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Foreword/Context

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 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 2015, 14 research activities focused on geological, geochemical and geophysical surveying were successfully carried out under the GEM program including the Core Zone – Labrador Trough activity of the Hudson-Ungava project (**Fig. 1**). 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.

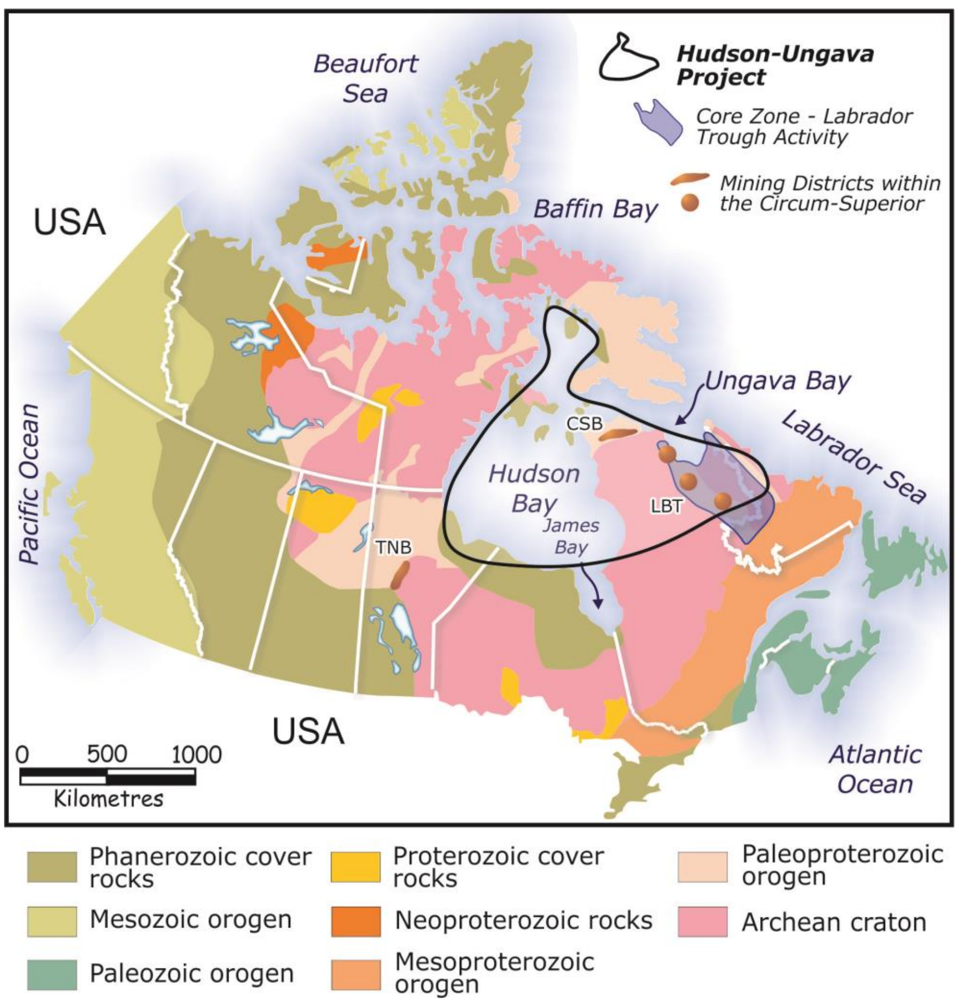

Figure 1. Simplified geological map of Canada showing the location of the Hudson-Ungava project and the Core Zone – Labrador Trough activity under the Geo-mapping for Energy and Minerals program (GEM-2) of the Geological Survey of Canada. TNB: Thompson Nickel Belt; CSB: Cape Smith Belt; LBT: Labrador Trough.

Introduction

In Canada and worldwide, most major magmatic Ni-Cu-(PGE), PGE, and Cr-Fe-Ti-V deposits are hosted by cumulate rocks from mafic and ultramafic intrusions of various ages. In northern Québec, a large number of mafic and ultramafic intrusions occur within the volcano-sedimentary Paleoproterozoic assemblages of the Labrador Trough. Still today, these mafic-ultramafic intrusions remain relatively poorly characterized in terms of geological, stratigraphic and geochemical context mainly because of their remote location and associated high exploration/development costs. However, recent industry driven exploration activities in the Labrador Trough clearly highlight a renewed interest for these types of mineralization within the northern part of Canadian Shield.

Geological investigations on mafic and ultramafic intrusions have been undertaken during the summer 2015 in the northern part of the Labrador Trough (**Figs. 1 and 2**) under GEM's Hudson-Ungava project, a collaborative effort between the ministère de l'Énergie et des Ressources naturelles (MERN) du Québec and the Geological Survey of Canada (GSC). The main goal is to reassess information on the overall geological context, the timing and stratigraphic framework, and the mineral potential of these mafic-ultramafic intrusions to host Ni-Cu-PGE mineralization across the entire northern Labrador Trough.

Geological Context

The Labrador Trough is known as the western part of the New Québec Orogen (NQO), located on the northeastern margin of the Superior Craton and extends for over 850 km from the Grenville front in Labrador to the Ungava Bay in northern Québec (**Fig. 2**). It is interpreted to represent the eastern portion of the Circum Superior Belt (e.g., Baragar and Scoates, 1987), more recently referred as the Circum Superiror Large Igneous Province (LIP) (e.g., Ernst and Buchan, 2004), a remarkably extensive areal grouping of mafic and ultramafic rocks occurrences emplaced in a relatively short timeframe (~1.88−1.86 Ga) along the margin of the Superior Craton. This Paleoproterozoic supracrustal sequence has been highly deformed and metamorphosed during the NQO event resulting from the collision between the Superior Craton and the Core Zone of the Churchill Province (Skulski et al., 1993).

The stratigraphic framework and the lithotectonic subdivisions, within the Québec's portion of the Labrador Trough have been synthesized by Clark and Wares (2004) and readers are referred to this report for an exhaustive description of the geological context. The Labrador Through consists predominantly of three cycles of sedimentation and/or volcanism separated by unconforminties (Clark and Wares, 2004). The two lower cycles (1^{st} cycle: Seward, Pistolet, Swampy and Attikamagen Groups - 2.17 to 2.14 Ga and 2^{nd} cycle: Doublet, Kosoak, Le Moyne Groups - 1.88 to 1.87 Ga) are interpreted as passive margin volcano-sedimentary sequences, while the uppermost cycle represent a molasse sequence (3^{rd} cycle: Chioak and Tamarack formations – 1.82 to 1.80 Ga; Clark and Wares, 2004, and references therein). The bulk of the supracrustal assemblage in the northern Labrador Trough belongs to the second cycle. The Labrador Trough has been subdivided into 11 lithotectonic zones including three sedimentary autochthonous/parautochthonous zones (Bérard, Cambrien et Tamarack), three sedimentary allochthonous zones (Mélèzes, Schefferville et Wheeler), and five allochthonous volcano-sedimentary zones where only the first cycle is observed within the Howse Zone. The second cycle is predominant encompass within the Payne, Gerido and Retty zones and the Hurst zone occurs in both the first and second cycles (Clark and Wares, 2004).

A series of mafic and ultramafic sills, referred to as the Montagnais sills, are distributed throughout the entire Labrador Trough but are mainly injected within cycles 1 and 2 over a relatively long time interval, from ca 2169 Ma to 1874 Ma (Clark and Wares, 2004).

Several types of Cu-Ni-PGE mineralization have been documented in the Labrador Trough such as (1) associated with picritic flows/sills; (2) Cu-Ni-(PGE) associated with aphyric gabbros; (3) Cu-Ni-(PGE) associated with glomeroporphyritic gabbros; and (4) PGE-Cu-Ni associated with layered mafic intrusions (Clark and Wares, 2004).

Methodology

The northern Labrador Trough is a large area that extends for more than 280 km long by approximately 80 km wide making it a geographically chalenging area to cover when investigating mafic and ultramafic intrusions (**Fig. 2**). During the 2015 field season, the focus was on the area near Kuujjuaq (**Fig. 2, Site #1**) essentially constrained within the 24K NTS sheet. The work was done in collaboration with the regional bedrock mapping project tackle by the MERN.. Based upon apparent structural continuity, the sector located between the lac LaRochelle and the lac Lacasse was targeted to better constrain the overall geological context of mafic and ultramafic intrusions in the area and to investigate their potential linkage with one another as well as with surrounding country rocks.

Three days of reconnaissance work were also undertaken in the Hope Advance Bay (**Fig. 2, Site #2**) and the Kangirsuk areas (**Fig. 2, Site #3**) to evaluate, compare and comprehend the overall geological settings and emplacement mechanisms of mafic and ultramafic intrusions in the northern portion of Labrador Trough.

Preliminary Results

Kuujjuaq area

The Kuujjuaq area consists essentially of a supracrustal sequence of the second cycle (Clark and Wares, 2004) and is comprised between the town of Kuujjuaq, to the south, and the baie aux Feuilles to the north, in the northern part of the Labrador Trough. In this area, the mafic and ultramafic sills of Montagnais are mainly intruded within the Baby and the Hellancourt Formations of the Koksoak Group and are respectively sedimentary- and volcanic-dominated formations (**Fig. 3**). In this sector, the volumetric proportions of mafic and ultramafic Montagnais sills are significantly higher within the sedimentary-dominated successions (i.e., Baby Formation) in comparison to volcanic-dominated successions (i.e., Hellancourt Formation).

During the 2015 field season, four main types of intrusions belonging to the Montagnais sills were identified: 1) mafic-dominated intrusions (MI), 2) ultramafic-dominated intrusions (UI), 3) ultramafic to mafic differentiated intrusions (UMI), and 4) glomeroporphyritic mafic-dominated intrusions (GMI) (**Fig.3**). The mafic-dominated intrusions (MI) are the most common and volumetrically abundant intrusions in the Kuujjuaq area (**Fig. 4A**). They are mainly composed of massive, to locally layered, fine- to medium-grained gabbro that extend over 20 km along strike with an estimated thickness ranging from 400 m to 1500 m. Vari-textured, quartz gabbro and pegmatitic patches are also some commonly observed features within the eastern part of these intrusions. Furthermore, small clusters of disseminated sulphides (≤5%) patches enriched in PGE are locally observed in MI (**Fig. 4B**). To date, the best known occurrences for this type of mineralization in the area are the Idefix (up to 16.2 g/t Pt+Pd– Northern Shield webstite), the Enish (up to 7.1 g/t Pt+Pd+Au– Midland Exploration Press release, September 3rd, 2015), and the Ceres (up to 31.0 g/t Pt+Pd+Au– Midland Exploration Press release, September 3rd, 2015) showings. The ultramafic-dominated intrusions (UI) consist of relatively thin intrusions (≤100 m wide) of, locally poikilitic, peridodite frequently discontinuous along strike. These intrusions mainly occur in the middle part of MI and contain locally gabbroic enclaves of various sizes. The UMI consist of ~130 m thick differentiated mafic and ultramafic intrusions that extend for at least 20 km along strike. The ultramafic zone of UMI is composed of, from bottom to top (west to east), a thin gabbroic unit overlain by a pyroxenitic unit and a poikilitic peridotite. The upper part of the ultramafic zone is characterized by the presence of centimetric to decimetric magmatic layering consisting in alternating peridotite and pyroxene-rich peridotite layers that gradually evolve into an olivine pyroxenite (**Fig. 4C**). The mafic zone consists mainly of gabbroic units of variable grain sizes with the presence of quartz increasing to the east (top). The glomeroporphyritic mafic-dominated intrusions (GMI) consist of plagioclases phenocrysts (porphyritic) or clusters of plagioclase aggregates (glomeroporphyritic; up to 5 cm in diameter) hosted in a fine- to medium-grained gabbroic matrix (**Fig. 4D**). The GMI, thus far, are restricted to the lower Baby and the Hellancourt Formations and have not been observed in the course of this study in the Upper Baby Formation.

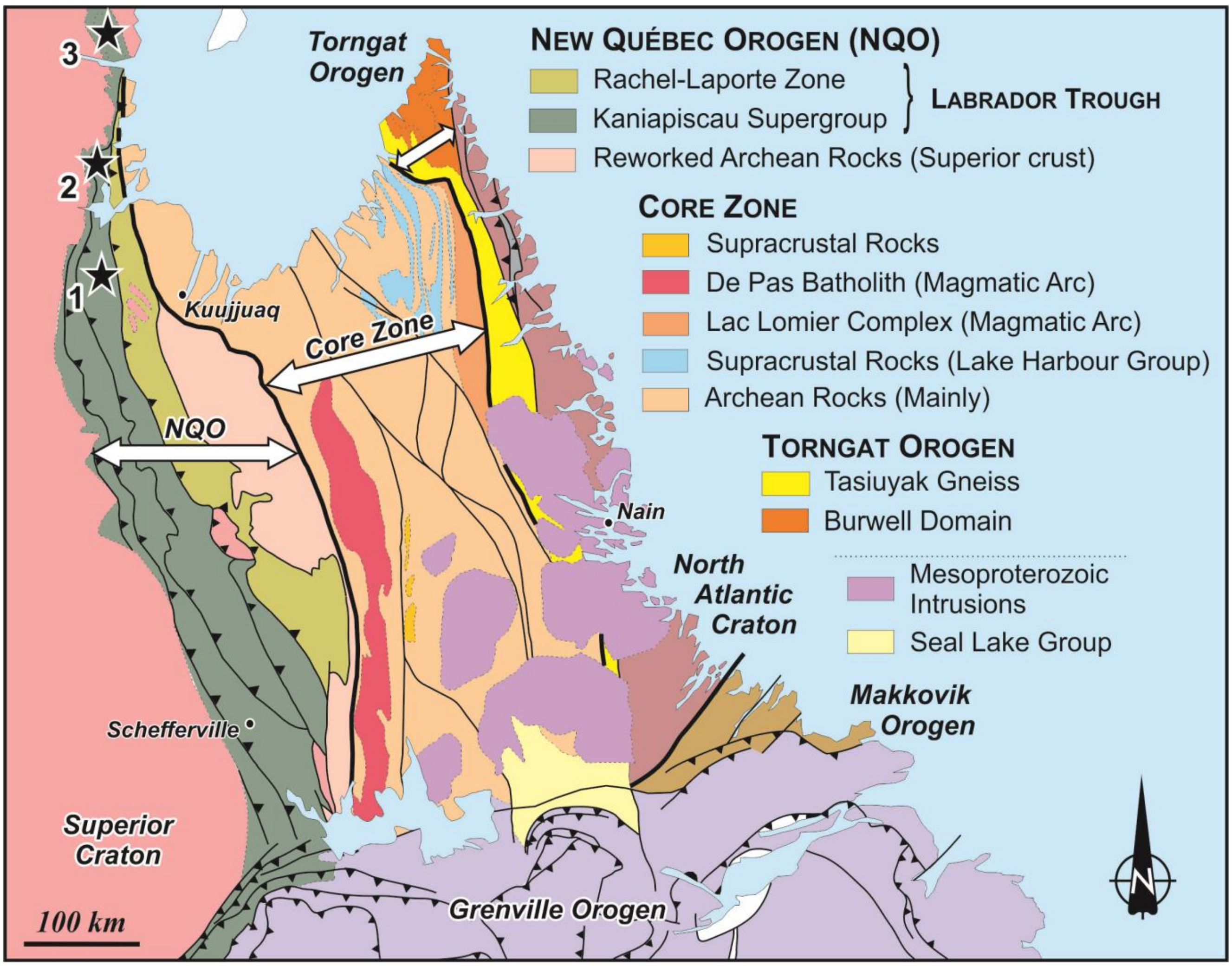

Figure 2. Simplified geological map of the eastern Churchill Province in northeastern Québec and Labrador showing the main tectonic subdivisions and the location of the study sites (modified from James et al., 2003). Black stars indicate studied sites: 1= Kuujjuaq area; 2= Hope Advance area; 3= Kangirsuk area.

Despite the fact that the Labrador Trough experienced several deformation events, the overall stratigraphy of the detailed study area can be consider mainly as a homoclinal succession generally east-facing based on sedimentary and volcanic structures and the magmatic differentiation occurring within the UMI. However, at this stage, the presence of any structural duplication cannot be ruled out and further investigation is necessary to resolve this.

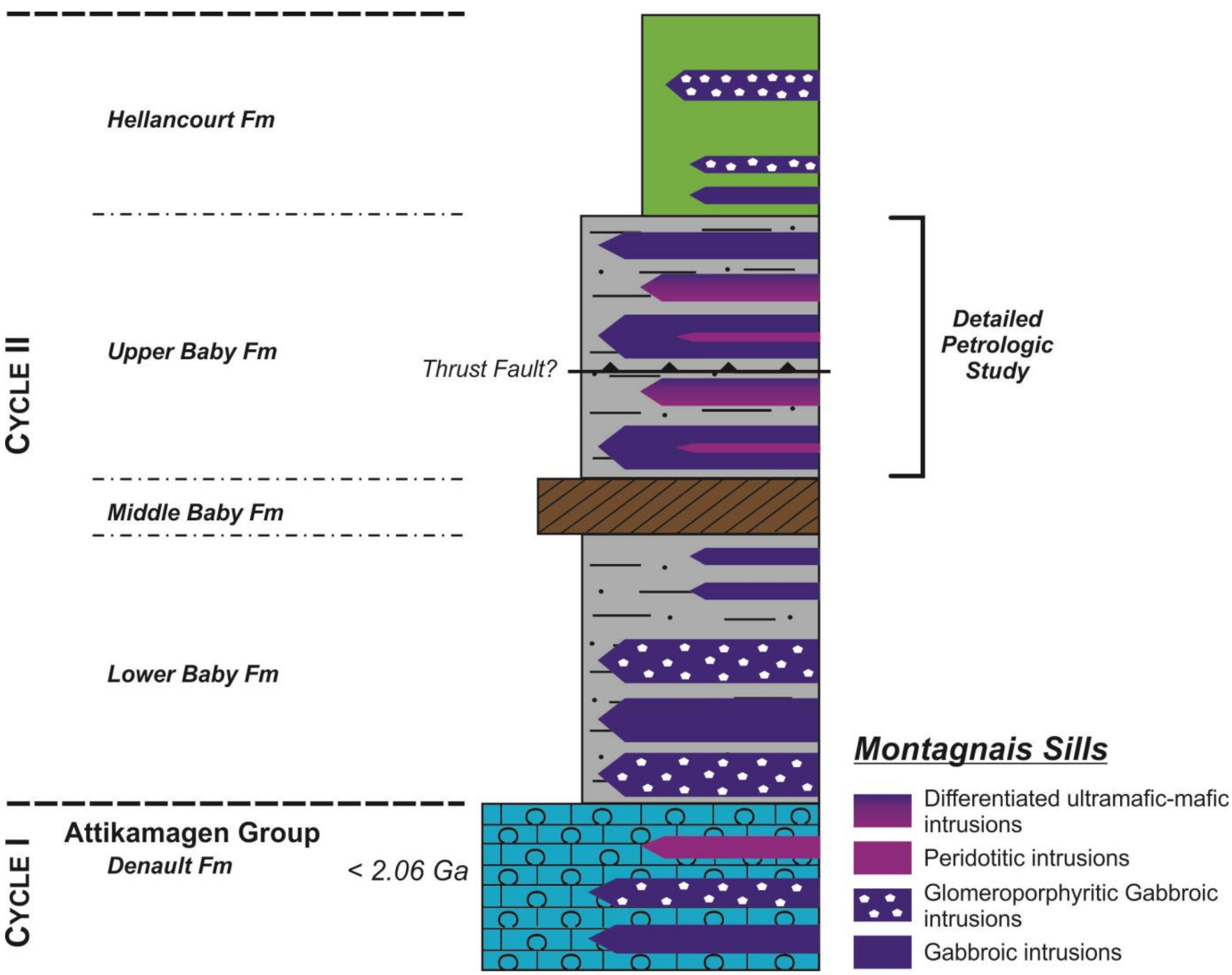

Figure 3. Schematic stratigraphic column showing the distribution of the various intrusions types in the Kuujjuaq area in the northern part of the Labrador Trough (adapted from Clark and Wares, 2004).

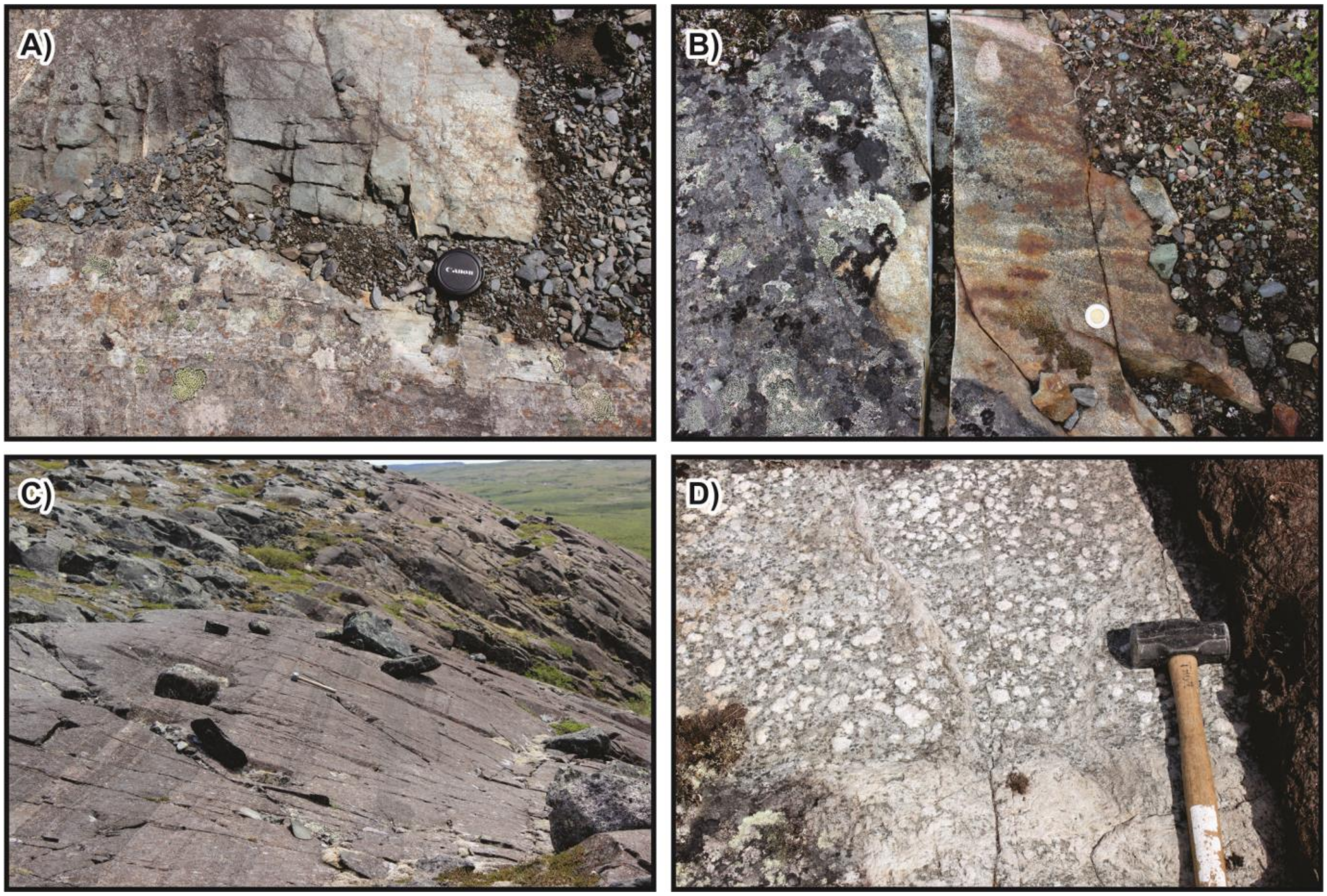

Figure 4. Field photographs of the main lithofacies within the Kuujjuaq area. A) Intrusive contact between the bedded sedimentary rocks of the Baby Formation (bottom) and the mafic-dominated intrusion (upper) of the Montagnais sills. B) Discrete PGE-rich rusty patches at the Ceres showing hosted within a mafic-dominated intrusion. C) Magmatic layering within the ultramafic-mafic intrusion. D) Glomeroporphyritic gabbroic intrusion within the Hellancourt Formation.

Hope Advance area

The Hope Advance area consists essentially of a supracrustal sequence located between the baie aux Feuilles and the Hope Advance Bay in the northern Labrador Trough (Wares and Goutier, 1990). Similarly to the Kuujjuaq area, the mafic and ultramafic intrusions of the Montagnais sills are mainly injected into a volcano-sedimentary succession but here mainly dominated by volcanic rocks of the Hellancourt Formation.

During the 2015 field investigation, several intrusions have been visited and similarly to the Kuujjuaq area, the mafic and ultramafic intrusions of the Montagnais intrusive suite can be grouped into four main types: 1) the mafic-dominated intrusions (MI), 2) ultramafic-dominated intrusions (UI), 3) the ultramafic to mafic differentiated intrusions (UMI: **Fig. 5A**), and 4) glomeroporphyritic mafic-dominated intrusions (GMI). Overall, all these mafic and ultramafic intrusion exhibits very similar textural features than the intrusions in the Kuujjuaq area such as the magmatic layering near the transition between the ultramafic and the mafic zones (**Fig. 5B**). However, some significant difference could be noted such as the higher proportion of mafic and ultramafic sills in the Hellancourt Formation in this area, the higher proportion of porphyritic and glomeroporphyritic intrusions and thicker ultramafic-dominated intrusions that are not restricted to the middle part of the MI.

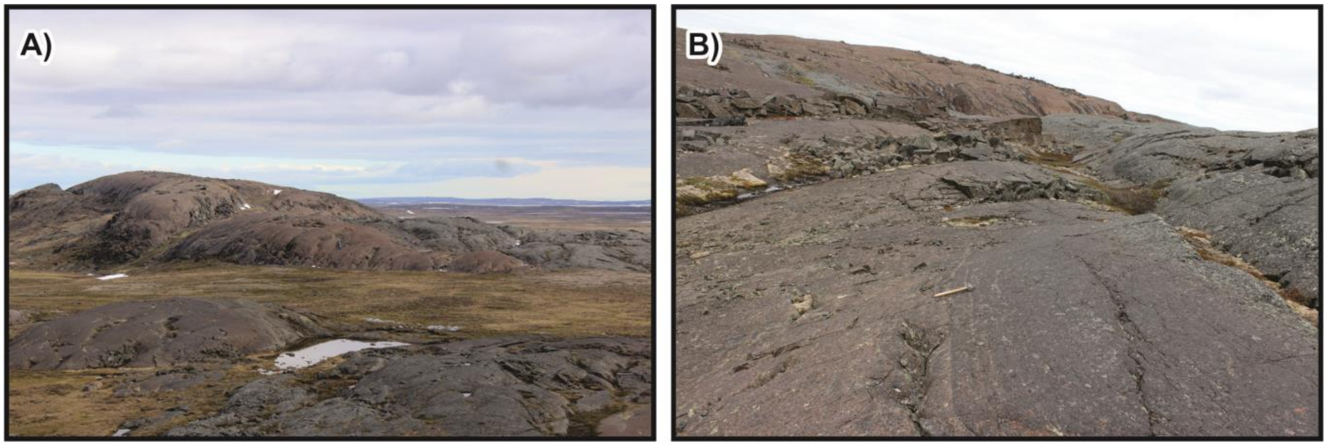

Figure 5. Field photographs of the main lithofacies within the Hope Advance area. A) Peridotite (orange-brown) and gabbro (dark grey) from a mafic and ultramafic intrusion. B) Magmatic layering within the ultramafic-mafic intrusion showing the peridotite (left side) and the pyroxenite ± olivine (right side).

Kangirsuk area

The Kangirsuk area consists essentially of the 80 km long and 20 km wide Roberts Syncline, located at the northern end of the Labrador Trough, just north of the Payne River. The Roberts Syncline cored by a thick basaltic succession interbedded with thinner and sporadic sulphidic/graphitic mudstone and rimmed by a thick sedimentary sequence (iron formation, turbidites, sulphidic/graphitic mudstone and minor dolomite) (Kiddie and Mungall, 2000). The volcanic succession is intruded by a significant amount of mafic and ultramafic subconcordant sills and one large mafic-dominated intrusion (Hardy, 1976). These subconcordant sills have been subsequently identified as (from the base to the top) the Qarqasiaq, the Chaunet, and the Chefs Lake intrusive complexes respectively whereas the large mafic-dominated intrusion has been identified as the Kyak Bay intrusion (Mungall, 1998; Kiddie and Mungall, 2000).

During the 2015 field investigations, the Qarqasiaq, Chaunet, and Kyak complexes were visited and sampled for subsequent petrographic and geochemical characterization. The Qarqasiaq Complex is composed of multiple units, largely ultramafic-dominated and locally overlain by gabbroïc units where Ni-Cu-PGE mineralization occurs generally along the basal contact (**Fig. 6A**). The contact between the ultramafic and the mafic components and the extrusive evidences (e.g., pillowed lower border zone and upper pillow breccia) reported by Mungall (1998) has not been observed during this reconnaissance work, still leaving some uncertainties regarding the actual relationships (i.e., are ultramafic and mafic components part of differentiated units? Are they extrusive in origin?). In comparison to the Qarqasiaq complex, the Chaunet complex consists of differentiated mafic and ultramafic sills but with a preponderant mafic component. Broad magmatic layering has been observed within the mafic component composed of fine-grained melanogabbro to medium-grained mesogabbro. Only the Twin lake ultramafic lobe, which hosts several Ni-Cu-PGE showings, has been visited within the Kyak Bay intrusion (**Fig. 6B**). It consists of a small ultramafic lobe composed essentially of a plagioclase-bearing pyroxenite with variable amount of olivine. This lobe is surrounded, in variable proportion, by gabbronorite and anorthositic gabbronorite that exhibit magmatic layering.

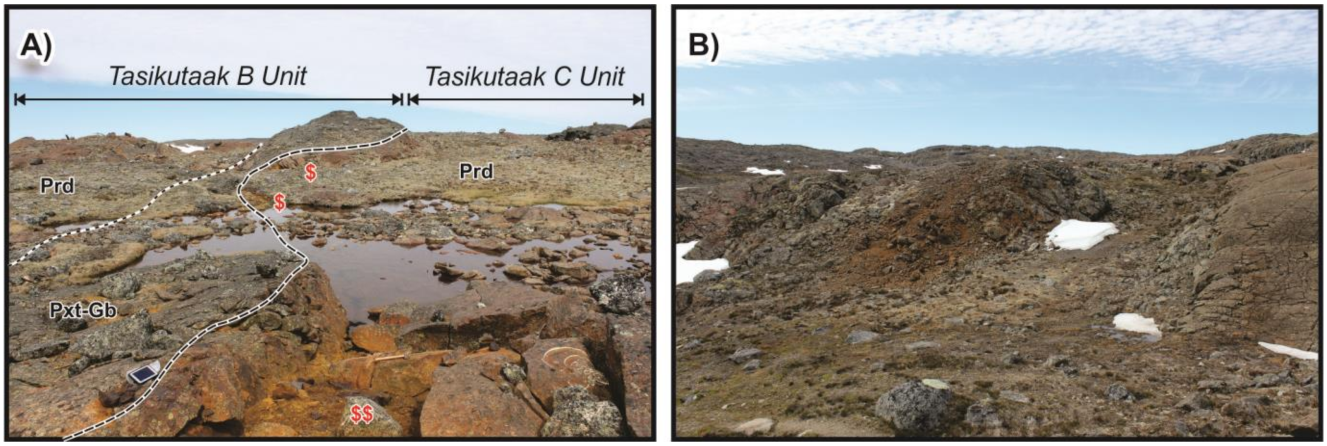

Figure 6. Field photographs of the main lithofacies within the Kangirsuk area. A) Ni-Cu-PGE mineralization at the basal contact of the Tasikutaak C differentiated unit. Prd: peridotite, Pxt-Gb: pyroxenitic to gabbroic unit, $-$$: Ni-Cu-PGE mineralization. B) Ni-Cu-PGE showing within the ultramafic-dominated lobe of the Kyak intrusion.

Geochronology

The Montagnais sills are common lithological units cutting almost all the supracrustal rocks of the cycles 1 and 2 across the entire Labrador Trough spanning over more than 280 Ma of mafic and ultramafic magmatism. The lower age constraint is defined by a maximum U-Pb age of 2169 ±2 Ma, which was obtained from a granophyre dike in the Cramolet gabbro sill at the base of the cycle 1 in the southern Labrador Trough, approximatively at 350 km south-southeast of Kuujjuaq (Rohon et al., 1993). The upper age constraint is defined by a minimum U-Pb age of 1874 ±3 Ma, which was obtained from a glomeroporphyritic gabbro sill intruding the mafic volcanic rocks of the Hellancourt Formation near the baie aux Feuilles (Machado et al., 1997). Two other Montagnais sills have been dated in the Labrador Trough over the years, one glomeroporphyritic gabbro sill, located at Howse Lake in the southern Labrador Trough in Labrador, gave an U-Pb age of 1884.0 ±1.6 Ma (Findlay et al., 1995) and another mafic-ultramafic sill, located in the Roberts Syncline in the northern part of the trough, gave an U-Pb age of 1882 ±4 Ma (Wodicka et al., 2002).

Nine mafic-ultramafic Montagnais sills have been selected and sampled for U-Pb age dating during the 2015 field season. These samples are mainly distributed along two main east-west transects, where one is located near the coastline of the baie aux Feuilles and the other is ~20 km inland. These geochronological transect crosscut most of the stratigraphy of the Labrador Trough including the Rachel-Laporte Zone (**Fig. 2**) and will give us overall timing of the mafic and ultramafic magmatism throughout the evolution of the Trough. Furthermore, these new geochronological constraints will help to compare the emplacement and the evolution of mafic and ultramafic magmatism that occurred in the northern part of the Labrador Through with other, highly Ni endowed, belts also located in periphery of the Superior Craton such as the Cape Smith belt (Québec) and the Thompson Nickel belt (Manitoba) (**Fig. 1**).

Future Works

More than 300 hand samples have been collected in the course of this study within the areas of interest. A subset of these will be selected to conduct petrographic, geochemical, and geochronological studies.

The petrographic examination of standard and polished thin sections will be used to characterize the different rock units and their relationship to one another within each intrusion-type near Kuujjuaq area and in a more reconnaissance stage within the Hope Advance and Kangirsuk areas. As well, mineralogical characterization of relict igneous phases (e.g., olivine, pyroxene, plagioclase, chromite) and the metamorphic phases (e.g., amphiboles) will be carried out via EPMA.

Whole-rock geochemical data (major, minor and trace elements) will be conducted to characterize the different rock units observed within the northern part of the Labrador Trough. More detailed investigations will be conducted to address possible geochemical variations within each intrusion-type in the Kuujjuaq area.

Sample preparation will be conducted this fall and analyses will be carried out subsequently over the winter.

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