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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 km^2. 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 km^2 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):

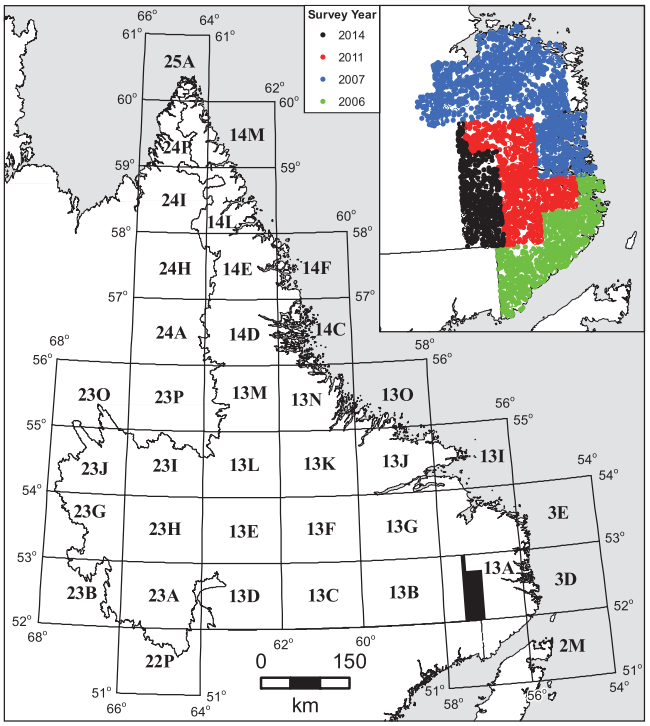

Figure 1. *Area of sample coverage. Inset: lake-sampling coverage in southeastern Labrador by year. Blue: 2006; Green: 2007; Red: 2011; Black: 2014.*

a) Late Paleoproterozoic (1800–1710 Ma) fine- to medium-grained pelitic schist and gneiss (Unit P_{3A}sp), quartzite (Unit P_{3A}sq) and quartz-feldspar psammitic schist and gneiss (Unit P_{3A}ss);
b) Late Paleoproterozoic (1710–1660 Ma) foliated to gneissic diorite to quartz diorite (Unit P_{3B}dr), foli-

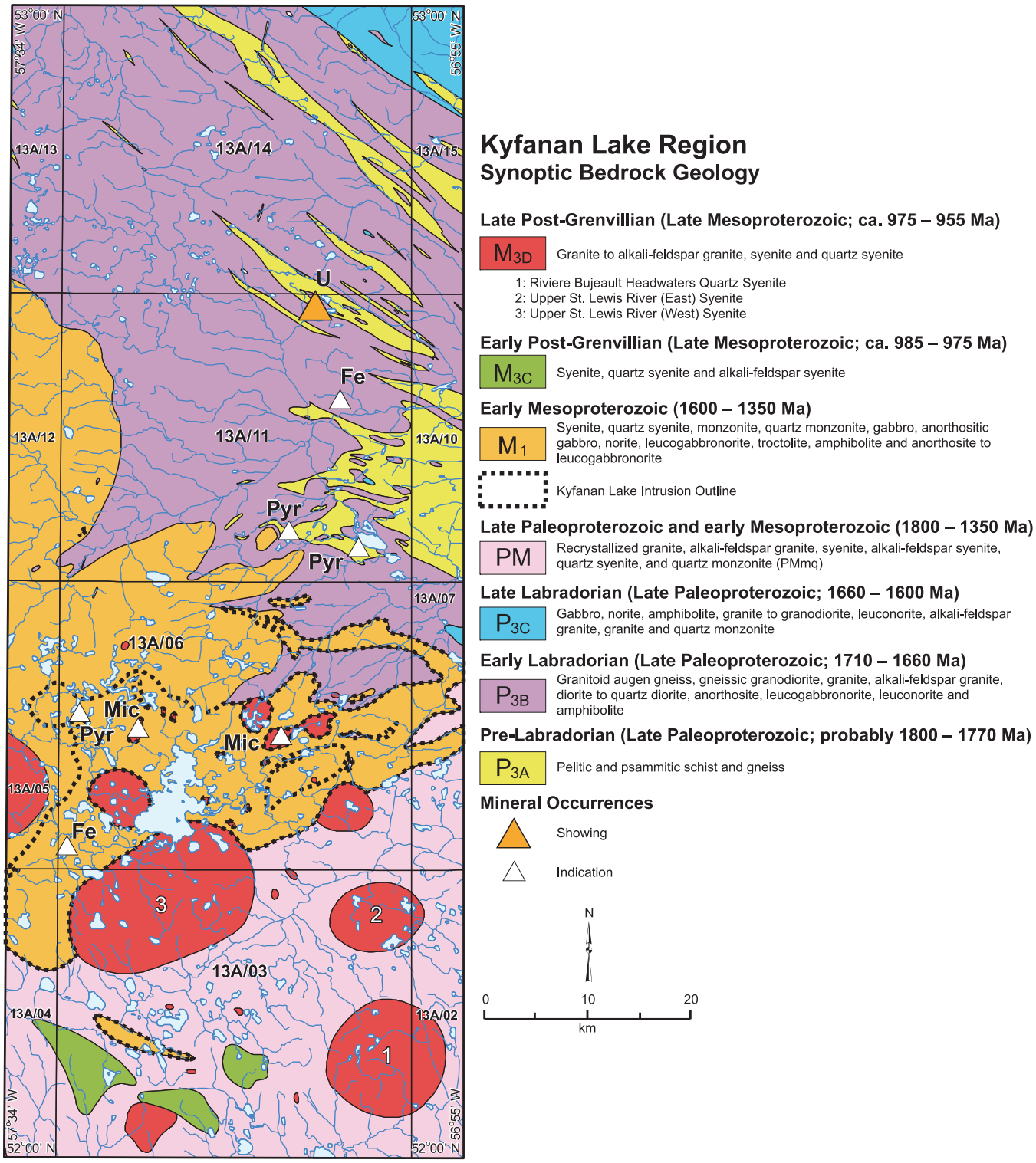

Figure 2. *Synoptic geological map of sampled area (Gower* et al.*, 1992; Gower, 2010; van Nostrand and Gower, 2010). U – Uranium, Fe – Iron, Pyr – Pyrite, Mic – Mica.*

ated to gneissic granodiorite (Unit P_{3B}gd), foliated to gneissic megacrystic/porphyritic granitoid rocks (Unit P_{3B}gp), foliated to gneissic quartz monzonite (Unit P_{3B}mq), foliated to gneissic granite and alkali-feldspar granite (Unit P_{3B}gr), amphibolite (Unit P_{3B}am), anorthosite and leucogabbronorite (Unit P_{3B}an), leucogabbronorite and leucogabbro (Unit P_{3B}ln), amphibolite and mafic granulite (Unit P_{3B}ag) and gabbro and norite (Unit P_{3B}rg);

c) Late Paleoproterozoic (1660–1600 Ma) mafic granulite (Unit P_{3C}ag), anorthosite and leucogabbronorite (Unit P_{3C}an), leucogabbronorite and leucogabbro (Unit P_{3C}ln), gabbro and norite (Unit P_{3C}rg), alkali-feldspar granite, granite and quartz syenite (Unit P_{3C}ga), megacrystic/porphyritic granite to granodiorite (Unit P_{3C}gp), quartz monzonite (Unit P_{3C}mq), and monzonite (Unit P_{3C}mz);

d) Early Mesoproterozoic (1600–1350 Ma) anorthosite (Unit M_1an), diorite (Unit M_1dr), granite (Unit M_1gr), monzonite to quartz monzonite (Unit M_1mq), syenite and quartz syenite (Unit M1yq) and ultramafic rocks (Unit M_1um); and

e) Late Mesoproterozoic (1200–900 Ma) intrusions of granite to alkali-feldspar granite (Unit M_{3D}gr), and syenite and quartz syenite (Unit M_{3D}yq).

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 M_1rg); leucogabbronorite and anorthositic gabbro (Unit M_1ln) and amphibolite (Unit M_1am), of the Kyfanan Lake intrusion;

c) Early Neoproterozoic (*ca.* 985–975 Ma) syenite, quartz syenite and alkali-feldspar syenite (Unit M_{3c}yq); and

d) Early Neoproterozoic (*ca.* 975–955 Ma) granite to alkali-feldspar granite (Unit M_{3D}gr), quartz monzonite (Unit M_{3D}mq); syenite, quartz syenite and alkali-feldspar quartz syenite (Unit M_{3D}yq) and leucogabbro to leuconorite (Unit M_{3D}ln).

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 P_{3A}ss) and granite (Unit P_{3B}gr) although the highest U_3O_8 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 glacofluvial 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 northwestward-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

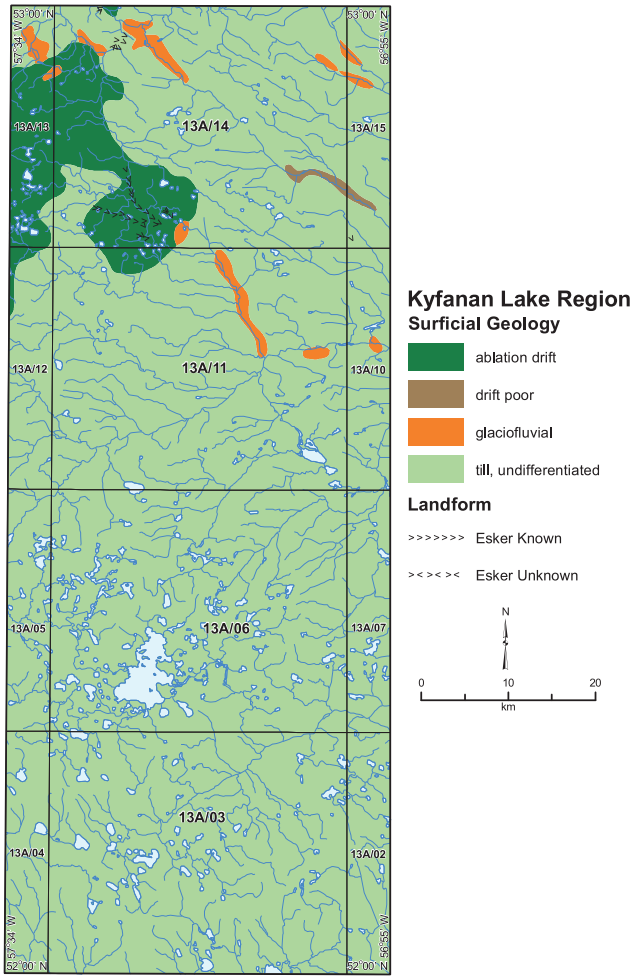

Figure 3. *Surficial geomorphology of the study area.*

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, Ni, Rb, Sb, Sc, Sm, 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, U1, W1, Yb and 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

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

Company	Year	Assessment File No.	Relevant NTS Sheets	Mapping	Prospecting	Lake Geochemistry	Aeromagnetics	Airborne EM	Airborne Radiometrics	Ground EM	Ground Magnetics	Drilling
Altius Resources Inc.	2008	013A/0075	13A/11, 13A/14		X		X			X		
Altius Resources Inc.	2009	013A/0071	13A/11, 13A/14	X	X	X						X
Cartaway Resources Corp.	1996	LAB/1241	13A/06				X	X	X			
Cartaway Resources Corp.	1996	13A/0037	13A/06									X
Cartaway Resources Corp.	1996	13A/0040	13A/06								X	
Cartaway Resources Corp.	1997	13A/0034	13A/06		X							
Greater Lenora Resources Corp., RJK Explorations	1995	013A/06/0029	13A/06				X	X				
Greater Lenora Resources Corp., RJK Explorations	1996	013A/06/0042	13A/06							X		
Greater Lenora Resources Corp., RJK Explorations	1997	013A/06/0030	13A/06	X	X							

and gneisses 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 km^2) 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 km^2, is much smaller than that for the sampling programs in western Labrador in 2009 (0.1 km^2) and 2010 (0.03 km^2), but larger than that for the sampling in 2011 of the area immediately east of the 2014 study area (0.007 km^2; Amor, 2013). The overall sampling density of one sample per 5.0 km^2 falls short of the target density of one per 4.0 km^2: 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 2. Sampling statistics

	2014	2011	2010	2009
Duration of program (days)	9	19	18	18
Days lost to bad weather	1	3.5	3.5	3
Total helicopter hours	67.3	98.5	98.1	108.5
Sites sampled	577	850	769	1,018
Field duplicate sites	24	44	42	51
Water-only sites	26	25	108	32
Minimum sampled lake depth (m)	0.1	0.05	0.3	0.2
Median sampled lake depth (m)	1.0	1.5	1.5	2.0
Maximum sampled lake depth (m)	22	22	15	14
Median lake area (km^2)	0.012	0.007	0.03	0.1

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-

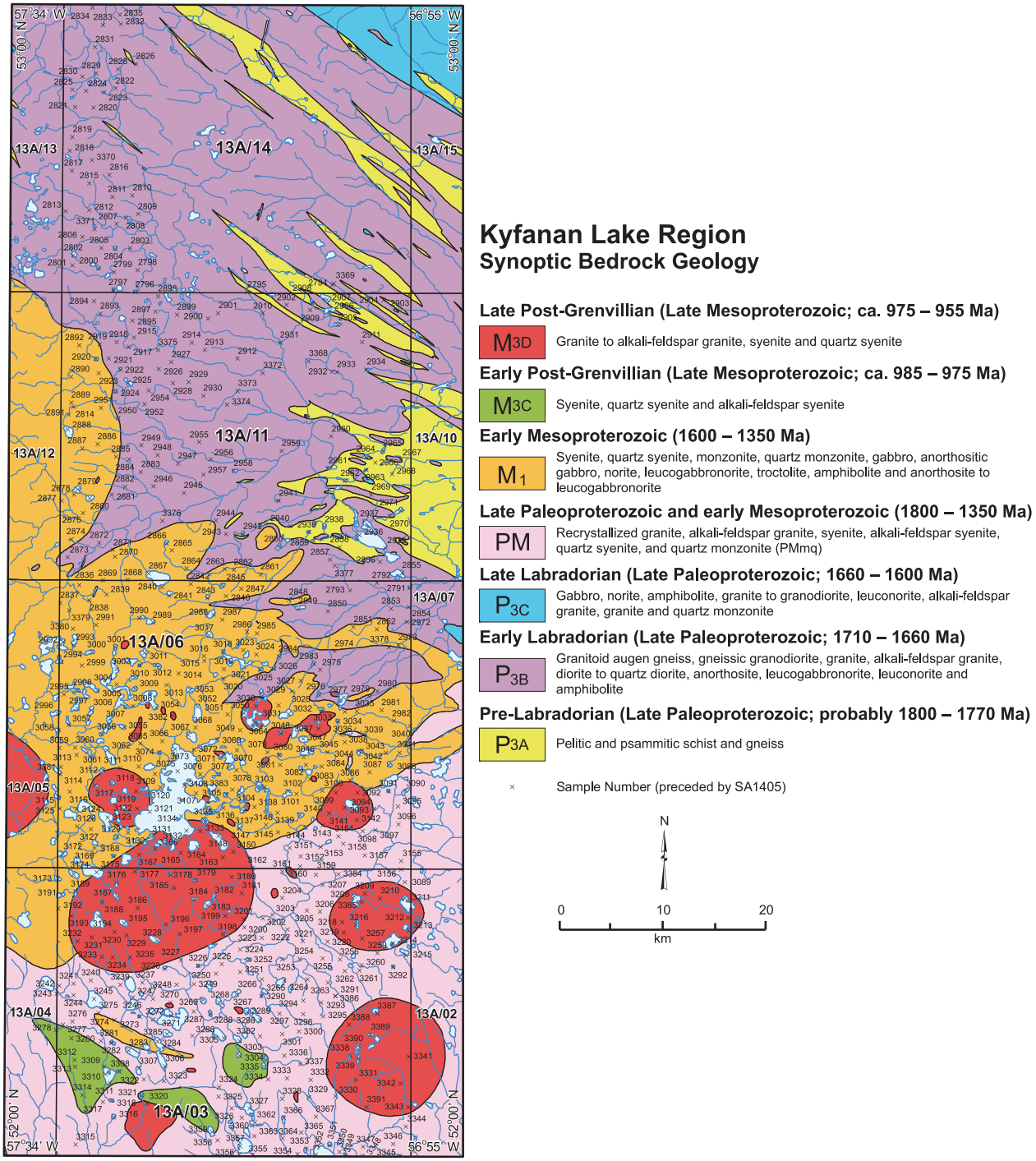

Figure 4. *Sample locations within the study area.*

tus, presence and nature of proximate mineralization, and water colour, suspended matter, date, sampler's initials and freehand remarks. The NTS 1:50 000-map sheet number, lake area and lithological classification of the upstream drainage cell were also documented subsequent to the sampling.

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 40ºC, before being disaggregated 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-$HClO_4$-HNO_3) digestion
- Ag by AAS after HNO_3 digestion
- F by Fluoride-ion Specific Electrode after Na_2CO_3/KNO_3 fusion
- Loss-on-ignition in muffle furnace (500ºC), 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, SO_4 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 HNO_3 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

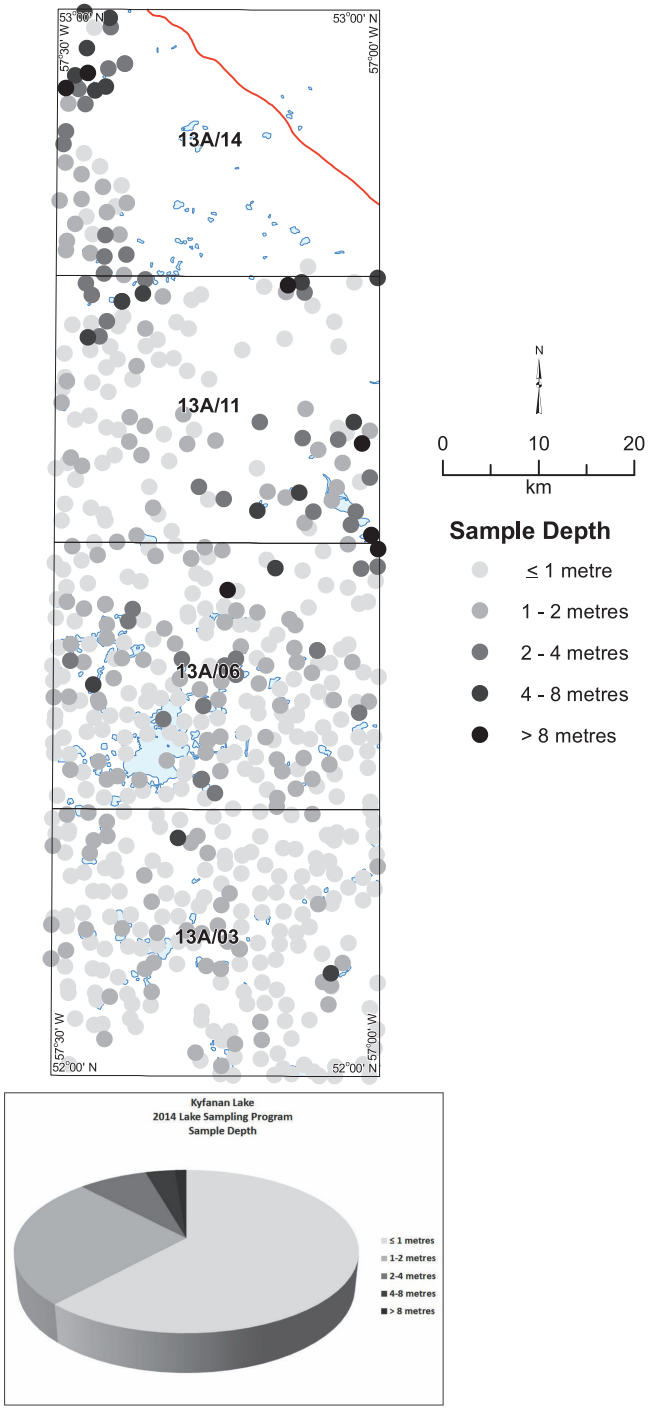

Figure 5. *Areal distribution of lake depths at sample locations and pie-chart showing frequency of sample depth classes in sampled lakes.*

2011 in the Alexis River region to the east, 72% in the Fraser Lake region (western Labrador) in 2010 and 75% in the Knox Lake region (western Labrador) in 2009. Furthermore, 1% of the samples were collected at water depths exceeding 8 m, compared to 1% at Knox and Fraser lakes, and 10% in

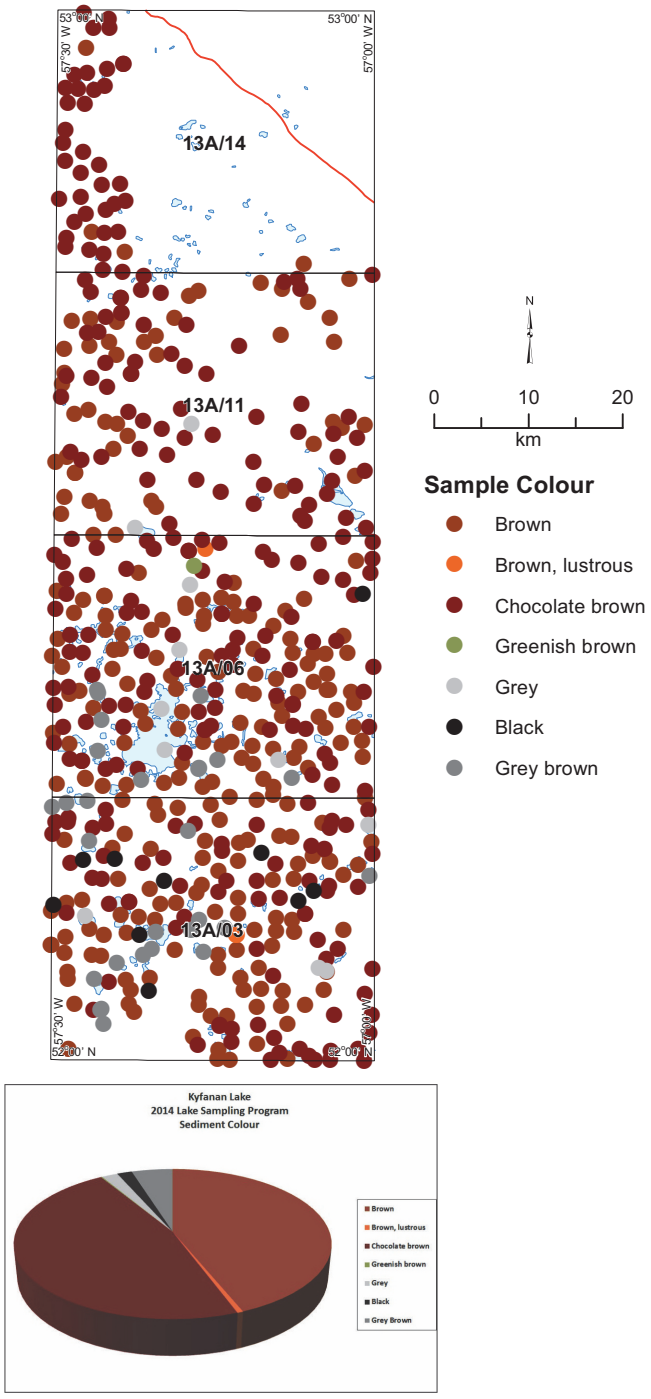

Figure 6. *Areal distribution of sediment colours at sample locations and pie-chart showing frequency of sediment colours sampled.*

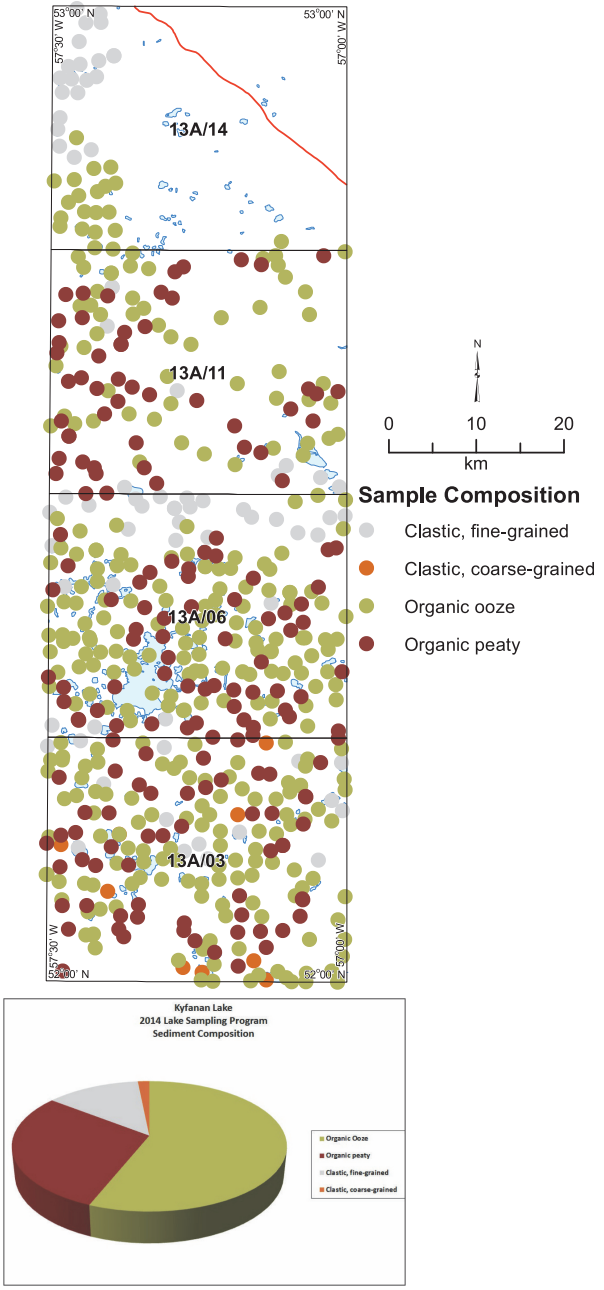

Figure 7. *Areal distribution of sediment composition at sample locations and pie-chart showing frequency of sediment textures sampled.*

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.

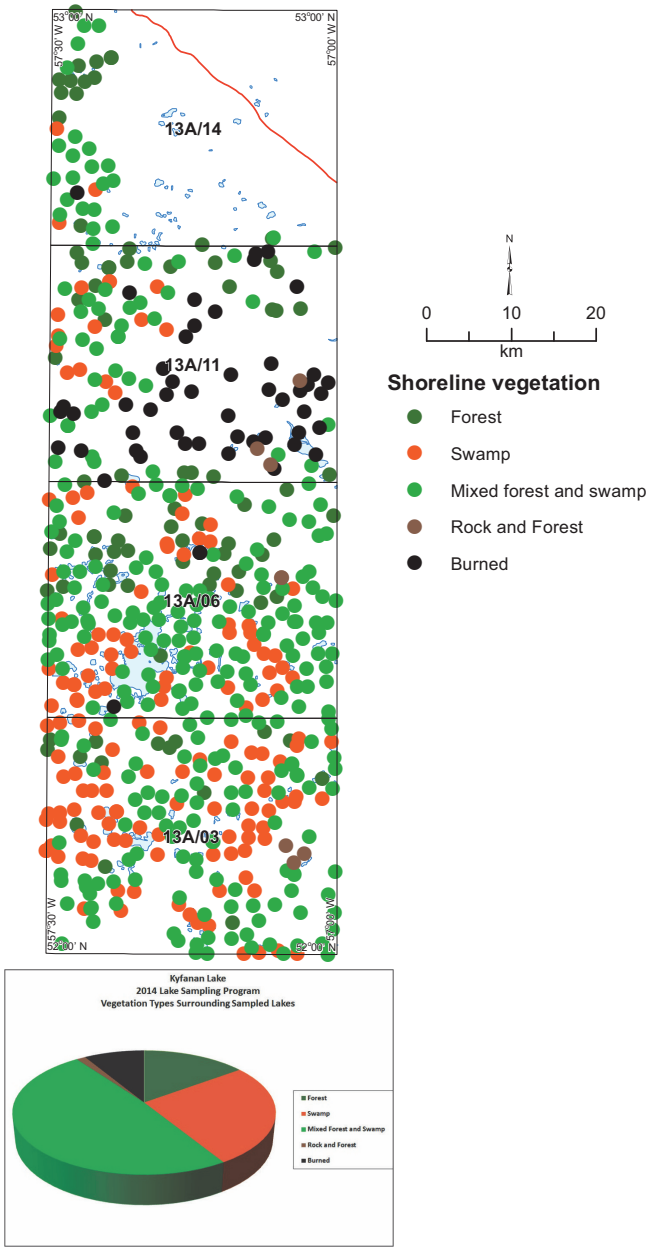

Figure 8. *Areal distribution of vegetation types at sample locations and pie-chart showing frequency of vegetation types surrounding sampled lakes.*

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 Kyfanan Lake. A total of 578 sites were sampled over a two-week period, at an overall density of one per 5.0 km^2. Sampled lake depths ranged from 0.1 to 22 m and the median area of the lakes sampled was 0.012 km^2.

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