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PRELIMINARY INTERPRETATION OF TILL GEOCHEMISTRY: CORMACK (NTS 12H/06) AND SILVER MOUNTAIN (NTS 12H/11) MAP AREAS, WESTERN NEWFOUNDLAND

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ABSTRACT

A two-year (2017 and 2018) surficial-mapping and till-sampling project was completed in the Cormack and Silver Mountain map areas in western Newfoundland. Mineral occurrences in this area are Au, Cu, Ni, Pb, Ti, Th, U and bitumen/oil shale. The objectives of this project were to update the surficial geology, reconstruct the glacial history and characterize the till geochemistry to support mineral exploration. Surficial sediments deposited during the advance and retreat of Late Wisconsinan glaciers include lodgement till and glaciofluvial sediments; recent alluvial and organic deposits were also mapped. Ice flow was documented in three spatio-temporal trends: an initial northeastward flow; a later shift toward the southeast, and a latest southwestward flow. The ice-flow movements are also reflected in the till geochemistry as down-ice element dispersal trends from areas of known mineralization. Most till samples with anomalous concentrations of elements of interest are derived from bedrock and mineralization within the study area, with the exceptions of Au and Pb in the Silver Mountain map area.

INTRODUCTION AND OBJECTIVES

The Cormack (NTS 12H/06) and Silver Mountain (NTS 12H/11) map areas are prospective for Au, bitumen/oil shale, Cu, Ni, Ti, Th and U (Geological Survey of Newfoundland and Labrador, 2016a). However, mineral exploration is hindered by glacially derived cover deposited during the Late Wisconsinan glaciation. A regional surficial-geology mapping and till-sampling program was undertaken in 2017 and 2018 to support surficial geochemical exploration.

The objectives of this multi-year project were to:

1) Map the surficial geology of the Cormack and Silver Mountain map areas (“the study area”) at 1:50 000, highlighting the distribution of glacial deposits and geomorphic features;

2) Reconstruct the late Quaternary geomorphic history of the map areas, including ice-flow direction(s) to support interpretation of till geochemistry for mineral exploration;

3) Analyze the geochemistry of till samples using current Geological Survey of Newfoundland and Labrador (GSNL) till-sampling methods to support regional exploration; and,

4) Identify any surficial geochemical anomalies that may be associated with unknown (and known) mineral occurrences (*see* Hashmi, 2018) and evaluate their provenance against the local surficial geomorphic history and bedrock units.

LOCATION, ACCESS AND PHYSIOGRAPHY

The study area is located in western Newfoundland and covers approximately 2000 km^2 between Eastings 500059 m and 455167 m and Northings 5510591 m and 5455264 m (Figure 1). This area is accessible by the Trans-Canada Highway (TCH), which passes through both map areas, as well as by several resource-access roads and recreational trails. Adies and Upper Humber rivers are the two primary drainages that flow through the east-central Cormack map area. The Upper Humber River also flows through the west-central Silver Mountain map area. The study area is poorly drained and contains numerous wetlands. The topography is strongly influenced by the underlying bedrock type, structure, and it’s erodibility. Highly resistive, intrusive rocks (*i.e.*, granitoid and gneissic rocks of the Long Range Inlier) in the northwest and west-central study area form moderately to steeply sloping, sparsely vegetated topographic highs. Sedimentary rocks (of the Deer Lake Basin) form flat to undulating topography at lower elevations in central and east-central parts of the Cormack map area, as well as the southeastern part of the Silver Mountain map area. The

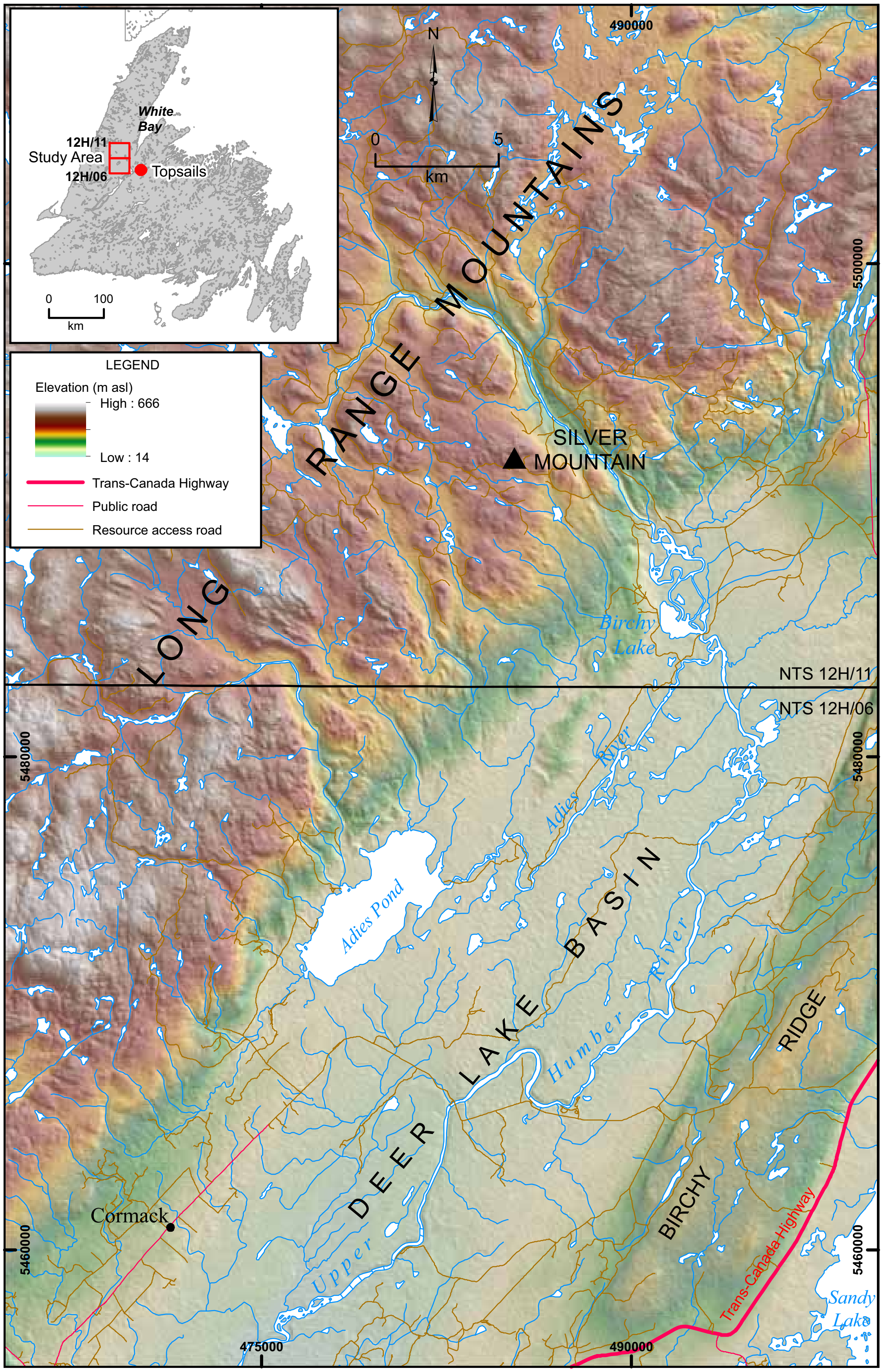

Figure 1. *Location, access and physiography of the study area. Inset map is the location of the study area within the island of Newfoundland.*

study area straddles portions of the eastern Long Range ecologic sub-region of the "Northern Peninsula Forest" and the north-central sub-region of the "Central Newfoundland Forest". Forests generally comprise Balsam fir, black spruce and eastern larch.

REGIONAL GEOLOGY

BEDROCK GEOLOGY

The bedrock geology of the study area is summarized from Colman-Sadd *et al.* (1990), Hinchey (2010), Minnett *et al.* (2010), Ivany (2011) and Sparkes (2011; Figure 2). The study area lies within the Humber (tectonostratigraphic) Zone, which comprises Proterozoic metamorphic basement rocks and younger intrusive bodies overlain by a Neoproterozoic to Paleozoic sedimentary klippe and later volcanic and sedimentary rocks. The oldest rocks within the study area consist of pre-Grenvillian (Paleo- and Mesoproterozoic) granitoid rocks, orthogneiss (including mafic varieties), and paragneiss and associated granitoid rocks of the Long Range Inlier, mapped in the west-central Silver Mountain map area and the northwestern part of Cormack map area. These rocks are intruded by Meso- to Neoproterozoic Main River and Potato Hill granitoid plutons. These are all crosscut by younger (613 Ma) Long Range mafic dykes. The basement rocks are overthrust by a klippe of Neoproterozoic to Middle Ordovician siliciclastic and carbonate rocks, preserved in the north-central Cormack map area. Early to Late Silurian, volcanic and siliciclastic non-marine rocks of the Sops Arm Group are present in the northeastern part of the Silver Mountain map area and include ash-flows, unwelded tuff, rhyolite, volcanic breccia and sandstone. The youngest rocks in the study area are Devonian to Carboniferous marine and non-marine sedimentary rocks mapped in the Deer Lake Basin. Within the Cormack map area, these consist of the North Brook, Rocky Brook and Humber Falls formations. The North Brook Formation comprises red to grey arkosic sandstone and conglomerate, red siltstone, and pink to grey micritic limestone. The Rocky Brook Formation consists of red and grey siltstone, green, grey and black mudstone, red sandstone, and minor oil shale. The Humber Falls Formation comprises light grey, pink, red, orange and light-green sandstone and mudstone.

MINERAL OCCURRENCES

All mineral occurrences discussed are retrieved from the mineral occurrence database system (MODS) of the GSNL. Elements of interest discussed in this report include Au, Cu, Ni, Pb, Ti, Th and U (*see* Geological Survey of Newfoundland and Labrador, 2016a).

Gold occurrences (Wild Puppy Au showing, West Viking Au showing, Viking Gold-Viking Trend prospect) lie along the Viking Trend, located in the northeastern part of the Silver Mountain map area (Ebert, 2009). Mineralization is hosted in the Main River pluton that intrudes rocks of the Long Range Inlier, and may include both intrusion-related and orogenic Au. Gold occurs as low-grade disseminations of 50 µm grains in sericite-altered host rocks, and as electrum, hosted within quartz veinlets and as inclusions in sulphides (Minnett *et al.*, 2012). Secondary commodities are Ag, Cu, Pb and Zn, which are hosted within chalcopyrite, galena and sphalerite, and are reported to occur as both low-grade disseminations and high-grade veins (Minnett *et al.*, 2012).

The two main Cu showings (with secondary Pb and Zn) are Birchy Ridge Road Copper #1 and Birchy Ridge Road Copper #2, located in the northeastern Cormack map area. Mineralization is hosted in structurally controlled, carboniferous vein systems in limestone of the Wigwam Brook Formation. Copper is present as chalcopyrite and bornite, Zn is present as sphalerite, and Pb is present as galena. Other associations with Cu may include U, Ag, Mo, Co, Ni and Au, and up to 0.27% Cu, 191 ppm Zn and 76 ppm Pb have been reported from drillcore (Patterson, 1981).

There is a Ni showing at Layden (also referred to as Taylors Brook), with subordinate Cu, Co and platinum group elements (PGEs). The Layden Ni showing is located in the central Silver Mountain map area. Mineralization is hosted in the Taylor Brook gabbro, which intrudes the Long Range gneisses (Geological Survey of Newfoundland and Labrador, 2016a). This showing contains massive- to semi-massive sulphides including pyrrhotite, chalcopyrite and pentlandite (*ibid*).

There are several Pb occurrences along the eastern boundary of the Silver Mountain map area; two lie within the map area. The Side Pond Pb prospect is located along the eastern boundary of the Silver Mountain map area. It is a stratabound, epigenetic deposit hosted by carbonates of the Gales Brook dolomite. Mineralization consists of disseminated pyrite and minor sphalerite, galena and barite. Turner's Ridge is a developed Pb prospect 800 m east of Route 77 (toward Sop's Arm). Mineralization consists of galena, barite, chalcopyrite and sphalerite hosted within dolomitic breccias of the Gales Brook dolomite. Up to 18 wt. % Pb, 0.3 wt. % Zn and 1.1 g/t Ag are reported from a drillcore sample (Crowley, 1977).

Titanium is documented at the East Branch Brook Titanium #1 indication in the southwestern Cormack map area. Mineralization is hosted within sedimentary rocks of

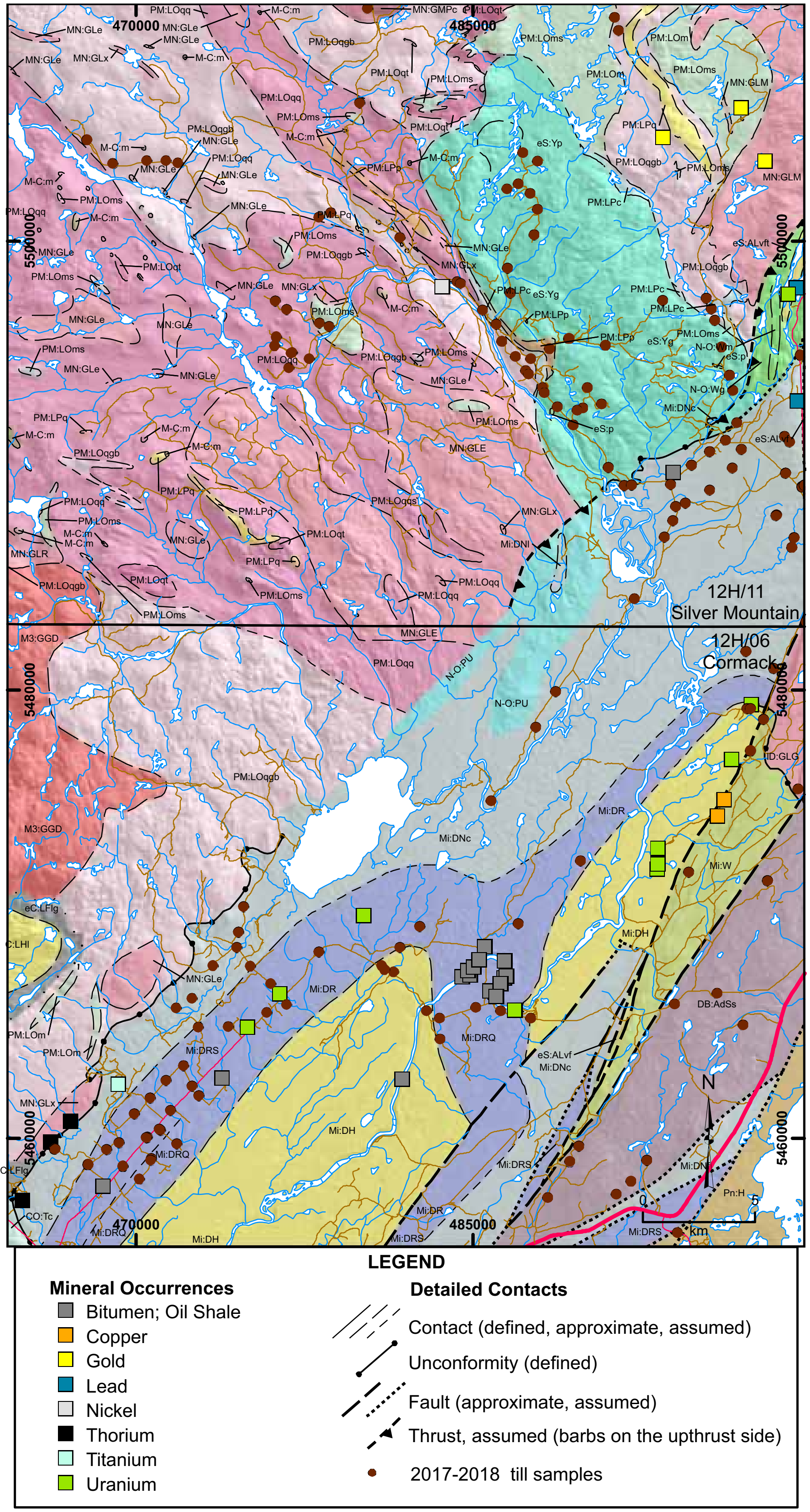

Figure 2. *Bedrock geology and mineral occurrences in the study area. Modified after Colman-Sadd* et al. *(1990).*

LEGEND

Post-Ordovician Units

Overlap Sequences

Pennsylvanian

Howley Formation

Pn:H	Grey to red sandstone, pebble–cobble conglomerate and siltstone, black carbonaceous shale, minor bituminous coal

Mississippian

Deer Lake Group

Humber Falls Formation

Mi:DH	Very light-grey, light-orange and red sandstone, pink to grey, pebble to cobble conglomerate, and mostly red, but also grey, siltstone

Rocky Brook Formation

Mi:DRQ	Squires Park Member: Grey to green siltstone, grey to green and black mudstone, grey dolomitic limestone and calcareous dolostone, dark-brown oil shale, very rare gypsum in drillcore
Mi:DRS	Spillway Member: Grey to red and brown, calcareous siltstone, grey to green mudstone, grey to cream and orange-weathering calacareous dolostone and dolomitic limestone, rare grey to red sandstone, and dark-brown oil shale
Mi:DR	Red calcareous siltstone and fine-grained sandstone, grey to green, siltstone and mudstone, black mudstone, grey calcareous dolostone, dolomitic limestone and dolomitic oil shale

North Brook Formation

Mi:DNl	Grey limestone breccia and limestone
Mi:DNf	Red to grey sandstone and interbedded red siltstone; lithologies arranged in fining-upward sequences
Mi:DNc	Mainly red to grey, pebble to boulder conglomerate and interbedded red to grey sandstone

Wigwam Brook Formation

Mi:W	Red, brown and grey sandstone; grey to red, pebble to boulder conglomerate; grey limestone

Late Devonian to Mississippian

Anguille Group (Deer Lake Basin)

Saltwater Cove Formation

DB:AdSs	Dark-grey sandstone and siltstone (locally dolomitic), black carbonaceous shale and mudstone, interbedded with light-grey sandstone, pebbly sandstone, and pebble to cobble conglomerate; rare limestone and dolostone

Early to Late Silurian

Sops Arm Group

Lower volcanic formation

eS:ALvf	Predominantly ash-flow tuffs and rhyolite flows, but also including unwelded tuff and volcanic breccia
eS:ALvft	Ash-flow tuff, welded and unwelded

Intrusive Rocks

Early Silurian to Late Devonian

Gull Lake intrusive suite

Gales Brook granite

ID:GLG	Megacrystic and fine-grained biotite granite, biotite-granite porphyry, chlorite-altered granite, and biotite ± muscovite microgranite dykes

Early Silurian

Taylor Brook gabbro

eS:Yp	Stock and dykes of massive pegmatitic leucogabbro, cutting layering of main Taylor Brook gabbro intrusion
eS:Yg	Typically medium-grained, mesocratic, layered gabbro, containing calcic plagioclase and various combinations of olivine, augite and orthopyroxene; minor fine-grained pyroxene-bearing diorite
eS:p	Tan to rose, massive to schistose, very fine-grained felsic porphyry

Laurentian Margin

Humber Zone (Shelf and Related Rocks)

Middle Cambrian to Early Ordovician

Port au Port Group

CO:Tc	Recrystallized limestone and deformed grey to white marble, derived by metamorphism of Port au Port Group

Neoproterozoic to Middle Ordovician

Undivided sedimentary units of Humber Zone

N-O:PU	Marble, variably recrystallized dolostone, quartzite and schist, probably derived from the Labrador, Port au Port, St. George and/or Table Head groups

Neoproterozoic to Middle Cambrian

Labrador Group

Hawke Bay Formation

C:LHl	Thick, massive to crossbedded, white and pink quartzite; thin- to medium-bedded, white, green and brown sandstone with minor conglomerate, shale and limestone

Forteau Formation

eC:LFlg	Medium- to thin-bedded, alternating grey and green shale and grey- to buff-weathering, limy siltstone and limestone; limestone with archeocyathids at base where unit overlies Bradore Formation; locally includes thin unit of green quartz sandstone and arkosic sandstone at base (representing Bradore Formation); grey calcareous phyllite and schist adjacent to Long Range Inlier

Late Mesoproterozoic to Late Cambrian

M-C:m	Dark-green, medium-grained, amphibole-bearing metagabbro, typically with subophitic texture

Late Mesoproterozoic to Neoproterozoic

Grenvillian granitoid rocks

Potato Hill pluton

MN:GLx	Potassium feldspar-megacrystic biotite ± hornblende granite
MN:GLe	Biotite ± hornblende granite

Main River pluton

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

East Adies River pluton

MN:GLE	Medium-grained biotite–hornblende granite

Rex Lake pluton

MN:GLR	Pink, fine- to medium-grained, variably epidotized leucogranite

Lomond River pluton

M3:GGD	Coarse-grained to megacrystic biotite ± hornblende granodiorite

Late Paleoproterozoic to Mesoproterozoic

Long Range gneiss complex

PM:LOqqs	Grey, medium-grained, quartzofeldspathic biotite schist
PM:LOqq	Green-grey, medium-grained, flecky-textured, biotite ± hornblende ± hypersthene, quartz dioritic to locally granodioritic gneiss
PM:LOqgb	Granitic to granodioritic biotite gneiss; locally migmatitic
PM:LOqt	Orthopyroxene-bearing tonalitic and quartz dioritic gneiss
PM:LOms	Dark green, medium-grained, amphibole-bearing, dioritic gneiss and amphibolite
PM:LOm	Amphibolite, dioritic gneiss, and mesocratic to mafic gneiss; minor meta-ultramafite
PM:LPc	Buff, grey or white, medium-grained, forsterite ± diopside marble; talc ± tremolite(?) marble; dark grey, forsterite–phlogopite ± diopside ± spinel calc-silicate rock; rare, layered, wollastonite clinopyroxene–bytownite calc-silicate rock
PM:LPp	Pelitic gneiss, locally associated with quartzite or mafic gneiss
PM:LPq	Quartzite and quartz-rich gneiss

Humber Zone (Slope and Related Rocks)

Neoproterozoic to Early Ordovician

Southern White Bay Allochthon

N-O:Wg	Fine- to medium-grained, dark-green to grey greywacke; rare quartz-pebble conglomerate. Maiden Point Formation equivalents

Iapetus Ocean

Dunnage Zone (Notre Dame Subzone)

N-O:Wm	Dark-green, medium-grained metadiorite and mafic schist (epidote + chlorite + albite schist)

Legend for Figure 2.

the Rocky Brook Formation resulting from hydrothermal activity associated with the reactivation of the Wigwam Fault. The main ore mineral is ilmenite and a grab sample contained up to 0.1 wt. % Ti, 48 ppm U, 48 ppm Cu as well as Pb (29 ppm), Zn (31 ppm) and Ag (0.4 ppm) (Wilkinson, 1981).

Uranium and Th occurrences in the Cormack map area are associated with sedimentary rocks of the Deer Lake Basin, as well as the Long Range Inlier granitoid and gneiss (Ivany, 2011; Sparkes, 2011). Uranium-bearing minerals include coffinite, uraninite and brannerite (Ivany, 2011). Uranium mineralization, associated with sedimentary rocks of the Deer Lake Basin is hosted in:

1) The unconformity between the North Brook Formation and the underlying carbonate and metasedimentary rocks along the western edge of Deer Lake Basin;

2) Sandstone, siltstone and mudstone of the Rocky Brook Formation; and

3) Sandstone of the Humber Falls Formation.

Silver has been noted as a secondary commodity in mineralization hosted in the Humber Falls Formation.

REGIONAL QUATERNARY FRAMEWORK

This summary of the regional and local Quaternary framework, *i.e.*, the glacial and deglacial chronology associated with the Late Wisconsinan glaciation (~80–10 ka BP) in Newfoundland, is based on work by Grant (1974, 1989), Batterson (1994), Batterson and Liverman (2001), Batterson (2003), Batterson and Taylor (2008), Organ and Amor (2017) and Hashmi (2020a, b).

Late Wisconsinan glaciation in western Newfoundland was characterized by discrete, relatively small ice caps originating within the Long Range Mountains and The Topsails that produced a complex ice-flow history for the region (Figure 1; Batterson and Liverman, 2001). At the onset of Late Wisconsinan glaciation, the study area was covered by topographically controlled glaciers originating in the Long Range Mountains. Batterson (2003) proposed that ice from The Topsails covered the lower part of the Humber River Valley (south of the Cormack map area) as well as crossed into Sandy Lake (which straddles the eastern boundary of the Cormack map area) and flowed out into White Bay (Organ and Amor, 2017). At the glacial maximum, ice flowing from the Long Range Mountains and The Topsails coalesced to create an ice divide that influenced the ice-flow movement in the study area. Ice retreat may have commenced as early as 13 ka BP. Ice sheets disintegrated primarily via ablation and ice stagnation, becoming isolated and shrinking into multiple, topographically controlled ice caps that retreated towards the Long Range Mountains (Grant, 1974). Shelf ice caps persisted until 11 ka BP, when the Younger Dryas cooling period resulted in a limited glacial re-advance (Shaw *et al.*, 2006). Deglaciation was mainly complete by 10 ka BP (Grant, 1974; Shaw *et al.*, 2006).

ICE FLOW AND ITS INFLUENCE ON GLACIAL DISPERSAL

The regional ice flow in the study area has been reconstructed (*see* Batterson, 2003; Geological Survey of Newfoundland and Labrador, 2016b; Organ and Amor, 2017; Hashmi, 2020a, b). It is based on the measurement of micro-scale ice-flow indicators such as striations and grooves, and macro-scale indicators such as bi-directional fluting, streamlined bedrock, uni-directional crag-and-tail, and roche moutonnée.

Ice-flow reconstruction suggests that at the onset of the last glaciation, glacial ice accumulated in the Long Range Mountains and flowed east and northeastward into the study area. This early ice flow was topographically controlled, and ice flowed out of the study area into White Bay to the northeast (Figure 1, inset map). Birchy Ridge, in the eastern Cormack area, is interpreted to be a local ice centre with a radial flow pattern from the ridge. In The Topsails (east of the study area; Figure 1), ice developed and flowed northwest into the study area (Organ and Amor, 2017). As glaciation progressed, an ice divide formed along the axis of the Long Range Mountains, resulting in a southwestward oriented glacial movement in the study area (Batterson, 2003). This proposed ice divide likely continued throughout the Late Wisconsinan, eventually disintegrating (*ca.* 12 ka BP) as deglaciation proceeded.

Glacial dispersal derived from bedrock is complex due to the chronology of glacial events and flow directions. It is likely that the earlier northeastward to southeastward glacial dispersal was subsequently re-entrained into the later southwestward flow, creating a palimpsest dispersal train.

METHODS

MAPPING

Field data were collected on surficial deposits using a Trimble GPS unit; data included map station, location (GPS coordinates; elevation), geomorphology, sediment grain size and clast content, thickness, lateral continuity, sedimentary structures and contact relationships between adjacent units.

Orientation of ice-flow indicators such as striations and grooves were measured where observed (Plate 1A). Surficial geology was mapped on aerial photographs and subsequently digitized using ESRI ArcMap™ (v.10.5) GIS software (*see* Hashmi, 2020a, b).

SAMPLING

Tills were sampled following GSNL protocols. Samples were collected at intervals of 1 km along forestry roads and trails *via* truck, ATV, or by foot traverse. Inaccessible regions were sampled using helicopter support at a spacing of one sample per 2 to 4 km^2. 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 C-horizon soil (developed in till; "C-horizon till"). Undisturbed C-horizon till is the optimal sampling medium as it is less affected by physical and chemical weathering processes such as surface washing, pedogenesis, remobilization *via* gravity and/or element mobility *via* hydromorphic dispersion (Levson, 2001). At a few sites, B–C horizon till were sampled due to thin till cover.

Each sample comprised 2–3 kg of material collected for geochemical analysis. Field duplicates were taken every 12–15 samples to evaluate site variability. Larger samples (10–15 kg) were also collected for heavy-mineral separation at selected sites with abundant, accessible C-horizon till.

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 such as agricultural activity in the vicinity. Weathering and soil-horizon information were also recorded, and photographs taken at each site.

SAMPLE PREPARATION

Till samples were submitted to the GSNL laboratory for preparation and geochemical analysis (Hashmi, 2020c, 2021). Samples were dried and sieved to -63 µm (230 mesh) to recover the silt and clay fraction. The silt and clay fraction is the optimal size fraction for geochemical analysis because it is easy and cost-effective to recover, and ore minerals (*e.g.*, sulphides) are preferentially concentrated in this fraction and enriched with respect to the "background" (Levson, 2001; Spirito *et al.*, 2011; Hashmi *et al.*, 2015).

ANALYTICS

The sieved silt and clay fraction was submitted for the following analyses:

1) Four-acid (hydrochloric, hydrofluoric, nitric, and perchloric acids) digestion followed by inductively coupled plasma-optical emission spectrometry (ICP-OES) to determine concentrations of 31 elements (Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Fe, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Sc, Sr, Ti, V, Y, Zn and Zr). Additionally, S analysis was also performed on the samples collected in 2018. The four-acid digestion is a near total leach that can dissolve oxides, sulphides and some silicates; however, the most resistant minerals (*e.g.*, zircon) may not be completely dissolved (C. Finch, personal communication, 2019);

2) Instrumental neutron activation analysis (INAA) to determine concentrations of 26 elements (As, Au, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Mo, Na, Rb, Sb, Sc, Se, Sm, Ta, Tb, Th, U, W and Yb);

3) Nitric acid digestion followed by ICP-OES to determine Ag concentration;

4) Alkaline fusion followed by ion-selective electrode (ISE) technique to determine fluoride ion (F-); and

5) Loss on ignition (LOI) *via* gravimetry to determine the percentage of organic matter.

Except for INAA, all analyses were completed at the GSNL laboratory in St. John's, NL; INAA was completed at Bureau Veritas, Mississauga, ON. A detailed description of each analytical procedure can be found in Finch *et al.* (2018).

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance measures include cleaning of sampling tools before the collection of each new sample to reduce the risk of cross-contamination. Field duplicates were also collected every 12 to 15 samples (depending on ease of collection) to determine site variability. Quality control measures include insertion of in-house and certified reference materials (Canadian Certified Reference Materials, CCRM) and laboratory duplicates into the sample series before the samples were shipped for analysis. Lab duplicates were also inserted to determine precision and CCRMs were inserted randomly to determine accuracy and reproducibility.

Precision at 95% confidence interval (CI) is reported for 11 lab duplicates for elements of interest; all are reported within ±10% and considered acceptable (Table 1). Gold measurements were below detection limits in eight duplicate pairs; therefore, only three pairs were used for precision calculation.

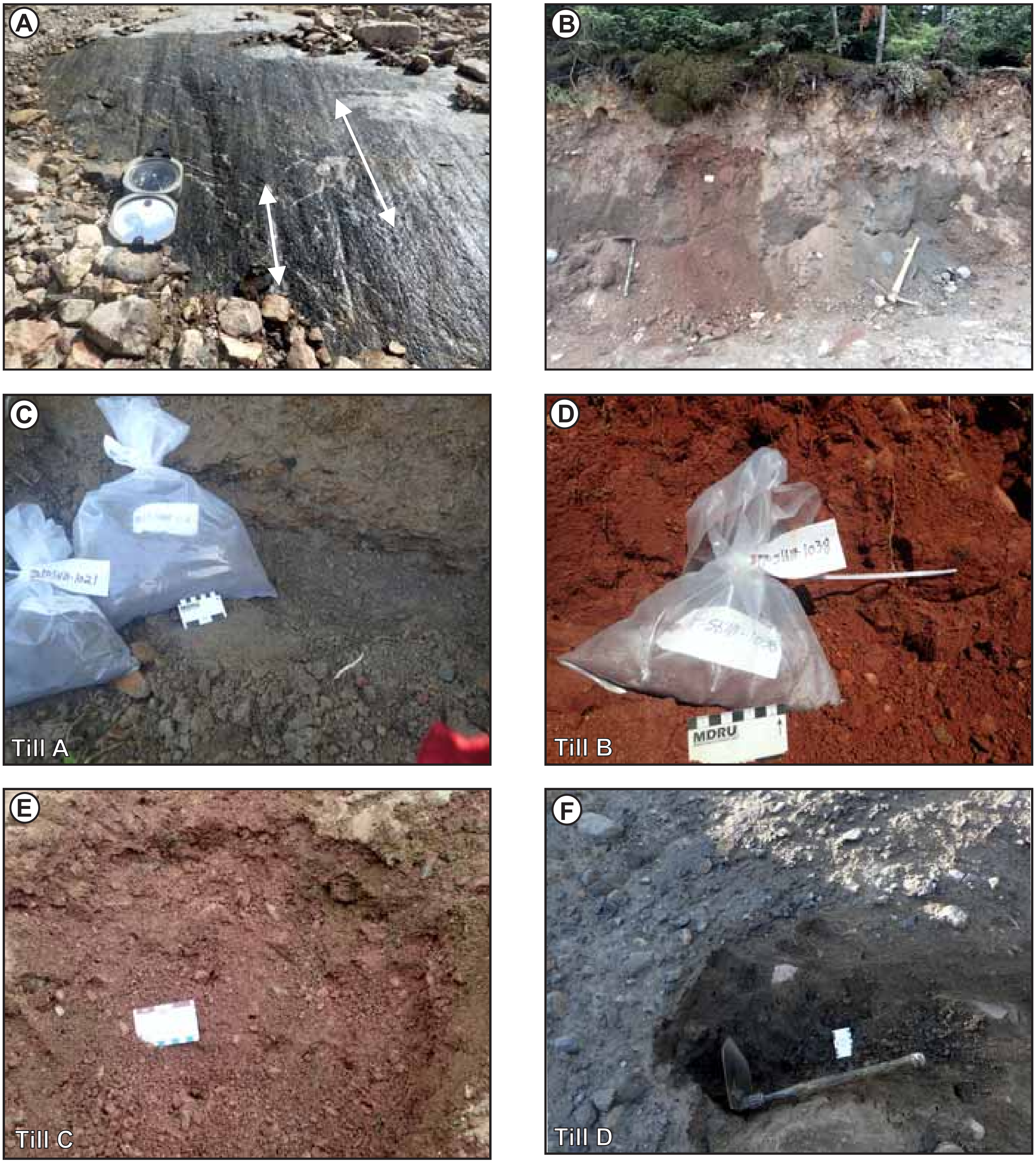

Plate 1. *A) Bi-directional ice-flow indicators (striations and grooves) on flat bedrock surfaces, taken in the north-central Silver Mountain map area; B) Exposed C-horizon till at sample site 17SH111-1099 in the central study area. Four distinct till types identified in the study area; C) Till A (sample 17SH111-1021) overlying Rocky Brook Formation, in west-central Cormack map area; D) Till B (sample 17SH111-1038) overlying North Brook Formation, in west-central Cormack map area; E) Till C (sample 17SH111-1066) overlying Taylor Brook gabbro, in the central study area; F) Till D (sample 17SH111-1131) overlying Long Range Inlier, in west-central Silver Mountain map area.*

Table 1. Calculated precision for elements of interest at a 95% confidence interval (CI)

Element	Analysis	No. of Duplicates	Precision (at 95% CI)
Cu	ICP-OES	11	10.1
Ni	ICP-OES	11	4.7
Pb	ICP-OES	10	5.9
Ti	ICP-OES	11	3.3
Au	INAA	3	1
Th	INAA	11	0.01
U	INAA	11	0.1

DATA PLOTTING AND PRESENTATION

Geochemical results were plotted and interpreted in ArcMap (v.10.5) and Microsoft Excel®. Data are plotted as percentiles using proportionally sized dots corresponding to <50th, 50–75th, 75–90th, 90–95th and >95th percentiles, where ≥90th percentile is considered anomalous. Correlation between elements of interest and associated elements was determined using Spearman Rank correlation, which is ideal because data do not need to be normally distributed. This method is also less sensitive to outliers than Pearson Product Moment correlation (Table 2). Elements with >40% of measured values that are below detection limits were removed from the dataset before a correlation matrix was generated. A correlation of >0.65 is interpreted as strong positive correlation with elements of interest. Both field and lab duplicate results are included in the correlation matrix and proportional dot plots. The complete dataset has been published (Hashmi, 2020c, 2021).

RESULTS AND DISCUSSION

SURFICIAL DEPOSITS AND FEATURES

The deposits and features described are based on recently released 1:50 000 surficial geology maps of the Cormack and Silver Mountain map areas (Hashmi, 2020a, b).

The oldest and most extensive surficial deposit type is a lodgement till, deposited during glacial advance. The lodgement till is mapped as a thin veneer over bedrock (*i.e.*, <1.5 m thick) on moderate to steep slopes, a till blanket (*i.e.*, >1.5 m thick) on moderate slopes, an eroded till adjacent to meltwater channels, and a lineated till in low-relief regions. The till colour, texture and clast content (lithology and abundance) suggest four distinct, locally derived lodgement till units in the study area, all deposited during the Late Wisconsinan glaciation.

Till “A” is a massive, greyish brown to light brown, silty to sandy diamicton (Plate 1C). It is fissile, matrix-supported (field estimate 75–85% fines; sand, silt and clay) and contains faceted, bullet-shaped, predominantly cobble-sized clasts. Clasts are predominantly grey siltstone and olive-green to grey mudstone, suggesting that the till is predominantly derived from the Rocky Brook and Humber Falls formations.

Till “B” is a massive, reddish brown to maroon, silty to sandy diamicton (Plate 1D). It is fissile and matrix-supported, and has a moderate clast content (20–40%). Clasts are dominantly pebble- to cobble-sized, silt-capped, faceted and bullet-shaped, red sandstone and less commonly, mafic intrusive rock. This till is inferred to have been predominantly derived from the Fe-rich sandstones of the Rocky Brook Formation.

Till “C” is a light, pearly pink brown, massive, silty to sandy diamicton with >40% clast content (Plate 1E). This till shows no fissility and has faceted, silt-capped, bullet-shaped clasts of mainly felsic to intermediate intrusive rocks. This till is inferred to have been predominantly derived from Grenvillian granitic rocks (*e.g.*, K-feldspar-rich Main River granite) and Long Range gneisses.

Till “D” is a grey to dark-grey, massive, fissile, silty sandy diamicton. Clast content is roughly 20–40%, and comprises faceted, silt-capped and bullet-shaped granule- to cobble-sized gravel of primarily mafic to ultramafic intrusive rock (Plate 1F). This till is likely predominantly derived from the mafic intrusive rocks of the Long Range Inlier as well as the Taylor Brook gabbro and/or the Long Range mafic dykes mapped throughout the study area.

Hummocky glaciofluvial deposits of coarse to medium sand and granule- to boulder-sized gravel, associated with glacial retreat, occur in valleys in the Long Range Mountains in the northwestern Cormack map area (Plate 2A). Eskers, comprising crudely stratified, fine to coarse sand and cobble- to pebble-sized gravel are mapped in south-central Cormack map area (Plate 2B). These are associated with glaciofluvial meltwater discharge. Normally graded, fine to medium sand (grading into granule- to pebble-sized gravel) has also been noted in the northeastern Silver Mountain map area (Plate 2C). These deposits may have formed in a littoral/nearshore environment, possibly associated with small-scale localized meltwater ponding. The depositional history of these deposits is still unclear. Colluvium, mapped as a veneer, fan or blanket on moderate to steep slopes, occurs predominantly within the Long Range Mountains.

Recent and modern fluvial deposits consisting of sand, silt, minor clay and granule- to boulder-sized gravel form

Table 2. Spearman rank correlation matrix for 157 till samples analyzed by INAA (suffix 1), ICP-OES (suffix 2) and ISE (suffix 9)

Spearman correlation, n=157	Al2 (%)	As1 (ppm)	Ba1 (ppm)	Be2 (ppm)	Br1 (ppm)	Ca2 (%)	Cd 2 (ppm)	Ce1 (ppm)	Co1 (ppm)	Cr1 (ppm)	Cu2 (ppm)	Dy2 (ppm)	Eu1 (ppm)	F9 (ppm)	Fe1 (%)	Hf1 (ppm)	K2 (%)	La1 (ppm)	Li2 (ppm)	Lu1 (ppm)	Mg2 (%)
Al2 (%)	1.00	-0.12	-0.19	0.11	0.37	0.19	0.34	0.08	0.45	0.10	0.53	0.25	0.17	0.26	0.50	-0.44	-0.14	0.02	0.07	0.09	0.54
As1 (ppm)	-0.12	1.00	0.13	0.58	-0.33	-0.74	-0.19	0.14	-0.30	0.31	-0.28	-0.67	-0.55	-0.30	-0.53	-0.27	0.57	0.01	0.85	-0.62	-0.01
Ba1 (ppm)	-0.19	0.13	1.00	0.24	-0.15	-0.20	-0.11	0.32	-0.28	-0.22	-0.11	0.01	0.05	0.25	-0.30	0.08	0.54	0.40	0.09	-0.06	-0.36
Be2 (ppm)	0.11	0.58	0.24	1.00	-0.31	-0.75	-0.10	0.52	-0.39	0.34	-0.27	-0.29	-0.28	0.07	-0.47	-0.10	0.70	0.38	0.75	-0.21	-0.12
Br1 (ppm)	0.37	-0.33	-0.15	-0.31	1.00	0.31	0.36	-0.14	0.27	-0.24	0.23	0.16	0.06	0.20	0.35	-0.15	-0.29	-0.33	-0.28	0.05	0.10
Ca2 (%)	0.19	-0.74	-0.20	-0.75	0.31	1.00	0.41	-0.28	0.65	-0.24	0.52	0.64	0.52	0.25	0.80	0.05	-0.79	-0.17	-0.86	0.50	0.40
Cd2 (ppm)	0.34	-0.19	-0.11	-0.10	0.36	0.41	1.00	0.11	0.56	-0.04	0.47	0.40	0.22	0.35	0.58	-0.20	-0.32	-0.03	-0.19	0.26	0.46
Ce1 (ppm)	0.08	0.14	0.32	0.52	-0.14	-0.28	0.11	1.00	-0.05	0.08	-0.11	0.31	0.25	0.41	-0.06	0.28	0.39	0.79	0.25	0.32	0.00
Co1 (ppm)	0.45	-0.30	-0.28	-0.39	0.27	0.65	0.56	-0.05	1.00	0.05	0.69	0.45	0.28	0.23	0.85	-0.26	-0.60	-0.13	-0.38	0.28	0.79
Cr1 (ppm)	0.10	0.31	-0.22	0.34	-0.24	-0.24	-0.04	0.08	0.05	1.00	-0.09	-0.23	-0.17	-0.17	-0.02	0.03	0.03	0.06	0.27	-0.03	0.19
Cu2 (ppm)	0.53	-0.28	-0.11	-0.27	0.23	0.52	0.47	-0.11	0.69	-0.09	1.00	0.40	0.29	0.28	0.61	-0.39	-0.34	-0.09	-0.26	0.18	0.61
Dy2 (ppm)	0.25	-0.67	0.01	-0.29	0.16	0.64	0.40	0.31	0.45	-0.23	0.40	1.00	0.75	0.59	0.65	0.28	-0.32	0.41	-0.59	0.83	0.28
Eu1 (ppm)	0.17	-0.55	0.05	-0.28	0.06	0.52	0.22	0.25	0.28	-0.17	0.29	0.75	1.00	0.41	0.47	0.25	-0.27	0.39	-0.51	0.69	0.11
F9 (ppm)	0.26	-0.30	0.25	0.07	0.20	0.25	0.35	0.41	0.23	-0.17	0.28	0.59	0.41	1.00	0.32	-0.03	0.10	0.36	-0.20	0.41	0.23
Fe1 (%)	0.50	-0.53	-0.30	-0.47	0.35	0.80	0.58	-0.06	0.85	-0.02	0.61	0.65	0.47	0.32	1.00	-0.10	-0.69	-0.06	-0.55	0.50	0.68
Hf1 (ppm)	-0.44	-0.27	0.08	-0.10	-0.15	0.05	-0.20	0.28	-0.26	0.03	-0.39	0.28	0.25	-0.03	-0.10	1.00	-0.05	0.38	-0.32	0.53	-0.48
K2 (%)	-0.14	0.57	0.54	0.70	-0.29	-0.79	-0.32	0.39	-0.60	0.03	-0.34	-0.32	-0.27	0.10	-0.69	-0.05	1.00	0.38	0.68	-0.29	-0.36
La1 (ppm)	0.02	0.01	0.40	0.38	-0.33	-0.17	-0.03	0.79	-0.13	0.06	-0.09	0.41	0.39	0.36	-0.06	0.38	0.38	1.00	0.13	0.43	-0.11
Li2 (ppm)	0.07	0.85	0.09	0.75	-0.28	-0.86	-0.19	0.25	-0.38	0.27	-0.26	-0.59	-0.51	-0.20	-0.55	-0.32	0.68	0.13	1.00	-0.56	-0.01
Lu1 (ppm)	0.09	-0.62	-0.06	-0.21	0.05	0.50	0.26	0.32	0.28	-0.03	0.18	0.83	0.69	0.41	0.50	0.53	-0.29	0.43	-0.56	1.00	0.06
Mg2 (%)	0.54	-0.01	-0.36	-0.12	0.10	0.40	0.46	0.00	0.79	0.19	0.61	0.28	0.11	0.23	0.68	-0.48	-0.36	-0.11	-0.01	0.06	1.00
Mn2 (ppm)	0.21	0.02	-0.12	0.00	-0.06	0.28	0.50	0.24	0.65	0.11	0.42	0.33	0.18	0.18	0.50	-0.10	-0.25	0.14	-0.02	0.19	0.62
Na1 (%)	0.06	-0.80	-0.10	-0.57	0.28	0.80	0.30	-0.07	0.34	-0.29	0.27	0.64	0.57	0.24	0.54	0.25	-0.62	-0.03	-0.83	0.66	0.09
Nb2 (ppm)	0.05	-0.33	0.06	-0.02	-0.03	0.13	0.02	0.27	-0.04	0.01	-0.09	0.46	0.42	0.25	0.16	0.49	-0.02	0.46	-0.18	0.54	-0.14
Ni2 (ppm)	0.29	0.48	-0.20	0.17	-0.09	-0.12	0.23	0.01	0.48	0.47	0.33	-0.20	-0.27	-0.10	0.22	-0.48	0.00	-0.11	0.38	-0.30	0.63
P2 (ppm)	0.25	-0.58	0.03	-0.52	0.34	0.75	0.51	0.10	0.63	-0.29	0.45	0.70	0.55	0.52	0.76	0.06	-0.50	0.12	-0.65	0.48	0.42
Pb2 (ppm)	-0.23	0.78	0.37	0.79	-0.36	-0.83	-0.22	0.37	-0.49	0.29	-0.36	-0.54	-0.46	-0.13	-0.69	-0.05	0.74	0.23	0.79	-0.43	-0.27
Rb1 (ppm)	-0.05	0.71	0.39	0.83	-0.37	-0.86	-0.30	0.35	-0.55	0.27	-0.32	-0.45	-0.37	-0.03	-0.66	-0.11	0.88	0.32	0.81	-0.37	-0.29
Sc1 (ppm)	0.48	-0.55	-0.33	-0.42	0.23	0.76	0.52	0.02	0.83	-0.02	0.64	0.70	0.53	0.34	0.92	-0.10	-0.63	0.04	-0.52	0.56	0.71
Sm1 (ppm)	0.12	-0.46	0.19	-0.10	-0.07	0.41	0.23	0.51	0.26	-0.18	0.21	0.89	0.73	0.55	0.43	0.41	-0.09	0.68	-0.41	0.75	0.12
Sr2 (ppm)	0.07	-0.73	0.11	-0.71	0.30	0.87	0.29	-0.13	0.44	-0.32	0.34	0.62	0.55	0.35	0.60	0.15	-0.61	-0.03	-0.83	0.45	0.16
Ta1 (ppm)	-0.23	0.42	0.03	0.57	-0.32	-0.59	-0.22	0.29	-0.40	0.35	-0.39	-0.28	-0.20	-0.19	-0.47	0.30	0.40	0.26	0.47	-0.06	-0.32
Tb1 (ppm)	0.16	-0.56	0.06	-0.18	0.02	0.52	0.32	0.41	0.36	-0.15	0.28	0.94	0.74	0.54	0.53	0.38	-0.23	0.53	-0.51	0.81	0.19
Th1 (ppm)	-0.24	0.72	0.25	0.76	-0.43	-0.90	-0.34	0.47	-0.54	0.27	-0.44	-0.49	-0.38	-0.18	-0.72	0.14	0.77	0.40	0.79	-0.35	-0.34
Ti1 (ppm)	0.27	-0.72	-0.26	-0.66	0.32	0.88	0.39	-0.13	0.66	-0.15	0.45	0.70	0.58	0.24	0.85	0.22	-0.75	-0.04	-0.76	0.62	0.39
U1 (ppm)	-0.33	0.75	0.23	0.67	-0.43	-0.86	-0.36	0.30	-0.60	0.20	-0.48	-0.55	-0.43	-0.21	-0.75	0.09	0.74	0.26	0.78	-0.43	-0.34
V2 (ppm)	0.43	-0.48	-0.40	-0.52	0.32	0.80	0.56	-0.15	0.82	-0.01	0.55	0.57	0.41	0.21	0.93	-0.09	-0.76	-0.17	-0.53	0.41	0.67
Y2 (ppm)	0.21	-0.71	0.01	-0.35	0.15	0.68	0.40	0.22	0.44	-0.26	0.41	0.99	0.76	0.57	0.64	0.26	-0.35	0.36	-0.64	0.82	0.26
Yb1 (ppm)	0.08	-0.62	-0.09	-0.24	0.05	0.51	0.27	0.32	0.29	-0.10	0.22	0.85	0.72	0.45	0.51	0.47	-0.28	0.44	-0.54	0.95	0.10
Zn2 (ppm)	0.68	-0.11	0.02	0.08	0.34	0.27	0.65	0.16	0.62	-0.04	0.70	0.44	0.22	0.44	0.61	-0.40	-0.10	0.10	0.03	0.19	0.59
Zr2 (ppm)	-0.39	0.46	0.17	0.52	-0.38	-0.71	-0.43	0.33	-0.65	0.23	-0.56	-0.38	-0.29	-0.25	-0.70	0.48	0.58	0.34	0.50	-0.15	-0.53

Table 2. (Continued) Spearman rank correlation matrix for 157 till samples analyzed by INAA (suffix 1), ICP-OES (suffix 2) and ISE (suffix 9)

Spearman correlation, n=157	Mn2 (ppm)	Na1 (%)	Nb2 (ppm)	Ni2 (ppm)	P2 (ppm)	Pb2 (ppm)	Rb1 (ppm)	Sc1 (ppm)	Sm1 (ppm)	Sr2 (ppm)	Ta1 (ppm)	Tb1 (ppm)	Th1 (ppm)	Ti1 (ppm)	U1 (ppm)	V2 (ppm)	Y2 (ppm)	Yb1 (ppm)	Zn2 (ppm)	Zr2 (ppm)
Al2 (%)	0.21	0.06	0.05	0.29	0.25	-0.23	-0.05	0.48	0.12	0.07	-0.23	0.16	-0.24	0.27	-0.33	0.43	0.21	0.08	0.68	-0.39
As1 (ppm)	0.02	-0.80	-0.33	0.48	-0.58	0.78	0.71	-0.55	-0.46	-0.73	0.42	-0.56	0.72	-0.72	0.75	-0.48	-0.71	-0.62	-0.11	0.46
Ba1 (ppm)	-0.12	-0.10	0.06	-0.20	0.03	0.37	0.39	-0.33	0.19	0.11	0.03	0.06	0.25	-0.26	0.23	-0.40	0.01	-0.09	0.02	0.17
Be2 (ppm)	0.00	-0.57	-0.02	0.17	-0.52	0.79	0.83	-0.42	-0.10	-0.71	0.57	-0.18	0.76	-0.66	0.67	-0.52	-0.35	-0.24	0.08	0.52
Br1 (ppm)	-0.06	0.28	-0.03	-0.09	0.34	-0.36	-0.37	0.23	-0.07	0.30	-0.32	0.02	-0.43	0.32	-0.43	0.32	0.15	0.05	0.34	-0.38
Ca2 (%)	0.28	0.80	0.13	-0.12	0.75	-0.83	-0.86	0.76	0.41	0.87	-0.59	0.52	-0.90	0.88	-0.86	0.80	0.68	0.51	0.27	-0.71
Cd2 (ppm)	0.50	0.30	0.02	0.23	0.51	-0.22	-0.30	0.52	0.23	0.29	-0.22	0.32	-0.34	0.39	-0.36	0.56	0.40	0.27	0.65	-0.43
Ce1 (ppm)	0.24	-0.07	0.27	0.01	0.10	0.37	0.35	0.02	0.51	-0.13	0.29	0.41	0.47	-0.13	0.30	-0.15	0.22	0.32	0.16	0.33
Co1 (ppm)	0.65	0.34	-0.04	0.48	0.63	-0.49	-0.55	0.83	0.26	0.44	-0.40	0.36	-0.54	0.66	-0.60	0.82	0.44	0.29	0.62	-0.65
Cr1 (ppm)	0.11	-0.29	0.01	0.47	-0.29	0.29	0.27	-0.02	-0.18	-0.32	0.35	-0.15	0.27	-0.15	0.20	-0.01	-0.26	-0.10	-0.04	0.23
Cu2 (ppm)	0.42	0.27	-0.09	0.33	0.45	-0.36	-0.32	0.64	0.21	0.34	-0.39	0.28	-0.44	0.45	-0.48	0.55	0.41	0.22	0.70	-0.56
Dy2 (ppm)	0.33	0.64	0.46	-0.20	0.70	-0.54	-0.45	0.70	0.89	0.62	-0.28	0.94	-0.49	0.70	-0.55	0.57	0.99	0.85	0.44	-0.38
Eu1 (ppm)	0.18	0.57	0.42	-0.27	0.55	-0.46	-0.37	0.53	0.73	0.55	-0.20	0.74	-0.38	0.58	-0.43	0.41	0.76	0.72	0.22	-0.29
F9 (ppm)	0.18	0.24	0.25	-0.10	0.52	-0.13	-0.03	0.34	0.55	0.35	-0.19	0.54	-0.18	0.24	-0.21	0.21	0.57	0.45	0.44	-0.25
Fe1 (%)	0.50	0.54	0.16	0.22	0.76	-0.69	-0.66	0.92	0.43	0.60	-0.47	0.53	-0.72	0.85	-0.75	0.93	0.64	0.51	0.61	-0.70
Hf1 (ppm)	-0.10	0.25	0.49	-0.48	0.06	-0.05	-0.11	-0.10	0.41	0.15	0.30	0.38	0.14	0.22	0.09	-0.09	0.26	0.47	-0.40	0.48
K2 (%)	-0.25	-0.62	-0.02	0.00	-0.50	0.74	0.88	-0.63	-0.09	-0.61	0.40	-0.23	0.77	-0.75	0.74	-0.76	-0.35	-0.28	-0.10	0.58
La1 (ppm)	0.14	-0.03	0.46	-0.11	0.12	0.23	0.32	0.04	0.68	-0.03	0.26	0.53	0.40	-0.04	0.26	-0.17	0.36	0.44	0.10	0.34
Li2 (ppm)	-0.02	-0.83	-0.18	0.38	-0.65	0.79	0.81	-0.52	-0.41	-0.83	0.47	-0.51	0.79	-0.76	0.78	-0.53	-0.64	-0.54	0.03	0.50
Lu1 (ppm)	0.19	0.66	0.54	-0.30	0.48	-0.43	-0.37	0.56	0.75	0.45	-0.06	0.81	-0.35	0.62	-0.43	0.41	0.82	0.95	0.19	-0.15
Mg2 (%)	0.62	0.09	-0.14	0.63	0.42	-0.27	-0.29	0.71	0.12	0.16	-0.32	0.19	-0.34	0.39	-0.34	0.67	0.26	0.10	0.59	-0.53
Mn2 (ppm)	1.00	0.08	0.06	0.39	0.42	-0.08	-0.18	0.53	0.26	0.15	-0.04	0.31	-0.09	0.33	-0.11	0.51	0.30	0.24	0.49	-0.21
Na1 (%)	0.08	1.00	0.17	-0.46	0.59	-0.70	-0.76	0.59	0.44	0.77	-0.47	0.54	-0.74	0.69	-0.72	0.52	0.68	0.65	0.09	-0.50
Nb2 (ppm)	0.06	0.17	1.00	-0.34	0.18	-0.19	-0.04	0.17	0.51	0.17	0.33	0.51	0.00	0.40	-0.04	0.16	0.43	0.55	0.07	0.21
Ni2 (ppm)	0.39	-0.46	-0.34	1.00	-0.02	0.21	0.16	0.18	-0.20	-0.29	0.00	-0.20	0.14	-0.11	0.06	0.21	-0.24	-0.32	0.34	-0.14
P2 (ppm)	0.42	0.59	0.18	-0.02	1.00	-0.63	-0.64	0.68	0.55	0.76	-0.51	0.60	-0.63	0.73	-0.65	0.67	0.69	0.49	0.42	-0.57
Pb2 (ppm)	-0.08	-0.70	-0.19	0.21	-0.63	1.00	0.83	-0.64	-0.31	-0.71	0.53	-0.42	0.84	-0.82	0.82	-0.68	-0.58	-0.45	-0.15	0.64
Rb1 (ppm)	-0.18	-0.76	-0.04	0.16	-0.64	0.83	1.00	-0.62	-0.21	-0.77	0.54	-0.33	0.85	-0.79	0.81	-0.70	-0.49	-0.38	-0.07	0.61
Sc1 (ppm)	0.53	0.59	0.17	0.18	0.68	-0.64	-0.62	1.00	0.48	0.55	-0.46	0.58	-0.65	0.78	-0.70	0.84	0.70	0.59	0.58	-0.63
Sm1 (ppm)	0.26	0.44	0.51	-0.20	0.55	-0.31	-0.21	0.48	1.00	0.45	-0.07	0.95	-0.20	0.50	-0.29	0.35	0.86	0.77	0.31	-0.12
Sr2 (ppm)	0.15	0.77	0.17	-0.29	0.76	-0.71	-0.77	0.55	0.45	1.00	-0.59	0.50	-0.80	0.76	-0.77	0.60	0.65	0.46	0.19	-0.60
Ta1 (ppm)	-0.04	-0.47	0.33	0.00	-0.51	0.53	0.54	-0.46	-0.07	-0.59	1.00	-0.13	0.66	-0.39	0.62	-0.41	-0.32	-0.09	-0.23	0.66
Tb1 (ppm)	0.31	0.54	0.51	-0.20	0.60	-0.42	-0.33	0.58	0.95	0.50	-0.13	1.00	-0.33	0.61	-0.42	0.47	0.92	0.82	0.34	-0.22
Th1 (ppm)	-0.09	-0.74	0.00	0.14	-0.63	0.84	0.85	-0.65	-0.20	-0.80	0.66	-0.33	1.00	-0.77	0.90	-0.72	-0.55	-0.36	-0.26	0.80
Ti1 (ppm)	0.33	0.69	0.40	-0.11	0.73	-0.82	-0.79	0.78	0.50	0.76	-0.39	0.61	-0.77	1.00	-0.79	0.87	0.71	0.61	0.31	-0.56
U1 (ppm)	-0.11	-0.72	-0.04	0.06	-0.65	0.82	0.81	-0.70	-0.29	-0.77	0.62	-0.42	0.90	-0.79	1.00	-0.72	-0.59	-0.40	-0.30	0.78
V2 (ppm)	0.51	0.52	0.16	0.21	0.67	-0.68	-0.70	0.84	0.35	0.60	-0.41	0.47	-0.72	0.87	-0.72	1.00	0.57	0.43	0.51	-0.66
Y2 (ppm)	0.30	0.68	0.43	-0.24	0.69	-0.58	-0.49	0.70	0.86	0.65	-0.32	0.92	-0.55	0.71	-0.59	0.57	1.00	0.85	0.39	-0.42
Yb1 (ppm)	0.24	0.65	0.55	-0.32	0.49	-0.45	-0.38	0.59	0.77	0.46	-0.09	0.82	-0.36	0.61	-0.40	0.43	0.85	1.00	0.24	-0.17
Zn2 (ppm)	0.49	0.09	0.07	0.34	0.42	-0.15	-0.07	0.58	0.31	0.19	-0.23	0.34	-0.26	0.31	-0.30	0.51	0.39	0.24	1.00	-0.45
Zr2 (ppm)	-0.21	-0.50	0.21	-0.14	-0.57	0.64	0.61	-0.63	-0.12	-0.60	0.66	-0.22	0.80	-0.56	0.78	-0.66	-0.42	-0.17	-0.45	1.00

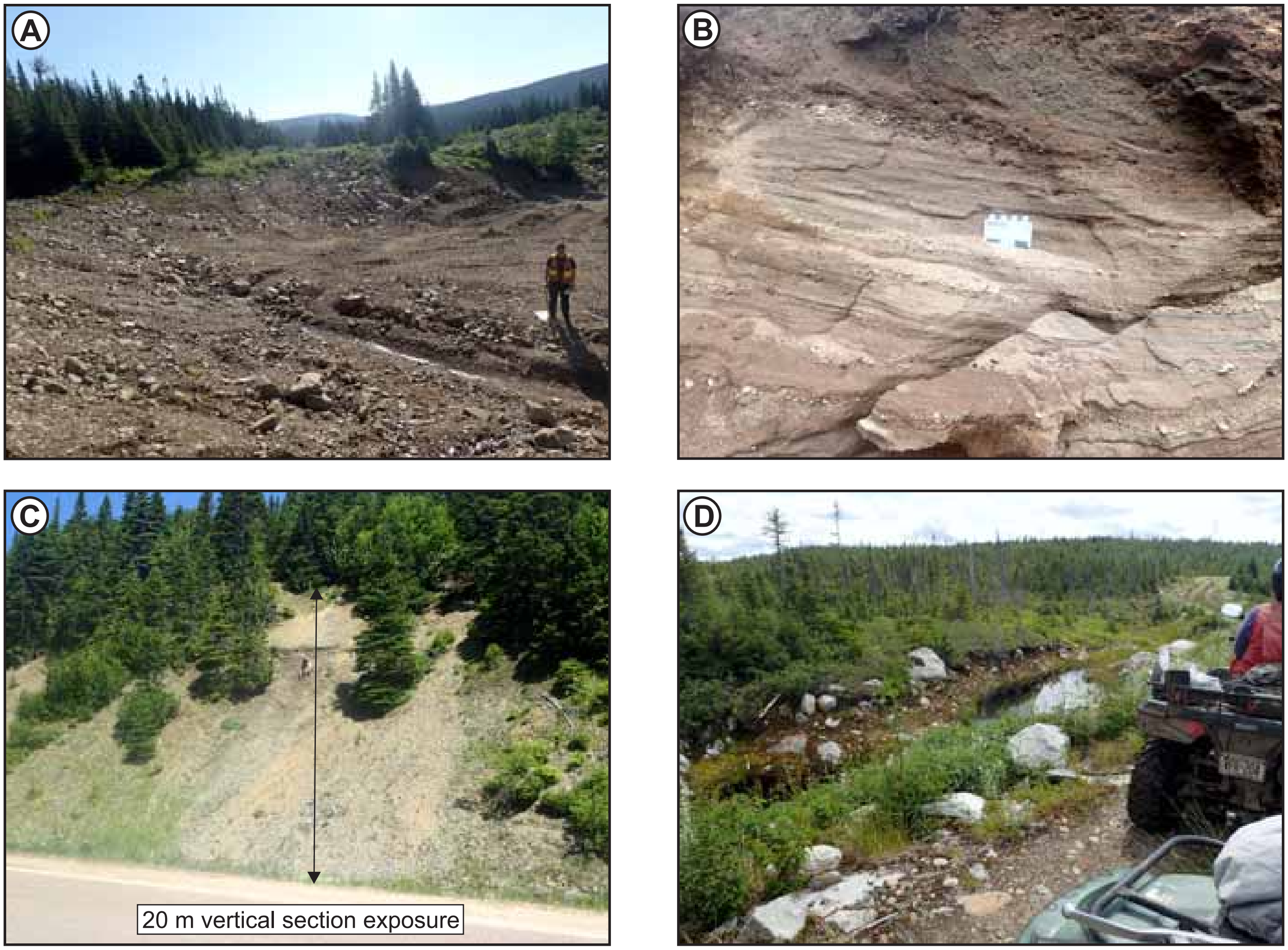

Plate 2. *A) Sand and gravel forming hummocky topography, in the northwest corner of the Cormack map area; B) Crudely stratified sand and granule- to pebble-sized gravel in the southwest corner of the Cormack map area; C) 20-m vertical section comprising sand and grading downward to cobble-sized gravel in the northeast corner of the Silver Mountain map area; D) Organic-till complex at low elevations in the north-central Silver Mountain map area.*

fans, plains and terraces and are mapped along modern river channels, including the Upper Humber, Whites and Adies rivers. Lastly, organic deposits, such as bog and fen, have been mapped in low-relief regions (primarily in Cormack map area) at low to moderate elevations (Plate 2D). They generally occur in bedrock depressions, over till blanket and till veneer.

TILL GEOCHEMISTRY

Elements of interest in the study area, based on MODS reports, are Au, Ni, Cu, Pb, Th, Ti and U. Ranges of measured values of these elements in till samples are presented below, including likely sources of anomalous values and correlations with other elements (Table 3).

Gold by INAA ranges from <2 (below detection limit) to 46 ppb. Anomalous Au (*i.e.*, ≥90th percentile) was identified in till samples collected in the northeastern Cormack and southeastern Silver Mountain map areas (Figure 3; Table 3). The highest Au content is in sample 18SH111-1015, collected above the North Brook Formation. Some of the till samples with anomalous Au in the southeastern Silver Mountain map area also contain anomalous Co, Cu and Ni. Anomalous Au in till in the southeastern Silver Mountain map area may be derived from Au occurrences in the Hampden map area (12H/10) which is farther up-ice (northeast) and outside the study area.

Nickel by ICP-OES ranges 19–212 ppm. Anomalous Ni is present in till samples collected in central and southeastern Silver Mountain, and central and southwestern Cormack map areas; one isolated till sample with anomalous Ni is also present in southeast Cormack map area (Figure 4). Nickel is not correlated with any other element; however, samples with anomalous Ni and Cr only occur in the south-

Table 3. Maximum concentrations of element of interest and their respective sample number, soil colour, location and provenance

Element	Maximum Concentration	Sample	NTS Map Sheet	UTM Coordinates NAD 27 Zone 21 Easting	Northing	Till Colour	Munsell Colour	Till Type	Provenance
Au	46 ppb	18SH111-1015	Silver Mountain (12H/11)	495546	5490627	dark reddish brown	5YR 3/2	Inconclusive	Outside the study area (?)
Cu	121 ppm	17SH111-1085	Silver Mountain (12H/11)	484306	5498178	grey	10YR 5/1	Till D	Long Range Inlier and/or Taylor Brook gabbro (?)
Ni	121 ppm	18SH111-1002	Cormack (12H/06)	466367	5459538	dark reddish brown	2.5YR 2.5/3	Till A + Till B?	Rocky Brook Formation and North Brook Formation (?)
Pb	99 ppm	18SH111-1018	Silver Mountain (12H/11)	498889	5491311	dark brown	7.5YR 3/3	Till A?	North Brook Formation
Ti	17133 ppm	17SH111-1078	Silver Mountain (12H/11)	490919	5495356	dark grey	7.5YR 4/1	Till D	Taylor Brook gabbro (and Long Range Inlier (?))
Th	34 ppm	17SH111-1068	Silver Mountain (12H/11)	499956	5497947	brown	7.5YR 4/4	Inconclusive	Southern White Bay allochton and rocks outside the study area (?)
U	15 ppm	17SH111-1032	Cormack (12H/06)	471806	5459756	brown	7.5 YR 5/3	Til A	Rocky Brook and Humber Falls formations (?)

west corner of Cormack map area. The highest Ni concentration (212 ppm) is present in till sample (18SH111-1002) collected in the southwestern Cormack map area. The till in this sample is dark reddish-brown to brown and likely derived in part from Rocky Brook and Humber Falls formations. However, the source of anomalous Ni is difficult to determine. Samples with anomalous Ni in the central and northeastern Silver Mountain map area are all likely derived from the Taylor Brook gabbro. Based on the spatial distribution of these anomalous values, it appears that Ni was dispersed during the earlier northeastern to southeastern glacial movement.

Copper by ICP-OES ranges 7–121 ppm. Anomalous Cu in till was only detected in the central and eastern Silver Mountain map area (Figure 5). Copper correlates well with Zn and Co, and samples with anomalous Cu overlying the Taylor Brook gabbro also have anomalous Co and Ni. Sample 17SH111-1085, collected over Taylor Brook gabbro, <1 km northeast (down-ice) of the Layden Ni occurrence within the Long Range Gneissic Complex in the central Silver Mountain map area, contained the highest Cu content (121 ppm). Further work is needed to determine whether this sample was derived from the Taylor Brook gabbro or the Layden Ni occurrence (which has secondary Cu).

Titanium by ICP-OES ranges 0.4–1.7 wt. %. Titanium correlates well with major elements Ca, Fe, Na, as well as Dy, Co, P, V, Sc, Sr and Y. There is a Ti occurrence (East Branch Brook Titanium #1) reported in southwestern Cormack map area, however none of the till samples with anomalous Ti are recovered from this area (Figure 6). Anomalous Ti is noted in till samples from east-central Silver Mountain map area over the Taylor Brook gabbro, and from several samples collected over the Long Range Gneissic Complex. Till samples with anomalous Ti collected over the Taylor Brook gabbro also contained anomalous concentrations of both Zn and Cu (*i.e.*, ≥90th percentile); however, Ti, Zn and Cu are not correlated in the dataset.

Lead by ICP-OES ranges <1 to 99 ppm and correlates well with Th, Sb, Rb, U, Cs, Li, As, Be, K and Zr. Anomalous Pb is predominantly noted in till samples collected in eastern Silver Mountain and southwestern Cormack map areas (Figure 7). Some of the samples that have anomalous Pb in the eastern Silver Mountain map area also contained anomalous concentrations of Au, Cu, Ni, As, Cr, Sb and Zn. The highest Pb content is in sample 18SH111-1018, collected <2 km southwest (down-ice) of Turners Ridge Pb occurrence in southeastern Silver Mountain. Glacial dispersal of Pb in the eastern Silver Mountain map area is interpreted as northeastward to southeastward during early glacial phases, and later re-entrained into till, dispersed to the southwest. This dynamic may

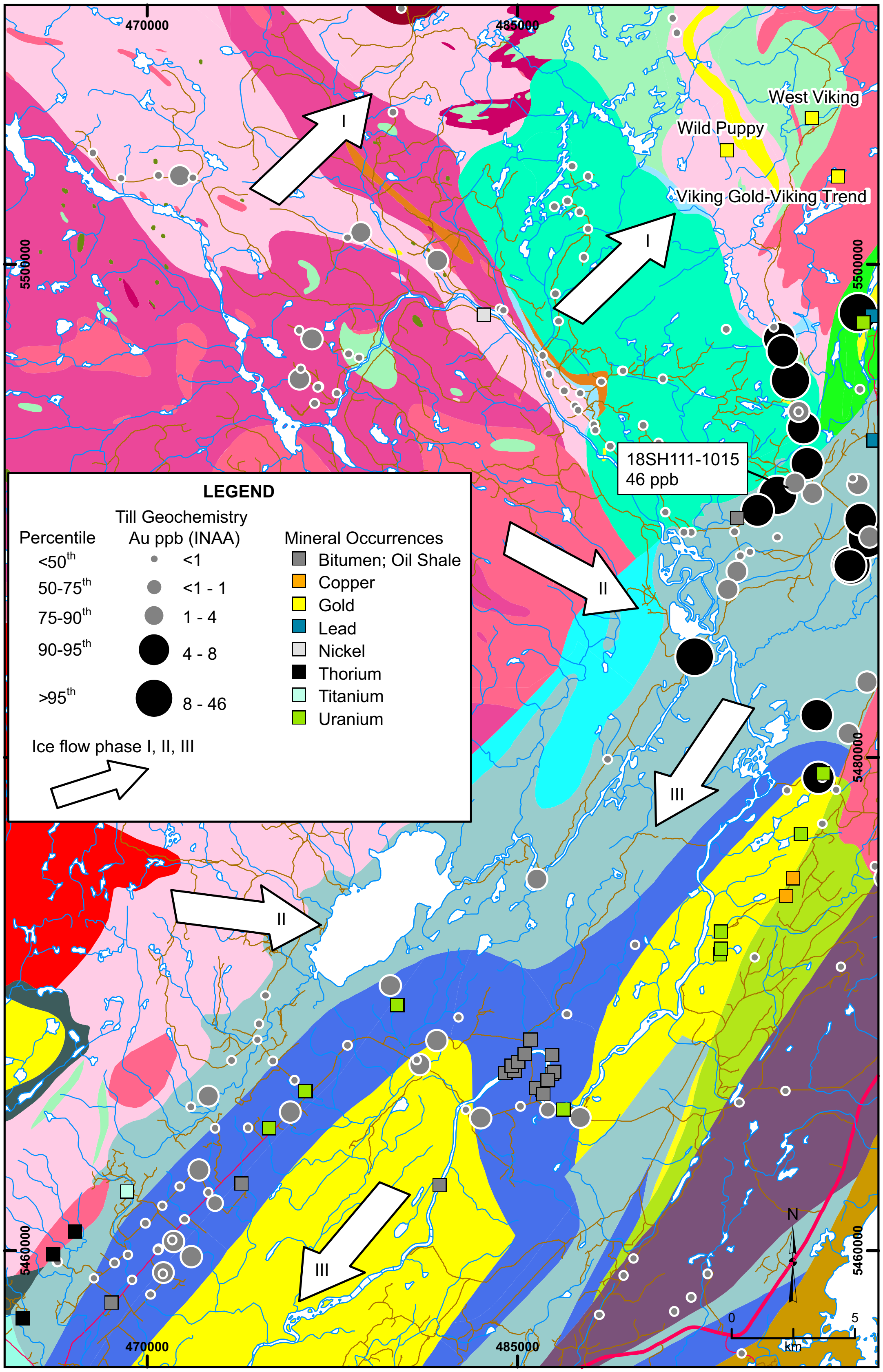

Figure 3. *Proportional dot plot of Au distribution in till samples; arrows indicate ice-flow movement in the study area.*

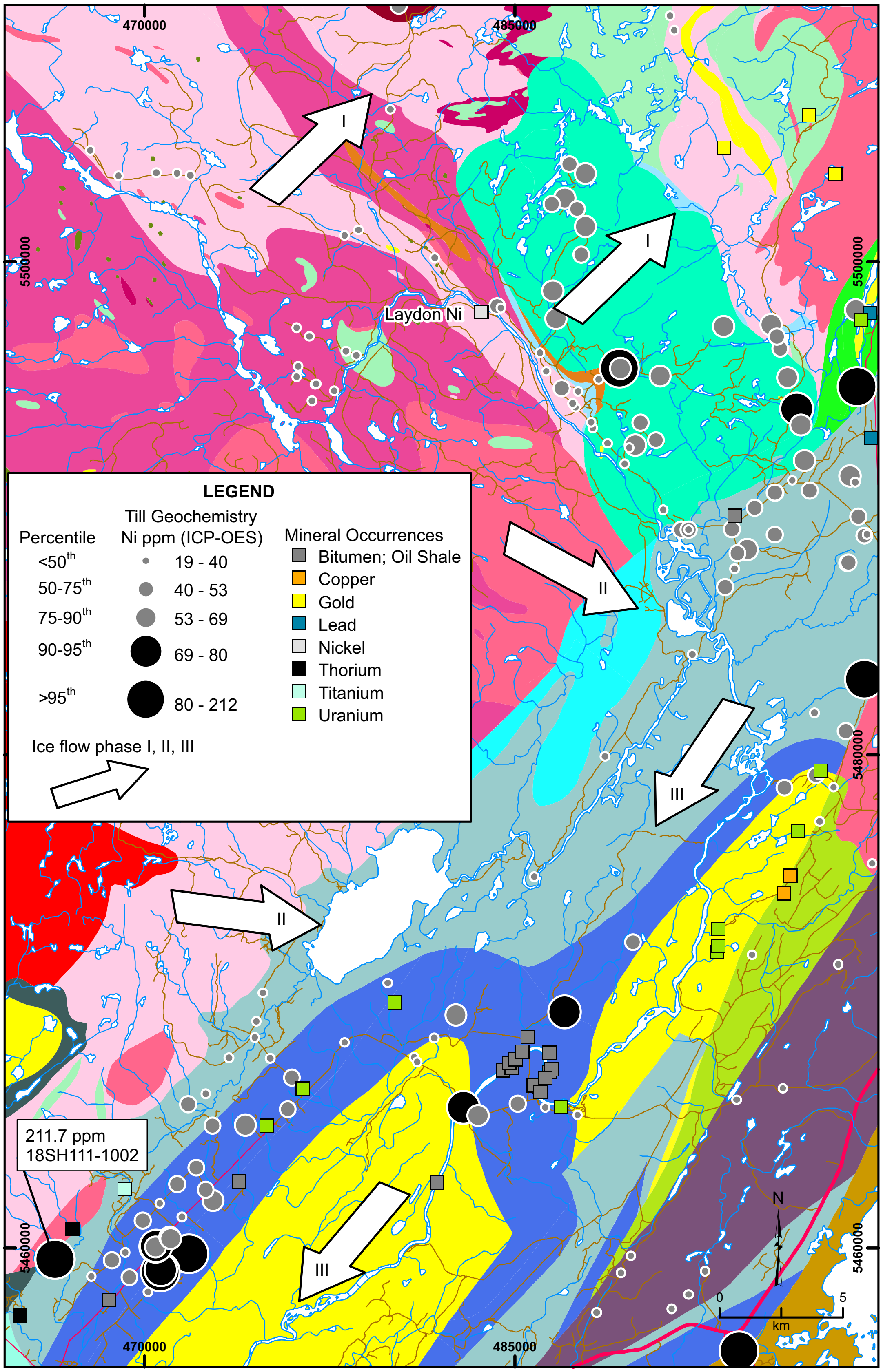

Figure 4. *Proportional dot plot of Ni distribution in till samples; arrows indicate ice-flow movement in the study area.*

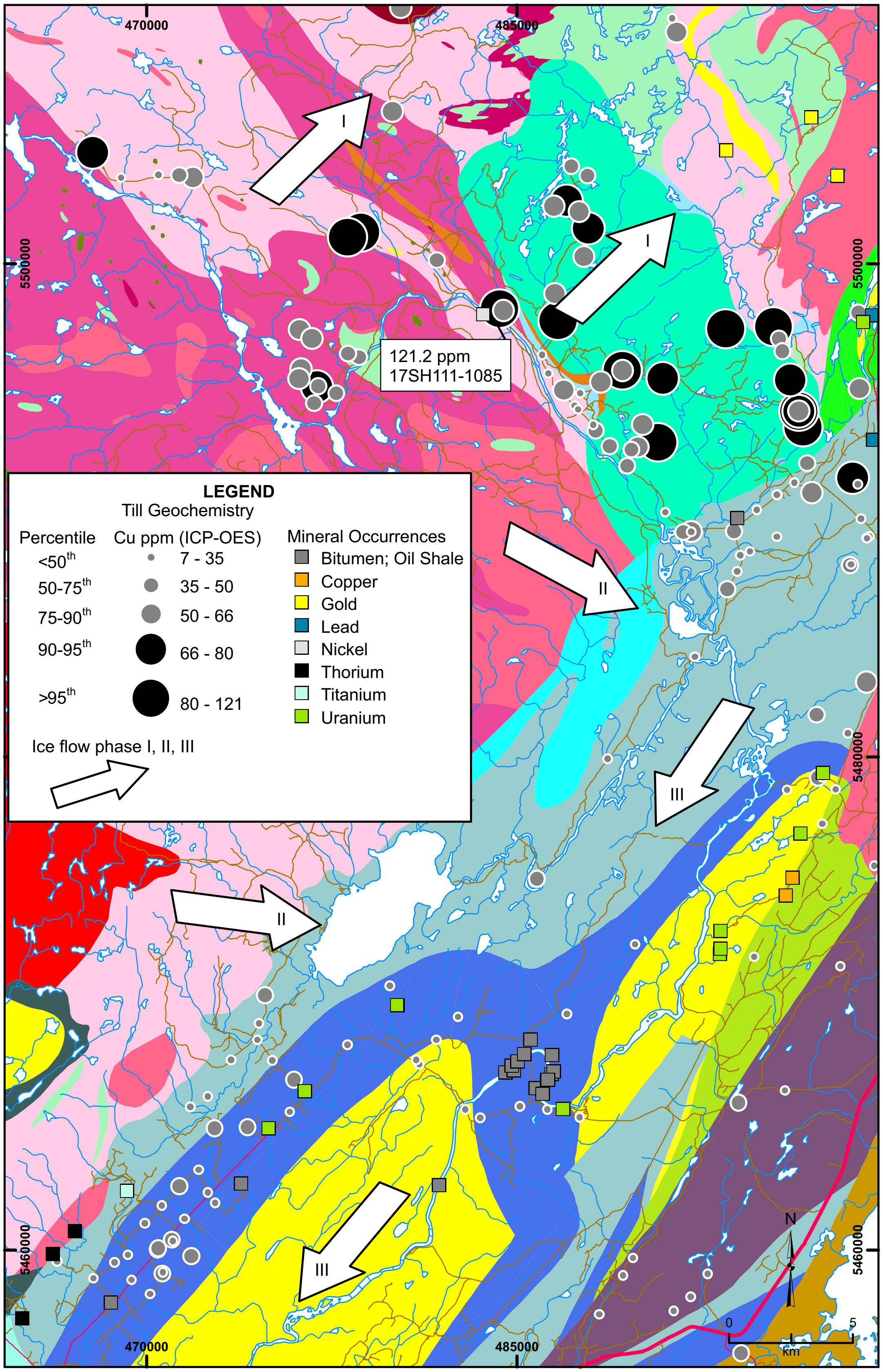

Figure 5. *Proportional dot plot of Cu distribution in till samples; arrows indicate ice-flow movement in the study area.*

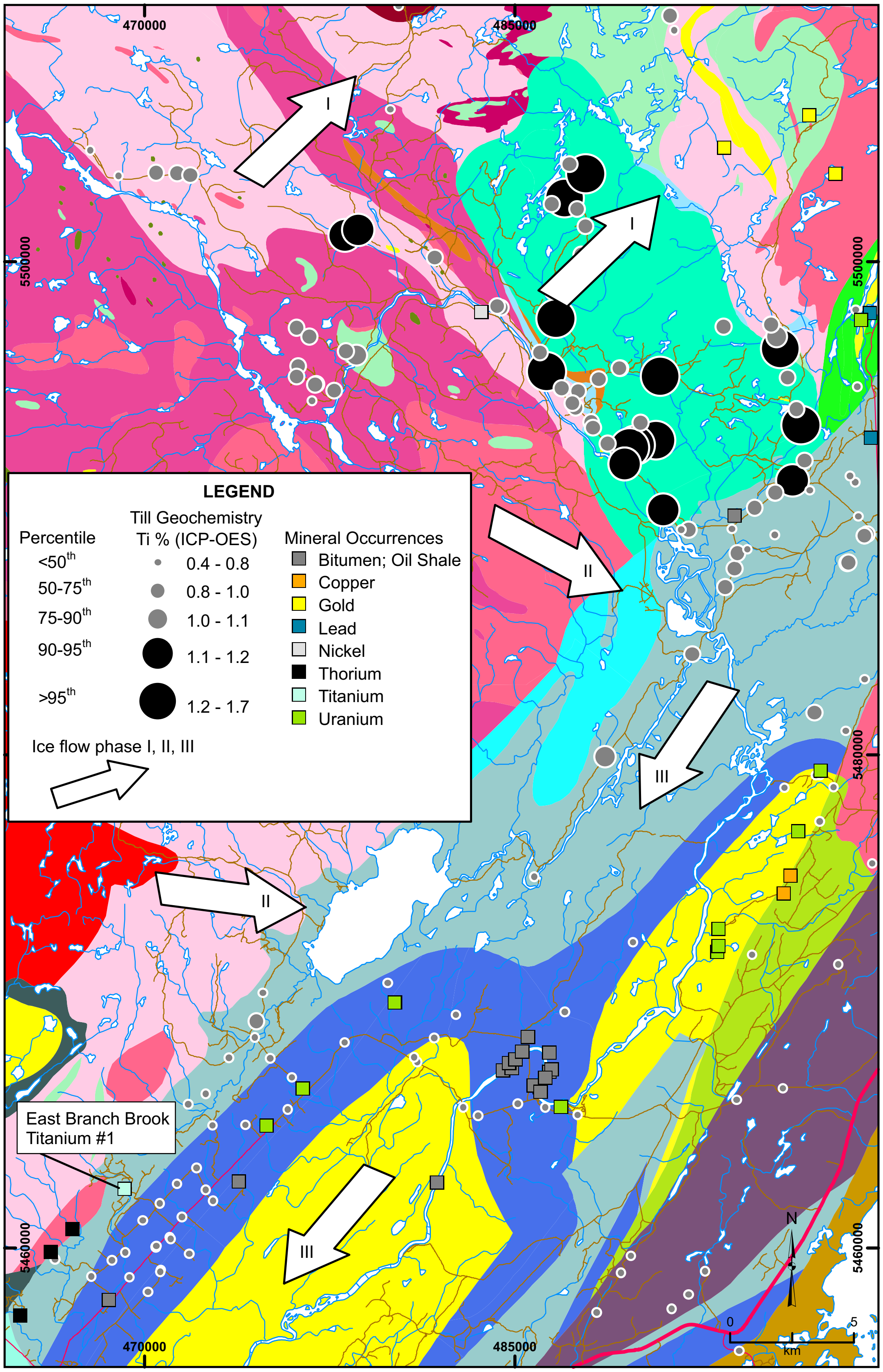

Figure 6. *Proportional dot plot of Ti distribution in till samples; arrows indicate ice-flow movement in the study area.*

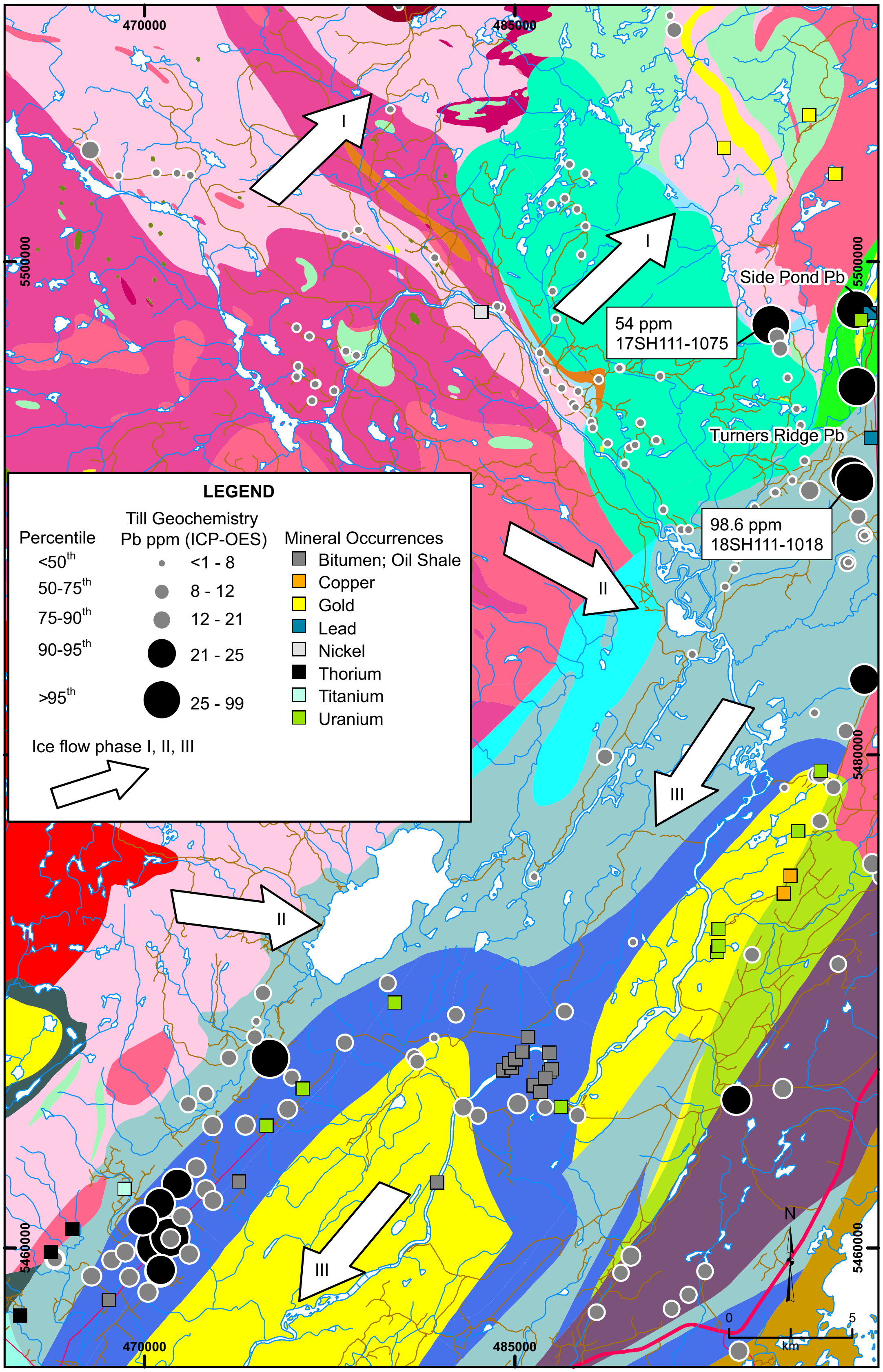

Figure 7. *Proportional dot plot of Pb distribution in till samples; arrows indicate ice-flow movement in the study area.*

explain the presence of anomalous Pb (54 ppm, sample 17SH111-1075) southwest of the Side Pond Pb occurrence. In southwestern Cormack map area, samples with anomalous Pb also contained anomalous concentrations of Ti, Th, U and Ni. These till samples, which vary from reddish brown to greyish brown, may suggest that they are derived from two distinct rock types (most likely the Humber Falls and Rocky Brook formations). Some of the Pb (as well as Zn) is likely to have been derived from the East Branch Brook Titanium #1 occurrence, which is reported to also contain Cu, Pb, Zn, Ag and U (Wilkinson, 1981).

Thorium by INAA ranges 3–34 ppm and correlates well with As, Pb, U, as well as Be, K, Li, Rb, Ta and Zr. Samples with anomalous Th content are in southwestern Cormack and southeastern Silver Mountain map areas (Figure 8). In the Cormack map area, some samples with anomalous Th also contained anomalous concentrations of As, Pb, Ni, Sb and U. In the southeastern Silver Mountain map area, some samples with anomalous Th also contain anomalous As, Au, Pb, Sb, U and Zn. Sample 17SH111-1068 contained the highest Th concentration (34 ppm); it was collected <1 km northeast of the Determination Zone U occurrence and was most likely derived from it.

Uranium by INAA ranges 1–15 ppm and correlates well with As, Be, K, Li, Pb, Rb, Th and Zr. Most of the samples with anomalous U are located in the southwestern Cormack map area, in close proximity to several U occurrences and most likely derived from them (Figure 9). The highest U concentration (15 ppm) was measured in sample 17SH111-1032, collected approximately 6 km southwest of the Cormack U occurrence. Only 2 samples in southeastern Silver Mountain map area contained anomalous U. Of these, sample 17SH111-1068 contains 6 ppm U and was collected <1 km northeast of Determination Zone U occurrence and was most likely derived from it.

CONCLUSIONS AND FUTURE WORK

New surficial mapping efforts in the Cormack and Silver Mountain map areas in western Newfoundland have resulted in an updated reconstruction of glacial ice flow and sediment deposition. This information is critical for the effective utilization of till geochemistry as a tool for prospecting and mineral exploration.

Lodgment till is the oldest and most extensively mapped Quaternary deposit type; four distinct, locally derived units have been identified in the study area. Till occurs as till veneer on steep slopes of the Long Range Mountains, as till blanket in low-relief regions, and as eroded till around meltwater channels. Glaciofluvial sand and gravel associated with glacial retreat is mapped as hummocks in valley bottoms, as a veneer in low-relief areas, and as eskers. Modern alluvial deposits (fans, terraces, plains) are mapped in valley bottoms, along river channels, and around lakes and meltwater channels. Organic deposits include peat in bogs, and fens are mostly mapped in low-relief regions at low to moderate elevations.

Three main ice-flow movements that influenced glacial dispersal in the study area, associated with the Late Wisconsinan glaciation, are documented. An initial (topographically defined) northeastward flow (I) at the onset of glaciation. This earliest flow initiated from the Long Range Mountains and later shifted toward the southeast (II). During glacial maximum, a latest southwestward flow (III) produced by flow deflection along an ice-divide by the coalescence of glaciers from the Long Range Mountains and the Topsails. This ice-flow chronology has produced a complex glacial dispersal regime in the region as noted in the element dispersal pattern down-ice of known mineral occurrences.

Documented mineral occurrences in the study area include Au, Cu, Ni, Pb, Ti, Th and U. Anomalous Au is noted in till samples in northeastern Cormack and southeastern Silver Mountain map areas. Even though Au does not show a strong positive correlation with any other elements, samples with anomalous Au also contain anomalous Co, Cu and Ni. Based on the dispersal dynamics, Au in till samples collected in southeastern Silver Mountain map area is likely derived from Au occurrences in the Hampden map area (NTS 12H/10), farther up-ice (northeast; earliest documented ice-flow direction) and outside the study area. It is recommended that future work focus on identifying the source of this Au. Anomalous Ni concentrations are noted in till samples collected in central and southeastern Silver Mountain and central and southwestern Cormack map areas, as well as one isolated sample in southeastern Cormack map area. The source of anomalous Ni content in the southeastern Cormack map area is difficult to determine; samples with anomalous Ni in the central and northeastern Silver Mountain map area are likely derived from the Taylor Brook gabbro. All anomalous Cu samples are located in the central and eastern Silver Mountain map area. Anomalous Cu in till samples overlying the Taylor Brook gabbro also had anomalous Co and Ni. Samples with anomalous Cu are likely to have been derived from the Long Range Gneissic Complex as well as the Taylor Brook gabbro. Anomalous Pb is predominantly noted in till samples collected in the eastern Silver Mountain and southwestern Cormack map areas. Some of the Pb in the southwestern Cormack map area is likely to have been derived from the East Branch Brook Titanium #1 occurrence. Most of the samples with anomalous Ti were collected in the east-central Silver Mountain map area and are likely derived from the underlying Taylor Brook gabbro. Till samples with anomalous Ti collected

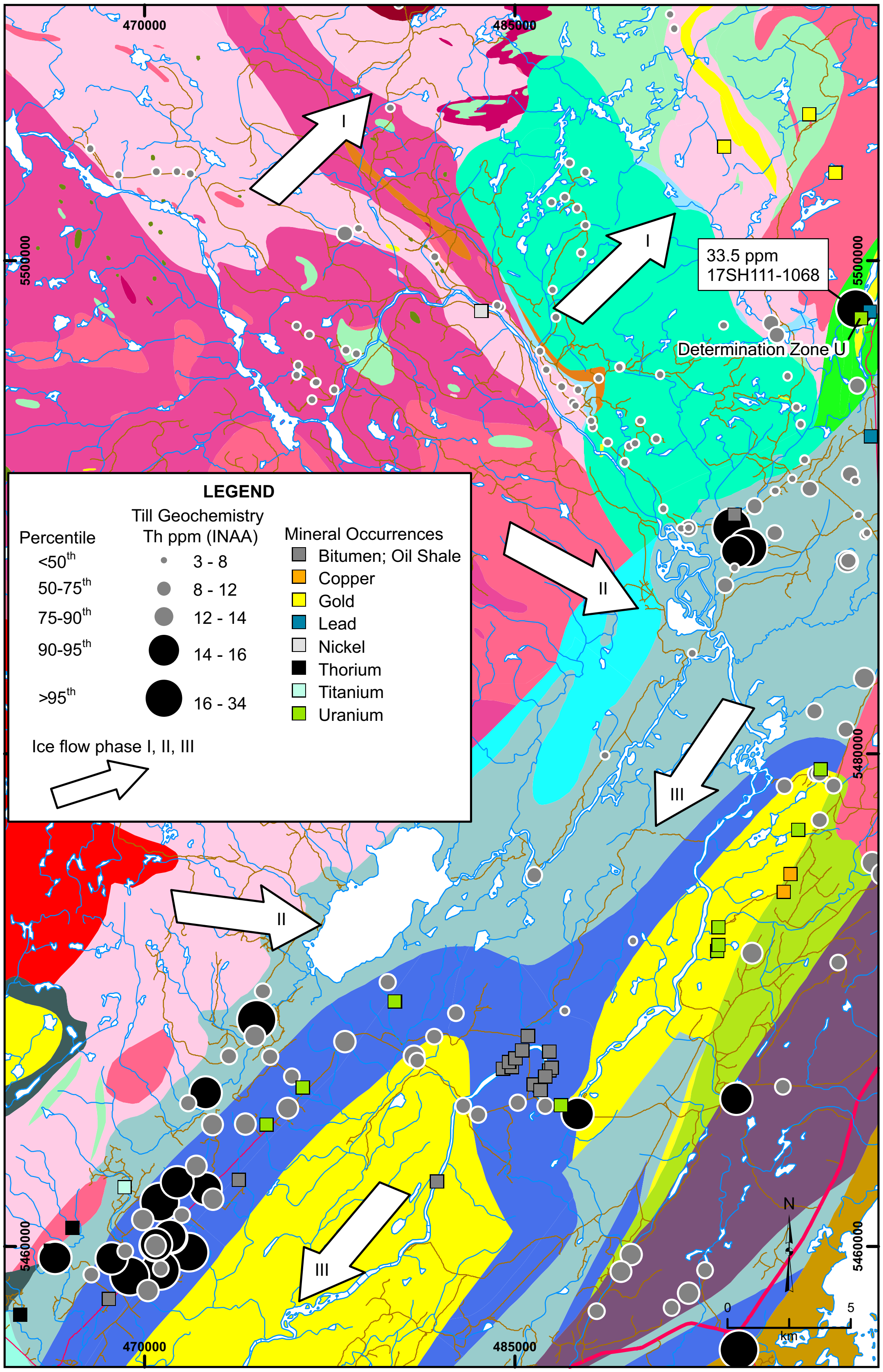

Figure 8. *Proportional dot plot of Th distribution in till samples; arrows indicate ice-flow movement in the study area.*

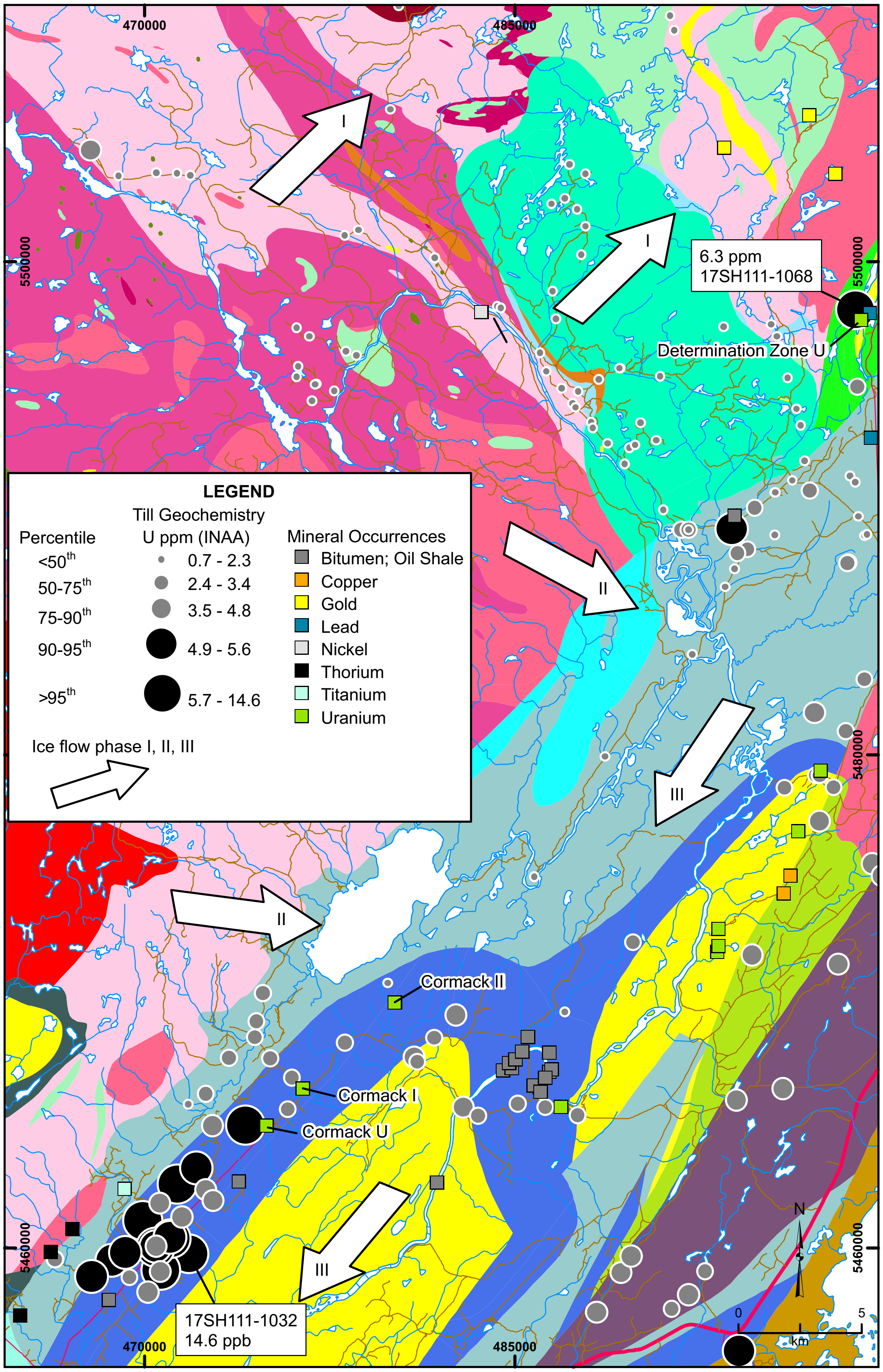

Figure 9. *Proportional dot plot of U distribution in till samples; arrows indicate ice-flow movement in the study area.*

over the Long Range Gneissic Complex are thought to be locally sourced. Samples that have anomalous U and Th are in the southwestern Cormack and southeastern Silver Mountain map areas. In the Cormack map area, some till samples with anomalous U and Th are in close proximity to the Cormack I and II, U and Th occurrences and are likely derived from them. In the southeastern Silver Mountain map area, a till sample with the highest U and Th concentrations is located <500 m east-southeast of the Determination Zone U occurrence and most likely derived from it.

As part of this study, 10 kg bulk till samples were collected for heavy-mineral separation and identification; however, the samples have yet to be analyzed. Further work in the region may benefit from the following:

1) Lithological study of the pebble (4–64 mm) fraction to determine rock types present within the till samples. This exercise can assist in deducing the most likely bedrock sources for the pebbles (as well as the silt and clay fraction geochemistry), and will refine our understanding of glacial flow direction and distance,

2) Heavy-mineral separation from bulk till samples to target robust indicator minerals of interest (*e.g.*, chalcopyrite, galena, gold grains, ilmenite) from which the respective elements discussed in this report (Cu, Pb, Au, Ti) may have been derived. Additionally, counts and textural characterization of gold grains in till may facilitate provenance studies (*e.g.*, abundant pristine gold grains suggest a proximal source) to better define the source of the gold and transport distance (DiLabio, 1991). This additional work may help in better delineating surficial geochemical (and buried mineralogical) targets for follow up work, and

3) Study of indicator-mineral chemistry *via* scanning electron microprobe (SEM) and laser ablation ICP-MS to determine distinct lithological provenance of individual indicator mineral grains.

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