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Report of 2015 activities for regional surficial mapping, till and stream sediment sampling in the Tehery-Wager GEM 2 Rae Project area

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Report of 2015 activities for regional surficial mapping, till and stream sediment sampling in the Tehery-Wager GEM 2 Rae Project area

Isabelle McMartin, Justin Byatt, Iyse Randour and Steve Day

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 2015, GEM program has successfully carried out 14 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.

Project Summary

This publication summarizes the 2015 field work completed along the northwestern shores of Hudson Bay, mainland Nunavut, as part of the surficial geology component of the GEM 2 Tehery-Wager Activity within the Rae Project. The report outlines field methods and discusses preliminary results regarding the regional surficial geology and Quaternary history, the mapping of surficial materials using remote sensing, and the applications of glacial and stream sediment sampling for mineral exploration. The work was undertaken to provide new geological knowledge on the nature and composition of surficial materials deposited during the retreat of the Laurentide Ice Sheet, successive marine inundation and emergence, and addresses a number of scientific questions relevant to the mineral exploration industry. The findings will support informed decision making for resource exploration and development, and for land use management.

Introduction

GEM 1 reconnaissance scale bedrock mapping, till and stream sediment surveys in the Tehery-Cape Dobbs region in 2012 identified areas with potential for base- and precious metal mineralization in supracrustal strands and for ultramafic/mafic and kimberlite sources outside the known kimberlite field (Day et al., 2013; McMartin et al., 2013; Wodicka et al., in prep.). As a follow-up, surficial geology studies and targeted surface sediment sampling were initiated in 2015 to address a number of scientific questions relevant to the mineral exploration industry in a large area extending between Wager Bay and Chesterfield Inlet east of 93° longitude (Fig. 1). Apart from the Wager Bay map sheet (NTS 56G: Dredge and McMartin, 2007), the area has not been mapped or mapped only at a reconnaissance scale for surficial geology, with little or no ground truthing (Aylsworth, 1990; Dredge et al., 2013a-c). The main objectives of the GEM 2 Tehery-Wager surficial geology component are to provide a glacial and post-glacial history framework required for interpreting the nature and transport history of surficial sediments, and to collect till and stream sediment samples at various targeted sites for provenance studies and mineral potential evaluation. The key scientific questions addressed in these studies include: 1) what is the nature of glacial transport in proximity and distal to the Keewatin Ice Divide; 2) what is the age of the weathered bedrock terrain under the ice divide and potential for preservation of an older, relict landscape under a cold-based glacier regime; 3) what is the limit of post-glacial marine inundation, glacial retreat pattern and rate, and influence on surficial sediment composition and redistribution; and 4) how can we improve on current remote predictive mapping methods to enhance surficial geology mapping and field methods. This report briefly describes the 2015 field work methods and discusses preliminary results.

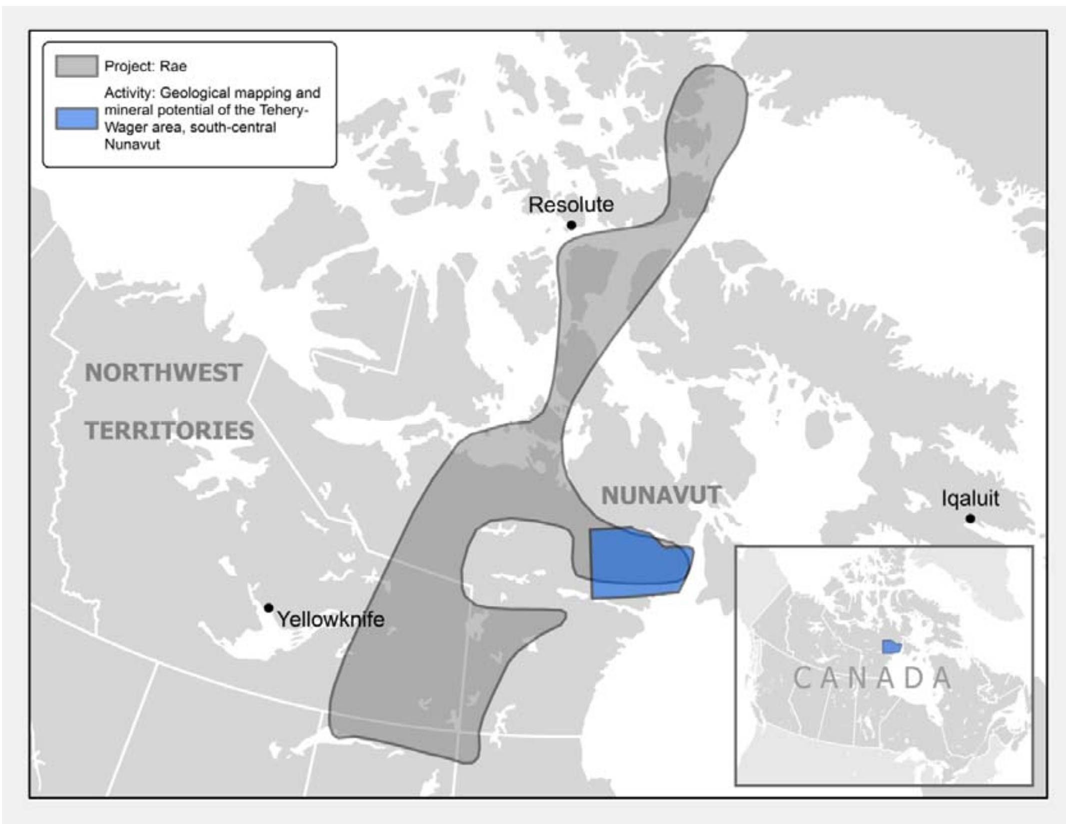

Figure 1. *Location of the GEM 2 Tehery-Wager activity area within the Rae project associated with this report.*

Methodology

Surficial geology observations

Field observations were collected in July 2015 at 111 stations accessed by helicopter or along foot traverses (Fig. 2). In addition to the actual stations on the ground, numerous observations were noted on paper maps and air photos; GPS-referenced photographs were collected directly from the helicopter. The work involved collecting observations on surface sediments, landforms and small-scale glacial erosional features on bedrock, measuring the elevation of the post-glacial marine limit, and verifying the reconnaissance surficial geology maps in NTS 56A and 46D compiled during the GEM 1 program (Dredge et al., 2013a-c). Sites and traverses were chosen based on previous work, nature of the surficial geology as observed on air photos and satellite imagery, targeted bedrock units and/or geochemical anomalies, and logistics shared with other project participants (see Wodicka et al., 2015; Steenkamp et al., in press).

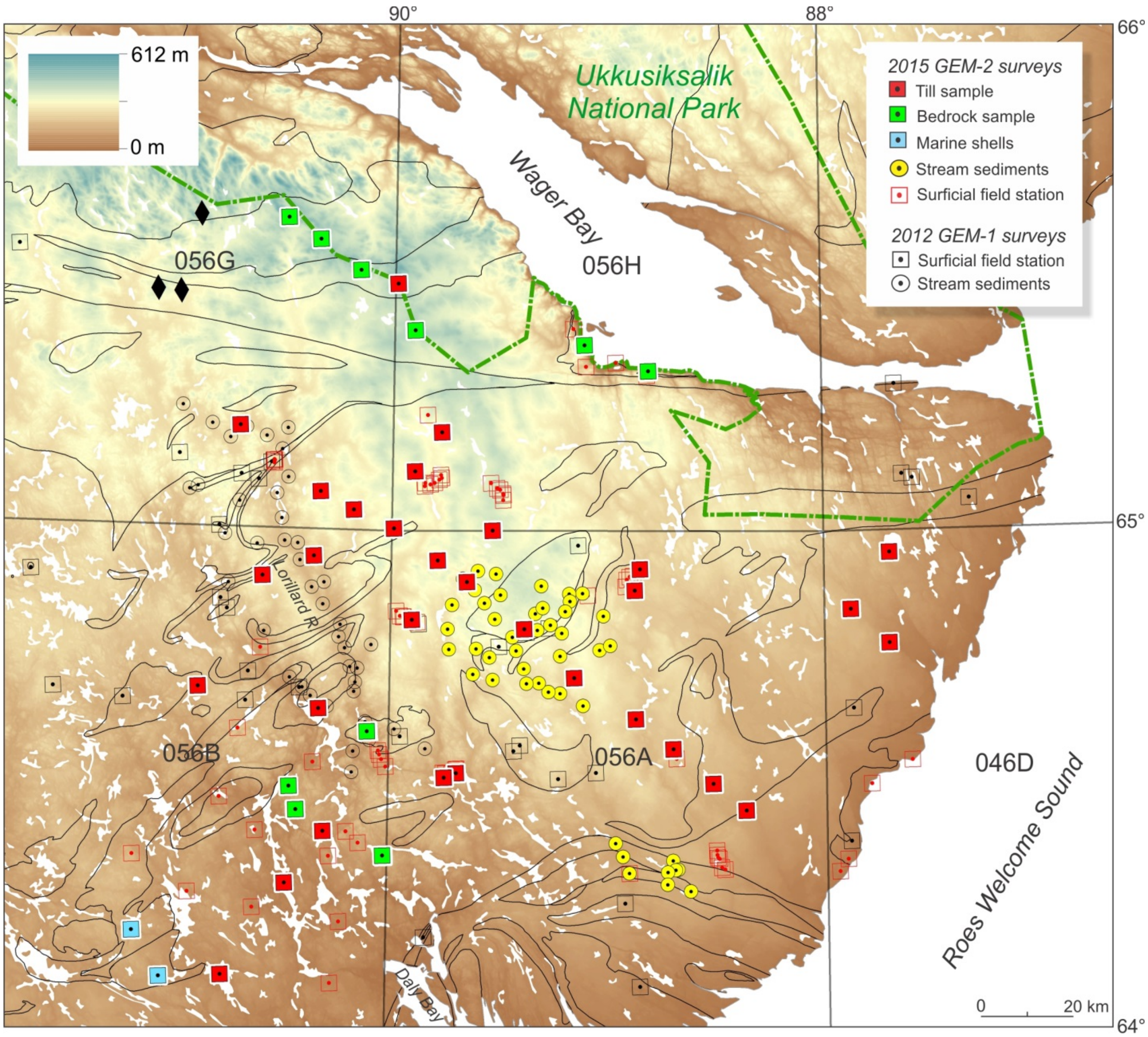

Figure 2. *Location map of till and stream sediment samples collected in 2015. Bedrock and marine shell samples collected for Quaternary age dating are also shown. Surficial geology field observations and/or till samples and stream sediment samples collected in 2012 are indicated. Known kimberlite bodies appear as black diamonds. Bedrock units presented in Wodicka et al. (2015) are outlined. DEM generated from CDED 1:250 000 topography. NTS map divisions shown.*

Geochronological samples

Three different types of landforms were sampled for cosmogenic nuclide dating. Four bedrock samples were collected in weathered upland terrain south of Wager Bay under the Keewatin Ice Divide to constrain the relative age of potentially preserved (older) surfaces under a cold-based dome (Fig. 2); these outcrops are characterized by the absence of glacially polished surfaces or ice flow indicators (cf., McMartin and Dredge, 2005). Six bedrock samples were collected at or slightly below the post-glacial marine limit to date the timing of marine emergence. At one of these sites, a glacially polished surface was also sampled immediately above the marine limit. These sites are characterized by intensely wave-washed surfaces surrounded by bouldery beaches forming a distinct trimline with unmodified till-covered surfaces above (Fig. 3a). The exposure ages will help constrain the time of the maximum marine stand in Wager Bay and Chesterfield Inlet. Finally, one sample was collected from a sub-angular boulder perched on smaller boulders resting on a glacially polished outcrop, above the elevation of the marine limit, to provide a minimum deglaciation age. All sample sites were from non-vegetated flat outcrops (1°-3°) removed as far as possible from nearby slopes (Fig. 3b), or from the flat-top portion of the perched boulder. This ensures that the surfaces have had full exposure to cosmic rays (no shielding) after deglaciation or marine emergence. A ~25 cm x 25 cm grid surface was sawn on the outcrop and the ~2 cm thick cuttings (~2 kg) were removed with a chisel (Fig. 3b-c). The lithology collected was granitic to ensure enough quartz mineral grains for ^{10}Be and/or ^{26}Al exposure age dating (Gosse and Phillips, 2001).

Marine mollusks are rare in the study area. Marine shells were found at only two sites near the Connery River that flows into Hudson Bay northeast of Chesterfield Inlet (Fig. 2). They were collected at the surface of frost boils developed in till mixed with marine sediments. The two sites lay 12 km apart at elevations of approximately 120 and 80 m above sea level (asl). Only one date from a site at 126 m elevation east of Borden River in NTS 56A is available for the entire region between Chesterfield Inlet and Wager Bay (GSC-289: corrected ^{14}C age of 6600±170 years; Craig, 1965). Single shells of Hiatella arctica from each of the two 2015 samples will be submitted for radiocarbon age determinations. The new radiocarbon dates will provide information when sea level stood near the respective elevations, and also give minimum deglaciation ages for the outer part of Chesterfield Inlet.

Field validation of RPM classification maps

Remote predictive maps of surficial materials were produced for the area east of 90° longitude south of Wager Bay using a combination of Landsat-8, Radarsat-2 C-HH and C-HV and DEM/slope data following the method of LaRocque et al. (2012) developed for the northeast Thelon River area, Nunavut. The method was first tested over the GEM 1 north Wager Bay area for which GPS field station data were available. The method uses Random Forests to classify the remote images based on training areas that were delineated from GPS data and photo-interpretation (Byatt et al., in press). Classification accuracies and mapping accuracies by comparison with the GPS field sites were well above those obtained over the same area by Campbell et al. (2013), which only used Landsat images and a maximum likelihood classifier. Using this same method and based on new training areas that were delineated from photo-interpretation, a preliminary RPM map with 15 classes was established for the southern part of Wager Bay. The purpose of the 2015 field work was to collect GPS field observations over relevant sites to assess the mapping errors and eventually correct the map. Two types of field data were collected: field observations at the visited sites and aerial photographs between visited sites. The 45 sites that were visited are located in ten areas of interest that represent the surface material diversity of the area. For each visited site, the recorded observations included the geographic coordinates, ground photos of the site (surface and material) and ground photos of the area surrounding the site. Each site was also described, with an attempt to classify it as one of the 15 surface material classes of the map.

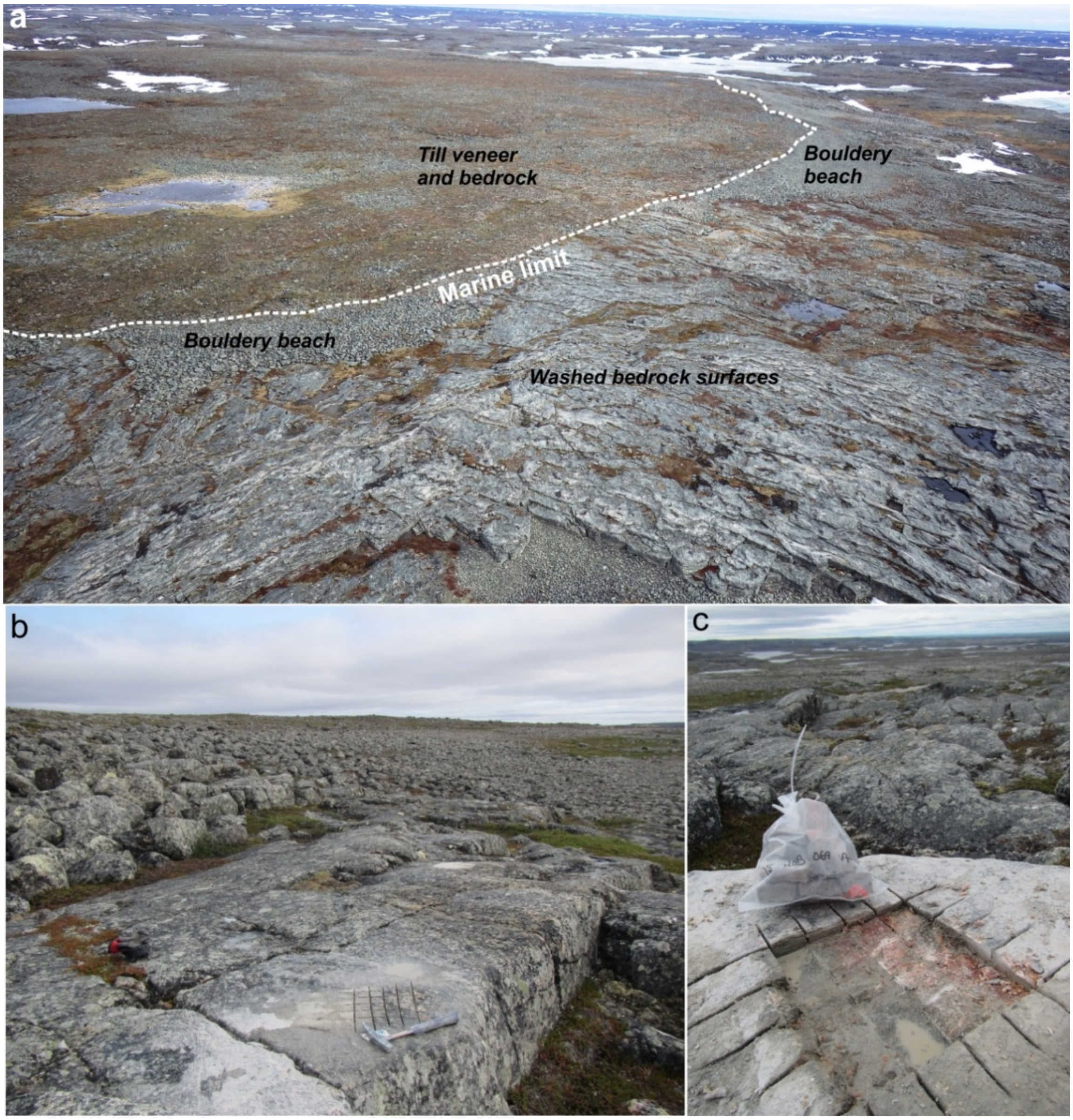

Figure 3. a) *Washed bedrock surfaces and bouldery beaches marking the post-glacial limit of marine inundation east of Lorillard River in NTS 56B.* ***b)*** *Flat bedrock surface immediately below marine limit sampled for cosmogenic nuclide exposure dating (site 15MOB069).* ***c)*** *Quartz-feldspathic granite gneiss collected with a rock saw and chisel.*

Till and stream sediment sampling

In total, 33 till samples were collected to provide more detail on geochemical anomalies identified in 2012, or to support bedrock mapping in drift covered terrain (Fig. 2). Till samples were also collected at approximately 10 km intervals along a 140-km long transect parallel to ice-flow (SE) to characterize the regional glacial transport (provenance); the transect overlaps parts of a regional Mg-rich olivine SE-trending dispersal train in till (McMartin et al., 2013) and crosses a NE-SW trending supracrustal belt that shows anomalous concentrations of Ag, Cu, Bi, Au and Co-Fe arsenide minerals in till and/or stream sediment samples (Day et al., 2013; McMartin et al., 2013). Samples were carefully collected on flat till surfaces in Cy-horizon material from hand dug pits in frost boils, at an average depth of 30 cm. At each site, one small sample (~3 kg) and one large sample (~10 kg) were collected. All samples will be processed for geochemistry, heavy minerals, clast analysis and texture.

Stream sediment and water samples were collected at 46 sites, predominantly from the headwaters of the Borden River (parts of NTS 056A), as well as from a small area further downriver (Fig. 2). Bulk stream sediment samples were wet sieved on site to obtain ~15 kg of < 2mm sized material from relatively high-energy, gravel rich sites and will be processed for their heavy mineral content (Fig. 4). Silt sediment samples consisting of representative fine-grained material were gathered from relatively lower energy environments within the active stream bed. After being dried to completion (<40°C), the silt samples will be sieved to obtain the <177 µm fraction for chemical analyses. Water samples were collected from the main flowing channel, filtered (0.45 µm) in situ and will undergo chemical analyses. Site-specific field observations were recorded at each location.

Figure 4. a) *Samples collected and field equipment used at a typical bulk stream sediment and water site.*
b) *Sieving sediments along an unnamed stream in the northwest quadrant of NTS 56A.*

Results

Regional surficial geology mapping and Quaternary history framework

Regional surficial mapping indicates the area is characterized by swaths of streamlined, thin and thick till extending southeast from the Keewatin Ice Divide zone, interspersed by a complex system of sub-glacial meltwater corridors and pro-glacial channels (Fig. 5). These southeast-trending corridors vary in width from 0.5 to 4 km and comprise large eskers, outwash plains, small irregular hummocks, short streamlined landforms, eroded till remnants, boulder lags, and washed bedrock (Fig. 6a). Continuous south-southeast-trending eskers cross-cut the corridors and streamlined till in the central part of the area (Fig. 5). Between the corridors, till surfaces show no sign of glaciofluvial erosion or reworking. Uplands southwest of Wager Bay are dominated by a mixture of till blankets and veneers, felsenmeer and weathered bedrock and indicate a major ice divide zone during the last glaciation from which ice flowed in opposite directions (McMartin and Dredge, 2005). Extensive areas of bedrock outcrop extend far inland along the coast between Chesterfield Inlet and the outer part of Wager Bay (Fig. 5). Folds and faults as well as small glacially scoured basins occupied by a myriad of shallow lakes are prominent features of the bedrock topography in these areas.

The predominant regional trend of streamlined till features indicates ice flow to the southeast, parallel to major 1st generation eskers, meltwater corridors and main striae direction (Fig. 5). The later more southerly esker trend, parallel to late southerly striations, cross-cut the southeast streamlined terrain and may be recessional features that formed after Daly Bay and Roes Welcome Sound were ice-free. Along and west of Lorillard River, this pattern differs and the dominant streamlined landforms and eskers are aligned to the south-southeast. Along the southern shores of Wager Bay, early north-northeast and late ice flows into and parallel to the bay are observed in the landform and striation record and suggest the KID lay in a narrow zone along and inland south of the bay during most of the last glaciation and deglaciation. No evidence for an early flow inland from Roes Welcome Sound/Southampton Island was found in the striation record; furthermore, Paleozoic carbonate clasts were only observed at the surface below marine limit suggesting these erratics were transported by icebergs and not reworked from till derived from the east.

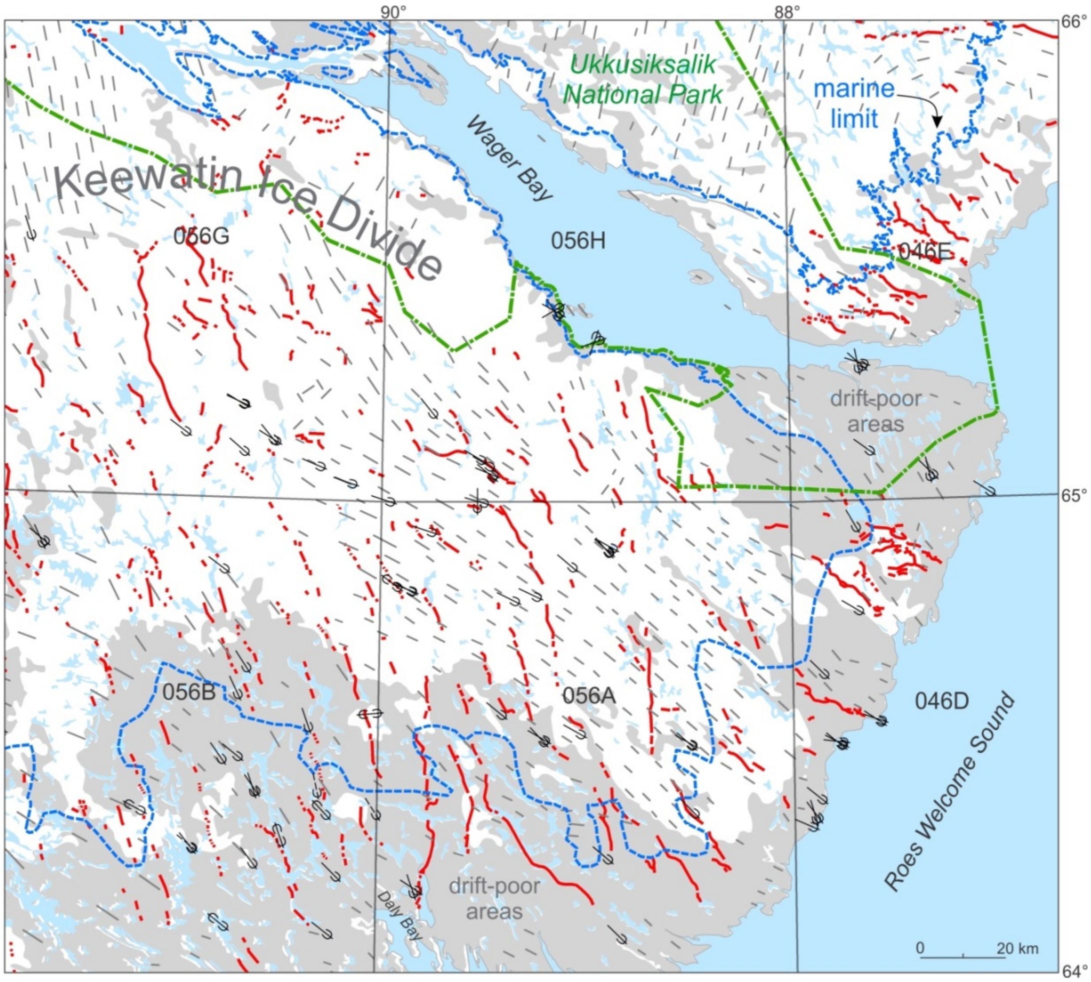

Figure 5. *Generalized landform and striation map. Striations are from GEM 1 and GEM 2 field work; streamlined forms from De Angelis (2007); generalized eskers (red lines) and drift-poor areas from Aylsworth and Shilts (1989); and marine limit from Prest et al. (1968) south of Wager Bay and McMartin et al. (2015) north of Wager Bay.*

The limit of marine submergence is variably defined in the study area. It increases from 119-125 m asl south of Wager Bay where it is characterized by fairly continuous washing surfaces, wave-cut notches and a few high level deltas, to about 145-160 m west of Roes Welcome Sound, as revealed by the highest beaches developed along esker flanks or upper limits of washed till (cf. Dredge et al., 2013 a-c). Northwest of Daly Bay, the marine limit varies between 138-152 m asl and is mainly defined by clear trimlines around small topographic highs between intact till above and bouldery beaches/washed bedrock surfaces below (Fig. 3a). Lowlands that skirt the coasts of Roes Welcome Sound and Chesterfield Inlet show evidence for post-glacial marine erosion and reworking of thin glacial and glaciofluvial sediments; marine veneers are sandy and occur as scattered deposits between rock ridges or glacial landforms (Fig. 6b); thicker marine sands and silts are limited and only found along the major river embayments just below marine limit (Borden River, Mistake Creek, Gordon River, Kamarvik Creek), or adjacent to a few large eskers within the meltwater corridors that extend to the coast.

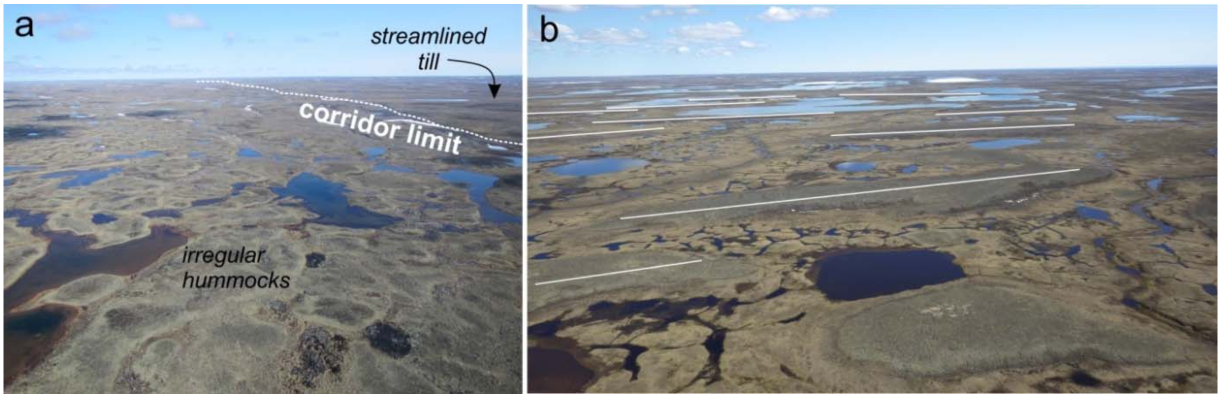

Figure 6. a) *Subglacial meltwater corridor with small irregular hummocks cross-cutting streamlined till terrain.* ***b)*** *Streamlined till interspersed by fine-grained marine sediments overlain by thin organic cover in which thermokarst ponds have developed.*

Remote predictive surficial materials mapping

Using the same methodology tested in the north Wager Bay area and based on training areas that were delineated from photo-interpretation, an RPM map with 15 classes was established for the southern part of Wager Bay (Fig. 7). The data collected during the field work is still being processed. The photographs taken from the helicopter have all been geolocated and sorted by time and date of capture. Both the GPS field observations and aerial photographs will be used to further refine the preliminary RPM map and to assess its mapping accuracy that is expressed by the percentage of GPS sites correctly mapped over the RPM map for each surficial material class.

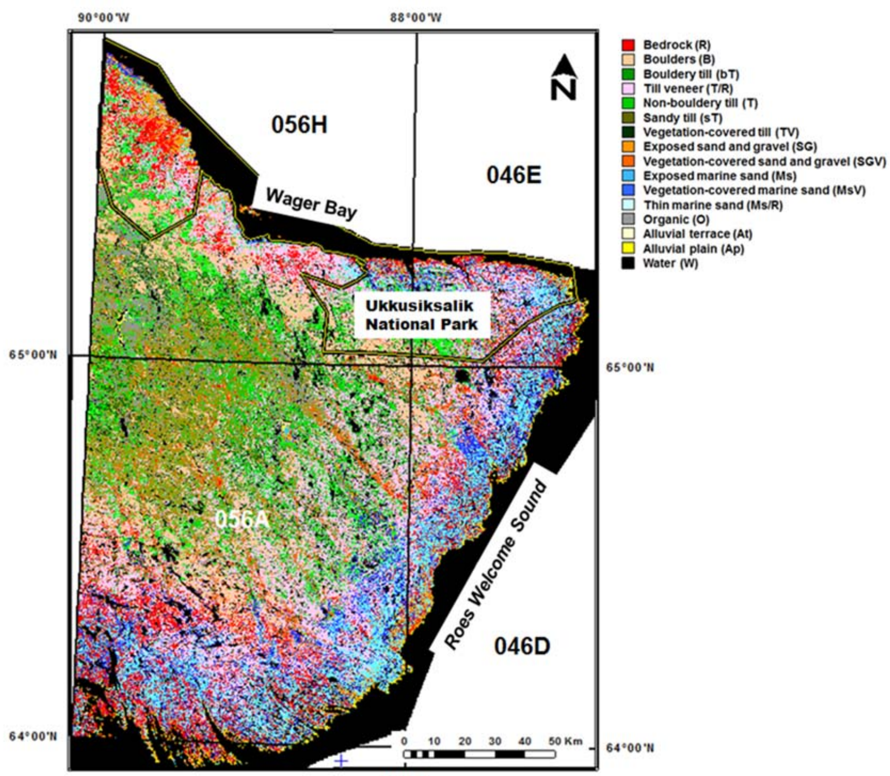

Figure 7. *Remote predictive surficial materials map for the southern Wager Bay area as produced by a Random Forest classifier applied to LANDSAT-8, RADARSAT-2 HH and HV and DEM and slope data.*

Till characteristics and provenance

Field observations indicate that surface till is commonly sandy and bouldery (Fig. 8a); it forms sorted nets more commonly than frost boils. Silt-rich and less bouldery till is found in the extensively streamlined blankets of NTS 56A-North or in subdued thick till hummocks closer to the ice divide in NTS 56H and 56G where frost boils abound (Fig. 8b). Several mineralized boulders were found at the surface of till immediately (<1 km) down-ice of mineralized outcrops suggesting an important local component. Short glacial transport distances linked with proximity to the Keewatin Ice Divide were suggested by previous till surveys (Dredge et al., 2005; McMartin et al., 2013). One gossanous area with sulphidic quartz-magnetite ironstone outcrops was found in NTS 56B while prospecting for mineralized boulders and till sampling. Preliminary interpretation of field pXRF analysis performed on several till sub-samples did not highlight any geochemical anomalies but further geochemical analysis will help to better evaluate provenance and mineral potential.

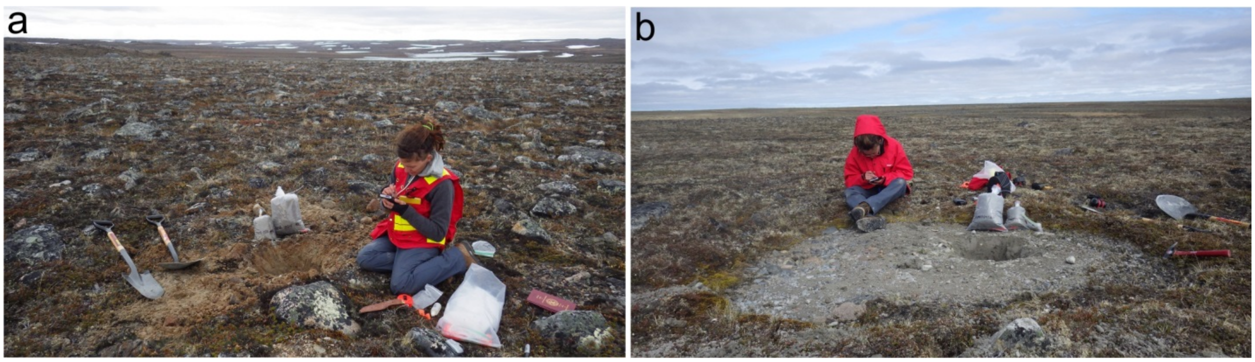

Figure 8. a) *Bouldery sandy till east of Lorillard River in the NE extremity of NTS 56B (site 15MOB024).* ***b)*** *Silty till in streamlined landform near Mistake Creek in NTS 56A (site 15MOB043).*

Summary of 2012 GEM 1 stream sediment survey

As part of the GEM 1 Tehery-Cape Dobbs project, a reconnaissance stream sediment and water study was carried out in 2012 along a 100-km long section of the Lorillard River (parts of NTS 56A, B and G; Fig. 2). Mineralogical and geochemical results for the samples collected from the 41 sites are presented in Day et al. (2013). The heavy mineral content of the bulk sediment samples provided several interesting distribution patterns. The greatest number of recovered pyrope garnet grains was from sites in the northern portion of the study area (approximately 50 km SSE of the Nanuq kimberlite cluster, Fig. 2). Chromite grains were most plentiful in several samples collected from different but adjacent watercourses roughly 100 km SSE of the Nanuq cluster and indicate a local ultramafic source. The presence of safflorite (cobalt-nickel-iron diarsenide $(Co,Ni,Fe)As_2$) in two adjacent unrelated sites - one site on the Lorillard River and the second site on a tributary, indicates a possible nearby source for these indicator grains commonly associated with Co-Ni-As ore deposits. Furthermore, McMartin et al. (2013) reported a silver anomaly in till samples collected less than 5 km from the safflorite-rich stream sediment sites. Further bedrock mapping and till sampling in this area is planned for 2016.

Conclusions

Targeted field work during the summer of 2015 in the eastern part of the Tehery-Wager study area has provided an opportunity to gather data on the history and pattern of glacial flow and ice margin retreat, to collect till and stream sediment samples for provenance and mineral composition, and to test preliminary RPM classifications maps with field observations. Future work will include data and map compilation, sample analysis, and interpretation. Additional field work is planned for 2016.

The surficial geology south of Wager Bay within the Douglas Harbour map sheet (NTS 56 H) will be compiled at 1:100 000 scale as part of a MSc thesis at UQAM by Iyse Randour under the supervision of Dr. Martin Roy; the thesis research will also include the detailed mapping of the marine limit for the entire project area, and the reconstruction of the regional glacial retreat pattern based on geomorphology, sediment distribution and the interpretation of radiocarbon and cosmogenic nuclide ages collected at and below marine limit.

An updated remote predictive surficial materials map will be prepared for the area east of 90° longitude (NTS 46E, 46D, 56A, 56G) as part of a M.Sc. thesis at UNB by Justin Byatt under the supervision of Drs. Brigitte Leblon and Armand LaRocque with the help of Dr. Jeff Harris (GSC); the map will be validated with the GPS field observations and aerial photos for mapping accuracy assessment.

Acknowledgments

This work was conducted as part of Tehery-Wager activity within the Rae Area of Interest of the GEM 2 Program. We are most grateful to Natasha Wodicka and Holly Steenkamp for project management and field logistics at the Lorillard River camp, and Étienne Girard and Rochelle Buenviaje for GIS support during and after the field work. In addition we gratefully acknowledge Discovery Mining Services in Yellowknife and Greg Tanuyak in Chesterfield Inlet for their expediting and assistance with camp logistics, Ookpik Aviation and Prairie Helicopters for expert fixed and rotary wing support, L. Levesque for the most enjoyable meals, and Polar Continental Shelf Program for logistical support (Project #05315). Finally we thank T. Peterson and C. Lawley (GSC colleagues), C. Guilmette (Université Laval) and K. Hatogina, J. Beales and B. Garrison (bedrock field assistants) for enthusiastic support and assistance during the surficial surveys, and bear monitors W. Angotinjoar and J. Autut and assistant cook R. Issaluk. Justin Byatt is supported by an NSERC PG, NBIF, and ACUNS scholarship as well as by a Northern Scientific Training Program grant and the NSERC Discovery grant awarded to Dr. Brigitte Leblon; Iyse Randour is supported by an NSERC grant. We thank Rod Smith for kindly reviewing the report.

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