Mercury in Soil Gas, Kejimkujik National Park (NTS 21A/06)

T. A. Goodwin and K. D. Page[1]

Introduction

The loons in Kejimkujik National Park (Fig. 1) have the highest levels of mercury (Hg) of any loon population tested in North America (Environment Canada, 1998). Mercury contamination is thought to have a negative impact on the nesting and hatching success rate of loons. For the past several years, a multi-disciplinary team of research scientists including meteorologists, chemists, biologists, geologists, limnologists, and GIS experts from various levels of government and universities have been studying the potential sources and processes that may account for these anomalous Hg levels.

The objectives of this study are (1) to determine if there is a naturally occurring geological source for the Hg and (2) to assess a relatively new Hg vapor flux sampling technique designed by Quicksilver Systems. To this end, various sample media including rock, soil, till, water, vegetation, and soil gas have been collected in and around the park and tested for Hg. Results for Hg in soil gas are discussed in this paper; results for the other sample media are pending.

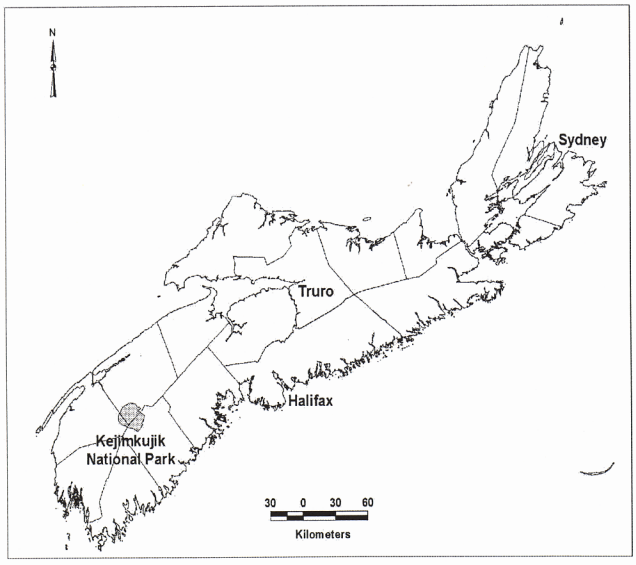

Figure 1. Map of Nova Scotia showing the location of Kejimkujik National Park.

Bedrock Geology

Kejimkujik National Park 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). These rocks were intruded by Devono-Carboniferous monzogranite (Scrag Lake Pluton and Kejimkujik Pluton) and leucomonzogranite (Davis Lake Pluton).

Structurally, the metasediments are characterized by a series of northeast-trending anticlines and synclines (Horne and Corey, 1994). Two significant northeast-trending zones of intense, brittle to ductile deformation are inferred to transect the study area, the East Kemptville Shear Zone (EKSZ, Kontak *et al.,* 1986) and the Tobeatic Shear Zone (TSZ, Corey, 1995). The traces of these shear zones, interpreted by the authors from lineaments identified in a 20 m digital shaded relief image, are shown in Figure 2.

Mineralized rocks, including metasediments and intrusives enriched in 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 and Corey, 1995). Corey (1995) suggests that the types and styles of mineralization observed in boulders and diamond-drill core from the Tobeatic Shear Zone are similar 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 containing Au-Cu-Ag-Pb-Zn-Sb-Se-Bi-U (Evans, 1993).

Surficial Geology

The surficial geology of the study area is characterized by a relatively thin stoney till (Stea *et al.,* 1992). A silty drumlin facies occurs locally, particularly along the eastern edge of the park boundary. The park also features ice-contact glaciofluvial deposits, organic deposits and bedrock-dominated terrain (Stea *et al.,* 1992 and Finck *et al.,* 1994).

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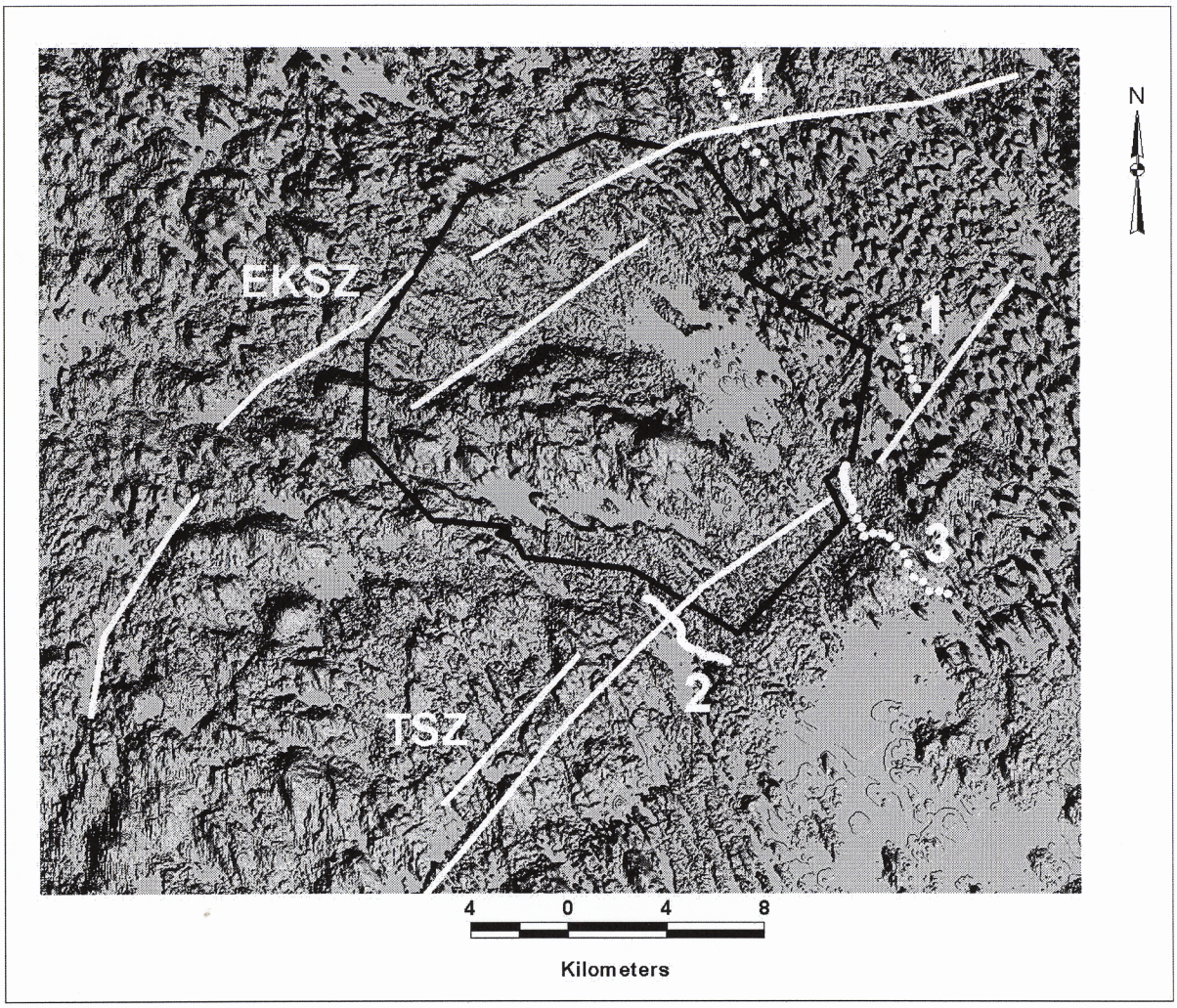

Figure 2. Shaded relief map (azimuth 135°, angle 45°, vertical exaggeration 5x) with inferred locations of the Tobeatic Shear Zone and East Kemptville Shear Zone. Lines 1-4 represent Hg vapor unit sampling locations.

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

Previous Geochemical Sampling Programs

Nova Scotia has been extensively covered by regional geochemical surveys from various sample media, including vegetation, till, stream sediment, stream water, lake sediment, and lake water. There are no known documented surveys for Hg in soil gas within the province. Only two regional geochemical surveys completed in the Kejimkujik area included analytical tests for Hg: (1) a 1977-1982 till survey, and (2) a 1977-1978 lake sediment survey (Rogers and Lombard, 1990, and references contained therein).

Methodology

Introduction

In September 2000, a total of 94 Quicksilver Hg vapor units were placed along four north-south lines around Kejimkujik National Park (Fig. 3).

Line 1 was designed to: (1) cross the Tobeatic Survey Zone and a doubly plunging anticline, (2) assess the presence of Au associated with the former West Caledonia Gold District, and (3) correlate Hg in soil gas results with till samples collected from the same site.

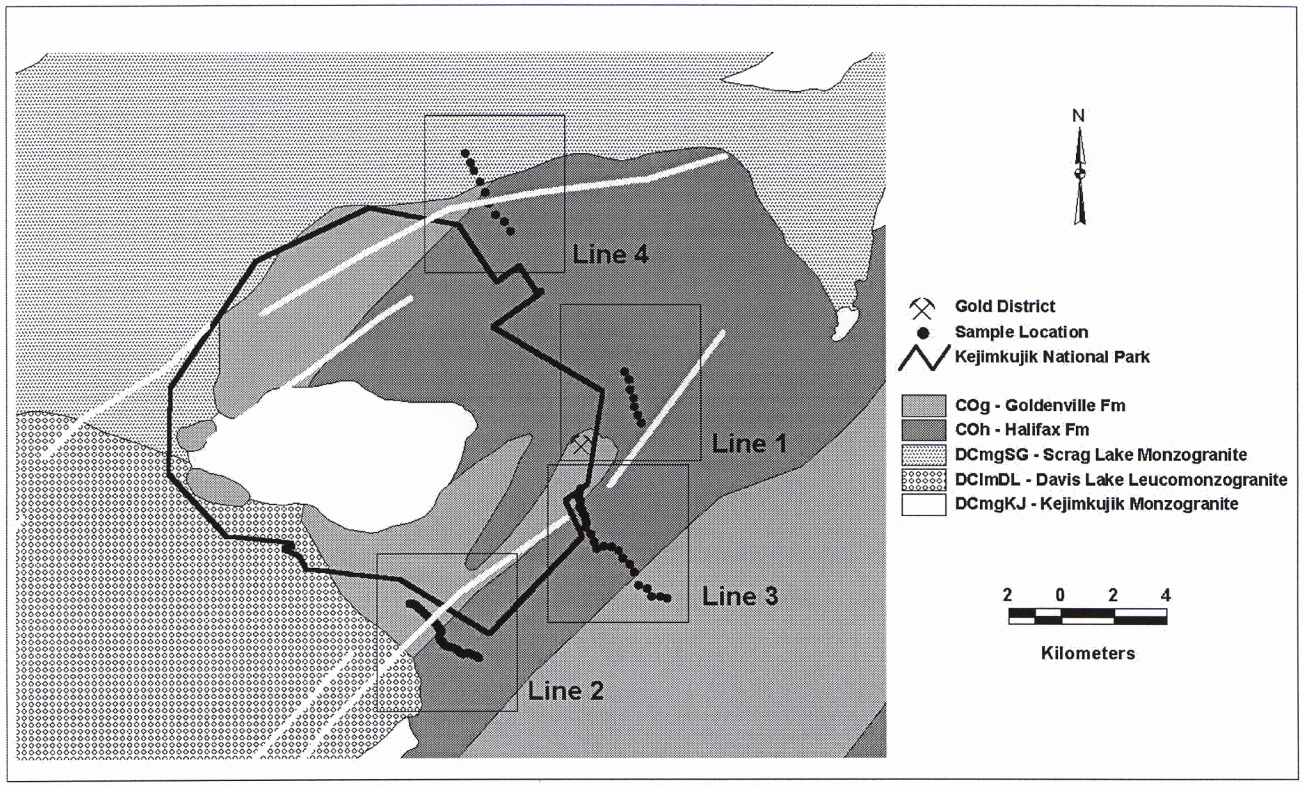

Figure 3. Simplified bedrock geology map with Hg vapor unit sample locations. Enlargements of Lines 1-4 are presented in Figures 5a-d.

The Hg vapor units were placed along a secondary dirt road at a sample spacing of 500 m.

Line 2 was designed to: (1) cross two lithological units (Goldenville and Halifax formations) and (2) cross the Tobeatic Shear Zone. The Hg vapor units were placed along a logging road at variable sample spacings of 100 and 200 m.

Line 3 was designed to: (1) cross two lithological units (Goldenville and Halifax formations), including the Goldenville-Halifax Transition Zone (GHTZ), (2) cross the Tobeatic Shear Zone, and (3) correlate Hg in soil gas results with till samples collected from the same site. The Hg vapor units were placed along a logging road at variable sample spacings of 100, 200 and 500 m.

Line 4 was designed to: (1) cross three lithological units (Scrag Lake pluton, Goldenville and Halifax formations), (2) cross the EKSZ, and (3) correlate Hg in soil gas results with till samples collected from the same site. The Hg vapor units were placed along Highway 8 at a sample spacing of 500 m.

Sampling Methodology

At each sample site, a 30 cm deep hole was dug by hand using a tree-planter style of shovel. The units were assembled at each site and placed at the bottom of the hole. A silver-coloured collector strip was removed from an air-tight glass tube and inserted into a plastic mesh holder (Fig. 4). A 20 cm by 20 cm piece of permeable fiberglass cloth (provided by Quicksilver Systems®) was placed over the cup. The cloth created an air pocket below the unit and provides protection for the unit by reducing soil contact with the collector. Each site was marked with a picket and the sample location was recorded by GPS (Garmin 12). The units were left buried and undisturbed for 30 days.

After 30 days, the Hg collectors were carefully retrieved by digging up each unit. The collector strip was replaced into the air-tight glass tube. The air-tight tubes were immediately sent via courier to Quicksilver Systems® in Bend, Oregon, for Hg analysis.

Analytical Methodology

At the laboratory (cf. Rehn and Rehn, 1996), each collector strip was removed from the air-tight glass tube and sprayed with distilled water in order to rinse off any soil or organic particulate. The strips were dried with lintless paper and placed in a clean glass tube for analysis.

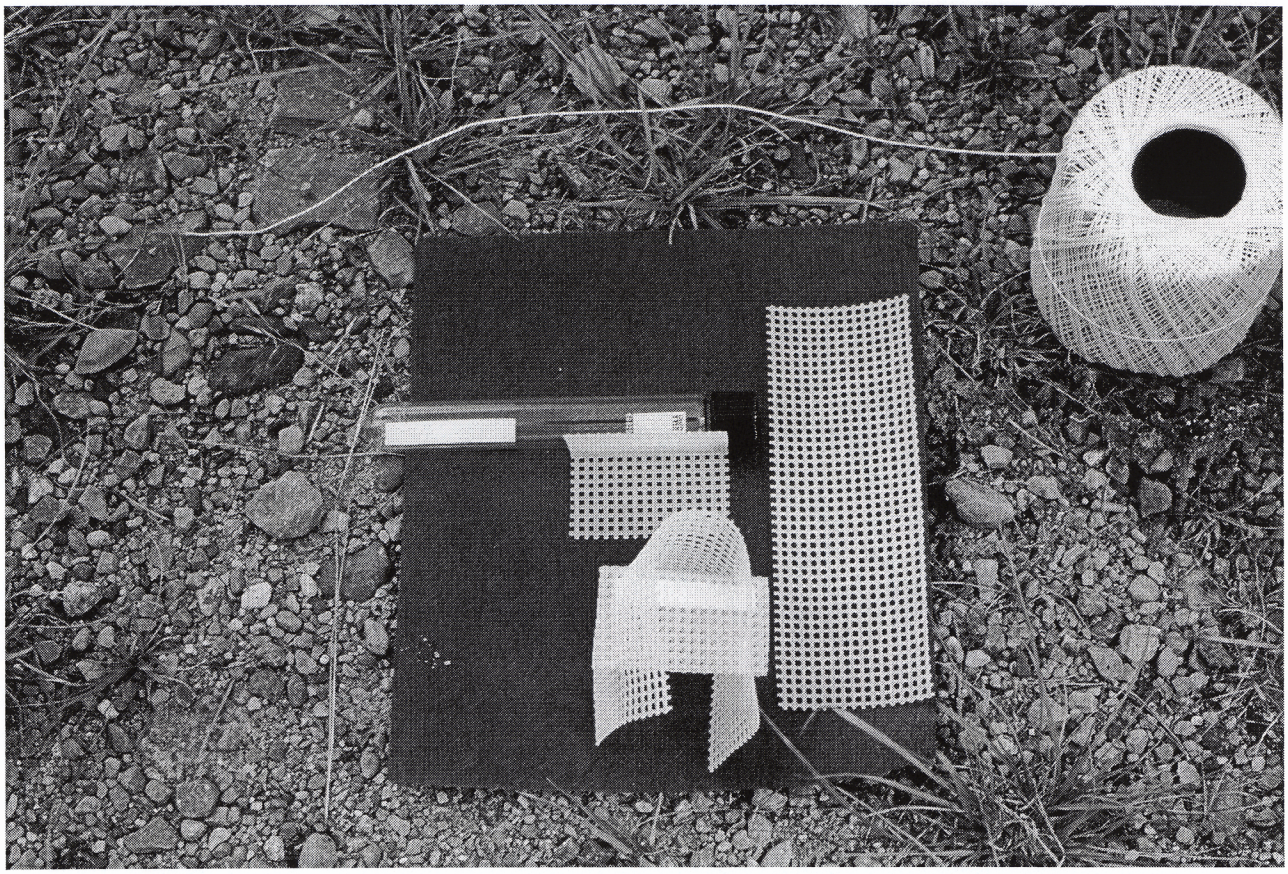

Figure 4. Quicksilver Systems® Hg vapor flux sampling unit showing the silver strip inside the air-tight glass tube, plastic mesh holder, and permeable fiberglass cloth.

The strips were heated to 700°C in a Thermolyne tube furnace, which forces Hg vapor into a stream of air. Mercury is then amalgamated onto a gold foil in a Jerome Gold Film Mercury Vapor Analyzer. Changes in the resistence of the gold foil compared to a reference gold foil represent the concentration of Hg (measured in nanograms). The lower and upper detection limits for the Jerome Vapor Analyzer are 0 nanograms and 100 nanograms, respectively.

Quality Assurance/Quality Control (QA/QC)

Certified reference standards are normally inserted with geochemical samples submitted for analysis in order to assess a laboratory's precision and accuracy. However, no known standards (apart from the previously mentioned reference gold foil) exist for the Quicksilver® Hg vapor units. Therefore, analytical control was limited to four randomly inserted "blank" Hg detection strips, that is, strips that were never buried.

Eleven field duplicates, placed within 1-3 m of the original unit, were used to determine site variance.

Results

Based on the limited Quality Control data (the four blanks and eleven field duplicates), the data are deemed to be of acceptable quality. All four blanks reported 0 ng Hg/strip and the results for field duplicates indicate the samples are representative of the area they were collected from.

The minimum reported Hg in soil gas value is 0 ng Hg/strip and the maximum value is 78 ng Hg/strip ($n = 94$, $\bar{x} = 4.7$, $sd = 9.3$). Based on a review of the data set using (1) a cumulative frequency plot, (2) rank and percentile, and (3) published results by Rehn and Rehn (1996), the authors have determined that background values for this study range from 0-6 ng Hg/strip and that levels $\geq$7 ng Hg/strip are considered anomalous. Apart from two highly anomalous levels (46 and 78 ng Hg/strip) all concentrations range between 0-15 ng Hg/strip. Results for lines 1-4 are presented in Figures 5a-d, respectively.

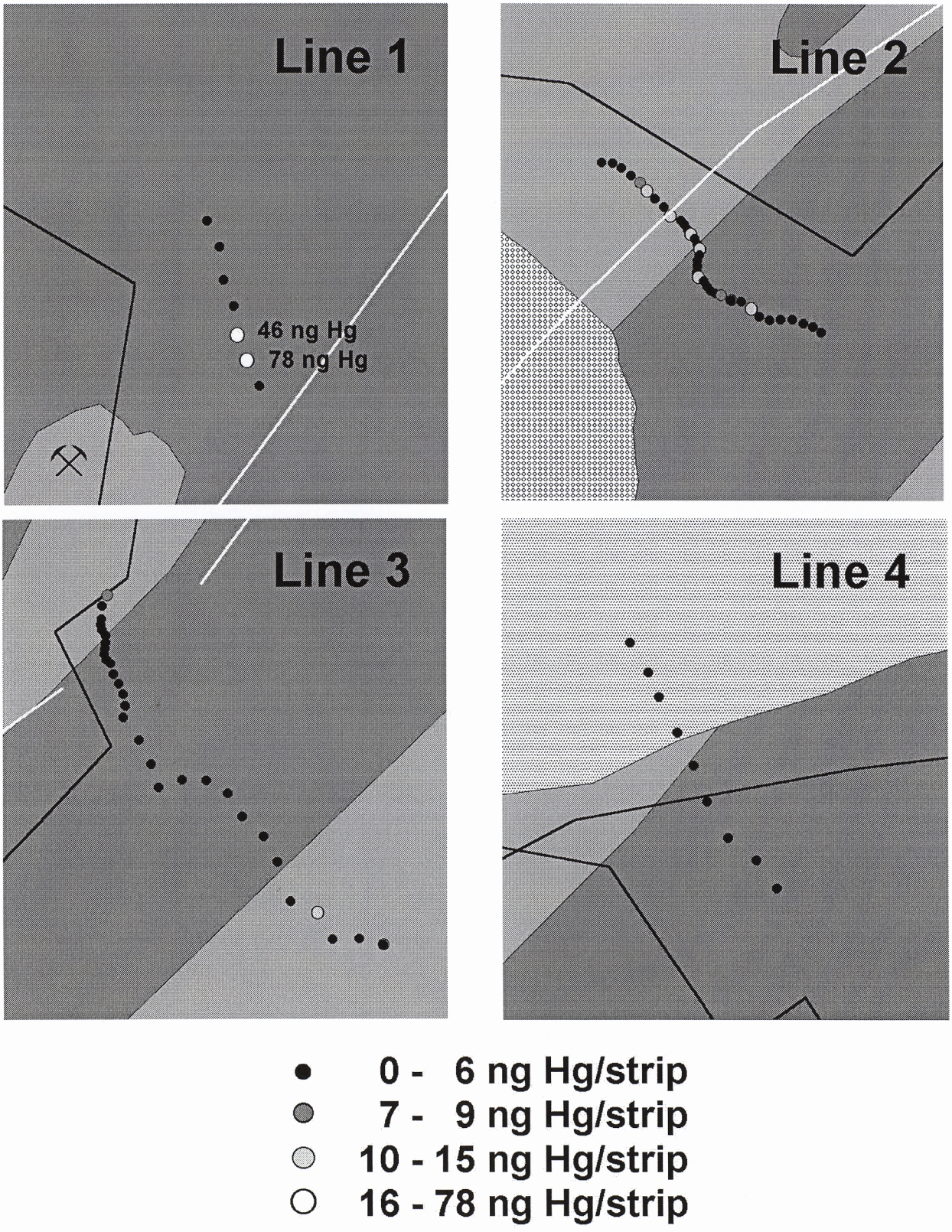

Figure 5a - 5d. Mercury in soil gas results for Line 1 to Line 4. Refer to Figure 3 for Legend.

Line 1

The highest Hg in soil gas values (46 and 78 ng Hg/strip) reported for this study occur at the southern end of Line 1 (Fig. 5a). The two consecutively spaced samples (500 m apart) were collected approximately 4 km northeast of known Au mineralization associated with the former West Caledonia Gold District. The district is characterized by a pair of doubly plunging, northeast-trending anticlines (Horne and Corey, 1994) and epithermal type textures (P. K. Smith, personal communication, 2000). The two anomalous sample sites are located on the inferred north edge of the Tobeatic Shear Zone.

Line 2

Line 2 (Fig. 5b) is characterized by eight anomalous sites (8-15 ng Hg/strip) that are flanked by at least two background values. This pattern was also noted by Rehn and Rehn (1996) across a drill-inferred, deeply buried (up to 160 m of unconsolidated Quaternary overburden) gold ore body. The eight anomalous sites are spatially associated with the Tobeatic Shear Zone and the inferred structural contact between the Goldenville and Halifax formations.

Line 3

Two single point anomalies (7 and 11 ng Hg/strip) were reported along Line 3 (Fig. 5c), one at the north end of the line and one at the south end of the line. The northern anomalous sample site is spatially associated with the Tobeatic Shear Zone and the inferred structural contact between the Goldenville and Halifax formations. The southern anomalous sample site is spatially associated with the Goldenville-Halifax Transition Zone.

Line 4

There were no anomalous Hg in the soil gas levels reported along Line 4 (Fig. 5d).

Discussion

The data indicate that there is a strong spatial relationship between Tobeatic Shear Zone, and anomalous Hg in the overlying soil gas. Rehn and Rehn (1996) also noted a positive relationship between vertical structures and anomalous Hg in soil gas. The inferred trace of the East Kemptville Shear Zone returned no anomalous Hg levels in the soil gas. The lack of response may be a function of sample distribution, or an absence of Hg in the shear zone at this location.

There also appears to be a positive relationship between the West Caledonia Gold District and anomalous Hg in soil gas.

Conclusions

Results from the 94 Hg vapor units indicate that several local geological sources of mercury potentially exist in the vicinity of Kejimkujik National Park. These sources include inferred structures and the Goldenville-Halifax Transition Zone. Further, the Quicksilver Systems® Hg vapor flux sampling unit is an effective sampling tool for detecting anomalous surface concentrations of Hg vapor produced by bedrock sources.

Further Studies

Results from the Quicksilver® survey will be compared to Hg results reported from the <63 microns fraction of till samples collected from the same sample site approximately one month earlier.

The placement of additional units to further assess site variance will commence early in 2001. This study is also designed to assess temporal variance over a period of several months. Proposed study areas include (1) the site of the highest Hg in soil gas values (46 and 78 ng Hg/strip) and (2) an additional background site for comparative purposes.

References

Corey, M. C. 1995: Diamond-drilling in the Tobeatic Shear Zone of southwestern Nova Scotia and the potential for epithermal-style base and precious metals; *in* Minerals and Energy Branch, Report of Activities 1994; Nova Scotia Department of Natural Resources, Report 95-1, p. 27-42.

Environment Canada 1998: Mercury in Atlantic Canada: A Progress Report; Canadian Wildlife Service, Sackville, New Brunswick, 117 p.

Evans, A. M. 1993: Ore Geology and Industrial Minerals: An Introduction; Blackwell Scientific Publications, Inc., Oxford, UK, 390 p.

Finck, P. W., Boner, F. J. and Graves, R. M. 1994: Glacial and till clast geology of Kejimkujik Lake, Nova Scotia; Nova Scotia Department of Natural Resources, Map 94-12, scale 1:50 000.

Horne, R. J. and Corey, M. C. 1994: Geological map of Kejimkujik Lake, Nova Scotia; Nova Scotia Department of Natural Resources, Map 94-05, scale 1:50 000.

Kontak, D. J., Mulja, T. and Hingston, R. 1986: The East Kemptville Sn deposit; preliminary results from recent mapping; *in* Tenth Annual Open House and Review of Activities, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Information Series No. 12, p. 97-103.

Rehn, P. and Rehn, W. 1996: Mercury vapor anomalies at the SECTION 30 deposit, Twin Creeks Mine, Nevada; *in* Geology and Ore Deposits of the American Cordillera, eds. A. R. Coyner and P. L. Fahey; Geological Society of Nevada Symposium Proceedings, Reno/Sparks, Nevada, April 1995, p. 769-778.

Rogers, P. J. and Lombard, P. A 1990: Regional geochemical surveys conducted by the Nova Scotia Department of Mines and Energy from 1957 to 1989; Nova Scotia Department of Mines and Energy, Open File Report 90-017.

Stea R. R., Conley, H. and Brown, Y. (compilers) 1992: Surficial geology of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Map 92-3, scale 1:500 000.