LAKE-SEDIMENT AND WATER-SAMPLING SURVEY IN THE KYFANAN LAKE REGION, SOUTHEASTERN LABRADOR

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Geochemistry, Geophysics and Terrain Sciences

ABSTRACT

The 2014 program of lake-sediment and water sampling in southeastern Labrador covered one partial and three complete NTS 1:50 000 map areas, over which, a total of 578 sites were sampled at an average density of one site per 5.0 km². Results for the analysis of 48 elements in sediment samples, and 29 elements in water samples, will be available during 2015. The sampled area is underlain by rocks of the Interior Magmatic Belt and Exterior Thrust Belt of the southeastern Grenville Province. The area has been the focus of recent exploration for magmatic Ni–Cu–Co–platinum group metals and pegmatite-hosted U.

INTRODUCTION

This report summarizes a 2014 helicopter-supported lake-sediment and water-sampling program carried out by the Geological Survey of Newfoundland and Labrador (GSNL) over an area of approximately 2900 km² in the Kyfanan Lake area of southeastern Labrador. The sampling area covers NTS map areas 13A/03, 13A/06, 13A/11 and part of 13A/14. The work is the continuation and completion of a detailed lake-sampling program inaugurated in 2006, and continued in 2007 and 2011 over the area to the north, south and east (McConnell and Ricketts, 2010; Amor, 2013; Figure 1).

Fieldwork was based in Mary’s Harbour (52.303°N 55.848°W; NTS map area 3D/05), and two fuel caches were established: on the Trans-Labrador Highway northwest of Port Hope Simpson at 52.895°N 57.145°W (NTS map area 13A/14); and near the end of the Bobby’s Pond woods road at the centre of NTS 13A/07 (52.528°N 56.286°W).

GEOLOGY AND MINERALIZATION

The sampled area is underlain by rocks of the Grenville Province (van Nostrand, 1992; Wardle et al., 1997; van Nostrand and Gower, 2010; Gower, 2010; Figure 2), which have been divided into the northern, Exterior Thrust Belt and the southern, Interior Magmatic Belt. In the north (NTS map areas 13A/11 and 14, and the northern part of NTS 13A/06), rocks of the Exterior Thrust Belt comprise the following (summary descriptions from (Gower, 2010; van Nostrand and Gower, 2010):

- a) Late Paleoproterozoic (1800–1710 Ma) fine- to medium-grained pelitic schist and gneiss (Unit P₃₆sp), quartzite (Unit P₃₆sq) and quartz-feldspar psammitic schist and gneiss (Unit P₃₆ss);
- b) Late Paleoproterozoic (1710–1660 Ma) foliated to gneissic diorite to quartz diorite (Unit P₃₆dr), foli-
Figure 2. Synoptic geological map of sampled area (Gower et al., 1992; Gower, 2010; van Nostrand and Gower, 2010). U – Uranium, Fe – Iron, Pyr – Pyrite, Mic – Mica.
ated to gneissic granodiorite (Unit P3Bgd), foliated to gneissic megacrystic/porphyritic granitoid rocks (Unit P3Bgp), foliated to gneissic quartz monzonite (Unit P3Bmq), foliated to gneissic granite and alkali-feldspar granite (Unit P3Bgr), amphibolite (Unit P3Bam), anorthosite and leucogabbrosomite (Unit P3Ban), leucogabbrosomite and leucogabbro (Unit P3Bln), amphibolite and mafic granite (Unit P3Bagr) and gabbro and norite (Unit P3Brg);

c) Late Paleoproterozoic (1660–1600 Ma) mafic granulite (Unit P3Caag), anorthosite and leucogabbronorite (Unit P3Cana), leucogabbronorite and leucogabbro (Unit P3Clgn), gabbro and norite (Unit P3Crg), alkali-feldspar granite, granite and quartz syenite (Unit P3Cga), megacrystic/porphyritic granite to granodiorite (Unit P3Cgp), quartz monzonite (Unit P3Cmq), and monzonite (Unit P3Cmz);

d) Early Mesoproterozoic (1600–1350 Ma) anorthosite (Unit M1an), diorite (Unit M1dr), granitite (Unit M1gr), monzonite to quartz monzonite (Unit M1mq), syenite, alkali-feldspar syenite and quartz syenite (Unit M1yq) and ultramafic rocks (Unit M1um); and

e) Early Neoproterozoic (ca. 985–975 Ma) syenite, quartz syenite and alkali-feldspar syenite (Unit M3cyq); and

e) Early Neoproterozoic (ca. 975–955 Ma) granite to alkali-feldspar granite (Unit M3Dgr), quartz monzonite (Unit M3Dmq); syenite, quartz syenite and alkali-feldspar quartz syenite (Unit M3Dyq) and leucogabbro to leuconorite (Unit M3Dln).

The southern portion of the sampled area (NTS map area 13A/03 and the southern part of NTS 13A/06) is underlain by rocks of the Interior Magmatic Belt, comprising:

a) Late Paleoproterozoic to early Mesoproterozoic (1800–1350 Ma) amphibolite (Unit PMam), granodiorite (Unit PMgd), recrystallized granite and alkali-feldspar granite (Unit PMgr); monzonite and quartz monzonite (Unit PMmq); syenite, alkali-feldspar syenite and quartz syenite (Unit PMyq) and megacrystic/porphyritic granite to quartz monzonite (Unit PMgp);

b) Early Mesoproterozoic (1600–1350 Ma) gabbro, norite and troctolite (Unit M1rg); leucogabbrosomite and anorthositic gabbro (Unit M1ln) and amphibolite (Unit M1am), of the Kyfanan Lake intrusion;

c) Early Neoproterozoic (ca. 985–975 Ma) syenite, quartz syenite and alkali-feldspar syenite (Unit M3yq); and

d) Early Neoproterozoic (ca. 975–955 Ma) granite to alkali-feldspar granite (Unit M3Dgr), quartz monzonite (Unit M3Dmq); syenite, quartz syenite and alkali-feldspar quartz syenite (Unit M3Dyq) and leucogabbro to leuconorite (Unit M3Dln).

There are only eight documented mineral occurrences within the bounds of the sampled area, of which seven, comprising occurrences of pyrite, iron (magnetite) and mica, are classed as indications (Stapleton et al., 2011; Figure 2).

Only one mineral occurrence, the Alexis River Tributary #4, MODS Number 013A/11/U 001, in the northeast corner of NTS map area 13A/11, has the status of showing. It consists mainly of limited pegmatite-hosted mineralization, within late Paleoproterozoic psammitic schist and gneiss (Unit P3Bagr) and granite (Unit P3Bgr) although the highest U3O8 analysis (0.753%) in drillcore was returned for what was logged as biotite-rich metapyroxenite (Carpenter, 2009).

SURFICIAL GEOLOGY AND ENVIRONMENT

No striation measurements have been made in the area covered by the 2014 survey. To the east, measured ice-flow directions are predominantly eastward; the five striation measurements within the area sampled in 2011 range between 077° and 092° (Taylor, 2001; Geological Survey of Newfoundland and Labrador, 2014).

Regional mapping of the surficial deposits (Klassen et al., 1992) indicates that the sampled area is mainly covered by undifferentiated till, rare glaciofluvial sediment in river valleys, and ablation till in the northwest (Figure 3). More detailed surficial mapping on NTS map area 13A/14 by McCuaig (2002a) indicates that the area sampled in 2014 is underlain by fluvial and glaciofluvial material in the north, and a mix of organic material and patches of hummocky till in the south. The marine limit is believed to have been almost 150 m above the present sea level (McCuaig, 2002b); about 9 km of the lower Alexis River valley, in the east of NTS map area 13A/11, falls below this elevation.

Elevations in the sampled area vary from less than 80 m above sea level (asl) where the Alexis River exits NTS map area 13A/11 at 52.6516°N 57.0000°W, to greater than 530 m asl at 52.0765°N 57.0868°W, in the southeast of NTS 13A/03. Major watercourses comprise the eastward-flowing St. Lewis River in NTS map area 13A/06, the eastward-flowing Alexis River in NTS 13A/11, and the northwest-flowing Paradise River in NTS 13A/14.

PREVIOUS WORK – GOVERNMENT

A geological map of Labrador was compiled by Wardle et al. (1997). Bedrock mapping has been completed in the survey area by Gower et al. (1988), Gower (2010) and van Nostrand and Gower (2010).

Lakes in the area were sampled as part of the federal National Geochemical Reconnaissance (NGR) Program (Geological Survey of Canada, 1984). Presumably owing to
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the lack of lakes large enough to sample, which was also noted during the current program, the average sample density was only one per 31 km$^2$ in NTS map areas 13A/03, 13A/06, 13A/11 and 13A/14, compared to the overall density in Labrador of one sample per 16 km$^2$.

The sediments collected during the NGR program were initially analyzed for Ag, As, Cd, Co, Cu, Fe, Mn, Mo, Ni, Pb, V and Zn using Atomic-Absorption Spectrophotometry (AAS) after aqua-regia digestion; F by Ion-Specific Electrode (ISE) analysis; Hg by cold-vapour-AAS; U by Neutron Activation/Delayed Neutron Counting (DNC), and Loss-on-Ignition by gravimetry. The water samples were analyzed for fluoride by ISE, and for U by fluorimetry. The lake-sediment samples were subsequently recovered from the archives in the mid-1980s and analyzed by Instrumental Neutron-Activation Analysis (INAA) for Au, Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Sm, Sn, Sr, Ta, Tb, Th, U, W, Yb and Zn (Friske et al., 1994).

Results of the NGR program indicate three areas of enrichment:

a) A lake-sediment sample collected at 52.7420°N, 57.1419°W, in the northeast corner of NTS map area 13A/11, returned U values of 926 ppm (as analyzed by DNC) and 1030 ppm (as analyzed by INAA); both analyses were the highest for their respective elements in all of Labrador. Other elements showing regional or local maxima in one or more samples in the vicinity include Au, Be, Dy, Mo, P, Tb and Th in lake sediment and U and fluoride in lake water. A local U maximum is defined by several neighbouring sediment samples, extending along regional strike for at least 25 km to the southeast (i.e., outside the area of 2014 coverage); this was confirmed by detailed lake-sediment and water sampling carried out by the GSNL in 2011 (Amor, 2013).

b) A local maximum of Ni, Cu and to a lesser extent Co and Cr over the Kyfanan Lake intrusion in the centre and west of NTS map area 13A/06.

c) Scattered anomalous and elevated values of REE, Nb, P and Ta in lake sediment, and fluoride in lake water, in NTS map area 13A/03, probably associated with the Rivière Bujeault Headwaters quartz syenite, the Upper St. Lewis River (east) monzonite, the Upper St. Lewis River (west) granite, and related intrusions (Gower et al., 1991; Figure 2).

McCuaig (2002b) collected 56 till samples during the surficial mapping of NTS map area 13A/14, as part of a larger surficial mapping and sampling program that also covered NTS 13A/10 and 13A/15. These were analyzed for Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Hg, Ir, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Th, U, W, Y, Zn by INAA; Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Fe, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Sc, Sr, Ti, V, Y, Zn and Zr by ICP-OES after multiacid (HF-HNO$_3$-HClO$_4$) digestion; Ag and Rb by AAS after HNO$_3$ digestion; and Pd and Pt by fire-assay ICP-MS.

There is minor overlap between the extent of this work, and the coverage of the 2014 lake-sampling program.

The areas to the north, east and south of that sampled in 2014 were the subject of earlier detailed lake-sediment and water-sampling programs (McConnell and Ricketts, 2010; Amor, 2013) of which the current study is the continuation and completion. Lake sediment and waters were analyzed for a broad suite of elements by INAA, ICP-OES and ICP-Mass Spectrometry (ICP-MS).

PREVIOUS AND CURRENT WORK – INDUSTRY

The study area has been the focus of past exploration for uranium in early Labradorian (1800–1660 Ma) granites.

Figure 3. Surficial geomorphology of the study area.
and gneissess in NTS map area 13A/11, and magmatic Ni–Cu–Co–platinum-group metal deposits in the early Mesoproterozoic (1600–1350 Ma) Kyfanan Lake (layered, mafic) intrusion in NTS map area 13A/06. The work is summarized in Table 1.

**SAMPLE COLLECTION**

Sampling was carried out from a float-equipped Bell 206-LR helicopter. A wooden platform was attached to the port side of the helicopter to facilitate sample retrieval but a winch was not used. Both sediment and water sampling followed procedures developed and described by McConnell (2009). Sample sites were selected by laying a 2 km (4 km²) grid over the area to be sampled and selecting one lake or pond within each cell for sampling. In general, smaller bodies of water were selected in preference to larger ones. In fact, over much of the sampled area the latter, and even the former, were absent; the median area of the sampled lakes, at 0.012 km², is much smaller than that for the sampling programs in western Labrador in 2009 (0.1 km²) and 2010 (0.03 km²), but larger than that for the sampling in 2011 of the area immediately east of the 2014 study area (0.007 km²; Amor, 2013). The overall sampling density of one sample per 5.0 km² falls short of the target density of one per 4.0 km²: a consequence of the paucity or absence of lakes or ponds of any kind in certain areas. A total of 601 samples, including 23 site duplicates, were collected. Figure 4 shows the sample coverage and Table 2 summarizes the sampling statistics, with corresponding 2009, 2010 and 2011 figures for comparison.

**Table 1: Summary of work filed for assessment in sampled area**

<table>
<thead>
<tr>
<th>Company</th>
<th>Year</th>
<th>Assessment File No.</th>
<th>Relevant NTS Sheets</th>
<th>Mapping</th>
<th>Prospecting</th>
<th>Lake Geochemistry</th>
<th>Aeromagnetics</th>
<th>Airborne EM</th>
<th>Airborne Radiometrics</th>
<th>Ground EM</th>
<th>Ground Magnetics</th>
<th>Drilling</th>
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<td>Altius Resources Inc.</td>
<td>2008</td>
<td>013A/0075</td>
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<td>X</td>
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<td>X</td>
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<td></td>
<td>X</td>
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<td>013A/0071</td>
<td>13A/11, 13A/14</td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
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<td>LAB/1241</td>
<td>13A/06</td>
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<td>X</td>
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<td>13A/0037</td>
<td>13A/06</td>
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<tr>
<td>Cartaway Resources Corp.</td>
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<td>13A/0040</td>
<td>13A/06</td>
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<td>13A/0034</td>
<td>13A/06</td>
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<td>Greater Lenora Resources Corp.</td>
<td>1995</td>
<td>013A/06/0029</td>
<td>13A/06</td>
<td>X</td>
<td>X</td>
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<td>RJK Explorations</td>
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**Table 2: Sampling statistics**

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<th>2014</th>
<th>2011</th>
<th>2010</th>
<th>2009</th>
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<tbody>
<tr>
<td>Duration of program (days)</td>
<td>9</td>
<td>19</td>
<td>18</td>
<td>18</td>
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<tr>
<td>Days lost to bad weather</td>
<td>1</td>
<td>3.5</td>
<td>3.5</td>
<td>3</td>
</tr>
<tr>
<td>Total helicopter hours</td>
<td>67.3</td>
<td>98.5</td>
<td>98.1</td>
<td>108.5</td>
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<tr>
<td>Sites sampled</td>
<td>577</td>
<td>850</td>
<td>769</td>
<td>1,018</td>
</tr>
<tr>
<td>Field duplicate sites</td>
<td>24</td>
<td>44</td>
<td>42</td>
<td>51</td>
</tr>
<tr>
<td>Water-only sites</td>
<td>26</td>
<td>25</td>
<td>108</td>
<td>32</td>
</tr>
<tr>
<td>Minimum sampled lake depth</td>
<td>0.1</td>
<td>0.05</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Median sampled lake depth</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Maximum sampled lake depth</td>
<td>22</td>
<td>22</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Median lake area (km²)</td>
<td>0.012</td>
<td>0.007</td>
<td>0.03</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The sampling plan prescribed two duplicate sample sites, randomly selected, in every sequence of 20 sample locations; however, this was not always complied with and the 601 samples include only 24 field duplicates. The areal distribution of duplicate pairs is also somewhat uneven. The two duplicate sites were typically separated by a distance of 50 to 100 m.

The following field parameters were recorded at each site: GPS waypoint number, UTM Zone, UTM Easting, UTM Northing, sample depth, nature of vegetation surrounding the lake, water level, sample colour, sample composition, potential sources of contamination, duplicate sta-
Lake-sediment samples were collected using a tubular steel sampler, fitted with a butterfly valve that opens on impact with the sediment and closes as the sample is retrieved. The device is designed so that once retrieved, it can be inverted and the contained sediment poured into a plastic container and thence into the sample bag. The rope used for retrieving the sampler is marked at 1 m intervals to

**Figure 4. Sample locations within the study area.**

Lake-sediment samples were collected using a tubular steel sampler, fitted with a butterfly valve that opens on impact with the sediment and closes as the sample is retrieved. The device is designed so that once retrieved, it can be inverted and the contained sediment poured into a plastic container and thence into the sample bag. The rope used for retrieving the sampler is marked at 1 m intervals to
estimate water depth at the point of sampling. Samples were stored in pre-numbered, water-resistant Kraft paper bags and air-dried at ambient temperatures for a few days before being shipped to the GSNL laboratory in plastic pails.

Water samples were collected in purified Nalgene bottles that were cleaned in the laboratory by leaching with acid and rinsing with distilled and de-ionized water. After collection, the sample bottles were refrigerated before being shipped in coolers.

SAMPLE PREPARATION AND ANALYSES

Sediment samples were dried at 40°C, before being dis-aggregated using a mortar and pestle and screened through a 180 micron (80 mesh) stainless-steel sieve. Results from the analysis of the following parameters are expected during the first quarter of 2015:

• Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, U, W, Yb, Zn and Zr by INAA
• Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Fe, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Sc, Sr, Ti, V, Y, Zn and Zr by ICP-OES after ‘total’ (HF-HClO₄-HNO₃) digestion
• Ag by AAS after HNO₃ digestion
• F by Fluoride-ion Specific Electrode after Na₂CO₃/KNO₃ fusion
• Loss-on-ignition in muffle furnace (500°C), by gravimetric methods

The water samples will be analyzed for the following parameters:

• pH by Corning combination pH electrode
• Conductivity by Corning conductivity sensor
• F by Fluoride-ion Specific Electrode
• Ca, Fe, K, Mg, Mn, Na, Si, SO₄ by ICP-OES
• Al, Ba, Be, Co, Cr, Cu, Li, Mo, Ni, P, Pb, Sr, Ti, V, Y, Zn by ICP-OES/ultrasonic nebulizer
• U by ICP-MS

With the exception of pH, conductivity and fluoride ion, all water analyses take place after 0.45 micron millipore filtration and HNO₃ acidification.

SUMMARY OF FIELD-SAMPLING DATA

The areal distribution and relative frequencies of sample depths, sample colours, sediment textural types and shoreline vegetation types are summarized in Figures 3–6.

Eighty-five per cent of the samples were collected at water depths of 2 m or less (Figure 5), compared to 64% in
the Alexis River region. Sampling depths are conspicuously deeper in the southeastern corner of NTS map area 13A/11, and the northwestern corner of both NTS 13A/11 and NTS 13A/14. The median water depth, at 1.0 m, was less than that for the corresponding sampling programs in 2009 (2.0 m), and 2010 and 2011 (both 1.5 m). The deepest sample was recovered at a water depth of 22 m in the northeast of NTS map area 13A/11; the lake in question is the same one that returned Labrador’s highest U values in the NGR survey (see above).

Sampled sediments were mostly (91%) reported as brown or chocolate brown (Figure 6) and these two types occur together over most of the sample area. There are no conspicuous exceptions to this generalization.
Samples consisting of organic ooze represent the most commonly encountered (56%) compositional type. Organic peaty material makes up 29% of the total (Figure 7). These are intermixed over most of the sampled area, with the exception of the northwestern corner of NTS map area 13A/14 and the north of NTS 13A/06; samples collected in these areas, making up 13% of the total, consist of the clastic fine-grained type. Clastic, coarse-grained samples only account for 2% of the total.

Forest, and mixed forest and swamp, collectively account for 64% of the sampled lakes’ shoreline vegetation types (Figure 8). Of the other types, there are conspicuous concentrations of swamp in NTS map area 13A/03 and in the south of NTS 13A/06, amounting to 26% of the total. The centre of NTS 13A/11 has been extensively burned; 9% of the sampled lakes have burned shoreline vegetation.

SUMMARY

The detailed sampling of lake sediments and waters in southeastern Labrador was continued in the summer of 2014 using a helicopter-supported lake-sampling program centred on Kyfan Lake. A total of 578 sites were sampled over a two-week period, at an overall density of one per 5.0 km². Sampled lake depths ranged from 0.1 to 22 m and the median area of the lakes sampled was 0.012 km².

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