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HUMUS AS A SAMPLE MEDIUM TO TARGET Au MINERALIZATION IN NEWFOUNDLAND: PRELIMINARY DATA FROM GLOVER ISLAND (NTS 12A/12 AND 13), JACKSON'S ARM (NTS 12H/15) AND NIPPERS HARBOUR (NTS 2E/13) MAP AREAS

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ABSTRACT

*A pilot project designed to test the suitability of humus as a sample medium for grassroots Au exploration was carried out during the 2022 field season. The Island of Newfoundland is highly prospective for Au; however, much of the bedrock is covered by wetlands and a variable till cover. In areas without unaltered, C-horizon till, an alternate medium that is abundant, easy to sample and can characterize the geochemistry of the underlying soil (*e.g.*, till) and bedrock is needed for geochemical analysis. The objectives are to test whether the geochemical signatures of Au and its conventional pathfinders are detectable in humus collected near Au occurrences. Three study areas comprising the Jackson's Arm and Nippers Harbour map areas, and Glover Island (parts of Corner Brook and Little Grand Lake map areas) were selected for this project. There are several notable Au occurrences in these map areas and regional infrastructure ranges from developed (*e.g.*, Nippers Harbour) to undeveloped (Glover Island; Corner Brook and Little Grand Lake map areas). In addition to humus, soil samples (developed on till) were also collected in select locations for comparison between humus and till geochemistry.*

INTRODUCTION

The Island of Newfoundland has many gold deposits (Sandeman, 2014; Honsberger *et al.*, 2019; Conliffe, 2021; Westhues, 2022). However, the paucity of till and concealment of bedrock by vegetation has made grassroots exploration targeting Au mineralization challenging. Furthermore, parts of the Island were also under the marine limit during deglaciation (Liverman, 1994; Hashmi, 2020), which can affect the geochemical signature of mineralization in basal till emplaced during glacial advance and glacial maximum. In 2022, the Geological Survey of Newfoundland and Labrador conducted a pilot study testing the usability and suitability of humus as an alternative sampling medium to conventional soils (developed in till and from hereon referred to as "till") in areas where till is thin or absent.

BACKGROUND

Humus is decomposed organic matter that typically forms above the mineral soil due to the oxidation, disintegration and decay of vegetation (*i.e.*, leaves, grass, lichen, woody debris, etc.). The process of humus development is known as humification (Kauranne *et al.*, 1992). The chemical composition of humus can reflect elements associated with mineralization in the underlying bedrock as well as from soils that are derived from mineralized rocks (*e.g.*, mineralized till dispersal; Dunn *et al.*, 1989). Tree and plant roots can adsorb and translocate trace elements from deeper soil or underlying bedrock, which are then concentrated in the humus layer during subaerial decomposition (Rogers and Dunn, 1993). Sampling humus is advantageous because it is developed under all vegetation, easy to identify and can characterize the geochemical signal of the surrounding area.

Humus has been used successfully in delineating the geochemical signature of precious- and base-metal deposits (*e.g.*, Au, Pb–Zn and Ni–Cu mineralization) in Canada (Hall *et al.*, 2003; Hashmi, 2018). Therefore, it may be well suited as a sampling medium in Newfoundland because it is abundant, well-developed and unaffected by adjacency airborne contamination due to low population density and sparse infrastructure development over most of the Island. Furthermore, advancements in the field of analytical chemistry have enabled the detection of Au at parts per trillion (ppt) levels (Leybourne and Cameron, 2010), which enhances the signal-to-noise ratio between background and anomalous element content and facilitates recognition of regional Au anomalies that might be undetected by standard analytical packages.

OBJECTIVES

The primary objective of this study is to determine if humus can successfully capture the geochemical signature of Au and its pathfinders in Newfoundland. A secondary objective is to determine whether humus development and its geochemical signature are affected by the proximity to developed areas, construction, historic exploration or mining activity. If the primary objective is successful, the workflow developed here may assist explorationists in conducting large-scale grassroots exploration surveys using humus as a sample medium in regions with little to no bedrock exposure or till (or in areas where till was affected by marine incursion).

Three study areas were selected: Jackson's Arm, Nippers Harbour and Glover Island. There are several significant Au occurrences within each area that have been explored or are currently being explored and warrant further geochemical sampling. Gold occurrences in these map areas were chosen according to the following criteria: 1) previous exploration efforts have detected elevated Au, and conventional Au pathfinders such as As, Bi, Sb and Pb in the bedrock and soil samples (McCuaig, 2003; McCuaig *et al.*, 2006); 2) the sites have variable levels of infrastructure development and consequently, variable levels of surface disturbance (*i.e.*, well-developed infrastructure and poorly developed, highly disturbed humus at Nippers Harbour, to undeveloped areas of Glover Island with well-developed, undisturbed humus), which may help identify potential surface contamination (McCuaig *et al.*, 2006; Conliffe, 2021); and 3) mapped Au occurrences are spatially distant from others, which permits a unique humus characterization without influence or interference from nearby mineralization.

STUDY AREA: LOCATION, ACCESS AND PHYSIOGRAPHY

JACKSON'S ARM (NTS 12H/15)

The Jackson's Arm area (Figure 1) comprises the easternmost foothills of the Long Range Mountains, west of White Bay and the westernmost part of the Baie Verte Peninsula. This region is easily accessible by regional Highway 420 and several service roads including Cat Arm Road. The two largest communities are Sop's Arm and Jackson's Arm. Close to White Bay, lowlands at elevations near sea level are characterized by flat to undulating topography; hilly terrain and highlands reach elevations of approximately 245 m above sea level (asl) (Plate 1A). Several brooks, including Doucer's Brook, Big Arm Brook and Main River, provide regional drainage into White Bay, however, the lowlands are poorly drained and have developed numerous wetlands. The study area straddles portions of the eastern Long Range region of the Northern Peninsula Forest ecoregion and the north-central region of the central Newfoundland Forest ecoregion. Forests generally comprise balsam fir, black spruce and eastern larch.

NIPPERS HARBOUR (NTS 2E/13)

The Nippers Harbour map area is situated along the northern and eastern coast of the Baie Verte Peninsula and easily accessible by regional highways 414, 415 and 416 and several gravel roads. La Scie, Snook's Arm and Harbour Round are the main communities in the Nippers Harbour map area. The topography varies from hills (up to 315 m asl) and undulating uplands and plateaus inland to steeply sloping, hilly, rugged coastal shoreline (Plate 1B). There are numerous wetlands and lakes (*e.g.*, Red Cliff Pond, Goat Pond and Loon Pond) throughout the region. The area is within the North Shore Forest ecoregion, dominated by black and white spruce and, to a lesser extent, aspen. The quality and height of vegetation declines toward the coast due to increased wind exposure, where shrubs, moss or barren ground dominate.

GLOVER ISLAND (NTS CORNER BROOK 12A/13 AND LITTLE GRAND LAKE 12A/12 MAP AREAS)

Glover Island is located within Grand Lake and is approximately 20 km southeast of Corner Brook. The northern part of Glover Island is within the Corner Brook map area (12A/13) and the southern part of the island is within the Little Grand Lake map area (12A/12). Glover Island is only accessible by boat or helicopter, and with steep shorelines and high cliffs, the island is generally uninhabited except for seasonal outfitters and research and mineral exploration personnel. The physiography is characterized by steeply sloping cliffs along the shoreline and undulating to flat topography inland with some hilly areas (Plate 1C). The highest peak on Glover Island is 595 m asl, which is 510 m above the surface of Grand Lake (McCuaig, 2003). It is dotted with lakes and abundant wetlands. Glover Island is within the Long Range Barrens ecoregion and the Buchans Plateau–Topsail area. Vegetation in this region is dominated by dwarf shrubs (moss heather, sheep laurel heath, and dwarf bilberry), black spruce and balsam fir.

REGIONAL BEDROCK GEOLOGY

The bedrock geology of the study areas (Figure 2) is summarized from Colman-Sadd *et al.* (1990), Cawood *et al.* (1996), McCuaig, (2003), McCuaig *et al.* (2006), Kerr (2006), van Staal (2007), Sangster *et al.* (2008), Minnett *et al.* (2010), Skulski *et al.* (2009, 2010), Pilote *et al.* (2014) and Conliffe (2021, 2022).

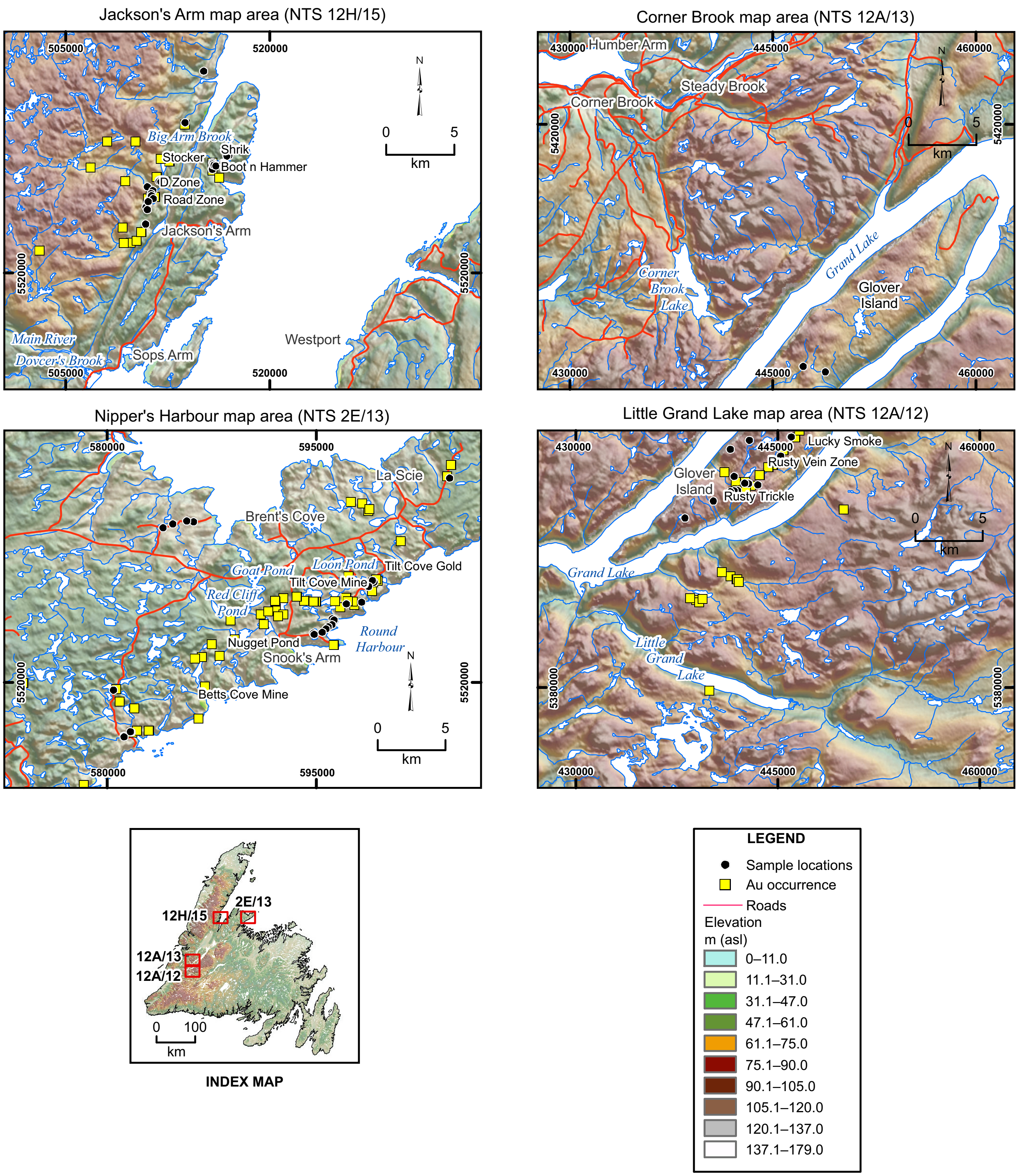

Figure 1. *Location, access, physiography and Au occurrences in (yellow boxes) the study areas, and the 2022 till and humus sampling sites (black circles); (inset) location of the study areas within the Island of Newfoundland. Coordinates reported in UTM zone 21, NAD27 datum.*

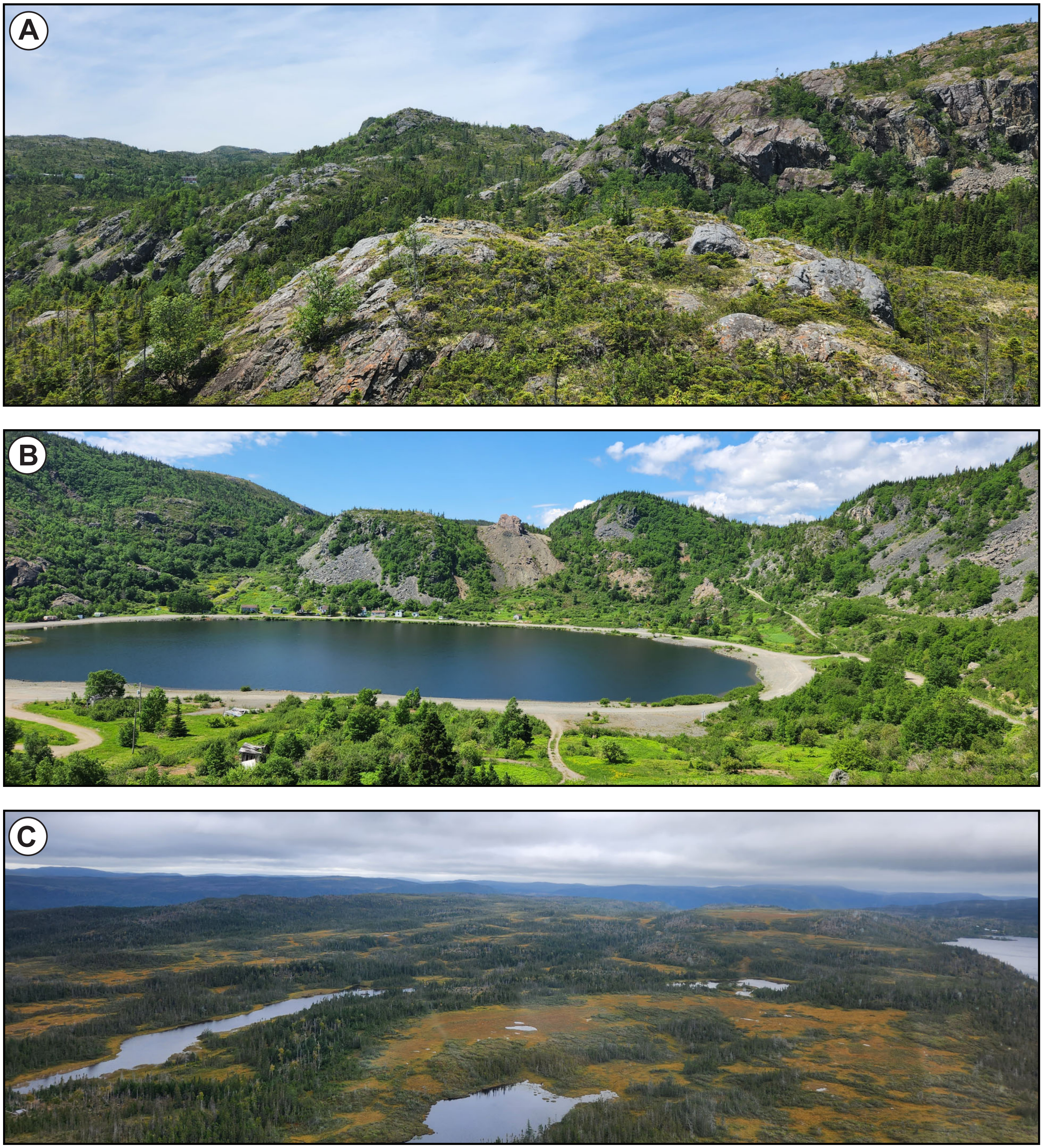

Plate 1. *Field photographs. A) Panoramic view of hilly terrain from the Boot n Hammer Zone in the Jackson's Arm map area (12H/15); B) Panoramic view overlooking Wisner Lake near the past-producing Tilt Cove Mine; C) Panoramic view of south-western Glover Island.*

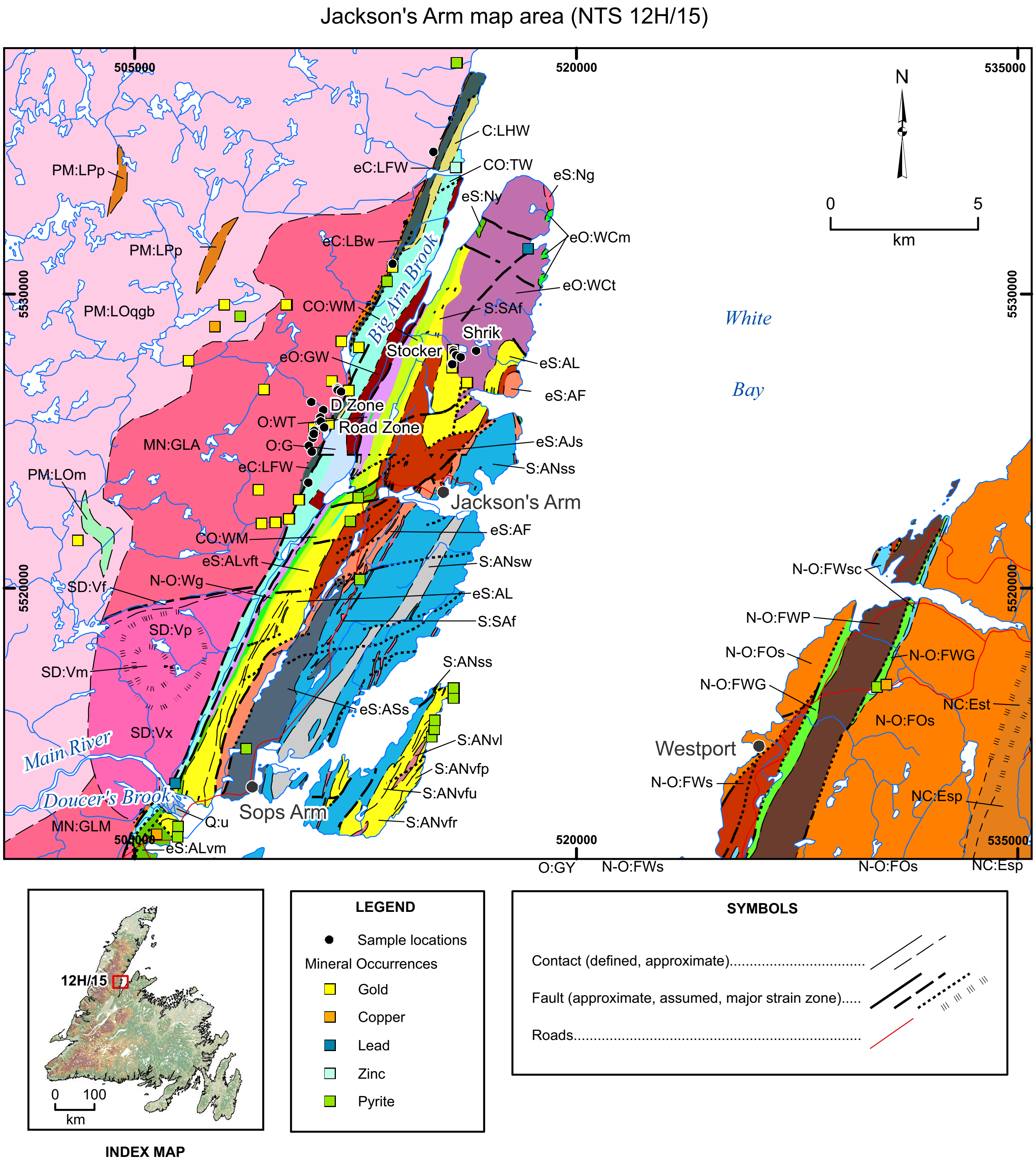

Figure 2. *Bedrock geology and select mineral occurrences in the study areas. Bedrock geology and legends modified after Colman-Sadd* et al. *(1990). Coordinates reported in UTM zone 21, NAD27 datum.*

LEGEND

POST-ORDOVICIAN UNITS
Pleistocene
Surficial deposits

Q:u Unconsolidated sediments

Early to Late Silurian
Sops Arm Group

Natlins Cove Formation

S:AN Mixed sequence of shallow marine sandstones and subaerial felsic volcanic rocks

Simms Ridge Formation

eS:AS Slate and argillite; minor limestone and calcareous tuff

Frenchmans Cove formation

eS:AF Bedded, polymictic conglomerate and sandstone

Jacksons Arm Formation

eS:AJ Massive, polymictic boulder to cobble conglomerate; minor mafic volcanic

Lower volcanic formation

eS:AL Ash-flow tuffs and rhyolite flows, mafic flows, conglomerate, sandstone, dolostone and limestone

S:A Felsic ash-flow tuffs and rhyolite flows; siltstone and sandstone, limestone,and conglomerate

POST-ORDOVICIAN UNITS
(Intrusive Rocks)
Early Silurian to Early Devonian

Devils Room granite

SD:V Megacrystic to medium-grained, biotite and biotite-muscovite granite; mylonitic granite and

Early to Late Silurian
Intrusions into Sops Arm Group

S:SA Quartz monzonite sills and felsite dykes and sills

Early Silurian
Intrusions into Coney Head Complex

eS:N Biotite microgranite, muscovite granite sheets, and mafic to intermediate dykes

LAURENTIAN MARGIN
Humber Zone (Shelf and Related rocks)
Early to Middle Ordovician
St. George Group

Watts Bight Formation

eO:GW Thick-bedded, grainy, bioturbated and argillaceous limestone

O:G Bioturbated, thinly bedded and laminated, clean and dolomitic limestone

Middle Cambrian to Early Ordovician
Port au Port Group

CO:TW Thick-bedded, white dolostone, dolomitic slate, and interbedded dark grey limestone

Neoproterozoic to Early Ordovician
Southern White Bay Allochthon
Taylors Pond Formation

O:WT Black graphitic slate with calc-silicate beds

Neoproterozoic to Middle Cambrian
Labrador Group

Hawke Bay Formation

C:LHW Quartz sandstone, sandy dolomite, oolitic *limestone, and calcareous slate*

Forteau Formation

eC:LFW Graphitic slate and phyllite, calcareous schist and marble

Bradore Formation

eC:LB Cross-bedded, arkosic, sandstone, pebbly sandstone and siltstone

Late Mesoproterozoic to Neoproterozoic
Grenvillian granitoid rocks
Leucocratic granitoids

Main River pluton

MN:GLM Pink, massive to foliated, potassium feldspar megacrystic biotite +/- hornblende granite

Aspy pluton

MN:GLA Potassium feldspar-megacrystic biotite +/- hornblende granite

Late Paleoproterozoic to Early Mesoproterozoic
Long Range gneiss complex
Orthogneiss (may include some paragneiss)

PM:LO Quartz dioritic, granitic-granodioritic, and mafic gneisses

Paragneiss

PM:LP Gneiss, quartzite and quartz-rich gneiss, and marble and calc-silicate rock

LAURENTIAN MARGIN
Humber Zone (Slope and Related rocks)
Middle to Late Ordovician
Granby Island Formation

O:GY Dark grey to black slate, argillite, and greywacke; minor boulder conglomerate

Neoproterozoic to Early Ordovician
Fleur de Lys Supergroup
Old House Cove group

N-O:FOs Buff to grey weathering, medium- to coarse-grained, and semipelitic schist

N-O:FO Medium- to coarse-grained schist

White Bay Group

Pigeon Island formation

N-O:FWP Mainly garnet-porphyroblastic, quartz-muscovite schist, locally magnetite rich

Garden Cove formation

N-O:FWG Green amphibolite and mafic schist

N-O:FW Pelitic, and graphitic schist, amphibolite, mafic schist, marble and carbonate schist

Southern White Bay Allochthon
Taylors Pond Formation

O:WTM Melange containing green sandstone, quartzite, serpentinite and talc blocks

N-O:W Tonalite and gabbro, slate, sandstone, and greenschist

Early Mesoproterozoic to Early Cambrian
East Pond Metamorphic Suite

Middle Arm metaconglomerate

NC:EM Mainly polymict metaconglomerate with interlayered psammitic schist

M-C:E Psammitic and semipelitic schist and gneiss; migmatite, quartzofeldspathic gneiss

IAPETUS OCEAN
Dunnage Zone (Notre Dame Subzone)
Neoproterozoic to Early Ordovician
Southern White Bay Allochthon
Coney Head Complex

eO:WC Biotite tonalite, gabbro and quartz gabbro

Figure 2. *Continued.*

Nipper's Harbour map area (NTS 2E/13)

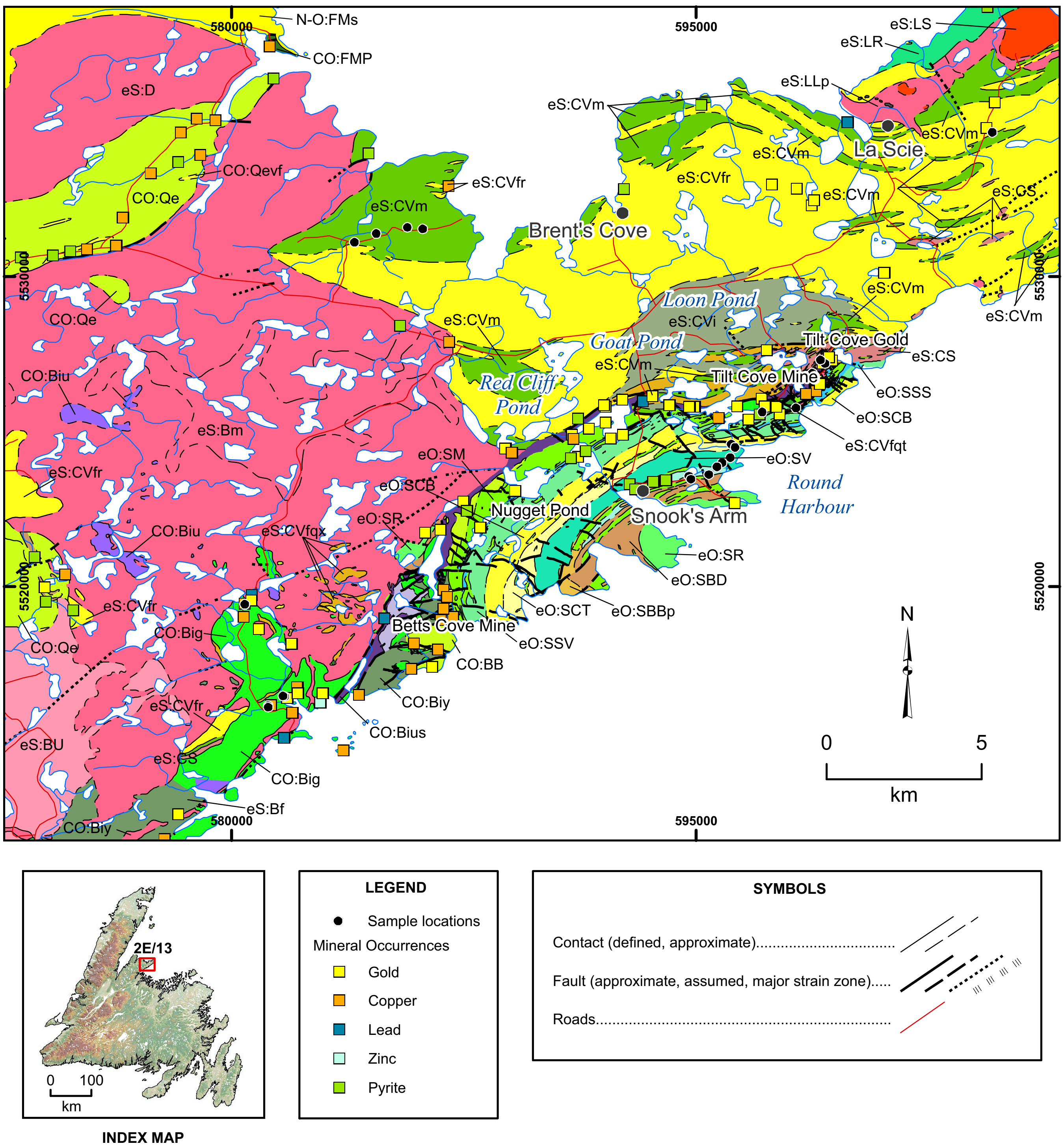

Figure 2. *Continued.*

LEGEND

POST-ORDOVICIAN UNITS (Overlap Sequences)

Early Silurian

King's Point Complex

Volcanic rocks

eS:KV Aphyric to porphyritic ash-flow tuffs, lapilli-tuffs, breccias, and intrusive equivalents

Cape St. John Group

Volcanic rocks

eS:CV Bimodal sequence of rhyolitic and ash flow tuffs, flows and andesitic to dacitic flows

Sedimentary rocks

eS:CS Cross-bedded sandstone and conglomerate, including minor mafic lava and felsic tuff

POST-ORDOVICIAN UNITS (Intrusive Rocks)

Early Silurian

La Scie intrusive suite

La Scie granite

eS:LL Fine- to medium-grained, pink, biotite granite; locally feldspar porphyritic

Seal island Bight syenite

eS:LS Grey-weathering, fine- to medium-grained syenite

Reddits Cove gabbro

eS:LR Dark grey-green, fine- to medium-grained, equigranular pyroxene gabbro

eS:L Biotite granite, riebeckite syenite, and pyroxene gabbro

Cape Brule Porphyry

eS:B Quartz-feldspar porphyry containing mafic and ultramafic xenoliths

Dunamagon granite

eS:D Medium- to coarse-grained, pink, biotite granite

Burlington granodiorite

eS:BU Mainly light grey to greenish grey, medium-grained, hornblende-biotite granodiorite and quartz diorite

LAURENTIAN MARGIN

Humber Zone (Slope and related rocks)

Neoproterozoic to Early Ordovician

Fleur de Lys Supergroup

Ming's Bight Group

N-O:FM Buff to grey weathering, psammitic and semipelitic schist with minor quartz pebble metaconglomerate

IAPETUS OCEAN

Dunnage Zone (Notre Dame Subzone)

Early Ordovician

Snooks Arm Group

Round Harbour Formation

eO:SR Clinopyroxene + plagioclase-phyric pillow lavas and sheet flows; thin red siliceous mudstone interbeds

Balsam Bud Cove Formation

eO:SB Basal member of pelagites and volcaniclastic turbidites interbedded with mafic volcanic rocks

Venams Bight Formation

eO:SV Pillow lavas and sheet flows

Bobby Cove Formation

eO:SC Basal member of andesite tuffs characteristic thick-bedded, crudely stratified, graded, block and lapilli tuffs

Scrape Point Formation

eO:SS Basal sedimentary member of breccia or conglomerate overlain turbiditic sandstones and siltstones

Mount Misery Formation

eO:SM Olivine-phyric tholeiitic pillow lavas and pillow breccias; uppermost lavas commonly hematized and/or strongly magnetic

eO:S Arc tholeiitic pillow lava, pillow and talus breccia and associated mafic dykes; evolved tholeiitic pillow basalt and massive flows

Late Cambrian to Early Ordovician

Pacquet Harbour group

CO:Q Pillow lava, pillow breccia, and other mafic volcanic rocks and diabase dykes

Betts Cove Complex

Betts Head Formation

CO:BBx Brecciated facies

CO:BB Olivine + chromite + orthopyroxene-phyric boninitic pillow lavas

CO:Biy Sheeted dyke complex

CO:Bigbx Brecciated gabbro-gabbronorite and related intrusive rocks

CO:Bigb Massive gabbro-gabbronorite, subordinate hornblende diorite and trondjemite

CO:Big Gabbro with pods and layers of pyroxenite cut by diabase dykes

CO:Biuc Layered cumulates comprising cumulate peridotites, pyroxenites (orthopyroxenite, clinopyroxenite, and gabbronorite

CO:Bius Schists derived from altered and deformed peridotites

CO:Biu Interlayered dunite, peridotite and pyroxenite, and serpentinized ultramafic and talc-carbonate rock

Neoproterozoic to Early Ordovician

Fleur de Lys Supergroup

Ming's Bight Group

Pelee Point schist

CO:FMP Dark green amphibolite and greenschist; minor raphitic and pelitic schist

Figure 2. *Continued.*

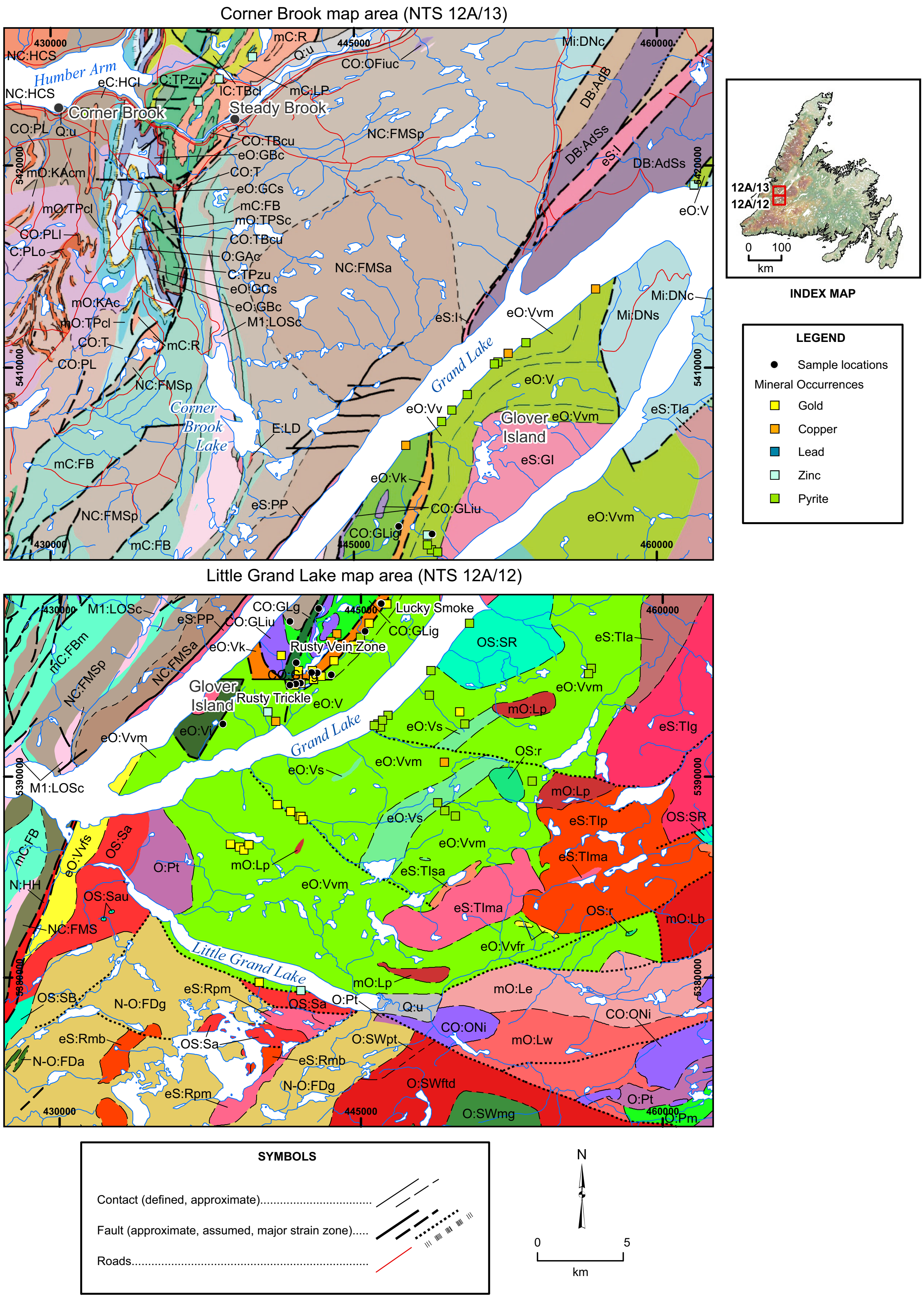

Figure 2. *Continued.*

Figure 2. *Continued.*

JACKSON'S ARM MAP AREA (12H/15)

The Jackson's Arm map area is dominated by rocks of the Humber (tectonostratigraphic) Zone of the Appalachian Orogen and represents the ancient margin of Laurentia (Williams, 1979; McCuaig, 2003). The oldest rocks are middle Proterozoic basement rocks of the Long Range Inlier and consist of granitic to granodioritic gneisses of the Long Range Gneissic Complex as well as granites of the Lake Michel Intrusive Suite. The Apsy Granite (part of the Lake Michel Intrusive Suite) hosts Au mineralization (*see* Mineral Occurrences: Jackson's Arm). The easternmost part of the study area (*i.e.*, the west coast of the Baie Verte Peninsula) is dominated by highly metamorphosed rocks of the Neoproterozoic to Silurian Fleur de Lys Supergroup, comprising schist, amphibolite and marble. Immediately east of the Long Range Inlier basement rocks, the Doucer's Valley fault complex is a major, northeast–southwest-trending fault system that separates the older Long Range Inlier from the younger, Cambrian to Ordovician, platform sedimentary rocks. These platformal rocks consist of autochthonous, clastic and carbonate rocks, including siltstone, sandstone and dolostone and are the remnants of the westward-obducting Iapetus Ocean, during the Taconic Orogeny. Farther east and lying unconformably over the platform sedimentary rocks is the south White Bay allochthon, which comprises marine siliciclastic, metavolcanic and felsic to mafic intrusive rocks of the Coney Head Complex (Kerr and Knight, 2004). Lastly, the youngest rocks are the volcanic and sedimentary rocks of the Silurian Sop's Arm Group, which lie unconformably over the Coney Head Group. These include rhyolite, tuff, sandstone, limestone and dolostone (Minnett *et al.*, 2010).

NIPPERS HARBOUR MAP AREA (2E/13)

The Nippers Harbour map area consists of rocks from both the Humber Zone to the west and the Dunnage Zone to the east that are fault-bounded between the Green Bay Fault to the east and the Baie Verte–Brompton Line to the west. Of these, the Precambrian to Paleozoic, Ming's Bight Group mapped to the north are the oldest and the only rocks associated with the Humber Zone in the Nippers Harbour map area. Cambrian to Early Ordovician, mafic to ultramafic, ophiolitic rocks (including boninite) of the Betts Cove Complex and Pacquet Harbour are the oldest rocks of the Dunnage Zone (within the Notre Dame Subzone) and are mapped in the northeast and central parts of the Nippers Harbour map area. These ophiolitic units are collectively termed the "Baie Verte oceanic tract" (BVOT; van Staal, 2007; Pilote *et al.*, 2014). The BVOT ophiolitic rocks are intruded by younger granitoids such as the Silurian Cape Brulé porphyry in the north-central map area, Burlington granodiorite to the southeast and the Dunamagon granite to the northwest (Pilote *et al.*, 2014).

Early Ordovician Betts Cove Complex is mapped in the northeastern Nippers Harbour map area, and consists of a lower ultramafic unit overlain by layered gabbro and massive gabbro that transitions into sheeted dykes and pillowed boninites of the Betts Head Formation. The Betts Head Formation boninites are further subdivided into boninites with low and intermediate TiO_2 contents. The uppermost unit, within the Betts Cove Complex, is the Mount Misery Formation (Skulski *et al.*, 2009), which comprises mafic to ultramafic-derived breccia and conglomerate, pillow breccias as well as pillowed basalts that are chemically transitional with, and are interbedded with intermediate TiO_2 boninites. The pillow breccias of the Mount Misery Formation host Cu–Au-rich volcanogenic massive sulphide (VMS) deposits such as those mined at the former Tilt Cove Mine (*see* Mineral Occurrences: Nippers Harbour). Volcanic rocks of the Snooks Arm Group are the cover sequence to the Betts Cove Complex. Of these, the Scrape Point Formation, which is stratigraphically the lowest unit of the Snooks Arm Group, is mapped in the northeastern corner of the Nippers Harbour map area. The lowest unit of the Scrape Point Formation is the Nugget Pond Horizon that consists of local basal conglomerate (breccia of basalt clasts cemented by jasper), red siltstone and jasper–magnetite iron formation. Rocks of the Nugget Pond Horizon underwent epigenetic albite–carbonate–quartz–pyrite alteration and host the Nugget Pond Au deposit (*see* Mineral Occurrences: Nippers Harbour). In the northwestern map area, metamorphosed volcanic and sedimentary rocks of the Early Ordovician Pacquet Harbour Group, are correlative to the Snooks Arm Group based on petrological and geochemical similarities (Skulski *et al.*, 2010). Volcanic and sedimentary units of the Pacquet Harbour Group consist of felsic tuff and rhyolitic flows, gabbroic dykes, pillow basalts as well as black chert and magnetite Fe formations.

Lastly, the youngest rocks are Late Ordovician to Early Silurian, volcanic and volcaniclastic rocks of the Cape St. John Group mapped in the northeastern Nippers Harbour map area. The Cape St. John Group includes a basal conglomerate, redbed arkose and siltstone, welded tuff and heterolithic crystal tuff containing ultramafic fragments as well as a pyroclastic breccia and conglomerate comprising basalt, pumice and rhyolite fragments.

GLOVER ISLAND (CORNER BROOK 12A/13 AND LITTLE GRAND LAKE 12A/12 MAP AREAS)

Glover Island lies at the boundary between the Humber and Dunnage (tectonic) zones of the Newfoundland Appalachians (Williams, 1979). The Humber Zone rocks are mapped in the west part of the Island and consist of highly deformed, undifferentiated rocks of the Corner Brook Lake Block, an allochthonous terrane that is interpreted to have been transported over 400 km (Knapp, 1982; Cawood *et al.*, 1996; Conliffe, 2021).

The Dunnage Zone rocks dominate the rest of Glover Island and consist of Cambrian to Early Ordovician, metasedimentary to metavolcanic rocks of the Grand Lake Complex, Early Ordovician, sedimentary to volcanic rocks of the Glover Group, and Early Ordovician to Silurian, intrusive complexes. Of these, the oldest rocks, *i.e.*, ophiolitic rocks of the Grand Lake Complex, are inferred to represent the southern extension of the BVOT (van Staal *et al.*, 2007). The Grand Lake Complex is characterized by altered ultramafic rocks, including schist, serpentinized peridotite, and wehrlite overlain by relatively unaltered gabbro, trondhjemite, tonalite, sheeted dykes, pillow lavas and basalt (Knapp, 1982; Cawood *et al.*, 1996).

The Grand Lake Complex is in fault contact with the Early Ordovician Glover Group, a sequence of sedimentary and volcanic rocks inferred as the cover sequence to the ophiolites (after Barbour *et al.*, 2012; Conliffe, 2021). Of these, the lowest stratigraphic unit is the Kettle Pond Formation, which is host to Au mineralization on Glover Island (Conliffe, 2021). The base of the Kettle Pond Formation is defined by a lower Basal Conglomerate Member that is overlain by felsic to volcanic rocks (Szybinski *et al.*, 2006). The Basal Conglomerate Member is characterized by strongly deformed, clast-supported, polymictic, pebble to cobble conglomerate. The Kettle Pond Formation overlying the Basal Conglomerate Member consists of interlayered, fine-grained felsic and mafic tuffs interspersed with thicker mafic volcanic rock units (Szybinski *et al.*, 2006; Barbour *et al.*, 2012). Overlying the Kettle Pond Formation are the volcanic rocks of the Tuckamore Formation, a thick sequence of pillow basalt and plagioclase–porphyritic flows with minor shale and massive sulphides (Knapp, 1982; Szybinski *et al.*, 2006). The Corner Brook Pond Formation is the youngest end member of the Glover Group and it unconformably overlies the Tuckamore Formation. The Corner Brook Pond Formation is characterized by sedimentary and volcanic rocks, including felsic epiclastic units with minor rhyolite, pillow basalt, shale, chert and carbonate rocks. The rocks of both the Grand Lake Complex and the Glover Group have undergone greenschist-facies metamorphism (Szybinski *et al.*, 2006; Conliffe, 2022). The Glover Group is intruded by the Silurian Glover Island Granodiorite on the northeastern side of Glover Island, and the youngest rocks on Glover Island are Carboniferous sedimentary rocks of the Deer Lake Basin that lie unconformably over the Glover Group (Cawood *et al.*, 1996).

MINERAL OCCURRENCES

All mineral occurrences described are retrieved from the Mineral Occurrence Database System (MODS) of the GSNL (*see* Geological Survey of Newfoundland and Labrador, 2021). Only the Au occurrences selected for humus or till sampling in each map area are discussed.

JACKSON'S ARM MAP AREA (12H/15)

There are several Au occurrences in the Jackson's Arm map area associated with the Doucer's Valley Fault System. These include Apsy Zone and Road Zone developed prospects associated with Silurian to Devonian plutonic rocks and are part of the Rattling Brook deposit, and Boot n Hammer, Stocker and Shrik showings associated with Precambrian plutonic rocks.

The region near the Rattling Brook deposit was first explored by Labrador Mining and Exploration Limited in 1982 following informal reports of gold mineralization found in drillcore during the Cat Arm hydroelectric project (1977–1978) (Harrington and Cullen, 2022). Follow up exploration by Labrador Mining and Exploration Limited reported Au ranging 1–2 g/t in sampled pyrite bearing granite along the Cat Arm access road (Harrington and Cullen, 2022). Copper–Au–Ag mineralization is hosted within Apsy Granite and the main ore minerals are chalcopyrite, arsenopyrite and pyrite (*see* Regional Bedrock Geology: Jackson's Arm). Gold mineralization occurs in intensely deformed, highly sheared and fractured zones with prevalent silicic and potassic alteration (Tuach, 1986). Other alteration minerals include Fe-carbonate, hematite and sericite. Up to 1.5 and 1.13 g/t Au have been reported in grab samples from the Apsy Zone and the Road Zone, respectively (Bruneau, 1984). Resource estimates (as of 2019) report an inferred resource of approximately 5.5 million tonnes of ore grading at 1.45 g/t Au (Harrington and Cullen, 2022).

The Boot n Hammer showing, Stocker showing and Shrik showing lie within the altered granodiorites of the Cambro-Ordovician Coney Head Complex of the south White Bay Allochthon. The Stocker and Shrik showings are approximately 100 m north and 400 m south of Boot n Hammer, respectively. At all three showings (*i.e.*, Boot n Hammer, Shrik and Stocker), Au is associated with disseminated pyrite (2–10%) within quartz veins and altered granodiorite. Up to 20.2 g/t gold and 1232 g/t silver has been recovered by assay from a grab sample at the Boot n Hammer showing (Geological Survey of Newfoundland and Labrador, 2021).

NIPPERS HARBOUR MAP AREA (2E/13)

The Early Ordovician ophiolitic rocks of the BVOT host Au and base-metal mineralization in the Baie Verte Peninsula. These ophiolitic rocks host VMS-style Cu and Au in felsic and mafic volcanic sequences as well as Au in hydrothermally altered mafic and ultramafic rocks. The volcanic cover sequence to the Betts Cove Complex (*i.e.*, the Snooks Arm Group) also hosts epigenetic Au associated with banded iron formation as well as in association with deformed mafic rocks (Skulski *et al.*, 2009, 2010). Of these, the deposits at past-producing Tilt Cove and Nugget Pond Au mines and Betts Cove platinum-group elements (PGE) occurrence are notable and will be discussed further.

The Tilt Cove deposit (which hosts the Tilt Cove Mine) was discovered in 1857 and mining began in 1864 (Signal Gold Inc., 2022). The Tilt Cove Mine is host to significant base- and precious-metal mineralization (Cu–Au–Ni–Ag–Zn) and is characterized as a VMS deposit. Between 1864 and 1967, 8 160 000 tonnes of ore, grading up to 12% Cu, and approximately 42 000 ounces of gold were mined at the Tilt Cove Mine (Signal Gold Inc., 2022). The host rocks are highly deformed (sheared, brecciated and chloritized), felsic extrusive, basaltic to andesitic pillow lavas and pillow breccia of the Mount Misery Formation of the Snooks Arm Group (also referred to as the Betts Cove Ophiolite Complex, *see* MODS; Geological Survey of Newfoundland and Labrador, 2021). Mineralization is hosted in massive sulphides dominated by pyrite and chalcopyrite, and to a lesser extent sphalerite, pentlandite, nickeline, maucherite, gersdorffite and millerite that form stockwork, clusters, stringers, and fine-grained disseminated veins. Gold and Ag are present as alloys; native Ag has also been noted (Skulski *et al.*, 2009).

The Betts Cove deposit hosts the past-producing Betts Cove Mine and contains Cu–Zn–Au mineralization. The Betts Cove deposit was discovered in the early 1860s and from 1875 to 1886 approximately 130 000 tonnes of ore grading 10% copper and 2450 tons of pyrite were mined (Signal Gold Inc., 2022). Copper–Zn–Au mineralization is hosted in massive to disseminated pyrite and chalcopyrite; Au mineralization is hosted along the (sheared) contacts between pillow basalt and gabbroic sills (Signal Gold Inc., 2022). The primary ore minerals are chalcopyrite, pentlandite and native Au, as well as secondary pyrite and pyrrhotite and ore samples have returned up to 10 g/t Au, 18.3% Cu and 2% Zn contents (Signal Gold Inc., 2022).

The Nugget Pond Au deposit is host to the past-producing Nugget Pond Mine. The deposit is hosted within the sedimentary, volcanic and volcaniclastic rocks of the Nugget Pond horizon of the Snooks Arm Group. Gold is associated with extensive quartz–albite–carbonate–pyrite alteration. Gold (and lesser Cu and Pb) are primarily hosted in chalcopyrite, pyrrhotite, pyrite and galena (to a lesser extent), although native Au is present locally and Ag occurs as Ag-tellurides. The former Nugget Pond Mine contained approximately 448 000 tonne of ore, grading approximately 12.3 g/t Au (Sangster *et al.*, 2008).

GLOVER ISLAND (CORNER BROOK 12A/13 AND LITTLE GRAND LAKE 12A/12 MAP AREAS)

All Au mineralization on Glover Island is hosted in the Basal Conglomerate Member and volcanic rocks of the Kettle Pond Formation of the Glover Group (Conliffe, 2021, 2022). These cover rocks are interpreted as the southern extension of the BVOT (van Staal *et al.*, 2007), which is host to numerous economic VMS occurrences such as the past-producing Tilt Cove Mine (*see* Mineral Occurrences: Nippers Harbour).

The Basal Conglomerate Member hosts the Lunch Pond Vein and Discovery Vein occurrences (*see* bedrock geology for Glover Island; Figure 2). Gold mineralization occurs as massive, quartz veins in strongly altered and deformed metaconglomerate; alteration minerals include carbonates, sericite, fuchsite and chlorite (Conliffe, 2021). Free Au is present in inclusions within pyrite and chalcopyrite, and up to 150 g/t Au over 1.5 m has been reported in a channel sample at Lunch Pond Vein (Conliffe, 2021).

Volcanic-hosted Au mineralization occurs in the strongly deformed felsic and mafic rocks (*e.g.*, felsic and mafic tuff, rhyolite) of the Kettle Pond Formation, such as at the Lunch Pond Vein, Keystone, Lunch Pond Southeast, Lucky Smoke and Rusty Vein Au occurrences. These volcanic rocks have undergone multi-phase alteration, consisting of earlier, regional chlorite–epidote alteration and later silicic and hydrothermal alteration (Conliffe, 2021). At the Keystone showing, silicified, quartz-rich sediment of the Glover Formation with inter-grain Fe-carbonate and/or Fe-oxide with approximately 5% pyrite returned up to 2070 ppb Au (Conliffe, 2021). Channel sampling at the Keystone showing returned 3.74 g/t Au over 4 m and up to 1.65 g/t Au over 4 m in drillcore. Drilling at the Kettle Pond South occurrence returned 4.8 g/t Au over 18.5 m, whereas drilling at the Lucky Smoke occurrence returned 10.18 g/t Au over 8 m. At Lunch Pond South extension developed prospect, drilling returned 1.74 g/t Au over 53.5 m, with an indicated mineral resource estimate of approximately 58 200 oz. gold and inferred mineral resource of 120 600 oz. Au (Puritch and Barry, 2017). Up to 11.3 g/t Au over 2 m was also reported in a channel sample and 1.79 g/t Au over 1.5 m in drillcore at the Rusty Vein occurrence.

There are also VMS-style mineral occurrences hosted in the Kettle Pond Formation, in stratabound, structurally controlled, volcanogenic stockworks having mixed felsic and mafic volcanic rock sequences of the Glover Formation. Strongly altered aphanitic, felsic and mafic tuffs as well as quartz-feldspar-porphyritic rhyolites host the majority of Au mineralization (Conliffe, 2021). The alteration is characterized by silica, sericite and to a lesser extent, chlorite and Fe-carbonate. Gold, Ag, Cu, Zn and Pb occur within hydrothermally altered, quartz-feldspar-porphyritic rhyolites as pyrite, chalcopyrite, sphalerite and galena (Geological Survey of Newfoundland and Labrador, 2021). The Rusty Trickle showing represents the largest known VMS-style occurrence on Glover Island. Here, the mineralized zone consists of stringer Zn–Cu–Ag mineralization hosted in quartz-feldspar–plagioclase rhyolites. Bedrock samples, collected within hydrothermally altered zones (in deformed quartz-feldspar-porphyritic rhyolites), from the Rusty Trickle Prospect have 0.5–12.9% Zn, 0.2–1.58% Cu, 0.15–1.16% Pb and 5.0–15.6 g/t Ag (Basha *et al.*, 2001; Conliffe, 2022).

REGIONAL QUATERNARY FRAMEWORK

This summary of the regional Quaternary framework, *i.e.*, the glacial and deglacial events associated with the Late Wisconsinan Glaciation on the Island of Newfoundland, is based on work by Grant (1974, 1986, 1989), Liverman (1992, 1994), Batterson and Liverman (2001), Batterson (2003), McCuaig (2003), McCuaig *et al.* (2006) and Shaw *et al.* (2006).

Although Labrador and the Great Northern Peninsula were affected by the continental-scale Laurentide Ice Sheet (LIS) during the Late Wisconsinan, most of the Island of Newfoundland was covered by the Appalachian Ice Complex, a series of smaller ice-caps originating on topographic highs (Batterson and Liverman, 2001). Shaw *et al.* (2006) proposed that the LIS coalesced with the Appalachian Ice Complex on the Great Northern Peninsula during glacial maximum; however, the LIS likely did not affect glacial flow within the study areas.

On the Island, separate, independent ice centres developed at the Long Range Mountains and the Topsails, as well as on the Avalon Peninsula (Batterson and Liverman, 2001; Organ and Amor, 2017). During the last glacial advance (*i.e.*, the Late Wisconsinan Glaciation), ice flow from these centres was predominantly radial. However, at glacial maximum, ice coalescence from multiple centres produced complex, multi-directional ice flow.

Ice retreat may have commenced between 13 000–10 000 years before present (BP); the coastal areas were the first to become ice-free 14 000–11 000 years BP (Batterson and Liverman, 2001). Ice sheets disintegrated primarily *via* ablation and ice-stagnation, shrinking and becoming isolated again as multiple ice-caps (Grant, 1974; Shaw *et al.*, 2006). Retreating glaciers became topographically controlled in the Long Range Mountains (Shaw *et al.*, 2006). Shelf ice-caps persisted until 11 000 years BP, when Younger Dryas cooling resulted in a limited glacial readvance on the Island (Shaw *et al.*, 2006). Deglaciation was mainly complete by 10 000 years BP (Shaw *et al.*, 2006).

ICE FLOW

Ice-flow movements are only discussed for two study areas where till samples were collected: Jackson's Arm and Glover Island (Figure 3).

Jackson's Arm Map Area (12H/15)

Three Late Wisconsinan ice-flow phases were identified in the Jackson's Arm map area (McCuaig, 2003; Hashmi, 2021). During glacial advance, glaciers that developed in the Long Range Mountains flowed east-southeastward, following topography, into White Bay (Plate 2A). At glacial maximum, ice flowed north-northeastward across White Bay. During glacial retreat, ice disintegrated *via* calving and stagnation. Ice flow was still active during this phase; local ice caps on peninsular uplands controlled ice-flow movement, which resumed east-southeastward flow into White Bay.

Glover Island (Corner Brook 12A/13 and Little Grand Lake 12A/12 Map Areas)

Batterson (2003) recognized that the Glover Island region was affected by radial ice-flow movement from an ice centre in the Topsails. The main ice-flow direction on Glover Island was west to west-northwestward, which influenced the glacial dispersal in the region (McCuaig *et al.*, 2006).

METHODS

MAPPING

Field data were collected using custom forms created for the ESRI Survey 123 mobile application. Data included site and sample spatial information (GPS coordinates; elevation), site geomorphology, till characteristics (*e.g.*, sediment grain size and clast content), sedimentary structures, and humus and till quality and description.

FIELD SAMPLE COLLECTION

During the 2022 field season (June–September), 79 humus and 8 till samples were collected for geochemical analyses. Samples were collected from a depth ranging from 3 to 30 cm. Sample depth was highly dependent on soil maturity and thickness. Individual samples comprised at least 500 g of humus and/or 2–3 kg till. The inability to collect both humus and till at each site was due either to poor humus development, or a lack of till at the site.

Humus samples were collected in areas directly above and in the vicinity of known Au mineralization, as well as in "background" areas, *i.e.*, outside of known Au mineralization, to compare their geochemical signatures with those collected proximal to mineralization. Humus samples were preferably collected near outcrop to increase confidence in a local source for geochemical signatures. A field duplicate was collected every 5 to 10 samples and a 750 g sample was collected for lab duplicates at every 15 sites (Plate 2B). At

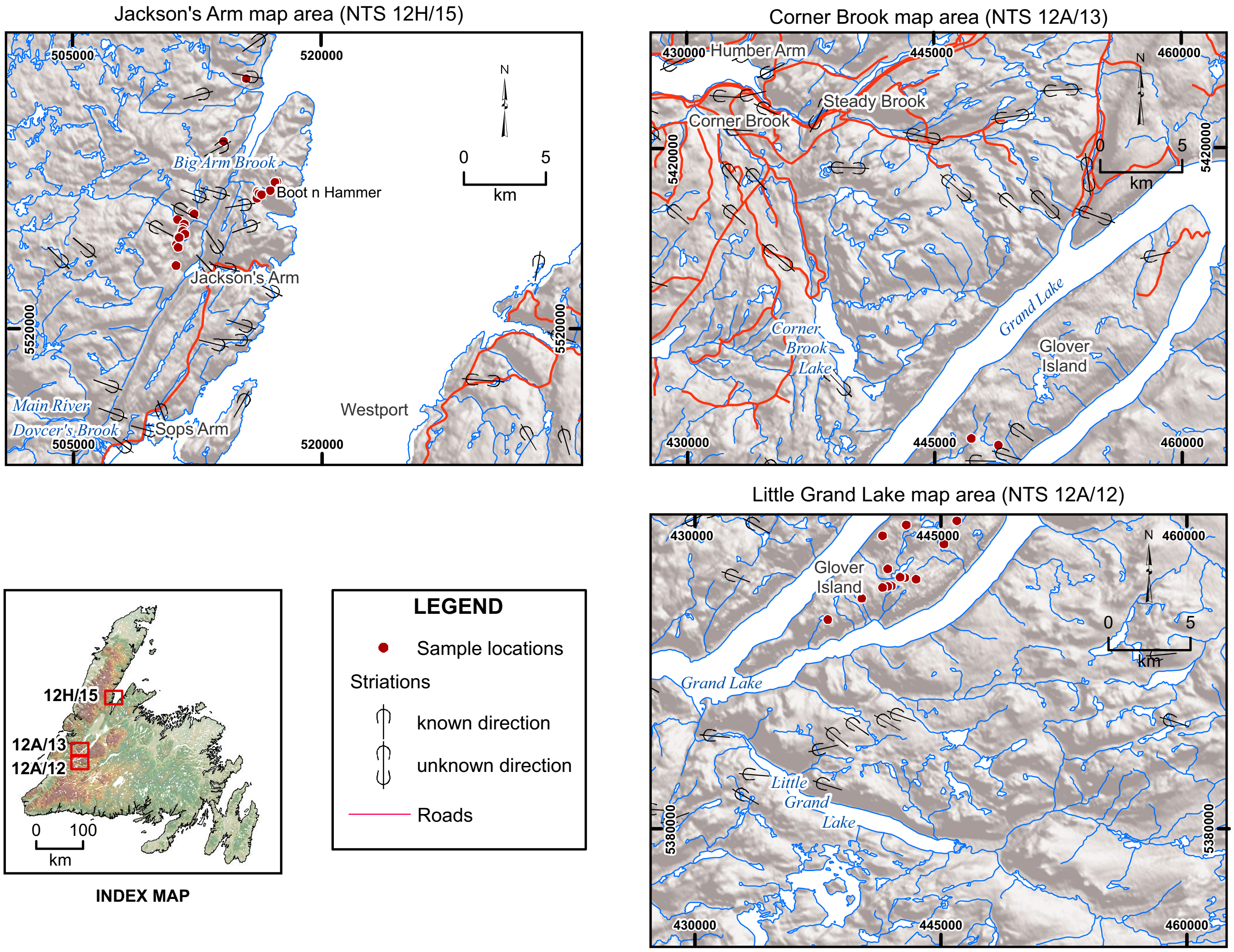

Figure 3. *Striation measurements from previous studies. Data retrieved from Grant (1986) and Geological Survey of Newfoundland and Labrador's striation database (2022).*

each site, surface vegetation, debris and shallow roots were cleared from the soil surface using a shovel and a reciprocating saw to expose the humified layer (Plate 2C–E). Samples were typically collected with a stainless steel knife at approximately 3 cm depth; deeper (5 cm) samples were collected in disturbed areas to avoid airborne dust, mineral or other particulate matter contamination. To reduce contamination, the sampling knife was cleaned with water (where available) prior to sample collection at each site. Care was also taken to avoid adding live vegetation and surface debris to the sample bag accidentally (Plate 2F). Humus samples were sieved onsite through a 5-mm-mesh stainless steel sieve to remove coarse roots, wood fragments and clasts. If present, charcoal within or overlying humus was noted. Photographs were taken to document each site.

Tills were sampled for geochemical analysis following GSNL protocols (Hashmi, 2021) near forestry roads and trails *via* truck, ATV, or by foot traverse; till samples collected on Glover Island required helicopter support (Plate 2E). Sample equipment included a mattock, a shovel and a geological pick. At each site, the sediment face was cleaned or a pit was dug to expose till. Samples were collected from a depth ranging from a few to tens of centimetres, from B- or BC- soil horizons. Each sample comprised 2–3 kg of material. Information collected at each sample site included location (GPS coordinates), site description, till colour, relative percentages of clasts and matrix (*i.e.*, sand, silt and clay), and general site observations such as evidence of post-depositional disturbances (*e.g.*, agricultural activity). Weathering and soil-horizon information were also recorded, and photographs taken at each site.

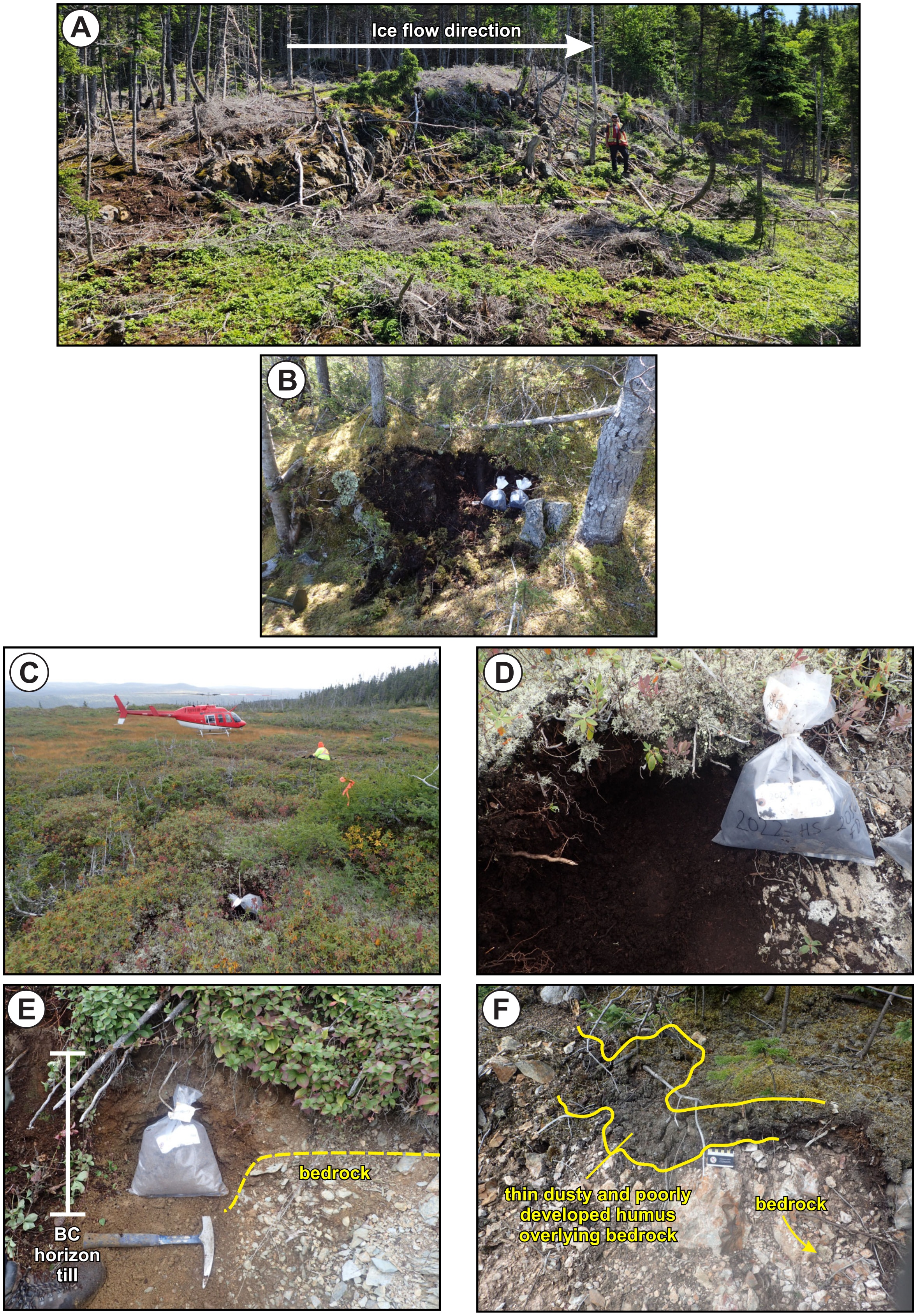

Plate 2. *Caption on next page.*

Plate 2. *Field photographs. A) Rôche moutonnée in the Jackson's Arm map area. S. Jackson for scale (1.75 m); B) Humus sampling in the Jackson's Arm map area; C) Humus sampling on Glover Island; D) Close up view of a field duplicate humus sample collected in the study area; E) Till sample collected on Glover Island; F) Thin, poorly developed and dusty humus sample in the study area.*

SAMPLE PREPARATION

In the lab, the sample bags were opened and air dried (covered with a paper towel). The samples were then spread onto non-reactive aluminum pans and fully dried in a Hotpack® oven at 45°C for 48–60 hours. Dry humus samples were returned to their plastic sample bags and gently crushed with a rubber mallet to break up larger pieces of decomposed organic matter. If a sample contained abundant roots, needles and woody material, it was first passed through a 2-mm (10 mesh) stainless-steel sieve to remove them. The crushed sample was then sieved through a 180-µm (80 mesh) stainless-steel screen using a RO-TAP® sieve shaker for 15 minutes and the fine fraction retained. After each sample, the sieve was cleaned in 4 stages: 1) dust and other particles were brushed out of the sieve and cleaned with compressed air, 2) the sieve was put through an ultrasonic cleaner for 50 minutes to remove any lodged particles, 3) the sieve was then rinsed with deionized water, sprayed with acetone and dried in an oven, and lastly, 4) the dried sieve was cleaned with compressed air again.

ANALYTICAL TECHNIQUES

The sieved humus samples were submitted to the Geological Survey of Newfoundland and Labrador geochemical laboratory for loss-on-ignition (LOI) *via* gravimetry to determine the proportion of organic content. The sieved humus fraction (<180 µm) was also submitted to ALS Canada Ltd. in North Vancouver, British Columbia, for two geochemical analyses. For the first, a 100 g aliquot was submitted for ashed aqua regia digestion (1:3 nitric to hydrochloric acid) and analyzed *via* inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectroscopy (ICP-AES). Here, the humus sample is ashed (fully decomposed) at 475°C for 24 hours, with an ashed yield of approximately 2 to 4 g and digested in aqua regia. A super-trace Au detection package was ordered to determine Au concentration at parts per trillion (ppt). Ashing of humus samples is useful because it concentrates the elemental contents; back-calculation of elemental concentration to the pre-ashed sample weight can reduce detection limits by an order of magnitude over other analytical methods. For the second analysis, a 1 g aliquot was digested in 25 ml Na pyrophosphate, and analyzed by ICP-MS.

For the till samples, a 100 g aliquot (<2 mm) was submitted to Geoscience Laboratories (Geolabs) in Sudbury, Ontario, for particle size analysis (PSA) to determine the percentage of clay, silt and sand. Additionally, the sieved <63 µm fraction was submitted to the GSNL geochemical laboratory for LOI. The sieved <63 µm fraction was then subsampled and approximately 150–450 g was submitted to ALS Canada Ltd. for aqua regia ICP-MS with added super-trace Au detection package and a 4-acid digestion, analyzed by ICP-MS, and for gold by fire-assay, analyzed by ICP-AES. A 300–500 g sub-sample of the <63 µm fraction was also submitted for clay separation followed by aqua regia and 4-acid digestions, both analyzed by ICP-MS.

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance measures include cleaning sampling tools with water (where available) and by hand before the collection of each field sample to reduce the risk of cross-contamination. Field duplicates were also collected every 5 to 10 samples (depending on ease of collection) to determine site variability. Quality control measures included insertion of laboratory duplicates and in-house and certified reference materials (Canadian Certified Reference Materials, CCRMs) into the sample series, before the samples were shipped for analysis. Lab duplicates were inserted to quantify instrumental precision; CCRMs were inserted randomly to determine instrumental accuracy and reproducibility.

FUTURE WORK

A detailed report is forthcoming on the analytical results and interpretation of the suitability of humus geochemistry as an exploration medium for delineating Au mineralization at the study sites. The report will include preliminary recommendations for humus sampling in a grassroots exploration program to target Au mineralization in Newfoundland.

SUMMARY

A humus- and till-sampling survey was conducted in the vicinity of Au mineralization in the Jackson's Arm, Nippers Harbour, and Glover Island (Corner Brook and Little Grand Lake map areas). The objectives of this survey were to determine whether the geochemical signature of Au and its pathfinders can be detected in decomposed vegetation (*i.e.*, humus) overlying known bedrock mineralization and till dispersal from mineralized bedrock, and to determine if anthropogenic influences can affect the quality of the humus as well as its geochemical signature. The geochemical results of this study may facilitate mineral exploration success by providing an alternate sample medium to target Au anomalies in regions of Newfoundland with little to no bedrock exposure or till.

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