Bill # 34

from Sierra Club

(1A)

Geological Survey of Canada

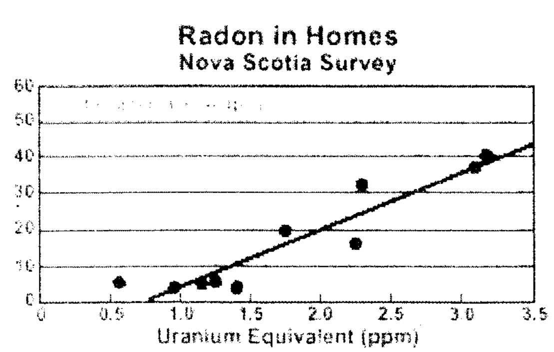
Environmental geochemistry and geochemical hazards
Radon

Nova Scotia

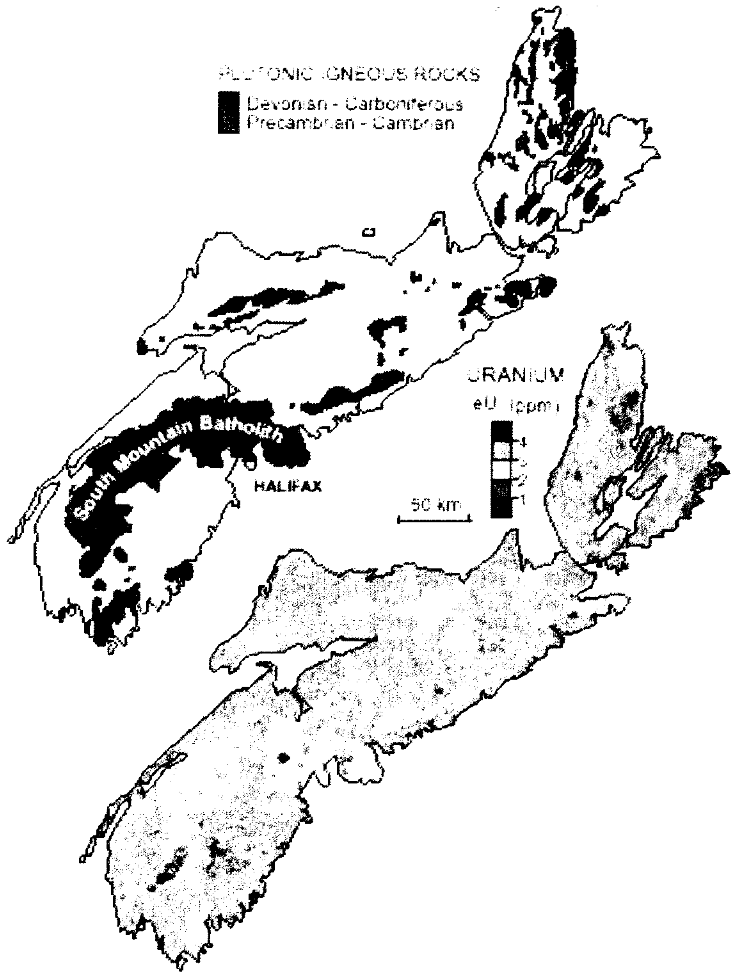
Radon (Rn-222), a radioactive gas associated with an increased incidence of lung cancer, is formed by the natural radioactive decay of uranium. Geological mapping of rocks and soils with a potential for high uranium content can be used to interpret regional variations in the concentration of radon in homes. Because of its effects on human health, radon is considered a potential "geochemical hazard" where it occurs at high concentrations.

Three factors must be assessed in order to determine the likelihood of increased radon levels in homes. They include: 1) the source - what is the uranium content of rocks and surficial deposits (see uranium map of Nova Scotia); 2) the transport pathways - how "open" and porous are the surficial deposits, and how fractured or broken is the bedrock; and 3) the capture points - how well constructed is the house, and how easy is it for radon gas to enter, accumulate, and leave? Although it is likely that radon concentrations in homes would relate directly to the concentration of uranium in bedrock and surficial deposits, the other two factors can be equally important. Thus, there can be considerable variation in the concentration of radon in homes.

To determine the linkage between geology and radon gas in homes, the Province of Nova Scotia surveyed 719 homes in 75 communities, finding average radon concentrations of 2.9 pCi/l (picocuries/litre). The graph of radon in homes shows the percentage of homes in ten communities having radon levels greater than 4 pCi/l plotted against the regional background level of uranium. The regional background concentrations are derived from airborne radiometric surveys of the Geological Survey of Canada (see uranium map of Nova Scotia). Areas of high uranium concentration are associated with intrusive rock types, principally the South Mountain batholith (see geology map of Nova Scotia) in southwestern Nova Scotia. Four pCi/l is the American standard for radon above which remediation action may be recommended. The Canadian standard is 20 pCi/l, and 22 homes out of the 719 surveyed exceeded that standard. This study indicates that uranium patterns derived from gamma spectrometric surveys provide an excellent predictor for the average concentration of radon gas characteristic of homes in different communities.



Radon in Homes



Geology map of Nova Scotia

This material was extracted from Figure 1H: "Environmental applications of gamma ray spectrometry surveys", by B.W. Charbonneau, R.J. Hetu and J.M. Carson (Radiation Geophysics), in "Environmental geochemistry and geochemical hazards", compiled by R.D. Knight and R.A. Klassen, included in "A synthesis of geological hazards in Canada", Geological Survey of Canada Bulletin 548, edited by G.R. Brooks, 2001.

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http://gsc.nrcan.gc.ca/geochem/envir/radon_e.php

from Sierra Club

(1B)

Radon Soil Gas in Nova Scotia[1]

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Introduction

The North American Soil Geochemical Landscapes Project (NASGLP; cf. Goodwin *et al.*, 2009b) is a trinational initiative involving federal, provincial and state geological surveys of Canada, the United States and Mexico and will produce the first continental-scale map of the soil geochemistry of North America. The program will provide a comprehensive continental-scale framework of inorganic, organic and microbiological soil geochemical data as well as radiometric data.

One component of the NASGLP that is unique to Canada involves the collection of radon soil gas measurements at each soil sample site. Radon sampling protocols including: (1) sample site selection, (2) field methods, and (3) the type and proper use of accepted sampling equipment, were designed by the Geological Survey of Canada (GSC) in conjunction with the Radiation Protection Bureau of Health Canada.

During the 2007 and 2008 field seasons, a total of 72 sample sites (including 3 field duplicates) were sampled for radon soil gas concentrations from across Nova Scotia at an average sampling density of approximately 1 sample per 800 km^2. This sampling program represents the first regional radon soil gas survey completed in Nova Scotia. A limited orientation program was also completed during the spring of 2008.

Preliminary regional results for radon concentrations are presented here for the first time.

What is Radon?

Radon 222 (Rn^{222}) is a naturally occurring, invisible, odourless, tasteless radioactive gas found throughout the environment. Radon is highly radioactive. It has a very short half-life of 3.8 days. Radon is produced when unstable uranium 238 (U^{238}) undergoes a natural, spontaneous radioactive decay by releasing ionizing radiation in the form of alpha and beta particles and high energy gamma radiation. During the decay process of U^{238}, new elements, including radon, are formed. Once formed, radon quickly decays into polonium 218 (Po^{218}) by discharging an alpha particle. It is the decay of radon and the release of alpha particles into the air that are potentially harmful to human health if these particles are inhaled and attached to the inner lining of the lungs.

Radon gas is heavier than ambient air and cannot be detected by humans, but its presence can be identified by sensitive instruments capable of detecting minute amounts of energy as alpha particles are released into the atmosphere. It is very mobile in air and water, but is limited by its short half-life. Radon is a commonly used pathfinder in mineral exploration, particularly in the search for uranium.

Radon and its parent element, uranium, occur naturally and can be found and measured in detectable concentrations in soils and rocks. Elevated radon is typically associated with rocks such as granite and shale that are enriched in uranium (Je, 1997).

Radon and Uranium in Nova Scotia

Radon soil gas data are severely lacking for Nova Scotia. Limited, but very focused radon data, collected by mineral exploration companies engaged in the search for uranium deposits during the 1970s and early 1980s, are tabulated in 'Uranium in Nova Scotia: A Background Summary for the Uranium Inquiry, Nova Scotia' (Nova Scotia Department of Mines and Energy, 1982).

[1]Funding provided by the Geological Survey of Canada and Health Canada
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Goodwin, T. A, Ford, K. L., Friske, P. W. B. and McIsaac, E. M.
2009: *in* Mineral Resources Branch, Report of Activities 2008;
Nova Scotia Department of Natural Resources,
Report ME 2009-1, p. 25-34.

The association of radon and uranium is well understood. Naturally occurring concentrations of uranium have been detected in all types of geochemical sample media (soil, till, lake bottom sediment, stream sediment, stream water, humus, vegetation and rock) throughout the province and analyzed by the Nova Scotia Department of Natural Resources and previously, the Nova Scotia Department of Mines and Energy. Uranium concentrations range from parts per billion (ppb) up to percentages in mineralized environments, depending on the sample medium analyzed. Examples of uranium concentrations in various sample media can be found in Nova Scotia Department of Mines and Energy (1982) and Lombard (1991), and references contained therein.

A compilation of airborne radiometric surveys covering Nova Scotia has been completed by the Geological Survey of Canada and demonstrates that uranium exists throughout the province (Carson *et al.*, 2003). Regional concentrations range from a low of 0.025 ppm to a high of 7.80 ppm (equivalent) uranium. These data also indicate that broad areas are characterized by background uranium concentrations, in contrast to other distinct areas that are characterized by their elevated (2x to 3x) background levels.

In addition to areas of elevated background levels, occurrences of uranium are also known throughout Nova Scotia. Many different styles of uranium mineralization, including granite vein-type, roll-front type, pegmatite-hosted, and black shale-hosted occur throughout the province.

The most significant uranium deposit currently known in Nova Scotia is the Millet Brook uranium deposit. Non 43-101 compliant total reserves reported by Chatterjee *et al.* (1982) for three zones outlined by 139 diamond-drill holes totalling 11 342 m are in the order of 453 592.4 kg (1.0 million pounds) of U_3O_8 with an average grade of 0.15-0.20% U_3O_8 (using an average cutoff of 0.10% over a 2.0 m width). Uranium exploration ceased in the province in September 1981, when the Government of Nova Scotia issued a moratorium on the issuing of new uranium licences and the renewal of existing licences. As of January 2009, the moratorium remains in effect and uranium exploration is not permitted in the province.

2007-2008 Sampling Program

A total of 72 sites were sampled for radon soil gas concentrations across Nova Scotia during the 2007 and 2008 field seasons resulting in an overall average sampling density of approximately 1 sample per 800 km^2 (Fig. 1). Goodwin (2008) and Goodwin *et al.* (2009b) provide a description and overview of the NASGLP sampling program as it pertains to Nova Scotia.

Additional detailed sampling for radon soil gas was conducted within the Halifax Regional Municipality (HRM) during the summer of 2008. Results of that sampling program are presented in Goodwin *et al.* (2009a).

Field Sampling Methodology

Introduction

Each sample 'site' is represented by a single radon (and permeability) level associated with a single geographic co-ordinate point. In reality, each reported level is actually a composite of five individual readings that have been averaged to represent the site. Each site is approximately 100 m^2 (10 m x 10 m). Hollow probes are inserted into the ground at each of the four corners and the fifth probe is located at the approximate centre of the sample site. Similarly, *in situ* gamma ray spectrometric readings of Total Count, eU, eTh and K were collected at each of the five probes and a mean level representing the site was calculated.

Sample location coordinates (UTM 20T, NAD83) were collected with a GARMIN GPS map 76Cx and crossreferenced to the NASGLP soil sample site. Descriptive notes were recorded for each sample site and a digital photograph was taken for future reference.

Soil Permeability

In situ soil permeability measurements were determined using Radon-JOK portable sampling equipment using the following procedure. Approximately 1 m long hollow probes are fitted with a long tip and each probe is hammered to a consistent depth of 60 cm. A thin punch wire is

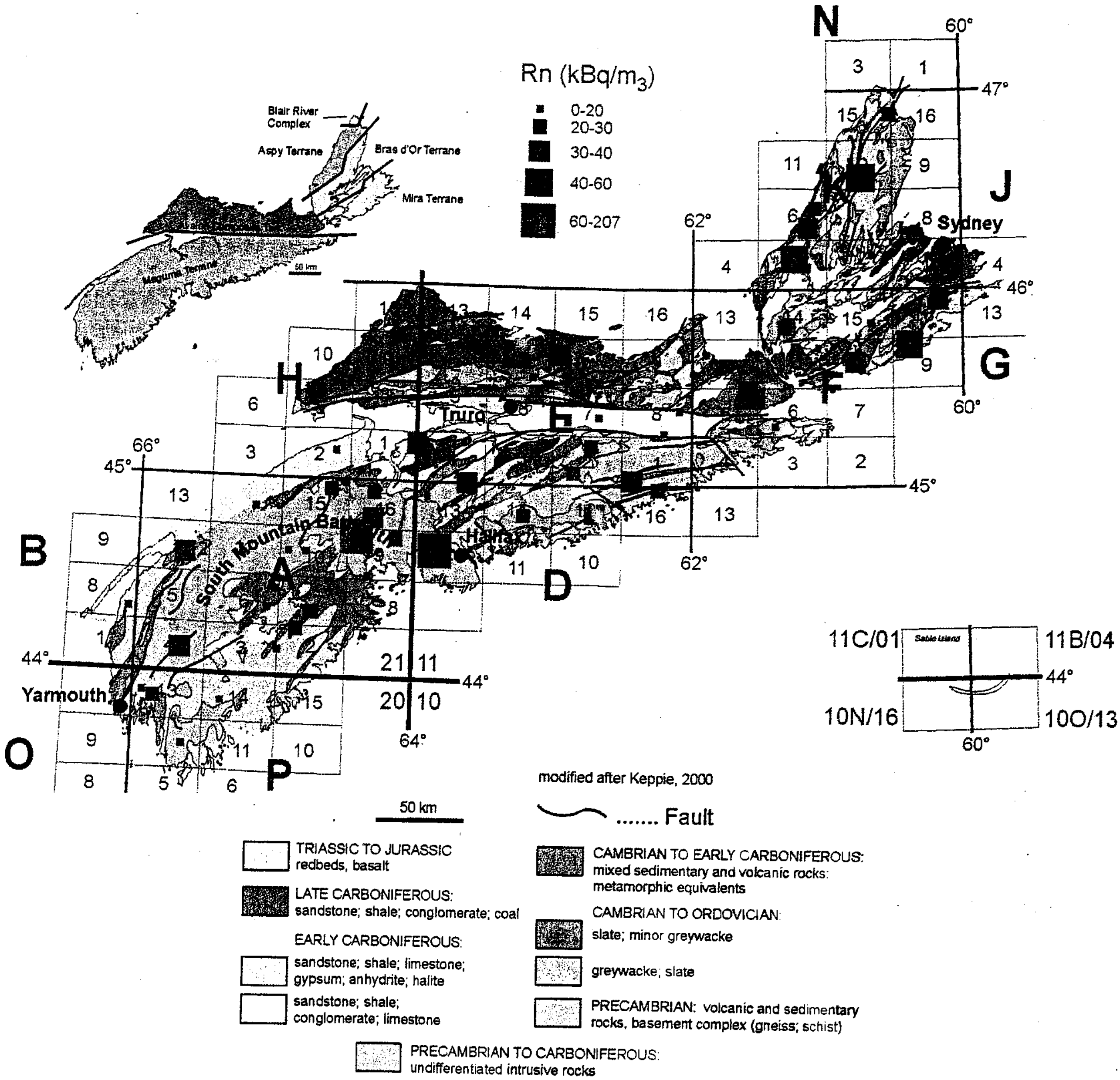

Figure 1. Sample locations and results for radon concentrations (kBq/m^3) in soil gas samples collected during the 2007 and 2008 summer field seasons. Note that radon in soil gas is measured in kBq/m^3. Radon in air is measured in Bq/m^3 (1 kBq/m^3=1000 Bq/m^3).

placed in the hollow probe. The punch wire is slightly longer than the hollow tube and the exposed end of the punch wire is covered with a spacer and an adjustable cap. Once the cap has been adjusted to the spacer, the spacer is removed, and a nylon mallet is used to drive the punch wire down until the cap reaches the top of the probe. The purpose of the spacer and the adjustable cap is to ensure the long tip is driven down to a consistent distance from the base of the probe, creating an empty space from which soil gas will be drawn.

The probe is then attached to the Radon-JOK portable sampling equipment using rubber tubing. The tubing is attached to expandable bellows. The bottom of the bellows is attached to one or two weights. When the weights are allowed to drop, soil gas is drawn into the bellows using negative pressure. The rate at which the bellows expand determines the soil permeability at the probe. A standard stop watch is used to measure the time it takes for the bellows to fully expand. If the bellows have not expanded after 20 minutes, the soil is recorded as having 'low permeability'.

Radon

After the soil permeability has been measured, the radon soil gas concentration measurements are determined using the RM-2 portable soil radon monitoring system. Five IK-250 Sampling Ionization Chambers (ICs) were prepared by measuring the IC background radon concentration by using ambient air. If the IC filled with ambient air was >0.7 kBq/m^3 then the IC was cleaned with deionized water until it read <0.7 kBq/m^3. (If an IC reading of <0.7 kBq/m^3 could not be achieved through cleaning, the IC was taken out of the queue and replaced with a different IC that, when tested, reported <0.7 kBq/m^3). Next the ambient air in the ICs is evacuated with the use of a converted bicycle pump fitted with a oneway reversible valve. The oneway valve draws air out of the IC creating negative pressure which is used to draw the 150 ml soil gas sample from the syringe into the IC.

The long tip for each probe is punched out as described above. Rubber tubing is used to attach the probe to a 150 ml syringe. To isolate the probe from ambient air, 150 ml of soil gas is removed, the tubing is clamped to isolate the system, then the soil gas in the syringe is discarded. The syringe is again attached to the probe and a fresh 150 ml sample is withdrawn from the probe.

This fresh sample is drawn into a clean IC, sealed and held within the IC for approximately 15 minutes. Next, the IC is connected to the ERM-3 electrometer and the radon concentration of the soil gas is expressed in kBq/m^3 after 2 minutes of processing time.

If water was drawn into the syringe at any stage, the syringe and affected equipment were replaced with new, dry equipment. The probe would then be moved (sometimes up to 5 m away from the original probe) and soil gas extracted from this new location. Groundwater extracted into the syringe was an issue more common in spring than during the drier conditions of summer. Spatially, groundwater was problematic in areas of lower topography, both regionally and locally.

Radioactivity

At each site radioactivity was measured by two means. A geometrics GR-101A gamma ray scintilometer was used to determine the ambient radioactivity associated with the entire site. At each probe, however, an Exploranium GR-320 spectrometer was suspended approximately 50 cm above the ground and measured *in situ* gamma ray spectrometric readings of Total Count, eU, eTh, and K using a five minute counting time.

2008 Orientation Survey

During the 2007 NASGLP field season, a number of issues were raised with regard to the acquisition of radon soil gas data. These included concerns regarding: (1) accuracy and precision of the radon data, (2) unacceptably high site variance, and (3) the optimum sampling depth.

In order to address these concerns, a limited orientation program was conducted in the spring of 2008 at several sites across Nova Scotia. These sites involved the acquisition of radon soil gas measurements over: (1) various surficial units and bedrock units, and (2) mineralized and unmineralized sources using various sampling depths in order to determine the optimum sampling depth. In the fall of 2008, an additional test over a mineralized bedrock source was undertaken to test how quickly radon dissipated in ambient air.

Results

A brief summary of the results of the orientation study are reported here for the first time. The results obtained from the orientation study were very useful and conclusions drawn were ultimately incorporated into the radon soil gas sampling protocols of the NASGLP. Results of regional, province-wide radon soil gas concentrations are also being reported here for the first time.

2008 Orientation Study

Temporal, spatial and duplicate testing of radon concentrations from various bedrock and surficial units suggest the RM-2 portable soil radon monitoring system is accurate and precise and the data collected during 2007 and 2008 are of excellent quality.

Site variance is strongly influenced by the texture of the material being tested. Uniform and coarse till (e.g. Beaver River Till - granite facies) exhibits moderate site variance. Clay-rich till, characterized by rare and randomly distributed friable sandstone clasts (e.g. Lawrencetown Till), exhibits a high degree of variability particularly when some probe tips end in (effectively) nonpermeable clay and other probes end in highly permeable, friable, disaggregated sandstone clasts (Table 1). These friable clasts probably also act like local radon 'sinks'. Retesting of the 92.9 kBq/m^3 probe site returned highly repeatable levels of 90.7 and 94.0 kBq/m^3. Similarly, retesting of the 63.1 kBq/m^3 probe returned a duplicate concentration of 62.8 kBq/m^3.

Notwithstanding the clay-rich till, characterized by randomly distributed friable sandstone clasts previously described, the optimum sampling depth was determined to be 60 cm. After 60 cm, radon soil gas concentrations remain nearly constant (Fig. 2). Testing of radon in soil gas by Neznal *et al.* (1997) also concluded that soil gas radon remains constant at depths ranging from 60-100 cm below the ground.

Radon soil gas concentrations associated with mineralized bedrock sources (C2 Zone, Millet Brook) are clearly discernable from unmineralized background sources. At Millet Brook, for example, radon concentrations in soil gas associated with known uranium mineralization were in excess of 500 kBq/m^3 and up to 1500 kBq/m^3.

A small study was also carried out over the C2 Zone at the Millet Brook deposit to assess radon concentrations in ambient air above a known uranium occurrence. Results of this study indicate that highly anomalous radon soil gas concentrations, in excess of 1000 kBq/m^3 at 60 cm depth, drop to 1 kBq/m^3 at the ground-air interface and drop to not detectable at heights $\geq$10 cm above the ground-air interface (Table 2).

2007-2008 Regional Radon Results

Radon in soil gas was detected at all sample sites (except one, described below) tested during the 2007 and 2008 sampling program, regardless of the soil type and conditions, or the underlying bedrock geology. It is important to stress that the radon soil gas concentrations measured for this project represent natural background conditions and are not related to what would be termed uranium occurrences.

The only location where soil gas radon was not detected was a sample site near Meaghers Grant. It is acknowledged that a very low concentration of radon soil gas probably exists at this site, but was less than the lower detection limit of the instrumentation. At this particular site, extraction of soil gas was extremely difficult from each of the five probes. This was the only site tested during the 2007 and 2008 field seasons where the required 150 ml of soil gas could not be evacuated from any of the five probes. Only about 100 ml of soil gas could be extracted from any of the probes. Further inspection of the soil profile at this site revealed thick red clay (effectively void of clasts) ubiquitous throughout the area. This site may represent previously unrecognized glaciolacustrine clay, characterized by its very low to negligible permeability. Water was drawn into the syringe at this site. New probe sites with drier soil conditions were located less than 20 m away upgradient. The presence of radon soil gas could not be tested at three other sites across the province because excessive groundwater was present and some water was drawn into the syringe on every attempt.

With the exception of the Meaghers Grant sample site, radon soil gas concentrations (calculated as the mean of the concentrations from the five probes) ranged from a low of 0.1 kBq/m^3 to a high of 207.0 kBq/m^3 with a mean of 25.3 kBq/m^3 (median of 20.8 kBq/m^3). It is also important to stress that the raw field data were used to calculate the mean radon level for each site.

Regional mean radon concentrations in soil gas results are presented in Figure 1. The highest radon concentration (207.0 kBq/m^3) in soil gas was from a site located approximately 5 km southeast of New Ross. The bedrock consists of Middle-Late Devonian leucomonzogranite. The second highest radon concentration of 88.3 kBq/m^3, collected from a site approximately 5 km south of Five Island Lake, is also located in Middle-Late Devonian leucomonzogranite. Leucomonzogranite is often

Table 1. An example of radon concentration variability associated with the inhomogeneous, clay-rich Lawrencetown Till. Data are from a 2008 retest of NASGLP site NS07 1008.

Depth (cm)	Radon (kBq/m^3)	Comments
10	3.0	probe ended in clay matrix
20	0.0	probe ended in clay matrix
30	92.9	probe ended in friable sandstone clast
40	63.1	probe ended in friable sandstone clast
50	0.0	probe ended in clay matrix
60	1.0	probe ended in clay matrix
70	0.5	probe ended in clay matrix
80	0.0	probe ended in clay matrix

Table 2. An example of the very rapid dilution of radon soil gas as it interacts with ambient air. Sample site located directly over uranium occurrence associated with the C2 Zone, Millet Brook.

Depth (cm)/Height (cm)	Radon (kBq/m^3)	Comments
80	0.0	ambient air above ground level
60	0.0	ambient air above ground level
40	0.0	ambient air above ground level
20	0.0	ambient air above ground level
10	0.0	ambient air above ground level
0	1.0	ambient air taken at ground level
-60	1491.0	soil gas

characterized by elevated concentrations of incompatible elements such as uranium, as well as tin, tungsten, lithium, beryllium and tantalum. A summary of the provincial bedrock geology can be found in Keppie (2000) and a more detailed description of the leucomonzogranite bedrock, host of the highest radon soil gas concentrations, can be found in MacDonald and Horne (1987). The next five highest radon concentrations (40.0 kBq/m^3 to 60.0 kBq/m^3) occur in variable geology in northern Nova Scotia and Cape Breton Island (Fig. 1).

The data have been presented in Table 3 on the basis of surficial geology (after Stea *et al.*, 1992). At the provincial scale, it is difficult to make any interpretations regarding the radon concentrations and the associated till units. A few general observations are possible.

The overburden that comprises the stony till plain can be derived from a number of bedrock types including slate, metasandstone and granite. In general, radon concentrations in soil gas were highest in the stony till plain material. Water was not drawn into the syringe in the stony till plain unless the sample site was located in a topographic low. The silty till plain/drumlin overburden more commonly was characterized by wetter ground, regardless of its topographic setting, so water was drawn into the syringe more often. The content of

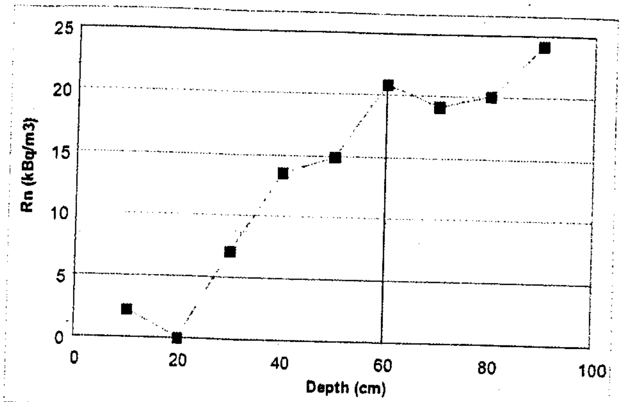

Figure 2. An example of radon soil gas concentrations increasing with depth. Note concentrations remain more constant at depths of 60 cm and deeper. Site location in the Three Mile Plains area near Windsor.

the silty till plain/drumlin material was highly and locally variable, ranging from silty-sand to clay. This variability, particularly when clay was present, increased variance within a site (described below). There were not enough samples collected from glaciofluvial or alluvial deposits to draw any meaningful conclusions.

Site variance was very high regardless of the till unit. The silty till plain/drumlin soil often exhibited the highest site variance. For example, radon concentrations for the five probes at site NS08 1008 were 0.0, 0.0, 23.4, 0.0, and 55.5 kBq/m^3. Site variance was tested in 2007 by collecting field duplicates from three sites. Field duplicates here are defined as a new grid of five probes located within 10 m of the original grid of five probes. Results of the field duplicates are presented in Table 4.

Site variance, either probe to probe variance within the same sampling site, or variance from site to site, was also noted in soil gas radon studies in Ontario (Chen *et al.*, 2008a). The 2007 and 2008 results for Nova Scotia clearly demonstrate that natural radon soil gas variability is related to: (1) the lithology of the underlying bedrock, (2) the texture and provenance of the overlying surficial material, and (3) the local geomorphologic terrain conditions.

Discussion

Results of the orientation survey indicate that anomalous radon in soil gas (up to 1500 kBq/m^3) is associated with granite-hosted, vein-type uranium occurrences (e.g. Millet Brook). The radon gas, however, dissipates very rapidly to negligible concentrations in ambient air a mere 10 cm above the ground directly over the mineralized source. Anomalous radon in soil gas probably exists with other styles of uranium mineralization (roll-front, pegmatite-hosted, black shale, volcanic and basal Windsor) known to exist throughout Nova Scotia.

Regionally, very high radon soil gas associated with leucomonzogranite is probably the result of the natural radioactive decay of uranium in late-stage, highly evolved granite characterized by its elevated concentrations of incompatible elements including U-Sn-W-Li-Be-Ta. These elevated uranium-bearing granites are spatially associated with the western and eastern ends of the South Mountain Batholith. The elevated uranium concentration in these rocks is clearly discernable in airborne (eU) radiometrics (Carson *et al.*, 2003) and regional lake-bottom sediment geochemistry (Lombard, 1991). Elevated uranium in C-horizon soil samples collected as part of the NASGLP are also associated with leucomonzogranite (Goodwin *et al.*, 2009b).

Additionally, high radon soil gas is also locally associated with sedimentary rocks of the Carboniferous Horton and Pictou groups. These high radon concentrations may be indicative of roll-front uranium mineralization within alternating red/grey bed sequences.

The optimum sampling depth of 60 cm, determined from the 2008 orientation survey, was introduced as part of the 2008 sampling protocol for radon soil gas. In 2007, however, the protocol required soil probes to be driven to 80 cm depth. Results of the orientation sampling also indicate that at depths shallower than 60 cm, radon concentrations decrease upwards towards the surface. This is significant because very few of the 2007 radon soil gas measurements were collected from the recommended sampling depth of 80 cm because of poor ground conditions (namely abundant boulders) nor were they collected from a constant depth. In fact, NS07 1037 is a typical sample site, where probes were driven to depths of 41, 48, 49, 50 and 61 cm. Results from 2007 should, therefore, be considered a minimum level for radon soil gas concentrations. In contrast, all 2008 soil gas samples were collected from 60 cm depth.

Table 3. Summary of radon concentrations in soil gas from across Nova Scotia. Basic statistics have been subdivided on the basis of various surficial units (after Stea *et al.*, 1992).

Till Unit	n	Min. (kBq/m³)	Max. (kBq/m³)	Mean (kBq/m³)	Comments
stony till plain	36	3.5	207.0	29.1	One site from 2007 drew water - no reading taken
silty till plain/ drumlin	29	0.0	48.4	20.8	One site returned zeros from all five probes, two sites drew water - no readings taken
glaciofluvial	2	16.6	21.8	19.2	Limited number of data points
alluvial deposits	2	12.5	25.6	19.1	Limited number of data points

n = number of sample sites

Table 4. Radon concentrations for field duplicates from three sites sampled during 2007. Note the high site variance.

Sample	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5	Mean
NS07 1017	0.0	8.1	0.0	10.6	5.6	4.9
NS07 1018	5.2	8.4	17.6	16.7	9.2	11.4
NS07 1034	2.6	53.0	3.4	7.7	0.1	13.4
NS07 1035	0.2	0.0	1.0	0.1	0.2	0.3
NS07 1050	17.0	4.8	9.8	35.9	18.4	17.2
NS07 1051	59.1	24.4	27.7	9.4	35.5	31.2

Discussion continues among participants of the NASGLP on how to determine the soil radon concentration that will be used to represent each site. Are five readings adequate to be representative of the site? Should the highest and lowest levels of the five readings be discarded and the mean calculated from the remaining three levels? Should zero levels or levels <1.0 kBq/m³ be eliminated before the mean is calculated?

The Nova Scotia survey used the mean of the radon concentrations from the five probes at each site as the radon concentration representative of the site. The decision to average the data collected from all five probes is based on the excellent precision and accuracy of the results obtained from: (1) the orientation survey in the spring of 2008, and (2) additional quality control tests (not described here) performed at most 2008 sites.

Chen *et al.* (2008a, b) also measured soil radon concentrations from five probes at each sampling site. They excluded the lowest reading and any level <1.0 kBq/m³ before calculating the mean value used to represent the sample site. On a direct comparative basis, the Nova Scotia results will be low relative to the Ontario results simply because the mean concentration was calculated differently for each survey.

The possibility that seasonal variance could influence site results was taken into account. In order to minimize seasonal variance, the survey was completed in the summer season of Nova Scotia, mid-June to mid-August. Temperatures were recorded at each site and barometric pressures, if required, can be obtained from Environment Canada. Site variance, recognized early in the 2007 sampling program, was ultimately determined to be caused by textural changes in the soil and not related to instrumentation.

Sundal *et al.* (2004) and Smethurst *et al.* (2008) identified highly permeable overburden as an important factor in outlining areas in Norway that are characterized by anomalously high radon soil gas regardless of the uranium concentration of the overburden. This may, in part, explain the moderately high radon soil gas concentration of 54.2 kBq/m^3 obtained in the Strathlorne-Lake Ainsle area, although additional research is required to confirm this association. The opposite occurs at the Meghers Grant sample site where radon was not detected in any of the five probes tested. This site is unique because very low permeability clays underlie the entire area and this inhibits airflow and resulted in exceptionally low radon soil gas concentrations.

The results of this study have resulted in a basic understanding of the relationships between radon concentrations in soil and bedrock type, as well as radon concentrations in soil and surficial geology. These relationships will assist in the development of a radon potential map of the province. In particular, the characteristics of the surficial geology including: (1) uranium concentration, (2) permeability, (3) thickness, and (4) areal extent are probably very important factors when dealing with indoor radon gas.

Conclusions

Measures of radon concentrations in soil gas collected from 72 sample sites at an average sampling density of approximately 1 sample per 800 km^2 during the 2007 and 2008 were part of the NASGLP. This province-wide program represents the first regional radon soil gas survey attempted across Nova Scotia. Results from the 2007 and 2008 summer sampling programs demonstrate that naturally occurring radon soil gas is present throughout Nova Scotia.

Radon soil gas concentrations ranged from a low of 0.1 kBq/m^3 to a high of 207.0 kBq/m^3 with a mean of 25.3 kBq/m^3. The highest concentrations were associated with late-stage, highly evolved Middle - Late Devonian leucomonzogranite on the eastern margin of the South Mountain Batholith.

Site variance was typically high among the five probes generally contained within a 10 m x 10 m sample site. Radon soil gas variability is related primarily to the lithology of the bedrock and the texture and provenance of the overlying surficial materials, and to a lesser extent on the local geomorphologic terrain conditions. Site variance was especially high in the clay-rich Lawrencetown Till.

A limited orientation survey was completed prior to the commencement of the 2008 sampling program. Testing of the RM-2 portable soil radon monitoring system over various mineralized and unmineralized bedrock and surficial units indicate the system is very accurate and precise. Radon concentrations in soil gas remained fairly constant at depths of 60 cm and deeper; therefore, the optimum sampling depth was determined to be 60 cm.

Radon concentrations up to 1500 kBq/m^3 were found associated with known, granite-hosted, vein-type uranium occurrences. The radon content of the mineralized soil is diluted by ambient air and dissipated very quickly, to the point that it is effectively nondetectable with the RM-2 system at heights 10 cm or higher above the mineralized overburden-air interface.

Results from this component of the NASGLP will be useful in establishing natural background concentrations for radon and assist in the development of a radon potential map for the province. These data, combined with the radon potential map, will assist in policy decisions regarding human health as well as issues pertaining to land-use planning, particularly when it relates to issues of indoor radon. In February 2008, Health Canada lowered its guideline for exposure to radon in indoor air from 800 Bq/m^3 to 200 Bq/m^3.

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from Sierra Club

Nova Scotia's Nuclear Moratoriums are a Green Advantage

Lifting Nova Scotia's ban on uranium mining and nuclear power were cited as one way Nova Scotia could help solve climate change, according to a recent article ("Uranium ban "a lost opportunity" October 12, 2007). The comments by the Natural Resource Minister and a financial analyst show just how serious the implications of global warming are, but going down the nuclear path is counter-productive, dangerous, and expensive.

In the early 1980's an inquiry conducted by Judge Robert McCleave led to a moratorium on uranium mining in Nova Scotia. The McCleave inquiry received hundreds of briefs from the province's medical society, local communities, teachers, farmers, woodlot owners, and business-people involved in tourism opposing uranium mining because of its serious environmental and health hazards.

In addition, Nova Scotia Power was forbidden from building a nuclear power plant in 1992. These were good decisions, which now ensure that Nova Scotia takes the right path towards a low-carbon future. At this point it would be counter-productive for the province to lift these moratoriums, both because of the dangers of uranium mining and because there are so many real solutions to climate change that desperately need to be implemented.

If we consider the cradle-to-grave process, mining is truly nuclear power's dirty secret. The mining process creates stockpiles of radioactive and toxic waste. Radioactive and toxic pollutants contaminate surface and groundwaters as well as livestock and wildlife. In a province where local communities utilize local water sources, livestock and wild game throughout the province, uranium mining is simply not safe.

The claim that nuclear does not contribute to global warming is false because greenhouse gases are released during the mining process as well as during plant construction and maintenance, refining, fuel transportation, and nuclear waste disposal.

Nuclear power is also expensive. In Ontario, cost overruns are responsible for $15 billion in debt that is now being charged to electricity customers. Nuclear only becomes financially viable when government's assume the major risk and liabilities associated with cost overruns, accidents and nuclear water management. Why would a provincial government currently in debt even be considering the extremely expensive and risky nuclear option?

Moreover, lifting the moratorium on uranium mining and nuclear power will divert us from real, clean and affordable solutions to climate change. Using nuclear energy to reduce a tonne of greenhouse gases is seven times more expensive than combined cycle natural gas, according to data from CIBC World Markets and the Ontario Power Authority.

Nuclear will not deliver the economic development that the government has stated they intend to support in the *Environmental Goals and Sustainable Prosperity Act* and the most recent economic development strategy. Allowing companies to dig up Nova Scotia and release long-term radioactive pollutants into our environment to make a few short-term bucks is nothing to do with sustainable economic prosperity.

In reality nuclear acts as a barrier to truly clean technologies. The huge expense of nuclear power sucks up money from better options, nuclear plants require large coal-based back-up power, and they create an inefficient and inflexible transmission system that hinders the development of renewables. It is not a coincidence that the European countries that have rejected nuclear have also become leaders in cutting-edge green technologies. Nova Scotia's existing rejection of nuclear power and mining keeps us from going down the wrong track.

There is not a shortage of solutions to fight climate change, there has only been a dearth of implementation thus far in Nova Scotia. Renewable energy producers are still waiting for the ability to sell to consumers, we have yet to tap the huge potential for energy savings, there are no standard rules or incentives for energy recycling, we have the third lowest per capita investment in transit infrastructure, we are ignoring the successful feed-in tariff policies that have propelled other jurisdictions towards renewable energy leadership, we cannot connect to the hydro resources in Quebec and we have yet to tap the potential for clean energy research, development, and innovation in our university sector.

The nuclear option is a dangerous, destructive, and expensive proposition that takes us well away from a vision of sustainable prosperity.

from Sierra Club

Appendix: Background materials on uranium mining in Nova Scotia

Some documents and presentations are referred to repeatedly in public discussions on the uranium issue. Until recently, the full text of some of these has been difficult to obtain. The Department of Natural Resources is to be congratulated on their decision to make the 1985 McCleave Report as well as the 1994 Report of the Inter-departmental Uranium Committee available on their web-site. It is useful to put both these documents as well as a more recent presentation by the Mining Association in context to show their relevance to the current situation in Nova Scotia.

1) The McCleave Report (1985)

During the late 1970s and early 1980s many residents of rural areas of mainland Nova Scotia discovered that invasive mineral exploration was being carried out on their properties. Farmers and woodlot owners found survey tapes, felled trees, and trenches dug on their land. Over time, it emerged that all of these activities were being carried out by over a dozen mining companies, some of them large multinationals such as Aquitaine, Shell and Saarberg, all of them exploring for uranium.

The extent of these incursions into agricultural and forest land, combined with self-education of many Nova Scotians about the environmental and health consequences of uranium exploration and mining, led to the matter becoming a major political issue by 1981. The response of the provincial government of the time was to establish a public inquiry with a provincial court judge, Robert J. McCleave, as sole commissioner. Judge McCleave invited briefs and submissions from the general public, the mining industry and its government advocates and from federal nuclear and regulatory agencies. The level of public concern and the sophistication of public knowledge was well-demonstrated by the number and range of briefs and presentations put before the commission. Of over 200 briefs, many of them giving detailed scientific background and references, there was only one, other than those presented by the industry and its government representatives, favouring uranium exploration and mining. As the hearings continued it became increasingly clear that the general public was not only rather well-informed, but also energetically opposed to Nova Scotia's becoming involved in uranium mining. Detailed and fully researched briefs opposing uranium exploration and mining were submitted by the Nova Scotia Medical Society, the Nova Scotia Federation of Labour, the Nova Scotia Federation of Agriculture as well as a host of community, wildlife and environmental groups. These briefs and submissions were heard and recorded in Stage One of the Inquiry which was scheduled to proceed to Stage Two which was to have consisted of expert technical testimony. Stage Two of the Inquiry never took place since the government of the day rendered it redundant by placing a moratorium on uranium exploration. In January 1985, Judge McCleave completed and released his report based on the submissions heard.

For those who attended many of the commission's hearings and who have read the subsequent report in its entirety, it is perplexing to find its contents cited by a DNR spokesperson as having deemed uranium exploration and mining "safe." [Chronicle

Herald, July 2008][1] Despite his many estimable qualities, the late Judge Robert McCleave was neither tasked nor trained to make a scientific or technical evaluation of the material placed before him. The report itself, while it contains a good deal of useful and relevant information, has no particular analytical method or any set of criteria by which "safety" could possibly be measured. Public statements by DNR officials have suggested that the McCleave Inquiry concluded that uranium mining could be conducted "safely" in Nova Scotia. In fact, the Commissioner's statements about "safety" are quite ambiguous and even at odds with the evidence to which he seems to refer. For example, under "General Conclusions" the following appears:

> "The inquiry accepts the argument that it would be improper to permit exploration but withhold the right to mine what has been found, at least until a re-determination is made during 1990. It is however satisfied that exploration can be carried out safely **within provisions suggested by the Medical Society of Nova Scotia,** [emphasis added] and it may be in the public interest to have better knowledge of the extent of the uranium resources which could be mined. In short the matter of exploration should be reviewed even if the ban on mining is to continue for another period of time, but that the 1990 consideration should report the technical and technological changes that would make it more likely that uranium mining could be carried out with its long-term tailings disposal properly secured. Apart from the tailings issue, the Inquiry clearly finds that the mining of uranium can be carried out if proper precautions are taken for the health of the miners and that the techniques also exist at the milling stage."

The brief by the Medical Society of Nova Scotia to which he refers recommended a comprehensive system of monitoring and inspection of all explorations (which has never been instituted) and, most importantly, concluded: **"We maintain the belief that uranium mining would be an unacceptable health risk for Nova Scotia."** This was a position unanimously adopted by the Medical Society of Nova Scotia at its annual meeting preceding the submission of its brief to the Inquiry.

While many of the briefs themselves, such as those submitted by the Medical Society and Environment Canada, contain useful background information which is still relevant, the manner in which much of this information is digested in the final report is considerably less useful than their original form.

2) Interdepartmental Uranium Committee Report June 1994 (DNR Open File Report ME 1994-6

Seemingly intended to fill the many gaps in technical analysis in the McCleave report as well as to make a case for lifting the moratorium on uranium exploration, this document displays many of the troubling consequences of DNR's role as both the promoter and regulator of mining activities. Recently, it has often been cited as providing information

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on the technical advances which have supposedly taken place in uranium mining methods since 1985. Section 4 ("Recent Advances in Uranium Mining Technology") is of particular interest in this regard. It acknowledges that unique problems are posed in attempting to contain uranium mine wastes, though it makes no reference to the numerous notable containment failures that have occurred. However, section 4.2.3. recommends the pervious surround method of tailings containment now being attempted at the Rabbit Lake Mine in Northern Saskatchewan. The willingness with which this method is embraced as a panacea for tailings containment is worrying on a number of counts:

a) Here, as elsewhere in the report, there is no acknowledgement that the high grade ores in Northern Saskatchewan are an economic justification for expenditures unlikely to be regarded as feasible in areas like Nova Scotia with low-grade ores and consequent slimmer financial margins.
b) The pervious surround system is inevitably very expensive because it requires continuous pumping and decontamination for a minimum of 15 years after the mine has closed down. No identification in this report of the probable bearer of this financial burden after mine closure, although presumably the cost would fall to the province.
c) Similarly, no acknowledgement here or elsewhere in the report that thinly populated areas like Northern Saskatchewan face an entirely different risk scenario than that posed in a small province like Nova Scotia where numerous towns as well as the province's largest city are all geographically close to any potential uranium mine.
d) Pervious surround is described in the report as if it is already the industry standard. This is far from the case, since it has so far only been used at Rabbit Lake for a few years. Since "safe" containment of uranium tailings essentially requires that they are sequestered in perpetuity, the system can only be regarded as an experiment.
e) It is worth noting that since this method was so uncritically lauded in this report, there have already been some serious problems resulting from higher-than-expected groundwater flows. Environment Canada noted in its brief to the McCleave Inquiry that, "In Nova Scotia, the wet climate, generally high water table, and generally acidic waters may pose special problems to radioactive waste management." [Environment Canada, 1982]

The report goes on to praise "Other technological advances in Mining" (4.2.4), notably the jet-boring method of extracting ore from the high-grade ore body at Cigar Lake in Northern Saskatchewan. In an otherwise standard description of this technique, a crucial fact is omitted. The indispensable first step of this technology is for the ore body to be frozen solid in order to attain "geotechnical stability." While this can be assumed as a matter of course in a Northern Saskatchewan winter where temperatures commonly remain as much as -60 degrees for considerable periods, it has no possible chance of occurring in Nova Scotia's latitude. That this essential piece of information is missing from the account presents the worrying question that here, and perhaps elsewhere in the document, the impulse to present uranium mining in the most favourable possible light has overwhelmed a scrupulous regard for accuracy.

3) Hansard transcript of Mr. Gordon Dickie's April 15 presentation to the Legislature's Select Committee on Resources regarding the province's uranium moratorium.

In general, lobbying of government by the mining industry is conducted in private, so the public is without access to the assertions that have been made. However, some indication of the content of the industry's argument for abolishing the existing moratorium can be inferred by the presentation to the Select Committee on April 15, 2008, on behalf of the Mining Association of Nova Scotia.

We are concerned that Mr. Dickie's information was inaccurate or misleading in several areas. While there is no indication that he intentionally mis-informed the Committee, he himself admitted that the information he was presenting was 26 years old, and it was evident that he had not recently re-familiarized himself with the subject.

Briefly, these are the areas on which the information needs correction:

a) Uranium mining in France:

Mr. Dickie rightly notes that the geology of France (as well as the UK and Spain) resembles Nova Scotia's. He refers, however, to French uranium mines as follows:

" . . .they are blessed with significant quantities of uranium mineralization. Toward two underground mines in Limoges, in order to get there we drove through the countryside - farms not unlike the Annapolis Valley - and came upon the first of two sites that day. The mine was just off of the highway and in all directions was farmland and working farms.

I guess that's an indirect way of indicating to you what the French do and how they've managed their industry. It's not northern Saskatchewan, it's sort of in the middle of farmland around what's called the Massif Central in France. Each particular mine and each particular ore body has its own set of criteria that need to be dealt with, and that's done through the environmental assessment process."

However, the fact is that France no longer mines uranium. The last mine closed in the summer of 2001. Rather than mine its own reserves, France now imports uranium from Australia and Canada as well as from mines in its former colonies in Africa. There have also been significant environmental problems with the French mines since their closure. There are numerous examples of leakage from tailings and waste rock piles reaching local rivers and lakes and even of criminal charges being brought against the national uranium mining company COGEMA. Even mines that have long been decommissioned and supposedly "reclaimed" have been identified as polluters. For example, seriously elevated radiation levels have been found around the former open pit uranium mine and mill at St Pierre du Cantal. Concentrations of radium-226 in soil on public grounds were found at up to 76,000 Bq/kg (that is up to 700 times the natural level in the area).

This information is easy to find from numerous reliable sources including the World Information Service on Energy and from French government documents.

The example of uranium mining in France should serve, not as a model for Nova Scotia, as Mr Dickie suggests, but as a warning.

b) On the radon hazard:

Mr. Dickie testified to the Committee as follows:

" There's a good thing about radon, though, and this is another concept of half-life, which means how much time is required for half of the radon to disappear, to transmute into the next daughter - it's three days. So that's why ventilation works so well with radon that as you extract it, it transmutes into something else and so you eliminate the issue of breathing radon in and having damage caused by alpha particles.

MR. CHAIRMAN: What does it transmute into?

MR. DICKIE: The next series down - I don't have that right in front of me but we'll provide that sort of decay chain of uranium for you. There are, I don't know, 15 or 20 different ones . . .

Anyone unfamiliar with the topic might assume from this that the radon is made to vanish by means of ventilation. The radon does not vanish with ventilation because it is being continuously produced by its predecessors (Radium 226, Thorium 230, Uranium 234, Proactinium 234, Thorium 234) in the Uranium 238 decay chain. So a continuous stream of radon is downwind from the ventilation system. Furthermore, radon's own decay products as the chain continues are extremely hazardous, including the deadly Polonium 210 which was used in the 2006 murder of Russian dissident Alexander Litvenenko. While these alpha emitters can't penetrate skin, they are dangerous when ingested via eating or breathing. Mr. Dickie's vagueness about the so-called "daughter products" of radon is particularly worrying since it's precisely those "daughter products" which have been responsible for the high rates of lung cancer for uranium miners.

Mr. Dickie also seems to imply that radon's short half-life makes it less dangerous. In fact, the reverse is true, because of the intense energy emitted by short-lived isotopes.

c) On uranium exploration:

Mr. Dickie presents the frequently-heard fall-back position of mining companies eager to overturn the uranium moratorium—i.e. that, given the environmental hazards posed by naturally occurring uranium, that mining companies are doing the public a favour by locating it. In his words,

"the problem with the moratorium is we don't collect the information. If we don't collect the information then we don't know anything about the risk, do we? "

To give him credit, he does not, as do some mining company representatives, falsely claim that mining is "taking the uranium away."

There are many ways in which the potential uranium risks can be determined without the ground disturbance which, in itself, increases the level of hazard. The most obvious is water sampling, an inexpensive tool already widely in use for commercial uranium exploration. Geobotanical surveys are now also used more frequently as a way of locating mineral deposits without land disturbance. [McLemore and Turner, 2006] However, when the sole motive is to locate an economically viable mineral deposit, exploration has very limited usefulness in assisting communities to evaluate potential health risks. It is much more helpful when water sampling and geobotanical surveys are conducted in conjunction with epidemiological evaluation of the population which may be at risk. One model for this is the extensive study undertaken in south central Virginia. [Wyatt, Reitz, Croley *et al*, 2008]

Exploration for uranium with the government's blessing provides a clear political signal that mining will be allowed to proceed if deemed commercially viable. While it's frequently implied that this would be many years in the future, the reality is that when Kidd Creek Mines were required to cease activity at their Millet Brook site near Windsor in the 1980s, they had already delineated what they considered to be a commercially viable ore body. They were poised to embark on the next stage of "exploration" which is bulk sampling. When asked by the Committee's Chair to clarify what he meant by "additional work" at that stage of exploration, Mr. Dickie, quite rightly responded,

"Beyond the drilling stage, the next stage of exploration typically is a bulk sample - you would extract perhaps between one ton and 20,000 tons for mill test work, is typically what you would do."

In effect, bulk sampling is comparable to mining on a small scale but without any of the environmental restraints which would apply to an actual mine. Most worryingly, if the uranium moratorium were to be overturned as the Mining Association is requesting and as Natural Resources Minister, David Morse appears to favour, bulk sampling could be underway very quickly. In other words, Nova Scotia would be rapidly on its way to becoming a uranium mining province with a government seemingly unaware of the consequences, a population which has been encouraged to think that the issue has gone away, and with mining regulations woefully incapable of either monitoring or controlling a type of mining which poses quite unique hazards.