowel, if necessary.

Step 6 - Extrude the sample.

REFERENCES - PARTS 1 - 3

Agriculture Canada Expert Committee on Soil Survey
1983: CANSIS manual for describing soils in the field 1982 Revised. <http://sis.agr.gc.ca/cansis/publications/manuals/describing_soils.html> {accessed December 16, 2009].

Burnham, C.P., 1980. The soils of England and Wales; Field Studies, v. 5, p. 349-368.

Commission For Environmental Co-operation, 1997. Ecological Regions of North America - Toward A Common Perspective, <http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf> [accessed December 16, 20009].

Garrett, R.G. and Kettles, I.M., 2009. North American Soil Geochemical Landscapes Project (NASGLP): Database of GRTS sample sites with notes on the sampling design and site selection procedure; Geological Survey of Canada, Open File 6300.

Kincaid, T. and Olsen A.R., 2009. spsurvey: Spatial Survey Design and Analysis. http://cran.r-project.org/web/packages/spsurvey/index.html [Accessed December 16, 2009].

National Land and Water Information Service, 2007. National Land and Water Information Service database; <http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1227209183756&lang=eng>[accessedDecember 16, 2009].

National Wetlands Working Group, 1987. The Canadian Wetland Classification System; Land Conservation Branch, Canadian Wildlife Service, Environment Canada Ecological Land Classification Series No. 21, 18 p.

Permafrost Subcommittee, Associate Committee on Geotechnical Research, 1988. Glossary of permafrost and related ground-ice Terms; National Research Council of Canada, Ottawa, Technical Memorandum No. 142, 156 p.

Soil Classification Working Group, 1998. The Canadian System of Soil Classification; Agriculture and Agri-Food Canada Publication 1646 (third edition), 187 p.; <http://www.pedosphere.com/resources/cssc3rd/> [accessed December 16, 2009].

Soil Classification Working Group, 2000: Soils of Canada. Agriculture and Agri-Food Canada, map, scale 1:6 500 000.

Stevens, D.L. and Olsen, R., 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association, v. 99, p. 262-277.

The R Project. 2009. <http://www.r-project.org/> [accessed December 16, 2009]

United States Department of Agriculture, 2002. Field book for describing and sampling soils, v.2; Natural Resources Conservations Service, National Soil Survey Center; <http://soils.usda.gov/technical/fieldbook/> [accessed December 16, 2009].

OTHER HELPFUL PUBLICATIONS - PARTS 1 - 3

Agriculture Canada Expert Committee on Soil Survey, 1983: CANSIS manual for describing soils in the field 1982 (revised).

Boden, A.G.
1994: Bodenkunliche Kartieranleitung, 4th ed. E. Schwizerbart Publishing Company, Stuttgart.

Canada Expert Committee on Soil Survey, 1982. The Canada Soil Information System (CanSIS) manual for describing soils in the field (1982 Revised); Research Branch, Agriculture Canada LRRI Contribution No. 82-52, 175 p.

Canadian Forest Inventory Committee, 2005. National Standard for Ground Plots: Data Dictionary, Version 4.3; National Forestry Institute, 72 p.

Denholm, K.L. and Schut, L.W. (comp.), 1993. Field manual for describing soil in Ontario. Ontario Centre for Soil Resource Evaluation, Guelph, Ontario.

Garrett, R.G., 1983: Sampling methodology; *in* Chapter 4 of Handbook of Exploration Geochemistry, (ed.) R.J. Howarth,, Vol. 2, Statistics and Data Analysis in Geochemical Prospecting. Elsevier, p. 83-110.

Scheyer, J.M. and Hipple, K.W., 2005. Urban Soil Primer; United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Centre, Lincoln, Nebraska, 77 p.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C. and Broderson, W.D. (ed.), 2002. Field book for describing and sampling soils, Version 2.0; Natural Resources Conservation Service, National Soil Survey Centre, Lincoln, Nebraska, 228 p.

PART 4

MEASURING SOIL GAS RADON AND NATURAL RADIOACTIVITY

Measuring soil gas radon and natural radioactivity in southern Saskatchewan. (Photo by J. Campbell)

BACKGROUND INFORMATION ON SOIL GAS RADON AND GAMMA RAY SPECTROMETRY

Radon is a naturally-occurring hazard and the second leading cause of lung cancer (World Health Organization, 2005). Soil gas radon that has entered into homes and other buildings is the main source of natural radiation exposure to humans (Figure 4-1). Prior to 2007, Health Canada's guideline for radon concentrations in Canadian homes was 800 Bq/m^3, above which remediation action was recommended. In 2007, Health Canada implemented a new radon strategy and lowered the threshold limit of radon exposure in Canadian homes and buildings to 200 Bq/m^3. This change is part of a new radon strategy for Canada and is one that harmonizes Canadian guidelines with international guidelines, practices and action levels.

An important objective of the new radon strategy is the identification of radon-prone areas in selected parts of Canada. In 2007, Natural Resources Canada - Geological Survey of Canada, entered into a partnership with Health Canada - Radiation Protection Bureau to identify radon-prone areas of Canada based on analysis of geoscience data. The identification of such areas based on geoscience data is a

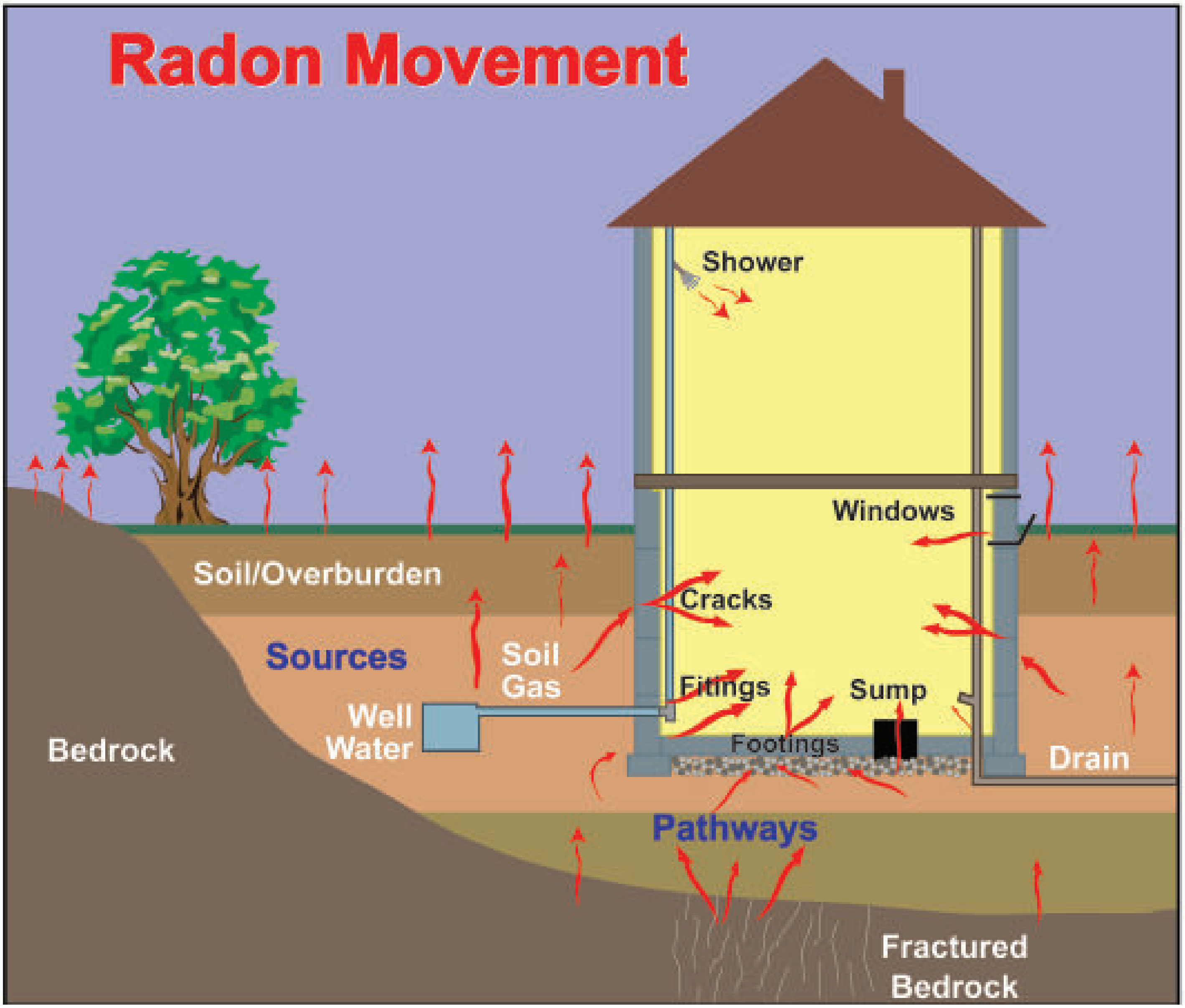


Figure 4-1. *Pathways of soil radon gas through soil, underlying sediments, and buildings.*

valuable supplement to radon risk assessment based on indoor radon measurements. This is especially important for areas where indoor radon measurements are not available or possible to acquire. Analysis of this supplementary data will be used to focus attention on high-risk areas where further testing and, possibly, remediation work is necessary.

To estiamte variations in radon risk potential, data from indoor measurements of radon will be supplemented with other important types of geoscience data, including the following:

- bedrock geology, including recognition of rock types such as certain granites and black shales that may be naturally enriched in uranium;
- surficial geology, including recognition of glacial deposits derived from uranium-rich bedrock and, in places, glacial lake deposits with characteristics that enhance the accumulation of radon within dwellings;
- airborne gamma ray spectrometry and geochemical data for surficial materials, such as lake and stream sediments which show regional patterns of uranium distribution in the surface environment; and
- soil survey data – including soil types and characteristics, soil chemistry, and soil gas radon concentrations.

In addition, new airborne gamma ray spectrometry surveys will be undertaken in selected areas of Canada where gaps exist in current coverage. Figure 4-2 shows the areas in Canada for which data do not exist. Data pertaining to soil gas radon and natural radioactivity is also being collected as part of the North American Soil Geochemical Landscapes Project (NASGLP) at Natural Resources Canada. This activity, supported by Health Canada, was established to acquire the following types of data:

- soil gas radon (Figures 4-3 and 4-4)
- soil permeability - direct (Figure 4-5) and indirect measurements
- in-situ gamma ray spectrometry (K, eU, eTh) (Figure 4-6); and
- laboratory gamma ray spectrometry (“public health” layer (0-5 cm), A-, B- and C-horizon soil samples) (Figure 4-7).

The data obtained from the airborne and ground based surveys will be compiled and interpreted. In each case, data from the in-situ surveys will be compared to data from existing and new studies. These include regional airborne gamma ray spectrometry surveys, the NASGLP and other geochemical sampling surveys, as well as the best available regional-scale information on bedrock and surficial geology. The aim is to develop new methodology for identifying areas with high risk potential for radon through the use of these proxy data.

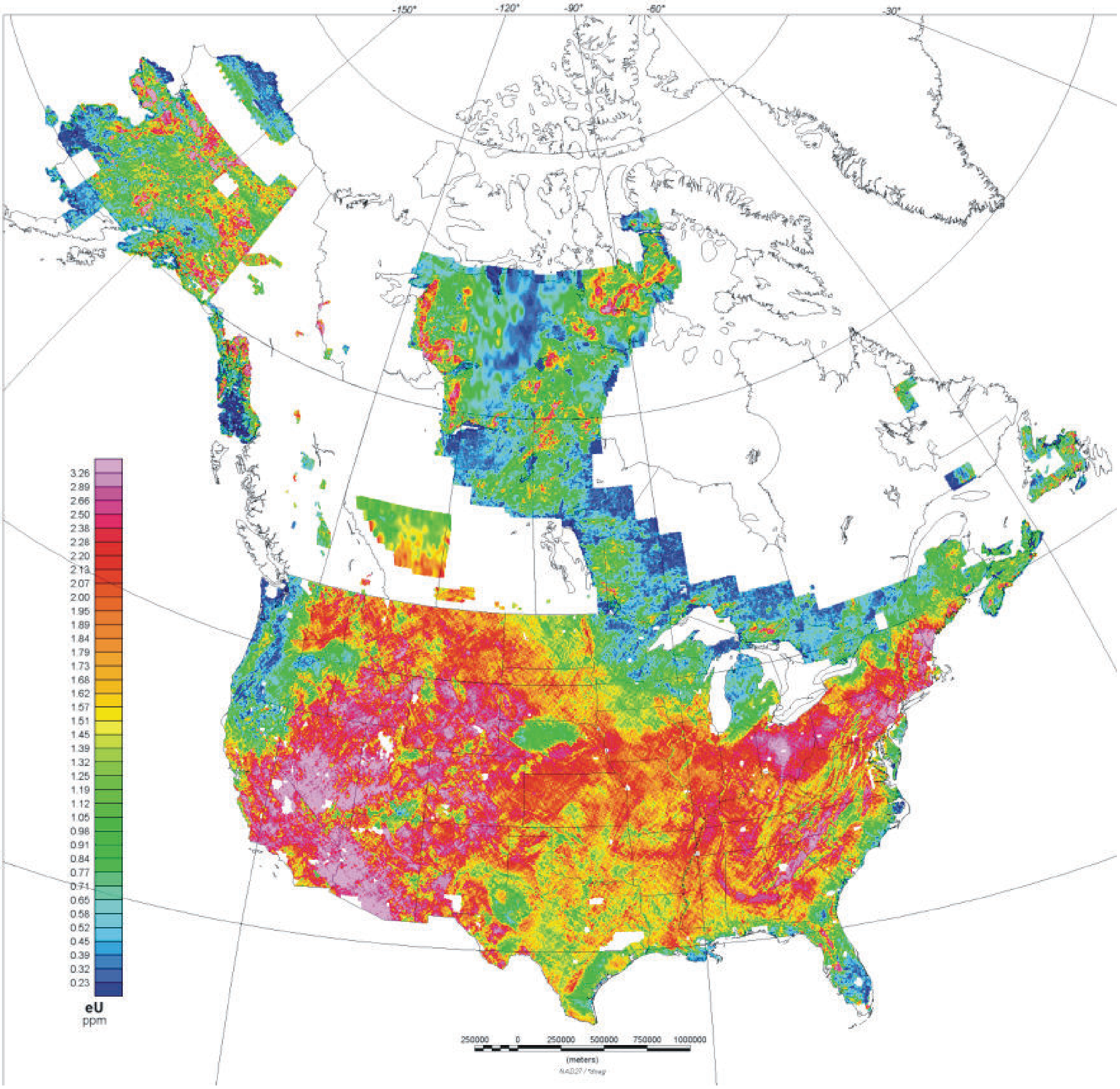


Figure 4-2. *Uranium distribution map of Canada and the United States compiled from airborne gamma ray spectrometry surveys (Darnley et al., 2003). Areas shown in red have high levels of uranium and those in blue, low levels. There are no data available for areas shown in white.*

Figure 4-3. *Top - Collection of soil gas sample from hollow steel probe using a 150 ml syringe. Probe was inserted 60 cm into the soil. Bottom - Gas sample in syringe is transferred from the syringe into the ionization chamber. (Photos by K. Ford)*

Figure 4-4. *Right - The measurement of the radon concentration in an ionization chamber filled with a soil gas sample using the ERM-3 electrometer.*

Figure 4-5. *Left - The RADON – JOK permeability apparatus attached to a hollow steel probe (bottom left of photo). The probe is inserted 60 cm into the soil.*

Figure 4-6. *Exploranium GR320 gamma ray spectrometer with 7.6 x 7.6 cm (3 x 3 inch) NaI detector used for the in-situ determination of potassium (K (%)), equivalent uranium (eU (ppm)) and equivalent thorium (eTh (ppm)) concentrations. (Photo by I. Kettles)*

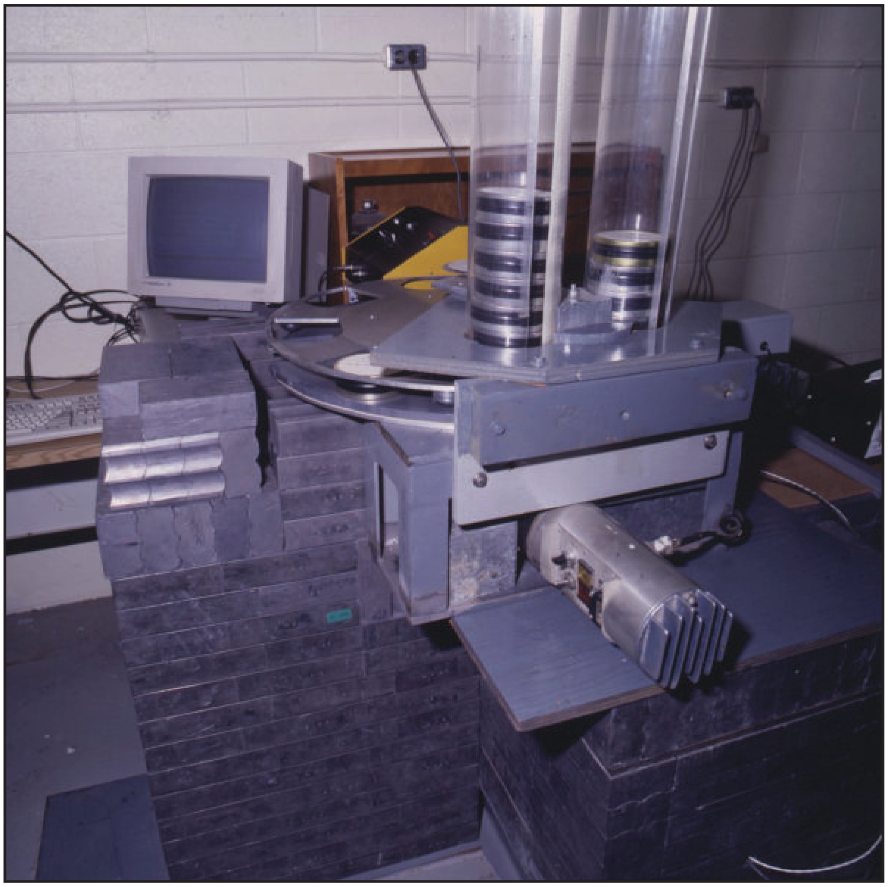


Figure 4-7. *The laboratory gamma ray spectrometer at Geological Survey of Canada is used for the K, eU and eTh analysis of bedrock, till and soil samples. The laboratory procedures are not described in this manual. (Photo by K. Ford)*

RECOMMENDED EQUIPMENT FOR FIELD MEASUREMENTS

Photos of some of the equipment isted are shown in Figures 4-8 and 4-9 and in Appendices 4-B, 4-C and 4-D.

Basic equipment checklist

30 hollow steel probes
5 punch wires
2 simple retractors
1 special retractor
4 drive heads
short lost tips (used for sampling soil gas radon only)
long lost tips (used for direct permeability measurements with the Radon-JOK apparatus)

Specialized equipment for sampling and measuring soil gas radon

10 – 150 ml syringes
rubber tubing (2 sizes) and tubing adapters
nylon hammer
ERM-3 soil radon meter
25 IK-250 ml ionization chambers (ICs)
modified foot pump
equipment manual

RADON-JOK soil permeability equipment

Note: For logistical reasons this unit may not be used for standard NASGLP soil survey sites but will be used for more detailed sampling in urban areas. These will be referred to as urban "fill-in" sites.

JOK Permeability Apparatus plus 1 special backpack for carrying the apparatus
3 tripod legs
long rubber tube
2 weights
2 spacer rings
2 distance screw heads
plum bob
manual and nomogram graph

RS-230 gamma ray spectrometer and accessories

RS-230 gamma ray spectrometer
USB data download cable
charger and cable
2 battery compartments (4 AA batteries)
4 rechargeable AA batteries
equipment manual

GR320 gamma ray spectrometer and accessories

Note: The apparatus may be supplied as a backup for the RS-230 unit or may be used as a primary field spectrometer

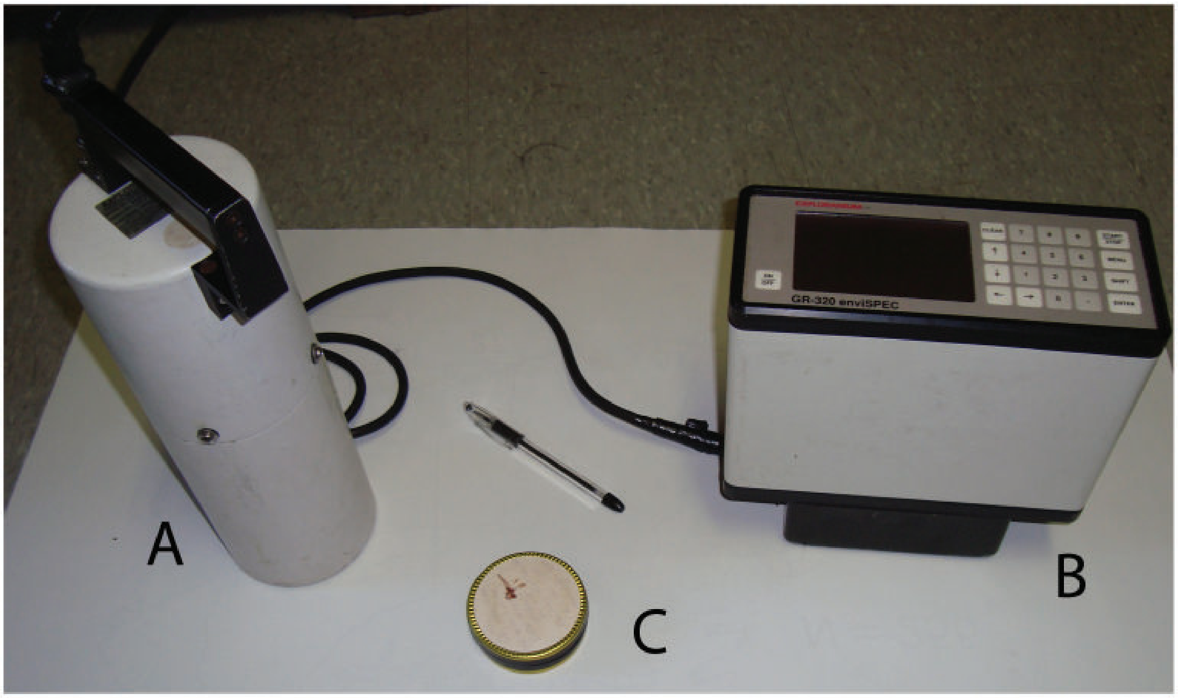
GR320 spectrometer console
GPX-21 detector
scintillometer
Cs-137 check source
2 detector cables
download (RS232) cable
charger and cable
GR-320 manual
Manual of Exporanium Radiation Detection Systems - GR320 Data Explore (v. 5.7 or other appropriate version)
pad calibration printout

Laptop computer equipment

laptop computer with appropriate field data templates and spectrometer data downloading software (preferably with serial port for GR320 data downloading, if required)
backup and recovery disk with manual
power cable and charger
USB mouse
USB memory stick
shoulder strap and carrying case

Extra field equipment and other useful tools and supplies

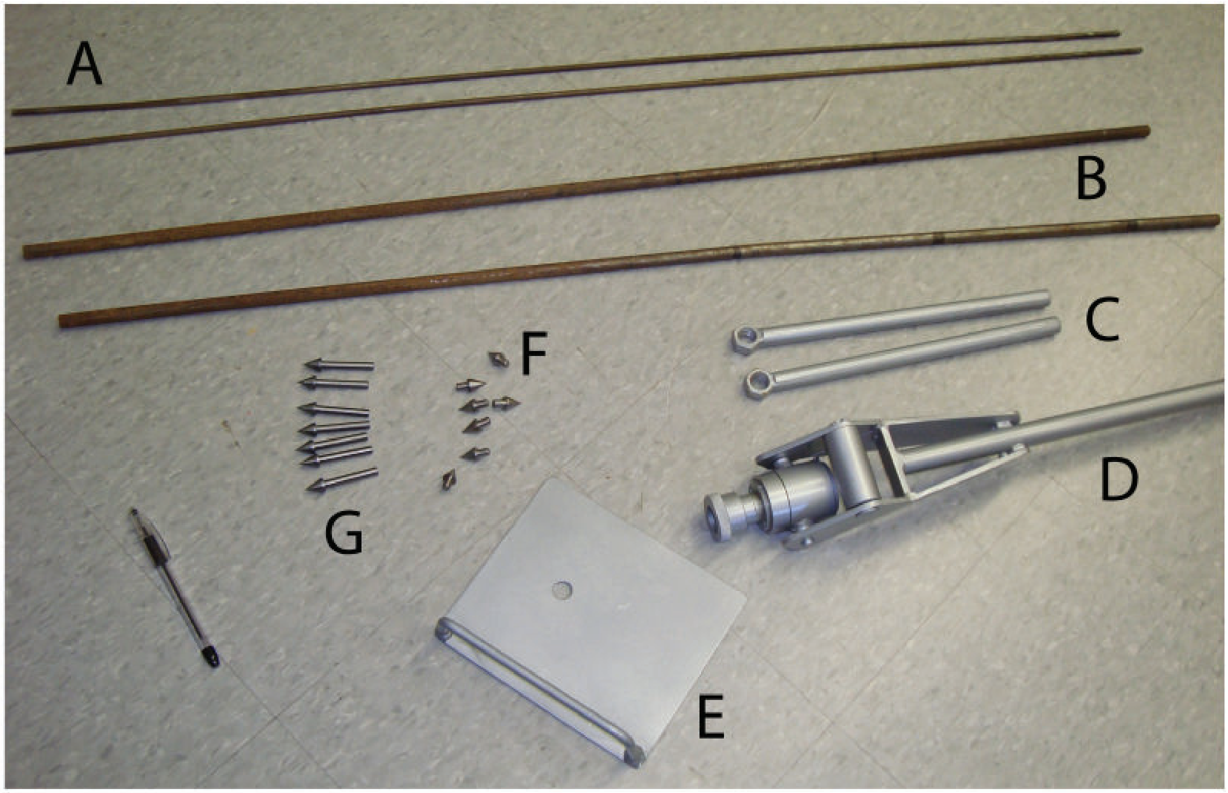
backpack for GR320 spectrometer and other equipment
orange tarp (2.14 m x 3.05 m (7 ft x10 ft))
clipboard
field vest
metric measuring tape
2 forceps – for tubing
camera tripod for spectrometer
multi-tool or pliers (to pull out punch wires)
Olfa knife
flagging tape (to tie around tops of probes and other small items)
work gloves
AA batteries
distilled water – for IC cleaning (may be purchased locally at any drug store)



A - GR320 gamma ray spectrometer - NaI I detector used for measuring soil concentrations of K (%), eU (ppm), and eTh (ppm).
B - GR320 gamma ray spectrometer console
C - Cs-137 check source

A - Ionization chamber
B - ERM2 electrometer used for measuring radon gas concentrations in the ionization chambers

Figure 4-8. Selected equipment required for measuring soil gas radon and natural radioactivity of soils



A - Punch wires to push out lost tips
B - Hollow steel tubes
C - Simple extractors
D - Complex extractor, used with plate (E) for removing probes
E - Plate
F - Short lost tips used for radon measurements only
G - Long lost tips for radon and permeability measurements when the permeability apparatus is used.

RS230 gamma
ray spectrometer

Figure 4-9. Selected equipment required for measuring soil gas radon and natural radioactivity of soils.

QUICK OVERVIEW OF REQUIRED FIELD PROCEDURES

Standard NASGLP site

1. The potential site area of approximately 10 m by 10 m is scanned to check for anomalous radioactive variations. This is accomplished using the RS230 spectrometer in Survey mode or, if the GR320 spectrometer is to be used, with the total count scintillometer. Avoid areas where localized anomalies such as radioactive boulders are detected.
2. The field crew member inserts the first probe and tests the availability of soil gas using the 150 ml syringe, and then sets up the spectrometer to start the first spectrometer measurement. If time permits, the remaining 4 probes may be inserted before the first spectrometer measurement is completed.
3. The crew member returns to record the spectrometer measurements and relocates the spectrometer for the next measurement. If the RADON-JOK permeability apparatus is being used, it is necessary to take measurements on the first 2 probes. If the permeability apparatus is not being used, there may be sufficient time to collect the soil gas at some probes and transfer it to the ionization chambers during the 5 minute counting period needed for the spectrometer measurements.
4. The priority is to finish the 5 surface spectrometer measurements first because the measuring of soil gas radon is time-senstive. The soil gas in the ionization chamber should be measured within 13 to 17 minutes after the soil gas was transferred into it.
5. The soil gas is collected in syringes and transferred to the ionization chambers. Once transferred, the measurement should be made using the ERM-3 electrometer after a wait time of 13 to 17 minutes.

Modifications for a more detailed urban "fill-in" site

- At urban sites, crew members set up 5 probes, take 5 spectrometer measurements as described above, and attempt 5 permeability measurements. Long lost tips are always used at these sites to insert the probes into the ground. At each probe, the permeability measurement has to be performed first.
- At the end of the site visit, it is desirable to have 5 spectrometry readings, 5 soil gas radon measurements and as many permeability measurements as possible.

NOTES ON FIELD PROCEDURES FOR SOIL GAS RADON AND GAMMA RAY SPECTROMETRY MEASUREMENTS

There are detailed instructions for use of the equipment required to measure radon, permeability and natural radioactivity of soils in the appendices associated with this part of the manual (4-B. 4-C. and 4-D). The notes that follow are based on insights from past field experience. They provide additional information and useful hints for carrying out the above types of field operations in a timely and efficient manner. The recommended procedures are suitable for most situations. However, for logistical or operational reasons some modifications may be required. It is important that all field information is properly recorded on the field data sheets, including any changes to standard procedures. Field personnel are encouraged to add additional information and relevant content to the field data sheets as necessary.

Night before the first site visit or between sites visited on the same day

The night before, if possible, verify that the background Rn concentrations for the ionization chambers (ICs) to be used the next day are at or below acceptable levels (approximately 0.7 kBq/m^3). If the background concentration is significantly greater than 0.7 kBq/m^3, the IC should be cleaned using a paper towel lightly dampened with distilled water. More information on background reduction techniques is provided in Appendix 4-F - Soil Radon Monitoring System. After cleaning, carefully reassemble the IC, evacuate it with the foot pump and add 150 ml atmospheric air. After equalizing the pressure, repeat the measurement. Repeat these steps, if required. If the Rn concentration is close to an acceptable value, you may choose to repeat the measurement the following morning.

Note 1**:** Opening ICs immediately after taking a measurement at the sample site reduces the radon concentration and production of new radon progeny. If the same IC has to be used again the same day, a background measurement with atmospheric air is required before refilling the IC with soil gas. Record the background reading and subtract it from the regular measurement.

Note 2: For proper IC maintenance, every 2 to 3 weeks check the integrity of the IC vacuum seal by evacuating all ICs and allowing them to sit for 8 to 12 hours. Afterwards, determine how easily a syringe full (150 cm) of air is pulled into the IC. Also, see Appendix 4-F - Soil Radon Monitoring System - for more instructions on IC maintenance.

Before leaving the field vehicle at the sampling site

Prior to visiting the sample site, evacuate the ICs to be used with the modified foot pump, usually 8 to 10 pulls. The pump can then be left in the field vehicle. After the first 2 or 3 pulls and after the last pull, check the tightness of the large ring at top of the IC because it commonly becomes loose during evacuation.

If a GR320 gamma ray spectrometer is being used, it is necessary to conduct a system test on the instrument prior to visiting the sample site. The supplied Cs-137 check source is used for the test and further instructions are provided below and in Appendix 4-G - GR320 - General Care and Operation. Record the GR320 serial numbers (console and detector) and the test results on a field data sheet. Leave the check source in the truck. *Do not lose it*. Turn off the GR320 to save battery power.

If an RS230 gamma ray spectrometer is being used, turn on the unit and allow it to stabilize before taking the first measurement. This ensures an accurate assay analysis. The RS230 will allow an assay even if the instrument is stabilized, but the assay results may be incorrect. In very low count rate environments, stabilization may take several minutes.

Make sure that you have all the required field equipment before leaving the truck.

At a standard NASGLP site

Take out the field data sheet to record measurements. An example of the sheet is shown in Appendix 4-A. Follow the step-by-step procedures listed below.

Step 1: Taking scintillometer measurements

While the soil team is searching for a suitable location for the sampling pit, survey a 10 x 10 m area in the vicinity of the pit to check for variations in total radioactivity. If the GR320 spectrometer is being used, use the total count scintillometer. If not, use the RS230 in 'SURVEY' mode. Record the range of values and estimated mean value on the field data sheet. Avoid measurements near any source of anomalous radioactivity, most commonly radioactive boulders.

Step 2: Hammering down the probes and setting up the spectrometer

Once a site for sampling is selected, it is necessary to hammer 5 steel probes fitted with lost tips into the ground. It is important to note that the target depth for each probe is 60 cm. If resistance is felt while hammering in the probes, *do not force them*. There may be a boulder in the soil. Extract the probe and try another location nearby. The hollow probes bend easily but they can be straightened out with a hammer or vise. Bring a large number of extra lost tips because relocations of probes may be required. Use punch wire to hammer down all lost tips. If short tips are being used, hammer them only to a depth where the punch wire can be easily grasped with pliers.

It is helpful to tie a short length of flagging tape around the top of each probe. This makes it easy to find the probes, especially in wooded areas with dense underbrush. Select probe locations that are distributed around, but not near or adjacent to, the soil pit. Avoid obviously wet or even damp ground. After the first probe is hammered in, set up the spectrometer using the camera tripod over or near the probe and start the first measurement. During the 5 minute count time for the first measurement, the remaining probes can be inserted. However, the crew member may wish to test the availability of soil gas at the first probe by attaching the 150 ml syringe and extracting the first 150 ml of soil gas.

If water is encountered at the 60 cm target depth, or no soil gas is available, as might be the case in very clay-rich soils, then the probe may be raised 5 or 10 cm and this test repeated. The remaining probes may then be inserted to this shallower depth. Record all depths and relevant comments on the field sheets.

If the permeability apparatus is *not* being used:
Short tips are needed. Attempt to carefully hammer down all lost tips to equal depths to ensure near constant volume at the bottom of each probe. Follow steps in Appendix4-B – Procedures for Soil Gas Radon Sampling.

If the permeability apparatus is being used:
Long tips are required for those probes attached to the apparatus. The first two probes *must* be inserted using the long lost tips. Follow Steps 5 to 9 in Appendix 4-C – Set Up for Measuring Soil Permeability- and see Appendix 4-D – Equipment for In-situ Permeability Measurements- for more information.

Step 3: Taking spectrometer and permeability measurements

Taking 6 – 300 second spectrometer measurements is recommended, 1 at each of the 5 probes and the sixth in the sample pit. The pit measurement is made after the soil sampling is completed but before the hole is filled in. Every effort should be made to acquire this 6th soil pit measurement. If there is further time, additional spectrometer measurements can be taken either on the soil pile or at other undisturbed surface sites.

The following is a list of the necessary steps:

a. Start the first spectrometer measurement with the spectrometer attached to the camera tripod and suspended approximately 50 cm above the ground.
b. If required, set up the permeability apparatus, using the instructions in Appendix 4-C – Set Up for Measuring Soil Permeability, If Required - and Appendix4-D – Equipment for In-situ Permeability Measurements. If the permeability apparatus is not being used, hammer in the remaining 4 soil gas probes and hammer down the lost tips. Also, refer to Step 4, below, for details on how to estimate permeability when the apparatus is not being used.
c. Record the first spectrometer measurement. Move and start the second spectrometer measurement.
d. If required, conduct the first permeability measurement. If the measurement is zero or near-zero (i.e. no movement on the weights after 3 to 4 minutes), record it on the field data sheet as “minimum permeability”. Stop and reconnect the long rubber hose to the second permeability probe. It is useful to separate the 2 permeability probes, inserted using long lost tips, by a distance of slightly less than two times the length of the long rubber hose. If this recommendation is followed, only one apparatus setup is required at a middle distance between the 2 probes. Be careful not to kink the hose or the apparatus will not function properly.
e. Record the second spectrometer measurement. Move and start the third measurement.
f. If required, conduct and record a second permeability measurement.
g. Record the third spectrometer measurement. Move and start the fourth measurement
h. Record the fourth spectrometer measurement. Move and start the fifth measurement

Adjustments for the more detailed urban “fill-in” sampling:

It is recommended that 5 permeability measurements be made or attempted. To accomplish this, all 5 probes must be hammered into the ground using the long lost tips. If the permeability is low, there will likely only be sufficient time to take the first 2 measurements. Soil gas radon samples can be collected from the same probe as the permeability measurements BUT the permeability measurement must be performed first.

It is useful to position probes 1 and 2, and probes 3 and 4 close enough to each other that the permeability apparatus hose will reach both probes. This will minimize the number of apparatus moves.

Step 4: Soil gas radon sampling

Remember that soil gas radon measurements are time-sensitive. Hence, as noted above, it is recommended that all surface spectrometer measurements be completed before the soil gas radon sampling is started. Step-by-step instructions for the radon sampling are given in Appendix 4-B – Procedures for Soil Gas Radon Sampling.

In some field situations, it is not possible or practical to take soil permeability measurements using the apparatus on account of field safety or logistical reasons, such as inaccessibility or rough terrain. When this is the case, estimates of soil permeability are made as follows: when collecting the soil gas sample with the syringe, evaluate the relative resistance encountered on the syringe pull and record the result on the field data sheet. For little or no resistance or an easy pull, record high permeability; for moderate resistance, record medium permeability; for high resistance or a hard pull, record low permeability.

For detailed, urban "fill-in" sites, permeability measurements should be attempted on all 5 probes, if the terrain is suitable and time permits. If there is insufficient time on account of the soil having low permeability, there needs to be a minimum of two measurements completed. Only long lost tips are used at these sites.

Taking 5 soil gas radon measurements is recommended. Seek assistance, where possible, from the soil sampling crew for measuring the radon because these measurements are time-sensitive. If the permeability apparatus was used at the site, it is possible to use the same probes for the radon measurements. Avoid being too close to the soil pit. All hollow steel probes for collection of soil gas radon can be inserted at the most suitable time and the lost tips hammered down. See Appendix 4-B – Procedures for Soil Gas Radon Sampling, and Appendix 4-E – Manual for Soil-Gas Sample Collection Sampling System - for further information.

Hint for collecting in low permeability soils - If you encounter a probe with a hard to very hard syringe pull, i.e. 50 ml/5 ml or equivalent on the first pull, and it is difficult to get the required 150 ml for the first sample, use the extractors to raise the probe 5 cm, from a depth of 60 cm to 55 cm, and try again. Be careful to maintain the seal between the soil and the outside of the probe. If the syringe pull is still hard to very hard, raise the probe another 5 cm to the 50 cm depth and try again. Be sure to record any changes to the probe depths on the field data sheet. If, at 50 cm, gas collection is still hard or very hard, check the time and make the decision to stop and move to the next probe.

The objective is to collect all or most of the soil gas samples from a consistent depth. If it is hard to collect a gas sample at the first probe, it is helpful to collect samples from the other probes at depths of 60 cm before returning to the first probe. If it is difficult to collect a sample at 60 cm at all probes, you may need to raise all to 55 cm or 50 cm. Pulling the probes to a shallower depth also applies if the top of the water table is high and water enters the syringe.

Step 5: Soil gas radon measurement

It is important to record the times that each IC is filled with soil gas from the syringe. Every effort must be made to start the measurement within the 13 to 17 minute window from the time the IC was filled. Remember to watch the time while collecting the soil gas samples.

1. Turn on the ERM monitor – make sure that the meter is set to “15”**.** To save time, the monitor can be turned on several minutes before the first IC reading is taken. *Do not touch* the IC and *be careful* to have no excessive movement while the measurement in progress. *Make sure* that the cap is always on the monitor reader if no IC is being measured. Handle the ERM-3 meter with care, especially the reading connector. Avoid contaminating it with dust. Radon measurements should not be performed while it is raining.
2. Measure all ICs in the same sequence they were filled. Record the time the measurement started. It should be between 13 and 17 minutes from the time IC was filled. Record the IC # and the radon reading on the field sheet.
3. If several “0.0” values are encountered at any site, it is wise to “re-zero” the meter and repeat the measurement to confirm that the low value is correct. Remember to record the start times when each IC is measured.
4. Open the ICs immediately after the soil gas radon measurements have been finished and the detector has been removed from the reading connector. This reduces the build-up of longer-term progeny. See the note below on testing for radon progeny contamination. The note also provides information on maintaining the ICs and reusing them the same day.
5. After all ICs are measured, turn off the monitor. Place the ICs in the carrying case and extract all probes using either the simple or complex retractor. Disassemble the equipment and pack the permeability apparatus if it was used. *Pay particular attention to collecting the smaller items and ensure that the field data sheet is properly completed.*

Note on testing for radon progeny contamination:
As stated above, opening the IC immediately after a measurement reduces build-up of longer-term progeny and shortens the time required before IC can be reused. The level of radon progeny contamination of the IC can be tested by taking a measurement on an atmospheric air sample (low radon) that has filled the IC, instead of a soil gas sample. The value should normally range from 0 to 0.7 kBq/m^3. The IC can be used the same day if the background value is acceptable or if a background measurement is performed immediately before that IC is to be used.

It is important to get into the habit of monitoring the IC background value routinely and making regular tests of the vacuum stability of each IC. It is helpful to cycle the use of all 25 ICs. The night before a site visit, determine which ICs may be used and measure their background radon concentrations. If they have levels below the normal maximum background of 0.7 kBq/m^3, no further action is needed. If the levels are higher, evacuate the IC, fill it with atmospheric air and remeasure. If the reading is still above 0.7, clean the IC with distilled water, dry it, and measure again. Repeat this procedure until the background level is 0.7 or less. Further information on cleaning and decontamination of the IC is described in the manual in Appendix 4-F. If the IC is to be used again on the same day or even the next day, a cleaning and decontamination of the IC is recommended as described in Appendix 4-F. Otherwise, take a “background” measurement with atmospheric air. Record the background radon value and subtract it from the measured soil gas value.

REFERENCES

Darnley, A.G., Duval, J.S., and Carson, J.M., 2003. The surface distribution of natural radioelements across the USA and parts of Canada: a contribution to Global Geochemical Baselines; <http://gsc.nrcan.gc.ca/gamma/dist/index_e.php> [accessed December 16, 2009]

World Health Organization, 2005. Radon and cancer. The World Health Organization, Fact Sheet No.291, June 2005; < http://www.who.int/mediacentre/factsheets/fs291/en/index.html> {accessed December 16, 2009].

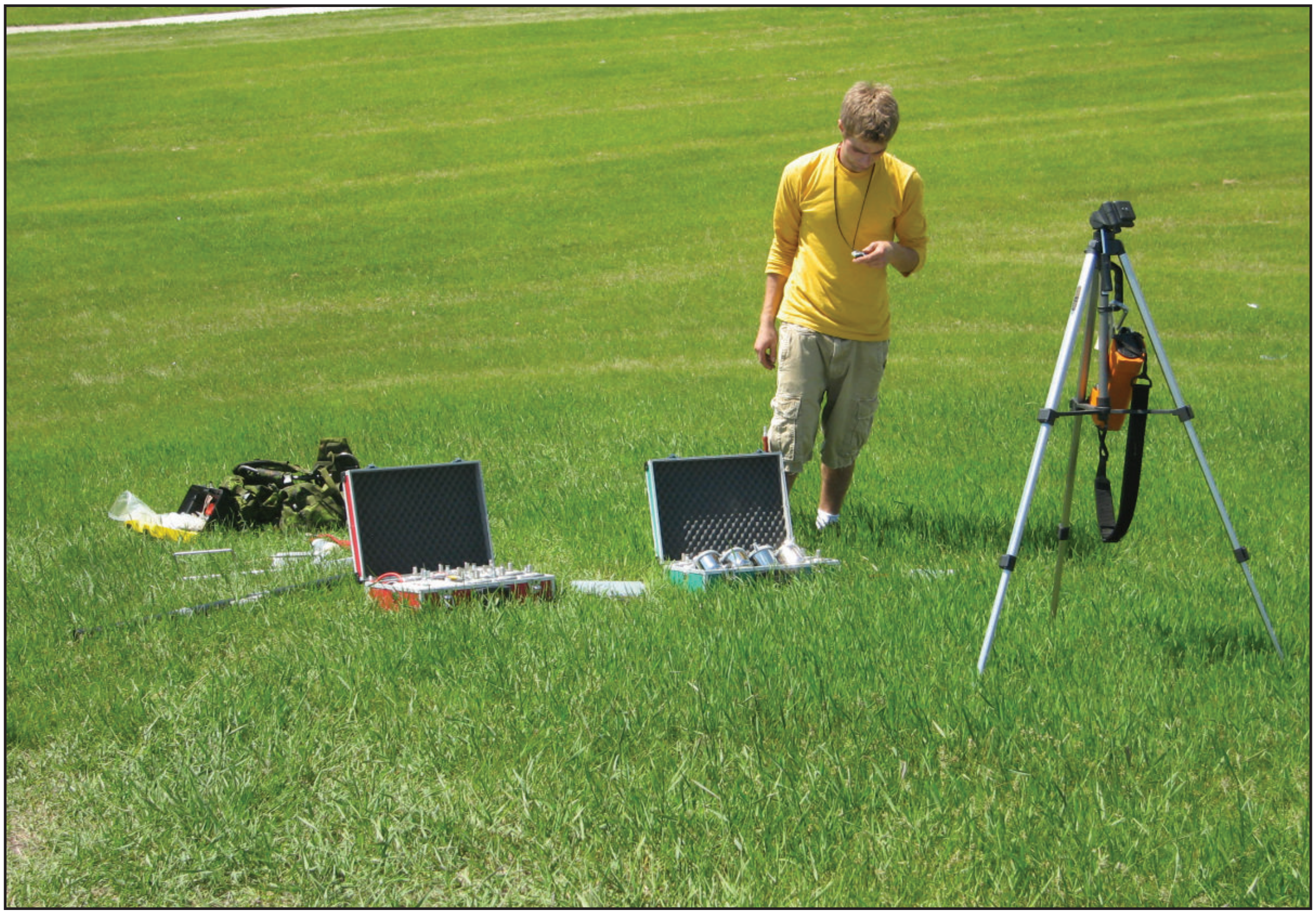
OTHER HELPFUL PUBLICATIONS

Barnet, I., Pacherova, P., Neznal, M. and Neznal, M., 2008. Radon in Geological Environment – Czech Experience, Czech Geological Survey Special Paper 19, 72 p.

Neznal, M., Neznal, M., Matolin, M., Barnet, I. and Miksova, J., 2004. The new method for assessing the radon risk of building sites, Czech Geological Survey Special Paper 16, 48 p.

Appendix 4-A

Field Card for Soil Gas Radon and Natural Radioactivity Measurements



Measuring soil gas radon and natural radioactivity from an urban park in Winnipeg, Manitoba. (Photo by H. Byker)

NASGLP Soil Sampling Field Data – Natural Radioactivity and Radon

Date:	Cell I.D.		Site I.D.	
RepStat :	Resampled Site : (Y)	(N)	NFI Plot:	
NTS Sheet #:	Lat. (NAD83)		Long. (NAD83)	
Weather:			Air Temp (C):	
Time (In):	Time (Out):			
Name of Sampler:				

Radioactivity: Spectrometer Serial # - ; GPX 21 Serial # (if applicable) - ;

System Gain (if applicable)	Peak	FWHM	Gain				

Spec #	Total (ppm)	K (pct)	eU (ppm)	eTh (ppm)	Total (cpm)	K (cpm)	eU (cpm)	eTh (cpm)	Scint. Value

Radon

Radon Station #	Depth (m)	1st Pull to / back to (ml)	Sample Vol. (ml)	Ion. Chamber #	Time IC Filled	Time of Meas.	Radon Bkd (kBq/m^3)	Radon Conc. (kBq/m^3)	Comment

Permeability

Permeability Station #	Depth (m)	1 or 2 Weights	Time Started	Measured Time (s)	Permeability (k/m^2)	Comment

Additional Comments:

Appendix 4-B

Procedures for Soil Gas Radon Sampling

Measuring soil gas radon in Manitoba (Photo by. H. Byker)

INSTRUCTIONS FOR SOIL GAS RADON SAMPLING

Step-by-step procedures

1. Pump out the 5 ionization chambers (ICs) with the modified pump (8 to 10 full motions) before leaving the vehicle. Check the tightness of each IC top after 2 or 3 pump motions.
2. At the site, insert a short tip into the end of the sampling probe. Use long tips for the probes at which permeability measurements will be taken.
3. Hold the tip in place and set it on the ground.
4. Drop the drive-in head on the top of the probe.
5. Hammer the probe with the nylon hammer to a desired depth of *60 cm*. The probe can be partially retracted 2 or 3 cm if the soil gas sample is difficult to acquire. It is helpful to inscribe depth marks on all probes with a permanent marker prior to their use.
6. Insert the punch wire into the probe
7. Gently hammer the punch wire several centimetres into the ground and remove it. Try to be as consistent as possible with the distance that the lost tip is hammered down in order to maintain a constant volume.
8. Attach the assembly of coarse tube, adapter, and small tube to the probe.
9. Connect the syringe to the small tube. Try to extract the first 150 ml of gas with the syringe. The method used to acquire qualitative information on the soil permeability using the syringe is described at the end of this section.
10. Clamp the small tube and disconnect the syringe from the small tube. Discard this first 150 ml of soil gas as it may be contaminated with atmospheric air. Reattach the syringe to the fine tube and unclamp the tube.
11. Extract another 150 ml of gas from the probe. Remember to coax out a full 150 ml. If a full 150 ml cannot be collected in a reasonable amount of time, record the actual volume collected and perform the adjustment correction described in Appendix 4-E.
12. Clamp the fine tube and remove both it and the syringe from the tube resizing adapter.
13. Attach the fine tube to the evacuated IC. Open the valve on the chamber and the soil gas in the syringe should be transferred instantly. If the syringe does not evacuate completely, select another evacuated IC and repeat the 150 ml soil gas collection. Again, throw away the first 150 ml which may be contaminated with atmospheric air. This incomplete soil gas transfer may indicate a problem with the IC vacuum caused by a leaking IC O-ring or valve, or a problem with the foot pump used to evacuate the IC.

Step 1. Pumping out the ICs with the modified pump.

Step 5. Hammering a sampling probe to desired depth of 60 cm.

14. Close the valve on the IC and remove the fine tube and syringe.
15. Repeat the above steps at the other 4 probes, filling 5 ICs. RECORD THE EXACT TIME that each IC was filled with 150 ml of air. If less than 150 ml was collected, record the actual amount on the field sheet. It is important that the ICs be measured 13 to 17 minutes after they are filled. Note: KEEP TRACK of the time when the first IC was filled. If all 5 ICs are not filled before the first one has to be measured, measure the ones already filled. Later, complete the rest if time permits. Attempt to space out the collection of the soil gas and the filling of the ICs by 3 or 4 minutes to allow for measuring time. REMEMBER that it takes 2 minutes for the monitor to start up and another 2 minutes for the monitor to zero from the time it was first turned on.
16. Before taking a reading on the IC, equalize the IC internal pressure by briefly opening (1-2 sec.) the IC valve. There will be a short hissing sound as the pressure equalizes, then close the IC valve.

Steps 9 and 11. Extracting soil gas with the syringe attached to the small tube.

Step 13. Attaching the soil gas filled syringe to the evacuated IC and recording the time the IC was filled on the data sheet.

Step 16. Taking a reading of the radon concentration collected from the soil gas.

Note on an alternative method for acquiring permeability information

This test is used for purposes of comparison with an actual permeability measurement or where it is not practical to make an actual measurement. For this test, it is necessary to carefully record the ease with which the syringe is filled (i.e. easy, moderate, hard (difficult)) and the volume of soil gas obtained after using the following procedure. Using an even and steady pull, attempt to fill the syringe to 150 ml, but, on this initial pull do not pump or "work" the syringe. Record whether it is easy, moderate or hard to fill syringe. Also record the volume of air without "over pulling" the syringe. Next, release the syringe handle and record the volume reading to which the syringe pulls back. Record both values, for example, 150/60 or 100/40. Next, carefully complete the 150 ml sample collection by slowly pumping or "working" the syringe, until the syringe does not pull back. Be sure to extract the 150 ml of gas.

Appendix 4-C

Set Up for Measuring Soil Permeability, If Required

Using the permeability equipment near Pembroke, Ontario, summer 2008. (Photo by I. Kettles)

SOIL PERMEABILITY APPARATUS SET-UP (IF REQUIRED)

Step-by-step procedures

1. Insert the long tip into the end of the sampling probe.
2. Hold the sharp tip in place and set it on ground.
3. Drop the drive-in head on the top of the probe.
4. Hammer the probe with the nylon hammer to a desired depth of *60 cm.* It is helpful to mark appropriate depths on all probes beforehand with a permanent marker.
5. Insert the punch wire into the probe.
6. Place the distance ring (spacer) over the punch wire and on top of the probe.
7. Place the distance screw on top of the distance ring and screw in the distance screw until it touches the distance ring.
8. Remove the distance ring.
9. Gently hammer the distance screw until it touches the top of the probe. Remove the distance screw and punch wire.
10. Open the transport case and remove the RADON-JOK apparatus.
11. Attach the tripod legs to the base.
12. Place the apparatus on the base.
13. Use the plum bob to level the equipment. It is important to ensure that the apparatus is level as a misalignment may cause the alarm and LED light to activate prematurely. If this happens, level the apparatus again.
14. Attach one of the two weights to the under side of the tripod base. Use the second weight only if needed.
15. With the valve on top of the apparatus closed and the rubber bladder compressed, attach the coarse long rubber hose to the probe and close the valve on top of the apparatus.
16. Set both switches to the “ON” position.
17. Fully open the valve to start suction.
18. Start recording the time after the first audible beep and stop after the second beep.
19. Detach the tube from the valve.
20. Turn the switches to the “OFF” position.
21. Remove the weight(s).
22. Return the bladder to the collapsed position.
23. Close the valve.
24. Disassemble the apparatus and return it to the case unless a second measurement needs to be taken.
25. Extract the probe using either the simple or complex retractor unless a soil gas sample needs to be taken.
26. Use a nomogram to estimate the permeability of the soils at the site and use the formula in Appendix 4-D to calculate the permeability later.

Appendix 4-D

Equipment for In-Situ Permeability Measurements

EQUIPMENT FOR IN SITU PERMEABILITY MEASUREMENTS

RADON – JOK

MANUAL

The **RADON-JOK** is a portable equipment, which has been developed for in situ measurements of gas permeability of soils. Its robustness and its simplicity is very practical for easy, quick and at the same time sufficiently exact in situ investigation.

radon v.o.s.
Novakovych 6, 180 00 Prague 8
Czech Republic
☎+fax: ++ 420 266 314 112,
☎+fax: ++ 420 266 317 550
e-mail: radon@comp.cz
www.radon-vos.cz
www.radon.eu

Features

The gas permeability of soils is one of the important factors which determine the possible radon sources of any given site. In situ measurements of the gas permeability are therefore needed to estimate the radon risk at specific sites.

The principle of the **RADON-JOK** equipment consists of air withdrawal by means of negative pressure. Air is pumped from the soil under constant pressure through a specially designed probe with a constant surface of contact between the probe head and the soil. The constant active area is created in the head of the probe (driven into the soil to a measured depth) by the extrusion of the tip by means of the punch wire inside the probe by an exact distance. The special rubber sack, with one or two weights, pumps the air from the soil and allows to perform measurements at very low pressures. The gas permeability is calculated from the equation /see below/ using the known air flow through the probe. The air flow is defined by the known air volume (= 2000 ccm) in the rubber sack (depression of the bottom of the sack between two notches) and by the pumping time measured. The great advantage of **RADON-JOK** is the possibility to perform measurements independently of any source of energy (electricity, compressed air...).

Theoretical framework for the gas permeability measurement is based on Darcy´s equation /Koorevaar et al. 1983/. The soil is assumed to be homogeneous and isotropic and a standard state is considered. Further more the air is assumed to be incompressible (pressure differences are very much smaller than the atmospheric pressure). The air flow can be expressed by the following equation:

$$Q = F \,.\, (k / \mu) \,.\, \Delta p$$

where

Q	$/m^3.s^{-1}/$	is the air flow through the probe,
F	$/m/$	is the shape factor of the probe (depending on its geometry),
k	$/m^2/$	is the gas permeability of the soil,
μ	$/Pa.s/$	is the dynamic viscosity of air (at 10°C $\mu = 1{,}75 \,.\, 10^{-5}$ Pa.s),
Δp	$/Pa/$	is the pressure difference between surface and the active area of the probe.

Critical point of use of this equation is the determination of the shape factor F. A solution has been presented by Damkjaer and Korsbech /A small Diameter Probe for In-situ Measurements of Gas Permeability of Soils, The Fifth International Symposium on the Natural Radiation Environment, Salzburg, 1991/ or by Van der Graaf and Meijer /1992/. Resultant formula is as follows:

$F = 2 . \pi . L \ / \ \ln \{ 2. L . [(4D-L)/(4D+L)]^{1/2} / d \}$

where

L /m/ is the length of the active area of the probe head,

d /m/ is the diameter of the active area,

D /m/ is the depth below the surface,

the approximation l >> d has been used.

For the presented system – the 12 mm diameter hollow steel probes (standard length 1,1 m) are similar to those for soil gas sampling. Only the shaft length of the sharp tip is larger. The probe is driven into the soil to a measured depth by a hammer, into the head of the probe a 45 long shaft of the tip is inserted. Then the tip is extruded by means of the punch wire inserted into the upper opening of the probe, the end of the shaft being 5 mm distant from the lower probe opening. The active surface of the probe is thus a cylindrical surface, 50 mm long and 12 mm in diameter. The shape factor F is then (the standard measurement depth D = 825 mm):

F = 0,149 m.

Using the **RADON-JOK** system, with the shape factor F = 0,149 m, the feasible range of measured gas permeability (**k**) is approx. from **k** = 10^{-11} m^2 to **k** = 10^{-14} m^2. The maximum detection limit (measured time of 8 s corresponds to **k** = 1.4 10^{-11} m^2) is determined by the resistance of the equipment, the minimum detection limit depends on the time spent in any given measurement (measured time of 3600 s corresponds to

$\mathbf{k} = 1.7\ 10^{-14}\ \mathrm{m}^2$). It is possible to extend the range to higher values using a probe with reduced shape factor.

As for the assessment of measured gas permeability values (**k**) in the framework of radon risk classification, it is possible

- to use measured values themselves,
- to derive the category of gas permeability using specified boundaries

(following boudaries are used in the Czech Republic:

high permeability	$\mathbf{k} > 4.0\ 10^{-12}\ \mathrm{m}^2$
medium permeability	$4.0\ 10^{-12}\ \mathrm{m}^2 > \mathbf{k} > 4.0\ 10^{-13}\ \mathrm{m}^2$
low permeability	$\mathbf{k} < 4.0\ 10^{-13}\ \mathrm{m}^2$),

- to use measured values for calculation of a so called "radon potential" derived from any of available radon potential models.

Description of the equipment and method of measurements

The special rubber sack with active volume 2000 ccm is placed in a metal frame. The withdrawal of the air is effected by one or two weights (1 weight – negative pressure about 2,16 kPa, 2 weights about 3,75 kPa) acting on a tie rod. The two notches situated on the tie rod switch on and off the light- and sound-signalization of the beginning and the end of measurements. This signalization is powered by 4 penlight batteries. The equipment is connected to the probe through a rubber tube 14/2 mm in diameter, the probe is 12/2 mm in diameter and 1,1 m standard length. On the head of this probe there is a "lost" sharp tip 12 mm in diameter with a shaft of 45 mm. The punch wire is 6 mm in diameter. The distance ring (length 50 mm) and the distance screw are used for the exact extrusion of the tip and the creation of an exact surface for the measurement.

Steps to follow in taking measurements:

1. to level the equipment in situ, basic plate horizontal, the initial state of the sack in the upper concracted position;
2. to drive in the hollow probe with the "lost" tip to the required depth;
3. to extrude the "lost" tip by means of the punch wire, the distance ring and distance screw by the exact distance (thus opening the defined measurement surface);
4. to connect the probe with the equipment cock by means of a rubber tube;
5. to attach the weight to the tie rod of the equipment (selection of one or two weights with respect to the assumed permeability);
6. to set the switches to position on, audio;
7. to start the suction by opening the cock to the full;
8. to measure the time interval between commencements of two acustic (or light) signals – stopwatch or watch;
9. to evaluate the gas permeability (**k** /m^2/) on the basis of the weight(s) used and the measured time interval (enclosed nomogram or calculation algoritmus).

For more details see the photo sequence.

Notes:

1. If the same probe is used for soil gas radon concentration measurement as well as for permeability measurement (the special type of "lost" sharp tip for gas permeability measurement must be used), it is necessary to start with the gas permeability measurement (higher underpressure during soil gas sampling could cause a destruction of an internal surface of the cavity and affect the permeability measurement).

2. In situ gas permeability measurements should not be performed under extreme meteorological conditions.

3. Time spent by the permeability measurement can be too long, especially in the case of low soil permeability and/or high groundwater saturation. Then it is recommended to use a minimum detection limit (f.e. measured time of 3600 s corresponds to **k** = $1.7\ 10^{-14}$ m^2) and express the result in a way **k** is lower than the detection limit.

4. To enlarge the number of measurements that can be performed with the same probe, it is useful to straighten the probe in the case of flex, as well as to rasp occasionally the crushed end of the probe.

5. For opening the defined measurement surface (length of the cavity in the soil of 50 mm) it is possible to make notches on each punch wire. Then it is necessary to use stable couples of probes and punch wires, because of variable lengths (each probe must be used with "its" punch wire). For this reason it is better to use the distance ring and the distance screw: to screw the distance screw till it touches the distance ring, to remove the distance ring, to extrude the "lost" tip by means of the punch wire and the adjusted distance screw).

6. At least once in 10 measuring days it is necessary to check the tightness of the system (particularly fissures in the sack). The test consists in checking whether with a closed cock and acting weights the bottom of the sack does not drop.

7. The penlight batteries that power the signalization should be checked regularly (the batteries are placed under the switches - for an exchange of batteries it is necessary to open the cover in the side of the panel).

The **RADON-JOK** equipment includes basic accessories:

1 RADON-JOK equipment proper, 1 transport case, 3 tripod legs, 1 rubber tube 14/2 mm, 5 probes 12/2 mm - length 1,10 m, 2 punch wires, 2 weights, 300 "lost" sharp tips – special type for permeability measurements, 2 simple retractors, 1 distance ring, 1 distance screw, 1 drive in head, 4 penlight batteries (already installed), 1 plummet, manual and nomogram.

PERMEABILITY MEASUREMENT, RADON–JOK - PHOTO SEQUENCE

Fig. 1: Inserting the sharp tip (special type for permeability measurements) into the lower end of the sampling probe (1)

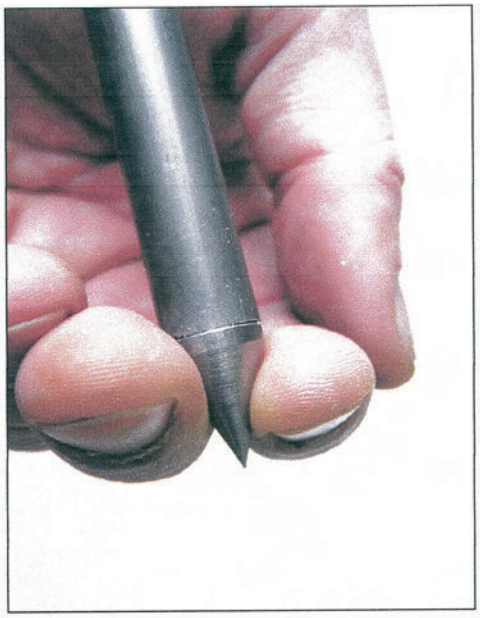


Fig. 2: Inserting the special sharp tip into the lower end of the sampling probe (2)

Fig. 3: The probe with the tip is prepared at the sampling place

Fig. 4: Preparing the drive in head

Fig. 5: The probe is pounded to the desired depth using the special hammer and the drive in head

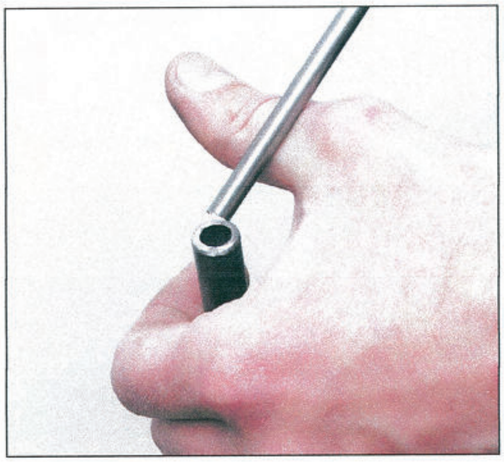


Fig. 6: Inserting of the punch wire into the probe

Fig. 7: The insertion of the distance ring

Fig. 8: Screwing the distance screw till it touches the distance ring

Fig. 9: The sharp tip is moved to the exact distance using the punch wire and the adjusted distance screw

Fig. 10: The sharp tip is moved to the exact distance – the defined measurement surface is opened

Fig. 11: Opening the transport case

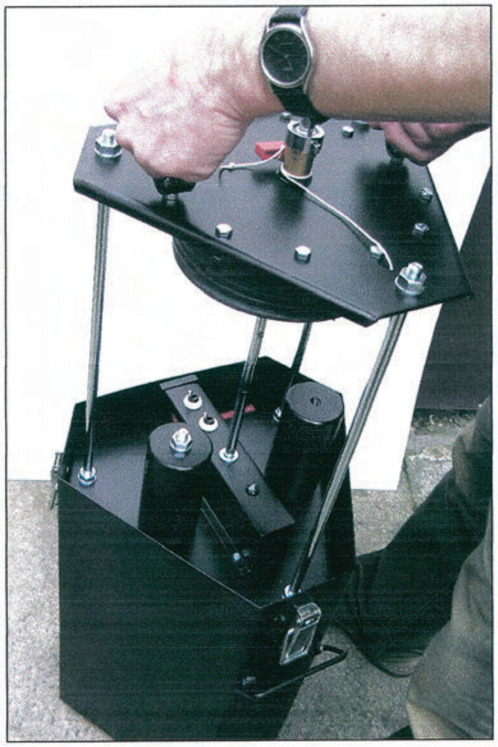


Fig. 12: Taking out the RADON-JOK

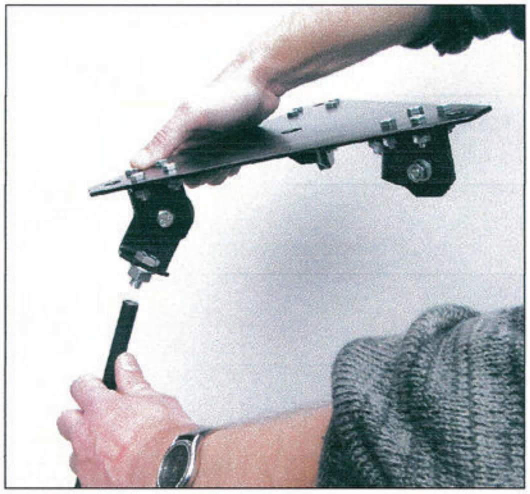


Fig. 13: Making the tripod mount

Fig. 14: Screwing the tripod leg

Fig. 15: Placing the equipment

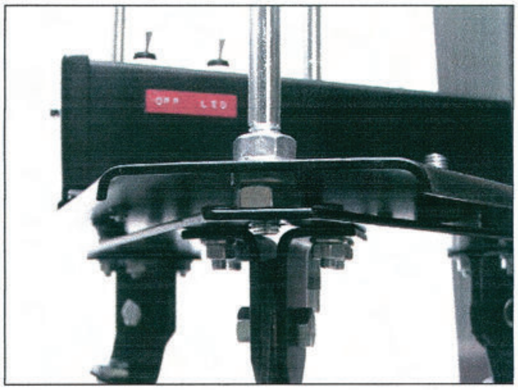


Fig. 16: Placing the equipment (detail)

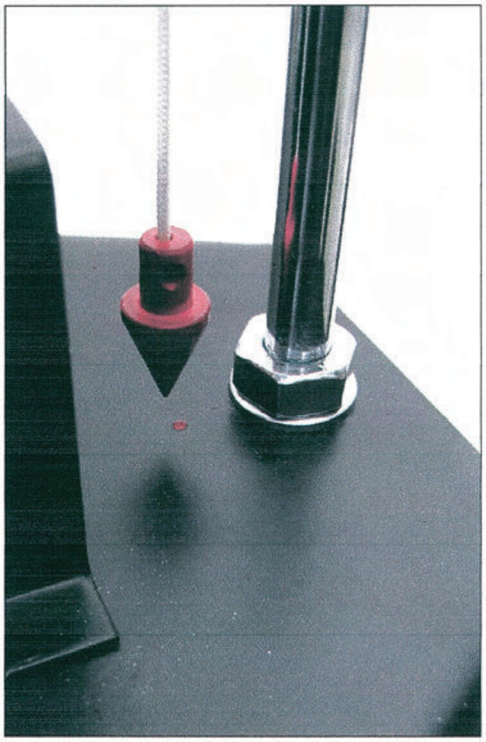


Fig. 17: The plummet used for leveling the equipment in situ, basic plate horizontal

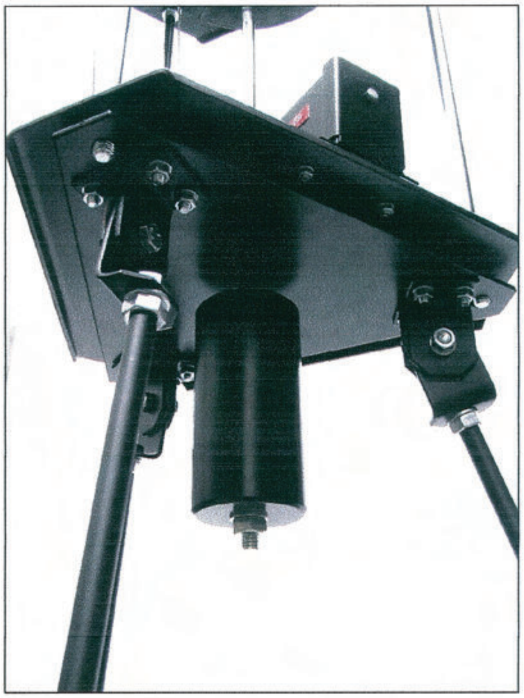


Fig. 18: Attachment of the first weight to the tie rod of the equipment, the initial state of sack in the upper concracted position

Fig. 19: Screwing the second weight

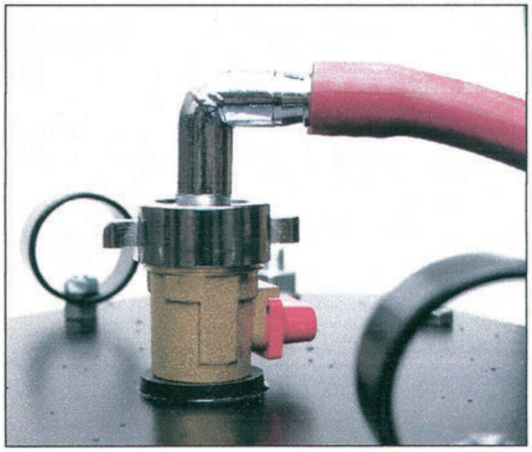


Fig. 20: The probe (with the opened defined measurement surface) is connected with the equipment cock by means of a rubber tube

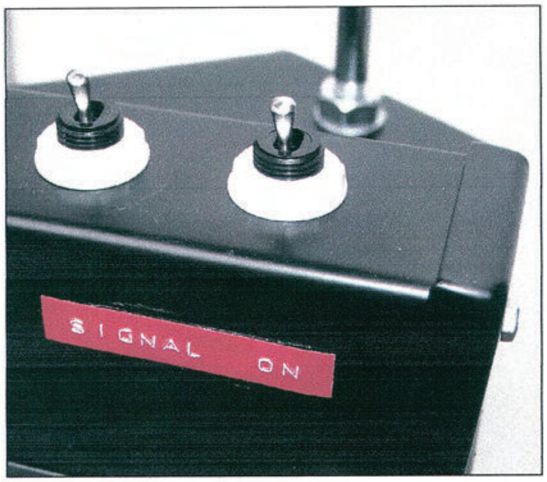


Fig. 21: The switches are set to position ON, SIGNAL

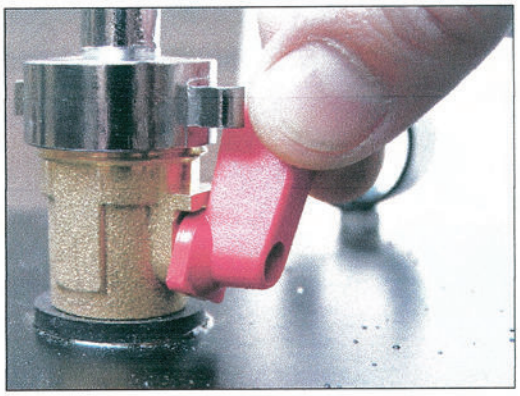


Fig. 22: The suction is started by opening the cock to the full, the time interval between two acustic and/or light signals is measured

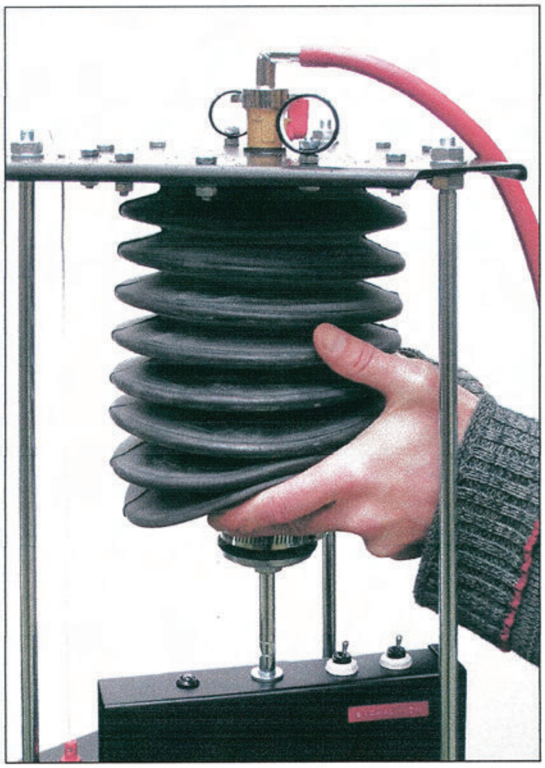


Fig. 23: The probe is disconnected and the sack is returned to the upper concracted position after the measurement (the cock is still open, the switches are set to position OFF, LED)

Fig. 24: The sack is returned to the upper concracted position, then the cock is again closed

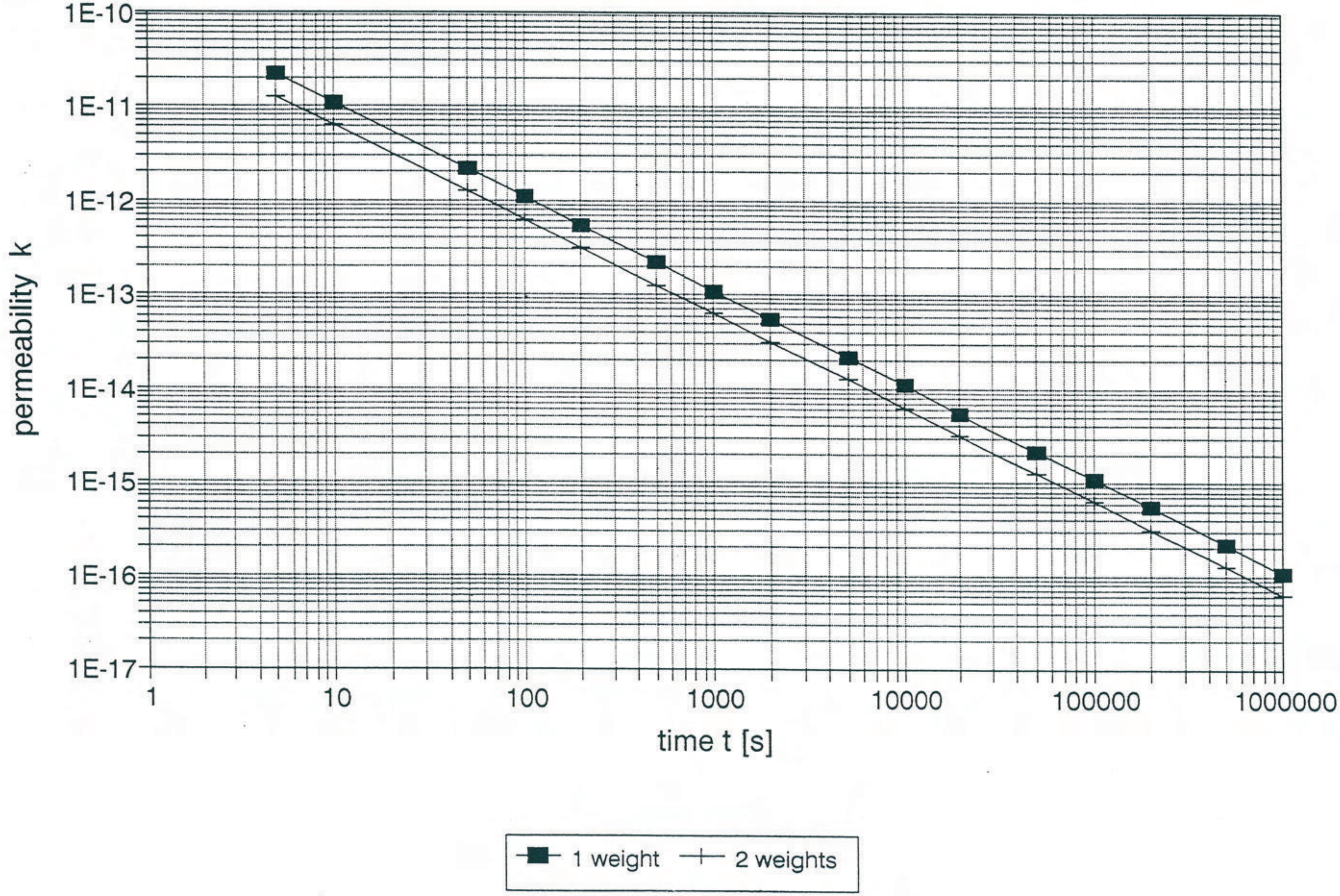
Fig. 25: Set up for retracting – the special retractor for easy retracting to the surface

Fig. 26: Retracting the probe to the surface using the special retractor

Fig. 27: Set up for retracting – simple retractors

Fig. 28: Retracting the probe to the surface using simple retractors

NOMOGRAPHIC CHART
OF PERMEABILITY



Appendix 4-E

Manual for Soil Gas Sample Collection

Sampling System

SOIL-GAS SAMPLE COLLECTION

SAMPLING SYSTEM

MANUAL

radon v.o.s.
Novakovych 6, 180 00 Prague 8
Czech Republic
☎+fax: ++ 420 266 314 112,
☎+fax: ++ 420 266 317 550
e-mail: radon@comp.cz
www.radon-vos.cz
www.radon.eu

Features

The soil gas sample for soil gas radon concentration measurement is usually collected using a small-diameter hollow steel probe with a free, sharpened lower end (a lost tip) combined with a large-volume syringe. The entire system must be perfectly sealed. The use of a sampling system that is not perfectly sealed, or that does not reach a sufficient level of vacuum to collect gas samples in soils of low permeability, may result in an underestimated soil gas radon concentration. Therefore, such system must not be used.

The internal volume of the cavity, which is created at the lower end of the sampling probe, must be large enough to enable the sample collection. It is recommended to use the minimum internal surface area that must enter the soil 940 mm^2 (corresponding to a cylinder having f.e. 10 mm in diameter and 30 mm height).

The soil gas samples are collected from a depth about 1.0 m below the ground surface (the depth of 0.8 m below the ground surface is used in the Czech Republic). If the soil gas samples cannot be collected due to extremely low soil permeability, high groundwater saturation, or presence of shallow, solid rock layers, the following modifications can be used. If the soil permeability is very low, the cavity at the lower end of the sampling probe can be enlarged by retracting the probe about 10 - 15 cm toward the surface. Sometimes (upper soil layers with higher permeability are not reached, the probe remains fixed in the soil, as well as contamination of the soil gas by atmospheric air can be avoided) the probe can be retracted to 0.5 m below the surface, while maintaining the perfect sealing of the whole system. A similar approach is often used when the sampling layer is saturated with water. In cases involving shallow solid rock layers, the minimal sampling depth can be changed to 0.5 m below the surface. Changing the position of the sampling points within the measured area (grid) can be done in all above described cases as well. However, all deviations from the standard sampling depth should be reported, including an explanation and an estimate of potential influence of these differences to the evaluation results.

Steps to follow in sampling the soil gas samples:

(0) The ionization chambers are evacuated with a hand-operated air pump.

1. Inserting the sharpened tip into the lower end of the sampling probe.

2. The probe is pounded to the desired depth using a special hammer and a drive in head.

3. Inserting of the punch wire into the probe.

4. The sharp tip is moved a few centimeters lower, which makes a cavity at the lower end of the probe.

5. The soil gas sample collection using a syringe. The first sample cannot be used for measurement as for a possible contamination by atmospheric air. It serves to introduce the soil gas into the probe.

6. The second sample (the second syringe volume) is introduced into previously evacuated ionization chamber and used for measurements. The rubber tube must be kept closed between the first and the second sampling.

For more details see the photo sequence.

Notes:

1. The resistance against sampling occurred during sampling, although it is a subjective description, gives the information about permeability, as well.

2. Soil gas sampling and soil gas radon concentration measurements should not be performed under extreme meteorological conditions.

3. In the case of sampling water instead of soil gas (as can be seen during the sampling in the connection of the rubber tube and the syringe) it is necessary to stop sampling and to clean the syringe.

4. To enlarge the number of samples taken with the same probe, it is useful to straighten the probe in the case of flex, as well as to rasp occasionally the crushed end of the probe.

5. Several times a day it is recommended to check the tightness of the syringe. The test consists in checking whether with a closed rubber tube it is not possible to collect the gas into the syringe.

6. If the same probe is used for soil gas radon concentration measurement as well as for permeability measurement (the special type of "lost" sharp tip for gas permeability measurement must be used), it is necessary to start with the gas permeability measurement (higher underpressure during soil gas sampling could cause a destruction of an internal surface of the cavity and affect the permeability measurement).

The **SAMPLING SYSTEM** includes following items:

25 small diameter hollow probes 12/2 mm - length 1,10 m, 2000 „lost“ sharp tips, 3 punch wires, 1 retractor (the special one for easy retracting to the surface, two parts), 3 drive in heads, 10 syringes, manual and additional needs (rubber tubes, sampling connector).

As a bonus, special hammer for easy driving the probes to the chosen depth is included.

SOIL GAS SAMPLING - PHOTO SEQUENCE

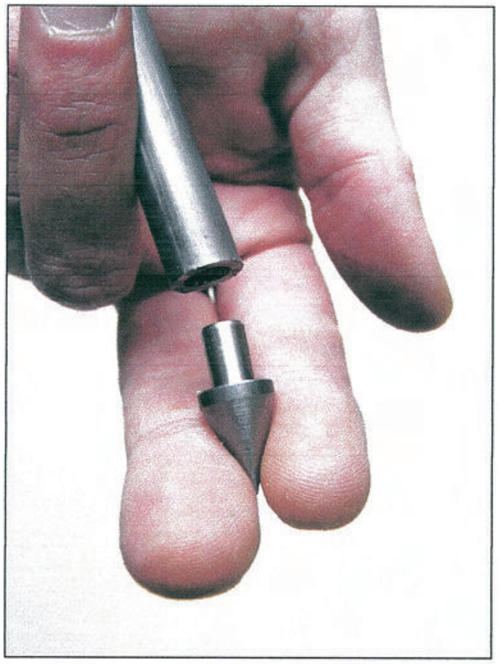


Fig. 1: Inserting the sharp tip into the lower end of the sampling probe (1)

Fig. 2: Inserting the sharp tip into the lower end of the sampling probe (2)

Fig. 3: The probe with the tip is prepared at the sampling place

Fig. 4: Preparing the drive in head

Fig. 5: The probe is pounded to the desired depth using the special hammer and the drive in head

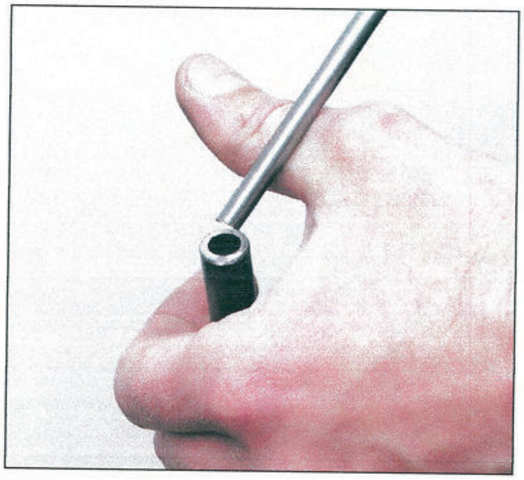


Fig. 6: Inserting of the punch wire into the probe

Fig. 7: The sharp tip is moved a few cenimetres lower, which makes a cavity at the lower end of the probe

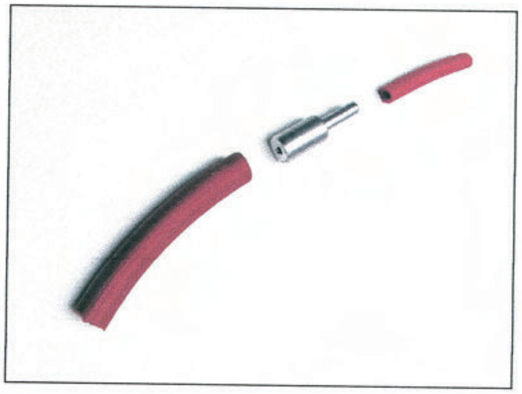


Fig. 8: Items for sampling connector

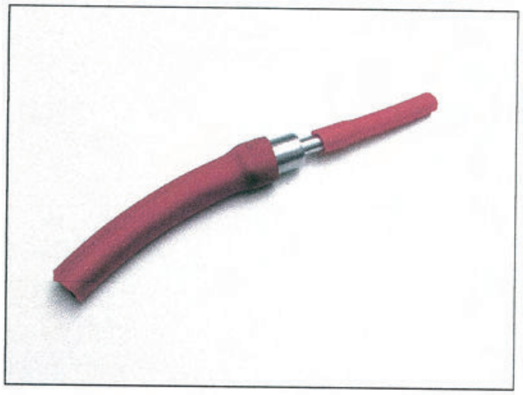


Fig. 9: Sampling connector

Fig. 10: Preparation for sampling

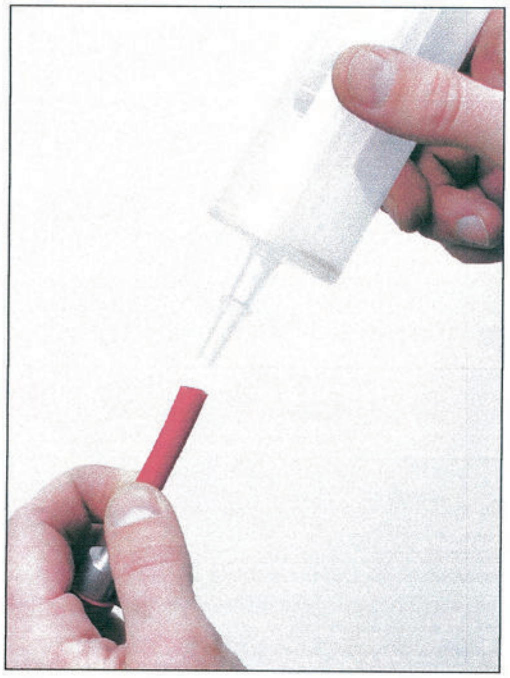


Fig. 11: Connection with the syringe

Fig. 12: The soil gas sampling (the first sample – not used for measurement)

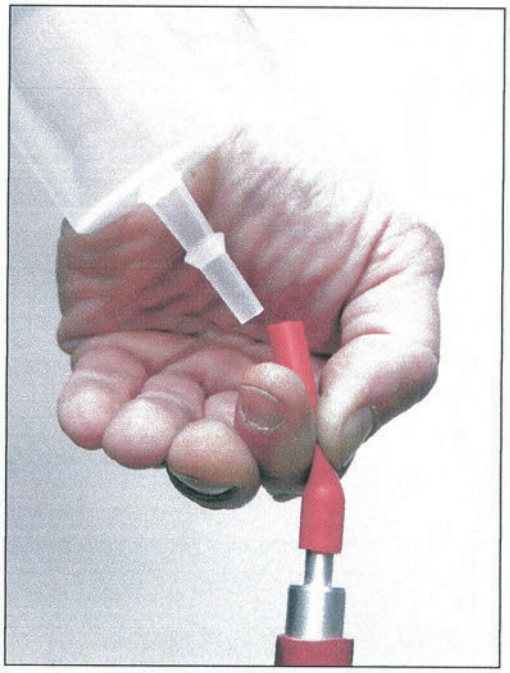


Fig. 13: The rubber tube must be kept closed between the first and the second sampling

Fig. 14: Deflation (the first sample)

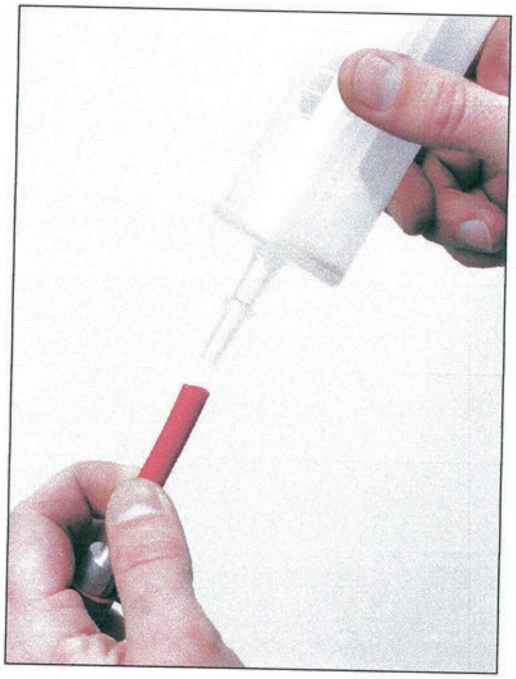


Fig. 15: Connection for sampling

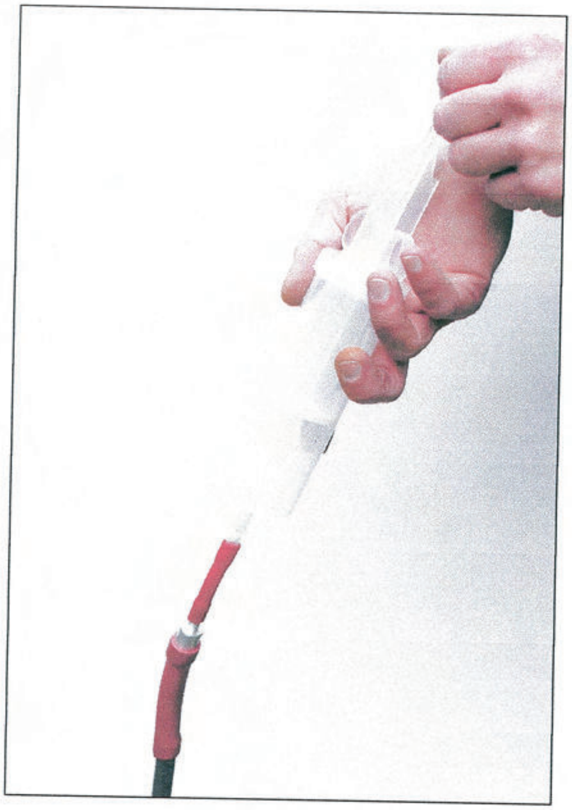


Fig. 16: The soil gas sampling (the second sample)

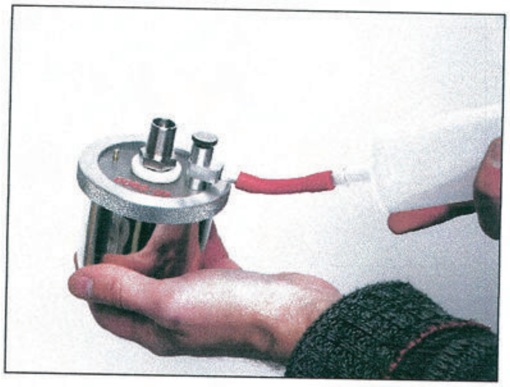


Fig. 17: The soil gas sample is introduced into previously evacuated ionization chamber (see the manual for RM-2)

Fig. 18: Set up for retracting – the special retractor for easy retracting to the surface

Fig. 19: Retracting the probe to the surface using the special retractor

Fig. 20: Set up for retracting – simple retractors

Fig. 21: Retracting the probe to the surface using simple retractors

Appendix 4-F

Manual for

Soil Radon Monitoring
System RM-2

SOIL RADON MONITORING SYSTEM RM-2

USER MANUAL

radon v.o.s.
Novakovych 6, 180 00 Prague 8
Czech Republic
☎+fax: ++ 420 266 314 112,
☎+fax: ++ 420 266 317 550
e-mail: radon@comp.cz
www.radon-vos.cz
www.radon.eu

producer:
Dr. Froňka *NUCLEAR TECHNOLOGY*
RNDr. Oldřich Froňka, Od Vysoké 272, Praha 5, 150 00
Czech Republic
☎+fax: ++ 420 241910683
☎mobil: ++ 420 602 654484
e-mail: Oldrich.Fronka@seznam.cz

1. A Portable Soil Radon Monitor

The measuring system RM – 2 is designed for the soil gas radon concentration measurement. The detection principle is based on an ionization chamber operating in a current mode. The substantial characteristics of the system RM – 2 are:

- very easy operation and handling;
- applicability under demanding weather conditions;
- easy cleaning and decontamination of the Sampling Ionization Chambers (IK-250) from radon progeny deposition;
- small dimensions and weight;
- first results are displayed 15 minutes after sampling

The measuring set of RM-2 consists of three basic components, an ERM-3 electrometer (an evaluation device), a set of IK-250 Sampling Ionisation Chambers and a hand-operated air pump. A self-contained operational unit, the ERM-3 electrometer, provides measurements of the ionisation electric current produced by radon and its progeny in the sensitive volume of the IK-250 Sampling Ionisation Chamber. The soil gas sampling is provided by a standard "lost tip method" sampling procedure (see the corresponding user manual *Soil gas sample collection*). Results of measured radon concentration are presented on the electrometer LCD display in units of kBq.m^{-3}.

Main features of the ERM-3 Soil Radon Meter:

- easy handling and maintenance, simple operational mode,
- portable device (in-situ measurement)
- fast measurement,
- fully automated measuring and computation process,
- integrated calculation mode - determination of the 3rd quartile of a data set
- high durability and mechanical defect resistance,
- small dimensions and weight,
- low energy consumption

2. Detection principle and measuring procedure.

Measuring system consists of a set of cylindrical ionization chambers IK-250 with a sensitive volume of 250 ml and of the electrometer ERM-3 (a voltage reader device). A detailed description of detector construction and operational properties are given in the paragraph 4. The measuring process can be started after the transfer of the soil gas sample into the sensitive volume of the ionization chamber. The RM-2 system operates in two measuring modes, depending on the time elapsed from the sample transfer into the detector:

(i) measurement starting 15 minutes after the transfer of the sample into the chamber;

(ii) standard equilibrium measurement (the radioactive equilibrium of radon and its progeny inside the ionization chamber is accomplished after 3h 20 minutes)

A time period needed for the measurement of one sample is 120 s. The soil gas is used as an operating gas inside the ionization chamber. The ionization current is amplified and then electronically and statistically processed. Processed results are subsequently displayed and stored in a memory of the ERM-3 Soil Radon Meter. Basic measuring functions are set-up from a control panel. The measuring device communicates with PC by a standard serial communication interface RS232. The PC is used for data transfer and for entering the calibration constant and other operating instructions (paragraph 16). For special purposes (e.g. investigation of ^{222}Rn and ^{220}Rn mixture in soil gas), the ionisation current can be measured each 2 seconds and subsequently stored in the PC memory.

When the soil-gas sample contains a significant activity of thoron (radionuclide ^{220}Rn), the delay of 15 minutes ensures that the thoron activity (half-time $T_{1/2} = 50$ s) has significantly decreased before the beginning of counting (after 15 minutes, the ionization chamber contains less than 1/400 000 of the primal thoron concentration).

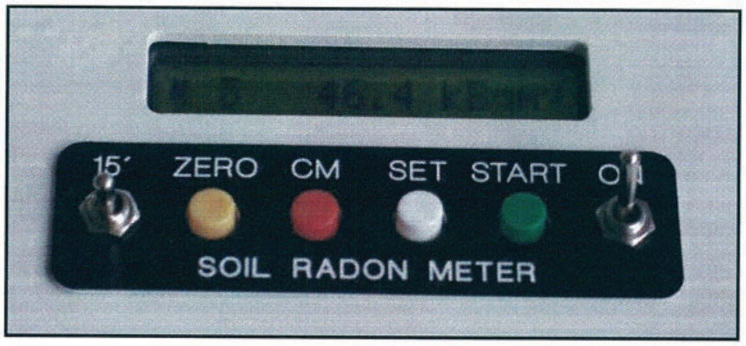
3. ERM-3 Soil Radon Meter (the electrometer unit)

ERM-3 Soil Radon Meter is built in a small plastic case with dimensions of 190 x 135 x 80 mm and weight of 600 g. The electrometer is transported in a plastic carrying case. When the plastic carrying case is opened, the upper panel of the ERM-3 Soil Radon Meter appears.

The main control components and functions of the operational unit:

the LCD display, the electrode reading connector with the stainless steel shield, short insulated cable with a crocodile clip, the on/off toggle switch, the operational mode toggle switch and four push functions buttons are placed on the top of the device case. The explicatory marks for each operational function are displayed on a proper label of the control panel (see picture A).

Picture A. *A close-up view of the ERM-3 electrometer control panel*



The battery slot is accessible from the bottom side of the electrometer case. The LCD display contrast can be set-up by a potentiometer accessible in the opening slot on the right side of the device case.

4. IK-250 Sampling Ionisation Chamber

Measuring system consists of a set of cylindrical ionization chambers IK-250 with a detection volume of 250 ml. A chamber case is a steel pressed piece with sheet metal thickness of 0.8 mm. The axial collecting electrode, made from brass, is fastened in the upper part of the chamber. The collecting electrode passes through a Teflon insulator impressed in a metal tube, operating as a protective electrode. The described set is fastened in an insulating bushing, placed in a centre of the upper part of the detector. A direct operating voltage of the detector is 40 V. In the upper part of the chamber, there is located a silicon hose with a vacuum safety valve providing input of soil gas sample into the inner detection volume. The input hose can be equipped with a filter providing radon decay products suppression.

The detector construction must be vacuum tight. A critical part of the IK-250 Sampling Ionisation Chamber is the high resistive electric insulator fixing the collecting electrode. The insulator is situated in the centre of the flat base of the chamber and it forms a special connector from the external side. The connector provides a connection with the reading connector of the ERM-3 Soil Radon Meter. The insulator is the most vulnerable part of the IK-250 Sampling Ionisation Chamber and must be kept clean and dry.

5. Operating modes of the measuring unit

The measuring unit (ERM-3) enables to set up two operation modes of the soil radon concentration measurement:

- The **"15 min."** mode: The measurement is started after 15 minutes from taking of the soil gas sample and its transfer into the ionisation chamber.
- The **"B"** mode - a steady state measurement: The measurement is started afterwards the activities of radon progeny and of radon itself have reached the radioactive equilibrium, i.e. at least 3 hours and 20 minutes from the transfer of the sample into the detector.

A toggle switch placed on the front side of the electrometer provides a switching between the **"15 min."** mode and the **"B"** mode (not marked on the control panel).

6. Push button functions

"ZERO" (a yellow button) – setting up of a zero signal level of the electrometer (electronic background). This process is automatically activated when the measuring unit is switching on. The activation of this zeroing process after the realization of approximately 15 measurements is recommended. If the time delay between two measurements is more than 30 minutes, the zeroing process is also recommended.

"CM" (a red button) – clearing of all data stored in the memory

"SET"(a white button) – calculation of the 3rd quartile of the stored set of soil gas radon concentration data.

"START" (a green button) – starting the measurement of the soil gas radon concentration

7. Measurement of the ionization current

The soil gas is used as an operating detection gas inside the ionization chamber. The detector operates in a non-saturated mode of a volt-ampere characteristic. The operating voltage between electrodes of the chamber is 48 V. The electric current sensitivity of the detector using the working voltage of 40 V is 85% of the saturated current. The direct ionization current is amplified and then electronically and statistically processed. The processed result is subsequently displayed and stored in the memory of the electrometer.

Measurement of one sample takes 120 s.

The 120 second period is divided into two processing parts. The system stabilization process is proceeding during the first 80 seconds. The remaining 40 seconds are used for measuring process, corresponding to statistical analyses of current measurements used for calculation of the radon concentration.

8. System preparation and measuring procedures

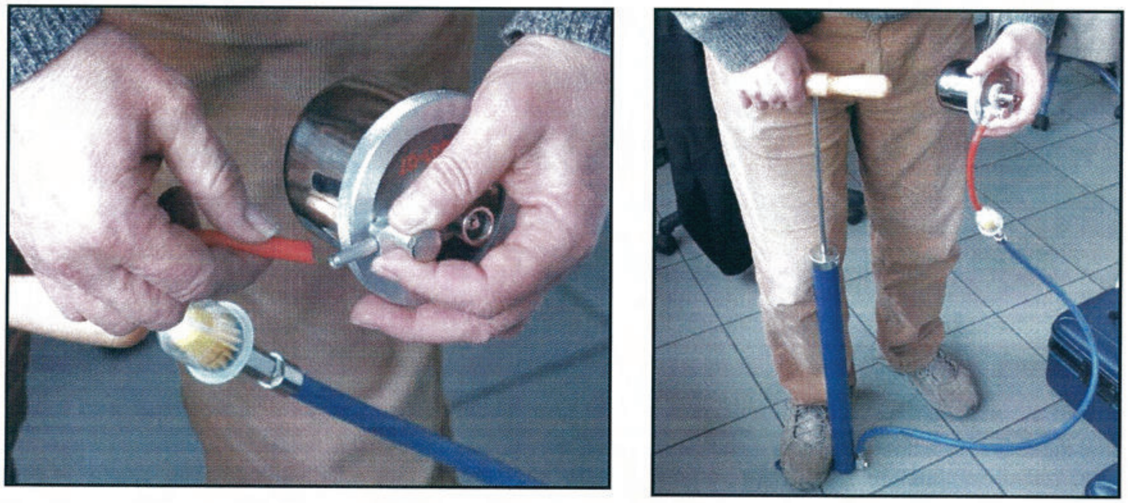
The soil gas sample collection and the transfer of the sample into the ionisation chamber are special procedures that are described in detail in other documents, dealing with sampling (*Soil gas sample collection – Sampling system*).

Detector preparation

A) *Ionization chamber background measurement*

The background measurement proceeds in the same manner as the standard measuring process given in paragraph 9.3. The ionization chamber is evacuated with a hand-operated air pump. The air pump is connected by a silicon hose with the input tube of the ionization chamber and the vacuum safety valve inlet is opened by turning a valve cap. The detector is evacuated by a repeated pump piston movement (8x). The valve is then closed immediately, while the pump is still connected to the ionization chamber (see picture B).

Picture B. *The air pump is connected with the input tube of the ionization chamber and the detector is evacuated*



B) *Transfer of the soil gas sample into the detector (see the photo sequence at the end of this manual)*

The soil gas sample, that has been collected using a syringe, is transferred into the ionization chamber. The syringe is tightly connected with the input tube of the evacuated ionization chamber by a silicon hose and the vacuum safety valve inlet is opened. The whole sample (usually 150 ml) is sucked into the detector and the syringe is disconnected. The pressure inside the ionization chamber is equalized to the outdoor pressure by a short opening of the safety valve. The real volume of the sample that has been transferred into the ionization chamber is recorded in a work-book.

The time tolerance for the **"15 min"** operational mode ranges from 13 to 17 minutes. The other possibility is to measure the soil gas radon concentration in the **"B"** mode, i.e. at least 3 hours 20 minutes after the soil gas sampling. If the time delay is longer than 5 hours 30 minutes, measured values must be corrected using the equation (1) due to the radon decay:

$$c_{\mathrm{COR}} = c_{\mathrm{MEAS}} \cdot \exp[(t-3.5)\cdot 0.0076] \qquad (1),$$

c_{COR} [kBq.m^{-3}] is the corrected soil gas radon concentration,
c_{MEAS} [kBq.m^{-3}] is the displayed result of the measurement,
t [h] is the time delay between of the soil gas sampling and the beginning of the measurement.

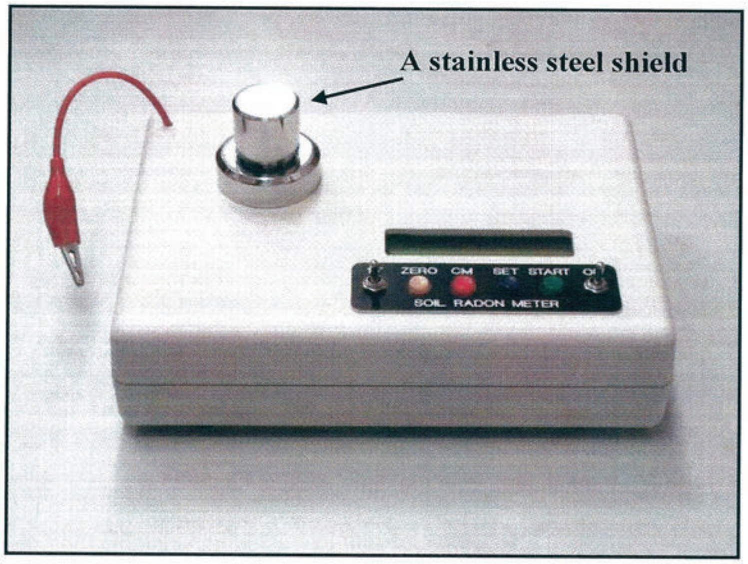
9. Operation (measuring procedure)

The measuring process and the use of programmed subroutines are described in this section.

9.1. Switching on

A toggle switch (marked **ON**) placed on the front side of the electrometer provides a switching on of the operational unit. A stainless steel shield, covering the reading electrode of the electrometer, must be always placed on the reader connector during the switching on process (see picture C). After switching on of the ERM-3 Soil Radon Meter, the LCD display shows a report **Start up ss** , informing about the system stabilization, including the time indication process (120 s).

Picture C. *The ERM-3 electrometer with covered reading electrode*



9.2. Setting zero

A setting-up of the zero current level of the electrometer (electronic background measurement) starts automatically when the starting up procedure has been finished. A manual activation of the zeroing process after the realization of approximately 15 measurements or after time delay between two measurements more than 30 minutes is recommended. The zeroing process is manually activated by pushing the yellow button "**ZERO**" on the control panel.

The information about the zero setting process is displayed on LCD panel of the electrometer **Zero ss** The measurement of the zero signal level takes 120 seconds and the LCD panel informs about the time remaining to complete the zero setting. When the zero setting has been complete the operational unit is prepared for the measurement and the LCD display indicates the status **New set**.

Attention! Be sure that the stainless steel shield covers up the reader connector during the each zero signal measurement. *The measurement of the electrometer electronic background with opened reading connector will result in false soil gas radon concentration measurements. Be accustomed to close the reading connector, when the measured ionization chamber is removed and the next measurement does not follow immediately!*

Because the electrometer provides measurements at a very low level of the electric current magnitude (some tenth of femtoampers, 10^{-15} A), some problems with the electronic background drifting can be met, especially when the weather conditions (temperature, relative air humidity) during the in-situ measurement are significantly variable.

For this reason, it is recommended to provide the zero setting-up process in the field operation frequently. The activation of the zeroing process after the realization of approximately 15 measurements is recommended. The repeated zero measurement is started by pushing of the yellow button **"ZERO"**. When the zero level setting has been completed, the last result of the soil-gas radon measurement is displayed.

When the result of the repeated setting zero measurement is out of an expected range, the notification **Error of zero!!!** is displayed. This is a fault warning that indicates the incorrect function of the device. The probable cause is the zero setting-up with the opened reading connector (see the above mentioned warning). The displayed warning message **Error of zero!!!** disappears after repeated pushing of the yellow button **"ZERO"**. A new setting of the zero level must be carried out before the start of the next measurement.

9.3. Measurement of the soil gas radon concentration

The toggle switch (marked **15´**), indicating the operating mode of the measurement, is switched to the selected status (**15 min** or **B**).

The LCD indicates the status **New set**, the electrometer is prepared for the radon concentration measurement. Remove the stainless steel shield, covering the reading connector. Plug in a crocodile clip of the voltage wiring of the operational unit to the metallic pin placed on the bottom flat base of the ionisation chamber and insert the IK-250 Sampling Ionisation Chamber connector into the reading connector of the Soil Radon Meter (see picture D).

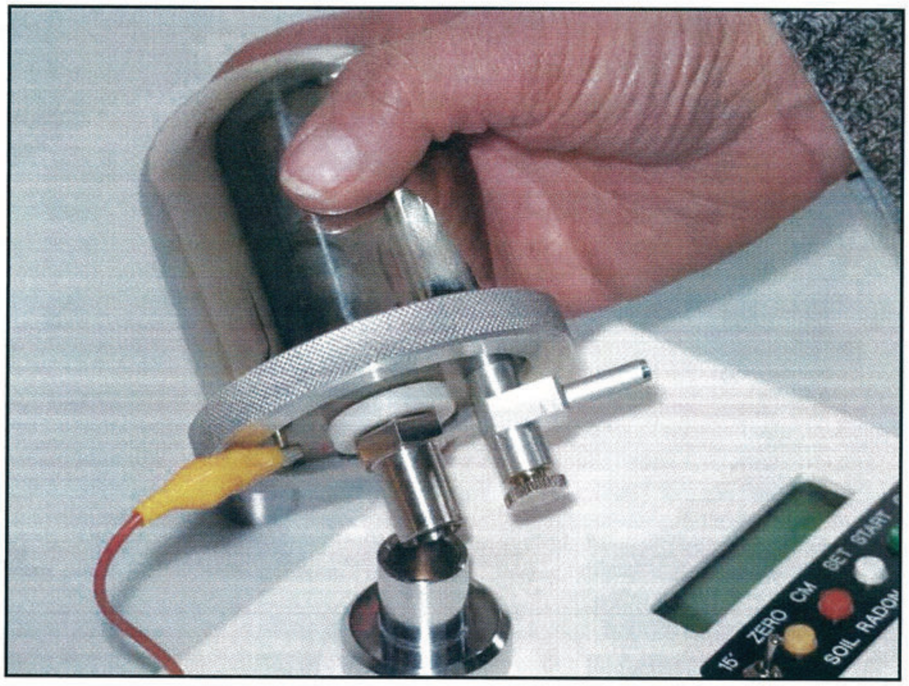
Note: *Do not forget to connect the crocodile clip correctly. When the electrical connection is not ensured properly, the ionisation chamber is operated under incorrect operating voltage and the resulting soil radon concentration will be false (the display may show very high concentrations e.g. > 900 kBq.m^{-3} or > 1200 kBq.m^{-3}).*

Highly Important Safety Note: *The operating voltage (40 V) is low enough and cannot endanger the operator because the electric current is limited up to 40 μA. The operation of a built in voltage source is absolutely safe from accidental touch by the operator.*

Avoid any contact of the crocodile clip with the inner surface of the reading connector, it would destroy the electrometer!

Note: *Do not touch the IK-250 Sampling Ionisation Chamber when the measurement is carried out. Ensure the operation of the device under stable condition, without movement. For example, it is not recommended to carry out measurement in a moving vehicle.*

Picture D. *The insertion of the IK-250 Sampling Ionisation Chamber connector into the reading connector of the Soil Radon Meter*



The measurement is started by pushing the **"Start"** button placed on the front side of the operational unit. The number of a current measurement and the time remaining to a completion of the measurement are displayed **#1 ss** during the measuring process.

The result of the measurement, i. e. the soil gas radon concentration, is displayed on the LCD panel **#1 xxx,x kBq.m^{-3}**. The number #1 indicates the serial number of the current measurement (1 to 64) and xxx,x presents the value of the radon concentration in the range from 0 to 900 for the **"15 min"** operating mode and from 0 to 1200 for the **"B"** mode. At the same time, the value of the soil gas radon concentration is stored in the memory. The capacity of the storage memory of the Soil Radon Meter is 64 values. The stored values can be used for the determination of the 3rd quartile of the data set (see paragraph 9.4.). Subsequently the crocodile clip is disconnected and the ionization chamber is removed from the reading connector. The next measurement of the radon concentration can be processed (next IK-250 detector can be installed into the reading connector of the Soil Radon Meter, the voltage crocodile clip is connected and new measurement is started by pushing the **"Start"** button).

9.4. Computation of the third quartile of a radon concentration dataset

The value of the 3rd quartile can be displayed after pushing the blue button **"SET"**, placed on the front side of the device, when the last sample measurement is finished. The calculation of the 3rd quartile can take several seconds and during this calculation process, the status report **...** is displayed on the LCD panel. The 3rd quartile is displayed in the format **Set xxx,x kBq.m^{-3}**.

When the internal memory of the device is full, the LCD display indicates the warning **Full set**. The memory can be cleared by pushing the red function button **"CM"**. The execution of this instruction is reported by displaying the information status **New set**.

Note: *The determination of the 3rd quartile of the soil gas radon concentration data set is correct only when each sample was measured only once and no measurements were repeated.*

10. Measuring of the soil-gas radon concentrations – instructions overview

Action	Displayed information
Switch on the ERM-3 Soil Radon Meter! *The stainless steel shield covers the reading connector.*	**"Starting up"**, *2 minutes* Start up ss
Zero setting-up process. (starts automatically when the starting up procedure has been finished) 120 seconds	**"Zero"** Zero ss
The electrometer prepared for measurement.	New set
Remove the stainless steel shield from the reading connector!	
Insert the connector of the ionization chamber into the reading connector!	
Connect the crocodile clip to the pin of the detector!	
Set-up the operational mode **"15 min."** or **"B"** by toggle switch.	
Push the **"Start"** function button!	#1 ss
Result of the measurement.	#1 xxx,x kBq.m^{-3}
Record the result into the work-book!	
Disconnect the crocodile clip! Remove the detector.	
Insert a new ionization chamber. Connect the crocodile clip to the pin of the detector!	
Push the **"Start"** function button!	#2 ss
Result of the measurement.	#2 xxx,x kBq.m^{-3}
. ..	
Setting-up the zero level during the measurement of the set of samples.	
Remove the ionization chamber!	
Cover the reading connector!	
Push the **"ZERO"** function button!	**"Zero"** Zero ss
Result of the measurement.	#N-1 xxx,x kBq.m^{-3}
Push the **"Start"** function button!	#N ss
Result of the measurement.	#N xxx,x kBq.m^{-3}
. ..	

Determining of the3rd quartile (the set of measurements is completed)	#15 xxx,x kBq.m^{-3}
Push **"Set"**function button!	Set xxx,x kBq.m^{-3}
Record the result into the work-book!	
Push **"CM"** function button!	"New set"
Push the **"Start"** function button!	#1 ss

11. Electronic stability control process - zero test operational mode

The ERM-3 Soil Radon Meter is equipped with a special software function that enables a test of the zero current setting and provides the automatic correction of the zero current setting. The zero test operation is activated via a special procedure: Be sure that the ERM-3 electrometer is off (t*he stainless steel shield covers the reading connector!*). Hold the **"Zero"** push button pressed while the device is switched on and keep holding the **"Zero"** push button pressed still about two seconds after the switching the electrometer on. The activation of the zero test operation is signalised by displaying the information **Raw =…** . The LCD panel will display the result of the zero test **Raw = xxx** after 120 seconds of processing. The displayed information xxx is the number corresponding to the current value of AD converter in units of LSB resolution (electronic background). The value of this parameter is characteristic and unique for each ERM-3 electrometer. The optimum range of the zero current setting is ±100 in LSB units from the characteristic value. The mentioned procedure is relating to the special instruction (command "B") that is accessible via PC terminal communication.

Note: If the zero setting is out of range, the ERM-3 electrometer displays the warning **Error of zero !!!** after the automatic zero setting during measurement.

Note: *Significant variations of the zero current setting in short period can be caused by polluted or wet insulator of the reading connector of the electrometer.*

To quit the zero test mode of the ERM-3 device, the system must be switched off.

12. Battery; changing the battery

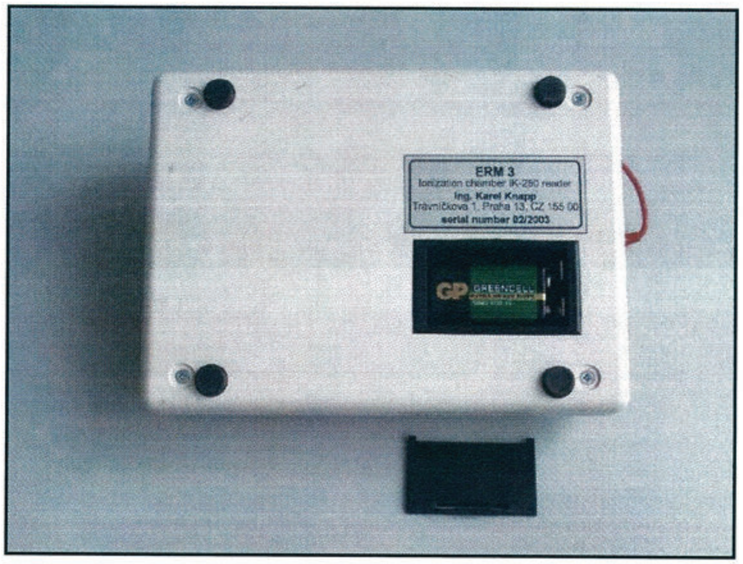
The ERM-3 Soil Radon Meter is powered from the 9V standard battery (model 6F22). The average power consumption is 4 mA and it fluctuates during the measuring process. The operational voltage of the electrometer is in the range from 6.5 V to 12 V.

The battery slot is accessible from the bottom side of the electrometer case (see picture E).

The battery capacity is controlled electronically. When the battery voltage drops down below the value of 7.5 V the LCD panel displays a warning **Battery low** after each pushing of the function buttons. The measurement may proceed, but the battery change is recommended. When the battery capacity is below the safe operational voltage the warning **Battery dead** is displayed and the system is blocked for other measuring operation. The battery change is necessary.

The ERM-3 electrometer can be powered by an AC/DC mains adaptor with following parameters and specifications (12V, 500mA, polarity +). A power supply slot is accessible from the right side of the electrometer case and marked with an appropriate label.

Picture E. *The battery slot of the electrometer*



13. Maintenance and manipulation

The insulators of the IK-250 Sampling Ionisation Chamber and the reading connector of the ERM-3 Soil Radon Meter must be kept clean and dry. Be careful when you handle and operate with the electrometer in the field.

The insulator of the ionisation chambers can be cautiously cleaned by a small soft brush, distilled water and afterwards repeatedly washed up using pure technical alcohol. A drying of the insulator can be done by a hand-operated hair drier. The IK-250 Sampling Ionisation chamber can be used again after the drying process is finished.

The reading connector can be cleaned up by compressed air (blowing the dust impurity out).

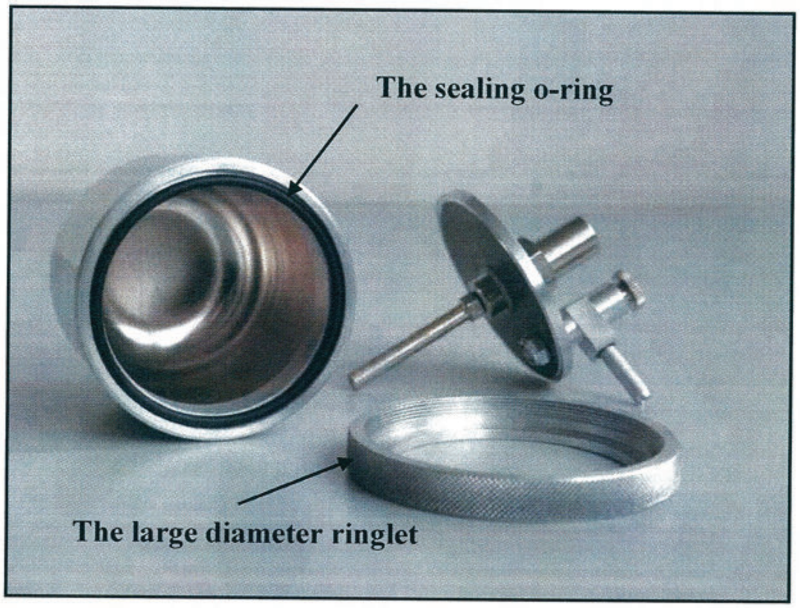
Recommendation: *The best way to avoid the insulator pollution is to save the ERM-3 Soil Radon Meter during operation and storing.*

Use a proper dust filter for a transfer of the soil gas sample into the detector. Connect the filter to the input tube of the ionization chamber. This procedure eliminates an abundance of impurities and the water droplets input into the chamber.

The flat base of the ionization chamber is fastened to the chamber case by the ringlet with a fine screw thread. The vacuum tightness of the detector is ensured by a sealing o-ring between the base and the case of the chamber. The detector design enables closing and opening of the chamber by easy screwing and unscrewing of the large diameter ringlet.

In case of a detector contamination by impurities, the ionisation chamber can be opened by unscrewing of the large diameter ringlet (see picture F) and the inner surface of the chamber can be cleaned by above mentioned procedures. The sealing o-ring of the chamber should be regularly (each quarter) lubricated by a mineral jelly to ensure the vacuum production and stability.

Picture F. *Dismantled ionization chamber for decontamination and cleaning purposes*



The level of radon progeny contamination of the ionization chamber can be tested by measuring of the signal from an atmosphere air sample (low radon concentration) filled in the detector instead of a soil gas sample. Using of a free atmosphere air sample is usually satisfactory. The reading should be in the range from 0 kBq.m^{-3} to 0.7 kBq.m^{-3}. If the contamination is caused by short time radon daughter products, the inner surface of the ionisation chamber can be cleaned, but the contamination decays itself during 24 hours. For repeated measurement within a short time period (1 hour), provided with the same ionization chamber, the detector background measurement is recommended before the next sample measurement. The result of the detector background measurement is recorded into the work-book and subsequently used for a correction of the next soil gas radon concentration measurement.

When the contamination of the chamber does not disappear after 24 hours, the inner surface of the detector should be decontaminated using a fine clout and the citrate acid (2 %), the distilled water and finally the pure alcohol. The drying process can be accelerated by the hand-operated hair drier.

Testing of the IK-250 Sampling Ionisation Chamber air- tightness (vacuum production and stability):

Evacuate the chamber by the hand-operated or electric air pump to maximum air pressure 10 Kpa (0,1 atm). After 12 hours, the opening of the vacuum safety valve must be accompanied by a sound of a suction of the air. The lack of sound represents an indication that the IK-250 Sampling Ionisation Chamber is not tight enough. The problem may be caused by an improper position or by a pollution of the sealing o-ring. The o-ring should be cleaned, slightly lubricated by a mineral jelly and **properly** insert into the chamber.

14. Useful remarks

The IK-250 Sampling Ionisation Chambers should be opened or evacuated immediately after the soil gas radon concentration measurement has been finished and the detector has been replaced from the reading connector. The radon is removed from the detection volume of the chamber and new radon progeny are not further produced. The radon progeny deposited on the inner surface of the chamber spontaneously decay within 24 hours.

Sign each detector of your set of IK-250 Sampling Ionisation Chambers clearly with a serial number.

Be accustomed to monitor the detectors background routinely and to provide regular tests of vacuum stability of each IK-250 Sampling Ionisation Chamber.

Important note: If the volume of the soil gas sample transferred into the detector differs from the standard value (150 ml), the measurement result must be corrected using the equation (2):

$$c_{\mathrm{cor}} = c_{\mathrm{meas}} \cdot \frac{150}{V_{\mathrm{in}}} \qquad (2),$$

c_{COR} [kBq.m^{-3}] is the corrected soil-gas radon concentration,
c_{MEAS} [kBq.m^{-3}] is the displayed result of the measurement,
V_{IN} [ml] is the volume of the transferred soil gas sample.

15. Technical data

15.2. Parameters of the Monitoring System RM-2

Measured quantity

- ionisation current produced by the alfa particles from the radon and its progeny inside the detection volume of the ionization chamber

Displayed quantity

- radon concentration in kBq.m^{-3}

Range of the measurement

a) With measuring and subtracting of the detector background	
- the **"B"** mode	3 to 900 kBq.m^{-3}
- the **"15 min"** mode	3 to 1200 kBq.m^{-3}
b) Without measuring and subtracting of the detector background	
- the **"B"** mode	5 to 900 kBq.m^{-3}
- the **"15 min"** mode	5 to 1200 kBq.m^{-3}

Electric current sensitivity of the chamber for a unit radon concentration

- $3.3 \cdot 10^{-15}$ A.Bq^{-1}.m^{3}

Gamma radiation sensitivity

- under conditions of standard gamma radiation background (dose rate less than 0.5μGy.h^{-1}) the response is insignificant

Uncertainty of the radon concentration (standard deviation)

- $\delta c_V = 0{,}33 \cdot (c_V)^{0.5}$
- result of measurement in format $c_V \pm \delta c_V$

Influence of air pressure
- for the range that can be met in the Czech Republic (920 to 1 000 hPa) ≤ 5 %

Outer dimensions of the reader
- 190 x 135 x 80 mm

Weight of the electrometer
- 600 g

Time of the measuring process
- 120 s

Battery capacity
- 9 V (6F22 Model)

Operational conditions
- temperature +5 to +40 °C
- relative air humidity ≤ 70 %

15.2. Parameters of the IK-250 Sampling Ionisation Chamber

Outer dimensions of the chamber
- maximal diameter 100 mm
- height 85 mm

Volume of the transferred soil gas sample
- 150 ml

Detection volume
- 250 ml

Weight of the chamber
- 300 g

Operational conditions
- temperature +5 to +40 °C
- relative humidity of the soil-gas sample ≤ 95 %

16. PC communication with ERM-3 electrometer

The Soil Radon Meter is equipped with a built in serial connection interface RS232 for standard communication with PC or notebook. A special serial cable is a component of enclosed accessories. The PC is used for the data transfer from the device memory and for entering the calibration constant and other operating instructions. An application of some selected functions is reserved only for a producer.

The PC communication is provided by standard terminal programme that is usually included in Windows operating system (Windows 3.11 and higher version).

The serial line setting:

Baud Rate	9600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

Terminal preferences:

CR->CR/LF	Inbound
Other parameters	default settings

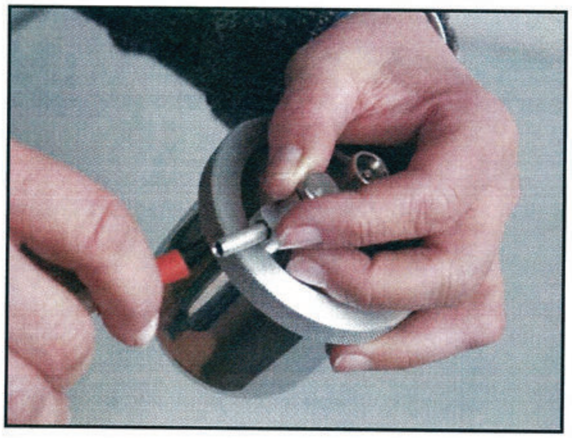
When the connection is set-up properly and activated, the symbol „ * “ as a command prompt is displayed.

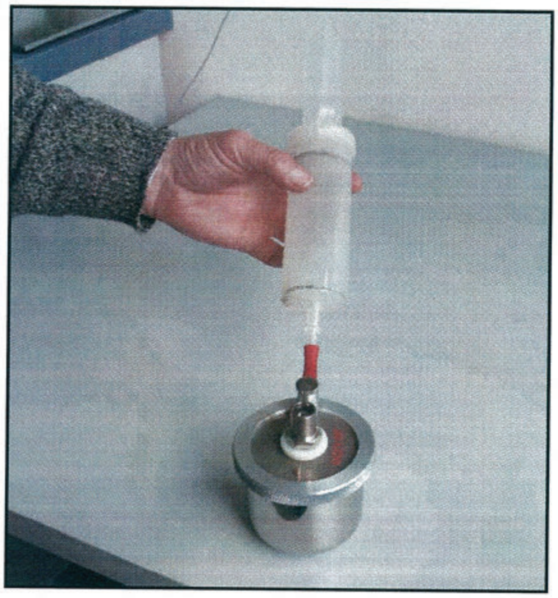
The measuring device is controlled by special commands listed below, each inserted instruction must be confirmed by pushing the enter key:

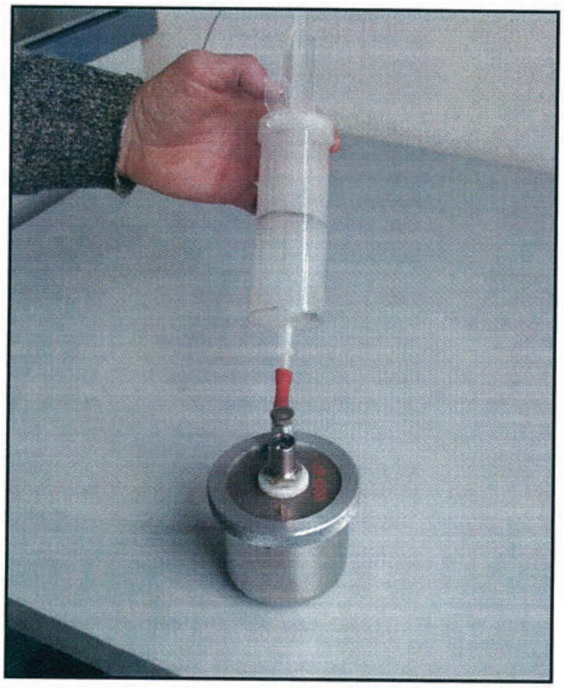
Common user commands:

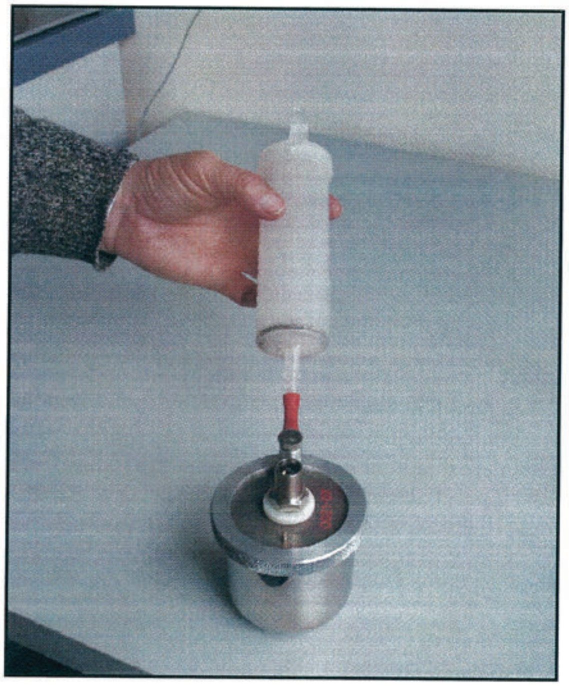
/	print out on the screen the current value of AD converter in units of LSB resolution (from -32768 to +32767)
B	print out on the screen the result of the last zeroing process (electronic background)
R	print out on the screen all measured and stored radon concentrations as a set of sorted data from the lowest to the highest value
U [xxx] [+]	activate the automatic AD converter data printout on the screen at interval [xxx] seconds (a range from 1 to 255); this function is useful for investigation of ^{222}Rn and ^{220}Rn mixture in soil gas

The photo sequence (the transfer of the soil gas sample into the ionization chamber)









Appendix 4-G

GR320 - General Care and Operation

GR 320 - GENERAL CARE AND OPERATION

General

- When shipping, use the sufficiently padded shipping case provided.

- When in the field, it is possible to turn off the GR320 unit between measurements to preserve battery power if a lengthy delay before the next measurement is anticipated. A fully charged battery typically will last several days. The battery power can be checked by turning on the instrument and starting to take a measurement or by performing a system test. Battery power cannot be checked while the instrument is plugged into an external power source and the charging unit is being used. It is good practice to charge the battery wherever a power source is available.

- When in the field, carry the spectrometer in a backpack with some padding. Tarps, sample bags, and rain gear may be placed at the bottom of the pack and used as such. The console and detector should be placed adjacent to each other in the pack. This allows the operator free hands and protects the instruments in poor weather. In most cases, the detector will slide down the same side of the console as the detector cable. Be careful not to jam the detector on top of the cable. If possible, place additional padding under the detector cable at the point where it enters the bottom of console.

- To take a measurement, only the detector needs to be removed from the pack. Ensure that the detector is stable and will not fall or be knocked over by a strong gust of wind. If necessary, hold the instrument for the required time or prop it up with the backpack.

- Do not expose the instrument to moisture. Do not use it in the rain or for at least 3 hours after a heavy rainfall. Moisture entering the electronic components may alter the background radiation concentrations.

- It is a good practice to check the instrument function. In addition to the regular system tests, the establishment of a base station near the camp or office is recommended. The base station should be set up in an area where the detector can be placed in exactly the same position each time it is tested. For example, a good site is a flat-lying outcrop composed of homogenous rock. Before starting a field program, it is useful to take five or six measurements at the base station to begin accumulating readings. While the field programme is ongoing, measurements should be taken at the base station each morning and evening. The measurements are saved, stored as a spectrum, and downloaded to a laptop hard drive for processing with the Explore software. It is wise to store the files of base station spectrum data and concentration data in separate computer directories.

- The cable connectors are expensive. Please treat them with respect!

- The contrast of the display screen can be adjusted by pressing the left arrow for lightening or the right arrow for darkening the display. If the display is very darkafter pressing On/Off, press the left arrow a number of times to lighten the screen image.

Instructions for the North American Soil Geochemical Landscapes Project

The following notes are to aid the field person who is learning to use the GR320 manual. It is recommended that the user also read the manual supplied by the manufacturer with the instrument for a more complete description of operating procedures.

- Connect the detector to the GR-320 console using the black cable supplied.

- Menu Item 1: System Test: In most instances the GR320 is equipped with a weak Cs-137 check source in the bottom of the detector. For the purposes of the NASGLP project this check source should be removed and placed in a small metal can. (Do not lose the Cs-137 source.) Place the can, source side up, under the detector. Turn on the GR320, highlight "System Test" and press "Enter". The GR-320 is set up to stabilize on K at 1460 keV but the change to Cs is accomplished by pressing "Shift". At this point the screen display shows "Gain stabilizer ON; Stab Cs 662 keV: Stab channel 55; Count level 5000". To start the system test, press "Enter" and wait for the 10 second countdown. Press "Enter" and observe the developing spectrum. When "PP" and "FW" appear at the top of the display, the first test is completed. Press "Enter" again to observe the results. Record "peak - fwhm – gain" values on the field data sheet. To stop the testing phase, press "Start/Stop", otherwise "System Test" will continue to cycle. Press "Menu" to return to the Menu page, at which point the stabilization mode is switched back to the default setting – K.

- Menu Item 2: Detector config: Press "Enter". The default setting is "Coarse gain – 1.0; Det #1 – On – Gain Value from system test"; Det #2 – Off; Mode NORMAL".

- Menu Item 3: Operational mode: Press "Enter". Default settings should be as follows: "Sampling Time – 300; Sampling Mode – Live; Meas. Mode – Single; Evaluation – Assay; No. of channels – 256; Control – Keyboard; Position – None"

- Menu Item 4: Stabilization: Press "Enter". The default settings are "Gain stabilizer – On; Stab. – K 1460 keV; Stab. Channel – 118; Count level – 250. Timeout – 100 sec.. If the "Timeout error" occurs during the measurement, reduce the count level to 125 and/or increase the Timeout value to 200 or 300 seconds.

- Menu Item 5: ROIs: Press "Enter". Do not adjust. These settings are determined by performing a Pad Calibration. Included with the GR320 is a Pad Calibration result (a one page document with 4 coloured spectra on the right hand side of the page). ROIs are listed on the lower left side and they should match those displayed on the GR320. Press "Enter" to obtain the next "Calibration" window. The top 4 numbers are "background" values, a typical series of numbers being "100, 26, 10, 6". (Background values can be adjusted if there is an opportunity to obtain "over water" measurements. See section in Appendix 4-G on collecting and processing over-water measurements.) The Calibration Matrix is displayed in the bottom part of the display window. These numbers should match those on the Pad Calibration sheet and should not be changed. If they are accidently changed, reset them to match those on the Pad Calibration sheet. To change a number, use the arrow keys to highlight the one to be changed and key in the new number. If the number is negative, key in the number and press "Shift". Use the arrow tabs to move the cursor to the next number. Press "Enter" to save the configuration.

- Menu Item 6: Data output: Press "Enter". The default settings are as follows: "Device – Data Memory;

Config – DET#1 only; DET#1 – ROI's+SPECTRUM".

- Menu Item 7: Line/Pos./Step: Press "Enter". The display should show "AUTO positioning not selected".

- Menu Item 8: Data memory: The display should show "Stored" with the number of measurements stored in the instrument memory. This should match the number of measurements taken. When "dumping" stored data to the laptop computer, connect the GR320 to the computer serial port and start the Explore software.

Downloading GR320 Measurements using Explore Software

It is recommended that the measurement data on the GR320 be downloaded at the end of each day and be processed and verified before the GR320 memory is re-initialized for use the next day. If for some reason, a measurement was not stored in the instrument memory but recorded only on the field data sheet, the two series of measurements will be out of sequence. When this occurs, download the data from the GR320 and process and save it as an ASCII file. Import the ASCII file into a spreadsheet and correct it immediately. It is not necessary to return to the field site to redo the missed measurement but the digital file must be corrected to match the field sheets.

- Connect the GR320 console to a serial port on the computer.

- Start the GR320 Explore software

- Select "Download data" from the Explore menu. Select "From GR320", then the appropriate "Com port" - usually 1, and "Baud Rate" – usually 9600. Press "OK".

- Select or create a new file to save the binary data (*.dat file). If this is the first time that data for a project are being saved, it is necessary to select or create a new project directory. Naming the file (*.dat) with the date the measurements were made is recommended. This makes it easier in the future to link data from the instrument with data from the field sheets. Before processing the first measurements, it is also good practice to copy the calibration files (*.cal file) into the same directory to locate them more easily at a later date.

- The display on the Explore window now indicates that Com port 1 is active, followed by instructions for downloading the GR320 data.

- Turn on the GR320 instrument, highlight Menu item 8, and press "2". At this point "Bytes – ROI's – Spec" numbers should start cycling. The number of spectra stored should equal number of measurements taken.

- The number of records loaded into the memory buffer should be displayed when the download is completed. Select "OK". If data downloading has to be repeated, select "Erase Buffer". If this step is missed the next set of measurements will be appended to the first one and cause confusion later.

- Select "Spectrum Analysis" from the Explore menu, then "Calculate". At this point there is a programme prompt asking for selection of a calibration file. Find and select the appropriate file (*.cal) and click "Open".

- The "Spectrum Analysis" window will display the "Spectrum Analysis Table" which has the following 5 columns filled with data: "Record" - spectra or measurement number; "LT" – live time; "K"- eK concentrations; "U" – eU concentrations; and "Th" –eTh concentrations. Scroll down to check that the number of records equals the number of field measurements taken. If there is a discrepancy, it is necessary to compare records from the digital data file with the data from the field sheets to locate the missing record(s). Note which measurement was missed and correct the "Record" number sequence in the ASCII file and the spreadsheet (See next step). Because of slight differences in background levels and the subsequent rounding of measurement numbers, the concentration numbers commonly do not match exactly.

- Select "Save ASCII" from the Explore menu and then select an existing file or create a new file. It is helpful to use the same naming convention with date as the data file (*.dat file). Make sure that the correct directory is selected before saving the file. Save data as a text file (*.txt). The text file can be then imported into a digital spreadsheet (e.g. Excel) for editing and the addition of metadata such as the station ID, location coordinates, scintillometer values and soil gas radon values.

- Save the spreadsheet file in the same directory as the other files. It is recommended that, each day as a minimum, the new data be saved as an ASCII file, imported into a spreadsheet, the number of measurements and results cross-checked with the field data sheets, and any discrepancies corrected. When these steps are completed, the data memory on the GR320 can be erased and the instrument can be hooked up to the charge unit, if required.

Collecting and Processing Over-Water Background Measurements

A file of calibration data (*.cal) is supplied with the GR320 and the instrument is programmed by the manufacturer with a set of default background values in counts per minute (cpm), typically 120, 48, 18, 6 cpm. Because the default values are slightly higher than those usually attained over water, it is recommended that local over-water background measurements be acquired where possible. If this is not possible, a more appropriate set of default cpm values are 100, 26, 10, 6. Note: In the GR320 (Menu item 5) the background values are in counts per minute (cpm) but in the Explore program cal file, the background values are listed in counts per second (cps).

Over-water measurements should be taken over a body of water that is large enough to collect measurements at least 100 metres from the nearest shore. At least 5 measurements of 2 minutes each are to be taken. The data are then processed separately or along with other measurements. This is accomplished by following the same procedure for downloading data as outlined above, to the point of selecting the appropriate calibration file (*.cal). At this point, select the "Unit" calibration file that is supplied with the GR320 instrument. The "Unit" file has been edited as follows: bkd's set to 0; stripping ratios set to 0; and sensitivities set to 1. As a result, the values reported in the "Spectrum Analysis Table" are the unadjusted counts per second that can be used as background values. Using the file of over-water measurements, calculate the average cps values for K, U and Th. Enter these numbers into the appropriate calibration file (*.cal file) for the GR320 instrument and save the resultant file. It is helpful to change the file name to reflect the location where the over-water data were acquired. Multiply each of the average cps values by 60, and enter the resultant values into the GR320 instrument according to the instructions given in Menu item 5. Save the new configuration.

PART 5

BACKGROUND INFORMATION ON SURFICIAL MATERIALS AND UNDERLYING BEDROCK

Exposure of glacial till overlying bedrock of the Canadian Shield near Crosby, Ontario.
(Photo by I. Kettles)

BACKGROUND INFORMATION ON SURFICIAL SEDIMENTS AND UNDERLYING BEDROCK

Some background information on the surficial materials in Canada and the bedrock underlying them are presented in this section. This information provides the users of this manual with a better understanding, within a regional context, of the types of soils they are likely to encounter in different regions of the country. Most material in this section, excluding information on bedrock geology, was previously released in Geological Survey of Canada Open File 5085 (See Kettles in Spirito et al., 2006).

Bedrock geology

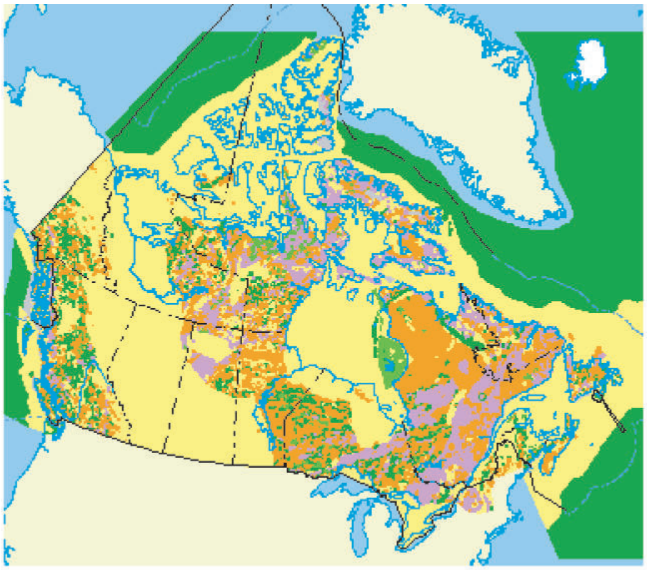
The geology of Canada (Figure 5-1) was summarized by Wallace (1948) . Canada is geologically one of the oldest countries in the world. Half of the country is underlain by Precambrian rocks of the Canadian Shield. This shield formed a large nucleus about which the North American continent was formed. The Canadian Shield consists largely of granite and gneiss, eruptive rocks which came up through older sedimentary rocks which were metamorphosed to marble and quartzite and gneiss, or through great beds of lava. In the beginning, these areas of ancient crystalline rocks formed ranges of mountains which have now been worn down to rounded hills with shallow valleys.

Younger rocks were deposited in the shallow seas around the margins of the Canadian Shield. In southern Quebec and Ontario there are Palaeozoic sandstones, limestones, and shales of Ordovician, Silurian, and Devonian age that were deposited in a shallow sea. The Carboniferous and Permian of the later Palaeozoic cover much of the Maritime provinces. The flat-lying sediments belonging to the latest division of the Mesozoic, the Cretaceous, underlie most of the prairie region of western Canada. Cretaceous beds, deposited at or near sea level, were elevated to form the Rocky Mountains.

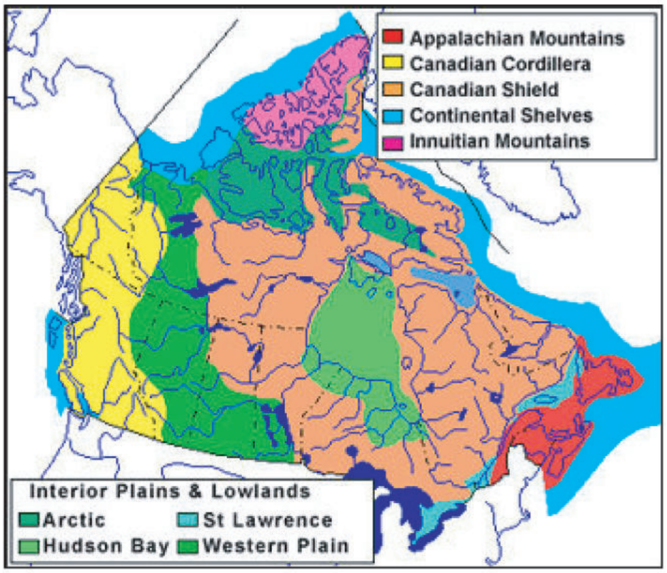
Progressing westward from the Rockies, there are the Selkirk and Gold ranges which are older and not quite so high. These are followed by the interior tableland of British Columbia which is cut by deep valleys and canyons, and the Coast range of mountains, formed in Jurassic times by the upwelling of molten rock. The Selkirk, Gold, and Coast ranges form the Cordillera and make up most of British Columbia. In the most westerly part of Canada, there is another range over parts of Vancouver and Queen Charlotte islands.

Surficial Sediments

Figure 5-2 shows the distribution of surficial sediments over the Canada landmass. The composition of the surficial cover in Canada differs in several important aspects from most other parts of the world where soils have developed from the in-situ weathering of bedrock. More than 95% of Canada was covered by glaciers periodically during the last 2 000 000 years and, as a result, the cover of surface sediments consists of materials that were eroded, transported and deposited by glaciers (Shilts, 1993; DiLabio, 1989; Dyke et al., 1989). This surface cover is composed of unweathered fragments of crushed bedrock mixed with reworked older soils and sediments. The clay- to boulder-size materials forming these deposits were eroded mostly from the underlying or nearby bedrock (0 to 10s of kilometres) but there is also a component of exotic material transported 100s to 1000s of kilometres by glacial ice or meltwaters before being deposited. Once deposited, these sediments have only been exposed to surface weathering and soil forming processes for the 8 000 to 10 000 years since the last glaciers melted. Since this is a very short period with respect to geologic time, the physical and chemical effects of weathering are generally confined to the uppermost 0-2 m.



http://atlas.nrcan.gc.ca/site/english/maps/environment/geology/majorrockcategories



Source:
ttp://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=
A1ARTA0006275

Figure 5-1. Maps showing the bedrock geology of Canada by major rock category (Atlas of Canada) and by geologic regions (Canadian Encyclopedia, 2008)

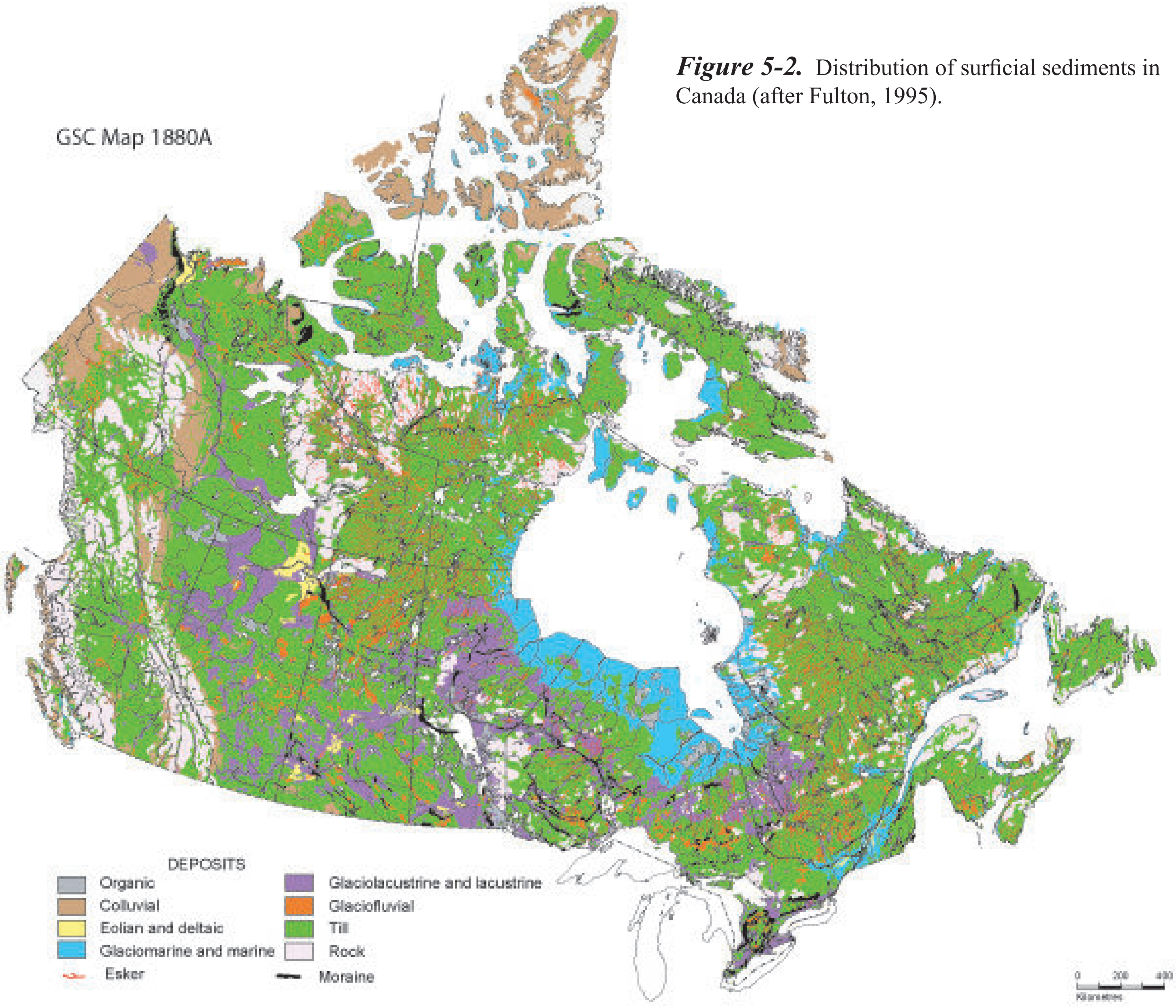


Figure 5-2. Distribution of surficial sediments in Canada (after Fulton, 1995).

The most widespread surficial deposits are diamictons, which are referred to collectively as till (Fulton, 1989; Dyke and Dredge, 1989; Shilts, 1993). They have been deposited either directly from, or in close association with, glacial ice (Figures 5-3 and 5-4). Tills are composed of pebble- to boulder-size clasts of bedrock in a matrix of variable amounts of fine sand, silt, and clay. Over many parts of Canada, especially over the Canadian Shield, till forms a discontinuous veneer, 0 - 1.5 m thick, which mantles and reflects the morphology and structure of underlying bedrock. In other areas, e.g., parts of the Prairies, the till cover is thicker, from several metres to more than 100 metres thick. At a regional scale, till deposits are thickest in areas such as southern Ontario and the Prairies which are underlain by sedimentary bedrock (Karrow, 1989; Klassen, 1989). The flat-lying, finely bedded, fine-grained nature, and weak cementation (lithification) of these bedrock strata made them more susceptible to glacial erosion than the massive crystalline bedrock that composes most of the Canadian Shield. The textural and lithologic composition of till depends mostly on the bedrock sources from which it originated. Where the till was derived from coarsely crystalline bedrock such as Precambrian granites, it is commonly stony and sandy, whereas in areas such as southern Ontario where it was derived from Paleozoic limestones and dolomites, the till is enriched in silt and clay and is more cohesive.

Figure 5-3. *Road cut exposure of till (in the vicinity of sampler) overlain by glaciolacustrine finely bedded fine sand and silt (bottom right). Both types of sediment were deposited over rugged Precambrian shield bedrock in south-central Ontario.*

Figure 5-4. *Exposure of fine-grained till bearing clasts of Paleozoic limestone and dolomite sampled near Manitouwadge, northeastern Ontario. The limestone and dolomite clasts were eroded and glacially transported from sedimentary bedrock in the James Bay Lowlands before being deposited on Precambrian shield terrain in northern Ontario.*

In some places glacial sediments have been reworked by meltwaters from the retreating glaciers and through other post-glacial processes (Dredge and Cowan, 1989). Glaciofluvial deposits are composed of complexly bedded and faulted, coarse bouldery to cobbly gravel interbedded with sand, gravel, and, in some places, bedded fine sand and silt (Figure 5-5). They are found in the landscape in various forms - eskers, kames, kame terraces, subaqueous fan deposits and outwash plains.

In some parts of Canada, tills or the bedrock surface are overlain by a cover of glacial lake or marine sediments consisting of thin (centimeters) to thick (more than 100 metres) deposits of rhythmically bedded clay and silt to fine sand or stratified gravel (Dyke and Dredge, 1989) (Figure 5-6). Some glacial lakes were local and small while others existed at the scale of the present day Great Lakes. During the last deglaciation, geographically vast areas were covered by Lake Agassiz in the Prairie provinces, Lake Barlow-Ojibway in northern Ontario and Quebec, Lake Iroquois and Lake Algonquin in southern Ontario, and by Lake McConnell in the western Northwest Territories (Dyke and Prest, 1987). In addition, marine waters invaded the isostatically depressed lowland coastal areas. The Tyrrell Sea occupied the Hudson Bay basin covering present-day coastal areas of Nunavut, Manitoba, Ontario and Quebec whereas the Champlain Sea invaded the St. Lawrence River and Ottawa River valleys (Dyke and Prest, 1987).

Figure 5-5. *Borrow pit in Eastern Ontario where glaciofluvial sand and gravel are being excavated.*

Figure 5-6. *Deposit of glaciomarine silt, sand and clay in eastern Ontario*

Along some river and stream valleys, there are older and modern alluvium deposits composed of silt, sand and gravel with minor organic materials (Dredge and Cowan, 1989). In places there are sand dunes and other types of wind blown deposits derived from alluvium or other fine-grained sediments (Wolfe, 2002). Organic deposits composed of peat and muck are also widespread (Tarnocai et al., 2000) (Figures 5-7 and 5-8).

Figure 5-7. *Deposit of peat excavated from the Mer Bleue peatland near Ottawa, Ontario..*

Postglacial modification of glacial sediments and soil formation

Soil-forming processes have altered the uppermost 2 m of till or other surficial materials. Below the upper 1 m or so, these deposits may show only minor effects of weathering. These are most commonly marked by signs of oxidation, which include colour changes from grey to brown, the presence of Fe-Mn oxide precipitates along the joints and fissures in the sediment, and the presence of disaggregated bedrock clasts (Shilts and Kettles, 1990; McMartin and McClenaghan, 2001).

Soil is defined as the naturally occurring, unconsolidated material or organic material at least 10 cm thick that is capable of supporting plant growth (Soil Classification Working Group, 1998). Canadian soils have been classified based on types, the degree of development, and the sequence of soil horizons and other layers in the surface cover. The major mineral horizons of mineral soils are A, B, and C (Figure 5-9) (Soil Classification Working Group, 1998). A-horizon is the mineral horizon formed at or near the surface in the zone of leaching or eluviation, or of maximum in-situ accumulation of organic matter (humus), or both. The B-horizon is the next lower horizon characterized by enrichment in organic matter, sesquioxides, or clays and characterized by a change in colour denoting hydrolysis or oxidation. The C-horizon is a mineral horizon comparatively unaffected by pedogenic processes and is considered as weathered parent material..

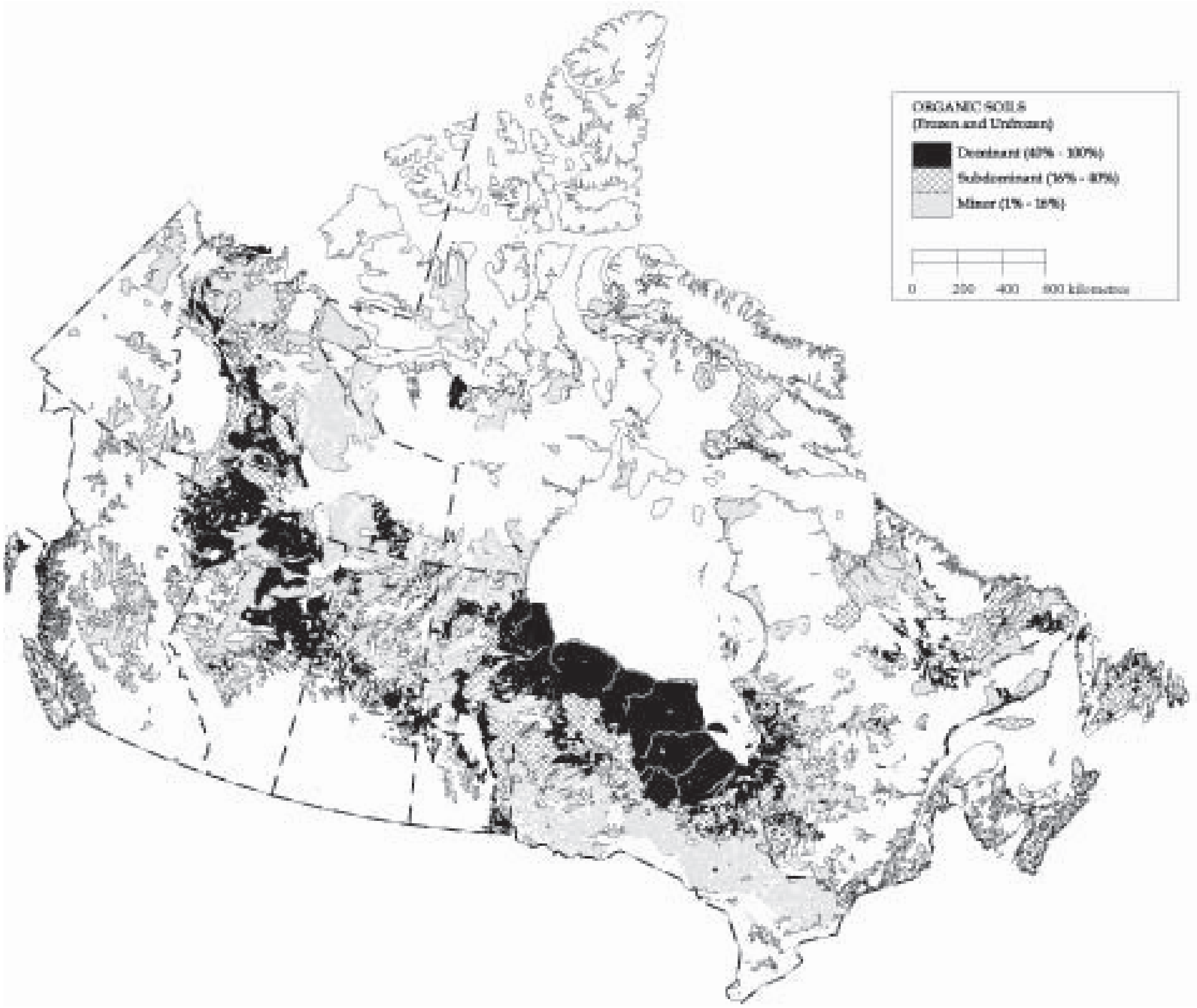


Figure 5-8. *Distribution of organic soils in Canada (after Soil Carbon Data Base Working Group, 1993).*

Distribution of Permafrost

The distribution of permafrost over Canada is shown in Figure 5-10. An estimated 42% of the Canada landmass is underlain directly by permafrost (Kettles et al., 1997). Based on this estimate, there will be more than 2500 NASGLP sites in permafrost-bearing areas. In addition, there are strong interrelationships between the distribution of peatlands and permafrost because of the insulating properties of peat and the poor drainage conditions in peatlands.

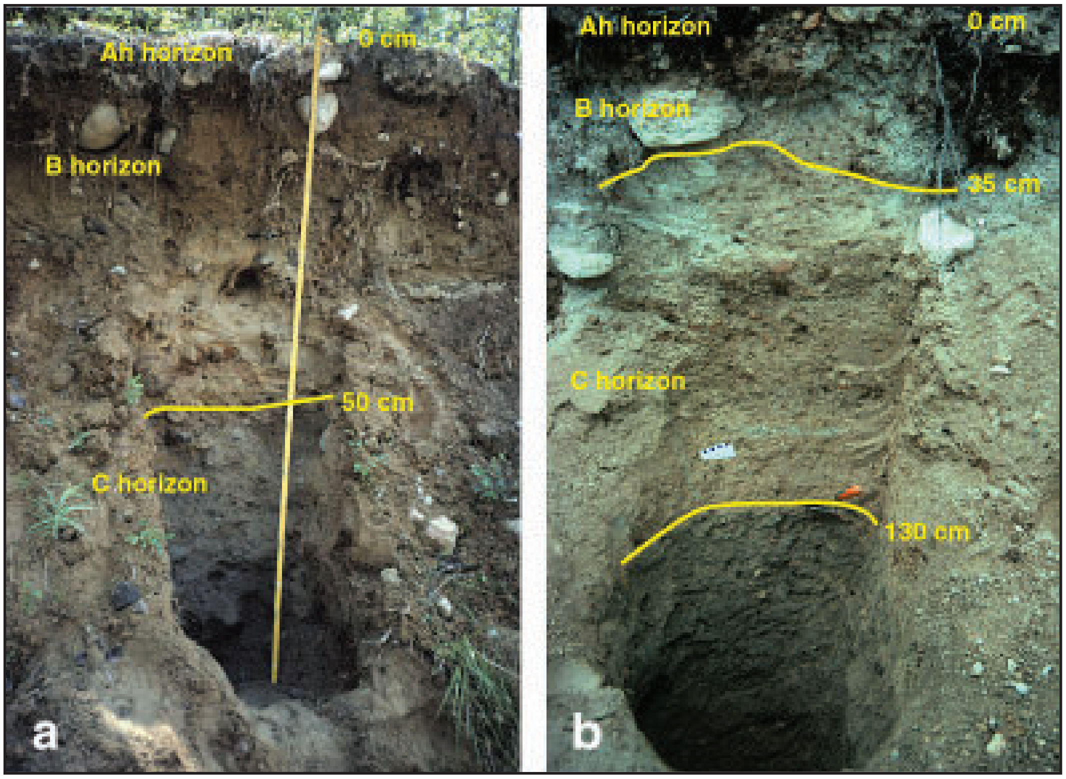


Figure 5-9. *Photographs of (a) a typical soil profile developed in till near Flin Flon, Manitoba, and (b) a soil profile in strongly calcareous till near The Pas, Manitoba, showing the Ah horizon. In soil sampling surveys samples were commonly collected from the Ah (humus) and B horizons (photo from McMartin and McClenaghan, 2001).*

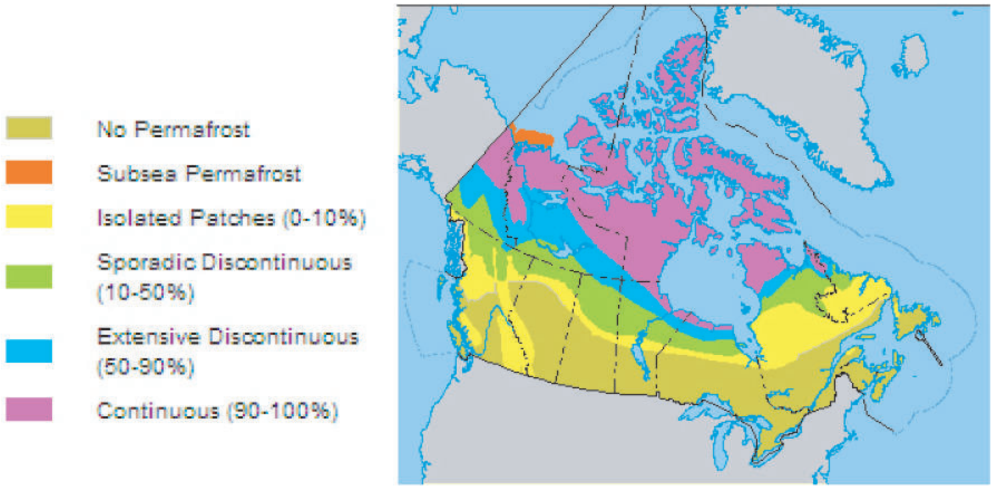


Figure 5-10. Distribution of permafrost in Canada (Atlas of Canada, 2003)

REFERENCES - PART 5

Atlas of Canada, 2003. Major rock categories; <http://atlas.nrcan.gc.ca/site/english/maps/environment/geology/majorrockcategories> [accessed December 16, 2009].

Atlas of Canada. 2003. Permafrost; <http://atlas.nrcan.gc.ca/site/english/maps/environment/land/permafrost> [accessed December 16, 2009].

Canadian Encyclopedia, 2008. Physiographic regions; <http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1ARTA0006275> [accessed December 16, 2009].

DiLabio, R.N.W., 1989. Terrain geochemistry in Canada; ***in*** Quaternary Geology of Canada and Greenland, Chapter 10, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 647-663.

Dredge, L.A. and Cowan, W.R., 1989. Quaternary geology of the southwestern Canadian Shield; *in* Quaternary Geology of Canada and Greenland, Chapter 3, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 214-235.

Dyke, A.S. and Dredge, L.A., 1989. Quaternary geology of the northwestern Canadian Shield; *in* Quaternary Geology of Canada and Greenland, Chapter 3, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 189-214.

Dyke, A.S. and Prest, V.K., 1987. Paleogeography of northern North America, 18000-5000 years ago; Geological Survey of Canada, Map 1703A, scale 1:12 500 000.

Dyke, A.S., Vincent, J-S., Andrews, J.T., Dredge, L.A., and Cowan, W.R., 1989. The Laurentide Ice Sheet and an introduction to the Quaternary geology of the Canadian Shield; *in* Quaternary Geology of Canada and Greenland, Chapter 3, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 178-189.

Fulton, R.J. (ed.), 1989. Quaternary geology of Canada and Greenland; Geological Survey of Canada, Geology of Canada, no. 1, 839 p.

Fulton, R.J. (comp.). 1995. Surficial Materials of Canada, Geological Survey of Canada, Map 1 880A, scale 1:8,000000.

Karrow, P.F., 1989. Quaternary geology of the Great Lakes subregion; in Quaternary Geology of Canada and Greenland, Chapter 4, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 326-350.

Kettles, I.M., Tarnocai, C., and Bauke, S.D., 1997. Predicted permafrost distribution in Canada under a climate warming scenario; *in* Current Research 1997-E; Geological Survey of Canada, p. 109-115.

Klassen, R.W., 1989. Quaternary geology of the southern Canadian Interior Plains; *in* Quaternary Geology of Canada and Greenland,.Chapter 2, (ed.) R.J. Fulton; Geological Survey of Canada, no. 1 (also Geological Society of America, the Geology of North America, v. K-1), p. 138-173.

McMartin, I. and McClenaghan, M.B., 2001. Till geochemistry and sampling techniques in glaciated shield terrain: a review; *in* Drift Exploration in Glaciated Terrain, (ed.) M.B. McClenaghan, P.T. Bobrowsky, G.E.M. Hall, and S.J. Cook; Geological Society Special Publication 185, p. 20-43.

Pidwirny, M. (2006). Soil Classification; Fundamentals of Physical Geography (second edition); <http://www.physicalgeography.net/fundamentals/10v.html> [accessed December 15, 2009].

Shilts, W.W., 1993. Geological Survey of Canada's contributions to understanding the composition of glacial sediments; Canadian Journal of Earth Sciences, v. 30, p. 333-353.

Shilts, W.W. and Kettles, I.M., 1990. Geochemical-mineralogical profiles through fresh and weathered till; *in* Glacial Indicator Tracing, (ed.) R. Kujansuu and M. Saarnisto; A.A. Balkema, Rotterdam, p. 187-216.

Soil Carbon Data Working Group, 1993. Soil carbon data for Canadian soils, Centre for Land and Biological Resources Research Research Branch, Agriculture Canada, Ottawa. CLBRR Contribution Number 92-179, 33 p. plus appendices.

Soil Classification Working Group, 1998. The Canadian System of Soil Classification, 3rd ed. Agriculture and Agri-Food Canada Publication 1646, 187 p.

Spirito, W. A., Rencz, A.N,; Kettles, I.M., Adcock, S.W., and Stacey, AP., 2004. Compilation of soil and till geochemical metadata for Canada - an update; Geological Survey of Canada, Open File 5085, 92 p.

Tarnocai, C., Kettles, I. M., Lacelle, B., 2000. Peatlands of Canada; Geological Survey of Canada, Open File 3834; 1 sheet.

Wallace, W.S. (ed.), 1948. The Encyclopedia of Canada, Vol. III, Toronto, University Associates of Canada, 1948, p. 23-26.

Wolfe, S.A., 2002. Eolian deposits of the Prairie provinces of Canada; Geological Survey of Canada, Open File 4118 (map).