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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 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 2014, GEM's new research program was launched with 14 field activities that include geological, geochemical and geophysical surveying (Fig. 1). These activities are being 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.

Summary

As one of the pillar activities of the GEM-2 Hudson-Ungava minerals project (Figure 1), the 'Core Zone and bounding orogens' project was initiated in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec (MERNQ) and the Newfoundland and Labrador Geological Survey to upgrade the geoscientific knowledge of this vast area with the primary objective of better assessing its economic mineral potential. Large portions of this area, covering approximately eight 1:250,000 scale NTS map sheets, remain known at reconnaissance level only, with basic information stemming from federal and provincial geological mapping from the 1950s and 1960s vintage. This new multidisciplinary, collaborative government/academia/industry project aims at filling knowledge gaps by gaining a better understanding of the geological evolution of the Core Zone, an ancient narrow tectonic plate caught between two larger continental plates (Superior and North Atlantic cratons), and the areas of collision (sutures) between these two plates. We postulate that a better understanding of the basic geology and tectonic evolution Core Zone and bounding orogens will lead to the refinement of metallogenic models, potentially increasing mineral exploration in the area.

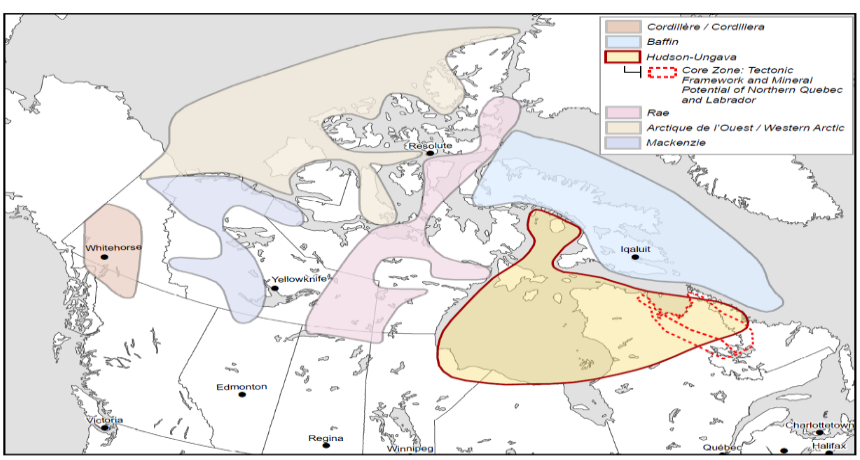

Figure 1. Location map showing the six broad GEM-2 project areas and highlighting the focus of the Core Zone project.

Introduction

The Core Zone (Fig. 2) forms one of the lesser known parts of the Canadian Shield. As such, this project aims to address a number of first-order scientific questions, the foremost being; *i)* what is the nature and character of the Core Zone and does it correlate with other parts of the Canadian Shield? *ii)* what is the nature of its bounding orogens? and *iii)* are there potentially untapped metallotects within this entire system? We know from earlier work based on sparse quantitative data that the Core Zone is an elongate sliver of Archean and Proterozoic continental crust (ribbon continent?) that was reworked between the colliding Superior and North Atlantic cratons during the Paleoproterozoic accretion and collision (James and Dunning, 2000; James et al., 1996; Wardle et al., 2000). However, much remains to be established regarding its internal composition and crustal framework. Recent mapping activities undertaken by the Québec and Newfoundland provincial geological surveys (e.g., James et al., 1996; Lafrance et al., 2014; Verpaelst et al., 2000; Hammouche et al., 2011; Simard et al., 2013) have begun to unravel information on its internal composition, age and structure, which had remained mostly at reconnaissance level since 'Operation Torngat' was undertaken by the Geological Survey of Canada (Taylor, 1979). Furthermore, the nature of its actual boundaries with the Superior Craton to the west, and North Atlantic Craton to the east, are not well defined from a tectonic evolution and accretionary perspective. The above questions are important to resolve from a metallogenic point of view since economic mineral prospectivity is intrinsically linked to specific tectonic environments and/or orogenic development. The primary goal of this project, conducted in collaboration with the Ministère de l'Énergie et des Ressources Naturelles du Québec (NERNQ), the Newfoundland and Labrador Geological Survey (NLGS), industry and academia, is to upgrade our understanding of the bedrock and surficial geology of the Core Zone and its bounding orogens and utilise this knowledge to better assess this vast region from a mineral potential perspective. This summary focuses on the bedrock mapping activity that took place in the central and northern Core Zone, while McClenaghan et al. (2014) present a summary of surficial and bedrock mapping undertaken across the south, and Corriveau et al. (2014) provide a summary of fieldwork targeted on the characterization of iron-oxide-copper-gold type mineralization in the Romanet Horst region.

Over the approximate five week span of field activities, the majority of mapping focussed on the central Core Zone, with five days targeted in the northern part of the Labrador Trough, northwest of Kuujjuaq, and another six days spent by M.G. Houlé in the eastern part of the Cape Smith Belt, around the Raglan mine area. In the central part of the Core Zone (Figure 2, box 1), earlier work by van der Leeden (1994) and Girard (1990) identified relatively low metamorphic grade supracrustal rocks (Hutte Sauvage group, Ntshuku and Pallatin suites) with a preliminary U-Pb zircon age of ca. 2.33 Ga on the Pallatin intrusive suite, interpreted as syn-volcanic, suggesting volcanic activity and sedimentation during the earliest Paleoproterozoic (2.50 to 2.33 Ga ago). Questions remain as to whether these sequences represent the remnants of a continental arc edifice as suggested by Girard (1990), or the base of an early-Paleoproterozoic rift sequence of similar age to the Huronian Supergroup. If the latter, do these sequences have similar potential for placer uranium deposits, having been deposited prior to the Great Oxidation event? An elevated gold occurrence is known to be associated with the Ntshuku assemblage, but the region has not been thoroughly explored for that commodity.

The central Core Zone and adjacent North Atlantic Craton were the site of voluminous anorthosite-mangerite-charnockite-granite (AMCG-type) and alkaline magmatism during the

Mesoproterozoic; possibly a far-field effect (i.e., upper-plate extension) of orogenic activity occurring at what was then the southeastern margin of Laurentia during the interval 1.45-1.20 Ga. This crustal extension and associated magmatic event generated important economic deposits including the 22 million ton Voisey's Bay Ni-Cu±PGE deposit, as well as the Strange Lake, Lac Brisson and Misery Lake rare earth element (REE) prospects. Fieldwork this summer was aimed at further examining the relationship between crustal extension and magmatism, and assessing the potential for intrusion-hosted deposits beyond those already known.

In the Labrador Trough (Figure 2, box 2), field activities consisted of a reconnaissance survey designed to establish priorities for subsequent variable-scale thematic studies to be undertaken in collaboration with the NERNQ. A preliminary east-west transect was completed from the 1st Cycle autochthonous sedimentary sequence in the west, across the 2nd Cycle allochthon, and into uplifted basement of potential Superior craton affinity to the east. The region will be further examined during the summers of 2015 and 2016 with the aim of determining the age and tectonic environment of supracrustal rocks; the age and tectonomagmatic significance of mafic and ultramafic intrusive suites, the tectonothermal evolution of the entire section, as well as the location and nature of the Superior – Core Zone boundary. Particular attention will be given to the potential for magmatic Ni-Cu-PGE linked to cratonic margins (e.g., Begg et al., 2010) and orogenic gold. In the Cape Smith belt, field activities consisted of a reconnaissance survey in the Raglan Mine area (Figure 1) to better understand the geological framework that hosts nickel mineralization within this world-class nickel district. This area will be further examined during the summer 2015 with the aim at better understand the main characteristics of these mineralized units and subsequently to determine any potential correlation with similar units in the northern Labrador Trough.

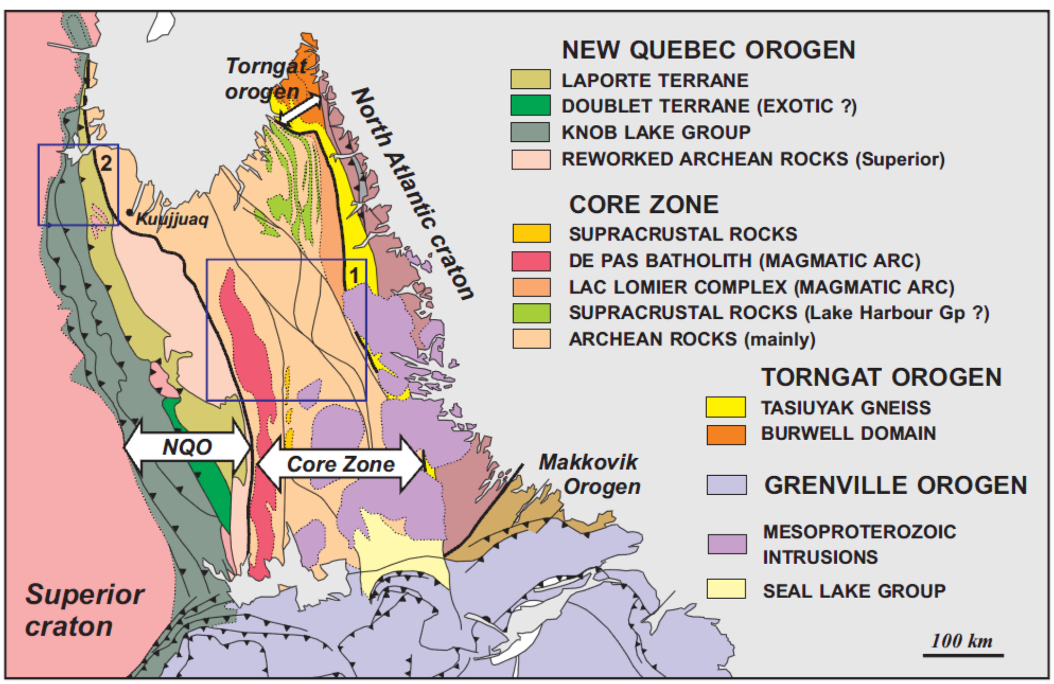

Figure 2. Simplified bedrock geological map of the Core Zone and bounding orogens. Boxes show areas visited this summer, 1) George River camp, Core Zone; 2) Labrador Trough, Kuujjuaq area. Modified after James et al. (2003)

Methodology

Prior to commencement of fieldwork, archived samples from GSC ‘Operation Torngat’ (Taylor, 1979) were identified, located on a digital map, photographed, and accompanying descriptive notes scanned for inclusion in a digital Atlas being prepared for publication in early 2015. Fieldwork in and around NTS map sheet 24A (Figure 2, box 1) was based out of the main MERNQ camp on George River and consisted of systematic helicopter-supported traverses across the main lithotectonic packages as outlined from aeromagnetic anomaly maps. In total, 98 stations were visited and the main lithologies were sampled for petrographic and geochemical analysis. Representative lithologies were sampled for tracer isotope (Sm-Nd, Hf) and radiogenic age-dating (U-Pb). Structural and kinematic analyses were also initiated, with focus on the principal high-strain zones and intervening crustal blocks. Where the thickness and condition of surficial sediments permitted, 10 kg samples of till were collected for geochemical and indicator mineral analysis. During the span of this project most of the major lithological packages were visited and a transect was completed from the Kuujjuaq domain (presumed western edge of the Superior Craton) east of the Labrador Trough, to the Tasiuyaq gneiss at the edge of the North Atlantic Craton. Nd and Hf isotopes will be analyzed to help define characteristics of the Core Zone with respect to known Superior and North Atlantic crust, and potentially correlative rocks on southern Baffin Island.

Logistics for fieldwork in NTS map sheet 24K (Kuujjuaq) were based from the hamlet of Kuujjuaq, and a helicopter-supported transect was completed from the eastern margin of the Superior Craton, across the main units of the Labrador Trough, to tectonically uplifted high-grade gneisses on the hinterland side of the Trough. A series of oriented samples were collected in order to obtain U-Pb monazite and ^{40}Ar-^{39}Ar muscovite ages of the different mineral fabrics, as well as pressure and temperature estimates in order to better constrain the tectono-metamorphic and tectono-thermal evolution of the region. A number of gabbro sills were collected for U-Pb dating to verify if the mafic-ultramafic suites exhibit distinct compositions indicative of several magmatic events of different ages, or if these sills relate to the same large magmatic event across the Labrador Trough.

Results

Numerous observations at various scales were made during the course of fieldwork, and the most fundamental are as follows:

i. The Core Zone may represent an Archean ribbon continent that has undergone lateral southward extrusion during the Paleoproterozoic, as a result of dextral oblique collision between the Superior and North Atlantic cratons. During deformation at peak metamorphic P-T conditions, strain partitioned in a series of interconnected ductile shear zones that accommodated the lateral extrusion of elongate crustal blocks measuring up to 60 km in width and 200 km in length. The inter-shear lenses appear to have undergone a significant amount of shortening along their short axis, accommodated by folding, and south-side-down extension along the long axis. Ductile southward flow has produced map-scale boudinage of competent lithologies, such as large mafic/ultramafic/potassic to alkaline igneous complexes (potential exploration targets?), as well as strong localized shearing in less competent units.

ii. The metamorphic grade of Paleoproterozoic cover on the Core Zone appears to decrease from granulite in the northern area near Ungava Bay, to lower amphibolite (staurolite facies) in the south, a possible effect of southward crustal flow. This has implications for the stability of prospective elements, such as gold in the Ntshuku supracrustal belt, for example (e.g., van Leeden, 1994). Along the boundary between the Superior Craton and Core Zone, transpression resulted in intense dextral shearing and locally strong transposition. Could these zones of high shear and fluid flow be conducive for remobilization of Au mineralisation in extensional jogs?

iii) The central part of the Core Zone is intersected by a number of important brittle fault zones oriented east-west, outlined at surface by steep-walled valleys and on aeromagnetic maps as narrow zones of relatively lower magnetic signature. These faults extend from the Labrador coast westwards perhaps as far as the Superior Craton (~ 450 km). They are thought to be temporally related to Mesoproterozoic crustal extension that led to the emplacement of alkaline magmas (e.g., Lac Brisson, Strange Lake, Misery Lake) as well as anorthosite-mangerite-charnockite-granite (AMCG) plutons. A few of the east-west faults were injected by gabbro that compositionally and texturally resembles N-NW trending gabbro dykes of the Falcoz suite which, in turn, could be related to the ca. 740 Ma Franklin suite. A number of previously unreported mafic to ultrapotassic(?) intrusions, as well as zones of sodic and potassic enrichment were identified along that east-west trend and it is tempting to consider a causal relationship between Mesoproterozoic extension and magma emplacement, as well as perhaps a putative temporal with the Romanet Horst in the Labrador Trough.

iv) The Labrador Trough northwest of Kuujjuaq contains all three cycles of trough stratigraphy, but is predominantly represented by 2nd Cycle metavolcano-sedimentary rocks of the Gerido belt, which are injected by numerous gabbroic and ultramafic sills being actively explored for Ni-Cu-PGE. One of the current models used by the mineral exploration industry is that PGE enrichment is possibly reef-style, where mineralization is strongly controlled by the internal stratigraphy of the host unit. During our reconnaissance work, numerous fold repetitions and potential thrust repetitions were observed, adding to potential structural complexities. We also observed numerous sedimentary structures that are sufficiently well preserved to determine direction of stratigraphic younging, providing critical information on bed attitude. Therefore, with the establishment of a few strategically placed traverses, it will be possible to gain a much better understanding of the fold and thrust architecture of the entire belt. This understanding will support both Ni-PGE exploration and could be beneficial to exploration for orogenic gold, particularly Telfer-type structure-related gold. Furthermore, detailed work by the exploration industry on the geochemical composition of individual mafic sills suggests there may be more than one generation of sills with differing potential for PGE mineralisation. We have begun a systematic belt-scale study of the radiometric age and geochemical composition of mafic and ultramafic flows and sills, based on samples archived at the GSC in Ottawa, as well as samples collected this summer. Results from in-situ method for U-Pb monazite and laser ^{40}Ar-^{39}Ar age dating on muscovite will help develop a quantitative understanding of the tectonic evolution in relation to development of mineral assemblages linked to evolution of the orogeny through time. Together, these new observations and datasets will permit a better understanding of the stratigraphic, magmatic and tectonic evolution of the Labrador Trough, a critical step toward a better understanding of the mineral potential and refinement of exploration strategies for various commodities.

v) Ni-Cu-PGE mineralization at the Raglan site, within the Raglan Trend, occurs within a series of high-grade ore deposits hosted in thick ultramafic-mafic complexes distributed along a > 50-kilometer east - west trend. Almost all deposits occur within footwall embayments interpreted to be produced from thermomechanical erosion of the footwall rocks by komatiitic magmas. However, the mode of emplacement is highly debated. Whether it is extrusive or intrusive in origin will influence the distribution and the style of mineralization within the komatiitic succession (Houlé et al., 2008). Thus far, preliminary observations strongly suggest that at least part of the Raglan Trend is extrusive in origin, based on the presence of several occurrences of breccia mainly located at the top of units (i.e., flow-top breccia) but locally internally to the ultramafic-mafic complexes. Samples from the Raglan Mine area in the Cape Smith belt will be analyzed for a comparative study with the mineral occurrences known in the Labrador Trough.

Future work

Over the course of the Fall-Winter 2014-15, at least 30 samples will be analyzed for U-Pb age dating, providing protolith age determinations, as well as metamorphic ages. Some of these samples will be analyzed for tracer isotope (Sm-Nd) determinations in order to help constrain the location of major crustal boundaries. Petrographic and lithogeochemical analyses will also be done on key lithologies. These data, in combination with structural analysis and bedrock mapping completed over the summer, will form the basis for publication of a new 1:750,000 scale synthesis map of the central part of the Core Zone and parts of the adjacent Superior and North Atlantic cratons. These data will also be used to test for potential correlations with the Meta-Incognita micro-continent on southern Baffin Island.

The synthesis map will also permit a better integration and interpretation of new till geochemical and indicator mineral analyses presently done by the MERNQ in NTS map sheet 24A, by the GEM-2 surficial geology activity in map sheets 23-I and 23-P (*see* McClenaghan et al., 2014), and by Kerry Robillard as part of a M.Sc. thesis to be completed at the University of Ottawa. In the summers 2015 and 2016 we plan to complete the thematic studies on the Core Zone and bounding orogens with equal attention drawn to the tectonic evolution and metallogeny of the Labrador Trough, and gain a better understanding of the Proterozoic-age supracrustal and magmatic suites of the Core Zone.

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