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B.M. Saumur, D.R. Skipton, and M.R. St-Onge

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Permanent link: https://doi.org/10.4095/305957

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Recommended citation
Saumur, B.M., Skipton, D.R., and St-Onge, M.R., 2017. Report of activities 2017, GEM-2 Baffin Project: regional bedrock mapping of northern Baffin Island (Pond Inlet and Mary River areas), Nunavut; Geological Survey of Canada, Open File 8304, 14 p. https://doi.org/10.4095/305957

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Saumur, B.M., Skipton, D.R., and St-Onge, M.R.

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 responsible land-use and 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 2017 field season, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork. Each activity included 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 partners as the program advances.

Project Summary

This report serves as a progress report on the fieldwork, map compilation and geoscience research undertaken in the GEM-2 North Baffin bedrock mapping activity in late 2016 and 2017, as part of GEM-2 Baffin Project (Fig. 1).

Geological maps inform industry, government, and community stakeholders of potential economic resources. During the past two decades, systematic and targeted mapping of Precambrian and Phanerozoic bedrock geology has been completed for large tracts of Nunavut. Updated regional bedrock map coverage for Baffin Island south of latitude 70°N was completed in 2016 (St-Onge et al., 2016). The activity described herein represents the first steps towards an updated geological framework north of 70°N, with the goal of producing maps at a scale and resolution commensurate with those produced for the southern portion of the island.

Improved geological maps will help determine the potential for diamonds, base metals and carving stone in northern Baffin Island. The area covered by the 2017 fieldwork (NTS sheet 37G, and 38B not including Bylot Island) includes the world-class Mary River iron mine operated by Baffinland Iron Mines

Corporation[1]. The hamlet of Pond Inlet is located along the northern coast of the study area, making it relatively easy to access for potential exploration work. The study area also includes portions of Sirmilik National Park, and in line with the mandate of Parks Canada, an updated geological knowledgebase for the park will benefit future generations of Canadians and park visitors.

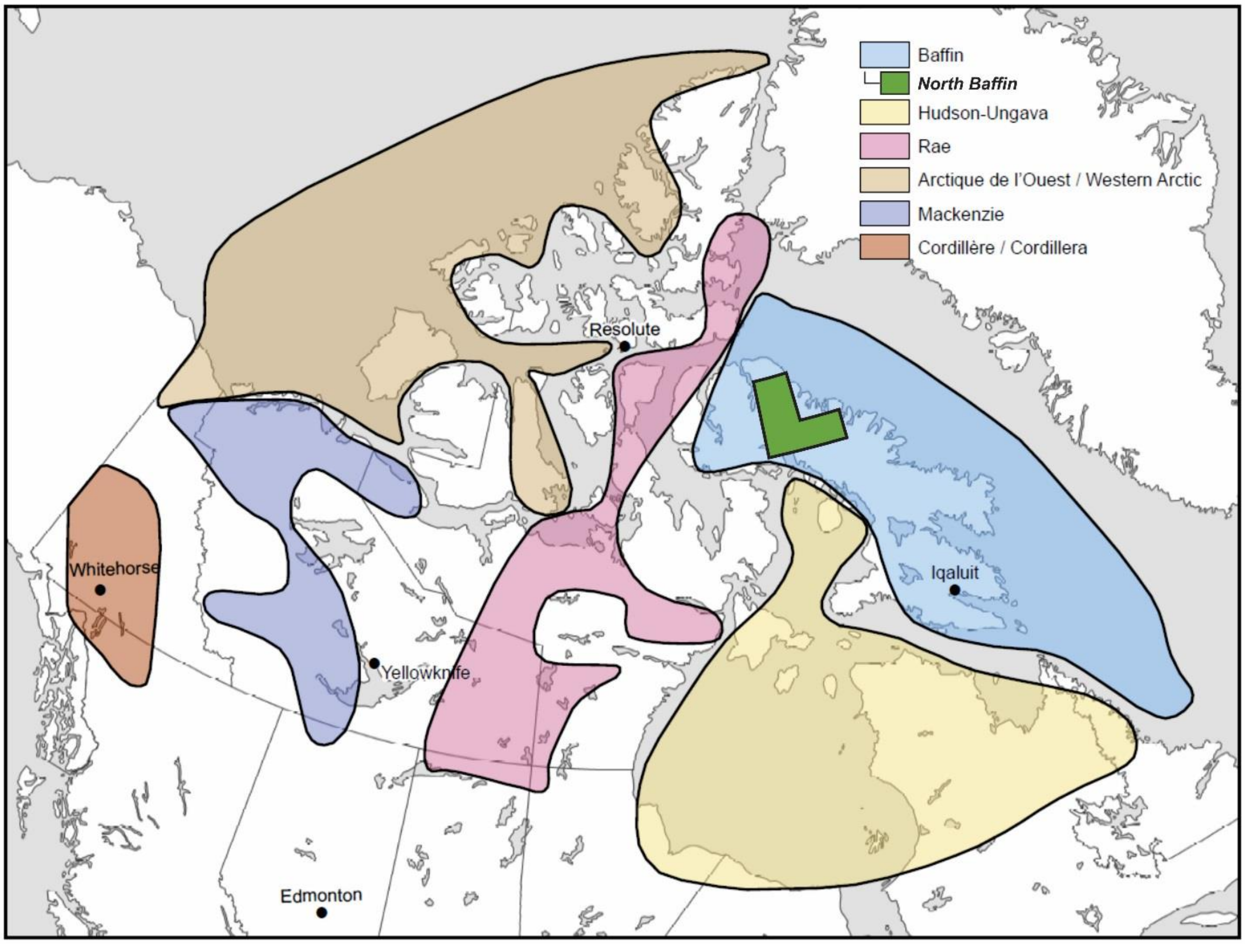

Figure 1: *2017 GEM-2 Projects. The location of the North Baffin Bedrock Mapping Activity, discussed herein, is indicated in green, as part of the Baffin Project. For further details the reader is referred to Figure 2.*

[1] http://www.baffinland.com/mary-river-mine/mary-river-mine/?lang=en

Introduction

The Archean granite-greenstone belts of northern Baffin Island are host to the world-class, high-grade/ large-tonnage, Mary River iron deposit. Despite this endowment, the greenstone belts and their associated basement gneisses remain poorly understood and under explored. Fundamental questions surround the extent, geometry, tectonostratigraphy, age and origin of northern Baffin Island's greenstone belts, and how they correlate with iron-, nickel- and gold-bearing greenstone belts of the Melville Peninsula and mainland Rae craton to the west (e.g. Skulski et al., 2003; Berman et al., 2010; Houlé et al., 2012; Corrigan et al., 2013; Sanborn-Barrie et al., 2014), and the Lauge Koch Kyst of Greenland to the east (Dawes, 2006, and references therein). Prospectivity for diamonds is strongly influenced by the antiquity and thickness of continental crust, as evidenced by Canada's newest diamond discovery, the Chidliak Kimberlite Province, which occurs in Archean basement rocks of southern Baffin Island (Nichols et al., 2013, 2014; Pell et al., 2017). However, across northern Baffin Island the extent of ancient basement versus younger plutons has not been established. Insights gained from the GEM Cumberland (Hamilton, 2014) and GEM-2 South Baffin (Chadwick et al., 2015) projects highlight significant structural reworking (sufficient to remobilize multiple metals) during the ca. 1.8 Ga Trans-Hudson orogen. By contrast, the extent and degree of Hudsonian or older reworking has not been established across much of northern Baffin Island. Does the geology of northern Baffin Island correlate with that of the central Baffin Island and Cumberland Peninsula, and what are the implications for past plate tectonics and present architecture of Baffin Island? Collectively, all of these unknowns constitute a major knowledge gap with important scientific and economic implications.

The GEM-2 North Baffin activity (Fig. 1, 2) consists of targeted and regional-scale bedrock mapping of Precambrian rocks in four 1:250,000 NTS sheets (38B, 37G, 37F and 37E). These areas were first mapped in the 1960's by the Geological Survey of Canada (GSC) (Jackson, 1969; 2000) with "A series" maps subsequently published in the 1970's (Jackson and Davidson, 1975; Jackson and Morgan, 1978; Jackson et al., 1978; Davidson et al., 1979). Further targeted mapping was conducted by the Canada-Nunavut Geoscience Office (CNGO) in the mid 2000's (Young et al., 2004; Johns and Young, 2006), and other studies on the Precambrian Shield of north-central Baffin Island have focused on various aspects of geochemistry, geochronology and tectonic evolution (e.g., Jackson and Berman, 2000; Bethune and Scammell, 2003a, b). Also noteworthy are unpublished theses on the metallogeny of the Mary River Fe-deposit (MacLeod, 2012; Howitt, 2013).

This activity stands on the shoulders of previous work, integrating data from legacy field campaigns and regional geophysical surveys with extensive new field data and state-of-the-art geochemistry and geochronology. GEM-2 North Baffin will contribute an updated, modern geological framework for Canada's Arctic, bringing the level of bedrock mapping in the northern Baffin Island area to the standard set on southern Baffin Island through previous GEM campaigns.

In this report we describe the activities carried out in the 2017-18 fiscal year, with fieldwork completed in the Pond Inlet – Mary River areas during July-August 2017. Fieldwork to the south (NTS 37F – Steensby Inlet and NTS 37E – Conn Lake) is planned for the summer of 2018 (Fig. 2).

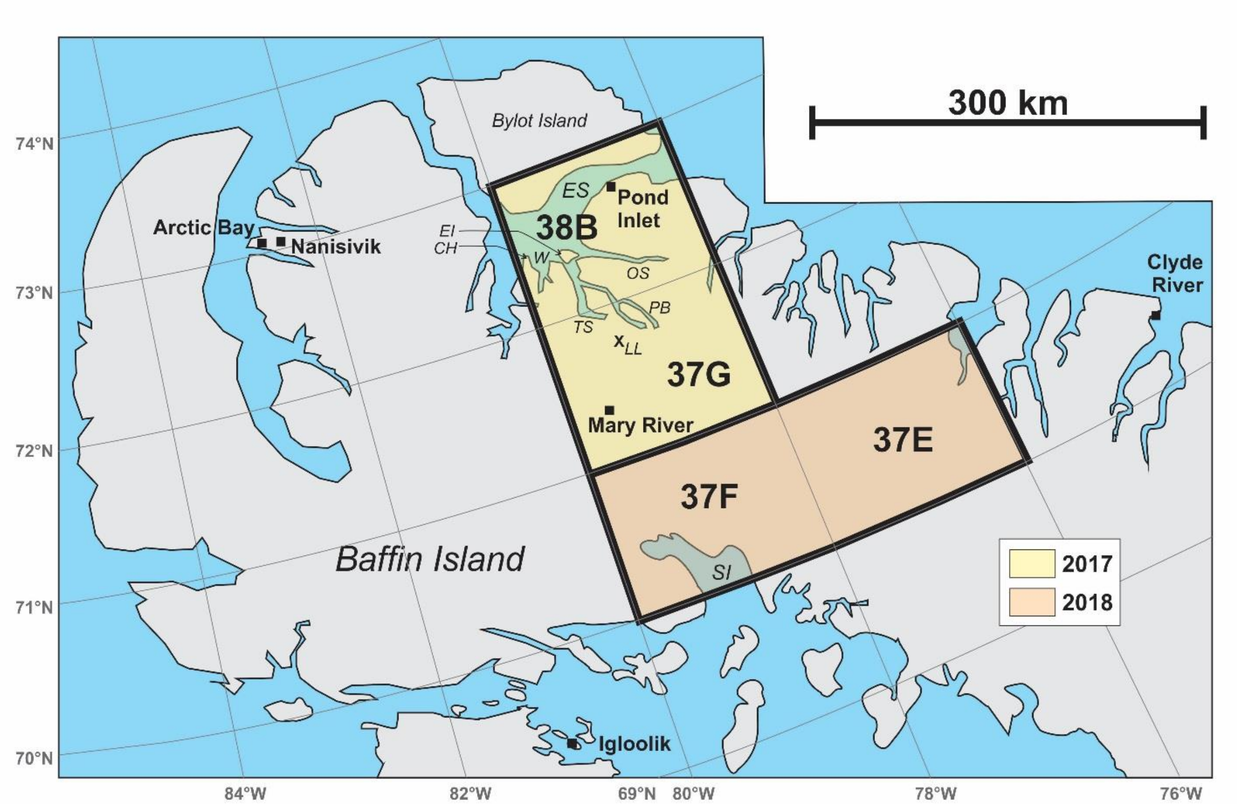

Figure 2: *GEM-2 North Baffin – Limit of mapping: summer 2017 (yellow) and summer 2018 (orange). ES: Eclipse Sound, OS: Oliver Sound, SI: Steensby Inlet, W: White Bay; CH: Cape Hatt; EI: Emmerson Island; PB: Paquet Bay; TS: Tay Sound; LL: Long Lake.*

Fieldwork Logistics and GIS Database Compilation

In the lead-up to the 2017 field season, preparations for fieldwork involved close collaboration with the Polar Continental Shelf Program (PCSP) regarding field logistics and applications for the required licences and permits (i.e., Nunavut Planning Commission, Nunavut Impact Review Board, Qitiktani Inuit Association, Nunavut Research Institute, Parks Canada). Successful in-person community engagement consultations were held in Pond Inlet in late January 2017, during which support from the Hamlet and the local Hunter's and Trapper's Organization was secured.

A comprehensive digital GIS environment, in support of both the 2017 and 2018 field seasons, was compiled in collaboration with NRCan technical staff. The environment enables the use of the Bedrock Data Model (Brouillette et al., 2015), whereby observations are compiled and brought into the GIS environment using consistent language and standard geological attributes. Such methods have been shown to streamline post-fieldwork map compilation and interpretation, enabling rapid map delivery and significant cost savings (e.g., St-Onge et al., 2016). The GEM-2 North Baffin GIS geodatabase includes legacy products stemming from previous work on northern Baffin Island (e.g., maps, field stations, aeromagnetic surveys), topographic data (e.g., toporama, digital elevation model), satellite imagery (landsat) and an airphoto mosaic (Fig. 3) constructed through the digitization of a collection of air photos. Prior to the start of the field activities, this database was used to plan 10-12 km traverses and site visits in the area of interest.

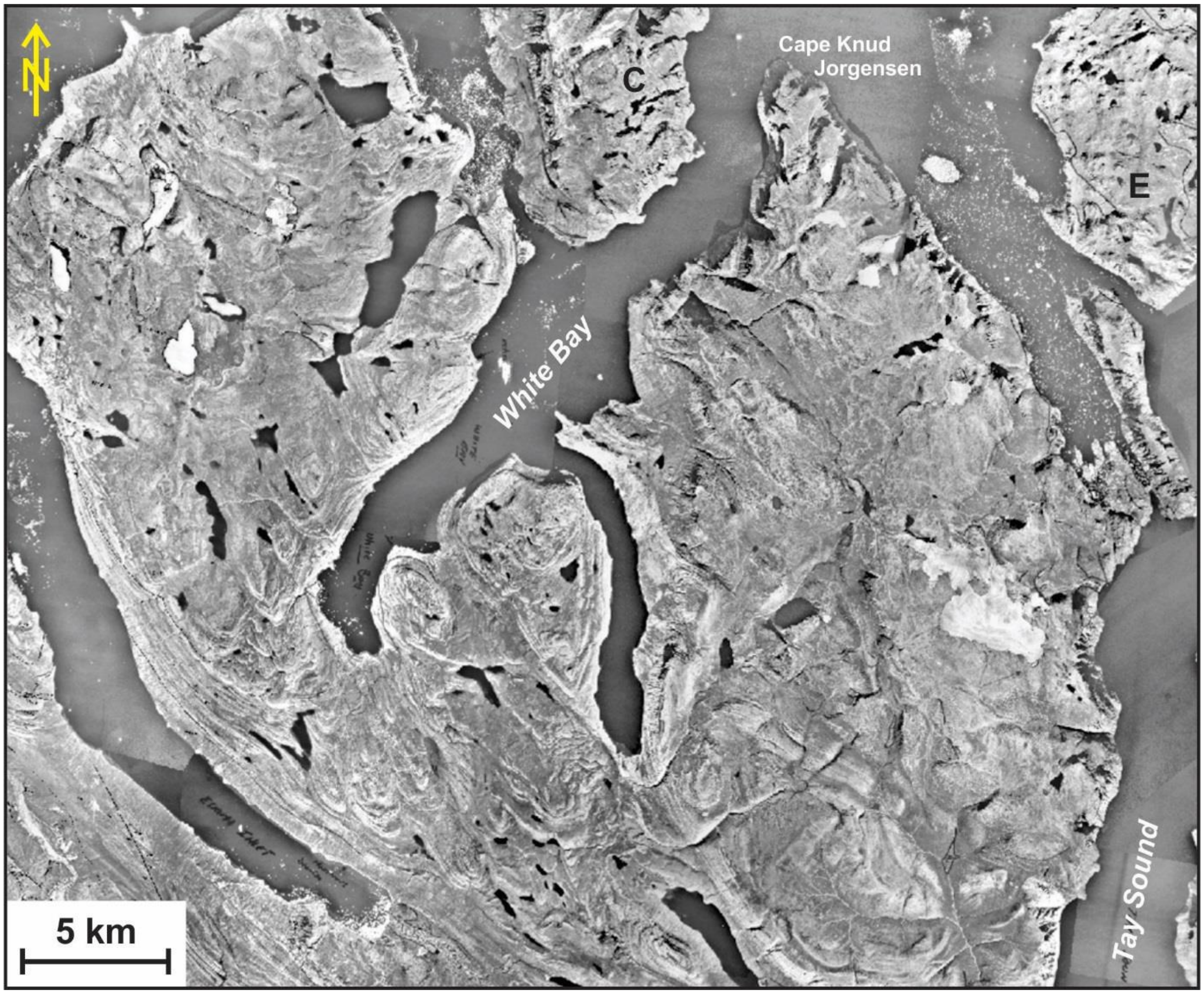

Figure 3: *A portion of the air photo mosaic developed for the GIS environment supporting the GEM-2 North Baffin mapping project. This mosaic covers part of NTS sheet 38B, in the vicinity of White Bay. E: Emmerson Island; C: Curry Island.*

Summer 2017 Fieldwork: Methods & Geological Highlights

Fieldwork was performed by a team of six to seven geologists based out of the community of Pond Inlet, Nunavut. The work consisted of helicopter-supported daily set-outs in areas west and south of the community, where teams of two geologists were dropped off to conduct foot traverses to document rock types and minerals in hand-held tablets, collect samples and take structural measurements using compasses. In addition, on selected occasions a geologist would have helicopter support throughout the day to visit a series of isolated outcrops separated by distances too great to cover on foot. The use of tablets and the GIS environment in the field enabled the immediate compilation and integration of daily observations and measurements within the digital geodatabase.

The coverage resulting from the 2017 field season, integrated with legacy field data, will enhance the regional geological knowledge of the area and support the production of three new 1:100,000-scale bedrock maps. Publication of the maps and release of the underlying ArcGIS database is planned for March 2018.

For an up-to-date, detailed account of the geology of the Pond Inlet–Mary River area stemming from this fieldwork, the reader is referred to Skipton et al. (2017, in prep.) and Bros and Johnston (2017, in prep.). Selected important scientific highlights and their relevance for understanding the geology, tectonics and economic potential of the area are presented below.

Mesoarchean basement and the Mary River Group. The potential stratigraphic basement to the prospective Mesoarchean Mary River Group (MRG), and younger crosscutting intrusions, were identified and mapped. The new observations indicate that the distribution of the MRG and other supracrustal units previously mapped as sedimentary-volcanic is not as extensive as portrayed on older maps. Nevertheless, exceptional exposures of the MRG were documented, most notably in the vicinity of Long Lake (Fig. 2; Howitt, 2013; Bros and Johnston, 2017, in prep.) where all volcano-sedimentary units and associated banded iron formation exhibit a pervasive stretching lineation (Figs. 4A-B). Ongoing work will provide a full documentation of the MRG's tectonostratigraphic context, which is essential for proper mineral exploration in the area.

Thrust fault zone of Eclipse Sound. Thrust imbrication of Archean (?) crystalline rocks and Paleoproterozoic (?) metasedimentary strata and leucogranite was documented along the southern shore of Eclipse Sound (Fig. 2), and is notably well exposed along the southern coast of Emmerson Island (Fig. 4C). Whether the structural imbrication is the far-field expression of the 2.5-2.4 billion-year old Arrowsmith, 1.96-1.92 billion year old Ellesmere-Inglefield or 1.88-1.80 billion year old Trans-Hudson orogen(s) will be determined with geochronology. The timing of the formation of the sedimentary protolith will also be determined with geochronology. These will have important implications for plate-tectonic reconstructions and, potentially, for regional correlations between North Baffin and mineralized terranes to the west, south and east

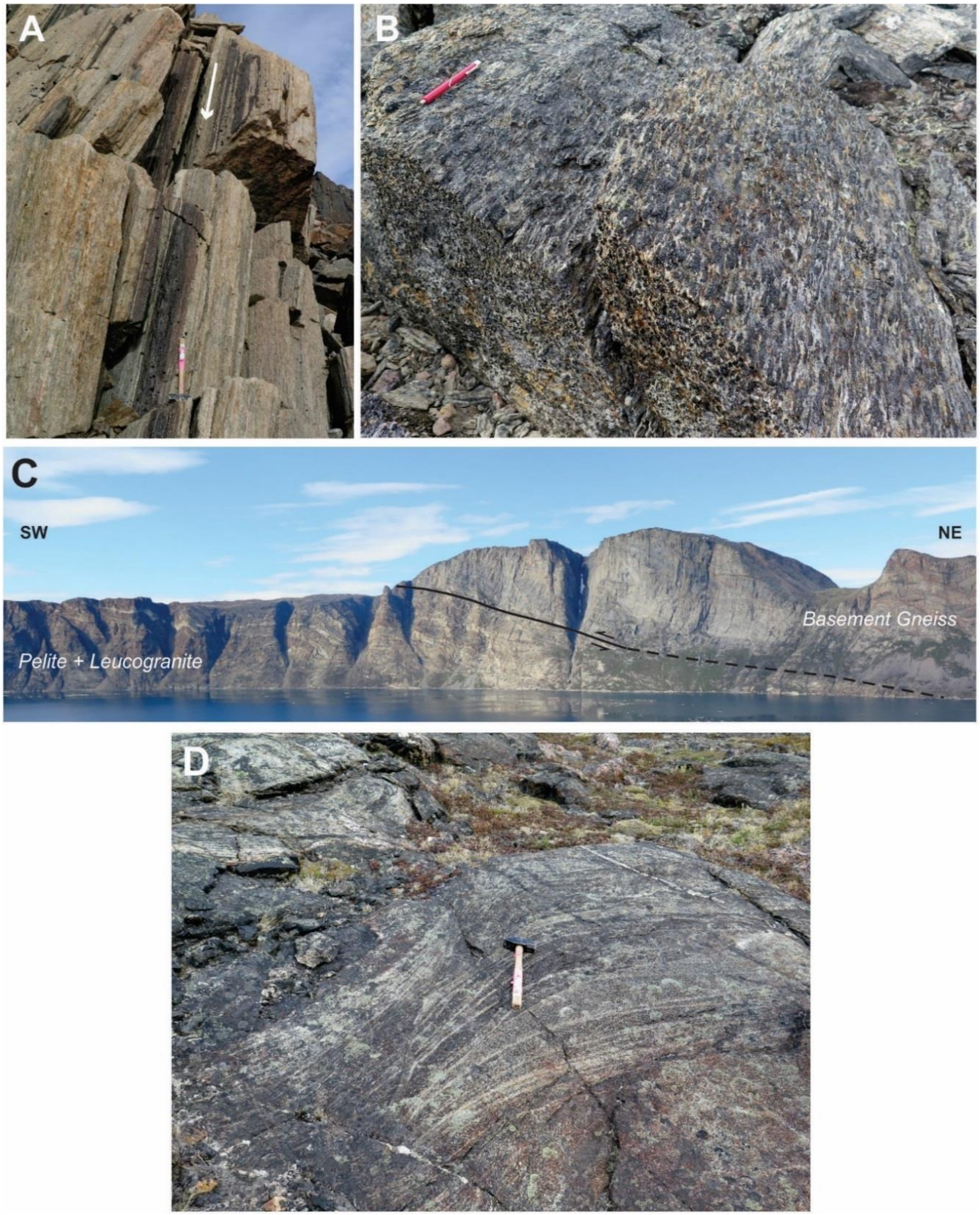

Figure 4: *Field photographs.* ***A)*** *Strongly lineated (L>S tectonite) psammite, Mary River Group (hammer for scale);* ***B)*** *Strongly lineated (L-tectonite) metamorphosed volcanic rock, Mary River Group, showing stretching lineation defined by rodded hornblende aggregates (pen for scale);* ***C)*** *Thrust fault exposed along the SE coast of Emmerson Island, juxtaposing basement gneiss with metasedimentary strata and leucogranite; the cliff faces NW, and the field of view is ~3 km;* ***D)*** *Rhythmic layering defined by plagioclase-rich (white) bands in mafic/ultramafic intrusion (hammer for scale).*

Mafic-ultramafic magmatic bodies of Oliver Sound. Layered mafic-ultramafic magmatic bodies were identified west of Pond Inlet and consist of dismembered and folded enclaves of mafic and ultramafic rock within reworked basement gneiss. In particular, a 5 km-scale mafic/ultramafic body near the junction of Oliver Sound and Eclipse Sound (Fig. 2) exhibits dm-scale rhythmic mineral layering defined by varying proportions of plagioclase and clinopyroxene (Fig. 4D). This layering is irregular along strike, exhibiting truncations and layer-scale deformation that possibly reflect dynamic magmatic conditions. Such mafic to ultramafic bodies appear to be spatially associated with the Eclipse Sound thrust fault zone, although the reasons and relevance of this spatial association remain ambiguous. Nevertheless, these bodies may provide insight on the tectonic environment prior to thrusting, and could be prospective for magmatic metals such as Ni and Cu.

Mesoproterozoic strata of the Bylot Supergroup (Borden basin) and links to mineralization. Southwest of Pond Inlet, siliciclastic rocks and dolostone of the Bylot Supergroup share a normal fault contact (White Bay Fault) with structurally underlying Archean basement rocks. The fault controls the local distribution and structure of the sedimentary rocks, with drag folds and monoclines formed in the immediate hangingwall of the fault (Fig. 4E-F). The Bylot Supergroup is known to host Mississippi Valley-type Zn-Pb-Ag mineralization at Nanisivik ~200 km W of the 2017 field area (Patterson and Powis, 2002), as well as gypsum occurrences. Furthermore, late faulting may have provided pathways for hydrothermal fluids, thereby promoting local remobilization and transport of metals.

Figure 4 (cont'd): E) *White Bay Fault Zone (WBFZ) exposed near Cape Hatt (view towards NW; Fig 2) – Mesoproterozoic strata (yellow) of the Bylot Supergroup (MESO), in the hangingwall of the fault, exhibit a gentle drag fold. Archean gneisses (A) form the footwall;* ***(F)*** *Aerial view of WBFZ exposed along Tay Sound (towards NW; Fig. 3) – open-folded MESO dolostone in hangingwall.*

Future Work

Data and observations stemming from the 2017 field season will lead to the compilation and publication of three new bedrock geology maps, in both English and Inuktitut, with an anticipated release date of March 2018. In addition, two new CNGO summary of activities papers (Skipton et al., 2017, in prep.; Bros and Johnston, 2017, in prep.) detailing field observations and preliminary interpretations, will be published by the end of the current calendar year. These products, as per past GEM-2 Baffin activities, will ensure rapid dissemination of results and efficient communication with stakeholders.

In addition to preparations for the summer of 2018 and the ensuing field season, we plan to conduct U/Pb geochronology on 12 samples to determine the timing of igneous crystallization and sedimentary deposition of major rock units in the 2017 map area. A geochronological and metamorphic investigation will be carried out on the Eclipse Sound thrust fault zone and metasedimentary strata. Furthermore, a Master's thesis, based at the University of Alberta, will focus on tectonostratigraphy, structural deformation and metamorphic petrogenesis of the MRG exposed at Long Lake (Bros and Johnston, 2017, in prep.). Finally, collaborative work at the University of Cambridge (UK) will concentrate on the pressure-temperature conditions and timing of MRG metamorphism.

Acknowledgements

The authors wish to thank the field team for their dedication and vitality throughout an exciting and productive summer. Without their many contributions, the field season would not have been as successful as it was. Three students were part of the team for the entire season: Erin Bros (NRCan FSWEP, U. Alberta) who proficiently led traverses, and two beneficiaries, Mick Appaqaq and Tyler Rowe, both Nunavut Arctic College students who provided skillful field assistance. The team also benefited from the participation of Drs. Natasha Wodicka (GSC Ottawa), Owen Weller (U. Cambridge) and Stephen Johnston (U. Alberta). Pierre Brouillette and Annick Morin (GSC Quebec) in addition to participating in field traverses, provided on-site technical support throughout the mapping season. Finally, Erik Polzin (Summit Helicopters) masterfully transported the team across the terrain of northern Baffin Island (and in doing so developed an uncanny ability to spot outcrop amongst piles of boulders).

The participation of two Nunavut Arctic College students was made possible by the Government of Nunavut Department of Economic Development and Transportation (GN EDT) through the Summer Student Employment Equity Program, and by the support and coordination of Paul Budkewitsch (GN EDT).

Fieldwork logistics were handled by PCSP, and logistics in Pond Inlet by the Tununiq Sauniq Co-Op; we are thankful to both for their assistance and consistent communication throughout the summer. The Sauniq Hotel provided rooms and delicious meals. We also acknowledge the help and/or support of the following: Government of Nunavut Housing, the Hamlet of Pond Inlet, the Hunter's and Trapper's Organization of Pond Inlet, Parks Canada (Sirmilik National Park), Baffinland Iron Mines Corporation, and the Qikiqtani Inuit Association.

The compilation and construction of the GIS database was enabled by the technical expertise of NRCan staff: Pierre Brouillette, Louis Robertson, Annick Morin and Guy Buller. Dan Kerr (GSC Northern) facilitated access to the GSC's internal airphoto collection. Finally, the project would not have been possible without dedicated managerial (Natalie Shea, Sonya Dehler), administrative (Rosemarie Khoun, Marlene Francis, Ryan Murphy, Jordan Stenzler) and engagement support (Kate Clark) from the GSC and the GEM Coordination Office.

An internal review by Natasha Wodicka improved the quality of this paper.

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