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2016 Report of Activities for Completing the Regional Bedrock Mapping of the southern half of Baffin Island: GEM 2 Baffin Project

Marc St-Onge, Owen Weller, Nicole Rayner

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 of 2016, the GEM program successfully carried out 17 research activities that 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 collaborators as the program advances.

Project Summary

This report serves as an update on the map compilation and publication, petrological research and geochronological lab activities undertaken as part of the GEM2 South Baffin bedrock mapping project during 2016 (Fig. 1).

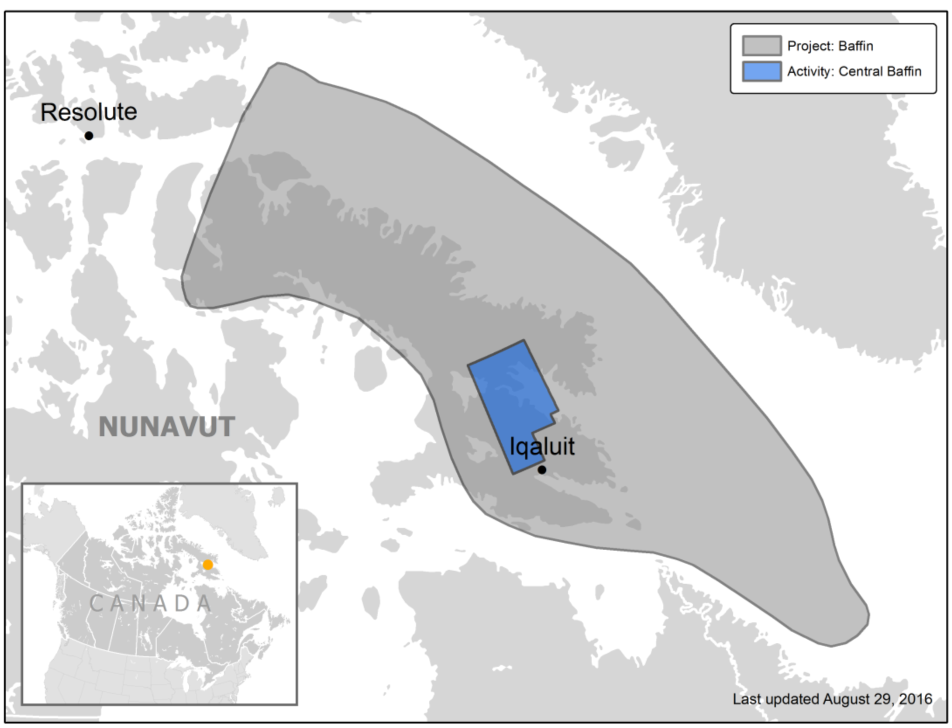

Figure 1: Sketch map illustrating the area encompassed by the GEM Baffin region of interest (grey outline/fill) and the 2015 bedrock geological mapping area (blue outline/fill).

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. The summer of 2015 saw the last gap filled in the regional bedrock coverage of Baffin Island south of latitude 70˚N: the Sylvia Grinnell Lake – Clearwater Fiord area (Rayner et al., 2015; Weller et al., 2015).

Improved geological maps help determine the potential for diamonds, base metals and carving stone in southern Baffin Island. The proximity of Nunavut's largest community, Iqaluit, makes exploration work in these areas easily accessible.

Introduction

Goals & Objectives

During the past two decades modern, systematic and targeted mapping of bedrock geology has been completed for large tracts of Baffin Island including: southern Baffin Island (1995-97; NTS sheets 25K, L, M, N on Fig. 2), central Baffin Island (2000-2002; not shown on Fig. 2), SW Baffin (2006; not shown), Cumberland Peninsula (2009-2011; NTS sheets 16E, L, 26H, I), Hall Peninsula (2012-13; NTS sheets 25O, P, 26A, B) and eastern Meta Incognita Peninsula (2014; NTS sheets 25J, G, Fig. 2, blue outline). Only one gap remained to finalize the updated coverage of the whole of Baffin Island south of latitude 70˚N: the Sylvia Grinnell Lake – Clearwater Fiord area (Fig. 2, green outline). Available geological information for the project area was limited to low-resolution helicopter reconnaissance work completed in the 1960s. Targeted, precise bedrock mapping was needed to help define the lateral extent of various metasedimentary strata, identify layered mafic/ultramafic sills as documented on both the Hall and Meta Incognita peninsulas, evaluate the carving stone potential in the vicinity of Iqaluit and Pangnirtung, and assist in constraining potential vectors to mineralization for a number of mineral commodities including diamonds, Ni, Cu, PGEs, Pb and Zn. Integration of surface bedrock observations with new geochronological, geochemical, geophysical, and detailed tectonostratigraphic and petrological data will lead to an improved understanding of the geological history and Precambrian architecture of the whole of the southern half of Baffin Island, its relationship to NW Baffin Island, the Ungava Peninsula and West Greenland, and result in a new modern compilation and geodatabase for the southern half of Baffin Island including the territorial capital region that will be incorporated in the Open Geoscience Canada in 3D project.

Scientific questions to be addressed

- What is the extent and tectonic affiliation (Lake Harbour Group, Piling Group, Hoare Bay Group) of the extensive metasedimentary packages shown in previous compilations and what are the implications for the present architecture and past assembly of Baffin Island?

- What is the western extent of the Archean Hall Peninsula Gneiss Complex (host to the Chidliak diamond district)?

- How does the geology of western Hall Peninsula match that of the central Baffin Island and Cumberland Peninsula and does a Paleoproterozoic tectonic suture separate these areas?

Portions of southeastern Baffin Island represent some of the last major missing tectonic pieces in our understanding of eastern Nunavut geology and the current bedrock tectonostratigraphic, geochronological, petrological and structural studies will largely resolve this uncertainty.

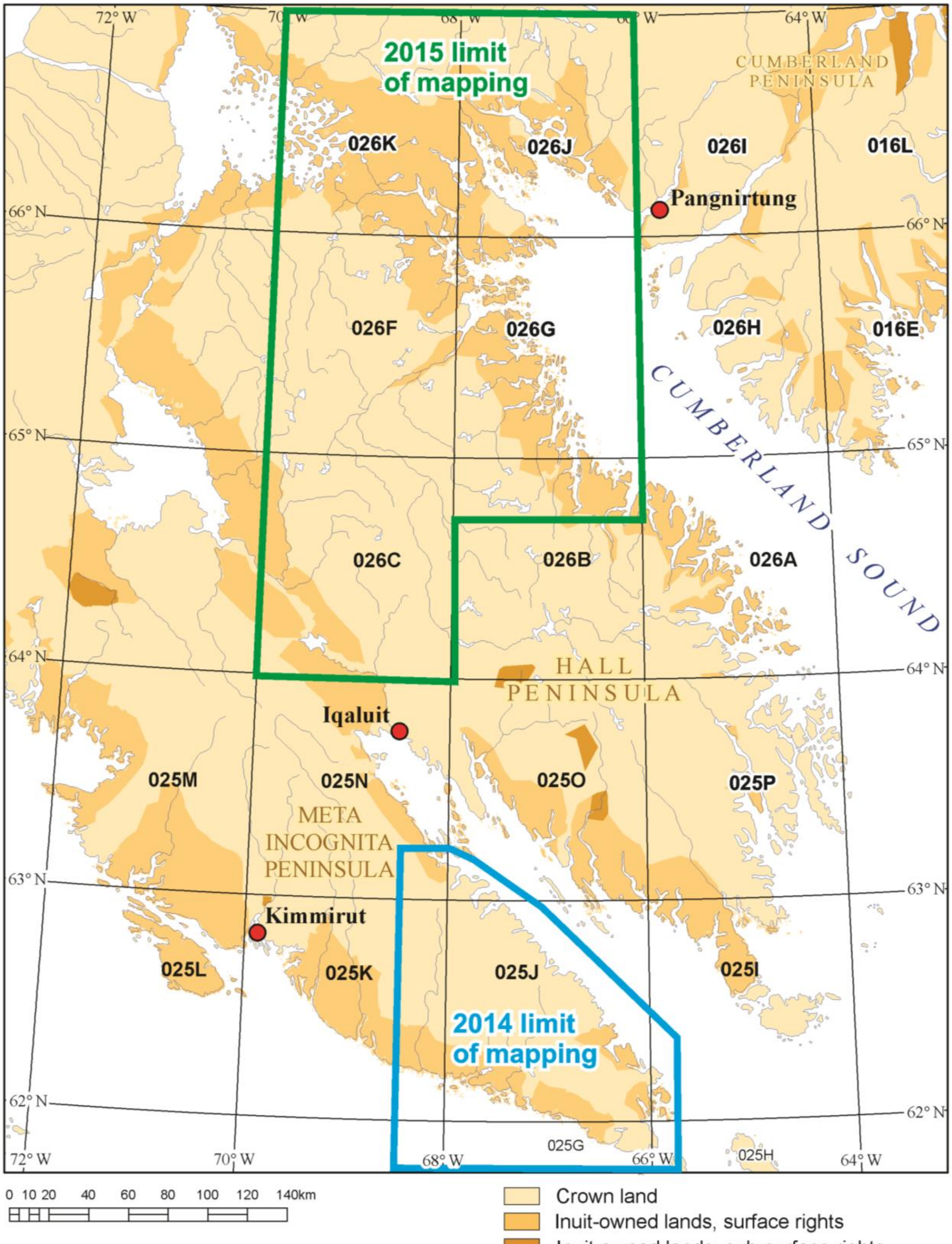

Figure 2: Overview of the area of interest for GEM activity "Completing the Regional Bedrock Mapping of the southern half of Baffin Island". Completed regional bedrock mapping areas are outlined in green (Sylvia Grinnell Lake – Clearwater Fiord, summer 2015) and blue (Meta Incognita Peninsula, summer 2014).

Publication of geological maps using the new Bedrock Data Model (BDM)

The new Geological Survey of Canada (GSC) Bedrock Data Model (Brouillette et al., 2015) was utilized to integrate and compile archival and newly-acquired geoscience data for southeastern Baffin Island. The ease of use of the menu-driven BDM and rapid digital compilation capability is demonstrated by estimated savings on the order of $2.4M on field reacquisition costs and the timely release of ten bedrock geological maps following the 2015 field season, an achievement that would have previously taken several years rather than a mere seven months following completion of field activities.

A BDM provides a field-to-office context for digitally recording, integrating and interpreting bedrock geological data and observations using a consistent science language, standard feature attributes and uniform line and point types. Prior to the GEM2 South Baffin bedrock mapping project, different models and methodologies were used within the GSC to produce geological maps, which as a result led to widely divergent map products and inconsistent delivery times.

As reported in Rayner et al. (2015), targeted strategic field work by a team of 10 research scientists, Canadian and international university graduate students, and three Nunavut Arctic College Inuit students enabled completion of the bedrock mapping of Baffin Island south of latitude 70°N (Fig. 2) during an eight-week field season in 2015. New field observations, measurements and samples were recorded into hand-held computers for transfer into the GSC BDM. During and following the field mapping campaign, the 2015 geological data were combined with remotely-sensed imagery, recently acquired aeromagnetic survey results, and legacy data and observations dating from the 1960s. The use of 1,752 legacy data points is estimated to have saved on the order of $2.4M on field reacquisition costs. Of note, the GSC BDM provides full control and flexibility to the compiling geologist in terms of digital data integration, line-type characterization and map unit attribution.

The full activity cycle, from community engagement to capturing legacy data, completing two months of new field work, and publishing full digital release packages for ten 1: 100 000 scale bedrock geological maps (St-Onge et al., 2016a-j) was concluded within a 12-month period. The maps were prepared for joint release with the Canada-Nunavut Geoscience Office in Iqaluit, providing a wealth of new information for an area of 50,000 km^2 (Fig. 2). The publication of full digital release packages, was followed by full Inuktitut versions of the same maps providing a tangible example of geoscience results being delivered and transferred in a useful way to northern Canadians.

For the northern communities of Pangnirtung and Iqaluit, the knowledge context has evolved from sitting on the edge of the last remaining bedrock geoscience gap for the whole of southern Baffin Island south of latitude 70°N to now benefiting from the most up-to-date digital geoscience coverage (Weller et al., 2015). In practical terms for northern stakeholders, the set of new maps constrain the 3-D geometry of the western margin of the prospective Hall Peninsula Gneiss Complex, host to the Chidliak diamond field, and document the distribution of a regional suite of layered mafic to ultramafic rock units with Ni-Cu potential, thus providing key knowledge for Natural Resources Canada's strategic priority of unlocking resource potential through responsible development and enabling northern communities to make informed decisions about land use and economic opportunities.

Discovery of the world's oldest high-pressure eclogite

Following the completion of field activities and in addition to the publication of new geological maps (above), the GEM Program also provides support for the follow-up laboratory work required to quantify the geological evolution surmised from the field observations. Thus much of the 2016 analytical focus for the GEM2 South Baffin bedrock mapping project has been on determining the pressure (P) and temperature (T) conditions of regional metamorphism in the greater Baffin area, which amongst other results has led to the discovery of the world's oldest high-pressure eclogite, a metamorphic rock indicative of subduction to great (>80 km) depth.

The Trans-Hudson Orogen (THO) is a middle Paleoproterozoic continental collisional belt that has been proposed to represent an ancient analogue to the Cenozoic Himalayan Orogen (St-Onge et al., 2006). Until this year, a notable divergence in this correlation has been the absence of high-pressure rocks in the THO compared with the Himalaya, and it has been debated whether this reflects a secular tectonic change – with the requisite cool thermal gradient precluded by warmer ambient mantle temperatures during the Paleoproterozoic – or a preservation phenomenon (Weller & St-Onge, submitted).

Petrological work during 2016 led to a new discovery of eclogite from the THO, which fills in the high-pressure gap in the comparative record between the two orogens. The eclogite was sampled from a mafic boudin associated with metavolcaniclastic schist and hosted by Archean basement orthogneiss of the lower-plate Superior craton. The THO eclogite was characterised by the assemblage garnet–omphacite–kyanite–rutile–biotite–zoisite at high pressure, prior to retrograde symplectite growth. The metavolcanic schist contains evidence of an early kyanite-grade history, prior to retrograde growth of lower-pressure plagioclase–gedrite–cordierite coronas around garnet.

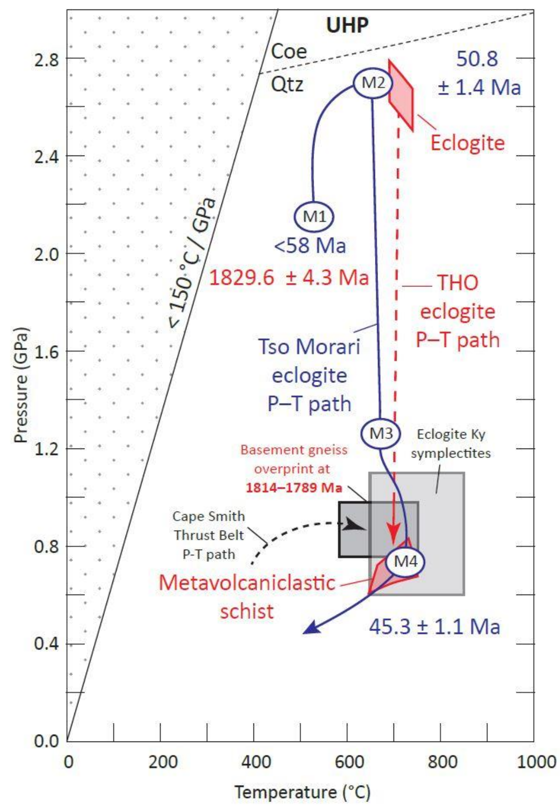

Figure 3: Integrated *P-T*-time results for the Paleoproterozoic Trans-Hudson eclogite (red data) and relative correspondence with the Cenozoic Tso Morari eclogite (blue data) from Weller & St-Onge (submitted). The inferred peak *P-T* conditions of the Trans-Hudson eclogite and retrograde equilibration of the metavolcaniclastic schist show a notable similarity with the equivalent peak M2 and retrograde M4 conditions of the Himalayan Tso-Morari eclogite. Furthermore, the retrograde schist *P-T* estimate is consistent with the formation of the spinel-plagioclase symplectites after kyanite in the eclogite (light grey area), and the metamorphic conditions associated with the base of the Cape Smith Thrust Belt (dark grey area). Finally, burial-exhumation cycles are also constrained to similar timescales of ca. 15 Myr.

Phase equilibria modelling of eclogite and schist revealed a multi-stage, approximately isothermal, decompression history from ~2.7 to 0.7 GPa at 700 °C (Fig. 3; Weller & St-Onge, submitted). This *P-T* history overlaps within error with derived *P-T* paths for the type Himalayan Tso Morari eclogite locality (St-Onge et al., 2013). U–Pb dating of monazite in the metavolcanic schist indicates that it experienced prograde metamorphism at ca. 1830 Ma, which provides a maximum age for the timing of peak eclogite-facies metamorphism in the THO (Fig. 3). Notably this age coincides with the onset of terminal Superior–Churchill collision in the eastern segment of the orogen, which is analogous with the relative timing of eclogite-facies metamorphism in the Himalaya.

Overall, the exceptional structural, thermobarometric and temporal similarities of the THO eclogite with eclogitic units in the Himalaya suggest that modern-day plate tectonic processes are applicable to at least the middle Paleoproterozoic. Analysis of global trends in metamorphic thermal gradients through time indicates that the THO eclogite extends the rock record of cool thermal gradients (<350°C/GPa) by over 1 Ga, making it the oldest high-pressure eclogite in the world documented to date (Weller & St-Onge, submitted).

Geochronological Results

U-Pb analytical work utilizing the Sensitive High Resolution Ion Microprobe (SHRIMP) in the Geochronology Laboratories of the GSC is now completed on 11 samples (nine metaplutonic and two metasedimentary rocks) from southern Baffin Island. The samples were collected during geological mapping of the Sylvia Grinnell Lake – Clearwater Fiord area in the summer of 2015 (Figure 2).

The bedrock of the map area is dominated by a metaplutonic suite ranging in composition from gabbro/quartz diorite to syenogranite (Weller et al., 2015). Cross-cutting relationships observed across many outcrops define a relative chronology of the various phases which can be broadly summarized as a transition from mafic, through intermediate/calk-alkaline compositions to more silicic compositions. A suite of samples from the various metagranitoid phases was collected for U-Pb dating to corroborate field crosscutting relationships and test correlations with regional plutonic suites including the Cumberland Batholith and the Qikiqtarjuaq Plutonic Suite.

The table below presents the preliminary interpretation of the U-Pb results and the resulting chronology of emplacement:

Relative chronology	**Lithology**	**Sample**	**Field constraint**	**Crystallization Age (Ma)***
6	Grt-Sil leucogranite	15SAB-D106A	cuts 4	ca. 1850
6	Bt-Grt monzogranite	15SAB-D236B	cuts 3a	ca. 1840
6	Bt-Grt monzogranite	15SAB-D77A		ca. 1850
5	Qz diorite	15SAB-S16A		ca. 1865
4	Bt-Opx monzogranite (equigranular)	15SAB-D283B	cuts 3a	ca. 1885
3b	Sugary Bt monzogranite	15SAB-D278A		ca. 1890
3a	Bt-Opx monzogranite (megacrystic)	15SAB-D283A		ca. 1890
3a	Bt-Opx monzogranite (megacrystic)	15SAB-R74A		ca. 1895
3a	Bt-Opx monzogranite (megacrystic)	15SAB-D236A		ca. 1895
2	Granodiorite	data pending		-
1	Mafic-ultramafic suite	not sampled		-

The reader is referred to an upcoming Open File Report (Rayner et al., in preparation) for full results and preliminary interpretations. Precise, absolute age constraints are an essential component of modern mapping, as they provide temporal calibration of geological observations, strengthen regional correlations and place time brackets on tectonometamorphic events. These new results, in conjunction with other recent, published results from across southern Baffin Island (Rayner et al., 2012; Berman et al., 2013; Rayner, 2013, 2014, 2015; From et al., 2015) will permit further refinements of our understanding of the tectonic evolution of this segment of the Trans-Hudson Orogen.

Conclusions

All the planned post-field objectives were accomplished on time. Ten new bedrock geological maps (full digital releases) plus Inuktitut versions were published within seven months of the end of field work in the Sylvia Grinnell Lake – Clearwater Fiord area. The observations and proposed tectonostratigraphic and plutonic correlations encapsulated in the set of maps are being tested through thesis research, geochronology, and *P-T*-time studies across the project area in order to develop a tectonic model that addresses the scientific questions posed at the beginning of this report.

Post-doctoral research documenting the *P-T*-time-deformation conditions of metamorphism for samples collected from Meta Incognita Peninsula and integrating advanced quantitative phase diagram modeling with petrographic observations and attendant geochronology is well advanced. That research was complemented with the discovery of samples from an eclogite locality in the Ungava Peninsula of the eastern Trans-Hudson orogen. As reported above, those samples have been modelled and dated and the results from the oldest high-pressure eclogite have been submitted for publication (Weller & St-Onge, submitted).

Laboratory work in 2015-2016 including bedrock geochronology to establish the age of the major plutonic rock packages was completed as summarized in this report. Full results will be made available as a GSC Open File and a CNGO Summary of Activities report in 2016.

Future works/next steps

The results of the GEM Southern Baffin Mapping activity will continue to be disseminated in an efficient and timely manner through publication of journal papers, GSC Open File reports, and CNGO Summary of Activities reports.

By the end of the project lifetime, results will have been synthesized and made available in the public domain with two MSc theses, peer-reviewed papers and, most significantly, a signature contribution for the southern half of Baffin Island to a new Geological Map of Canada through the Open Geoscience Canada in 3D project.

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