The North American Soil Geochemical Landscapes Project: Report on the 2008 Sampling Program and Preliminary 2007 Results[1]

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Introduction

The North American Soil Geochemical Landscapes Project (NASGLP) is a comprehensive, continental framework of inorganic, organic and microbiological soil geochemical data. The trinational initiative involves the federal, provincial and state geological surveys of Canada, the United States and Mexico and will produce the first-ever continental-scale map of the soil geochemistry of North America.

All sampling and analytical protocols including: (1) identification of the various soil horizons to be sampled, (2) the type, number and size of samples to be collected, (3) the type and proper use of accepted sampling equipment, (4) laboratory preparation, and (5) analytical procedures, were designed by the Geological Survey of Canada (GSC) in conjunction with numerous partners, including the National Forestry Service, Agriculture and Agri-food Canada, Environment Canada and Health Canada.

During the 2007 field season, 57 sites (including 3 field duplicates) were sampled across Nova Scotia. Preliminary results for several of the soil horizons were received in the fall of 2007 and spring of 2008, and are presented here for the first time.

2008 Sampling Program

An additional 15 sites were sampled during the 2008 field season, following nearly identical sampling protocols used in 2007, bringing the overall average sampling density to approximately 1 sample per 800 km^2 (Fig. 1). This is double the nominal sampling density for the NASGLP, but the highly variable bedrock and surficial geology of Nova Scotia required a tighter sampling density in order to make meaningful interpretations of the geochemical results (Fig. 2). All sampling took place on mainland Nova Scotia because Cape Breton Island had been sampled already at double the nominal sampling density during the 2007 field season. Analytical results are pending for the samples taken in 2008.

The sampling methodology used in 2007 and described by Goodwin (2008) and Goodwin *et al.* (2009) was used during the 2008 field season, with the following minor exceptions: (1) soil permeability readings were not collected during the regional 2008 sampling program, and (2) in 2008 Environment Canada did not collect additional sample material at each site.

2007 Results

All geochemical results are received and assessed by the GSC to determine data quality. Sample preparation and analytical methodologies were previously described by Goodwin (2008).

A summary of the 4-acid geochemical results for As, U and W, from the <63 µm fraction of the C-horizon, are presented in Table 1 and a description of each of these elements is presented below. Table 1 represents analytical results for 52 of the 57 sample sites. C-horizon soil was not available at two of the sites visited, and three field duplicate samples were removed to yield a total of 52 samples used for the basic statistical calculations.

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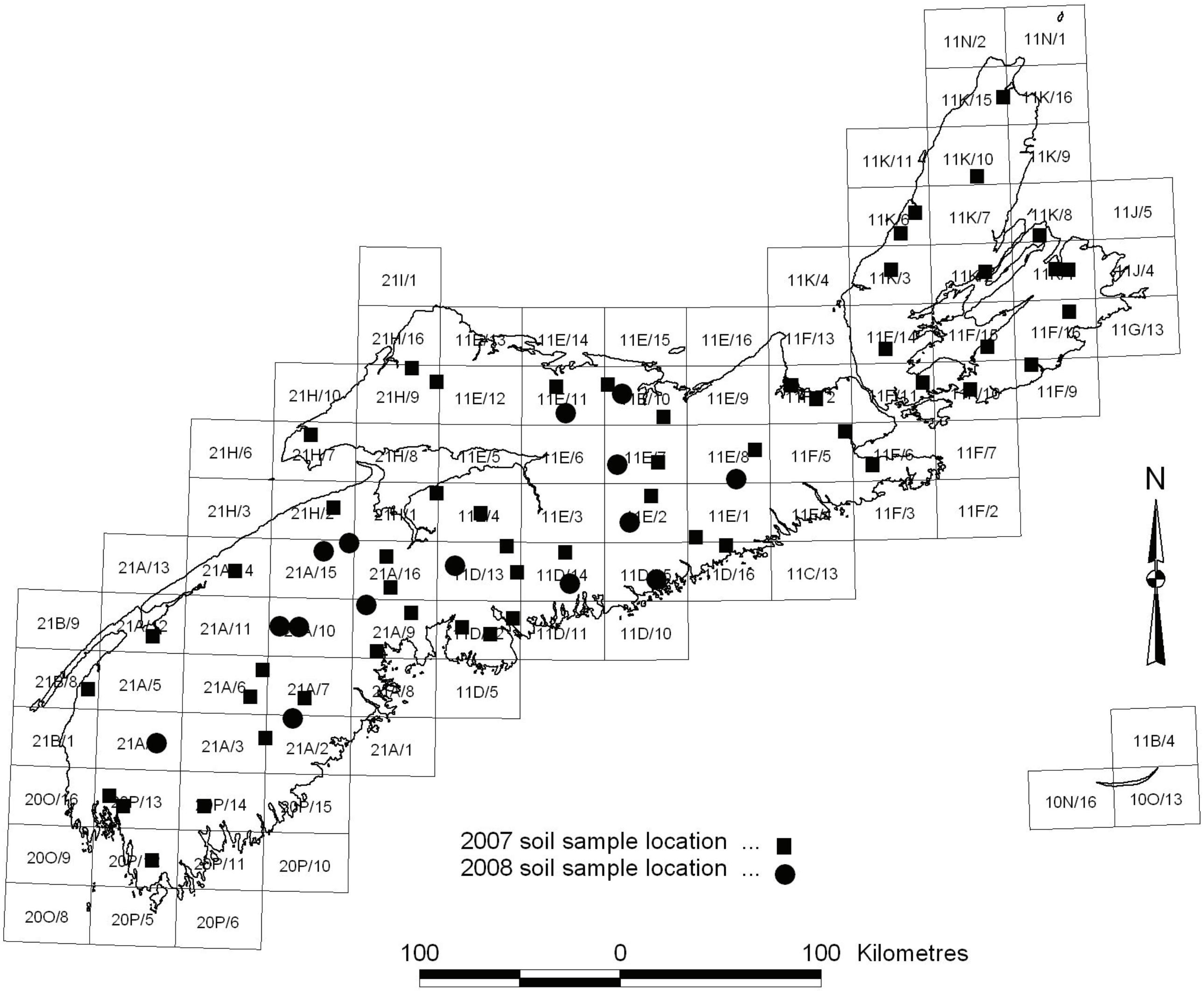

Figure 1. Locations for the 2007 and 2008 soil sample sites on an NTS reference map of Nova Scotia.

Arsenic

Arsenic concentrations in C-horizon soil samples ranged from a low of 2.2 ppm to a high of 345.7 ppm, with a mean concentration of 22.3 ppm, a median of 12.3 ppm and a mode of 10.0 ppm (Table 1). If these data are compared against the Canadian Soil Quality Guidelines of 12 ppm arsenic (for residential, parkland, agriculture, commercial and industrial lands), then 29 of the 52 sites (representing 56% of the sites sampled in 2007) naturally exceed the national guideline. The reader is cautioned that the Canadian Soil Quality Guidelines are for the <2 mm fraction while the data presented in Table 1 are for the <63 µm fraction.

The highest soil concentrations of arsenic are found in southern mainland Nova Scotia and reflect known arsenopyrite mineralization associated with many of the rock units found in the Meguma Terrane (Figs. 2 and 3). In fact, nine of the ten highest arsenic concentrations are from samples located in the Meguma Terrane, including the highest level of 345.7 ppm (Fig. 3). Previous till sampling in the area of the highest arsenic level identified numerous additional anomalies for various elements (Stea and O'Reilly, 1982).

The underlying bedrock of this particular sample site consists of metasandstone with minor metasiltstone of the New Harbour Formation, Goldenville Group (White and King, 2002). Outcrop is rare in the area because of extensive till

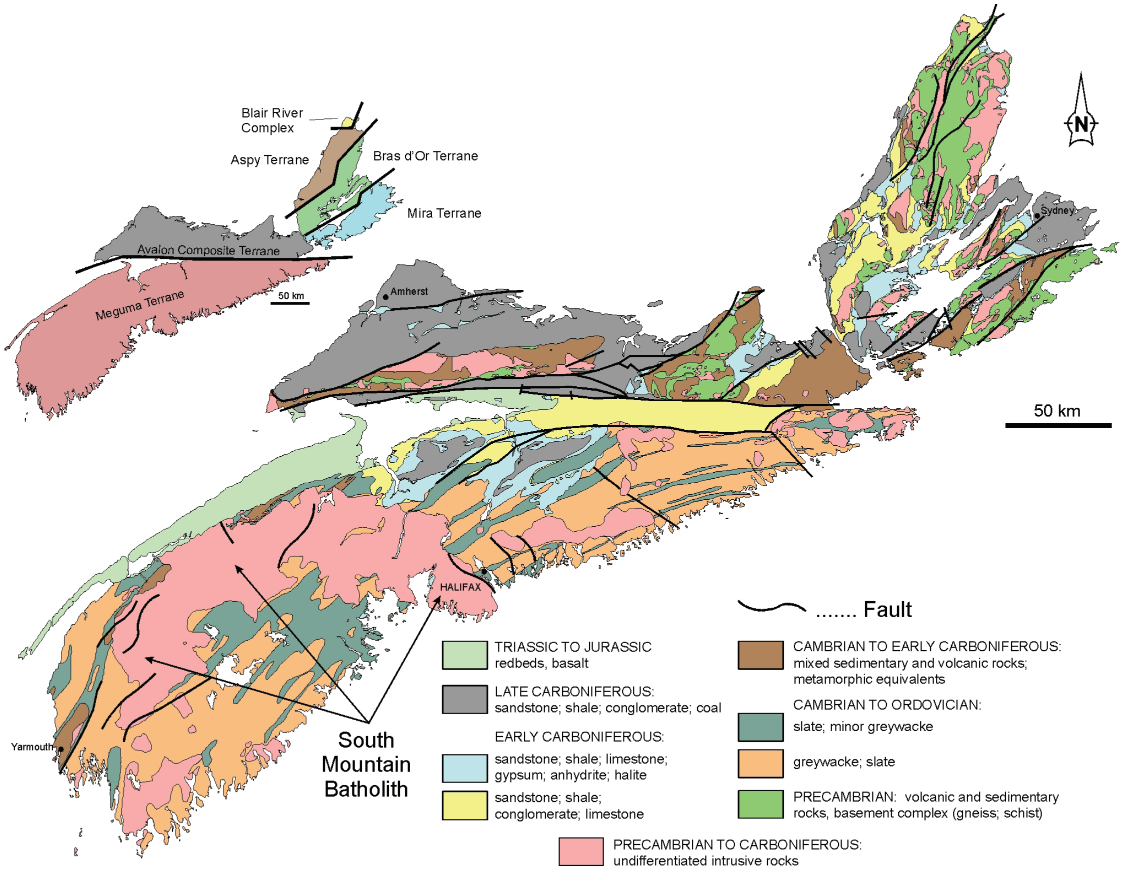

Figure 2. Simplified geological map of Nova Scotia. Inset shows the locations of terranes. The Cobequid-Chedabucto Fault Zone separates the Meguma Terrane to the south from the Avalon Composite Terrane to the north.

Table 1. Summary statistics (<63 μm fraction) for arsenic, uranium and tungsten from 52 C-horizon sample sites (2007) across Nova Scotia.

	Arsenic (ppm)	Uranium (ppm)	Tungsten (ppm)
Mean	22.3	3.3	1.6
Median	12.3	3.0	1.4
Mode	10.0	3.0	1.4
Standard Deviation	47.4	1.7	0.7
Minimum	2.2	1.3	0.7
Maximum	345.7	12.5	5.3
Number of Samples	52	52	52

cover. Regional bedrock mapping, however, indicates that the rocks show abundant evidence (e.g. cordierite spots) of proximal plutonic activity.

The C-horizon soil (glacial till) at this sample site is interpreted to be locally derived because (1) the majority (84%) of the >1 cm clasts recovered from the sample site reflects the inferred underlying bedrock and (2) the till matrix reflects the composition of the local bedrock. Further, clasts were typically very angular to subangular, indicating minimal transport by glacial ice and, therefore, proximity to the bedrock source. The till is further interpreted to represent a basal lodgment till because of its very high compaction.

The sample was further characterized by the presence of 14% quartz clasts. Abundant quartz

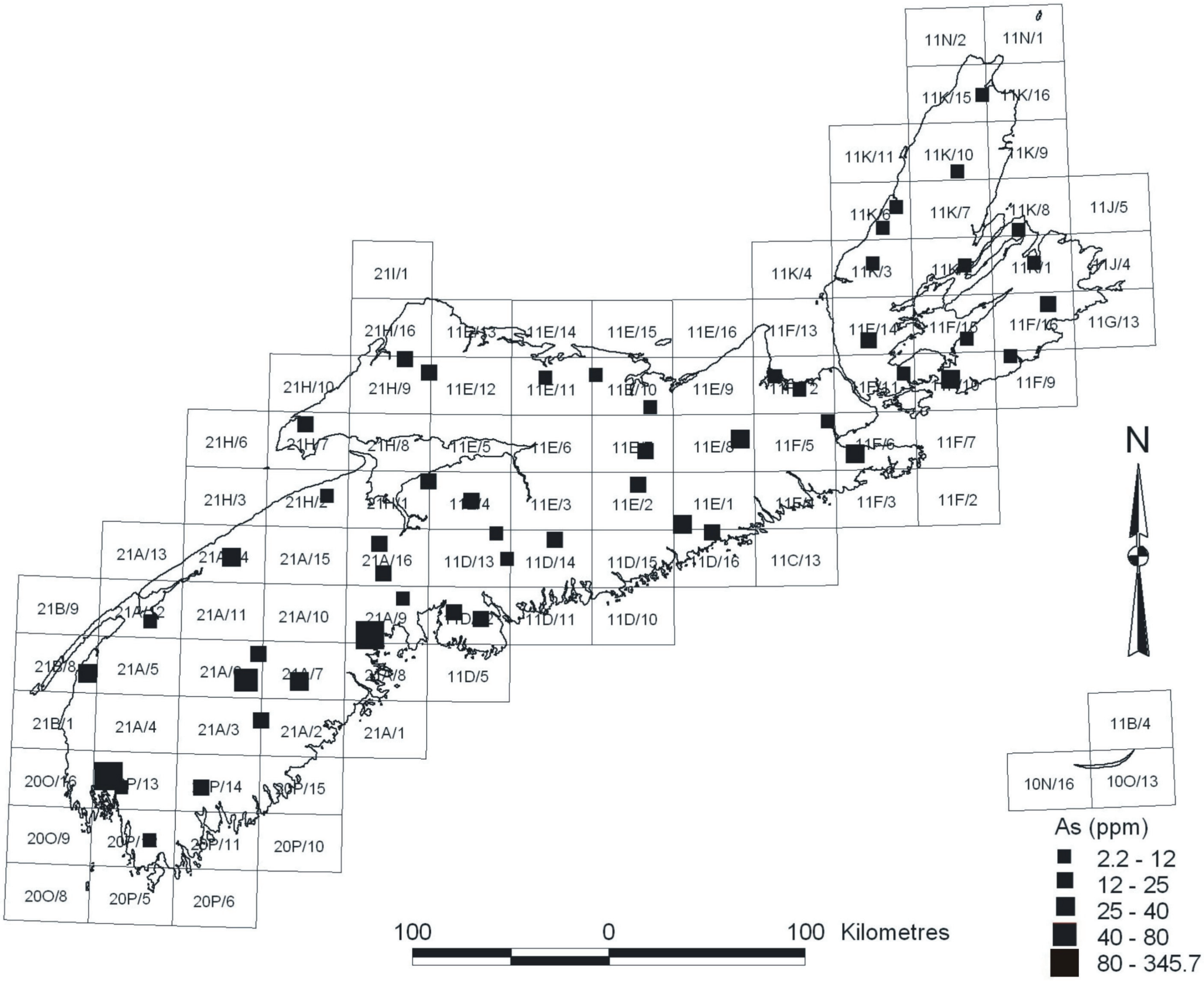

Figure 3. Arsenic concentrations (ppm) in C-horizon till samples, Nova Scotia.

veins were also noted in a number of outcrops located within several kilometres of the 2007 sample site (C. White, personal communication) and further reflect the local nature of the till.

Uranium

Uranium concentrations vary from a low of 1.3 ppm to a high of 12.5 ppm (Table 1). The mean uranium concentration is 3.3 ppm and is very similar to the median and mode concentration levels of 3.0 ppm.

Three of the four highest uranium concentrations in C-horizon soil samples are located on the eastern margin of the South Mountain Batholith (Fig. 2). The highest concentration of 12.5 ppm U occurs in highly evolved Middle-Upper Devonian leucomonzogranite, as does another anomalous site (5.9 ppm) also located in leucomonzogranite approximately 40 km to the northwest of the 12.5 ppm sample (Fig. 4). A third anomalous site (5.6 ppm U), located approximately 10 km from known uranium occurrences associated with the Millet Brook uranium deposit, was found in the less evolved Middle-Upper Devonian biotite granodiorite. A summary of the bedrock geology can be found in MacDonald and Horne (1987).

The second highest uranium concentration (7.8 ppm) in C-horizon soil was associated with a

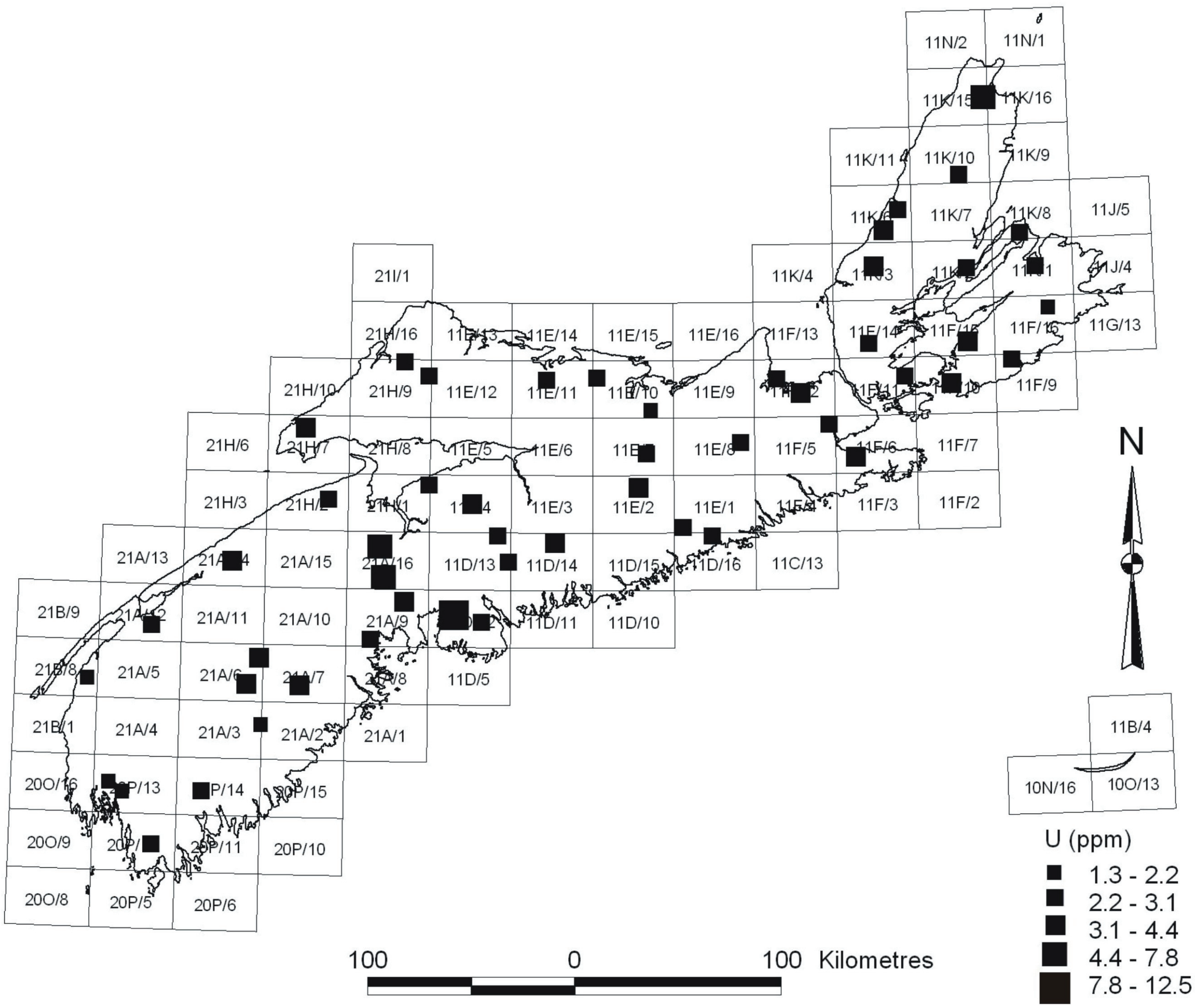

Figure 4. Uranium concentrations (ppm) in C-horizon till samples, Nova Scotia.

sample collected in northern Cape Breton Island. At this site, the underlying bedrock is exposed in a nearby brook and consists of coarse-grained Lower Devonian-Lower Carboniferous Horton Group sandstone and conglomerate with abundant granite clasts. The surficial geology of the area consists of glaciofluvial sand and gravel. The presence of granitic clasts both in the underlying Horton conglomerate and in the glaciofluvial material may account for the elevated uranium concentration associated with this sample site.

Tungsten

Tungsten concentrations in soil are low, ranging from a minimum concentration of 0.7 ppm to a maximum of 5.3 ppm (Table 1). The limited range in data results in a low standard deviation of 0.7 ppm as well as a tight grouping for the mean, median and mode levels.

Similar to uranium, tungsten is an incompatible element that is in typically enriched in highly evolved, late-stage granite. It would be expected, therefore, that the geochemical pattern for uranium and tungsten should be similar. Figure 5 shows that the tungsten pattern is similar to the uranium pattern, both elements closely reflecting bedrock chemistry. This is particularly evident with the spatial correlation of the highest uranium and tungsten concentrations on the eastern margin of

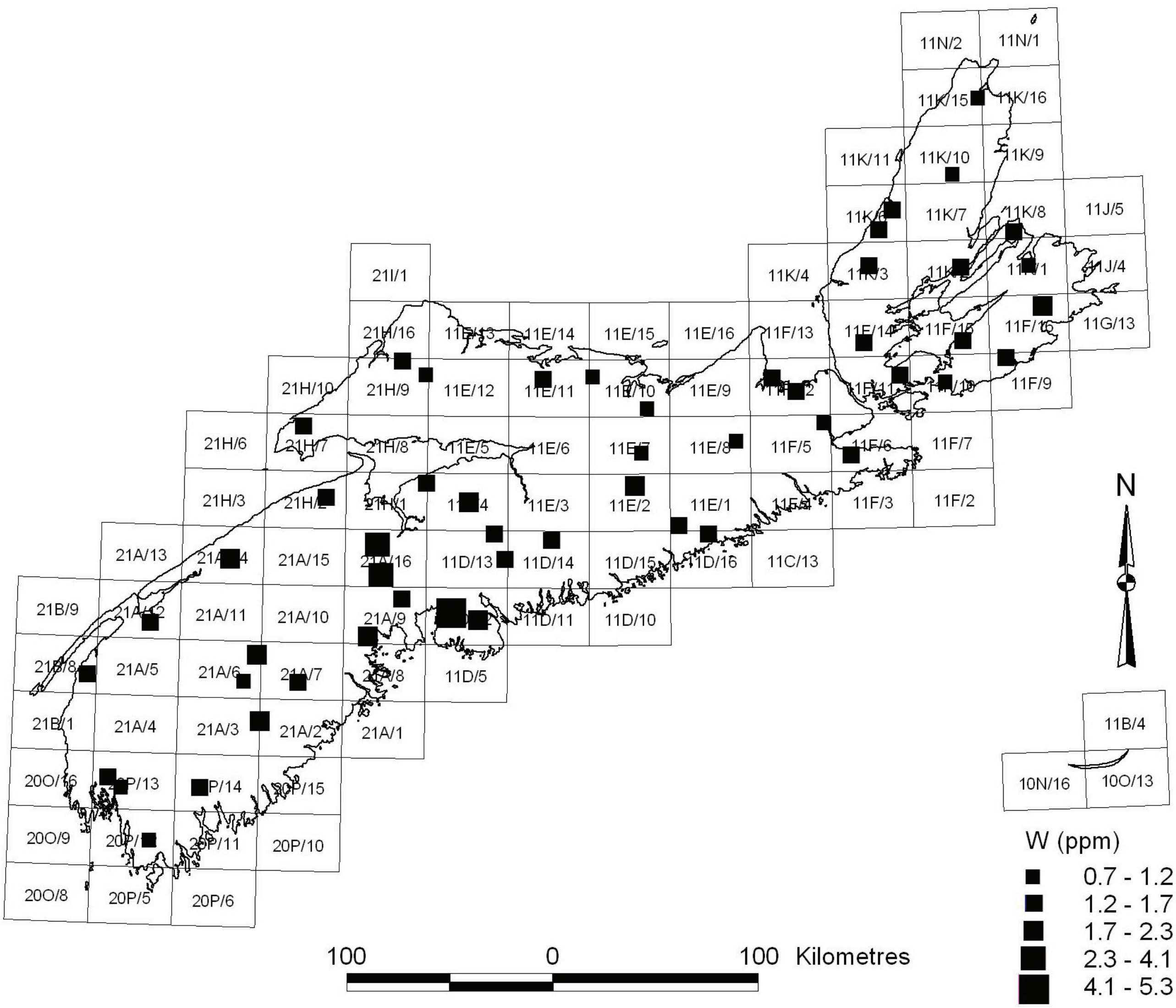

Figure 5. Tungsten concentrations (ppm) in C-horizon till samples, Nova Scotia.

the South Mountain Batholith (Fig. 2). Tungsten, however, is also associated with calc-silicate nodules in the Meguma Terrane (Mitchell, 2004).

Discussion

One of the objectives of the NASGLP is to demonstrate to regulators and decision makers that natural geochemical variability exists and is related to natural factors, such as surficial and bedrock geology, and local mineralization.

Elevated arsenic levels in the Meguma Terrane of southern mainland Nova Scotia are the result of the common arsenic-bearing, sulphide mineral arsenopyrite. Although the highest arsenic concentration in soil in southern Nova Scotia seems extraordinarily high, this result probably pales in comparison to natural arsenic concentrations in gold districts where arsenopyrite commonly occurs in concentrations of up to several per cent in rock.

Uranium occurs naturally in granitic rocks (as well as other rocks), and the granites of Nova Scotia are no exception. Upon closer inspection of the 2007 results, the highest uranium concentrations in soil are associated with late-stage leucomonzogranite, in particular units near the Halifax Peninsula. Leucomonzogranite is typically characterized by its elevated concentrations of incompatible elements such as uranium, as well as tin, tungsten, lithium, beryllium and tantalum. Soils derived from the less evolved granodiorite are typically characterized by lower concentrations of incompatible elements.

Tungsten concentrations are low throughout the province, but closely resemble patterns of other incompatible elements such as uranium.

The 2007 C-horizon soil results for arsenic, uranium and tungsten clearly demonstrate that natural geochemical variability does exist in Nova Scotia, and is related to natural factors such as bedrock geology.

Conclusions

During the 2008 field season, 15 sites were sampled as part of the NASGLP. Samples have been submitted for analysis and results are pending.

Preliminary results were received for 52 sites that were sampled across the province during the 2007 field season. The geochemical results for arsenic, uranium and tungsten in the <63 µm fraction of C-horizon soil 4-clearly demonstrate that natural variability is related to natural factors, including bedrock geology in Nova Scotia.

Interpretation of the preliminary results indicates that Nova Scotia is naturally enriched in arsenic. The majority of the soil samples collected from the Meguma Terrane exceed Canadian Council of Ministers of the Environment Guidelines for arsenic and reflect the common presence of arsenopyrite in this geological environment. Elevated arsenic also occurs throughout the remainder of Nova Scotia, but to a lesser degree. Uranium concentrations in soil discriminate late stage, uranium-enriched leucomonzogranite from less evolved granodiorite. Similar results are also noted for tungsten. Analytical results for the 2008 sampling program are pending.

Results from the 2007 sampling program clearly demonstrate that natural variance exists for elements in various rock types and will be useful in establishing guidelines for policy decisions regarding land-use planning for human and ecological health.

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