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Foreword
The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2016, GEM program has successfully carried out 17 research activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Summary
This activity report summarizes accomplishments of the GEM 2 Hudson-Ungava surficial activities focused on northeast Quebec and west central Labrador. These activities are being carried out in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec (MERNQ) and the Geological Survey of Newfoundland and Labrador (GSNL). This report complements the first two years' activity reports that were published by McClenaghan et al. (2014, 2015). The study area is underlain by Precambrian rocks of the New Quebec Orogen and southern Core Zone. Surficial sediments and landforms include thin veneers of glacial sediments (till), thicker glacial deposits of ribbed moraine and streamlined sediments, small esker systems, and glacial lake deposits in low lying areas.

The overall objective of these activities is to produce new regional geoscience data including surficial geology, geochemistry and radiometric maps to support natural resource exploration and responsible resource development in the Hudson-Ungava region. Activities include surficial and bedrock mapping, till geochemistry and indicator mineralogy, lake sediment geochemistry, geochemical database management and gamma ray spectrometry studies.

Surficial mapping led to an improved understanding of the surficial and bedrock geology of the study area and identification of key areas for more focused mapping and sampling in subsequent field seasons. Laboratory work led to improved sample processing and examination techniques for till samples. Data management has facilitated web access to GEM 1 and GEM 2 publications and data.

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McClenaghan, M.B., Paulen, R.C., Rice, J.M., McCurdy, M. W., Fortin, R., Spirito, W.A., Adcock, S., Ross, M., Pyne, M., and Dubé-Loubert, H., 2015. Report of activities for the Core Zone: 2015 surficial geology, geochemistry, and gamma-ray spectrometry studies in northern Quebec and Labrador; Geological Survey of Canada, Open File 7946.

Chapter 1 Project Overview

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Introduction

Bedrock mapping and mineral resource exploration in northern Quebec and Labrador is challenging because information about the bedrock geology is poorly documented and, in parts, bedrock is covered by surficial (glacial) sediments deposited by a complex sequence of glacial flows related to a migrating ice divide. For significant parts of northern Quebec and Labrador, there are no surficial geology maps, till geochemical data or indicator mineral knowledge. This lack of information results in poorly understood drift thickness, glacial history, and dispersal mechanisms and ultimately hinders mineral exploration.

To address these knowledge gaps and support resource exploration, the GSC as part of the GEM 2 Program and in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec (MERNQ) and the Geological Survey of Newfoundland & Labrador (GSNL) are conducting new surficial mapping and surficial geochemical studies as part of an integrated regional mapping program centred on Archean "Core Zone" rocks between the Torngat Orogen to the east and the New Quebec Orogen to the west (Wardle et al., 2002) (Figs 1.1, 1.2). These surficial activities will produce new regional geoscience data that will be used to greatly increase geological knowledge and support natural resource exploration and responsible resource development.

Activity reports summarizing field and laboratory activities in the first two years of the project were published in 2014 and 2015 (McClenaghan et al., 2014, 2015). This open file is the third activity report for the project and focuses on activities for 2016. Bedrock mapping and geochronology activities in 2016 for the entire Core Zone are summarized in Corrigan et al. (2016).

Scientific question to be addressed

The overall scientific question being addressed by these research activities is: how can improved bedrock knowledge, surficial mapping, surficial geochemistry, and indicator mineral sampling facilitate exploration and support resource discovery in the Hudson-Ungava region?

Goals and objectives

The specific goals and objectives include:

- Develop new glacial dispersal models to support increased exploration effectiveness and successes in Quebec and Labrador;
- Develop and improve exploration geochemistry methods to encourage exploration in prospective regions using till geochemistry, indicator minerals, and lake sediment geochemistry;
- Transfer new geoscience knowledge to the mineral exploration industry and academia through workshops, public presentations, conference posters, and talks;
- Increase the content, promotion, and awareness of the GSC's Canadian Database of Geochemical Surveys as an efficient exploration tool;

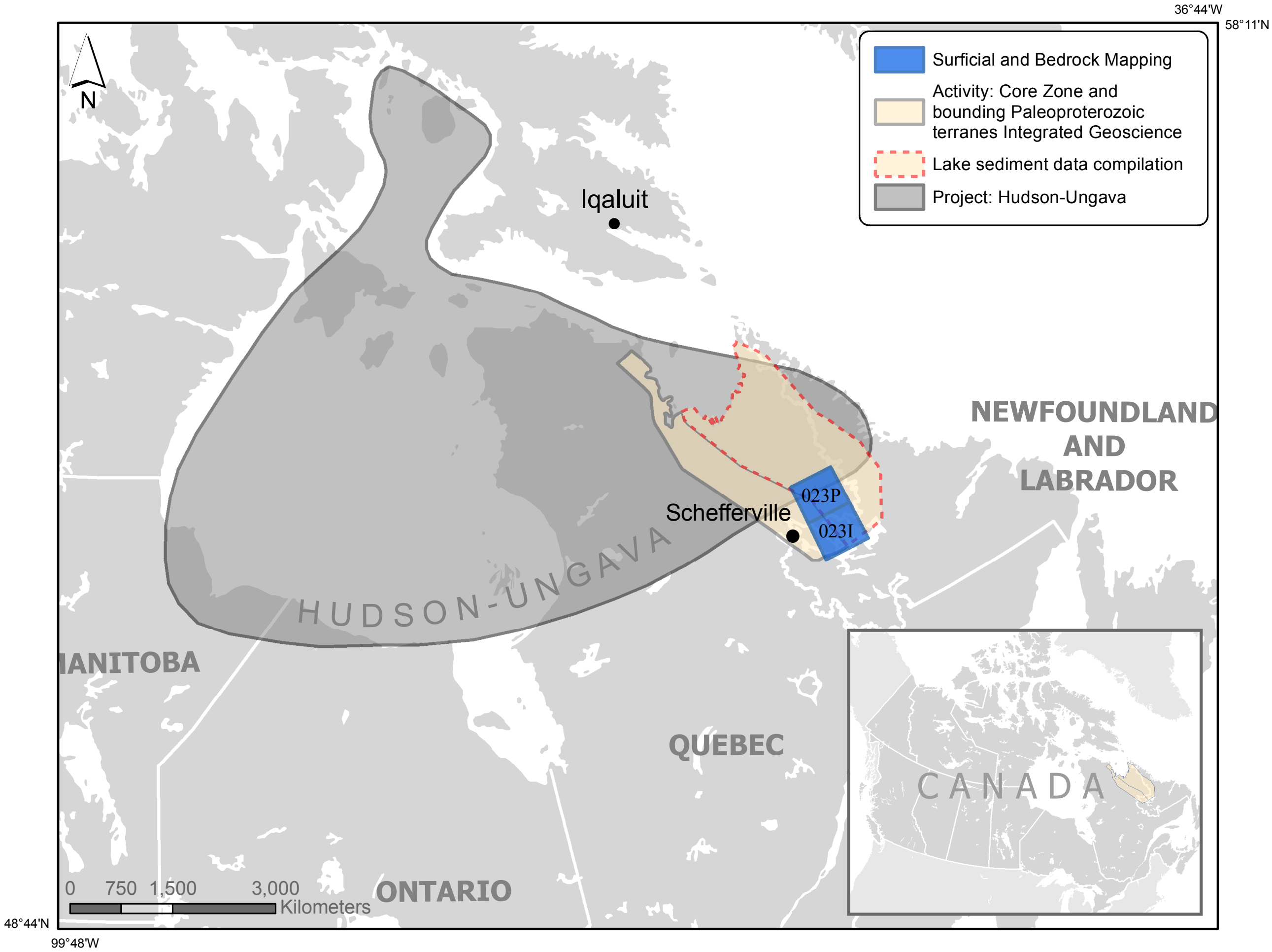

Figure 1.1. Location of the Core Zone and bounding terranes study area (beige polygon), south Core Zone surficial and bedrock mapping area (blue box), and the Core Zone lake sediment geochemical data compilation area (red dashed line) within the overall Hudson-Ungava GEM 2 project area (grey polygon).

• Increase bedrock knowledge with a view to determining the nature and heritage of crust exposed between the Archean North Atlantic and Superior cratons, given that mineral exploration strategies are predicated by whether the medial "core zone" shows affinity to the Archean Rae craton, to cryptic Meta-Incognita terrane, or constitutes a distinct crustal domain/block;
• Determine the timing of major penetrative deformation across the southern core zone, and assess its character and timing in light of current tectonic models involving 1.87 Ga collision with North Atlantic craton to the west and ca. 1.82 Ga collision with Superior craton to the east;
• Mentor and train highly qualified personnel (HQP).

Canadian Database of Geochemical Surveys
The Canadian Database of Geochemical Surveys (CDoGS) stores geochemical data and metadata from GEM and other surveys (Adcock et al., 2013). The public interface to the

database can be found at http://geochem.nrcan.gc.ca. During the past year, the database has continued to grow. It currently holds over 8 million geochemical analyses for samples of various types collected across Canada. Metadata for surveys carried out by the GSC and the Quebec (MERNQ) and Labrador (DNRNL) provincial geological surveys in the Core Zone and surrounding areas have been added to the database. New survey data from the Hudson-Ungava Core Zone project are being added as they become available.

All of the analytical data for regional National Geochemical Reconnaissance lake sediment surveys from Labrador have been imported into the database, including new ICP-ES data (McConnell and Finch, 2012). Figure 1.3 shows the ICP-ES data for Ni in 1665 lake sediment samples collected in Labrador in NTS 23G, H, I and J. Current work is focusing on developing generic database procedures to automate the compilation of compatible data into single datasets that can then be delivered to end-users as MS Excel files. As an example, an end-user will be able to quickly obtain all of the data for Ni-aqua regia-AAS analyses in NGR lake sediments for the entire country. This new capability will dramatically reduce the effort required to produce regional geochemical maps.

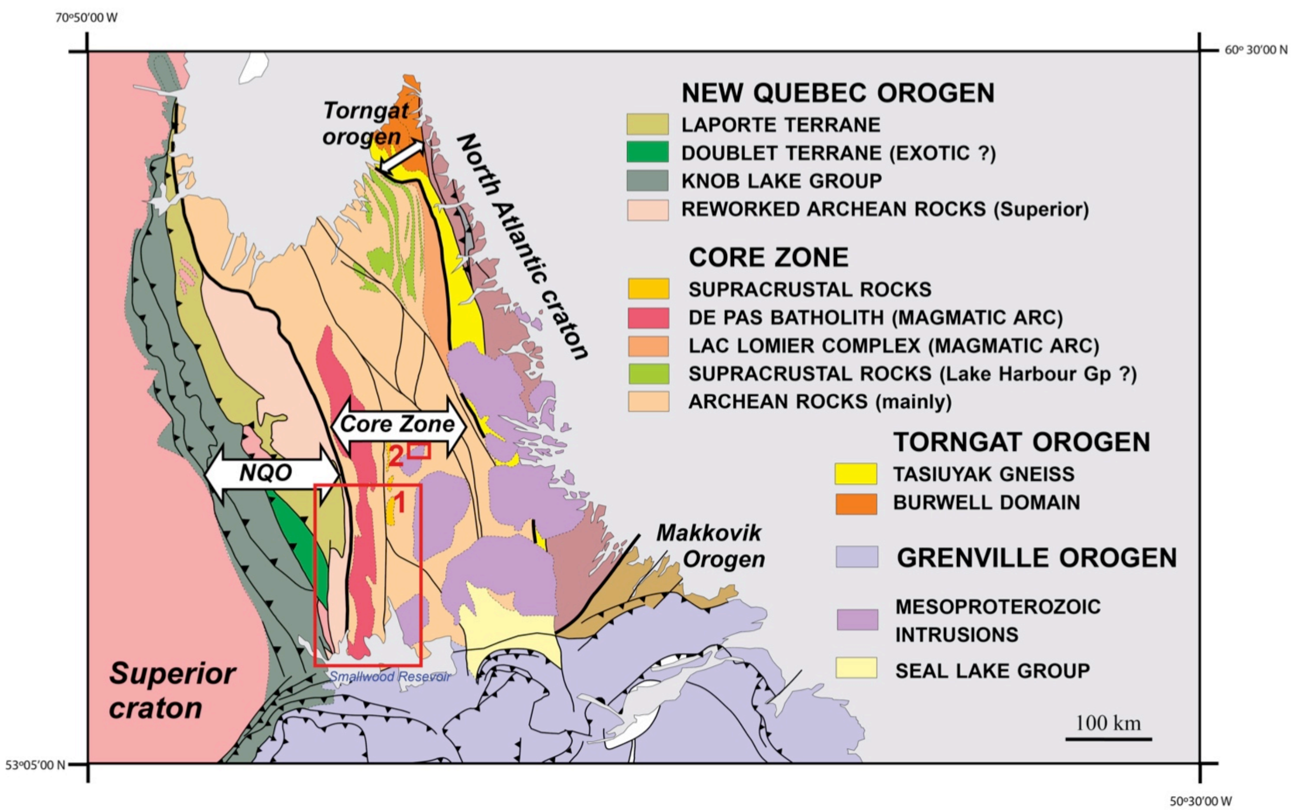

Figure 1.2. Simplified bedrock geological map of the Core Zone and bounding orogens. Boxes show areas under investigation: 1) south Core Zone surficial mapping; 2) Strange Lake area. Modified after James et al. (2003).

Acknowledgments
These surficial research activities are part of the GEM 2 Hudson-Ungava Project, which is under the scientific leadership of David Corrigan with GSC management support from Réjean Couture and Lila Chebab. I. McMartin (GSC) is thanked for her review of this report.

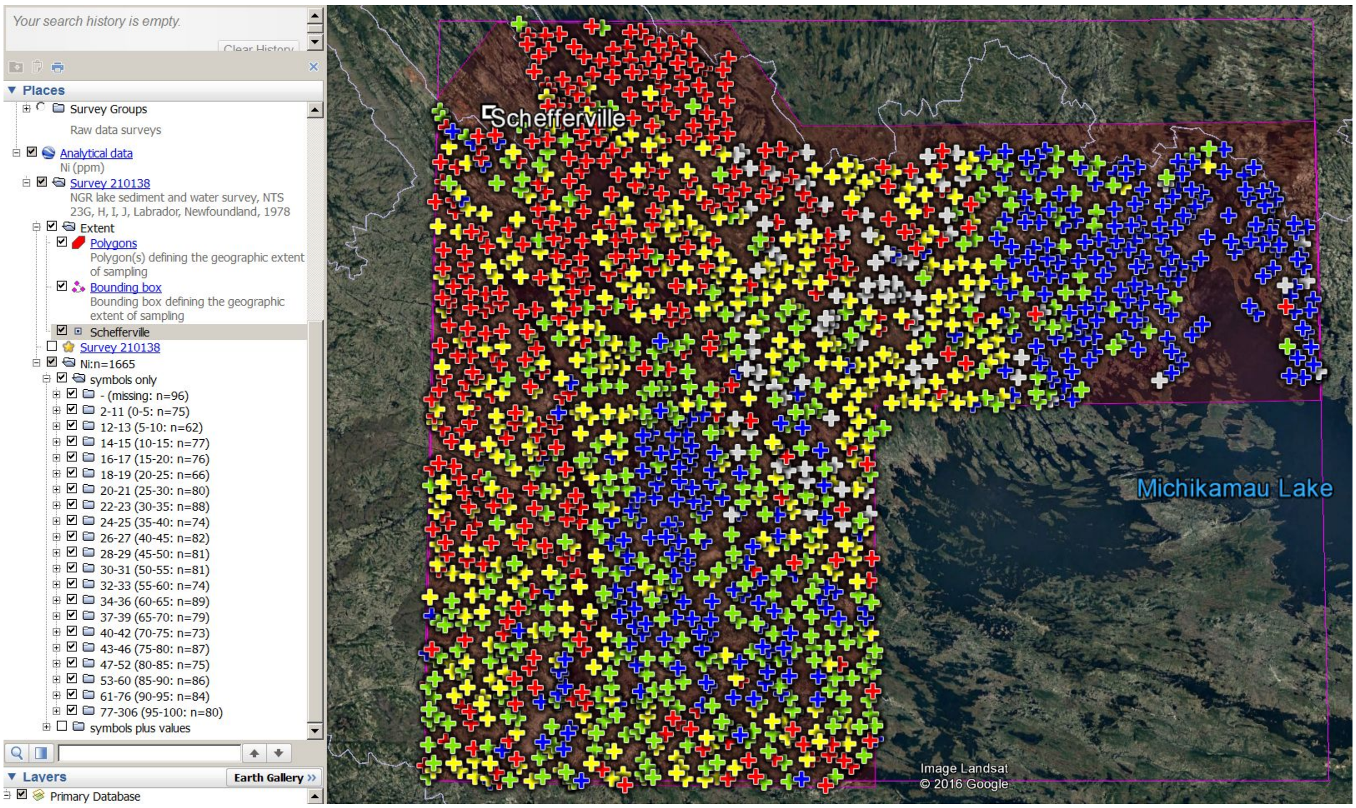

Figure 1.3 Nickel concentration (ppm) in 1665 lake sediment samples from a GSC survey in Labrador. Ni values are classified by quartile: red crosses indicate the highest values; blue crosses represent the lowest values.

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Chapter 2 Surficial Mapping

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Introduction

Surficial geological mapping was undertaken in the summers of 2014 to 2016 as a major part of the GEM 2 Hudson-Ungava Core Zone surficial activities. Surficial mapping activities focused on the erosional history of the Labrador ice centre, and the distribution, composition, and sedimentological properties of surficial sediments located within NTS map sheets 23I (Woods Lake) and 23P (Lac Résolution), within the provinces of Quebec and Newfoundland & Labrador (Fig. 2.1). This chapter focuses on the surficial mapping methods and preliminary results from the 2014, 2015, and 2016 field seasons. Previous fieldwork (McClenaghan et al., 2014, 2015) had identified regions of complex subglacial regimes, ice-flow chronologies, as well as regions of minimal glacial erosion, and a wide variety of surficial deposits.

Methods

Till sampling

Surficial sediment sampling was targeted at primary glacial deposits (i.e., till), using a sampling spacing of approximately 10 to 12 km. Sample density was controlled by a combination of the prospectivity of the bedrock, accessibility via helicopter, and potential for mapping ice-flow indicators. In regions of prospective bedrock with a high number of mineral showings or occurrences, a tighter sample density was employed, whereas sample density was increased in less prospective or till-poor regions and areas not conducive to helicopter landing. In the northern part of the study area, and at higher elevations where permafrost was discontinuous, mudboils were targeted for sample collection, following GSC till sampling protocols defined by Spirito et al. (2011) and McClenaghan et al. (2013). Outside regions characterized by discontinuous permafrost, samples were collected by digging below oxidized soil profiles targeting C-horizon till. Great care was taken in limiting cross-contamination between sample sites by cleaning shovels between sites and double bagging saturated samples to ensure fines were not lost through desaturation initiated by vibration created through helicopter transport. Specific care was taken to exclude any surficial organics or overlying soil horizons from collected samples and other general quality assurance and quality control guidelines were followed as outlined by Plouffe et al. (2013).

At most sample sites, two samples were collected: a 10 to 15 kg sample for indicator mineral processing; and a 3 to 5 kg sample for geochemical analysis, textural determinations, Munsell colour determination, loss on ignition (LOI), and archiving. If the sample site was located in Labrador, an additional 3 to 5 kg sample was collected for additional geochemical analysis at the Geological Survey of Newfoundland and Labrador. Paleo-ice-flow indicators such as striae, glacial grooves, rat tails and mini roches moutonnées were measured to assist in determining ice-flow vectors and relative chronology. Several stations initially investigated by previous workers (Klassen and Thompson, 1990, 1993) were revisited for detailed examination and interpretation.

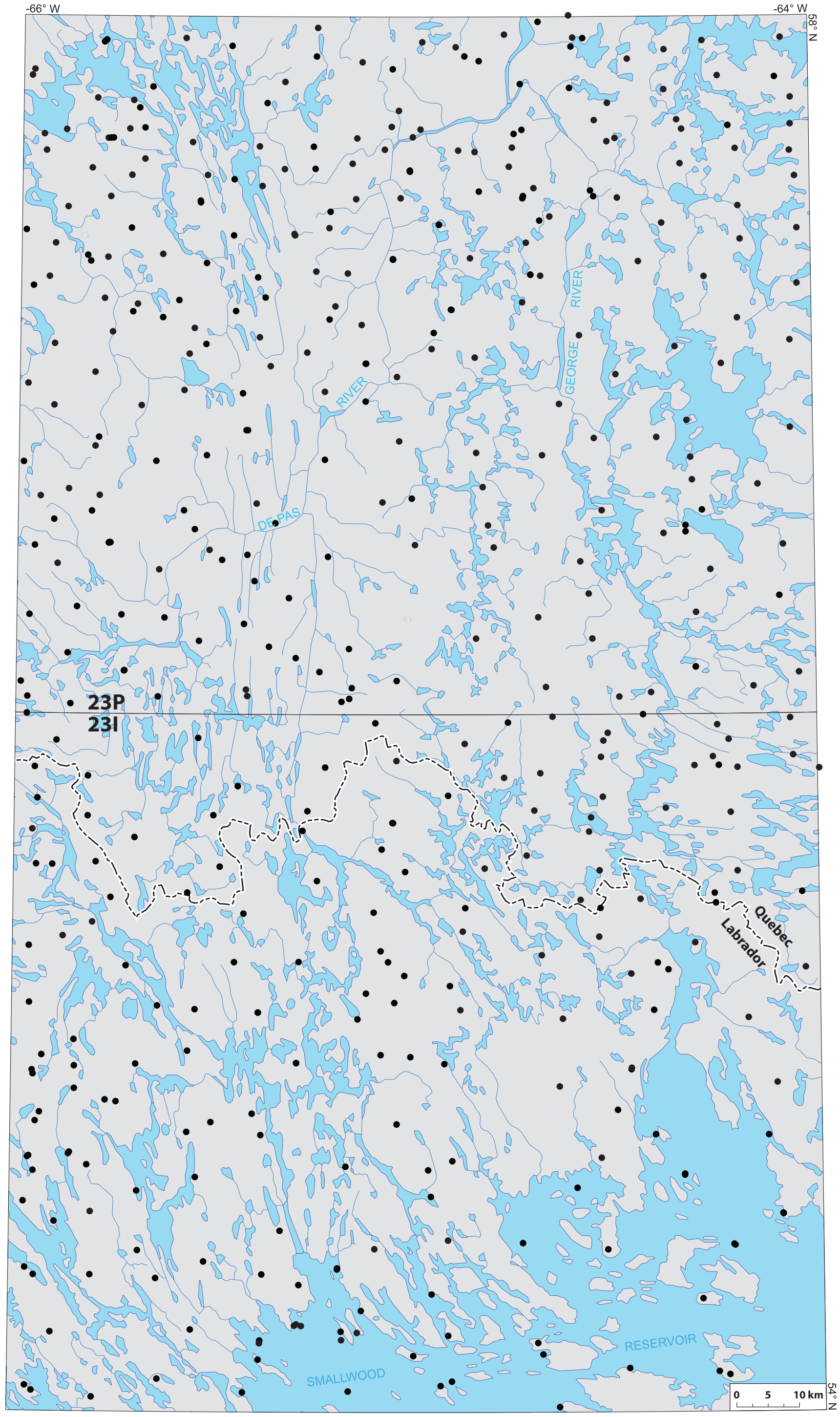

Figure 2.1. Study area with all the field stations from 2014-2016 (n = 483). The study area extends over the Woods Lake (NTS 23I) and Lac Résolution (NTS 23P) map sheets, straddling the Quebec-Labrador border.

Geochronological sampling

Samples of bedrock, boulders, and glacial sediments were collected for ^{10}Be cosmogenic analysis to determine age and inheritance and provide a chronological constraints on deglaciation and to evaluate levels of inheritance within glacial sediments (cf., Fabel et al., 2002; Staiger et al., 2006; Refsnider and Miller, 2013; Margreth et al., 2016). These cosmogenic nuclide samples were collected along a generally east to west transect crossing several inferred subglacial regimes to allow for a better understanding of subglacial conditions in relation to ice flow chronology and sediment dispersal. Optically Stimulated Luminescence (OSL) samples of glaciolacustrine littoral sediments were also collected from former shorelines of glacial lakes McLean, Naskapi, and an unnamed glacial lake in the Smallwood Reservoir area, following procedures outlined by Aitken (1998), Duller (2004), and Lian and Roberts (2006). These OSL samples were collected in order to provide approximate time constraints on glacial lake formation and inundation during deglaciation of the region.

Results

A variety of surficial deposits and landforms were identified throughout the area in 2016?. In general, the northern map sheet (NTS 23P) contained abundant highland clearings, covered by till veneers dotted with perched erratics, and draped by till blankets that infilled the valleys. Paleoflow indicators measured within this map sheet suggest a complex ice flow chronology including complete reversals of ice flow vectors (Fig. 2.2). Eskers were only observed to the east of the De Pas Batholith, well away from the ice divide that occupied the central portion of the Lac Résolution map sheet (NTS 23P). Evidence of meltwater reworking and erosion was also identified throughout the northern map sheet, including glaciofluvial deposits, Nye channels, eskers, kames, lateral meltwater channels, and washed bedrock surfaces associated with the aforementioned meltwater landforms. Two glacial lakes inundated the area: glacial Lake Naskaupi (Ives, 1959; Barnett and Peterson, 1964) in the northeast, and smaller glacial Lake MacLean (Barnett, 1967) in the northwest. Areas affected by the inundation of glacial lakes Naskaupi and MacLean are defined by winnowed till deposits, washed bedrock surfaces, and littoral beach deposits.

Field observations relating to surficial geology and ice flow indicators were made at 172 locations during the 2016 summer field season; these sites included 90 sites where till samples were collected for geochemical analysis, 84 sites where till samples were collected for heavy mineral identification, 69 stations where paleo-ice flow measurements were recorded, 7 sample sites for cosmogenic nuclide analysis, and 3 sites where samples were collected for OSL dating. Over the course of the three field seasons, a total of 483 field locations were visited (Fig. 2.1), of which 280 till samples were collected for geochemical analysis, 258 samples were collected for heavy mineral identification, 251 paleo-ice flow measurements were taken, 12 sites were sampled for cosmogenic nuclide analysis, and 6 sites were sampled for OSL dating.

Geochemical samples (3 to 5 kg bags) were submitted to the GSC Sedimentology Laboratory for sample preparation and subsequent geochemical analysis, following the same procedures as for the 2014 and 2015 samples (McClenaghan et al., 2016a). Heavy mineral samples (10 to 15 kg) were submitted to Overburden Drilling Management Limited (ODM) for heavy mineral identification, following the same procedures as for the 2014 and 2015 samples (McClenaghan et

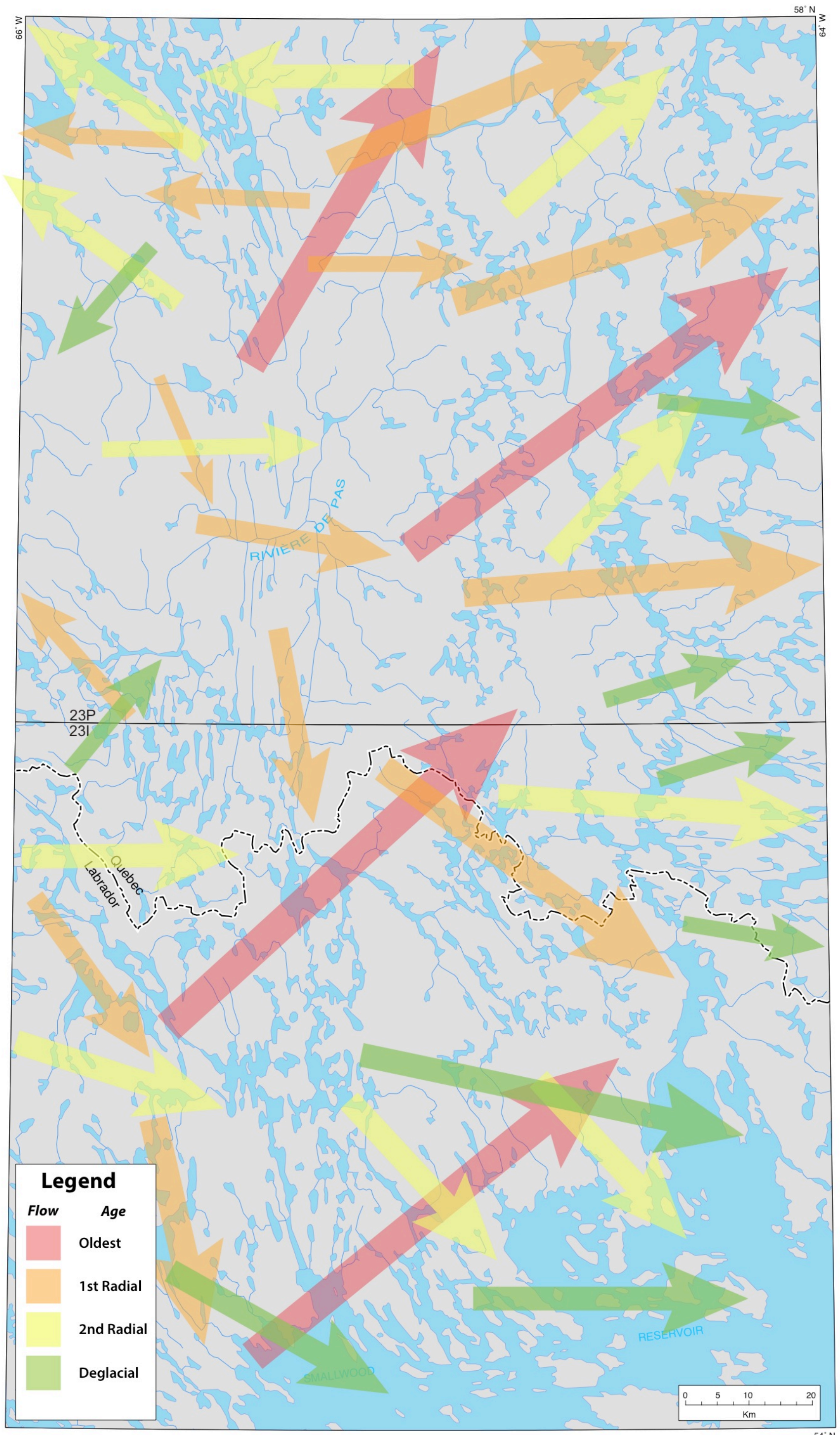

Figure 2.2 Generalized summary of mapped ice-flow indicators from the study area, 2014-2016. Red arrows indicate the oldest flow direction observed in the region, and was likely from the Quebec Laurentian highlands (cf., Veillette et al., 1999). Orange arrows indicate the earlier phase of radial flow from the Labrador ice centre during the main Wisconsin phase of the Laurentide Ice Sheet. Yellow arrows indicate a later phase of radial flow from the ice centre. Green arrows indicate deglacial flow trajectories, including the ice streams that were directed to the Labrador coastline to the east.

al., 2016b). Geochemical samples (3 to 5 kg bags) collected in Labrador were submitted to the Geological Survey of Newfoundland and Labrador's Geochemical Laboratory in St. John's, for sample preparation and analysis. The methods to be used are described in Open File NFLD 3273 (Brushett and Amor, 2016).

In the southern map sheet (NTS 23I), swamps and fens constitute the majority of the low-lying regions. Most of this map sheet is located just south of the zone of semi-continuous permafrost (Heginbottom et al., 2010) and, as a result, much more of this region is tree-covered, with barren rock knobs found in some regions. The surficial geology in this region is less variable with regions of till veneer, till blankets, some glaciofluvial deposits, and radially oriented eskers trending east and south from the approximate center of the map sheet. Evidence of fast flowing ice via megascale glacial lineations was also identified throughout the region. A large, shallow glacial lake filled the basin that the current Smallwood Reservoir occupies, with maximum glaciolacustrine washing limits about 8 metres above current reservoir levels. Unmapped on the 'Glacial Map of Canada' (Prest et al., 1968; Dyke, 2004), this glacial lake inundated more than 50% of the Woods Lake (NTS 23I) map sheet, south of the drainage divide that divides Quebec and Labrador. This lake is herein informally referred to as 'glacial lake Low' named after A.P. Low of the Geological Survey of Canada, who first recognized that the final disintegration of the continental ice sheet occurred in this region (Low, 1896). Areas affected by the inundation of this glacial lake are defined by winnowed till deposits, strandlines, wave-cut benches in glacial landforms, and littoral beach deposits.

Discussion and future work

The landscape of the Woods Lake - Lac Résolution region shows clear indications of an extensive and complex glacial history, characterized by multiple ice-flow trajectories including ice-flow reversals. The subglacial regime fluctuated drastically across the study area such that some regions were affected by high rates of erosion, large sediment deposition, and long glacial transport distances. Other regions are characterized by low levels of till production, large erratics, and more complex glacial transport histories.

Currently, a general ice flow hypothesis has been established, and the legitimacy of this model will be tested against measured field and lab data: cosmogenic nuclide, OSL, geochemical, heavy mineral, and pebble lithology, all of which will be completed and released in forthcoming GSC Open Files and other journal publications. Through this work a better understanding of the surficial deposits and glacial dispersal of materials will be obtained. These data will be an excellent resource to natural resource exploration and responsible resource development.

Acknowledgments

The surficial mapping activity is part of the GEM 2 Hudson – Ungava Project, under the scientific leadership of David Corrigan and surficial activity leader Beth McClenaghan, with GSC management support from Réjean Couture and Lila Chebab. This research benefitted from the support of the Polar Continental Shelf Program. Norpaq Aviation provided excellent and professional expediting services. Financial assistance, as part of J. Rice's Ph.D. thesis, was also provided through the Northern Scientific Training Program on behalf of the Canadian Polar Commission. Alain Rioux and Maxime Gauthier of Innukopters Inc. provided professional and efficient helicopter service. Special thanks to Clara Schattler of Gestion Porlier for superb accommodations and meals. Isabelle McMartin (GSC) is thanked for her review of this report.

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Chapter 3 Lake Sediment Geochemistry

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Introduction

The goal of this lake sediment geochemistry activity is the publication of geochemical maps for northeastern Quebec and adjacent areas of Labrador in support of mineral exploration as well as a better understanding of the bedrock geology and surficial processes that influence the distribution of elements in centre-lake bottom sediments. At the outset of this activity, it was established that existing lake sediment geochemical data sets for areas of Labrador within the Labrador Trough and adjacent eastern Core Zone that were available from the Newfoundland and Labrador government were not compatible with data for these areas available from the government of Quebec. In order to produce seamless geochemical element concentration maps for northwest Labrador and northeast Quebec (Fig. 3.1), aliquots of Labrador lake sediment from archived samples in Ottawa and St. John’s were submitted to a commercial geochemical laboratory for reanalysis using a modified *aqua regia* digestion, similar to that employed by Quebec to generate geochemical data.

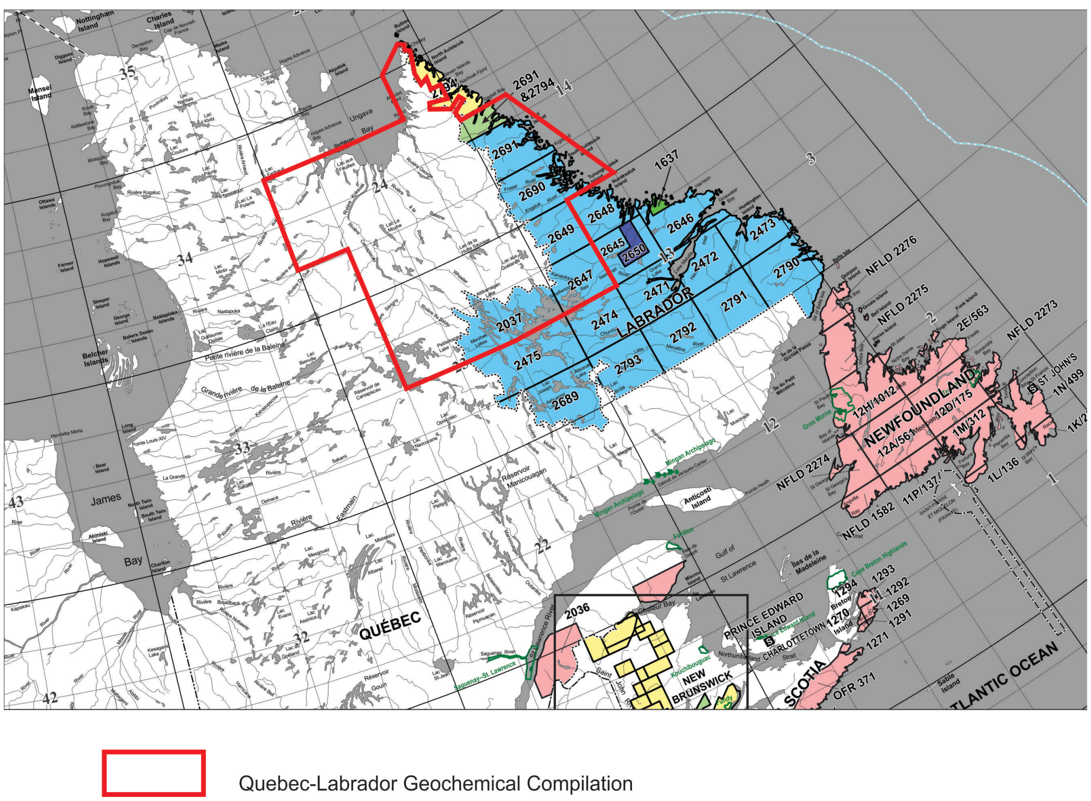

Figure 3.1. Areas of Labrador (blue) within the study area (red line) from which archived lake sediment samples were reanalyzed to produce an internally consistent database for the study area.

Database
Geochemical data for 26,727 lake sediment sample sites in northeastern Quebec were acquired through the office of the Bureau de la connaissance géoscientifique du Ministère de l'Énergie et des Ressources naturelles. From these data, records for 24,224 sites containing geochemical data compatible with Labrador reanalysis data were selected for the geochemical compilation database. Because sample density over the Labrador Trough in Quebec is much greater than the rest of the sampled area, a random selection of the 10,492 samples within this zone was chosen from the dataset to produce a more consistent distribution of sample points across the study area.

The Labrador dataset comprises records for 5,510 samples. A subset of 2,070 samples from the GSC Archive Collection, Ottawa was prepared for analysis and submitted to a commercial laboratory. Aliquots from 3,440 archived samples stored in St. John's were sent to the same commercial laboratory. The lake sediment samples were analyzed for 65 elements by aqua regia/ICP-MS. Geochemical data for lake sediments received from the commercial laboratory were evaluated for quality in terms of accuracy and precision. Geochemical data for 53 elements are available for all samples. The Labrador samples were analyzed for an additional 12 Rare Earth Elements, which are not considered in the current work. The elements determined are listed in Table 3.1. The data that will be used to compile geochemical maps consist of multi-element analyses of lake sediments for NTS map areas: 23-K, 23-N, 23-P, 24-B, 24-C, 24-E, 24-G, 24-J, 24-K, 24-L and 24-P (Quebec only); 13-L, 13-M, 14-D, 14-E, 14-L, 23-I, 23-J, 23-O, 24-A, 24-H, 24-I (Labrador and Quebec); and 14-C and 14-F (Labrador only).

The analytical data from Quebec were released after sampling programs were conducted in 1982 to 1984, 1997, and 2009. Data are available from the The new Labrador re-analyses data were released by McCurdy (2016) and McCurdy et al. (2016). Values for loss-on-ignition (LOI) are also available for all samples and were reported in a series of GSC Open File reports between 1978 and 1994.

Comparison of Datasets
An R (2016) function was written to scan nearest-neighbour sample pairs (separated by a distance of 5 km or less), identify the minimum value (possibly the less than detection limit (LDL) value) and determine the percentage of the data at that value. If this percentage exceeded 10, the result of the subsequent paired t-test was ignored as there would be too many equal or very similar results that would bias the average difference down and the result of the test. A second R function was written that log transformed ($\log_{10}$) the data and fed it to the R t-test function, which has an option for the paired t-test. If the 95% confidence interval around the average difference of the $\log_{10}$ values included zero the test was considered a 'Pass'. Paired t-tests were carried out on low (<18.4%) and high (≥18.4%) loss-on-ignition subsets separately and then on the combined data. Based on the paired t-test results one would be confident in plotting maps across the border for Cu, K, Li, Mg, Pb, Rb, S, Th, Ti and U, as these passed all three tests. The maps for: Ba, Cd, Cr, Hg, and Ni are considered less reliable.

An alternate procedure used the average difference between the pairs in $\log_{10}$ units: the average difference was anti-logged and the difference from one (equivalent to zero difference between the logarithms) was expressed as a percentage. Where the difference was ≤10% the element was deemed acceptable for mapping, and where >10% and ≤15% the element was deemed acceptable with caveats. Based on the ≤10% criterion, the following elements were determined to be

Table 3.1. Elements analyzed in current investigation[1]

Element	Units	L.D.L.	< L.D.L	Element	Units	L.D.L.	< L.D.L.
Ag	PPB	2	10	Na	%	0.001	32
Al	%	0.01	0	Nb	PPM	0.02	0
As	PPM	0.1	5009	Ni	PPM	0.1	0
Au	PPB	0.2	4337	P	%	0.001	0
B	PPM	20	21622	Pb	PPM	0.01	0
Ba	PPM	0.5	0	Pd	PPB	10	21465
Be	PPM	0.1	1547	Pt	PPB	2	18100
Bi	PPM	0.02	3534	Rb	PPM	0.1	4
Ca	%	0.01	1	Re	PPB	1	12577
Cd	PPM	0.01	5	S	%	0.02	513
Ce	PPM	0.1	0	Sb	PPM	0.02	6281
Co	PPM	0.1	0	Sc	PPM	0.1	6
Cr	PPM	0.5	2	Se	PPM	0.1	384
Cs	PPM	0.02	14	Sn	PPM	0.1	1867
Cu	PPM	0.01	0	Sr	PPM	0.5	1
Fe	%	0.01	0	Ta	PPM	0.05	21718
Ga	PPM	0.1	28	Te	PPM	0.02	15496
Ge	PPM	0.1	12979	Th	PPM	0.1	350
Hf	PPM	0.02	8186	Ti	%	0.001	12
Hg	PPB	5	86	Tl	PPM	0.02	298
In	PPM	0.02	15737	U	PPM	0.1	26
K	%	0.01	227	V	PPM	2	105
La	PPM	0.5	10	W	PPM	0.1	8587
Li	PPM	0.1	57	Y	PPM	0.01	0
Mg	%	0.01	3	Zn	PPM	0.1	0
Mn	PPM	1	0[2]	Zr	PPM	0.1	213
Mo	PPM	0.01	0				

[1] *Labrador samples also analyzed for Dy, Er, Eu, Gd, Ho, Lu, Nd, Pr, Sm, Tb, Tm and Yb.*
[2] *Mn data include 213 analyses exceeding upper detection limit of 10,000 ppm.*
LDL = lower detection limit

'mappable': Al, Ba, Cd, Co, Cr, Cu, Ga, Hg, K, Li, Mg, Ni, P, Pb, Rb, S, Sr, Th, Ti, Tl, U & Zr. Relaxing the criterion to ≤15% allows for the inclusion of: Be, Ca, La, Sc & Y.

Conclusions

Results from statistical and graphic comparisons of geochemical data from Quebec and Labrador lake sediment samples indicate that analytical data for up to 27 elements can be used to create geochemical element concentration maps for the entire study area. Additional elements may be suitable for mapping if some form of levelling is used.

Future Work and Next Steps

An article outlining the methods and parameters employed to present the geochemical distribution of elements based on data from the Quebec-Labrador dataset will be published in the December 2016 issue of EXPLORE, the newsletter of the Association of Applied Geochemists. A simplified version of a geological base map for the entire Core Zone study area is being prepared and will be used as a base map for plotting the lake sediment geochemical data. Geochemical map formatting layout and accompanying notes are in preparation and maps will be released in Spring 2017. A poster and oral presentation highlighting the lake sediment geochemical dataset will be given at the Newfoundland & Labrador Mineral Resources Review, November 2nd – 5th, 2016, in St John's.

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We wish to thank Patrice Roy, Bureau de la connaissance géoscientifique du Quebec, and Réjean Couture, Geological Survey of Canada, for their timely assistance with establishing the contacts essential for the production of multi-provincial geochemical compilation maps. Isabelle McMartin (GSC) is thanked for her review of this report.

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Chapter 4 Gamma-ray Spectrometry Studies

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Introduction

In recent years, new airborne magnetic and gamma-ray spectrometry coverage of the Core Zone and Labrador Trough areas of northern Quebec has been completed by Géologie Québec with contributions from the GSC, through its GEM program. Airborne gamma-ray spectrometry (AGRS) provides unique and spatially continuous compositional information about surface materials that can be used in various aspects of regional mapping and resource exploration. However, AGRS end-products appear to be only partially utilized during the data integration and interpretation phases of mapping and exploration projects. In order to promote its usage as part of exploration programs in northern Quebec, AGRS end-products significance need to be documented in the specific context of the Core Zone and Labrador Trough areas. The specific goal of this activity is to develop an interpretation methodology for airborne gamma-ray spectrometry data for the Core Zone area. This will be achieved by 1) providing case studies for NTS sheets 23I and 23P, to complement the surficial mapping activities and indicator mineral studies conducted as part of the south Core Zone GEM 2 project, and by 2) presenting a re-analysis of the GSC's East and West Schefferville airborne surveys of 2009 with an emphasis on discriminating U and Th anomalies. This new knowledge will support natural resource exploration and responsible resource development by contributing to refined bedrock and surficial geology mapping and by helping to resolve potential geochemical anomalies related to mineral deposits.

Methodology

Airborne gamma-ray spectrometry measurements provide the surface concentrations of Potassium (K), Uranium (U) and Thorium (Th), usually presented as maps of their distributions. Physical and geochemical processes at the surface and the inherent statistical noise of radioactive decay result in a complex spatial distribution. To reduce this complexity and to enhance the readability of gamma-ray spectrometry maps for end-users, the study area can be reduced into a set of *radiometric domains* (Campbell et al., 2007; Fortin et al., 2014), where a radiometric domain is heuristically defined as an area of finite extent that presents a distinctive radiometric signature.

For the study areas, NTS 23I and 23P, this exercise of image segmentation is being conducted on the available AGRS imagery. The domain tracing process can be validated in two ways. First, the distribution of airborne measurements that are contained in a given domain should present a Poisson distribution in order to reflect the law of radioactive decay. If this mathematical condition is verified, it should then be confirmed in a second step that the variability observed from domain to domain in the airborne data corresponds to a similar variability in ground truthed measurements. Radiometric domains will be validated by handheld gamma-ray spectrometry. Ground spectrometry measurements will be conducted at pre-planned field stations selected to correspond to radiometric domains, and also at till sampling stations planned as part of the south Core Zone surficial mapping activities. If possible, till samples will be collected at each field station for analysis at the GSC’s gamma-ray spectrometry laboratory to provide volume concentrations of K, U and Th in till.

In addition, surficial and bedrock mapping activities, till geochemistry and indicator minerals studies conducted as part of the south Core Zone project will provide a detailed characterization of the geological and radiation environment at each field stations. This knowledge will allow the determination of which components of the surficial material contribute to the gamma-ray signal coming from the surface, and interpretation of linkages with bedrock and surficial geology. In turn, this new knowledge could potentially feed back into mapping activities and provide complementary information to the map compilation processes.

The radiometric domains provide local baselines of the gamma-ray signal from which readings can be identified as anomalous. They also define the magnitude that a target should exhibit to be detectable above background. A review of selected mineral deposit types occurring in the area will be conducted in terms of related surface geochemical anomalies, and the implications for ground or airborne detection by gamma-ray spectrometry will be considered.

Results

Further work of data collection and compilation was completed during 2016 to support interpretation of the airborne gamma-ray spectrometry coverage. Till samples for analysis at the GSC’s gamma-ray spectrometry laboratory were prepared from larger bulk samples collected during the 2015 field season. At most gamma-ray field stations visited in 2015, a till sample was collected. For each till sample station, two splits were prepared: 1) raw till, and 2) till dry sieved to <2 mm. The two samples were then used to fill 200 cm^3 tins, and all the samples were analyzed at the GSC’s gamma-ray laboratory for volumetric concentration of K, U and Th. A total of 153 till samples in bulk and <2 mm were analyzed.

In preparation for the summer 2016 field season, the distribution of ground gamma-ray spectrometry field stations from 2015 was reviewed. A few repeat points were selected and areas requiring further coverage were identified. A total of 144 new ground spectrometry measurements were acquired on bedrock outcrops and/or till substrate at most of the pre-identified sampling stations (Fig. 4.1) bringing the total coverage to 245 ground measurements. Till samples were also collected at these sites and will be prepared for analysis at the GSC's gamma-ray laboratory in a similar manner as described above.

Figure 4.2 presents a brief example of the data integration and interpretation process. An area of high Thorium concentration (green) is bordered on its west side by an area of comparatively higher Uranium concentration giving a blue hue to the ternary image. In both cases, the local bedrock appears as the main contributor to the airborne-measured radioelement geochemistry, as seen from the ground measurements on outcropping bedrock. This signature is also present in the till, although in diluted concentrations, expressing the mixing of locally derived and distal materials.

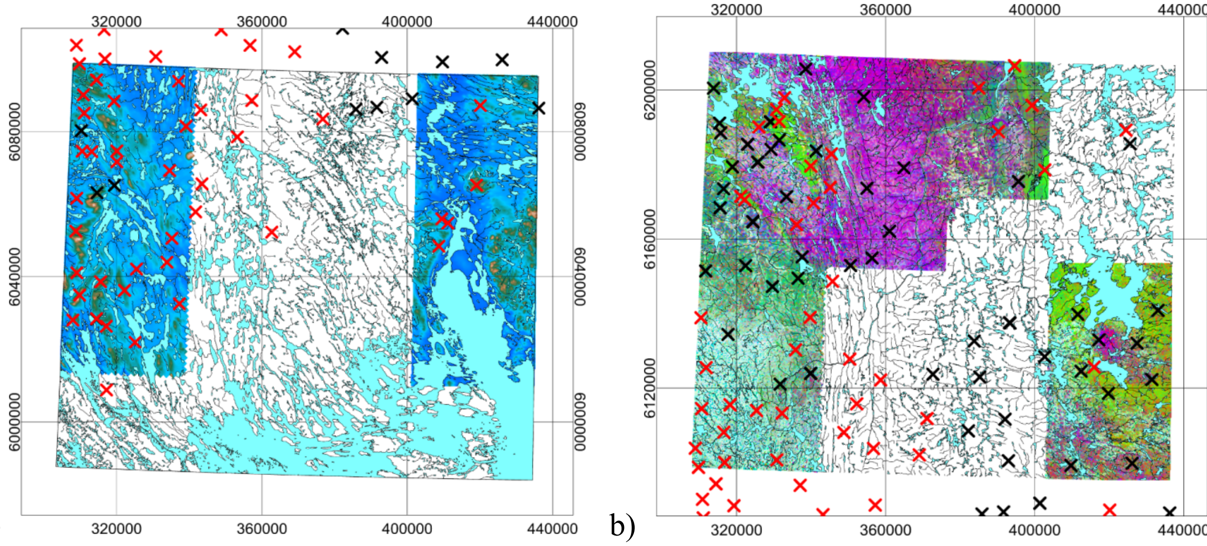

Figure 4.1. 2016 field season ground gamma-ray spectrometry data sites (red) in NTS sheets: a) 23I and b) 23P. Coordinates are in NAD83 UTM Zone 24. Black marks indicate locations of ground truthing measurements collected during the 2015 field season. Background imagery is K-U-Th ternary images. Compilation process of the ternary images is briefly described in Chapter 4 of McClenaghan et al. (2015).

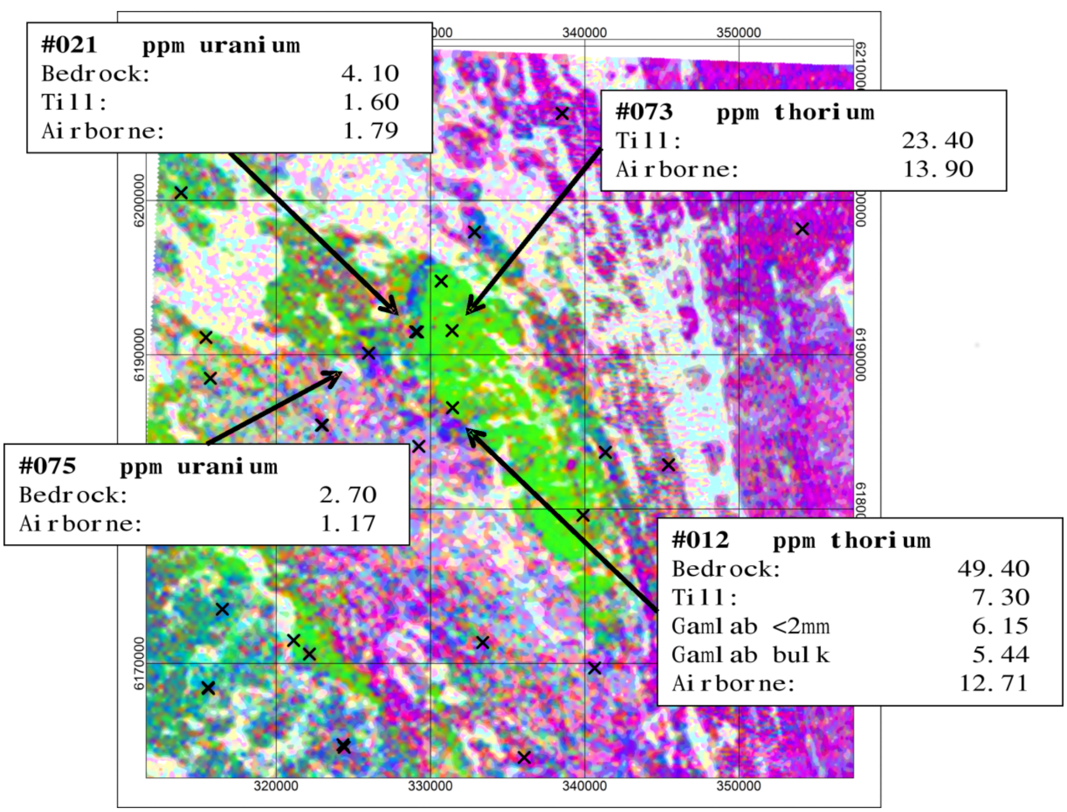

Figure 4.2. Comparison of airborne, ground, and laboratory gamma-ray spectrometry data (see text for details).

Conclusions

A comprehensive database of ground gamma-ray spectrometry measurements, till geochemistry and volumetric radioelement concentrations has been assembled and will further the development of an interpretation methodology for airborne gamma-ray spectrometry maps in NTS 23P and 23I. Work on the interpretation of the radioelement domains in relation to surface geochemistry and surficial and bedrock geology is ongoing.

Future work and next steps

Data integration and analysis are ongoing and will reach two goals. First, from the preliminary tracing, final radiometric domains will be defined for NTS 23I and 23P. Then, linkages with bedrock and surficial geology will be investigated. Work on re-processing of the East and West Schefferville surveys will begin when final radiometric domains are defined, as this information will be used a priori for this process.

Acknowledgments

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