Multi-element Distribution in Humus, Soil and Till Associated with the Upper and Lower Seal Harbour Gold Districts (NTS 11F/04)

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Introduction

Field work associated with the second year of a three-year multi-disciplinary project, initiated in the spring of 2003 as part of the Geological Survey of Canada's Metals in the Environment (MITE) Program, was completed during the summer of 2004. The main objective of the MITE project is to examine the distribution of metals in the environment associated with past-producing gold districts throughout the province by characterizing regional and local background concentrations and speciation of the elements. Further, it is anticipated that off-site transport of the elements from mine waste such as tailings and waste rock dumps, and the transformation and fate of these elements in receiving environments, can be quantified.

During the period from 1862 to 1982, 1,198,619 troy ounces of gold were produced from over 50 gold districts (Bates, 1987) in Nova Scotia. After crushing in a stamp mill, the gold was recovered from the host rock using one of three extraction methods: (1) gravity separation, (2) cyanidation and (3) mercury (Hg) amalgamation. Historical records suggest that up to 25% of the mercury added during the amalgamation process was routinely lost to the tailings and/or to the atmosphere (Eaton, 1978).

In May 2003, ten past-producing gold districts were chosen for the initial stage of reconnaissance level, multi-media sampling and subsequent evaluation (Goodwin *et al.*, 2003). These sites were selected and prioritized on the basis of the following criteria: (1) known history of Hg amalgamation; (2) extensive tailings deposits and (3) little or no previous environmental work available. After sampling each of the ten districts during the 2003 field season, the Upper and Lower Seal Harbour gold districts were chosen for detailed follow-up work during the 2004 field season.

Bedrock Geology

Southern Nova Scotia is part of the Meguma Terrane, which is in part defined by the Meguma Group, a 9000 m thick succession of siliciclastics that hosts most of Nova Scotia's gold deposits (Ryan and Smith, 1998). The Meguma Group consists of two formations: the basal metasandstone-dominated Goldenville Formation which is conformably overlain by slate and meta-siltstone of the Halifax Formation (Ryan and Smith, 1998).

Polyphase deformation characterizes the Meguma Group rocks. The rocks form a series of tight, upright, variably plunging, northeasterly trending, asymmetric folds (Ryan and Smith, 1998). Numerous structural elements define the complex deformation of the eastern part of the Meguma Group (O'Brien, 1983; Smith, 1983). Regional greenschist to lower amphibolite facies metamorphism characterizes the Meguma Group rocks (Ryan and Smith, 1998).

Folded Meguma Group metasediments were intruded by Devonian granitoids, including granodiorite, monzogranite and leucomonzogranite (MacDonald and Horne, 1987). Contact metamorphic minerals near the voluminous granitoid intrusions include biotite, andalusite, cordierite, staurolite and sillimanite (Ryan and Smith, 1998).

Lode-gold occurs within numerous vein types, mainly in rocks associated with the Goldenville Formation. The veins generally occur on the crests and flanks of regional anticlines and domes that measure up to 4 km long and up to 0.5 km wide within a gold district (Sangster, 1990). The nature and classification of veins in the Meguma Group strata have been summarized by Smith and Kontak (1988).

Quartz is the dominant vein mineral but carbonates also commonly occur. Associated

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sulphides include pyrite, pyrrhotite, arsenopyrite, galena, chalcopyrite and sphalerite (Ryan and Smith, 1998). Most gold occurrences tend to be spatially associated with thicker than normal, interstratified slate (argillite) beds in the Goldenville Formation metasandstones (Sangster, 1990).

Arsenopyrite characterizes all the gold districts in variable amounts up to 5%. It is most abundant in wall rocks, but also occurs within quartz veins (Sangster, 1990).

Gold in Nova Scotia

The first vein-hosted gold discovery in the Meguma Terrane occurred at Mooseland in 1858 by Lieutenant C. L'Estrange while hunting moose (Malcolm, 1929). This led to a major gold rush for Nova Scotia and by the beginning of the Twentieth Century, the Government of Nova Scotia had recognized 60 gold districts throughout the province. Production continued relatively unabated until the beginning of the Second World War in 1939. Since 1939, only limited, sporadic production occurred except from 1983-1987 when a federal exploration incentive, coupled with relatively steady gold prices, allowed for some limited production (Ryan and Smith, 1998).

For historic and descriptive geological details, Malcolm (1929) summarizes the first 70 years of gold exploration and mine development in the Meguma Terrane of Nova Scotia. Bates (1987) summarizes the historic milling methods (i.e. stamp mills, etc.) used to crush the gold ore, and gold extraction methodologies involving the use of shaker tables in combination with amalgamation (the addition of mercury) or cyanidation (crushed ore is dissolved in a mixture of lime and cyanide).

History of the Upper and Lower Seal Harbour Gold Districts

Historical production (1893-1944) from the Upper Seal Harbour gold district totalled 57,027 ounces of gold recovered from quartz veins in the Goldenville Formation (Sangster, 1990). The majority of the production from the district came from the Richardson Belt, first discovered in 1892 by Howard Richardson (Malcolm, 1929). At the hinge of the anticline, quartz veins attained thicknesses of up to 6 m, thinning down the limbs of the fold (Malcolm, 1929). At this gold district, gold is known to occur in three distinct settings: (1) bedding-concordant (or ribbon) quartz veins; (2) irregular *en echelon* quartz veins stratabound within slate units; and (3) disseminated gold within arsenopyrite-rich black slate beds (Ryan and Smith, 1998). The re-furbished (1988) Boston Richardson headframe served as a prominent landmark during the 2004 regional sampling program. Cement and timber foundations at the Boston Richardson mill site, located on the southwest shore of Gold Brook Lake, are the last remaining evidence of the former, grand mill site structure.

Prospecting first occurred in the Lower Seal Harbour Gold District as early as 1868 when glacially dispersed, gold-bearing boulders were found (Malcolm, 1929). A total production of 34,295 ounces of gold was recovered from the district from1894-1942 (Sangster, 1990). Like most significant deposits, the Lower Seal Harbour gold district is located in metasedimentary rocks of the Goldenville Formation.

Similar to the foundations noted at Upper Seal Harbour, deteriorating cement foundations and cement shaft collars characterize the Lower Seal Harbour gold district today, as does a small, free-standing cement building that presumably was used as a vault to store gold. The cement foundation of the former cyanide plant is still relatively well preserved. Both the Upper and Lower Seal Harbour gold districts also showed extensive evidence of exploration and mining as trenches, pits, waste rock piles and tailings characterize both districts.

Surficial Geology

Generally, most of the surficial deposits and associated landforms throughout Nova Scotia were formed during the Wisconsinan glaciation in the last 70,000 years (Lewis *et al.*, 1998). Superimposed till sheets and various multiple-flow directional indicators have been mapped and document that Nova Scotia is characterized by a complex ice flow history (Stea *et al.*, 1992, Stea and Finck, 2001).

The oldest observed ice flow indicators on land are directed toward the east and southeast and are responsible for the formation of the Hartlen Till associated with the Caledonia Phase (75-40 ka).

South and southwest flow of the Escuminac Phase (22-18 ka) followed and was responsible for deposition of the Lawrencetown Till. The Scotian Phase (18-15 ka) was characterized by an ice divide situated over most of Nova Scotia, and the resulting ice flow varied from northwestward in northern Nova Scotia to south and southeast in southern Nova Scotia followed by formation of the Beaver River Till. The Chignecto Phase (13-12.5 ka) was characterized by shifting ice flow associated with several small ice caps, the remnants of waning stages of the Scotian Phase glacier (Stea and Finck, 2001).

Enrichment of gold and arsenic, with lesser enrichment of copper, lead, zinc, tungsten bismuth, tellurium and iron, characterize the gold deposits of the Meguma Terrane (Kontak and Smith, 1993). These elements are commonly geochemically enriched in soil and till down-ice from known gold occurrences (Coker *et al.*, 1988) resulting from mechanical dispersion (erosion, transportation and deposition) by advancing glacial ice. Glacial dispersal distances vary in Nova Scotia from hundreds of metres to several kilometres down-ice from source (Stea and Fink, 2001).

Methodology

Introduction

During the 2004 field season, 22 regional A-horizon humus, B-horizon soil and C-horizon till samples were collected from the Upper and Lower Seal Harbour gold districts from an area covering approximately 120 km^2 (Fig. 1).

Prior to the humus/soil/till sampling program, a review was undertaken of the local: (1) ice flow history, (2) bedrock stratigraphy, (3) bedrock structure, (4) vein orientation and (5) mining development (including the location of tailings ponds and mill structures for each district). To determine the best location for sample collection, sample sites were carefully chosen to provide: (1) a broad aerial distribution of sample sites, (2) representative coverage of the major surficial units within the study area, (3) representative coverage of the major rock units within the study area and (4) easy access by taking advantage of pre-existing roads.

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

Field Sampling Methodology

A-horizon humus samples were collected by lifting the live, moss-covered forest floor and collecting the underlying black, decaying humus material by hand. Generally, the A-horizon was relatively thin, averaging about 2 cm to 3 cm in thickness. At several sites, however, the depth increased to approximately 10 cm thick. Pebbles and soil attached to the humus were removed and any living plant matter was also selectively removed prior to placement into a Kraft bag. Approximately 250 g of humus were collected from each site.

B-horizon soil samples were also collected at each site from an average sampling depth of 20 cm. Approximately 500 g of soil were collected by shovel and/or auger and placed into Kraft sample bags for future geochemical analysis. Visible organic material and large clasts were selectively removed by hand at each sample site.

The C-horizon till samples were also collected by shovel and/or auger from small hand-dug pits with an average sampling depth of approximately 125 cm (minimum sampling depth was 80 cm). Approximately 500 g of till were collected from each site and placed into Kraft sample bags for future geochemical analysis. Once again, all visible organic material was removed from the sample prior to placement into the Kraft bag. The >1 cm clast fraction was removed (with a plastic sieve) and washed in the field. Estimates of the relative proportions of metasandstone, slate, granite, quartz and “other” clasts were recorded and photographed digitally for future reference. The clasts were then discarded in the field.

In addition to the regional multi-media sampling program, detailed sampling of B-horizon soil was completed within and proximal to the footprint of the former Boston Richardson Mill (Fig. 1) complex site located on the southwestern shore of Gold Brook Lake. Sixteen B-horizon soil samples were collected from an average sampling

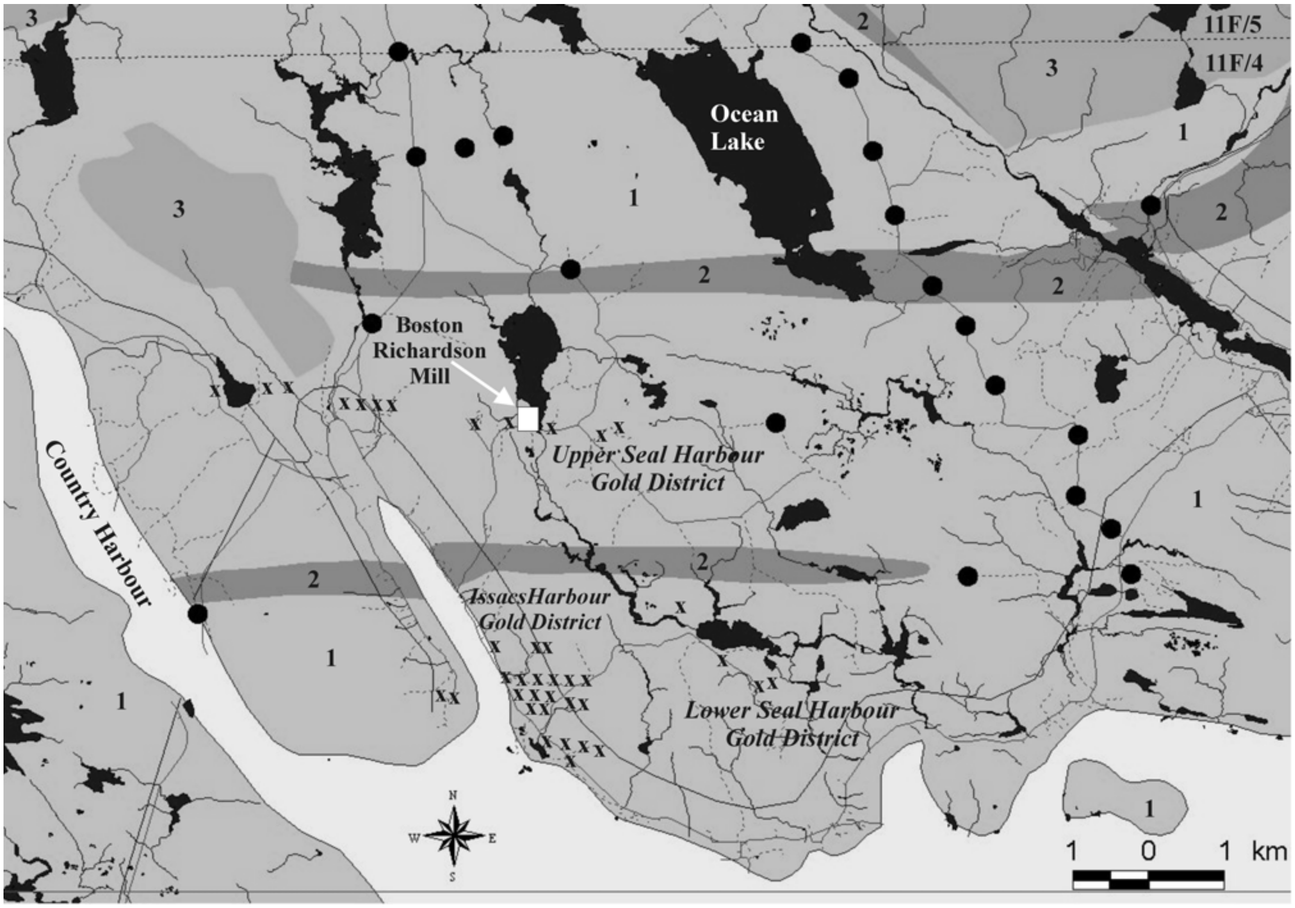

Figure 1. Locations of regional humus, soil and till samples. Sample locations are solid circles and shafts are represented by an x. 1 = Goldenville Formation, 2 = Halifax Formation, 3 = granite.

depth of 20 cm to determine the extent of surface enrichment of As and Hg (plus other elements) associated with the milling of ore and the subsequent recovery of gold (utilizing mercury amalgamation). Each sample site represents a composite of a minimum of three sample sites from within a 10 m^2 area. The majority of the sites exhibited some form of visible anthropogenic influence, including the presence of one or more of the following: tailings, cement/timber foundations, waste rock piles, rock walls built from waste rock, old bricks, steel pipes, charcoal and proximity to old roads.

Laboratory Preparation and Analytical Methodology

All humus, soil and till samples were prepared at DalTech Minerals Engineering Centre (Dalhousie University) in Halifax, Nova Scotia. All samples were air dried for several days to a maximum drying temperature of 30 degrees Celsius (°C) to minimize loss of volatile elements such as mercury. Two vials (approximately 15 g to 30 g) of <2000 µm (<2 mm) and two vials (approximately 15 g to 30 g) of <63 µm were prepared for each medium of humus, soil and till.

Prepared humus, soil and till samples were sent to ACME Analytical Laboratories Limited of Vancouver, British Columbia, for a 15 g ICP-MS multi-element analysis following an aqua regia digestion.

Quality Assurance/Quality Control (QA/QC)

Quality assurance/quality control (QA/QC) measures were incorporated into the sampling program and the preparation and analytical procedures to ensure the highest confidence in the quality of the data.

In the field, personnel were trained with respect to standard sampling procedures and the acquisition of necessary site description information. One field duplicate was collected from the regional geochemical program to test for natural site variance. (No field duplicates were collected during the detailed soil sampling program associated with the former Boston Richardson Mill site because of the overwhelming evidence of contamination).

Each sample site was photographed with a digital camera for future reference. For the detailed soil sampling program associated with the former Boston Richardson Mill site, however, only representative pictures of the overall mill site were taken.

Due to the lack of an available humus reference standard, CANMET (Canadian Certified Reference Materials Project – CCRMP) lake sediment standard LKSD-4 was inserted as a reference control material because of its high organic content. A laboratory prepared preparation split was also inserted with these humus samples.

CANMET till standard TILL-1 and an in-house reference standard (informally referred to as STEA-1) were inserted with all regional soil and till batches. A laboratory prepared preparation split was also inserted with both the soil and till samples.

Results

Analytical results are pending for all samples.

Discussion

Overall, the clast and matrix composition of the till strongly reflects the underlying bedrock lithology, indicating that the till is locally derived. The local nature of the till is further demonstrated by the angularity of the clasts, the presence of large boulders, and the compact nature of the till. Till samples collected within the study area were dominated by metasandstone facies of the Beaver River Till.

Locally, on the extreme eastern end of the study area, a slate facies till (SH04 SC08) associated with the Halifax Formation slate was encountered. The area was further characterized by relatively abundant slate outcrop. It should be noted that there was less clay in the matrix than anticipated for slate facies till, and there were numerous sub-rounded to rounded clasts suggesting there may be some degree of fluvial reworking considering the proximity to the New Harbour River. Clear evidence (sorted beds, rounded clasts etc.) of fluvial re-working and deposition was noticed at lower elevations (near the New Harbour River).

An increase in the number of granite clasts and the presence of a slightly coarser sand matrix was noted in several of the till samples collected from the northeastern part of the study area. Granite plutons, represented as local topographic highs, are known to exist immediately north of the study area.

All regional humus, soil and till samples collected in the field were deemed to be of excellent quality and not influenced by any anthropogenic effects (i.e. tailings, waste rock piles, garbage, etc.). Conversely, almost all of the 16 soil samples collected within and near the footprint of the Boston Richardson Mill complex showed visible anthropogenic effects.

The regional sample sites, in general, were biased north of the Upper and Lower Seal Harbour anticlines (and east of the main workings) in order to minimize the (cumulative) affect of glacial erosion, transportation and deposition of mineralized bedrock material associated with the gold districts. However, any effects of glacial erosion, transportation and deposition of mineralized bedrock material associated with known gold mineralization farther up-ice (i. e. Forest Hills) could not be ruled out.

Conclusions

During the 2004 field season, sample sites were visited and geochemical samples were collected as part of a regional sampling program at the Upper and Lower Seal Harbour gold districts. At each site, an A-horizon humus, B-horizon soil and C-horizon till sample were collected. The <63 μm and

<2000 µm (<2 mm) fractions for all humus, soil and till samples were prepared at DalTech Minerals Engineering Centre (Dalhousie University) in Halifax, Nova Scotia. These prepared humus, soil and till samples were subsequently sent to ACME Analytical Laboratories Limited of Vancouver, British Columbia, for a 15 g ICP-MS multi-element analysis following an aqua regia digestion. Quality assurance/quality control (QA/QC) measures were incorporated into all stages of the sampling program to ensure the highest confidence in the quality of the data.

In addition to the regional multi-media sampling program, detailed sampling of B-horizon soil was completed within and near the footprint of the former Boston Richardson Mill site located on the southwestern shore of Gold Brook Lake. Sixteen composite B-horizon soil samples were collected from an average sampling depth of 20 cm. The detailed B-horizon soil samples were prepared in an identical manner as the regional B-horizon soil samples using the same QA/QC protocols.

The Upper and Lower Seal Harbour sampling program is part of a 3-year multi-disciplinary project, initiated in the spring of 2003 as part of the Geological Survey of Canada's Metals in the Environment (MITE) Program. The main objective of the MITE program is to examine the distribution of metals in the environment associated with past-producing gold districts throughout the province by characterizing regional and local background concentrations and speciation of the elements. This study will assist the understanding and quantification of off-site transport of various elements from mine waste (tailings and waste rock dumps), and the transformation and fate of these elements in receiving environments (e.g. streams, lakes, etc.).

Analytical results are pending for all samples.

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