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GEOLOGY AND GEOCHEMISTRY OF MAFIC-ULTRAMAFIC SILLS IN THE NORTHERN PERMITS, RAGLAN Ni-Cu-(PGE) DISTRICT, CAPE SMITH BELT, NUNAVIK, QUEBEC

D.J. McKevitt[1], C.M. Lesher[1], and M.G. Houlé[2]

INTRODUCTION

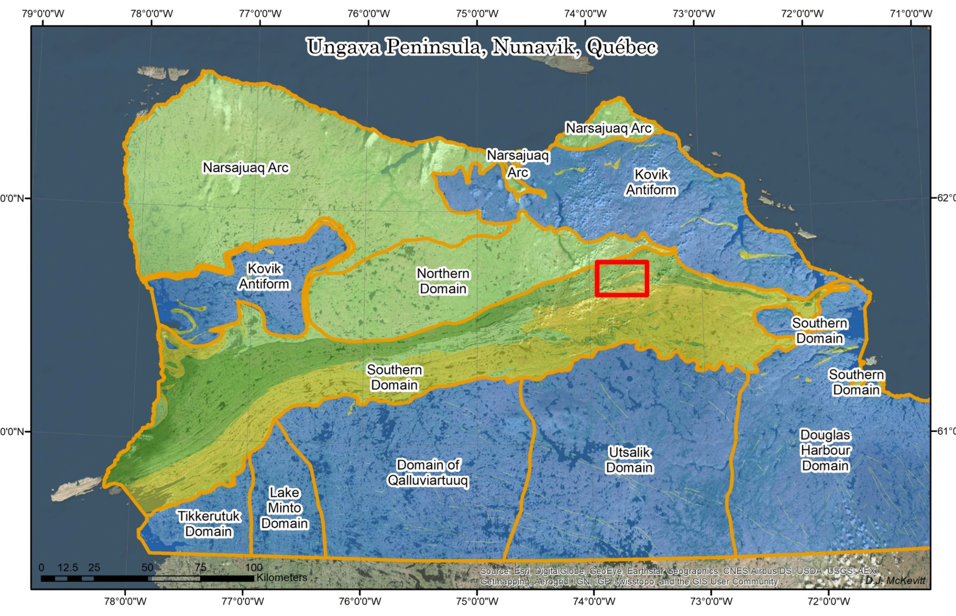


Figure 1: Geologic domains of the Ungava Peninsula. Blue represents Archean domains and greens represents Proterozoic domains. Units north of the Southern Domain are "suspect" accreted terranes; the Northern Domain is interpreted as an ophiolite. The Cape Smith Belt lies along the Southern Domain – darker green is Chukotat Group and Povungnituk Group is yellowish-green colored. Field work area outlined in red (area of Fig. 3). Data from St-Onge et al. (2007).

The Cape Smith Belt (CSB) in Nunavik (Québec) formed during 1.9-1.8 Ga deformation between the Superior Province (Archean) to the south and "suspect" terranes (Proterozoic) to the north along an arc-continental collisional zone (the foreland thrust belt of the Ungava Orogen) (**Fig. 1**) (Lesher, 2007; St-Onge and Lucas, 1993). Two main tectonostratigraphic units form the CSB: an older Povungnituk Group that represents the transition from initial rifting (lower part) and continental basalt volcanism (upper part), and a younger Chukotat Group which represents opening of an ocean basin (Francis et al., 1983).

The geologic structure of the Cape Smith belt (east-central part of the CSB) is dominated by approximately E-W trending faults and fold axes resulting from southward-directed thrusting. All rocks have been regionally metamorphosed to lower greenschist facies. Although fresh mineralogy is rare in the mafic to ultramafic units (ubiquitous serpentine – tremolite +/- talc alteration), primary igneous structures and textures are well preserved (Lesher, 2007).

High-grade magmatic Ni-Cu-(PGE) sulfide mineralization was discovered in the Katinniq area in 1956; exploration and development led to first production in 1997 (from the Katinniq underground mine). Mining along the E-W mineralized trend continues today at Glencore's Raglan Mine (**Fig. 2**). The Raglan formation hosts Ni-Cu-(PGE) sulfide mineralization within peridotite-dominated conduit facies assemblages along the contact between the Povungnituk and Chukotat groups (Lesher, 2007). A variety of thick peridotite-gabbro units occur within an apparently thrust-repeated northern panel of Povungnituk – Chukotat rocks located in the Northern Permits area (**Figs. 2-3**); however, no economic mineralization has been discovered so far in this panel. The Raglan formation units along the southern panel have been well characterized, but the peridotite-pyroxenite-gabbro units in the northern panel (especially along the Povungnituk-Chukotat contact) are poorly constrained.

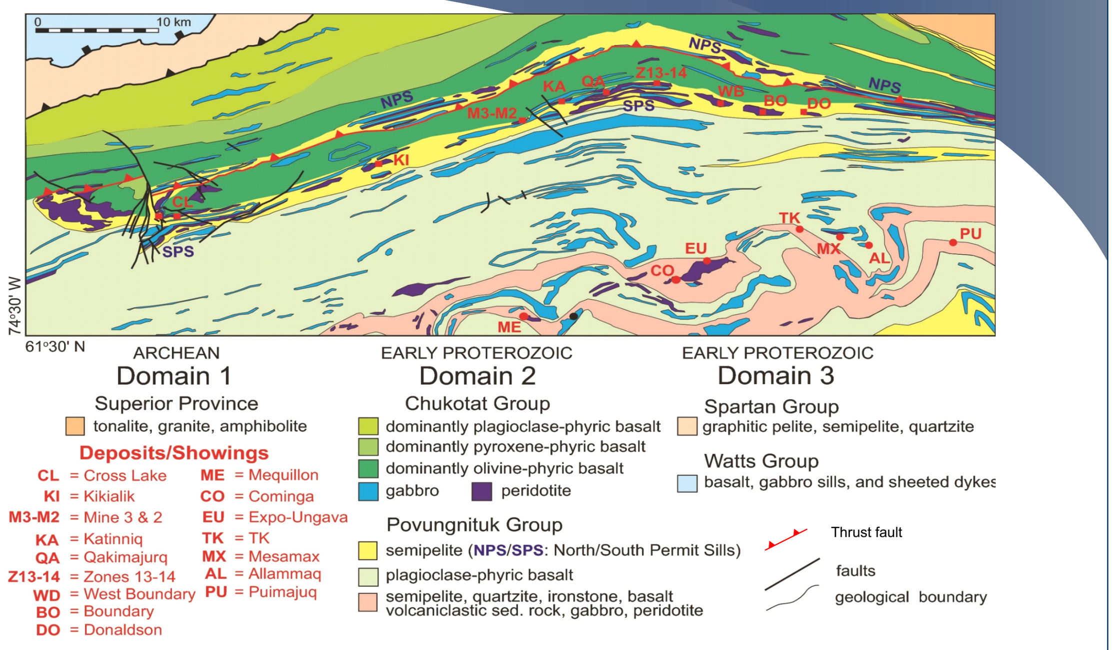


Figure 2: Geological map of the Raglan area (modified after St-Onge and Lucas, 1993) showing major deposits and current mining operation along the Raglan formation. Note the E-W trending, northward dipping reverse thrust fault (in red). Other thrust faults has been suggested, to the north and to the South, by previous workers between Povungnituk and Chukotat Groups but those contacts may actually be semi-conformable.

OBJECTIVES AND METHODS

Figure 4: Ultramafic units (sills?) form maroon-colored ridges against Chukotat basalt in the background with trucks on road for scale. Photo facing north.

The primary goal of this research project is to texturally and geochemically characterize the mafic and ultramafic units that occur on the thrust-repeated northern panel (i.e., Northern Permits) within the Katinniq area (**Fig. 2**). This characterization will help constrain whether the Northern Permits units represent invasive lava channels and channelized sheet flows (like the Raglan formation) or channelized sills and sheet sills (like those in the Povungnituk Group) in order to better understand the difference in metal endowment between the well-endowed southern panel and the less-endowed northern panel of the Raglan formation within the Katinniq area.

Five weeks of field work were conducted in July-August 2017 along ~23 km of the northern panel (i.e., Northern Permits). During 22 field days, 167 samples were collected from 200 field stations (**Fig. 3**). Mafic-ultramafic units were targeted according to quality of historic sampling and geochemical analyses, exposure, and lithologies. In particular, three styles of units were sampled in detail along transects perpendicular to trend: mafic-dominated (the Tiriganiaq Gorge area), ultramafic-dominated (the Deception Ridge area), and differentiated mafic/ultramafic (the NC20C Gorge area). Furthermore, regional sampling provided coverage of scattered (and less well-exposed) units across this area. Igneous and volcanic textures and structures, and rare contacts, were noted in an effort to identify environments of emplacement (**Figs. 4-16**).

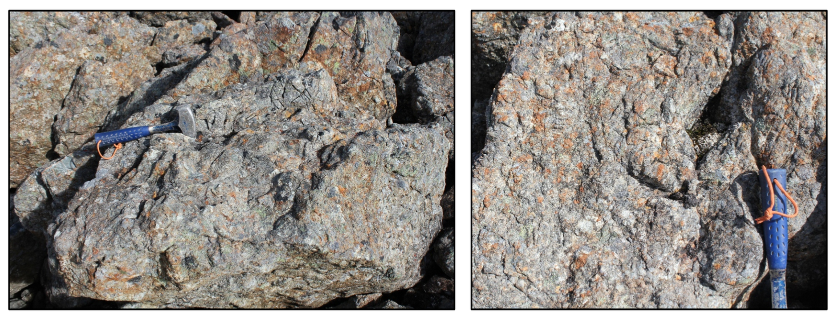


Figure 11: Possible flow-top breccia in uppermost part of a 70 m thick pyroxenitic / komatiitic basalt unit bounded to the north and to the south by alternating basalt / pyroxenitic units.

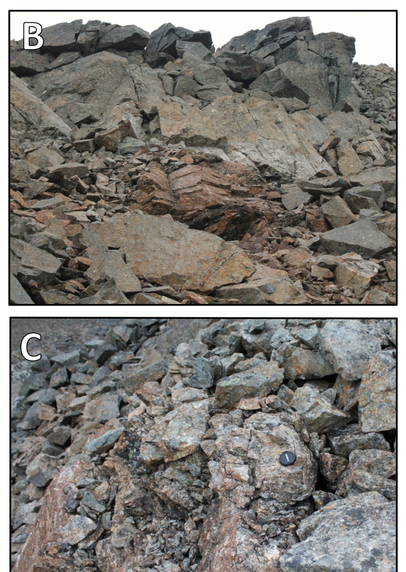
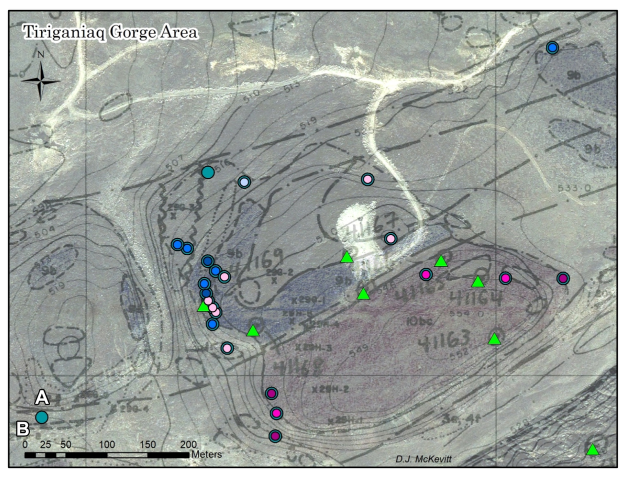


Figure 5: A) Columnar jointed olivine pyroxenite units in [concealed] contact with melagabbro. Hammer for scale. B) Similarly columnar-jointed olivine pyroxenite in contact with overlying basalt along cliff face. C) Close-up of the contact presented in figure 5B showing a possible flow-top breccia. Camera lens cover for scale. Abundant sulfide staining nearby. These units may represent extrusive lava facies.



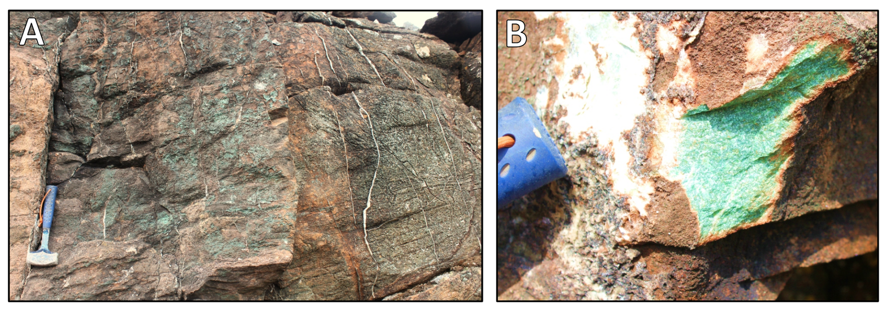
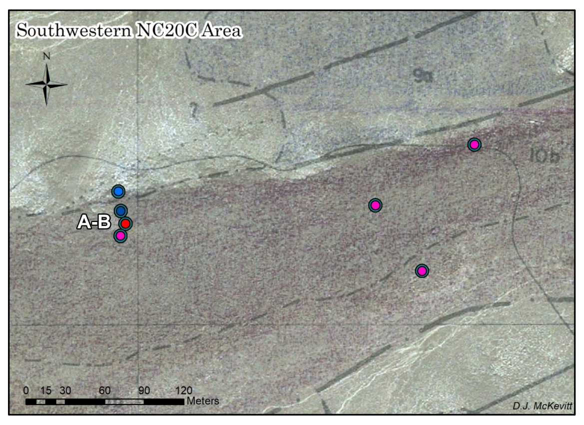


Figure 9: Detailed sampling through the Tiriganiaq Gorge area. Semi-transparent map overlayed on aerial imagery is from 1:10000 scale mapping by C.J.A. Coats (1982). Gabbroic units have been colored blue and ultramafic units colored purple. Note massive, pillowed basalt in the southeastern corner, abruptly bounded on the north side by a steep cliff (i.e., fault). Same legend as Fig. 6. A) Carbonate (iron-) and fuchsite alteration and quartz veining along the gabbroic hill's southern side, evidence of significant shearing and fluid flow. B) Close-up of fuchsite / carbonate alteration. Photo locations shown by letters on map.

Figure 10: Thick sequences of well-preserved pillowed basalt of the Chukotat Group. Hammer for scale.



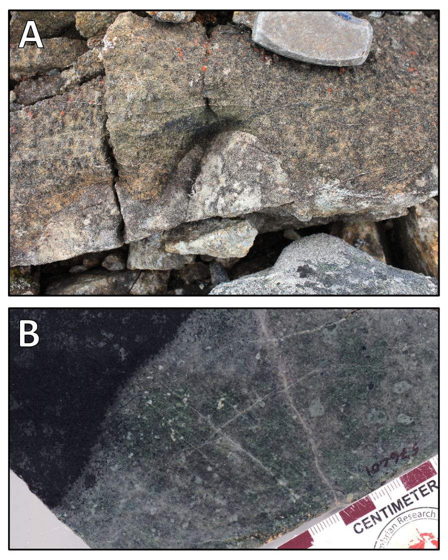


Figure 12: Samples taken across an olivine pyroxenite-gabbro unit located SW from the NC20C Gorge area. Same legend as Fig. 6. Basemap overlayed as noted in Fig. 9. A) Internal contact between green melagabbro and oikocrystic olivine pyroxenite. B) Internal contact shown in a wet slab.

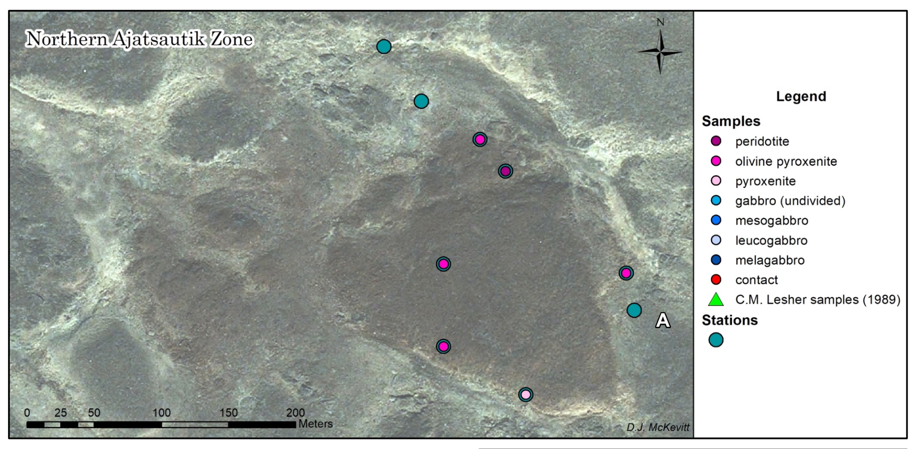


Figure 6: Previously unmapped ultramafic bodies in northern Ajatsautik zone identified on aerial imagery. They are surrounded by pillowed Chukotat basalts and minor pyroxenite units whereas gabbro is absent from this area. Photo shows a possible flow-top breccia in flanking pyroxenitic / komatiitic basalt units. Photo location shown by letter on map.

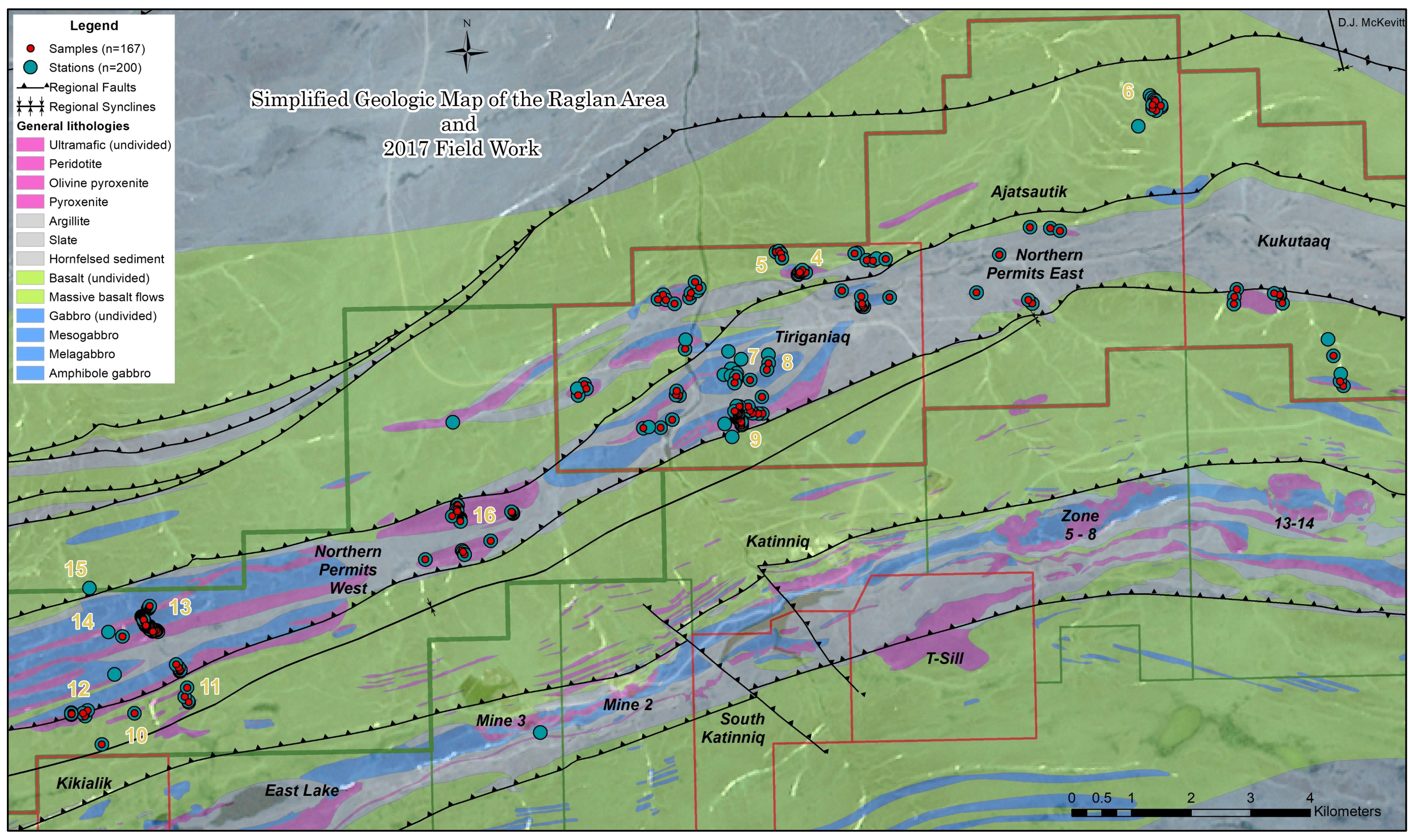
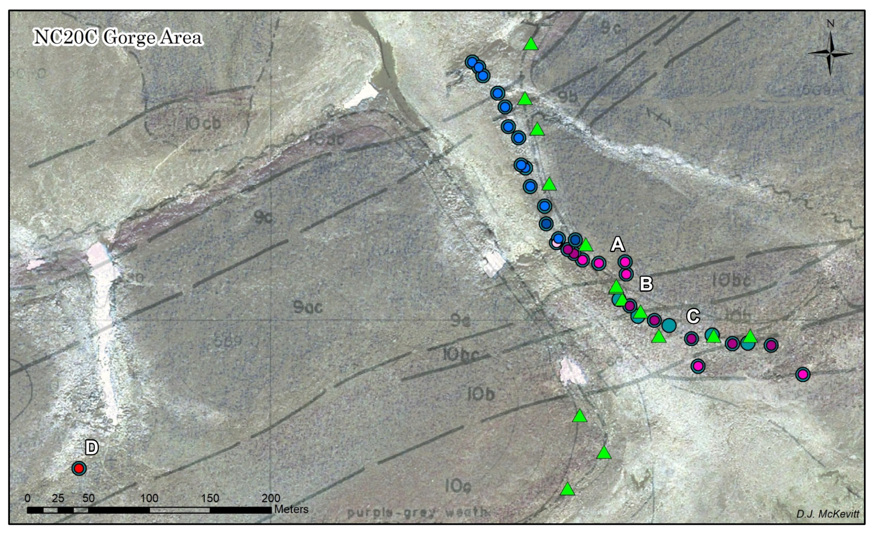


Figure 3: Geological map of the Raglan area, showing station and sample locations of the 2017 field season. Raglan Mine property and permit zones outlined in red and green. Geology and property lines are from Glencore. Faults and fold axes from St-Onge et al. (2007). Gold-colored numbers indicate locations of Figs. 4-16.



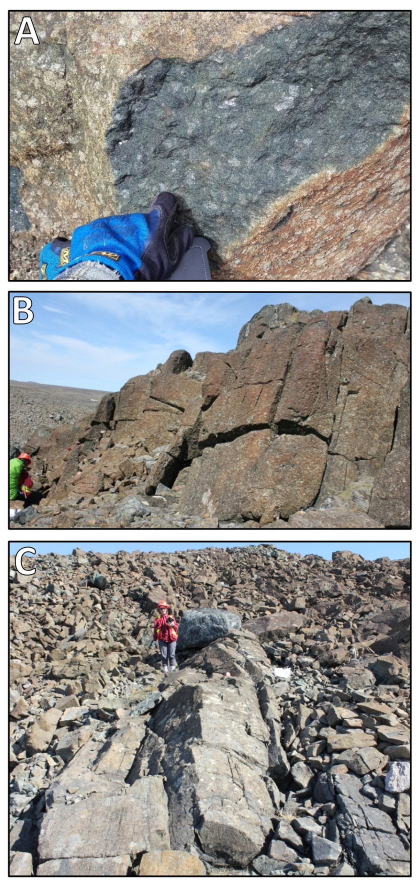


Figure 13: Detailed sampling across the NC20C Gorge area. Same legend as Fig. 6. Basemap overlay as noted in Fig. 9. A) Coarse pyroxene oikocrysts up to 30+ mm. Moving from the southern margin of the ultramafic section northwards "up-section", oikocrysts increase in diameter from 3-4 mm to a maximum of about 35 mm, while subsequently decreasing in abundance. B, C) Columnar-jointed olivine pyroxenite located near the top of the ultramafic section (B) and larger columns near the base (C). The northern edge of the gabbroic section is similarly jointed perpendicular to a sharply sheared and serpentinized boundary. D-F) Irregular but sharp contact between oikocrystic olivine pyroxenite and green melagabbro located approximately 430 m SW along strike from the covered contact within the gorge (D). Same contact show in a wet (E) and dry (F) slab. This very uneven contact displays "flame structures" reminiscent of load-cast sedimentary structures. Similar internal structures and overall architecture were noted by Arndt (1982) in 20-100 m thick layered olivine-cumulate-pyroxenite-gabbro Proterozoic lava flows on Gilmour Island in Hudson Bay. Like the contact in Fig. 12, this appears to be a "sandwich zone" with sulfides concentrated along the contact and within alteration veins. Photo locations shown by letters on map.

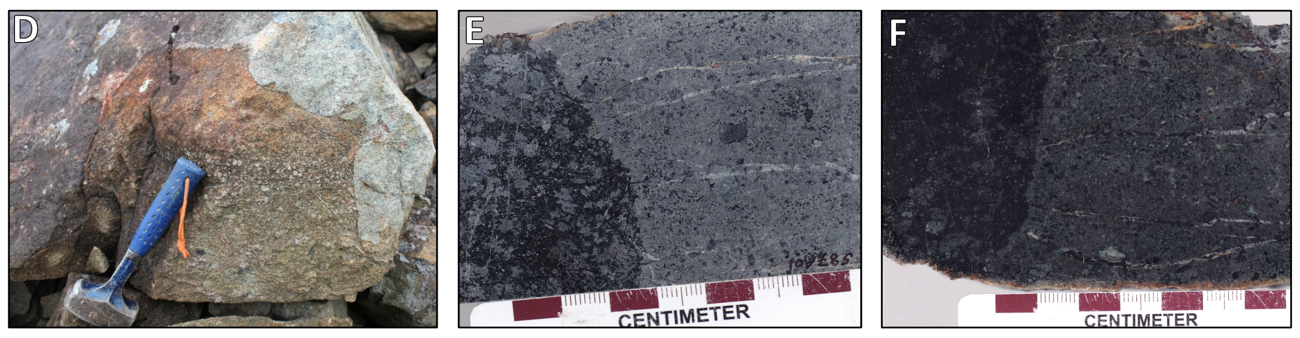
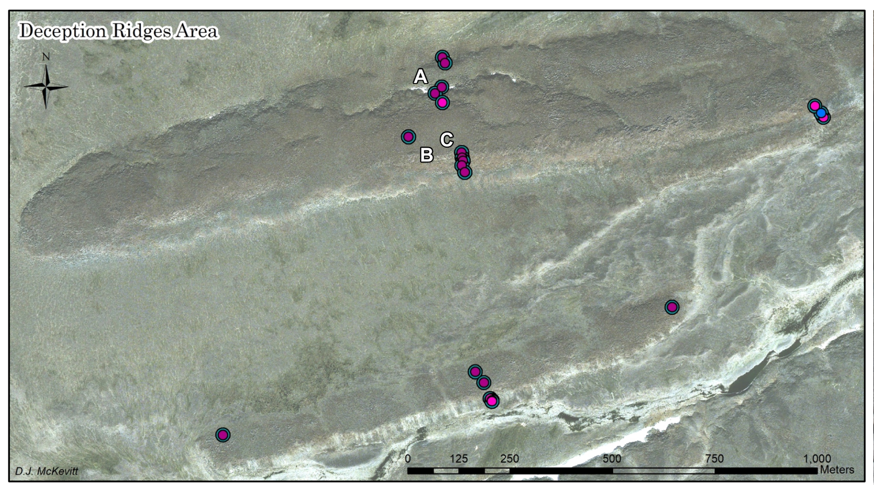


Figure 7: Contact of a gabbroic unit with sediments (well-exposed behind the geologist). The sediments here have been weathered away, revealing a cross-jointed pattern of rounded, pillow-like fine-grained gabbro (i.e., basalt) along the slope. Within 40 cm of the "wall", fine-grained basalt transitions to medium-grained mesogabbro. Sample 469A01 taken along the slope face; 469A02 taken 40 cm to the left of the face. This appears to be the chilled margin of an intrusive unit.



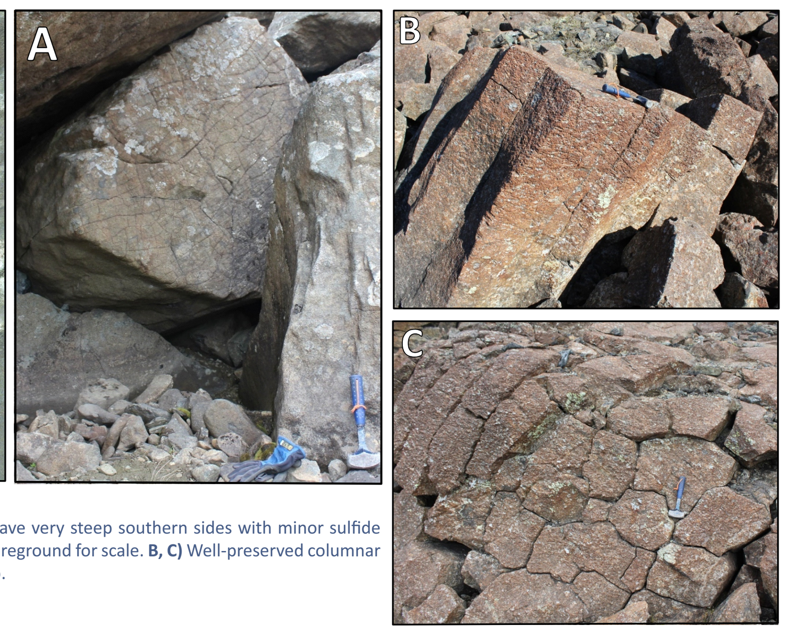
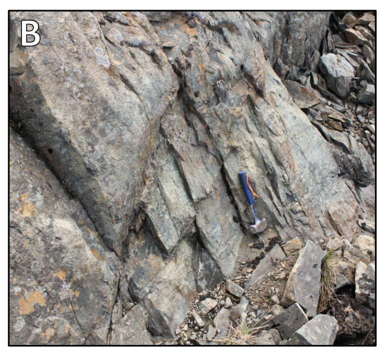


Figure 16: Detailed sampling across Deception Ridge (north) and Little Deception Ridge (south). Both units have very steep southern sides with minor sulfide mineralization. Same legend as Fig. 6. A) Possible polygonal jointing in peridotite blocks; hammer and glove in foreground for scale. B, C) Well-preserved columnar jointing in olivine pyroxenite along the top of the ridge; hammer for scale. Photo locations shown by letters on map.

Figure 14: A) Strongly sheared and serpentinized, 2-3 m thick contact between pyroxenite / komatiitic basalt to the south (right) and sedimentary rocks to the north (left). The zone itself may be comprised of sheared ultramafics. Note the abundant quartz veining. This is similar to the contact on the north side of the NC20C Gorge. B) Close-up showing the uneven contact with tan-colored pyroxenite / komatiitic basalt.



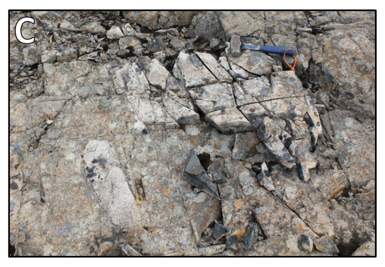


Figure 8: A sharp contact between a gabbroic unit (with chilled margin) and sedimentary rock, located approximately 600 m NE along strike from the location of Fig. 7. A) Argillite / hornfelsed sediment on the left, running up against a gabbro hill to the right. B) Close-up of the sharp contact, with minor sulfide staining along its length. Hammer is leaning against the sedimentary rocks. C) Photo taken a few meters upslope, showing hornfelsed sedimentary clasts (lighter tan – white) within a fine-medium grained basalt-gabbro.

FUTURE WORK

Approximately 150 thin sections will be studied and 140 samples analyzed for whole rock geochemistry (major, minor, trace, REE and PGE elements) to compare with previous work along the main mineralized trend (i.e., Raglan formation). A geochemical database of over 7,000 analyses spanning the Cape Smith Belt (under compilation since August, 2016) will be used to understand the Northern Permits units in a regional context.

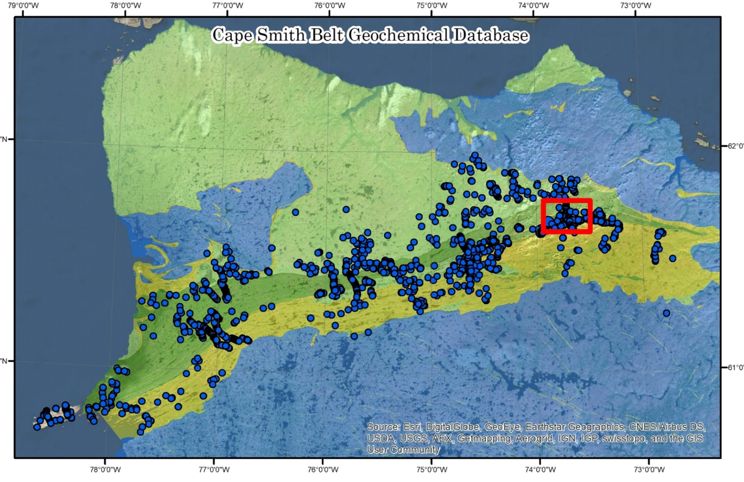


Figure 17: Geological map of the Cape Smith Belt along the Ungava Peninsula showing the locations of more than 7,000 geochemical analyses included in geochemical database compiled by the senior author. Red rectangle bounds the area of the on-going study.

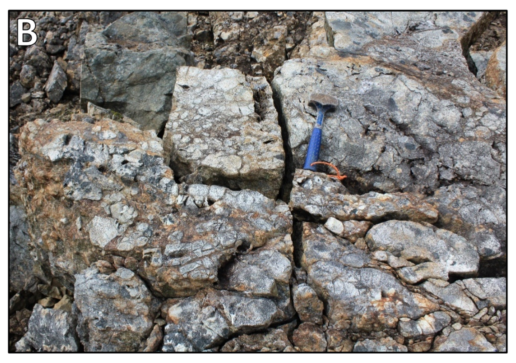


Figure 15: Pyroxenite / komatiitic basalt with interflow sediments. A) Contact between interflow sediments / breccia (upper) and basalt pillows and polygonal joints (lower). B) More cohesive pillows (right) transitioning to breccia and interflow sediments to the left. In both images, hammer head points north.

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[1] Harquail School of Earth Sciences, Mineral Exploration Research Centre, Goodman School of Mines, Laurentian University, Sudbury, Ontario P3E 2C6

[2] Geological Survey of Canada, 490 rue de la Couronne, Québec, Quebec G1K 9A9

For more information, please contact D. McKevitt (dmckevitt@laurentian.ca)

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