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Report of 2016 activities for the surficial mapping and sampling surveys in the Tehery-Wager GEM-2 Rae Project area

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Isabelle McMartin, Steve Day, Iyse Randour, Martin Roy, Justin Byatt, Armand LaRocque and Brigitte Leblon

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.

Project Summary

This publication summarizes the 2016 field work completed south of Wager Bay, mainland Nunavut, as part of the surficial component of the GEM-2 Tehery-Wager Activity within the Rae Project area (Fig. 1). The report outlines field methods and field observations regarding the regional surficial geology and glacial history, the detailed mapping of the post-glacial marine limit, and the targeted sampling of glacial and stream sediments. The 2016 field work is a continuation of the work undertaken in 2015 to provide new geological knowledge on the nature and composition of surficial materials deposited during the last glaciation and following ice retreat, post-glacial marine inundation and emergence. The findings will support informed decision making for resource exploration and development, and for land use management.

Introduction

Rationale and background

An appropriate Quaternary geological framework is essential for the implementation of successful mineral exploration programs in glaciated, drift-covered terrain. Targeted surficial geology studies as well as glacial and stream sediment sampling for geochemistry and mineral indicators was initiated in 2015 east of 91° longitude between Wager Bay and Chesterfield Inlet as part of the GEM-2 Tehery-Wager Activity in the Rae Project area (Byatt et al., 2015, 2016; McMartin et al., 2015a, 2015b, 2016; Randour, 2016; Randour et al., 2016a, 2016b). Concurrent bedrock (Wodicka et al., 2015, 2016a, 2016b; Steenkamp et al., 2015, in press) and gravity (Tschirhart et al., in press) studies were also completed in the same area. This activity was a follow-up to GEM-1 reconnaissance scale bedrock mapping, till and stream sediment surveys in the Tehery-Cape Dobbs region in 2012 which had 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).

Regional context

Surficial geology mapping south of Wager Bay (NTS 56G: Dredge and McMartin, 2007) indicated that ice flowed in opposite directions from a major ice divide zone within the study area during the last glaciation (i.e. Keewatin Ice Divide: KID) and that weathered terrain in the uplands southwest of Wager Bay coincided with parts of the ice divide (McMartin and Dredge, 2005). Regional mapping as well as reconnaissance-scale till sampling also showed extensive areas of subglacial and pro-glacial meltwater reworking of glacial sediments, and poorly defined glacial dispersal trains (Dredge et al., 2005, 2006). Two adjacent preliminary surficial geology maps in the western part of the activity area and presumably underlain by the continuation of the KID show conflicting glacial flow directions; all eskers and streamlined landforms indicate a northward flow in one map (Thomas and Dyke, 1981) and a southward flow in the other map (Aylsworth, 1990). More recently, preliminary surficial geology maps compiled at 1:100 000 scale in the eastern part of the study area during the GEM-1 program (Dredge et al., 2013a-c) suggested a complex deglacial history with major glaciofluvial corridors and glacial sediment units variously reworked by glacial meltwater and/or marine action.

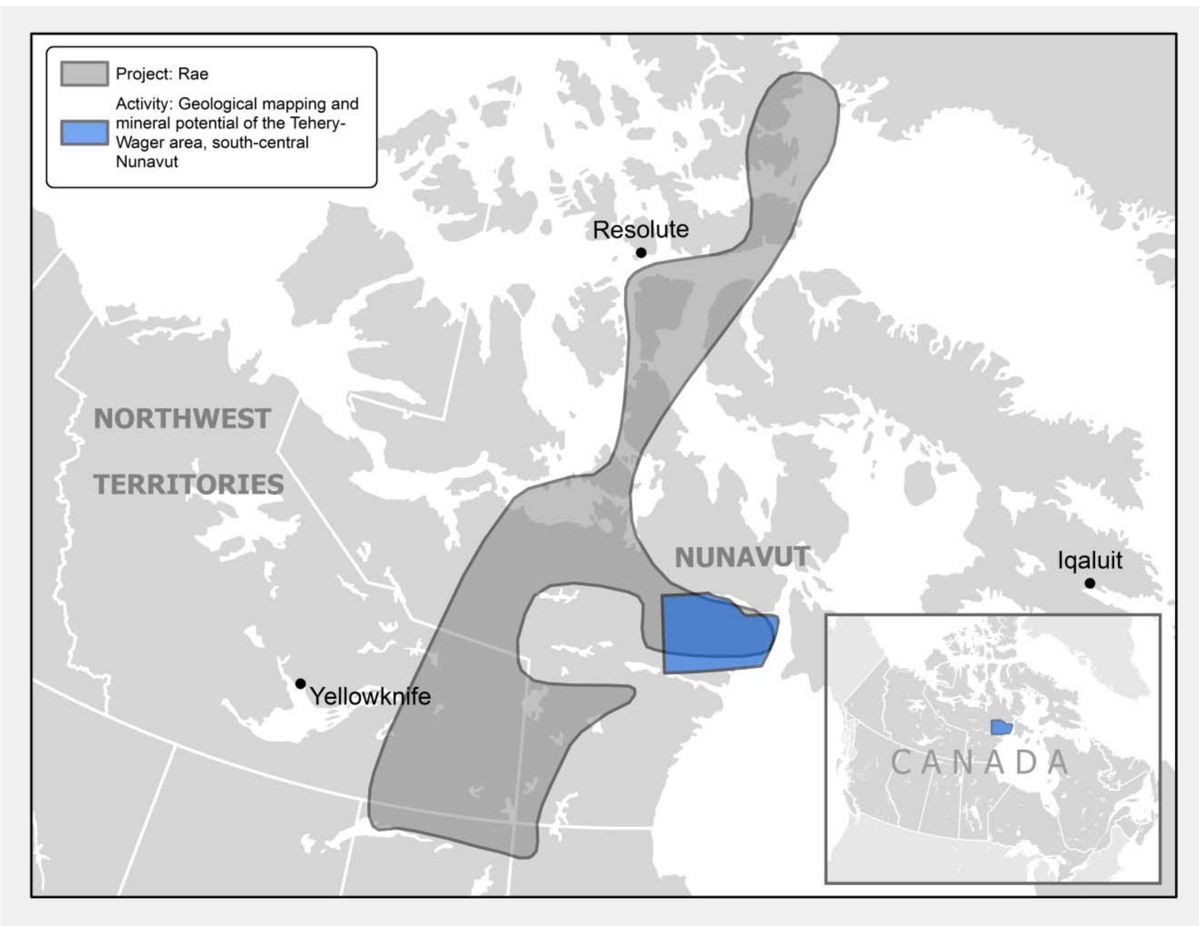

Figure 1. *Location of the GEM-2 Tehery-Wager activity area within the Rae project associated with this report.*

Goals and objectives

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 KID; 2) what is the age of the weathered terrain under the ice divide and potential for preservation of an older, relict landscape under a cold-based glacier regime; 3) what is the glacial chronology and retreat pattern; 4) what is the limit of post-glacial marine inundation and influence on surficial sediment composition and redistribution; and 5) how can we improve on current remote predictive mapping methods (RPM) of surficial materials to enhance surficial geology mapping and field methods.

In 2016, surficial geology studies and targeted surface sediment sampling continued in the central and western part of the GEM-2 activity area to gain new information on the surficial geology, glacial dynamics and chronology, nature of glacial transport and marine reworking, and to evaluate mineral potential and follow-up on sources of anomalous areas determined in 2015. Mapping protocols and classification of surficial materials using RADARSAT-2 C-HH and C-HV, LANDSAT-8 OLI, DEM and slope data were also developed for the GEM-1 Wager Bay North area, and an updated RPM materials map using these protocols will be prepared for the eastern part of the Tehery-Wager GEM-2 area. This report briefly describes the 2016 field work methods and field observations, and provides and update of the remote predictive surficial mapping progress.

Methodology

Surficial geology field observations

Field observations were collected during 2 weeks in July 2016 at 85 stations mainly accessed by helicopter (Fig. 2). In addition to the ground stations, GPS-referenced photographs were taken and observations were noted from the helicopter and recorded in the Ganfeld system from a GIS-based tablet. The work at each ground station involved collecting observations on surface sediments (texture, color, structure, sorting, secondary processes, etc.), landforms, periglacial features, and small-scale glacial erosional features on bedrock. Altitude measurements of the post-glacial marine limit were also collected along Wager Bay with GPS altimeters and barometer altimeters calibrated to benchmarks (Randour et al., in press). Observation sites were chosen based on: 1) specific questions regarding the surficial sediments, landforms and ice-flow directions as observed on air photos and satellite imagery, or from previous mapping, 2) planned till sampling transects across the ice divide, 3) targeted geochemical anomalies, and 4) logistics shared with other project participants (see Wodicka et al., 2016b; Steenkamp et al., in press).

Sampling for cosmogenic nuclide exposure dating

Three samples were collected for cosmogenic nuclide exposure dating in 2016. One bedrock sample was collected in weathered upland terrain southwest of Wager Bay under the Keewatin Ice Divide to further constrain the relative age of potentially preserved (older) surfaces under a cold-based dome (McMartin et al., 2015a; Fig. 2); the sampled outcrop consists of highly weathered Hudson Suite granite characterized by altered and open joint surfaces, ice-wedge polygons developed in thick weathered felsenmeer and grus, and the absence of ice-flow indicators, except for a few glacially transported erratics (Fig. 3a). Another bedrock sample was collected on a glacially polished quartzite outcrop within the Paliak supracrustal belt about 15 km from the previous weathered sample to date the timing of deglaciation and compare relative erosion rates between glacially eroded and weathered bedrock surfaces. Finally, one sample was collected from a glacially transported sub-angular Hudson Suite granite boulder resting on weathered and spalled granitic gneiss outcrop over the ice divide zone (Fig. 3b-c). This site was first visited in 2004 (McMartin and Dredge, 2005) and the weathered outcrop was sampled in 2015 (station 15MOB053); the age dating of the glacial erratic will provide a minimum deglaciation age and will be compared with the relative exposure age from the nearby weathered bedrock surfaces. Sampling methods with a rock saw are described in McMartin et al. (2015a).

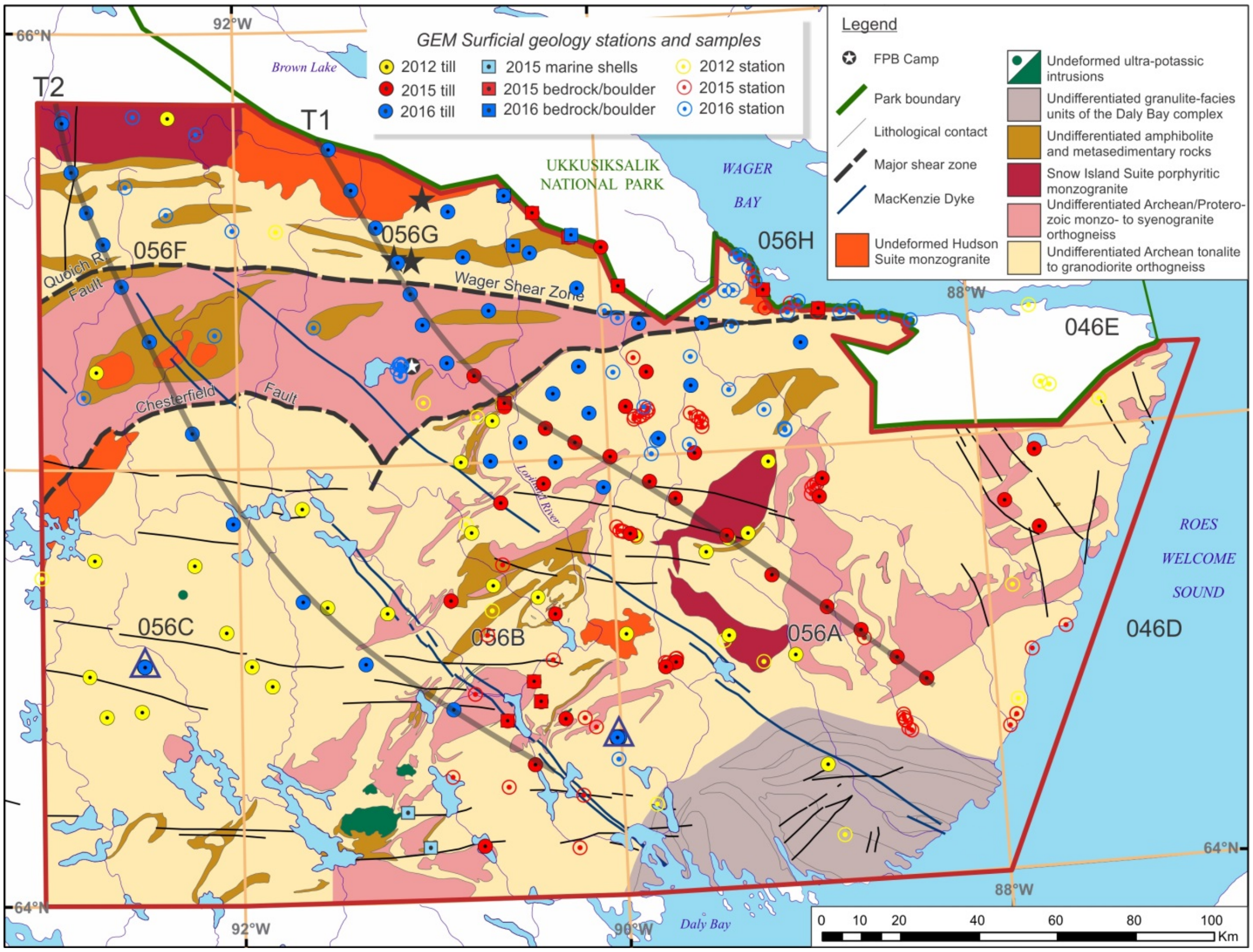

Figure 2. *Location map of till samples and surficial geology observations collected in 2012, 2015 and 2016 as part of GEM-1 and GEM-2 projects. T1 and T2 transects are indicated (see text). Bedrock and boulder samples collected for cosmogenic nuclide exposure dating are also shown, as well as the two marine shell samples dated for ^{14}C. The two detailed sites sampled in 2016 for the marine reworking study are indicated with a triangle. Known kimberlite bodies appear as black stars. Bedrock units derived from Wodicka et al. (2015) and Steenkamp et al. (2015).*

Till sampling

Till samples were collected at 40 sites to provide more detail on geochemical anomalies identified in 2015, namely a chromite grain anomaly in NTS 56G-SE (Fig. 2). Till samples were also collected at about 10-25 km intervals along two 200 km-long transects roughly parallel to ice-flow and across the KID to characterize the regional glacial transport (T1 and T2). The most eastern transect (T1) was started in 2015 and 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); to the NW of the supracrustal belt, this transect intersects a SSE-trending kimberlite indicator mineral train derived from one of the Nanuq kimberlite pipes, and extends on the north side of the ice divide. The western transect (T2) also extends over the ice divide zone and crosses the Wager Bay Shear Zone, the Chesterfield Fault Zone, and the limit of post-glacial marine inundation. Samples were carefully collected on flat till surfaces in Cy-horizon material from hand dug pits in frost boils, at an average depth of 40 cm. At each site, one small sample (~3 kg) and one large sample (~10-12 kg) were collected. At one site, one field duplicate sample was collected 10 m away from the original. All samples will be processed for geochemistry, heavy minerals, clast analysis and texture.

Figure 3. *a) Deeply weathered Hudson granite outcrop sampled for cosmogenic nuclide exposure dating under the Keewatin Ice Divide southwest of Wager Bay in NTS 56G (station 16MOB144). Note angular glacially transported quartzite boulder resting on the weathered bedrock in the middle of the photo. b) Sampling flat-top glacial erratic of Hudson granite resting on weathered granitic gneiss (station 16MOB147). c) Boulder surface after collection by a rock saw and chisel (station 16MOB147).*

Two carefully selected sites at the marine limit were sampled in detail to evaluate the effects of marine reworking on till texture and geochemical composition (see Fig. 2 for location). The first site is characterized by intensely wave-washed surfaces surrounded by bouldery beaches forming a distinct trimline with unmodified till-covered surfaces above; the second site forms a clear trimline around a small topographic high forming wave-cut notches between intact till above and reworked till below the marine limit. At each site, two vertical profiles in till were sampled at approximately 10 cm intervals in frost boils: one located immediately above the marine limit and one directly located below (see Randour et al., in press). In addition to the profile samples, five field duplicate samples at an average depth of 40 cm were collected nearby each frost boil to measure site variability. A total of 54 small (~3 kg) samples were collected for this detailed study.

Stream sediment and water sampling

Stream sediment and water samples were collected at 67 sites in 2016, predominantly from the headwaters of the Lorillard River (parts of NTS 056G), as well as a transect across a nearby Paleo-proterozoic supracrustal package in NTS 56F (Fig. 4). 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. 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.

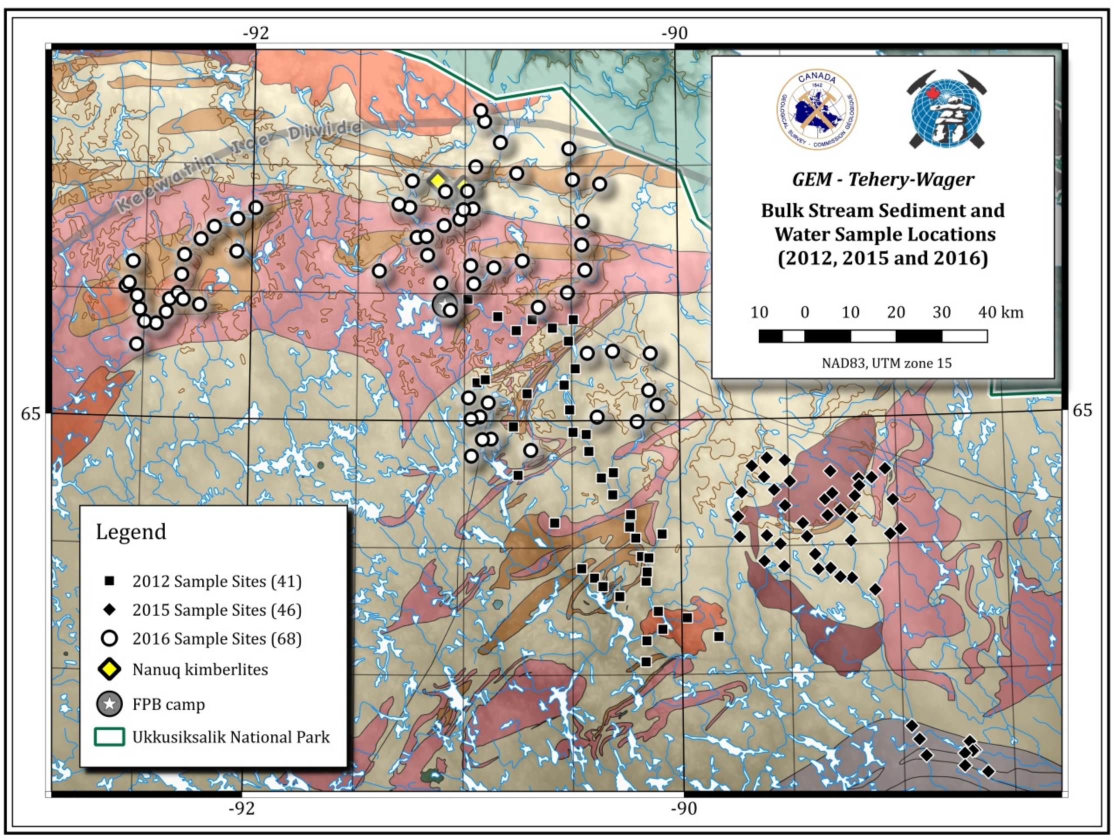

Figure 4. *Location map of stream sediment and water samples collected in 2012, 2015 and 2016. Bedrock geology derived from Wodicka et al. (2015) and Steenkamp et al. (2015).*

Results

Surficial geology

Targeted surficial geology mapping indicates that the uplands south of Wager Bay and Brown Lake are dominated by a mixture of till blankets and veneers, bouldery till with giant ice-wedge polygons, weathered bedrock terrain and felsenmeer and coincide with the KID zone. The weathered terrain forms an extensive area 50 km by 15 km southwest of Wager Bay mainly above 400 m altitude (Fig. 3a & 5). West of the weathered terrain, the ice divide zone is characterized by thick bouldery till (Fig. 6a), or widespread felsenmeer and thin bouldery till with few lakes and rare outcrops (Fig. 6b).

The orientation of ice flow indicators in the study area can be regrouped into ice flow sets oriented SSE, SE, ESE and NNW. The ice divide zone itself is relatively narrow and characterized by either the absence of ice-flow indicators (i.e. weathered terrain or felsenmeer) or by the presence of opposing directions (NNW and SSE). In NTS 56F, the new striation mapping now permits to relocate the ice divide axis in the middle of the map sheet at latitude ~65°30', rather than at the boundary between 56F and 56C (lat 65°). South of the divide, the predominant regional trend of streamlined till features indicates ice flow to the SE and ESE, parallel to main striation directions (Fig. 5). Late SSE striae, parallel to a later more SSE esker trend, cross-cut the predominant streamlined terrain in patchy areas. In contrast, west of Lorillard River, as well as towards the uplands of Wager Bay, the dominant streamlined landforms, eskers and striations are aligned to the SSE. Finally, along the southwestern shores of Wager Bay in NTS 56H, early northward and late ice flows into the bay are observed in the landform and striation record and suggest that the KID lay in a narrow zone inland southwest of the bay. These northward directions are not observed at Masivak Creek and further east within 46E, where the dominant ice flow directions revert to the SE, hence confining a zone where the central axis of the KID continued into Wager Bay.

A complex system of sub-glacial meltwater corridors and proglacial meltwater channels are interspersed between swaths of streamlined, thin and thick till that extend outward from the KID. The south-southeast- to southeast-trending meltwater corridors vary in width from 0.5 km to 4 km and start immediately south of the KID central axis; they comprise large eskers, pitted outwash plains, small irregular hummocks and ridges (Fig. 6c), short streamlined and blunted landforms, boulder lags, and washed bedrock surfaces. Continuous south-southeast-trending eskers cross-cut some of the corridors in the central and eastern part of the area. North of the KID, very few eskers are present and meltwater corridors are absent. Where proglacial meltwater channelized systems abound, especially in NTS 56G and 56H, till surfaces show extensive erosion and/or reworking, leaving erosional remnants of reworked till, boulder lags, boulder pavements and washed bedrock surfaces, with bouldery alluvial bars and sandy outwash fans and terraces at their distal ends (Fig. 6d-e-f).

The post-glacial limit of marine inundation was mapped, characterized and measured within the study area (Randour et al., in press). Maximum marine stands increase from ~118 m asl south of Wager Bay in NTS 56H to 140 m west of Roes Welcome Sound and stay relatively constant westward at 140-150 m (NTS 56C). At the marine limit, erosion and reworking of glacial sediments have formed bouldery beaches, wave-washed surfaces, terraces, glaciomarine deltas, and wave-cut notches in till. Below the marine limit, silty sandy marine veneers and blankets are scattered in low areas; bouldery beaches skirt some esker ridges or fill in embayments between bedrock outcrops along the coastal areas.

Till and stream sediment surveys

The till samples collected at a regional scale in 2016 will be processed following the same procedures as for the 2015 samples (McMartin et al., 2015a). They will be analyzed for matrix texture, colour, carbon content, pebble count analysis, as well as geochemistry of the <0.063 mm fraction using ICP-MS modified aqua regia digestion, ICP-MS 4-acid digestion, and ICP-ES/MS lithium borate fusion.

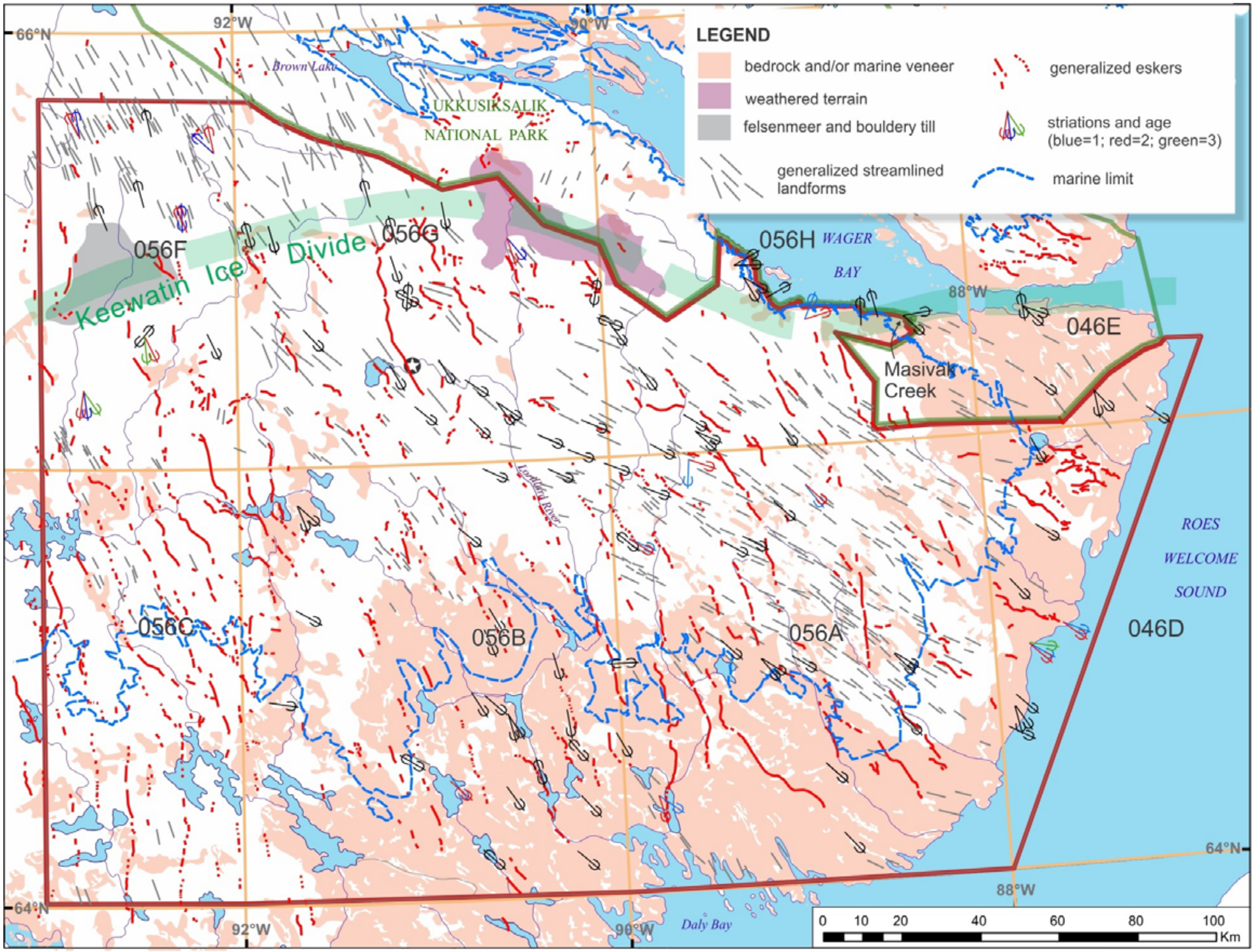

Figure 5. *Generalized landform and striation map. Striations from GEM-1 and GEM-2 field work; eskers and bedrock areas from Aylsworth and Shilts (1989); marine limit from Dredge and McMartin (2005) in NTS 56G, McMartin et al. (2015c) north of Wager Bay and Randour et al. (in press) in the rest of the area.*

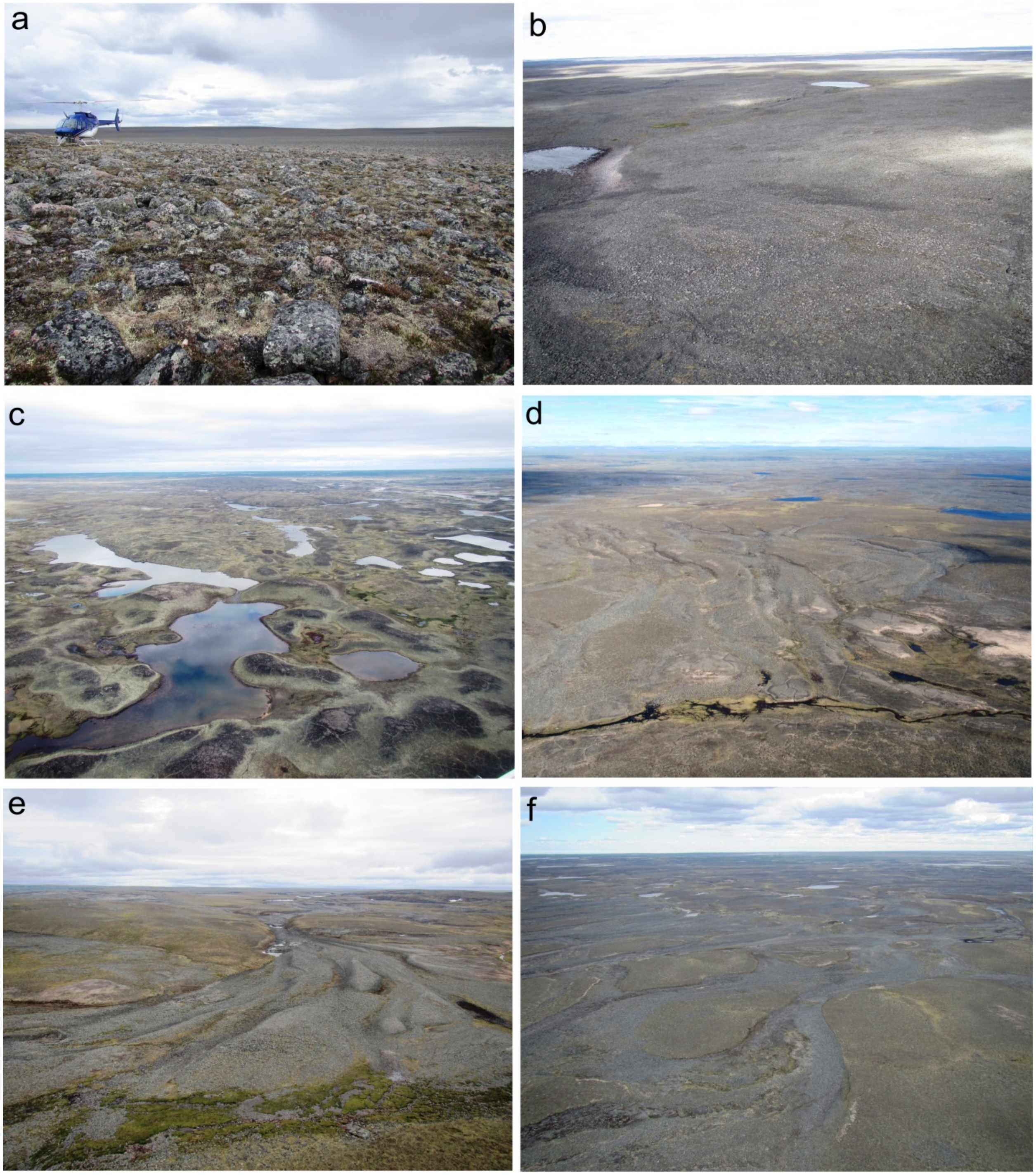

Figure 6. a) *Bouldery thick till terrain over the KID in 56G near the National Park boundary.* ***b)*** *Featureless felsenmeer terrain with few lakes and rare outcrops over the KID in 56F.* ***c)*** *Hummocks and ridges of sandy diamicton within a meltwater corridor in 56H.* ***d)*** *Sub-parallel proglacial meltwater channels with sandy outwash fans at their distal ends in 56H.* ***e)*** *Bouldery alluvial bars forming a large fan-shaped deposit down-stream of a meltwater channel in 56G.* ***f)*** *Erosional till remnants and nested proglacial channels filled with boulders and/or washed outcrops in 56H.*

Heavy mineral processing, precious metal grain counts and visual indicator mineral identification will be completed for each sample. The till samples collected in the soil profiles for the marine reworking study will be processed for geochemistry and texture only.

Stream waters collected in 2016 will be analysed by ICP-MS/ES, Ion Chromatography, pH probe, conductivity probe and titration, to obtain trace element and anion concentrations as well as pH, conductivity and alkalinity measurements. Silt samples will undergo aqua-regia/ICP-MS, 4-Acid/ICP-MS and Instrumental Neutron Activation analyses, generating concentration data for over 65 elements. The HMC fraction of the bulk sediment samples will be picked for gold and precious metals, kimberlite indicator minerals (KIMs), magmatic or metamorphosed massive sulphide indicator minerals (MMSIMs), along with a 100 grain mineral count. Stream samples collected in 2016 will follow identical processing and analytical procedures as samples taken in 2015 (McMartin et al., 2015a). All results from the till and stream surveys in terms of provenance and implications for mineral exploration and economic potential will be presented separately.

Remote predictive surficial materials mapping

Remote predictive maps of surficial materials using a combination of Landsat-8, Radarsat-2 C-HH and C-HV and DEM/slope data were first produced over the GEM-1 Wager Bay North area for which georeferenced field station data were available (Byatt et al., 2016). The same method will be used to produce an updated surficial materials map with 15 classes for the area east of 90° longitude south of Wager Bay within the GEM-2 Tehery-Wager Activity area. The method uses Random Forests to classify the remote images based on training areas that were delineated from field data collected in 2015 and air photo-interpretation (Byatt et al., 2015).

Conclusions

Targeted field work during the summer of 2016 in the west and central part of the Tehery-Wager study area has provided an opportunity to gather data on the nature, distribution and patterns of surficial sediments and landforms, relative and absolute chronology of potential relict weathered terrain and relative erosion rates, and changes in ice flow trends during the last glaciation and following ice margin retreat. Regional till and stream sediment samples were collected for provenance and evaluation of mineral potential, and detailed till samples were collected in frost boil profiles to document the effects of marine reworking on till composition in periglacial environments. Future work will include data and map compilation, sample analysis, and interpretation of 2015 and 2016 datasets. The new field observations will also help to compile or update the surficial geology maps at a scale useful for land-use management and resource exploration (1:100 000) in an area of complex glacial history near the Keewatin Ice Divide, glacial meltwater reworking and/or modification by wave and currents below the post-glacial marine limit.

The preliminary surficial geology map south of Wager Bay within the Douglas Harbour map sheet (NTS 56 H) is being compiled at 1:100 000 scale as part of an M.Sc. thesis at UQAM by Iyse Randour; the thesis research also includes the detailed mapping of the marine limit for the entire project area, the study of the effects of marine reworking on till composition, 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 an M.Sc. thesis at the University of New Brunswick by Justin Byatt; the map will be validated with georeferenced field observations and aerial photos for mapping accuracy assessment, using the classification method developed for an area north of Wager Bay.

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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 FPB camp, and Étienne Girard for GIS support during and after the field work. In addition we gratefully acknowledge Discovery Mining Services in Yellowknife for their assistance with camp logistics, Helen Moffat and Boris Kotelewetz in Baker Lake for their expediting services, Ookpik Aviation and Prairie Helicopters (Erik Polzin) for expert fixed and rotary wing support, Debbi Guilfoyle for the delicious meals, and Polar Continental Shelf Program for logistical support (Project # 059-16). Finally we thank Vicki Tschirhart and Owen Weller (GSC colleagues), and Jillian Kendrick, Loraine Lebeau, Allan Lion, Ryan Bayne and Billy Garrison (bedrock field assistants) for enthusiastic support and assistance during the surficial surveys, and bear monitors Timothy Evviuk and Alexander Alooq. Iyse Randour is supported by an NSERC grant and RAP bursary; 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. We thank Roger Paulen (GSC Ottawa) for kindly reviewing the report.

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