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# GEM 2 Hudson-Ungava Project: southern Core Zone surficial geology, geochemistry, and bedrock mapping activities in northern Quebec and Labrador

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Publications in this series have not been edited; they are released as submitted by the author.

Contribution to the Geo-mapping for Energy and Minerals Program (GEM-2) 2013-2020

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**Summary**
This report is a summary of GSC field work, lab work, and data compilation carried out between April and September 2014 for the surficial geology component of the GEM 2 Hudson-Ungava project. The activities are focused on northeast Quebec and west central Labrador and are being carried out in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec and the Geological Survey Newfoundland and Labrador. The study area is underlain by Precambrian rocks of the New Quebec Orogen and southern Core Zone. Surficial sediment cover consists of thin veneers of glacial sediment flanked by thicker glacial deposits of ribbed and streamlined sediment, small esker systems, and glacial lake sediments in low lying areas.

The overall objective of these activities is to produce new regional geoscience data including glacial transport trends and surficial geology and geochemistry 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.

Field work 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. Lab work led to improved sample processing and examination techniques for till samples. Data management has facilitated access to GEM 1 and GEM 2 publications and data.

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**Foreword**
The Geo-mapping for Energy and Minerals (GEM) program of the Geological Survey of Canada (GSC) 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 (2008-2013), GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer of 2014, GEM's new research program was launched with 14 field activities that include geological, geochemical, and geophysical surveying and sampling. 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.

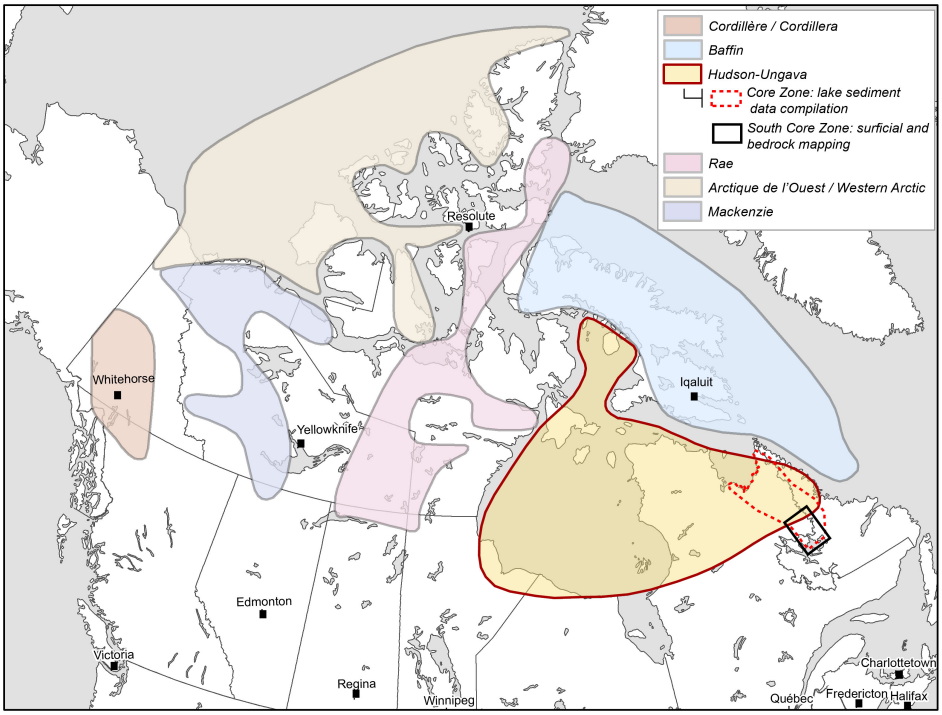


***Figure 1. Location of the southern Core Zone surficial and bedrock mapping area (black box), and the Core Zone lake sediment geochemical data compilation area (red dashed line) within the Hudson-Ungava GEM 2 project area. Also shown are the five additional GEM 2 project areas.***

## Introduction

Bedrock mapping and mineral resource exploration in northern Quebec and Labrador is challenging because the bedrock geology is poorly documented and, in parts, bedrock is covered by surficial (glacial) sediments deposited by a complex sequence of glacial flow 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, 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.

This report describes activities initiated and preliminary results for the first 6 months of the southern Core Zone surficial research carried out in five main activities: surficial mapping and till sampling, bedrock mapping, testing new heavy mineral methods to enhance bedrock and

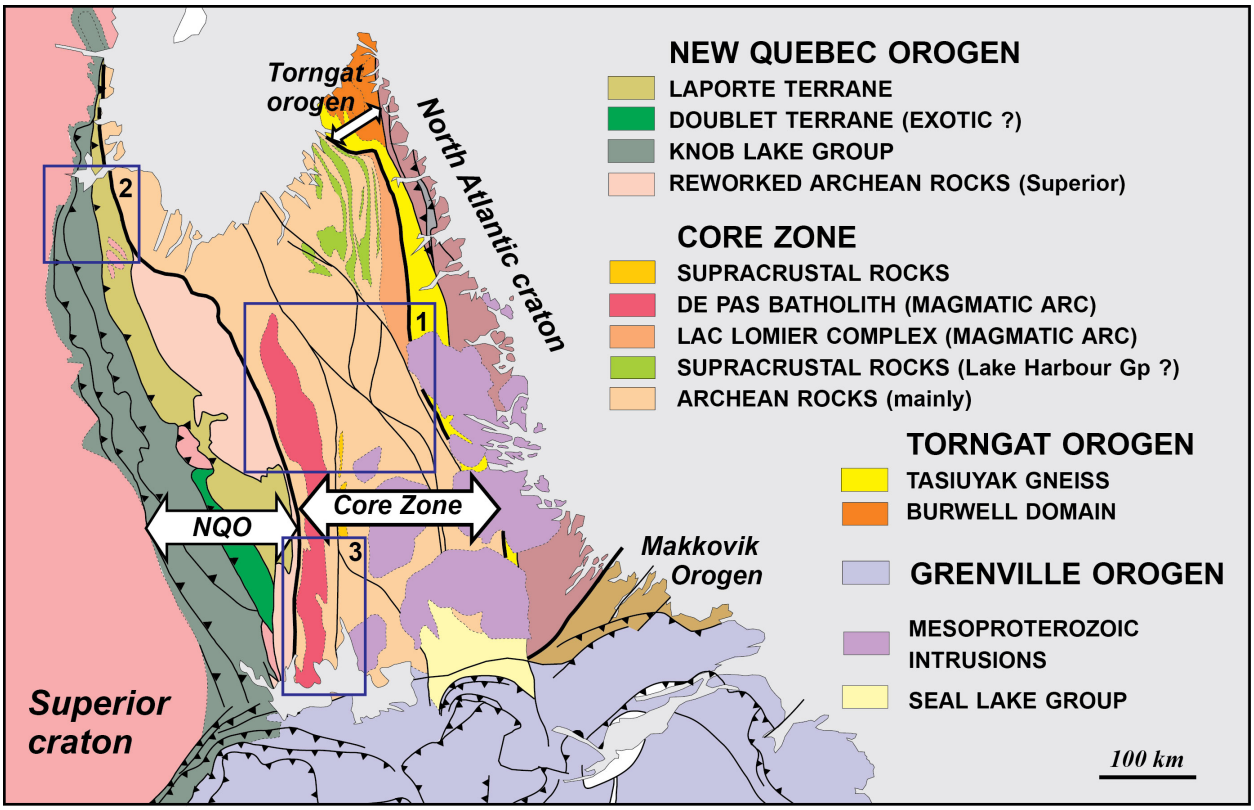


***Figure 2. Simplified bedrock geological map of the Core Zone and bounding orogens. Boxes show areas visited this summer: 1) George River camp, Core Zone bedrock mapping by Corrigan et al. (2014); 2) Labrador Trough, Kuujjuaq area bedrock mapping by Corrigan et al. (2014); 3) south Core Zone surficial mapping (this study). Modified after James et al. (2003).***

surficial mapping, lake sediment geochemical data compilation, and updating and coordination of the GSC's GEM surficial geochemical database.

**Goals and objectives**

The overall objective of the southern Core Zone surficial activity is to produce new regional geoscience data and knowledge to support natural resource exploration and responsible resource development. To this end, specific goals and objectives include:

• Document 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 mineral methods, and lake sediment geochemistry;

• Transfer surficial and geochemical knowledge for the study area 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 surficial geochemistry/indicator mineral database as an efficient exploration tool;

• Increase bedrock coverage and 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) through support of one Ph.D. and one M.Sc. research project, and training of several B.Sc. level students.

**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?

**Methodology**
In April, 2014, GSC surficial and bedrock mappers attended a 1-day workshop in Quebec with (Wardle et al. 2002Q mappers to discuss overall research plans and coordinate 2014 field activities. GSC researchers also consulted with Newfoundland and Labrador Geological Survey (GSNL) scientists to discuss overall research plans.

*Surficial mapping and till sampling:* Background information on the regional Quaternary context was observed on a field trip to the Hudson Ice Divide in the Caniapiscau Reservoir area in July, 2014. Reconnaissance-scale (1:250 000) surficial mapping was initiated across the southern Core Zone in August, 2014 in the Woods Lake (NTS 23I) and Lac Résolution (NTS 23P) map areas (Fig. 1). Initial work consisted of compiling and evaluating all existing Quaternary, surficial geology, and surficial geomorphological information available for the study area and general region around the Hudson Ice Divide (Labrador Sector) of the Laurentide Ice Sheet (Dyke and Prest, 1987; Klassen, 1999; Veillette et al., 1999). This previous research provided preliminary information on the types and distribution of the surficial sediments and glacial history. Aerial photographs (1:60 000 scale) were used to make preliminary terrain and glacial landform interpretations. Aerial photograph analysis contributed regional ice-flow information through the identification of glacial lineations and drumlinoid forms. This knowledge was ground-truthed and augmented by detailed local ice-flow direction information obtained by measuring striations, grooves and local roche moutonnées in the field. Fieldwork in 2014 was based from the McGill University Subarctic Research Station, in Schefferville, Quebec. Fieldwork was conducted by helicopter traverses across the majority of the NTS 23P and 23I (Fig. 2) study area at a reconnaissance scale. At each ground-truthing field station, some or all of the following observations were made: GPS-verified UTM location, geographic features, nature of unconsolidated surface material, lithology of larger erratics, orientation of striations and grooves on bedrock surfaces, elevations of post-glacial deposits (glaciolacustrine) and active geological processes.

*Bedrock mapping and sampling*: To maximize insight into the evolution of the southern Core Zone region (Fig. 1) as efficiently and effectively as possible, bedrock information related to lithology, mineral assemblages, metamorphic grade, structural state and relative deformational history was gathered from each station where surficial mapping was conducted. All bedrock data was collected digitally in a hand-held device (GETAC) to ensure rapid integration with surficial

data. Key bedrock lithologies were sampled: weathered samples contributed to an archive of representative rock types for till and dispersal analyses, while select fresh and unaltered samples were collected for major and trace element analyses, thermobarometry and geochronology. At all localities, significant and/or distinctive bedrock erratics (e.g. Labrador Trough jasper, dolomite, stromatolites etc.) were documented and sampled to contribute key information for understanding the complex ice flow in the region.

*Heavy mineral methods*: This activity focuses on the <0.063 mm heavy mineral fraction of till, a size fraction not currently used in GSC regional mapping and till sampling surveys because methods do not yet exist to systematically recover and analyze these very small minerals. This size fraction of till is, however, of particular interest given that significant precious and base metals, as well as key oxide and silicate minerals significant for mapping bedrock lithology (e.g. zircon), may reside in this fraction. The first step in the research to date was the purchase and testing of a Hydroseparator™ (e.g. Rudashevsky et al., 2002) for separating <0.063 mm sized heavy minerals from till samples at Queen's University. Several minerals with a wide range in mineral densities, including apatite (3.16-3.22 g/cm$^3$) hornblende (3-3.4 g/cm$^3$), sphalerite (3.9-4.1 g/cm$^3$), corundum (3.98-4.1 g/cm$^3$), and magnetite (5.1-5.2 g/cm$^3$) were mixed with quartz (to simulate till matrix) and run through the Hydroseparator™ at size fractions of <20, 20-45 and 45-63 μm to develop the methodology for recovery.

*Lake sediment data compilation:* This activity focuses the compilation of lake sediment geochemical data for the entire Core Zone (Fig. 1). GSC, MERNQ and GSNL researchers identified the area to be covered by the data compilation and contributed provincial geochemical datasets for the compilation. The use of different sample digestions and analytical methods for the two provincial data sets currently makes the integration of these data into one dataset for the purpose of producing and interpreting geochemical maps difficult. To surmount this issue while providing the broadest range possible of elements for mapping purposes, GSC is preparing to re-analyze some lake-sediment samples from Labrador using modern procedures comparable to those used by MERNQ.

*Canadian Database of Geochemical Surveys:* This activity focuses on the coordination and linking of provincial and GSC surficial geochemical databases. Initial activities included maintenance and enhancement of the GSC's Canadian Database of Geochemical Surveys (CDoGS) database (http://geochem.nrcan.gc.ca) that supports all GEM 2 projects. This activity extends to maintenance and enhancement of the website framework to continue to comply with Treasury Board WCAG guidelines and remain up-to-date with NRCan website templates.

**Results**

*Surficial mapping and till sampling:* A total 107 field stations were examined for ground-truthing and ice-flow indicator mapping during the 2014 survey. Of these, 49 were made in the Woods Lake (NTS 23I) map sheet and 58 were made in the Lac Résolution (NTS 23P) map sheet (Fig. 3). Large-scale landforms were documented and photographed from the air (Fig. 4) and site-specific observations on former glacial flow were made on outcrops at individual stations (Fig. 5). A total of 37 till samples were collected for recovery of indicator minerals and till matrix geochemical analysis. All samples have been submitted to the GSC Sedimentology Lab for sample preparation and archiving, or to a commercial heavy mineral processing lab

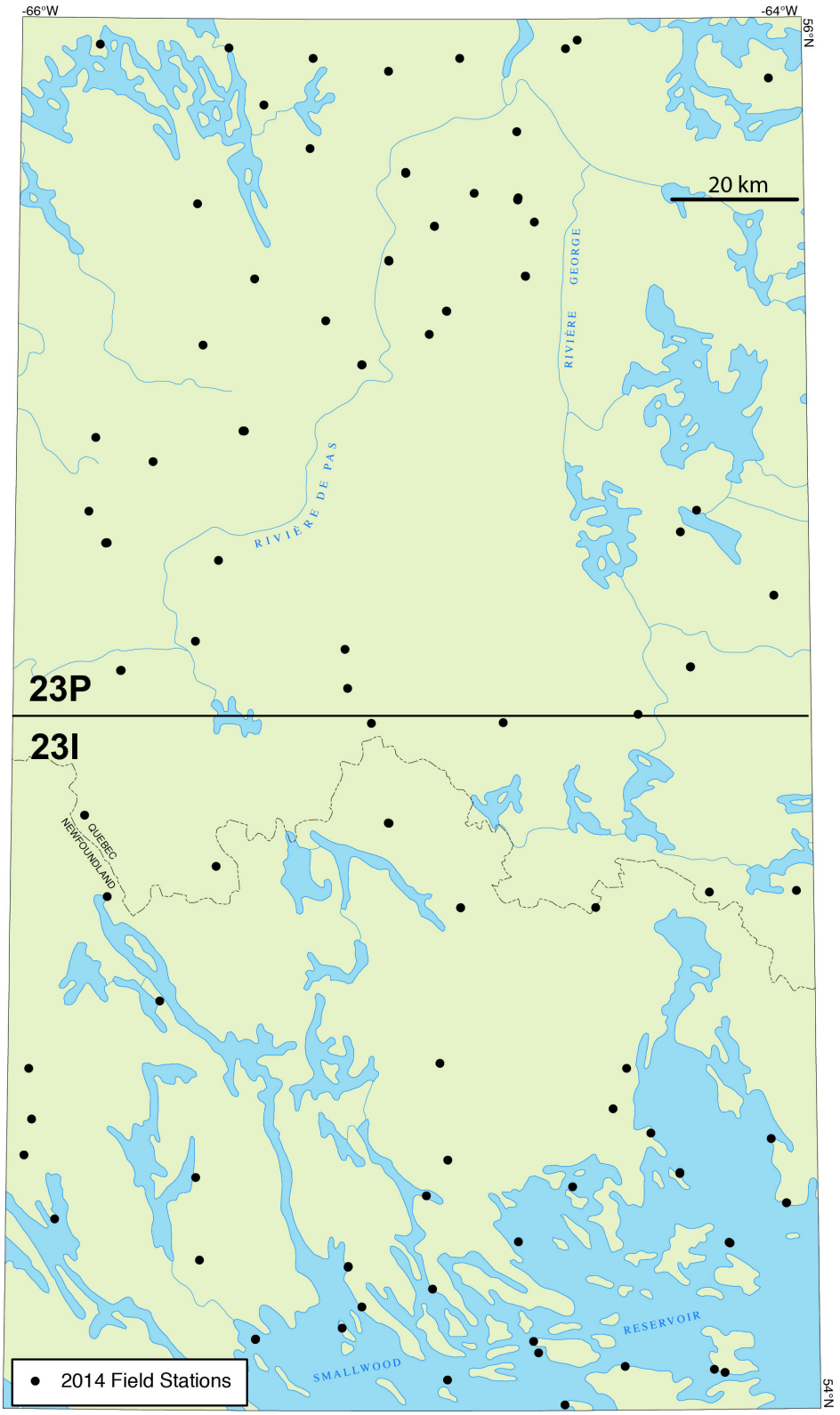


***Figure 3. Area covered by surficial mapping consisting of the Woods Lake (NTS 23I) and Lac Résolution (NTS 23P) map sheets, showing the ground-truthing stations from summer 2014 field work.***

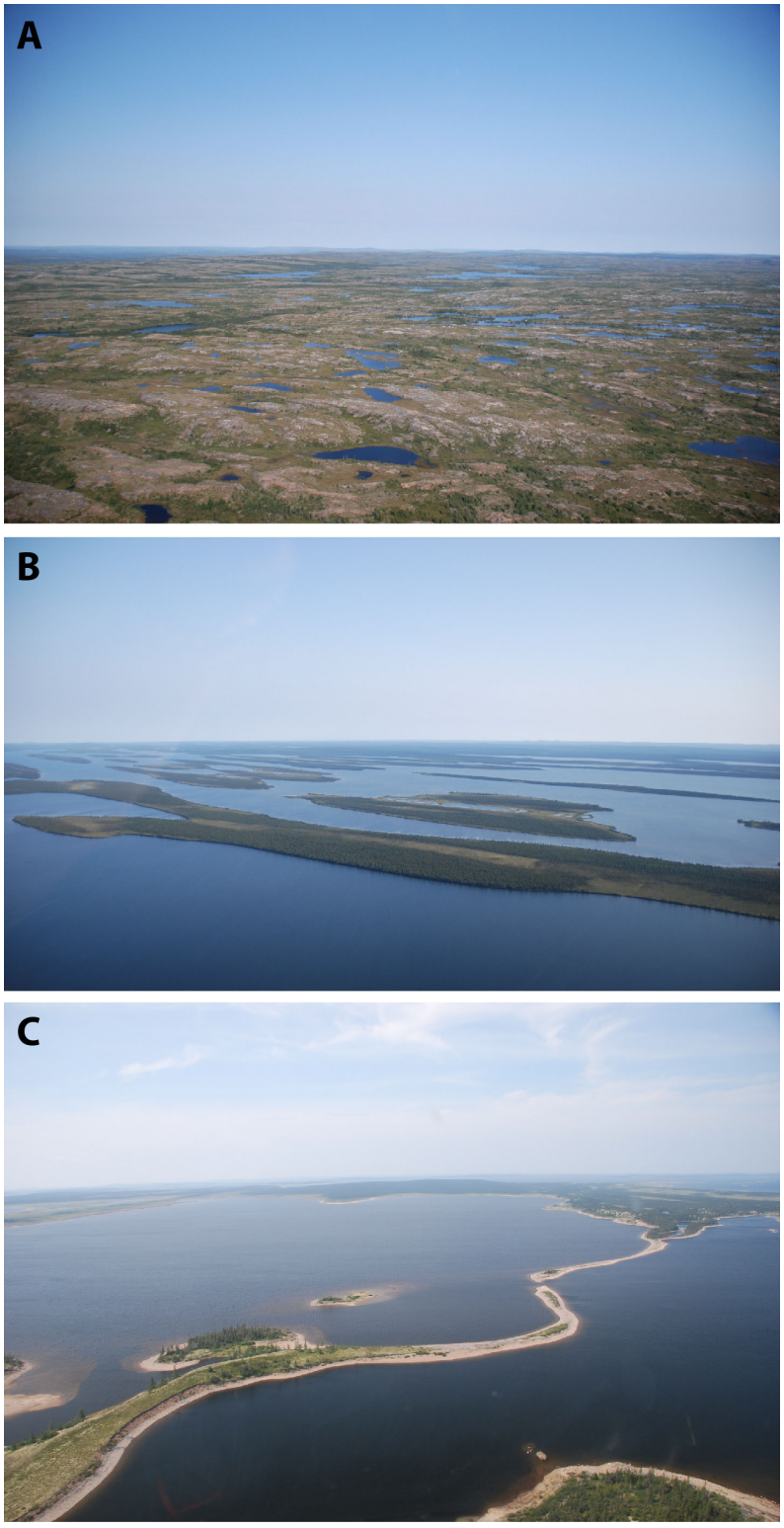


***Figure 4. Aerial photographs of the study area: A) low-relief upland George Plateau consisting of outcrops and till veneer interspersed with numerous small lakes; B) glacially streamlined terrain in the Smallwood Reservoir; C) a small esker in the Smallwood Reservoir.***

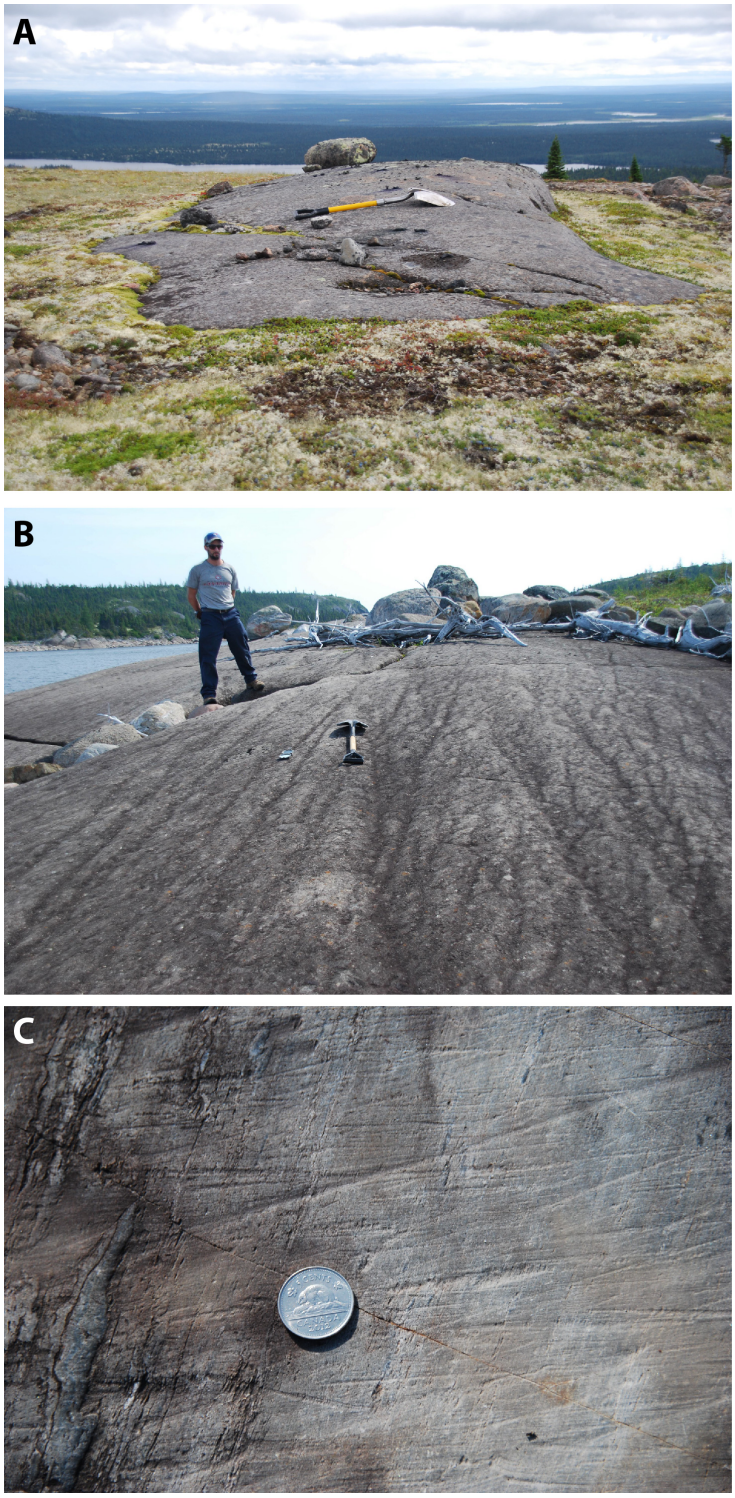


***Figure 5. Examples of bedrock outcrops with glacial flow indicators in the study area: A) sculpted outcrop with a stoss and lee form to indicate former ice flow direction (from left to right, shovel for scale); B) two sets of glacial grooves preserved in coarse-grained anorthosite; C) cross-cutting relationships between sets of striations seen on polished, bedrock surfaces (Canadian 5-cent coin for scale, 21 mm diameter).***

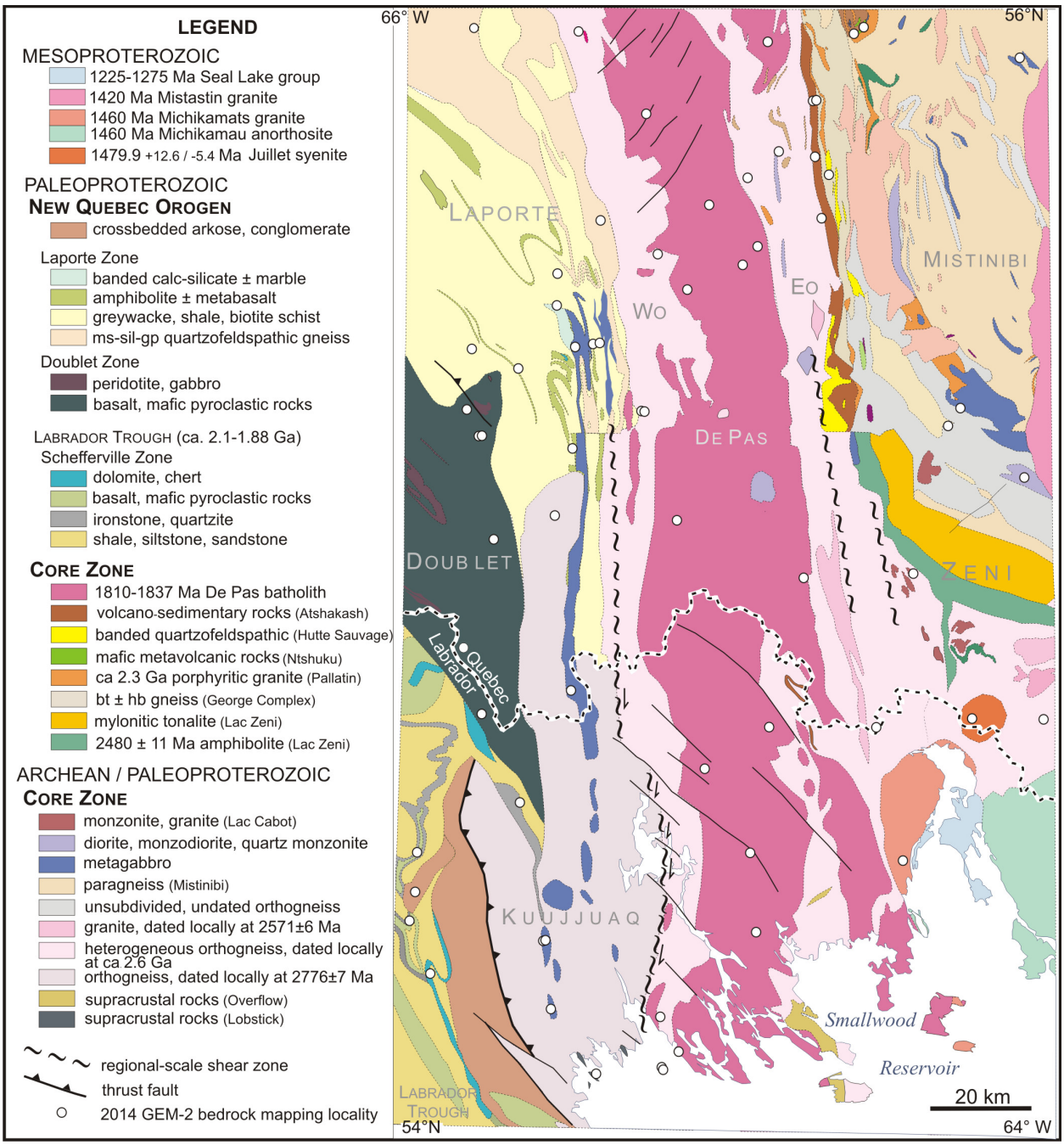


***Figure 6. Bedrock geology of the GEM 2 southern Core Zone project area (NTS 23P, 23I) highlighting crustal domains within the New Quebec Orogen and southern Core Zone. White dots indicate localities where bedrock mapping was carried out in August 2014 in tandem with surficial mapping. Abbreviations: Eo – eastern orthogneiss domain; Wo - western orthogneiss domain. Geology from Wardle et al. (1997) and Ministère de l'Énergie et des Ressources naturelles (2010).***

*Bedrock mapping and sampling:* Integrated bedrock mapping at helicopter-accessible sites, in tandem with surficial mapping, investigated major units across the New Quebec Orogen and southern core zone (Fig. 6), from west to east, including the Labrador Trough, a volcano-sedimentary continental margin sequence with linkages to Superior craton; Doublet zone, a metabasalt-dominated succession cut by gabbro-peridotite sills less clearly established as having

a connection to Superior craton, and possibly an exotic mafic-ultramafic block; Laporte zone, a clastic-dominated succession of unknown age, affinity and provenance; Kuujjuak domain, an orthogneiss domain cut by gabbro that yielded a late-Archean age (2789 +17/-5 Ma) (James and Dunning 2000) and is postulated to represent a thrust-bound wedge of reworked Superior craton; western orthogneiss domain to determine affinity, age and tectonometamorphic history of metaplutonic rocks into which the western De Pas batholith was emplaced; central, topographically high, well-exposed 1.837-1.81 Ga DePas batholith (James et al. 1996; Dunphy and Skulski 1996; James and Dunning, 2000) to investigate potential for relatively early, subduction-related phases, assess strain history, and recover the pre-De Pas emplacement history from inclusions and enclaves; eastern orthogneiss domain,
including a porphyroclastic granodiorite mylonite from the George River shear zone, to determine affinity, age and tectonometamorphic history of metaplutonic rocks into which the eastern De Pas batholith was emplaced; dismembered Atshakash-Hutte Savage supracrustal belts (Girard 1990, 1992); northeastern Mistinibi paragneiss domain; Lac Raude metagabbro complex; circular, post-tectonic ca.1.48 Ga Juillet pyroxene syenite; ca 1.46 Ga Michikamats granite - Michikamau anorthosite complex.

*Heavy mineral methods*: For all minerals tested to date in the three different size fractions, heavy minerals over a range of densities were recovered from the quartz matrix readily using the Hydroseparator™ and key volumes and velocity settings for the Hydroseparator™ were established for future testing of till samples.

*Lake sediment database compilation:* Lake sediment geochemical data for areas in Quebec have been provided to GSC by MERNQ. Of the approximately 6,700 GSC's Labrador lake sediment samples identified as a priority for reanalysis, 2,500 were removed from the GSC archive at Tunney's Pasture and shipped to the GSC Sedimentology Lab for repackaging and relabeling in preparation for submission to a commercial geochemical lab. Two BSc students assisted with this work.

*Canadian Database of Geochemical Survey:* New data were added to the GSC database (surveys, some raw data) and are now available through the website together with tables of control reference samples (related to QA/QC evaluation of data). The CDoGS website was refreshed with the latest NRCan templates and latest TB WET tools (Web Experience Toolkit). Metadata for every major GEM 1 geochemical survey have been added to the database.

**Conclusions**

*Surficial mapping and till sampling:* The landscape of the Woods Lake and Lac Résolution region is the product of a complex glacial history, with the potential for multiple ice-flow trajectories and ice-flow reversals. No evidence of long-term cold-based glaciation was observed, indicating that all areas were subjected to warm-based glacial flow and erosion at some time during the Quaternary. That observation, however, does not eliminate the possibility of a transition from warm-based flow to cold-based flow during the Wisconsin, which could form relict terrain (c.f., Kleman et al., 1994; Kleman and Hattestrand, 1999), as the Hudson Ice Divide of the Laurentide Ice Sheet occupied part of the study area. Future fieldwork will help decipher the complex glacial history of the region.

*Bedrock mapping and sampling:* Integrated lithological and structural mapping together with targeted sampling of key units for future geochemical and geochronological analysis is shedding significant insight into the character and tectonometamorphic evolution across the New Quebec Orogen and southern Core Zone. This knowledge will be used to strengthen the foundation on which interpretations of heritage, affinity, and mineral prospectivity of this under-explored region are based.

*Heavy mineral methods*: Hydroseparation is a viable technique to recover very small (<0.063 mm) heavy minerals from the matrix fraction of till samples. This technique will allow the routine recovery and examination of very small heavy minerals that, until now, were too small to be recovered from till and analyzed systematically.

*Lake sediment database compilation:* An internally consistent database of lake sediment geochemistry over the Labrador Trough and associated eastern Core Zone covering areas of Labrador and Quebec can be created by reanalyzing lake sediments collected by the GSC in Labrador in 1978, 1982, 1983, and 1985 by the same procedures used by MERNQ.

*Canadian Database of Geochemical Surveys:* Both the database and website are growing with the addition of GEM 1 surveys, legacy surveys in Hudson-Ungava GEM 2 area, and GEM 1 raw data. The database will accommodate new data from GEM 2 surveys when published.

**Future work 2014-2015**

*Surficial mapping and till sampling:*

• 2 Short Course presentations, *Mineral Exploration Under Cover*, Newfoundland & Labrador Geological Survey Mineral Review, November 5, 2014
• Attend Mineral Review, St John's, Newfoundland November 5-8, 2014
• Short Course presentation, *GEOL 5806 - Modular Course in Exploration Geochemistry*, Laurentian University, Sudbury, December 6-7, 2014 on indicator mineral methods in support of bedrock mapping and mineral exploration
• Organize workshop, *Indicator Mineral Methods in Mineral Exploration,* 27th International Applied Geochemistry Symposium, Tucson, April 17, 2015
• Geochemical and indicator mineral analysis of till samples
• Production of surficial geology map at 1:100 000 scale for NTS 23I/SE

*Bedrock mapping and sampling:*

• Integrate findings for the southern Core Zone with new observations from the northern Core Zone (Corrigan et al., 2014)
• Prioritize samples for geochemical and geochronological analysis
• Document 2014 findings in a GSC Current Research report

*Heavy mineral methods*:

• Continue to test different mixtures of mineral species/densities in till to optimize heavy mineral recovery over a range of densities in a single sample.

*Lake sediment database compilation:*
• Subsample archived GSC lake sediment samples held at GSNL. The preparation of all priority samples for analysis is expected to be completed in mid-December. Geochemical analysis of the lake sediment samples will be carried out by March 31, 2015.

*Canadian Database of Geochemical Surveys:*
• Content development for the *CDoGS* website: geochemical surveys carried out in GEM 1 currently not in the database will be added.
• Legacy GSC and provincial surveys in the Hudson-Ungava GEM 2 area will be added to benefit current GEM 2 work in that region

**Future work 2015-2017**
*Surficial mapping and till sampling:* Fieldwork in support of surficial mapping will continue in the summers of 2015 and 2016, with the intention of producing surficial geology maps at 1:100 000 scale and regional-scale till geochemical and indicator mineral datasets.

*Heavy mineral methods*: Lab testing of heavy mineral characterization of the <0.063 mm fraction of till will continue, including determining the minimum volume of till needed to produce a representative mineral grain counts, testing of Mineral Liberation Analysis (MLA) methods for rapid SEM identification of minerals in the <0.063 mm heavy mineral fractions produced through hydroseparation, and finally testing of GEM 2 till samples.
• Convene Workshop, *Indicator Mineral Methods in Mineral Exploration,* 27th International Applied Geochemistry Symposium, Tucson, April 17, 2015
• Three workshop presentations, *Indicator Mineral Methods in Mineral Exploration,* 27th International Applied Geochemistry Symposium, Tucson, April 17, 2015

*Lake sediment database compilation:* Once the re-analysis of the archived GSC lake sediment samples is completed, the research team will merge the Quebec, Labrador and GSC datasets to produce a series of single element and synoptic geochemical maps of the Core Zone for publication as GSC open file maps.

*Canadian Database of Geochemical Surveys:* Content development for the *CDoGS* website with continue with data from geochemical surveys carried out in GEM 1 not currently in the database and new survey data for the Hudson-Ungava Core Zone project being entered.

**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. Our research is also conducted in collaboration with MERNQ and the GSNL. Surficial geological input and satellite imagery was provided by Hugo Dube-Loubert and Virginie Daubois (MERNQ). We thank James Conliffe (GSNL) for providing a bedrock geological tour of Labrador Trough exposures near Schefferville. Surficial mapping was supported by the Polar Continental Shelf Program. Pilot Les Phillips from Universal Helicopters is thanked for letting us get his helicopter dirty! Field logistics were provided by the McGill University Subarctic Research Station, Schefferville, with local information and contacts provided by our host, Neil Ednie. Digital field data management was efficiently provided by

Gabriel Huot-Vézina (GSC Quebec) and Matt Pyne (GSC Ottawa) is acknowledged for ongoing GIS support. Emilie Rufiange (University of Ottawa) provided assistance in the field. Guillame Allard (MERNQ) and Steve Amor (GSNL) provided lake sediment geochemical data and advice for the lake sediment compilation activity. Research on heavy mineral methods is supported by GSC through a Research Affiliate Program (RAP) Bursary to M.Sc. student Jessica Pickett and is being supervised by Dan Layton-Matthews (Queen's University). Dan Kerr (GSC) is thanked for his review of this open file.

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