Soil and Till Geochemistry of the Halifax Regional Municipality, Nova Scotia

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Introduction

Historically, there has been a general lack of geochemical sample sites within or near the populated areas of the province. As the demand for new homes with rural settings increases, existing subdivisions are expanded and new subdivisions are built to meet this demand. Recent construction of new roads and basement excavations in the Halifax Regional Municipality (HRM) has created a unique opportunity to sample relatively undisturbed soil/till profiles, in the area (NTS 11D/11, 12, 13 and 14).

The objectives of the soil and till geochemical sampling program are to: (1) establish a historical geochemical baseline reference for the HRM area, (2) compliment a paper by Lewis *et al.* (1998) that describes the engineering and geotechnical characteristics of the surficial sediments of HRM, but didn't report on corresponding geochemical data, (3) compliment pre-existing regional geochemical data sets available at the Nova Scotia Department of Natural Resources (NSDNR), (4) demonstrate the existence of natural geochemical variability that characterizes different surficial units, and (5) demonstrate that by simply changing media type, sample collection depth, size fraction analyzed, or the acid digestion used, there will be associated variability with the reported analytical results. Newly exposed "fresh" outcrops often displayed ice flow indicators (e.g. striations) that were also mapped during the geochemical sampling program.

Geology and Geochemistry

Bedrock Geology

The Cambrian-Ordovician Meguma Group metasediments are the oldest rocks within the HRM study area. The Meguma Group consists of the metasandstone-dominated Goldenville Formation overlain by the slate-dominated Halifax Formation (Fig. 1).

Structurally, the metasediments are characterized by a series of northeast-trending anticlines and synclines and northwest-trending extensional structures (Lewis *et al.,* 1998). Regional greenschist to amphibolite facies metamorphism characterizes the Meguma Group metasediments; locally, contact auroles associated with granitoid intrusions are common (Lewis *et al.,* 1998).

Gold and arsenic occurrences characterize several former gold districts (e.g. Waverley) that occur within HRM (Environment Canada, 1985). Locally, slates of the Halifax Formation can contain high (up to 10%) but variable concentrations of sulphide, dominated by pyrite and pyrrhotite with lesser amounts of arsenopyrite, cobaltite, glaucodot, chalcopyrite and covellite (Haysom, 1994). Once exposed to the atmosphere, sulphide-rich slates are susceptible to alteration and may form acid surface waters, commonly referred to as acid rock drainage (ARD), which are very harmful to the environment.

The Meguma Group metasediments have been intruded by Devonian granodiorite, monzogranite and leucomonzogranite (MacDonald and Horne, 1987). These intrusive rocks, apart from being mineralogically and genetically distinct from the Meguma Group metasediments, are also distinct in the fact that they are characterized by their massive, non-foliated texture (MacDonald and Horne, 1987; Lewis *et al.,* 1998). Locally, variable quantities of sulphides associated with quart veins are present, as are granite-related pegmatite dykes and quartz greisens (MacDonald and Horne, 1987; Lewis *et al.,* 1998). Alteration includes but is not limited to large zones of cordierite enrichment plus local areas of moderate hematite, limonite,

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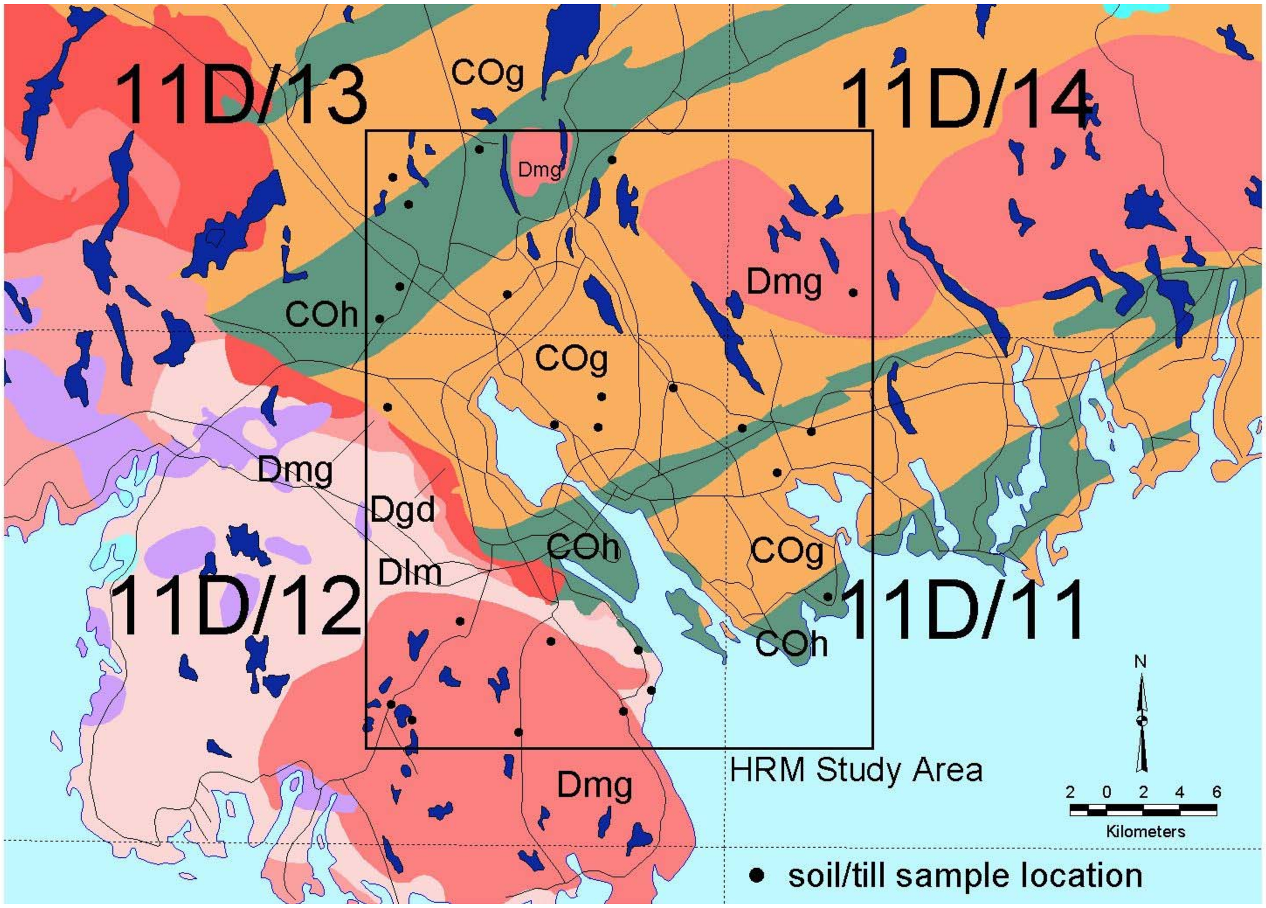

Figure 1. Geological map of the HRM study area. Geology modified from Keppie (2000). COg = Cambro-Ordovician Goldenville Formation, COh = Cambro-Ordovician Halifax Formation, Dmg = Devonian monzogranite, Dlm = Devonian leucomonzogranite and Dgd = Devonian granodiorite.

manganese, kaolinite and chlorite alteration (MacDonald and Horne, 1987).

Lewis *et al.* (1998) provide a detailed description on the geological setting of the HRM, including the lithology and structure of the Meguma Group metasediments and granitoid intrusives. Prime (2001) reported on the bedrock aggregate potential of HRM with respect to continued urban growth, as well as land-use and environmental issues.

Surficial Geology

Recent surficial mapping that included the HRM study area has been completed by Stea and Fowler (1979, 1981) and Finck and Graves (1987). Surficial sediments sampled within the current HRM study area include a local quartzite till derived from the Goldenville Formation metasandstone, slate till derived from the Halifax Formation slate, and granite till derived from intrusive granitoid rocks (Stea and Fowler, 1979, 1981). Distally derived Lawrencetown Till, including ground moraine and drumlins, also covers a large part of the study area (Stea and Fowler, 1979, 1981). Large areas of bedrock-dominated terrain characterized by thin till cover are also common, particularly over the granite terrain. A summary of the Tertiary and Quaternary geology of HRM is presented in Lewis *et al.* (1998).

Mapped ice flow indicators show that ice movements within the study area included flow to the southeastward (youngest), southward and southwestward (oldest, Finck and Graves, 1987).

Previous Geochemical Sampling Programs

Nova Scotia has been extensively covered by numerous regional geochemical surveys, including analysis of vegetation, till, stream sediments, stream waters, lake sediment and lake waters, and several of these surveys have included all or some of the current HRM study area.

Two regional till mapping and sampling programs have been completed over mainland Nova Scotia. One survey covered the Meguma Group metasediments while the other survey concentrated on the granitoid rocks of the South Mountain Batholith (SMB). The aerial distribution of the Meguma sample locations is similar to the distribution of the HRM till survey (Stea and Fowler, 1979, 1981). However, the Meguma survey was completed almost 25 years earlier than the current HRM study and analyzed the <2 µm fraction for approximately half the elements as the HRM survey. The SMB survey, however, overlaps the HRM study area boundary in the southwest corner (Boner *et al.,* 1990; Finck *et al.,* 1990a, 1990b). A regional bedrock mapping and sampling program was conducted during the same time as the regional SMB till program (Ham *et al.*, 1989, 1990).

Additional till geochemical surveys have also been completed by numerous exploration companies in their search for gold, tin, tungsten and other commodities. For example, Seabright Resources completed an extensive helicopter-assisted regional soil and till sampling program over the Meguma Group metasediments during 1986, 1987 and 1988 (Woodman *et al*., 1994). Samples from their survey were collected within the extreme northwest corner of the HRM study area.

One of the most comprehensive regional geochemical studies of the current HRM study area was a 1977-1978 lake sediment bottom survey completed over southern mainland Nova Scotia (Bingley and Richardson, 1978). The main objective of this regional geochemical survey was to promote mineral exploration within the province.

Methodology

Introduction

During the 2001 and 2002 field seasons, a total of 25 sites were sampled at an average sampling density of approximately one sample site per 10 km^2 (Fig. 1). At some sites, additional soil and/or till samples representing field duplicates and profile samples were also collected. Most samples were collected from roadside exposures, and a few samples were collected from building excavations or along footpaths. Prior to the field sampling program, sample sites were carefully chosen to provide: (1) a broad aerial distribution of sample sites over the study area, (2) representative coverage of the major surficial units within the study area, (3) representative coverage of the major rockl units within the study area, and (4) easy access by taking advantage of pre-existing roads. In the field, sample sites were ultimately selected based on the availability of a fresh, undisturbed soil/till profile. Sample sites were immediately rejected if evidence of anthropogenic influences were observed (e.g. dumps, garbage, spillage, fences).

Sampling Methodology

B-horizon soil samples were collected by shovel and/or auger from an average sampling depth of about 30 cm. Approximately 500 g of soil were collected at each site and placed into a Kraft sample bag for geochemical analysis. All attempts were made to remove as much organic material as possible prior to placing the sample in the sample bag.

At each soil sample site, a C-horizon till sample was collected by shovel and/or auger from approximately 1 m depth. Again, approximately 500 g of till were collected at each site and placed into a Kraft sample bag for geochemical analysis, and all attempts were made to remove as much organic material as possible prior to placing the sample in the sample bag. Five of the till sites also had an additional till sample collected from an average sampling depth of 2 m. One site also had a sample (HRM 2001-3010) collected from 3 m depth.

Samples collected during the 2001 field season were prefixed with HRM 2001, while samples collected during the 2002 field season were prefixed with HRM 2002. Soil samples were then assigned a number, for example the soil sample collected during 2001 at site 10 was designated HRM 2001-10. Till samples, on the other hand, were assigned a number based on their depth (1 m depth = 1000 series, 2 m depth = 2000 series and 3 m depth = 3000 series) and site number. For instance, the till sample collected at 1 m depth, site 10, was assigned HRM 2001-1010 while the sample at 2 m depth was assigned HRM 2001-2010 and the sample from 3 m depth was assigned HRM 2001-3010.

At each sample site, detailed field descriptions including observations on till type, colour and texture were recorded. Sample sites were geo-referenced to the Universal Transverse Mercator (UTM) grid (NAD 27) with a GARMIN GPS 12 using the averaging function. Each sample site was photographed for future reference.

Analytical Methodology

Till samples were forwarded in Kraft bags to DalTech Minerals Engineering Centre in Halifax, Nova Scotia, for drying and sieving. All soil and till samples were dried to a maximum drying temperature of 35° C.

Once completely dried, approximately 10 g of the <63 μm fraction were sieved and placed into a set of pre-labeled vials for Hg analysis. An additional 30 g of the <63 μm fraction were sieved and subsequently placed into a set of pre-labeled vials for multi-element geochemical analysis.

The vials containing 10 g of the <63 μm material were forwarded to ACME Analytical Laboratories of Vancouver, British Columbia. A subsample of approximately 1 to 2 g was analyzed for Hg by Cetac Cold Vapour Atomic Absorption (Cetac CV-AA) with a lower detection limit (LDL) of 1 ppb.

The larger 30 g vials were sent to ALS CHEMEX (formerly Bondar Clegg) in Val d'Or, Quebec, for geochemical analysis. An subsample of approximately 1 g was analyzed for multi-element geochemistry by Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP/AES) following an aqua regia digestion.

The third set of 50 g vials was retained by the author for archival purposes.

Quality Assurance/Quality Control (QA/QC)

Rigorous QA/QC protocols and procedures were implemented at all stages of the soil and till sampling program, including program planning, training, sample collection, sample preparation and sample analysis, to ensure the integrity of the data set. These procedures included: (1) collection of field duplicates, (2) insertion of preparation splits, (3) insertion of certified and in-house reference standards, and (4) inter-laboratory testing of random samples.

Results

Analytical results for concentration of elements (Hg-Ag-Cu-Pb-Zn-Mo-Ni-Co-Cd-Bi-As-Sb-Fe-Mn-Te-Ba-Cr-V-Sn-W-La-Al-Mg-Ca-Na-K-Sr-Y-Ga-Li-Nb-Sc-Ta-Ti-Zr-S) are pending.

Discussion

The opportunity to sample fresh soil and till profiles increases with urban and commercial growth as new roads and building foundations are created. Similarly, the opportunity to map fresh glacial ice flow indicators is also increased. However, this unique opportunity is often short lived. For example, fresh profiles are often lost as basement excavations are backfilled in rapidly expanding subdivisions. Similarly, fresh ice flow indicators on recently cleared bedrock are forever lost as shallow bedrock is often blasted for new road access or basement foundations. The stoss/lee feature shown in Figure 2 no longer exists because it was blasted in the summer of 2002 and a new building was erected.

Figure 2. Stoss/lee metasandstone outcrop of the Goldenville Formation. Ice flowed from left to right. This outcrop in the Atlantic Acres Industrial Park was blasted in the summer of 2002. A building now occupies the site.

During the initial planning phase, attempts were made to randomly sample all surficial units equally. However, the slate facies of the Beaver River till was the least sampled unit for several reasons. First, it's aerial distribution is limited when compared to the other facies of the Beaver River till (e.g. greywacke facies) and large areas mapped as slate till have been sterilized from sampling because they occur in the downtown commercial core of Halifax-Dartmouth.

In general, till in the study area is locally derived and is representative of the bedrock it was derived from. However, not all till sampled necessarily was derived from the local bedrock. The Lawrencetown till is characterized by a red clay-rich matrix derived from younger Carboniferous sedimentary rocks to the north and by foreign erratics originating as far away as the Cobequid Highlands (Lewis *et al.,* 1998). In a few sites where the drumlin facies of the Lawrencetown till was sampled, local greywacke cobbles and boulders were impregnated into the top of the drumlin resulting in a hybrid till facies (Lewis *et al.,* 1998).

In order to determine variance associated with the analysis of different size fractions, one sample site (HRM 2001-3a, 1003a and 2003a) also had the <180 µm fraction analyzed while a second sample site (HRM 2002-26a and 1026a) also had the <2000 µm fraction analyzed for Hg and multi-element geochemistry. An additional comparative study was also undertaken to determine variance associated with the use of a "total" multi-acid digestion of sample HRM 2002-26t.

Overall, analytical data are expected to show natural geologic variance related to different surficial and bedrock types, as well as variability associated with different size fractions, different acid digestions, different sample media and different sample depths. Therefore, when comparing analytical data, it is imperative to compare one set of results to previously reported results or established guidelines, that the comparisons are made for similar sample media, collected in a similar manner, and that samples were prepared and analyzed in a similar methodology.

In addition to natural geologic variance, the B-horizon soil has a high probability of being affected by anthropogenic effects, such as airborne pollution, even in areas considered remote. Anthropogenic effects, however, are limited to approximately 40 cm depth, thus potentially affecting only the B-horizon soil samples collected for this survey (Henderson and McMartin, 1995).

Future geochemical studies within HRM should include a lithogeochemical study involving all bedrock types to characterize their geochemical signature. Additionally, an acid rock drainage study on the same survey should be completed in order to rank the potential of various rock types to produce ARD and map their spatial distribution for land-use planning.

Conclusions

Twenty-eight soil samples and 34 till samples were collected from within the Halifax Regional Municipality (HRM) at an average sampling density of approximately one sample site per 10 km^2. Strict QA/CQ protocols were an integral part of the sampling program.

Samples have been forwarded to several laboratories for multi-element geochemical analysis. Analytical results are pending and will serve as an historical geochemical baseline reference.

References

Bingley, J. M. and Richardson, G. G. 1978: Regional lake sediment surveys foe eastern mainland Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 371, Scale 1:100 000.

Boner, F. J., Finck, P. W. and Graves, R. M. 1990: Trace element analysis of till (-230 mesh), South Mountain Batholith, N.T.S. sheets 11D/5, 12, 13, 21A/3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16, 21H/2 and 20P/13; Nova Scotia Department of Mines and Energy, Open File Report 90-006, 108 p.

Environment Canada 1985: Metal contamination of lakes in the Waverley area. -- [Halifax] : Nova Scotia Department of the Environment; Environment Canada, Inland Waters Directorate, 6 p.

Finck, P. W., Boner, F. J. and Graves, R. M. 1990a: Heavy mineral till geochemistry (tin) of the eastern and central South Mountain Batholith; Nova Scotia Department of Mines and Energy, Open File Report 90-004, 21 p.

Finck, P. W., Boner, F. J. and Graves, R. M. 1990b: Heavy mineral till geochemistry (tin) of the western South Mountain Batholith; Nova Scotia Department of Mines and Energy, Open File Report 90-005, 41 p.

Finck, P. W. and Graves, R. M. 1987: Glacial geology of Halifax and Sambro; Nova Scotia Department of Mines and Energy, Map 87-2, Scale 1:50 000.

Ham, L. J., Marsh, S. W., Corey, M. C., Horne, R. J. and MacDonald, M. A. 1989: Lithogeochemistry of the eastern portion of the South Mountain Batholith, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 89-001, 62 p.

Ham, L. J., Corey, M. C., Horne, R. J. and MacDonald, M. A.1990: Lithogeochemistry of the western portion of the South Mountain Batholith, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 90-007, 31 p.

Haysom, S. J. 1994: The opaque mineralogy, petrology, and geochemistry of the Meguma Group metasediments, Rawdon area, Nova Scotia: unpublished B. Sc. thesis, St. Mary's University, Halifax, Nova Scotia, 45 p.

Henderson, P. J. and MacMartin, I. 1995: Mercury distribution in humus and surficial sediments, Flin Flon, Manitoba, Canada; Water, Air Soil Pollution v. 80, pp. 1043-1046.

Keppie, J. D. 2000: Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Map ME 2001, Scale 1:500 000.

Lewis, C. F. M., Taylor, B. B., Stea, R. R., Fader, G. B. J., Horne, R. J., MacNeill, S. G. and Moore, J. G. 1998: Earth Science and Engineering: Urban

Development in the Metropolitan Halifax Region, *in* Urban Geology of Canadian Cities, eds. P. F. Karrow and O. L. White; Geological Association of Canada Special Paper 42, pp. 409-444.

MacDonald, M. A. and Horne, R. J. 1987: Geological Map of Halifax and Sambro; Nova Scotia Department of Mines and Energy, Map 87-6, Scale 1:50 000.

Prime, G. 2001: Overview of bedrock aggregate potential in the Halifax-Dartmouth Metropolitan area, Nova Scotia; Nova Scotia Department of Natural Resources, Economic Geology Series ME 2001-1, 74 p.

Stea, R .R. and Fowler, J. H. 1979: Pleistocene geology, eastern shore region, Nova Scotia (sheets 1-3), Scale 1:100 000, *in* Minor and Trace Element Variations in Wisconsinon Tills, Eastern Shore Region, Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 79-4, 30 p.

Stea, R. R. and Fowler, J. H. 1981: Pleistocene geology and till geochemistry of central Nova Scotia, (sheet 4), 1980; Nova Scotia Department of Mines and Energy, Map 81-1, Scale 1:100 000.

Woodman, K. K., Duncan, D. R., Graves, R. M., Hudgins, A. B. and Rogers, P. J. 1994: Compilation of Seabright Resources Inc. Till and Soil Geochemical Data, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Report 94-021, 238 p.