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NEW SURFICIAL GEOCHEMISTRY AND INDICATOR-MINERAL SURVEY TO TARGET CRITICAL METALS (BASE METALS, PGES, REES, U): REVISITING THE ALEXIS RIVER VALLEY REGION (NTS MAP AREAS 13A/10, 14 AND 15), SOUTHEASTERN LABRADOR

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ABSTRACT

A 6-week humus- and till-sampling survey was completed in the Alexis River Valley region (NTS map areas 13A/10, 14 and 15) in southeastern Labrador during the 2023 field season. Previous work in the early 2000s indicated that this region is prospective for critical metals, such as rare-earth elements (REE), platinum-group elements (PGE), base metals and U; however, there was only a limited follow up.

Forest fires have affected much of the region, but the resultant contamination of the soil, if any, is not known. Equally, there is no record of mining or other industrial activities that may have contaminated the surficial sediments. A humus- and till-sampling program was designed having three main objectives: 1) incorporate new methods in analytical chemistry to delineate potential critical-metal mineralization; 2) recover potential ore and indicator minerals of rare-earth elements (REE), platinum-group elements (PGE), and base-metal sulphide (BMS) minerals in till; and 3) determine the geochemical signature of potential critical-metal mineralization and whether forest fires in the region have had an effect on humus geochemistry.

INTRODUCTION

Southeastern Labrador is endowed in critical metals such as REEs, PGEs, base metals (*e.g.*, Co, Cu, Pb, Mo, Ni, Ti, Zn) and U (Gower, 2019; Magyarosi, 2022; Natural Resources Canada, 2022). Quaternary glaciations (~2.6 Ma; Fulton and Hodgson, 1979) have resulted in the deposition of glacial sediments (variable thickness) over bedrock, which inhibits exploration of the underlying bedrock.

Till sampling in the Alexis River Valley region (NTS map areas 13A/10, 14 and 15) in the early 2000s (*see* McCuaig, 2002a, b) highlighted elevated values for noble and critical metals; however, there was limited follow-up by industry. Select archived till samples from McCuaig (2002a, b) were resubmitted in May 2023 for analyses using current techniques in analytical chemistry to determine if follow-up work was needed. The analyzed archived samples returned elevated to highly anomalous noble- and critical-metal values. Therefore, a 6-week surficial sampling survey was undertaken, with the objective of further delineating the geochemical and mineralogical signatures of critical metals using current analytical techniques.

Although forest fires have affected this region, there is little to no apparent anthropogenic contamination from the forest fires, nor from mining or industrial activity. Hashmi (2023a, b) demonstrated that on the island of Newfoundland, humus is a suitable sampling medium for detection of Au mineralization in underlying bedrock or till. This study in Labrador expands on that pilot project to determine whether humus can also reflect the geochemical signature of critical metals, if present, in the underlying bedrock and/or till. The results of the work may assist exploration geologists with conducting regional baseline exploration surveys using humus and/or till as a sample medium, in regions with little to no bedrock exposure and/or regions where till is affected by marine incursion.

STUDY AREA: LOCATION, ACCESS AND PHYSIOGRAPHY

The study is located in the Alexis River Valley region in southeastern Labrador (Figure 1), approximately 15 km west of Port Hope Simpson and encompasses 1:50 000 NTS map areas 13A/10, 14 and 15. The main roads consist of the Trans-Canada Highway (TCH) that crosses all three map

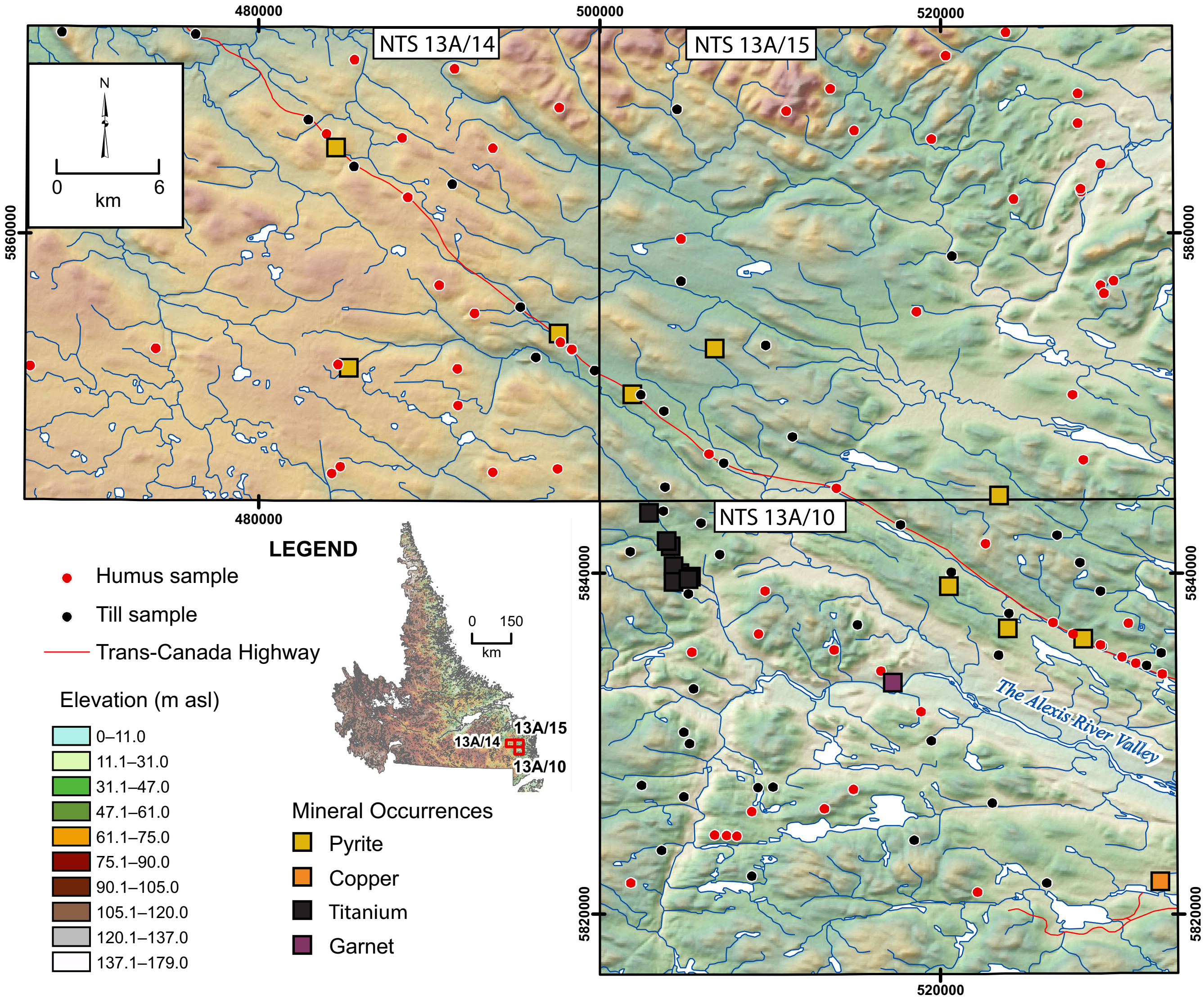

Figure 1. *Location, access, physiography and 2023 humus and till sample locations in the study area.*

sheets as well as two forestry roads in NTS map area 13A/10 that are accessible *via* the TCH. All other areas are accessible only by helicopter or boat.

The study area lies within the Mecatina Plateau physiographic region and Mid-Boreal Forest (Paradise River) ecoregion, an ocean-influenced ecoregion that is part of the Boreal Shield ecozone having an oceanic to perhumid high-boreal ecoclimate (Wiken, 1986; McCuaig, 2002a; Plate 1A). The uplands (up to 580 m asl; Plate 1B; McCuaig, 2002a) dominate the northeastern study area (mainly NTS map area 13A/15) and northwestern corner of NTS map area 13A/14, whereas poorly drained bogs, wetlands and hummocky topography dominate the southwestern study area (mainly southwestern NTS map area 13A/14). The Alexis River Valley (<500 m asl) is located in southern NTS map area 13A/10. Multiple forest fires have affected the study area and nearly all of the vegetation in NTS map area 13A/15 and along the Alexis River Valley appears to be relatively young (<50 years old; Foster, 1983). Podzolic (humo-ferric) soils are developed on glacial sediments (till: lodgement and ablation, glaciofluvial: sand and gravel), and consist of O-, Ae-, B- and C-horizons (Sandborn *et al.*, 2011). Uplands are rocky and dominated by a thin B-horizon soil developed on till and vegetation including krummholz black spruce and lichen. Vegetation in the Alexis River Valley and protected slopes and drainage ways include Douglas fir, and black and white spruce, whereas sedges, cottongrass and spaghnum moss dominate the lowlands and wetlands.

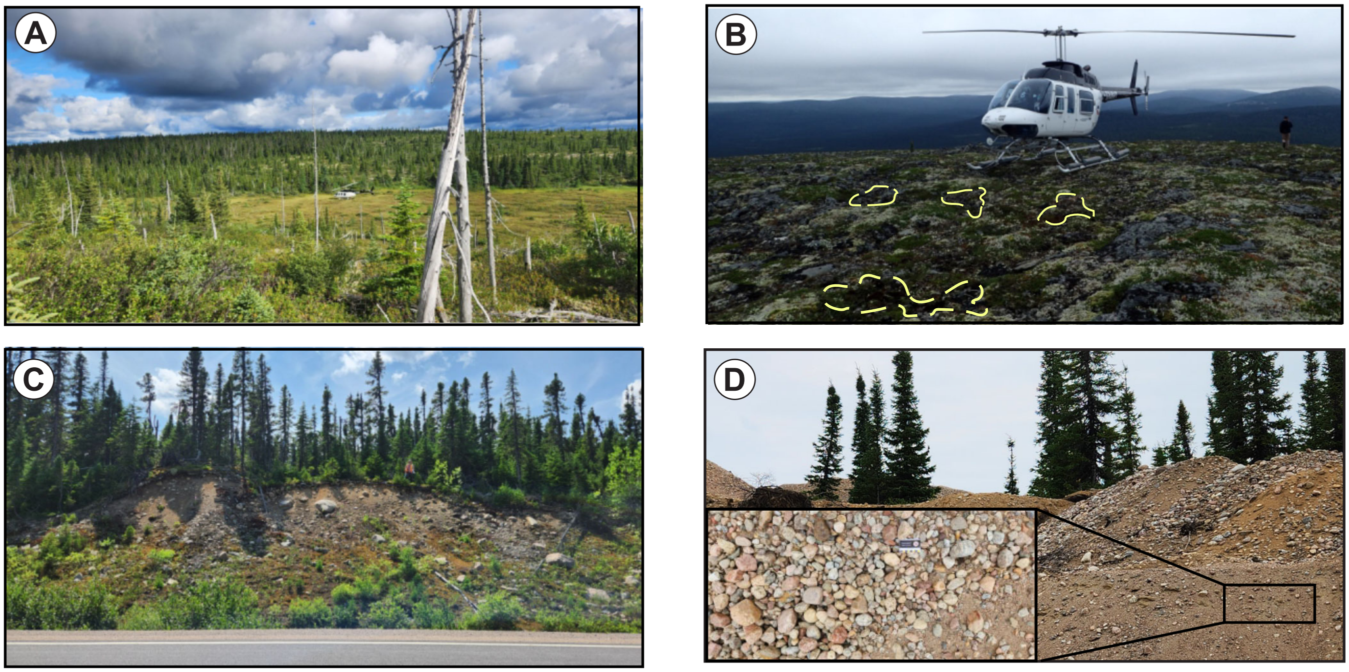

Plate 1. *Field photographs. A) Panoramic view overlooking the study area in NTS 13A/10; B) Thin, poorly developed mud-boils outlined in yellow dotted lines in NTS 13A/15; C) Rare ~20 ft thick till exposed in NTS 13A/15; D) Poorly sorted, coarse sand and pebble to boulder, glaciofluvial deposit in NTS 13A/14.*

GEOLOGY

BEDROCK GEOLOGY

The bedrock geology of the three NTS map areas (Figures 2–4) is summarized after van Nostrand *et al.* (1992), Gower (2019) and Magyarosi (2022). The combined NTS study areas lie within the Mealy Mountains and Lake Melville terranes of the Grenville Province, a region affected by the Paleoproterozoic Eagle River orogenesis, the late Paleoproterozoic Labradorian orogenesis, the late Mesoproterozoic Grenvillian orogenesis and Neoproterozoic events.

The oldest rocks are pre-Labradorian supracrustal rocks (~1.8–1.7 Ga) composed of pelitic sillimanite–garnet–biotite gneiss, psammitic gneiss, quartzite, calc-silicate rocks and mafic volcanic rocks. Rocks of the late Paleoproterozoic (~1.6–1.7 Ga) Labradorian orogenic event consist of anorthositic, mafic and ultramafic rocks, as well as granitoids. Early Labradorian mafic and anorthositic rocks include the Alexis River anorthositic intrusion and the Upper Eagle River mafic intrusion. The Alexis River anorthositic intrusion consists of anorthosite and leucogabbronorite, whereas the Upper Eagle River Intrusion consists of leucogabbronorite and gabbronorite. Early Labradorian granitoid rocks consist of granitoid gneisses composed of mainly quartz diorite, granodiorite, monzonites and granite. Late Labradorian (~1.6 Ga) rocks occur predominantly in northeastern NTS map area 13A/15, and consist of mafic and anorthositic rocks including gabbronorite, leucogabbronorite, anorthosite and leucotroctolite. Of the Grenvillian orogenic event (~1.2–0.9 Ga), only a single pluton is mapped in south-central NTS map area 13A/10 and consists of massive, weakly foliated, granite to alkali-feldspar granite. The youngest rocks in the region are the Neoproterozoic Long Range dykes.

MINERAL OCCURRENCES

Pyrite and Ti indications discussed here are retrieved from the mineral occurrence database system (MODS) of the Geological Survey of Newfoundland and Labrador (GSNL, 2021).

Titanium (Ti)

Several Ti indications (Alexis River West #1–13) are noted in the northwestern NTS map area 13A/10 map area (Figure 2), where Gower *et al.* (1988) documented ilmenite, magnetite and pyroxene in anorthosite (GSNL, 2021). This anorthosite is associated with the ~1.6–1.7 Ga (early Labradorian) Alexis River anorthositic intrusion that consists of massive, weakly to strongly foliated (gneissic) anorthosite and leucogabbronorite that are commonly layered and exhibit cumulate textures (Gower, 2019).

Pyrite (FeS_2)

Several pyrite indications are noted in all the map areas. Of these, the Alexis River Tributary #'s 5, 6 and 7, Gilbert River and Jeffries Pond are associated with pre-Labradorian (~1.7–1.8 Ga) supracrustal rocks, comprising fine- to medium-grained pelitic schist and gneiss. At Alexis River Tributary # 5, pyrite is contained within sulphide- and magnetite–sulphide-rich pegmatite that intrudes the host rocks (garnet–sillimanite pelitic gneiss). At Alexis River Tributary

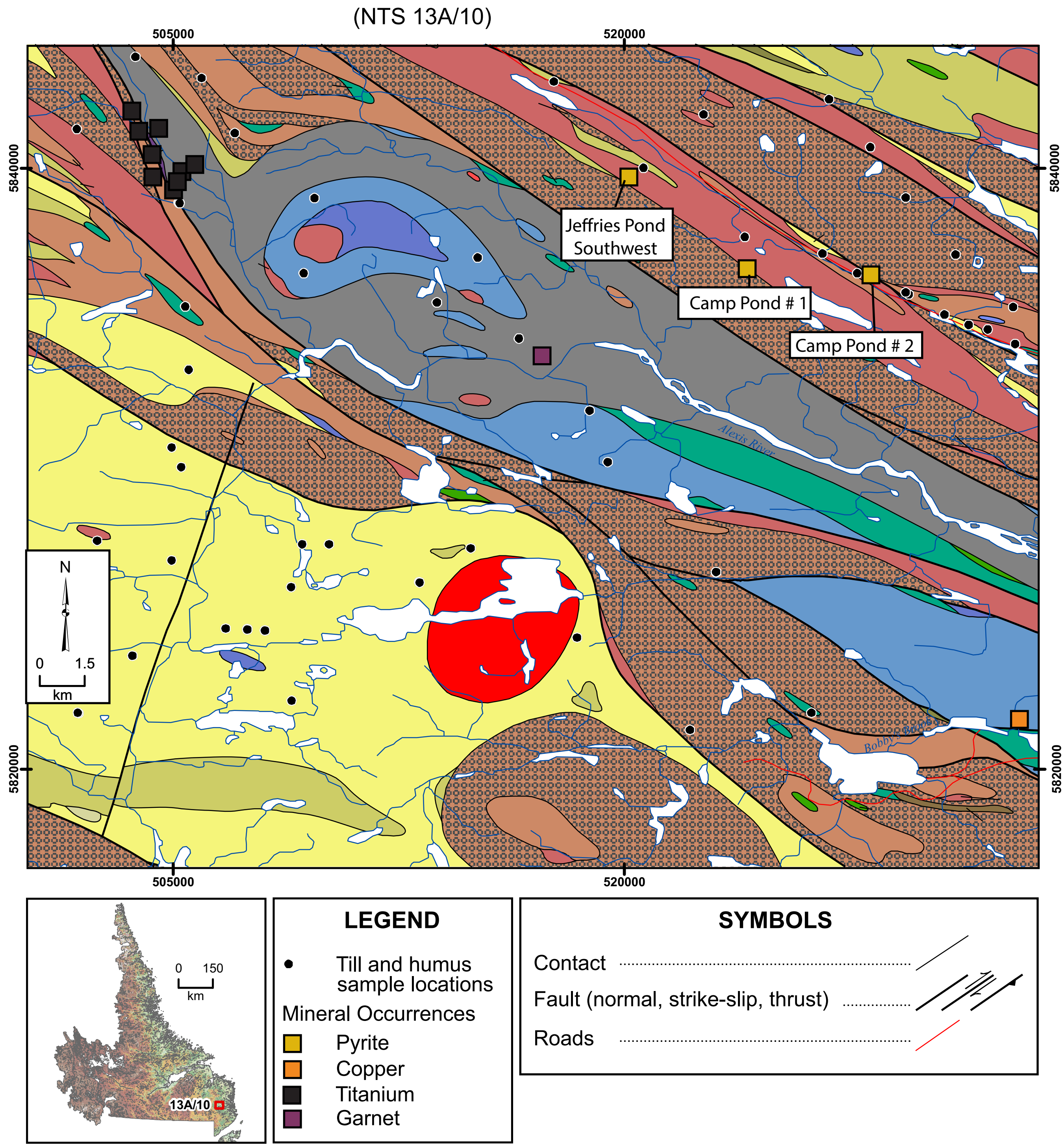

Figure 2. *Bedrock geology and mineral occurrences in the NTS 13A/10 map area. Bedrock geology and legend modified after Gower (2019).*

LEGEND (FIGURES 2, 3 and 4)

NEOPROTEROZOIC

- Nd — Long Range dykes

LATE MESOPROTEROZOIC (M_3 1200–900 Ma)
LATE POST-GRENVILLIAN INTRUSIONS (M_{3D} ca. 975–955 Ma)

- M_{3D}gr — Massive to weakly foliated granite to alkali-feldspar granite

AGE GENERALLY POORLY CONSTRAINED

- p — Pegmatite

LATE PALEOPROTEROZOIC (P_3 1800–1600 Ma)
LATE LABRADORIAN GRANITOID INTRUSIONS
(P_{3C} 1660–1600 Ma)

- P_{3C}ga — Alkali-feldspar granite, granite and quartz syenite forming discrete plutons
- P_{3C}gp — Megacrystic/porphyritic granite to granodiorite
- P_{3C}mn — Monzonorite and monzogabbro
- P_{3C}mq — Quartz monzonite, including rare quartz syenite
- P_{3C}mz — Monzonite, including minor syenite

LATE LABRADORIAN ANORTHOSITIC AND MAFIC INTRUSIONS (P_{3C} 1660–1600 Ma)

- P_{3C}ag — Weakly to markedly foliated mafic granulite, plus leucocratic and melanocratic variants
- P_{3C}am — Weakly to markedly foliated amphibolite, plus leucocratic and melanocratic variants
- P_{3C}rg — Massive to strongly foliated gabbro and norite, commonly layered; subophitic and locally coronitic
- P_{3C}ln — Primary textured to recrystallized leucogabbronorite and leucogabbro; locally coronitic
- P_{3C}um — Massive, weakly or strongly foliated ultramafic rocks, commonly layered and locally showing cumulate textures

EARLY LABRADORIAN MAFIC AND ASSOCIATED ROCKS (P_{3B} (1710-1660 Ma) e.g., Alexis River anorthosite (assigned here although age is uncertain)

- P_{3B}ag — Weakly foliated to gneissic amphibolite and mafic granulite, plus leucocratic and melanocratic variants
- P_{3B}an — Weakly foliated to gneissic anorthosite and leucogabbronorite
- P_{3B}ln — Weakly foliated to gneissic leucogabbronorite and leucogabbro; locally coronitic
- P_{3B}rg — Weakly foliated to gneissic gabbro and norite

EARLY LABRADORIAN GRANITOID AND ASSOCIATED ROCKS (ca. 1678 and 1671 Ma)

- P_{3B}dr — Foliated to gneissic diorite to quartz diorite, and compositionally equivalent well-banded gneiss; in part derived from leucogabbronorite
- P_{3B}gd — Foliated to gneissic granodiorite and compositionally equivalent well-banded gneiss
- P_{3B}gp — Foliated to gneissic megacrystic/porphyritic granitoid rocks, augen gneiss
- P_{3B}gr — Foliated to gneissic granite and alkali-feldspar granite, and compositionally equivalent well-banded gneiss
- P_{3B}mq — Foliated to gneissic quartz monzonite, grading into diorite or syenite, and compositionally equivalent well-banded gneiss
- P_{3B}am — Amphibolite skialiths, lenses and layers (mainly remnants of former dykes)

PRE-LABRADORIAN SUPRACRUSTAL ROCKS (P_{3A} 1800–1710 Ma)
(Age uncertain; certainly pre-1670 Ma, probably 1800–1770 Ma)
Sedimentary protolith

- P_{3A}sc — Calc-silicate rocks, compositionally layered, medium grained
- P_{3A}sp — Fine- to medium-grained pelitic schist and gneiss
- P_{3A}sq — Quartzite, meta-arkose, thin to thick bedded
- P_{3A}ss — Quartz-feldspar psammitic schist and gneiss; medium grained and commonly rusty-weathering
- P_{3A}sx — Metasedimentary diatexite; coarse grained to pegmatitic and characteristically white-weathering

#6, the pyrite occurs within garnet–sillimanite pelitic gneiss, whereas at Gilbert River, the pyrite (and minor molybdenite) is hosted within well-banded schistose biotite–sillimanite pelitic gneiss interlayered with quartzite. Pyrite at the Alexis River Tributary #7 indication is associated with garnet–sillimanite pelitic gneiss (GSNL, 2021). Similarly, at Jeffries Pond, pyrite is also hosted within rusty sillimanite-bearing metasedimentary gneiss and quartzite.

Camp Pond #'s 1 and 2, and Jeffries Pond Southwest pyrite indications are associated with early Labradorian (~1.7 Ga) granitoids that consist of foliated to gneissic granite, alkali-feldspar granite and compositionally equivalent banded gneiss. At Camp Pond #2, pyrite is hosted within amphibolite associated with granitic gneiss, whereas at Camp Pond #1, pyrite is hosted within rusty, fine- to medium-grained, foliated garnet–biotite, quartz-rich gneiss. Lastly, at Jeffries Pond Southwest, pyrite is hosted within rusty garnet–amphibole-bearing granulite.

REGIONAL QUATERNARY FRAMEWORK

This summary of the regional Quaternary framework, *i.e.*, the glacial and deglacial events associated with the Late Wisconsinan Glaciation in southeastern Labrador, is based on work by Fulton and Hodgson (1979), King (1985), Josenhans *et al.* (1986), Grant (1989, 1992), Batterson and Liverman (2001), McCuaig (2002a, b), Shaw *et al.* (2006) and Ullman *et al.* (2016).

The Laurentide Ice Sheet (LIS) covered all of Labrador, extending onto the northern tip of the Northern Peninsula (Newfoundland) during the last glacial maximum (LGM; ~22 ka BP) of the Late Wisconsinan Glaciation, (Grant, 1992; McCuaig 2002a, b; Shaw *et al.*, 2006; Ullman *et al.*, 2016). During the LGM, the LIS flowed in a general east–southeastward direction in the study area. The LIS eroded and sculpted the underlying granitic, anorthositic and gneissic bedrock and deposited a thin (<1 m) and discontinuous till in the study area that is matrix-supported, poorly sorted, with a silty sand texture and up to 40% clasts that range from granule to boulder-sized (Plate 1B, 1C).

Deglaciation in the study area may have begun as early as 13 ka BP (radiocarbon years before present; King, 1985; McCuaig, 2002b). Radiocarbon dates taken along the Labrador coast indicate that it is likely that most of south-eastern Labrador was covered by ice until about 11 ka BP (King, 1985). Ice retreat is constrained by the Paradise Moraine, an ice-marginal deposit (McCuaig, 2002b), mapped in the northwestern portion of the study area (NTS

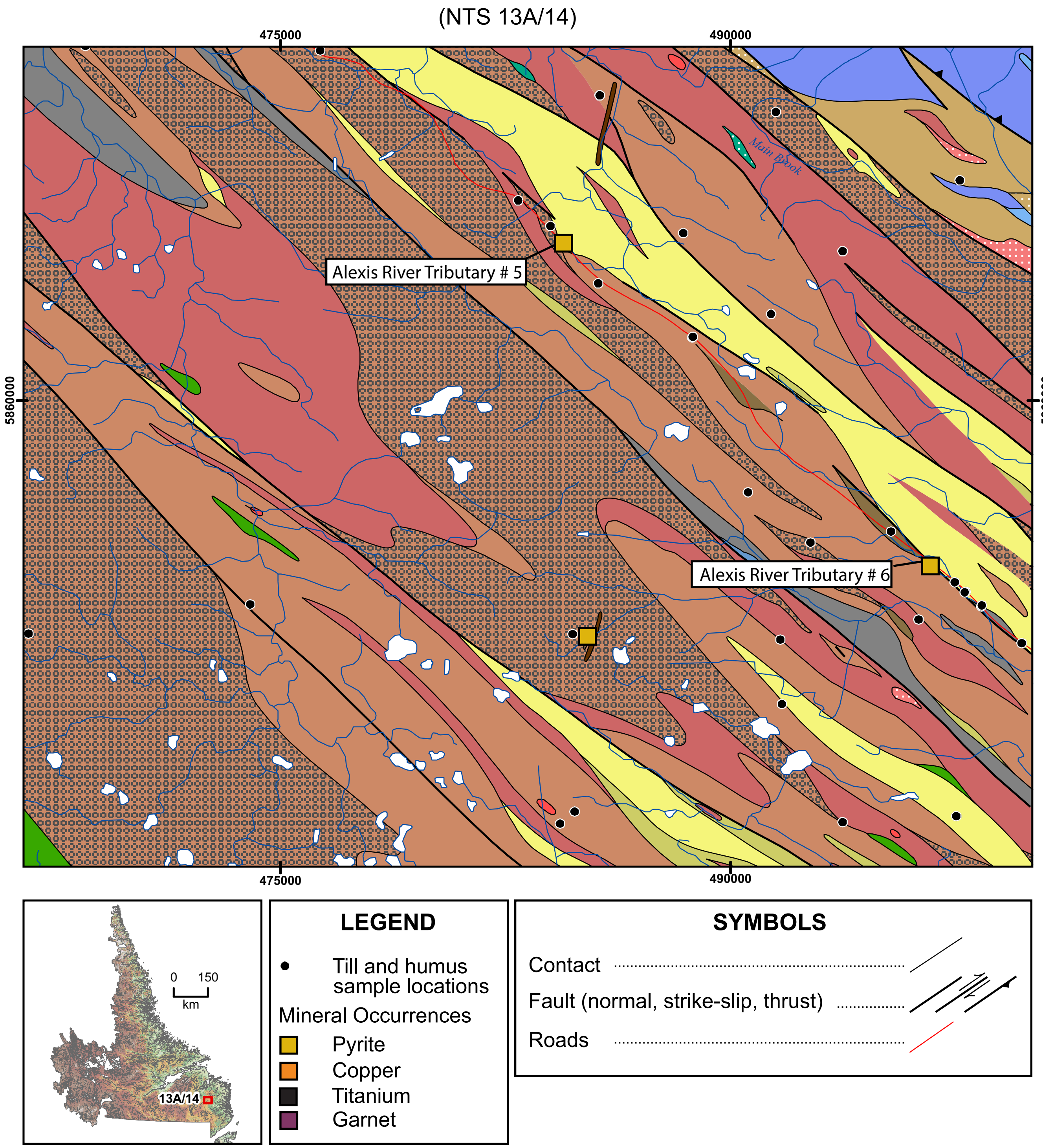

Figure 3. *Bedrock geology and mineral occurrences in the NTS 13A/14 map area. Bedrock geology and legend modified after Gower (2019).*

map area 13A/14; King, 1985; McCuaig, 2002a). The Paradise Moraine comprises glaciofluvial sand and gravel that form hummocks, kettles, ridges and doughnut-shaped features resulting from ice-retreat and subsequent stagnation in the region (Plate 1D). Surficial exposure dates from ^{10}Be dating of boulders from Paradise Moraine suggest that the western most study area may have deglaciated by 10.4 ± 0.6 ka (Ullman *et al.*, 2016).

Marine limits in southeastern Labrador are approximately 150 m asl (Josenhans *et al.*, 1986; Grant, 1992; McCuaig, 2002b). In the southeastern corner of the study

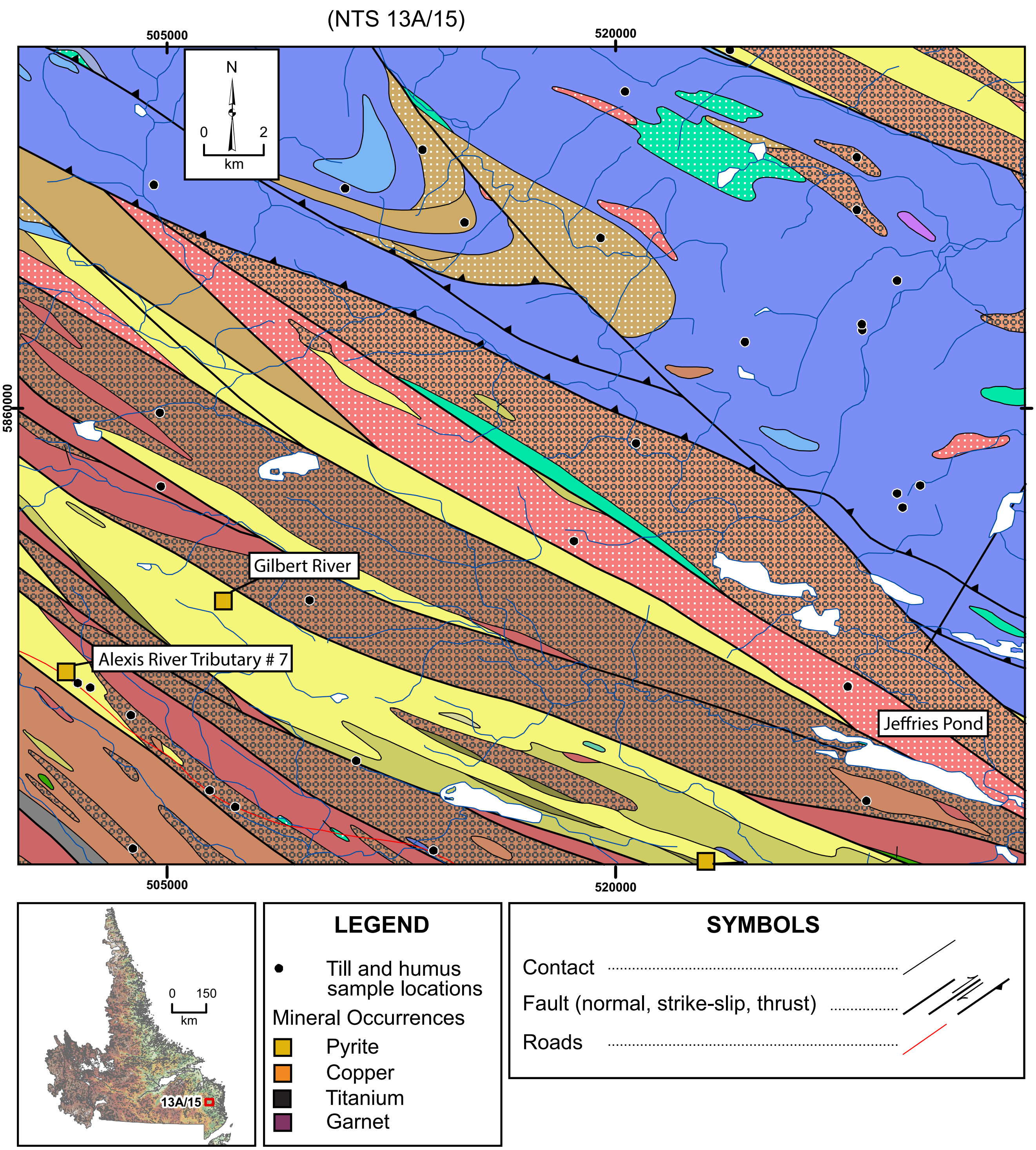

Figure 4. *Bedrock geology and mineral occurrences in the NTS 13A15 map area. Bedrock geology and legend modified after Gower (2019).*

area, marine sediments were documented at elevations between 110 and 150 m asl (McCuaig, 2002b). Further, *Clinocardium ciliatum* shells from marine sediments, underlying glaciofluvial terraces adjacent to the Alexis River, along the eastern boundary of NTS map area 13A/10 at an elevation of 6 m asl were (radiocarbon) dated to ~8.5 ka BP (King, 1985; McCuaig, 2002b). This date suggests that the eastern study area was ice-free and inundated by marine waters by at least 8.5 ka BP (McCuaig, 2002b). The LIS may have completely disintegrated by ~6.7 ka (Ullman *et al.*, 2016).

ICE FLOW

Airphoto interpretation of macro-scale ice-flow indicators by Fulton and Hodgson (1979) indicated an east–southeastward and southeastward glacial movement and an eastward flow north of Alexis River. Conversely, small-scale, ice-flow indicators such as striations, grooves, and rat-tails are rare because the bedrock is weathered and "crumbly". McCuaig (2002a, b) measured ice-flow movement at eight sites that showed eastward flow, ranging from 77 to 99° (Figure 5). McCuaig (2002a, b) also documented a roche moutonnée in NTS map area 13A/10 oriented east (80 to 107°).

METHODS

SAMPLING

During the 2023 field season (July and August), 76 humus and 73 till samples were collected for geochemical

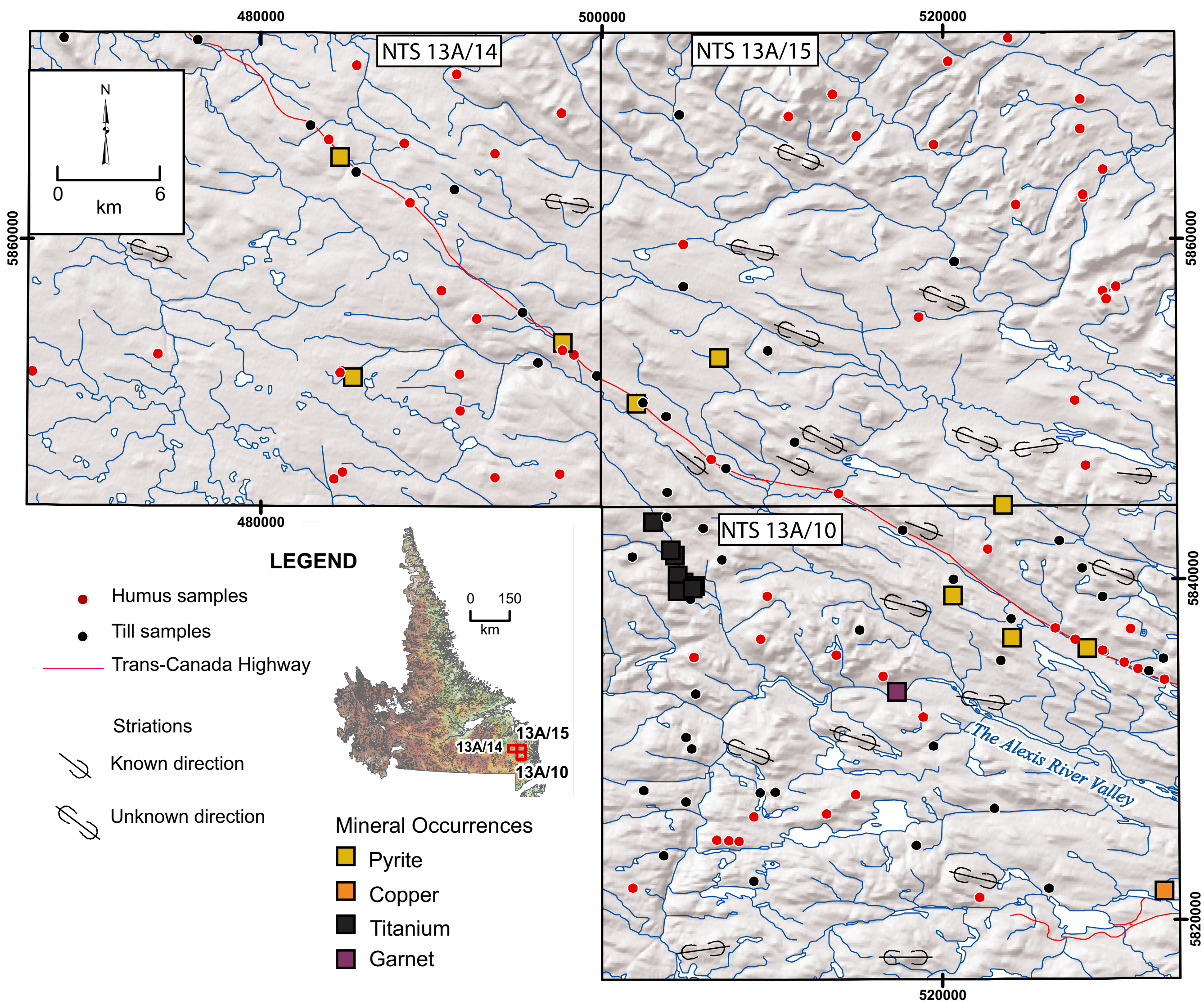

Figure 5. *Striation measurements from previous studies. Data retrieved from McCuaig (2002a, b) and Geological Survey of Newfoundland and Labrador's striation database (2022).*

analyses. At each sample site, 0.5–1 kg humus (O-horizon soil), and 2–3 kg till (B-, BC- or C-horizon soil developed on till; “B-, BC- or C-horizon till”) were collected. At 15 till sites, an additional 12–16 kg sample was also collected for heavy mineral separation. Humus samples were preferentially collected near outcrop to ensure that its geochemistry either reflected the till or bedrock composition. Collection of both humus and till samples at every site was not possible due to either a lack of humus, or a lack of till at the site. A field duplicate was collected every 10 samples for both humus and till samples.

At each humus-sample site, a shovel or reciprocating saw was used to cut through the vegetative mat and expose the humus. The sample was then collected from a smaller hole within the exposed profile (*see* Hashmi, 2023a, b). Sample depth varied from a few to tens of centimetres (Plate 2B), based on the maturity and thickness of the humus. In areas where vegetation appeared “dusty”, the humus sample was collected as deep as 5 cm to avoid airborne dust. The sample was collected using a stainless steel knife that was cleaned by hand and with water (where available) at each site to avoid cross contamination. The sampled material was placed carefully in a plastic bag to ensure that the live vegetation and other soil horizons (such as Ae-, and B-horizon) were avoided; coarse roots, wood fragments and mineral matter were removed from the collected sample.

At each till-sample site, the sediment face was cleaned or a pit was dug to expose the sediment (Plate 2C, D). Sample equipment included a mattock, a shovel, and a geological pick. Till samples were collected from a depth ranging from a few to tens of centimetres. Nearly all till samples were collected from the B- or BC-horizon because till was typically only a thin veneer. B-horizon till is not the ideal sampling medium because it may be enriched in precipitated Fe, and Al- and Mn-oxides and depleted in metals of interest such as Ni, Cu, PGEs, *etc.* (Kauranne, 1992). Ideally, C-

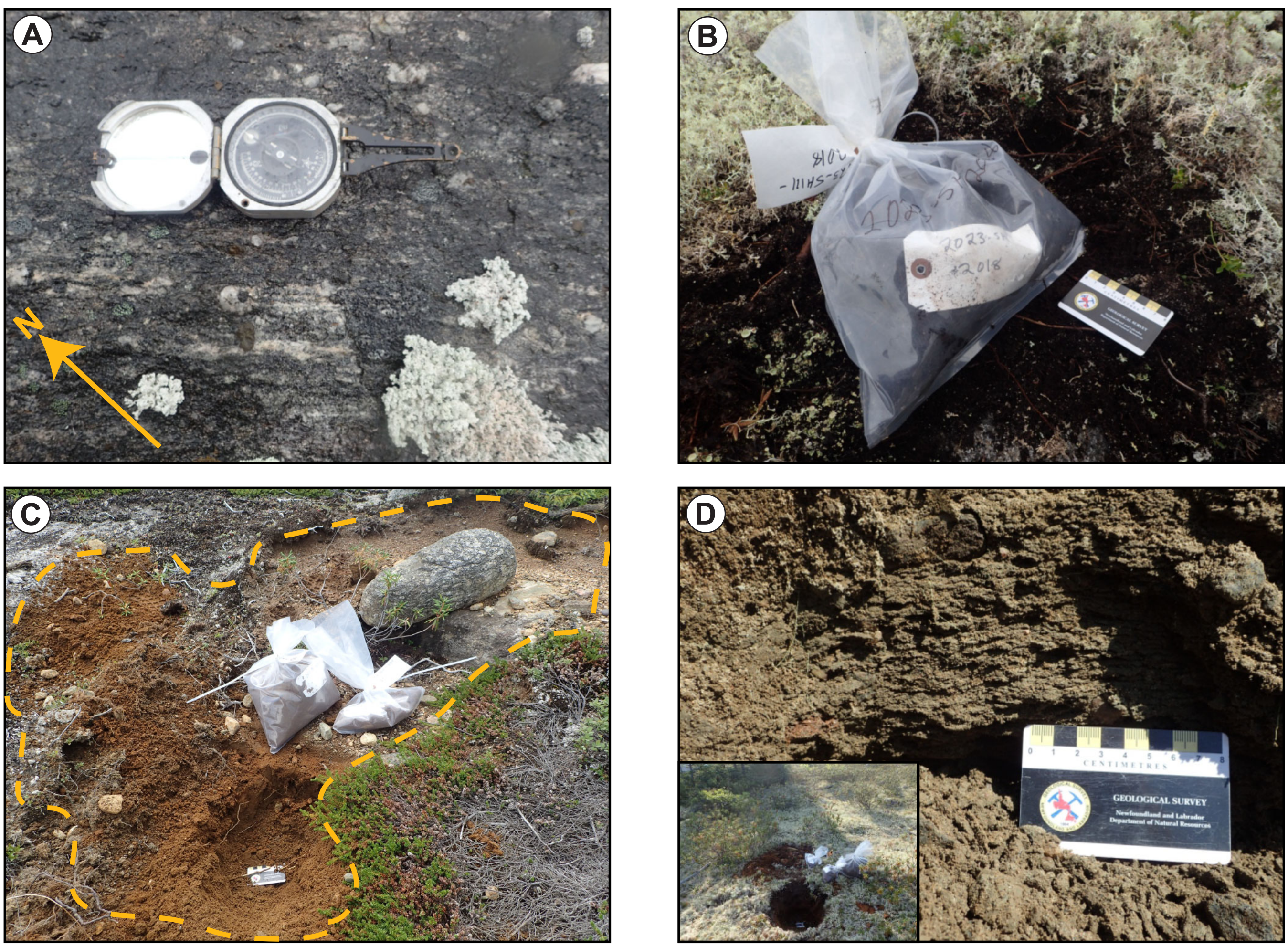

Plate 2. *Field photographs. A) Poorly developed rat-tails (in NTS 13A/14) indicating ice flow to the southeast; B) Humus sample; C) BC-horizon till sample collected from a mudboil in NTS 13A/10. The yellow dotted line delineates the sampled mudboil; D) Well-developed fissility in a lodgement till in NTS 13A/10.*

horizon till should be sampled because it is less affected by physical weathering processes such as surface washing, and/or chemical weathering processes such as hydromorphic dispersion (McClenaghan *et al.*, 2020).

Field data for both humus and till samples were collected using the ESRI Survey123 application with a custom form. Information collected at each sample site included location (GPS coordinates and elevation), site description, geomorphology, and general site observations such as evidence of post-depositional disturbances such as forest fires. Additional information specific to humus samples included humus development, charcoal or evidence of forest fire and mineral matter present within the sample. Additional information specific to till samples included grain size (*i.e.*, field level estimate of the percentage of sand, silt and clay), clast content, unit thickness and sedimentary structures. Photographs were also taken at each sampling site.

SAMPLE PREPARATION AND ANALYTICAL TECHNIQUES

The humus samples were analyzed by ALS Canada Ltd. Laboratory in North Vancouver, British Columbia. The samples were dried, milled and passed through a 180 µm sieve. The sieved humus sample underwent ashing. Here, a 100 g prepared humus aliquot is ashed (decomposed) at 475°C for 24 hours, with an ashed yield of approx. 2–4 g. Ashing of humus samples is useful because it concentrates the element content, such that the back calculation to pre-ashed sample weight can reduce the detection limit by an order of magnitude. The ashed humus sample then underwent aqua regia digestion (1:3 nitric to hydrochloric acid) with an inductively coupled plasma-mass spectrometry (ICP-MS) finish and inductively coupled plasma-atomic emission spectroscopy (ICP-AES) finish. A super trace detection package to determine Au and REEs at parts per trillion (ppt) levels was also added to this procedure.

The 2–3 kg till samples were shipped to the GSNL Laboratory in St. John's. The samples were dried and sieved to the <63 µm fraction and submitted in-house for (1) loss-on-ignition (LOI) to determine organic content; and (2) multi-acid digestion with an ICP-MS finish and inductively coupled plasma-optical emission spectroscopy (ICP-OES) finish, to determine minor- and trace-element content (*see* Finch *et al.*, 2018). An additional aliquot was also submitted to ALS Canada Ltd. for (1) multi-acid, near-total digestion followed by ICP-MS and ICP-AES finish. This method includes ultra-trace detection for REEs; and (2) PGE and Au detection by fire assay with an ICP-MS finish.

Lastly, 15 till samples, weighing 12–16 kg were submitted to IOS Services Géoscientifique Inc. for indicator mineral processing. Here, the samples were wet sieved and screened to remove the pebble fraction (16–64 mm). The sample underwent fluidized bed processing and pre-concentration on a shaking table followed by heavy-liquid separation (specific gravity: 3.3), magnetic screening (to remove magnetic minerals), and fine-screening to <50 µm. Indicator mineral counts were performed using IOS Services Géoscientifiques Inc.'s ARTmin™/ARTGold™ technology on the 63–150 µm and 150–250 µm grain fractions. Rare-earth minerals (REMs), platinum-group minerals (PGMs), base-metal sulphide minerals (BMS: chalcopyrite, pentlandite, pyrrhotite, pyrite) and gold grains in these size fractions were identified and counted.

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance measures included cleaning of sampling tools with water (where available) and by hand before the collection of each new sample to reduce cross contamination. Field duplicates were collected to determine site variability. Quality control measures included insertion of field duplicates for humus samples and till samples. Prepared laboratory duplicates were also inserted into till samples to determine precision before the samples were shipped to ALS Canada Ltd. for analyses.

FUTURE WORK

Analytical results are pending. Deliverables for this project will be an updated report on the humus and till geochemistry as well as ore and indicator mineral data (with interpretation) for the study area. The report will also include recommendations for analytical methods and best practices suited to targeting selected critical metal mineralization using till and humus for grass roots exploration programs in Newfoundland and Labrador.

SUMMARY

A 6-week humus and till sampling survey was conducted in the Alexis River Valley region in southeast Labrador (NTS map areas 13A/10, 14 and 15). The objectives of this survey were to determine whether decomposed vegetation (*i.e.*, humus) overlying bedrock mineralization and mineralized till dispersal can be used to fingerprint the geochemical signature of REEs, PGEs, U and base metals. The geochemical and mineralogical results of this study, when published, will facilitate the mineral exploration industry by providing the following: 1) a geochemical study to test the effectiveness of humus in targeting critical metal anomalies in the surficial environment with little to no bedrock exposure or till; 2) an update on recommended analytical techniques that can better detect critical metal mineralization in surficial media; and 3) recovery of critical metal ore minerals

(PGMs, REMs, BMS) in the <250 µm grain size that can be targeted in grass roots mineral exploration.

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