Mercury in Till, Kejimkujik National Park Area (NTS 21A/06), Nova Scotia

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Introduction

Environment Canada (1998) identified loons in Kejimkujik National Park (Fig. 1) as having the highest levels of mercury (Hg) concentration in blood of any loon population tested in North America. A multi-disciplinary team of research scientists has been studying the potential source(s) and process(es) that may account for the anomalous Hg levels in loons from the park. As part of the overall research objective, this study examines naturally occurring (geogenic) Hg in the <63 micron size fraction of till in the Kejimkujik National Park area as a possible source of Hg in the food chain.

A study of Hg in soil gas was also undertaken during the 2000 field season till sampling program. Results for Hg in soil gas from the Kejimkujik Park area have previously been reported by Goodwin and Page (2001). All work to date has been carried out through funding from Health Canada under the Toxic Substance Research Initiative (TSRI).

Geology

Bedrock Geology

The study area consists of Cambro-Ordovician metawacke and minor interbedded metasiltstone of the Goldenville Formation overlain by finely laminated slate and metasiltstone of the Halifax Formation (Horne and Corey, 1994; Corey and Horne, 1994). These rocks were intruded by Devono-Carboniferous monzogranite (Scrag Lake Pluton and Kejimkujik Pluton) and leucomonzo-granite (Davis Lake Pluton) of the South Mountain Batholith (Horne and Corey, 1994; Corey and Horne, 1994).

Structurally, the metasediments are characterized by a series of northeast-southwest anticlines and synclines (Horne and Corey, 1994; Keppie, 2000). Two significant northeast-southwest zones of intense brittle-ductle deformation are inferred to transect the study area. The East Kemptville Shear Zone (EKSZ: Kontak *et al.,* 1986) cuts across the northern boundary of the park and the Tobeatic Shear Zone (TSZ: Corey, 1995) cuts across the southern boundary of the park (Fig. 2).

Mineralized zones, including Au-As-Sn-W-Mo-Cu-Ag-Pb-Zn-Ba, and variably altered (chloritized, silicified, kaolinized, hematized), brecciated boulders exhibit a strong spatial relationship with known and inferred structures (Horne and Corey, 1994; Corey, 1995). Corey (1995) suggests the types and styles of mineralization observed in boulders and diamond-drill core from the Tobeatic Shear Zone are similar

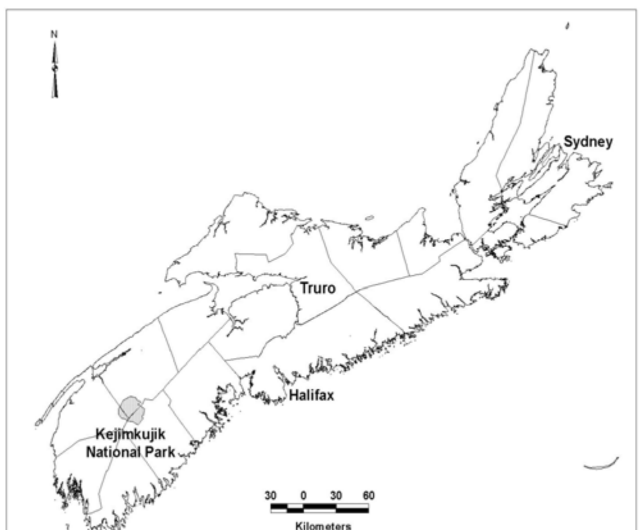

Figure 1. Map of Nova Scotia showing the location of Kejimkujik National Park.

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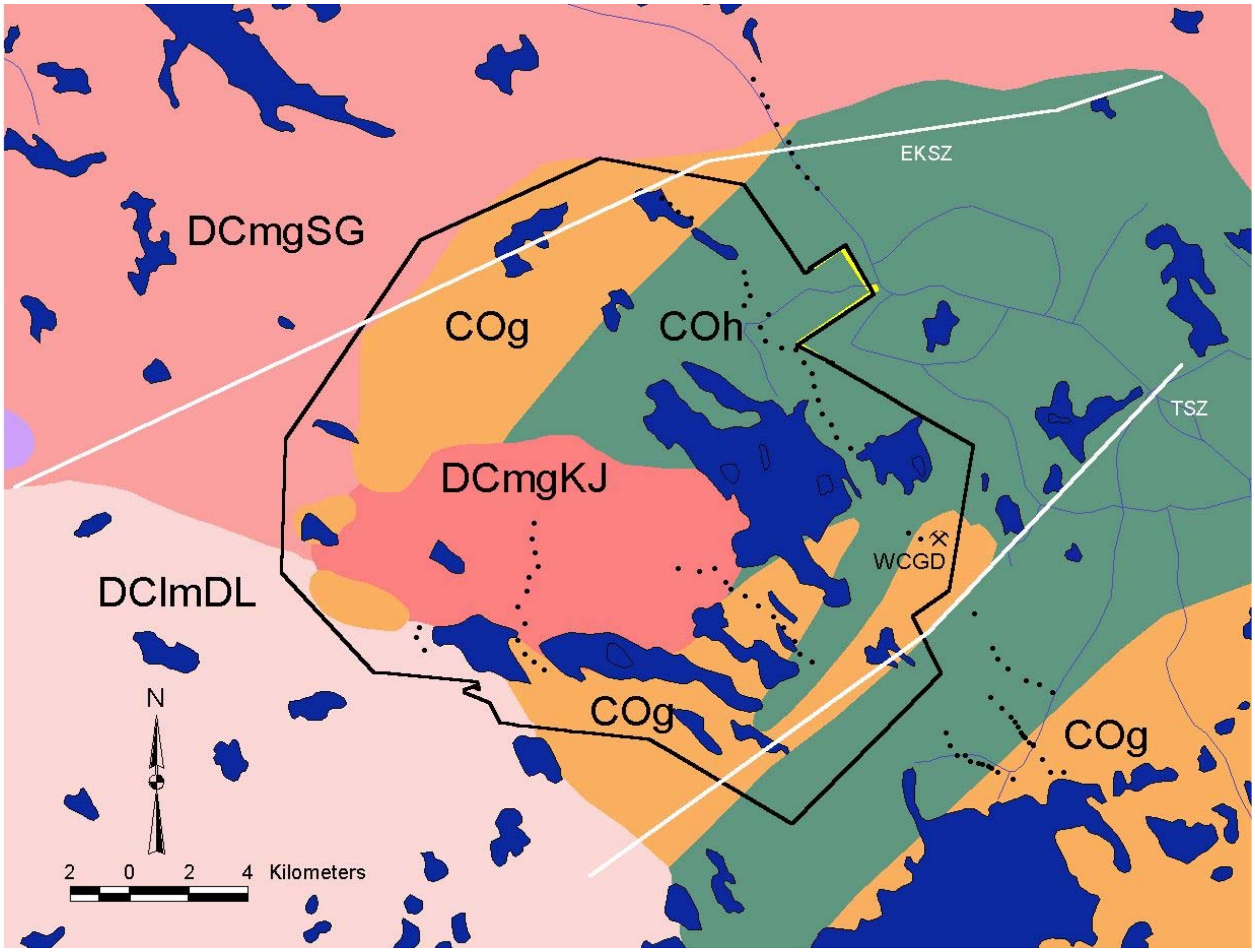

Figure 2. Geological map of the Kejimkujik National Park area, showing till sample locations (dots). Geology after Horne and Corey (1994). DCmgSG = Scrag Lake monzogranite, DCmgKJ = Kejimkujik monzogranite, DClmDL = Davis Lake leucomonzogranite, Coh = Halifax Formation, COg = Goldenville Formation, TSZ = approximate trace of the Tobeatic Shear Zone, EKSZ = East Kemptville Shear Zone and WCGD = West Caledonia Gold District. Note: the six samples collected along the western shore of Little Tobeatic Lake are not shown. Little Tobeatic Lake is approximately 14 km southwest of the southern park boundary.

to epithermal deposits elsewhere in the world. Epithermal deposits are characterized by the presence of Hg in the form of cinnibar (HgS) among other ore minerals, including minerals containing Au-Cu-Ag-Pb-Zn-Sb-Se-Bi-U (Evans, 1993).

Surficial Geology

The surficial geology of the study area is dominated by: (1) the Beaver River Till, a relatively thin, stoney till that is locally derived; and (2) the Shelburne River Till, a more distally derived till that is geomorphologically characterized by hummocks, ridges and a rolling ground moraine (Finck *et al.,* 1994b). Locally, however, the surficial geology is characterized by a silty drumlin facies, particularly along the eastern edge of the park boundary, and by ice contact glaciofluvial deposits, organic deposits, and bedrock-dominated terrain (Stea *et al.,* 1992; Finck *et al.,* 1994b).

Ice flow indicators suggest glacial ice originally flowed to the southwest, then shifted southerly, and finally flowed westward (Stea *et al.,* 1992). Field mapping during the 2000 and the 2001 field seasons confirmed the presence of these three flow directions.

Previous Geochemical Sampling Programs

Nova Scotia has been extensively covered by regional geochemical surveys from various sample media including vegetation, till, stream sediments, stream waters, lake sediment, and lake waters. Three regional geochemical surveys have been completed over the Kejimkujik National Park area. Two of these were till surveys, one designed to sample till associated with the South Mountain Batholith from 1984 to 1989 (Boner *et al.,* 1990) while the other survey was designed to sample till over mainland Nova Scotia between 1977 and 1988 (Stea, 1982, 1983; Stea and Grant, 1982). Both surveys included samples within the Kejimkujik study area; however, no analysis for Hg was made in either till survey.

A 1977-1978 lake sediment survey completed over southern mainland Nova Scotia sampled numerous lakes within the current Kejimkujik study area (Richardson and Bingley, 1980). The lake sediment was analyzed for gold and other elements, including Hg. The study area is characterized by Hg levels ranging from 10-860 ppb in lake sediment, however; locally monzogranite has slightly elevated Hg relative to Meguma Group metasediments.

Methodology

Introduction

During the 2000 and 2001 field seasons, a total of 97 till samples were collected at 500 m intervals along eight northwest-southeast roadside traverses located in the park, and to the northeast and southeast of the park (Fig. 2). However, some samples were also collected along footpaths (within the former West Caledonia Gold District) and from a pace and compass line along the west shore of Little Tobeatic Lake, 14 km southwest of the park.

The traverse lines were oriented to (1) sample the dominant till units, (2) cross all bedrock units (Goldenville Formation, Halifax Formation and granite), including the Goldenville-Halifax Transition Zone (GHTZ), (3) cross the Tobeatic Shear Zone and the East Kemptville Shear Zone, (4) assess the possible correlation of Hg with known Au mineralization associated with the former West Caledonia Gold District, and (5) to take advantage of pre-existing roads.

Sampling Methodology

Till samples were collected by shovel and/or hand auger from an average sampling depth of about 1 m. Approximately 500 g of till were collected at each site and placed into a Kraft sample bag for geochemical analysis. The Kraft sample bags were immediately placed in coolers, which also served as shipping containers to the laboratory. During the 2000 field season, an additional 3 kg sample was collected from each sample site and placed into 6 ml plastic sample bags for clast identification and count.

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

Analytical Methodology

The 500 g till samples were forwarded in the Kraft bags to DalTech Minerals Engineering Centre in Halifax, Nova Scotia, for drying and sieving. All samples were dried to a maximum drying temperature of 35°C.

Once dried, approximately 10 g of the <63 microns fraction were sieved and placed into a set of pre-labeled vials for Hg analysis. An additional 50 g of the <63 micron fraction were sieved and subsequently placed into two sets of pre-labeled vials for gold and multi-element analysis.

Vials containing the 10 g of the <63 micron material were sent to ACME Analytical Laboratories of Vancouver, British Columbia. A subsample of 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.

One set of the larger 50 g vials was sent to Bondar Clegg in Val d'Or, Quebec, for geochemical analysis. A 30 g subsample was analyzed for gold by Fire Assay/Atomic Emission Spectroscopy (FA/AES) and a 1 g sample was analyzed for multi-element geochemistry by Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP/AES) following an aqua regia digestion.

The remaining set of 50 g vials was retained for archival purposes.

Quality Assurance/Quality Control

Strict Quality Assurance/Quality Control protocols and procedures were implemented at all stages of the till sampling program, including program planning, training, sample collection, sample preparation and sample analysis, to ensure the integrity of the data set. Quality Control procedures included: (1) the collection of field duplicates, (2) the insertion of preparation splits, and (3) the insertion of certified and in-house reference standards.

To assess precision, ACME also re-ran the first 34 samples submitted in 2000 for Hg by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) as a check on the Hg levels reported by the Cetac CV-AA method. Similarly, random samples for the Au and multi-element geochemistry results reported by Bondar Clegg were sent to a second laboratory for comparison.

Results

While the complete till data set is still currently being assessed and integrated with other geochemical, geological and geophysical data sets, some important preliminary Hg results (observations) are presented here for the first time.

Based on the Quality Control data, the analytical data are deemed to be of excellent quality. However, a minor degree of spatial variance was noted in several of the field duplicate pairs. The nature and extent of the spatial variance is not clearly understood at this time. A number of explanations, including sample inhomogeneity and/or the distribution of Hg within the till matrix, may be responsible for the variance.

The geochemical response for any element observed in till typically characterizes the parental bedrock material (geological variability) from which it was derived, its mode of transportation and deposition, and post-deposition weathering effects. Therefore, results for Hg in the <63 micron fraction of till have been subdivided on the basis of the various till units of Finck *et al.* (1994a, 1994b) observed during the till sampling program. Basic statistical results for Hg are presented in Table 1.

The slate facies of the Beaver River Till (SLB) has the lowest mean of Hg value (41.4 ppb) for the <63 micron fraction, followed by the greywacke facies (50.3 ppb) of the Beaver River Till (GWB) and the granite facies (67.3 ppb) of the Beaver River Till (GTB). Although samples were collected from areas designated as Shelburne River Till by Finck *et al.* (1994a, 1994b), no Shelburne River Till was observed in the 2000-2001 sampling program, indicating some minor modifications to the existing surficial maps is required.

The highest mean Hg value (99.3 ppb) in till came from six samples collected approximately 14 km southwest of the southern boundary of Kejimkujik National Park. This small population of samples was collected from the greywacke facies of the Beaver River Till (GWB), not from Shelburne River Till as indicated by Finck *et al.* (1994a). At this location, the Tobeatic Shear Zone is exposed on the western shore of Little Tobeatic Lake. Evidence of the shear zone includes a several-metre-wide west-southwest-trending quartz vein/stockwork system traceable for several hundred metres of strike length, associated variable carbonate-altered greywacke wallrock, and locally intense sulphide mineralization. Physical evidence of the shear zone, including quartz clasts and boulders and sheared, foliated and silicified meta-sedimentary boulders, was noted in several till pits. This zone was further delineated by diamond-drilling (Corey, 1995).

On a global scale, Jonasson and Boyle (1972) speculated that deep faulting and shearing may be a

Table 1. Mercury (ppb) in till (<63 microns).

	SLB* (slate till)	GWB* (greywacke till)	GTB* (granite till)	GWB* (samples of greywacke till from the Tobeatic Shear Zone)
Mean	41.4	50.3	67.3	99.3
Median	37.9	44.6	70.0	92.3
Std. Dev.	28.89	33.28	46.90	56.34
Min.	6.4	6.6	3.4	32.2
Max.	151.5	96.6	158.5	193
No. of samples	49	11	31	6

*Till unit descriptions from Finck *et al.* (1994a, 1994b).

characteristic of all Hg occurrences. In British Columbia, Plouffe (1997) observed an increase in Hg content in the <2 micron size fraction of till down-ice from major structures characterized by several Hg occurrences. Goodwin and Page (2001) suggested that there is a spatial correlation between the inferred trace of the Tobeatic Shear Zone and elevated Hg in soil gas in the Kejimkujik National Park area.

The Hg concentrations from this study are, in general, within the range of the normal Hg content in till (20-100 ppb, mean 50 ppb) reported by Jonasson and Boyle (1972). The exceptions are the six samples from the Tobeatic Shear Zone that have a mean value (99.3 ppb) two times the mean of normal till (50 ppb) reported by Jonasson and Boyle (1972). It is important to note that Jonasson and Boyle (1972) do not specify the size fraction of till analyzed or the analytical method used to determine the Hg content of till. Locally, the presence of elevated Hg along the Tobeatic Shear Zone indicates a spatial relationship between the shear zone and Hg. The shear zone, therefore, is a geogenic source of Hg in the Kejimkujik National Park area. However, the presence of Hg in every till sample collected for this study indicates that an additional source, or sources, of Hg exists.

On the basis of only two till samples, there does not appear to be a relationship between Hg and the former West Caledonia Gold District. The mean Hg level from the two till samples collected was 37.8 ppb. However, in order to quantify the relationship, significantly more till sampling from within the district is required.

The contribution from anthropogenic Hg affecting till samples collected during the 2000-2001 field season is believed to be nil. Henderson and McMartin (1995) reported that anthropogenic Hg fallout from within 3 km of a smelter in Flin Flon, Manitoba, was limited to a maximum depth of 45 cm. The minimum sample depth from the 2000-2001 sampling program was 50 cm. Only 4 of the 97 samples collected for the 2000-2001 sampling program were from a depth of 50 cm. There appears to be minimal potential for excessive anthropogenoic Hg in the Kejimkujik National Park area. No smelters exist in Nova Scotia and the closest heavy industry is located approximately 60 km to the east.

Conclusions

A total of 97 till samples were collected mostly from roadside traverses and analyzed for mercury (Hg) as part of a larger study in an attempt to identify a source of high Hg levels in the blood of loons from Kejimkujik National Park.

Naturally occurring Hg in the <63 micron size fraction of till exists in the Kejimkujik National

Park area. Mean Hg levels are variable and dependent on the till unit sampled. For example, the lowest mean value of 41.4 ppb Hg characterizes the slate facies of the Beaver River Till, compared to 50.3 ppb for the greywacke facies and 67.3 ppb for the granite facies. These mean levels are similar to the normal Hg content of till reported by Jonasson and Boyle (1972) of 50 ppb. However, local geological influences such as shearing, brecciation, alteration and mineralization may influence the Hg content of till. Till samples collected from the greywacke facies of the Beaver River Till over the Tobeatic Shear Zone returned the highest mean Hg level for this study, 99.3 ppb. The elevated response over the Tobeatic Shear Zone is two times the normal Hg content of till (Jonasson and Boyle, 1972).

Further Studies

The issue of spatial variance of Hg in till needs to be resolved. Additional sampling involving the collection of field duplicates is required. Additional sampling from within the West Caledonia Gold District is also required to assess if a correlation exists between the gold mineralization and Hg.

The source of Hg in till will need to be identified. This would involve the determination of the form(s) of mercury and its relationship to till, whether it is: (1) being adsorbed onto clay, (2) present within the crystal lattice of one or more minerals, or (3) in the form of clastic grains. The relative abundance of Hg in a stratigraphic section also needs to be determined, as does the glacial comminution terminal grade. This will involve detailed depth profile sampling of the till unit(s), size fraction analysis, sequential leach analysis, clast counts, mineralogical identification and mineral probing.

In order to put the concentration of Hg in till from the Kejimkujik National Park area into proper context, the Hg content of till throughout the province will have to be assessed. Once this work is complete, results can be compared to comparable studies throughout Canada.

Additional new data sets, including recent bedrock and surficial geologic mapping, detailed ground magnetics, and lithogeochemistry have yet to be integrated with the till geochemical data set. Once all the data have been fully integrated, correlation of Hg with the new data sets and other elements from the till can be undertaken.

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