

Heavy Mineral Analysis of Till Samples within the QUEST Project Area, Central British Columbia (NTS 093J)

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Introduction

The McLeod Lake map area (NTS 093J), within Geoscience BC's Quesnellia Exploration Strategy (QUEST) Project area, has shown good potential for Cu and Au porphyry and volcanogenic massive sulphide (VMS) mineralization (Ward et al., 2011). Previously, mineral exploration activity has been hindered in this area due to the thick cover of surficial deposits, therefore, regional-scale till sampling has been carried out to target potential zones of mineralized bedrock. Detailed investigations of regional-scale till samples with elevated or anomalous values help identify potentially mineralized zones within covered bedrock units (e.g., Levson, 2001; McClenaghan et al., 2002; McClenaghan, 2005). The preferred sampling medium for till geochemical surveys is basal till, as it is commonly considered a first derivative of bedrock (Dreimanis, 1989; Levson, 2001). In its entirety, this Quaternary geology project is designed to provide both regional and detailed till geochemical surveys and the Quaternary framework necessary to interpret these data. Geochemical data from this project provide new exploration targets and also provide geological context for companies to interpret their own geochemical and geological datasets. This report adds to previous Geoscience BC publications that have dealt with the Quaternary geology (Ward et al., 2009; Sacco et al., 2010) and analysis of the clay and silt+clay fractions of basal till by inductively coupled plasma–mass spectrometry (ICP-MS) following aqua-regia digestion and induced neutron activation analysis (INAA; Ward et al., 2011). This paper discusses INAA results from the heavy mineral fraction of 136 samples from six 1:50 000 map areas in the QUEST Project area (Figure 1).

Keywords: *geochemistry, regional till geochemical survey, heavy minerals, Cu-Au porphyry, VMS*

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Physiography, Bedrock and Quaternary Geology

The study area occurs in the heart of the QUEST Project area, northwest of Prince George. The majority of this area lies in the relatively low relief area of the Interior Plateau (Mathews, 1986), including its subdivisions, the Fraser Basin and Nechako Plateau. It is characterized by glacial lake deposits, drumlinized drift and glaciofluvial outwash and esker deposits (Holland, 1976).

The majority of the study area straddles four of the terranes that make up the Canadian Cordillera (Cache Creek, Slide Mountain, Quesnel, Kootenay) whereas the most north-eastern corner of it extends into the Rocky Mountain assemblage. The Quesnel terrane dominates the study area and is composed primarily of Late Triassic to Early Jurassic arc volcanic rocks of the Witch Lake succession and volcanoclastic rocks of the Cottonwood River succession, both part of the Nicola Group (Logan et al., 2010). The Cache Creek terrane is composed of Pennsylvanian and Permian limestone in the southwestern portion of the study area, with basalts occurring just to the south of the study area. A complex assemblage of intrusive and extrusive rocks of the Slide Mountain terrane occurs in the east. The Rocky Mountain assemblage in the northeastern corner of the study area comprises Silurian to Devonian sandstone and quartzite. Stratigraphically overlying these terranes are a series of overlap assemblages ranging from Upper Cretaceous to Miocene sedimentary rocks and Cretaceous to Pliocene volcanic rocks (Struik, 1994; Logan et al., 2010). See Figure 1 for a more comprehensive presentation of the bedrock units of the study area.

The study area was repeatedly affected by the Cordilleran Ice Sheet over approximately the last two million years (Armstrong et al., 1965; Clague, 1989), the most recent being during the Fraser glaciation. The major sources of regional ice that covered the study area advanced from accumulation centres in the Coast, Skeena and Cariboo mountains (Tipper, 1971; Levson and Giles, 1997; Plouffe, 1997, 2000). The dominant ice flow direction in the study area, and thus main sediment transport, was northeasterly

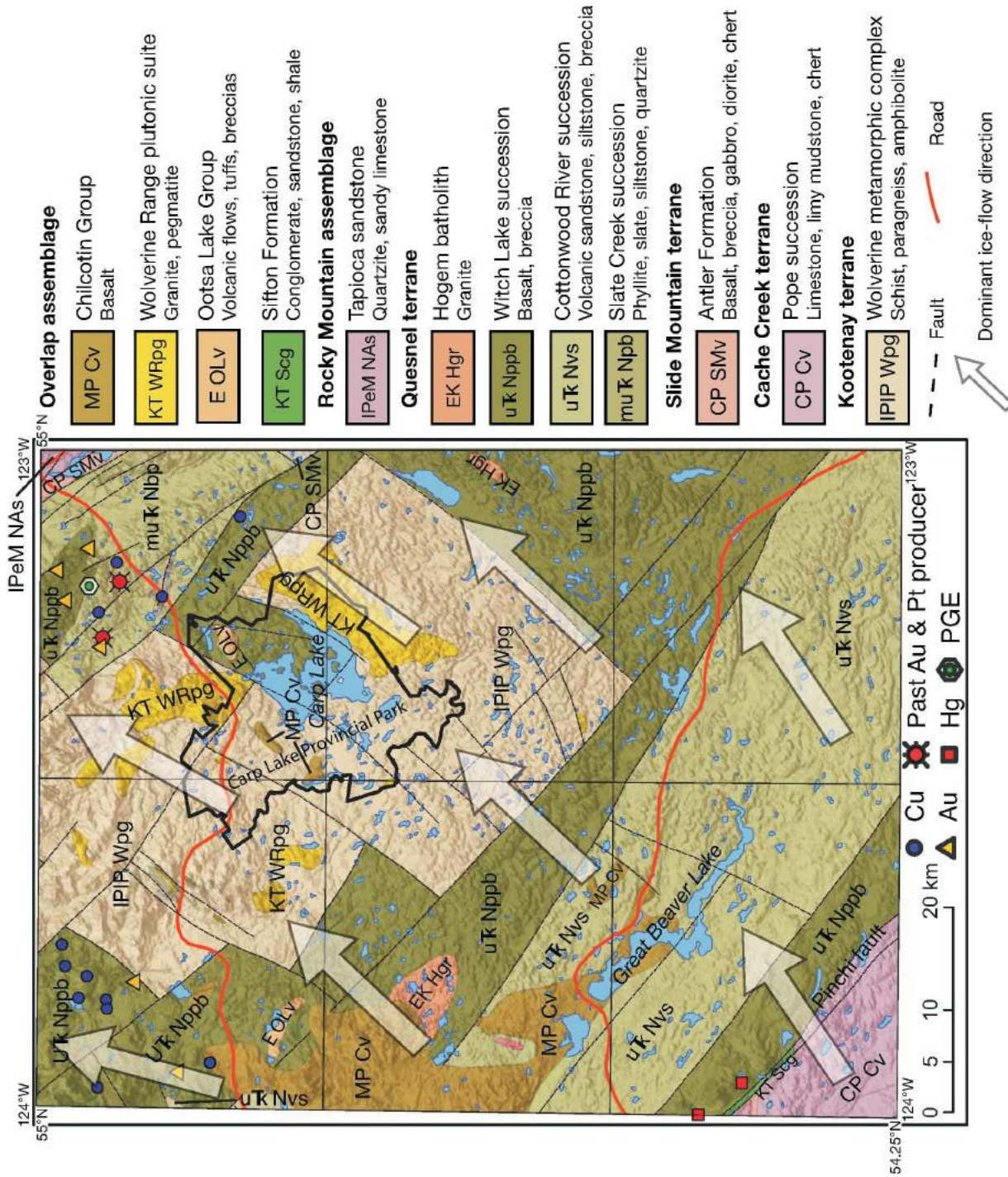


Figure 1. Major bedrock geological units of the study area, central British Columbia (modified from Struik, 1994 and Logan et al., 2010). Also shown are mineral occurrences for different commodity types (after BC Geological Survey, 2011) and the dominant ice-flow direction (light-coloured arrows; after Sacco et al., 2010).

with minor deviations to a more northerly direction in the north and a more easterly direction in the southern portions of the study area. Little information exists on ice flow during the glacier's advance into the area, but it is likely that ice flowed eastward from the Coast Mountains and was subsequently deflected to the northeast by interaction with ice flowing north from sources in the Coast and Cariboo mountains to the south (Plouffe, 1997, 2000).

The regional Quaternary framework and bedrock geology are described in more detail in Sacco et al. (2010) and Ward et al. (2011).

Field and Analytical Methods

Field Sampling

Basal till samples were collected at a total of 712 sites. The sampling regime included collecting three separate 800–900 g samples at each sample site for: 1) analysis of the clay-sized (hereafter referred to as clay) fraction by aqua-regia digestion followed by ICP-MS at Acme Analytical Laboratories Ltd. (Vancouver); 2) analysis of the clay plus silt-sized (hereafter referred to as clay+silt) fraction by INAA at Activation Laboratories Ltd. (Ancaster, Ontario); and 3) archiving at the Geological Survey of Canada. In addition, at every 4–5 sites (136 samples in total), a 10–15 kg sample was collected for heavy mineral separation and gold grain counts. The heavy mineral separations and counts were conducted at Overburden Drilling Management Limited (Nepean, Ontario). The <0.25 mm fraction of the heavy mineral concentrates were then analyzed by INAA at Becquerel Laboratories Inc. (Mississauga, Ontario). Results of the ICP-MS analysis, INAA and some heavy mineral grain counts were reported and discussed in Ward et al. (2011), and heavy mineral INAA results and selected grain counts from the large samples are reported here.

Analytical Methods

Heavy mineral concentrates were separated on large till samples at Overburden Drilling Management Limited. One hundred and thirty-six samples, 10–15 kg each, were panned for gold grains, platinum group metals (PGM) and uraninite. Bulk samples were disaggregated, followed by separation of the >2 and <2 mm fractions. The <2 mm fraction was then pre-concentrated on a shaking table, with the finest, heaviest fraction being panned. Gold, uraninite and PGM were then examined under optical microscope to provide grain counts as well as grain morphology. More detailed descriptions of the methods are provided in Averill (2001). Sulphide and cinnabar grains were also counted, although where the number of grains was >20, these counts are estimates.

The table concentrate was then sieved and the <0.25 mm fraction subsequently separated using heavy liquid at

3.2 g/cm³. This <0.25 mm fraction was then analyzed by INAA at Becquerel Laboratories Inc. under their BQ-NAA-1 package with the addition of Hg. Samples were placed in vials and were stacked into 30 cm long bundles for irradiation at the McMaster Nuclear Reactor (Hamilton, Ontario), which has flux of 8×10^{12} neutrons/cm²/sec. After a typical decay period of six days, the irradiated samples were loaded onto a high resolution, coaxial germanium detector that constructed a spectrum of gamma-ray energies versus intensities. The counting time was twenty to thirty minutes per sample. Quantitative elemental contents were derived by comparison of peak positions and area with library standards. Several elements, such as Hg, Ni, Zr, Rb, Au, had variable and higher than usual detection limits because of very high Cr, REE and Th contents (S. Simpson, personal communication, 2011). For example, Au usually has a detection limit of 2 ppb but here it ranges from 5 to 42 ppb depending on the sample.

Results

Au, As and Hg Contents

All till samples processed for heavy minerals ($n = 136$) contain visible gold (Figure 2a; Ward et al., 2011). Not surprisingly, the distribution of Au contents in the heavy mineral concentrates (Figure 2b), determined by INAA, mimics the Au contents in the silt+clay fraction, previously determined by INAA (Ward et al., 2011, Figure 4b). In the heavy mineral analysis, Au ranges from below detection (5–42 ppb depending on the sample) to 2630 ppb. Gold contents show clearly anomalous values around the 95th percentile (~750 ppb), although there is also a subtle change in the slope around the 80th percentile (~400 ppb). The highest values correspond to the area identified as having potential porphyry Cu-Au-style mineralization (cf. Ward et al., 2011). The highest gold grain numbers and INAA contents are associated with the margin between gravity lows and higher values (Figure 2b). This likely represents the contact between the felsic intrusions of the Wolverine metamorphic complex and the more mafic rocks of Quesnel terrane.

Arsenic is typically considered a pathfinder element for Au. Arsenic contents range from 9 to 414 ppm, show clearly anomalous values around the 95th percentile (60 ppm). The spatial distribution of As contents mimic those of Au and most anomalous values are in the north-western part of the study area, coincident with the margin of low gravity values with higher values, with slightly lower contents in the northwest (Figure 3a).

Cinnabar counts range from 0 to 400 grains. Anomalous cinnabar grain counts (>60 grains) occur in the western part of the study area, and mark the start of a trend of decreasing values to the southeast (Figure 3c). Because of the large number of cinnabar grains identified, the samples were also

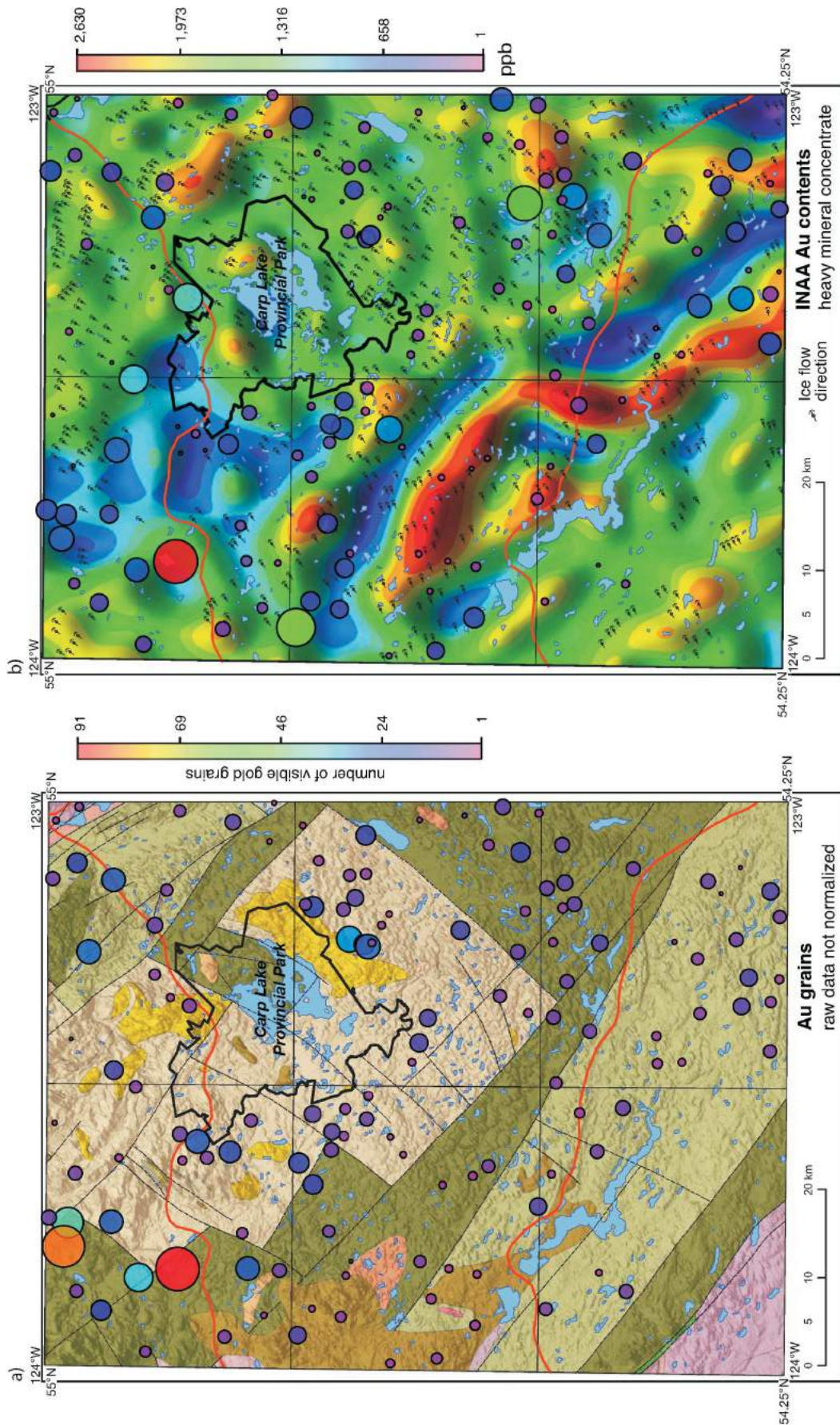


Figure 2. Proportional dot maps of Au contents in heavy mineral separates from till samples: **a)** Au grain counts, with data overlain on the bedrock geology map presented in Figure 1, and **b)** Au contents by instrumental neutron activation analysis (INAA), with data overlain on a gravity geophysical map (gravity highs in red; lows in blue) modified from Sanders Geophysical Limited (2008) with ice flow from Tipper (1971).

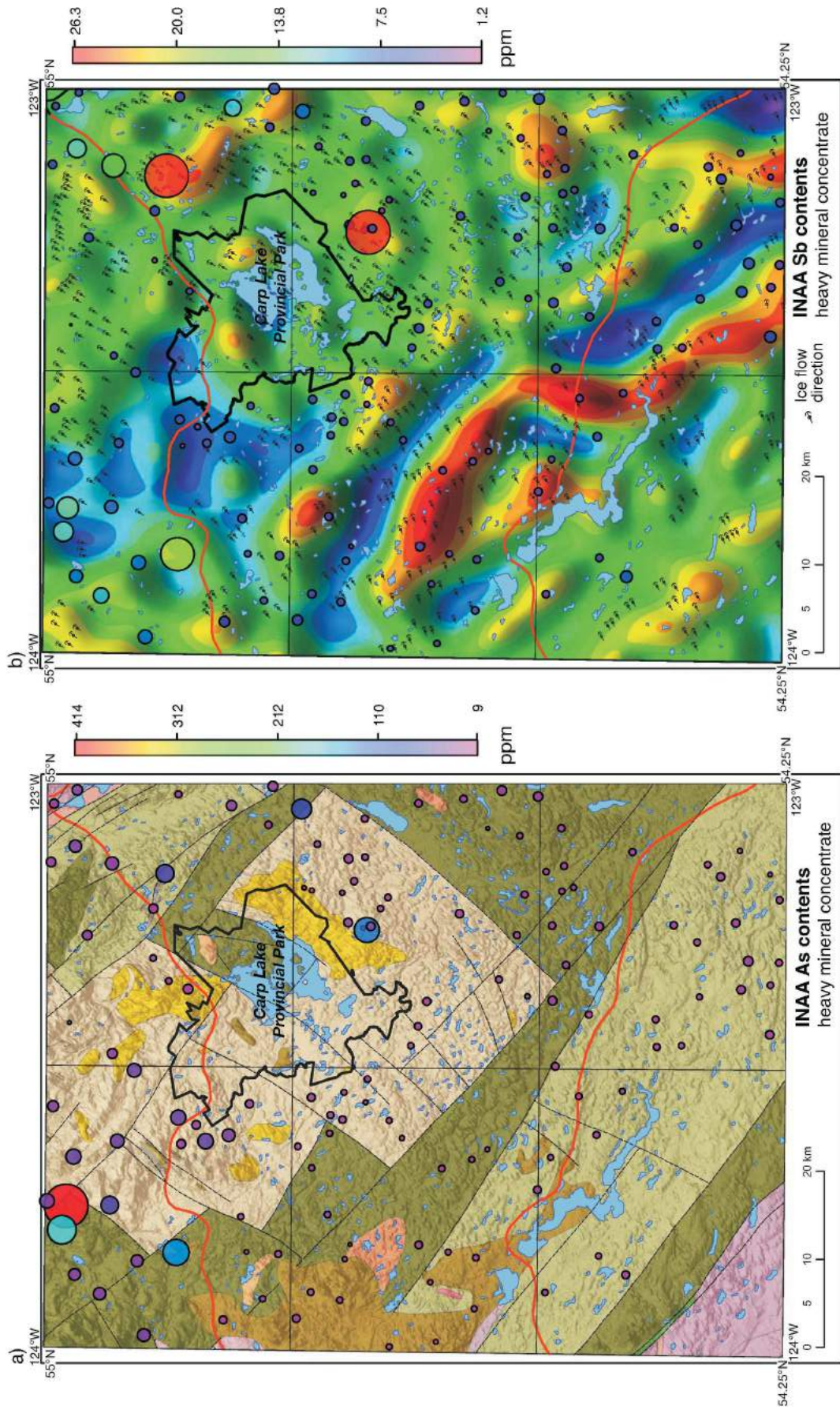


Figure 3. Proportional dot maps of selected elements in heavy mineral separates from till samples: **a)** As contents by instrumental neutron activation analysis (INAA), with data overlain on the bedrock geology map presented in Figure 1, and **b)** Sb contents by INAA, with data overlain on a gravity geophysical map (gravity highs in red; lows in blue) modified from Sanders Geophysical Limited (2008) with ice flow from Tipper (1971).

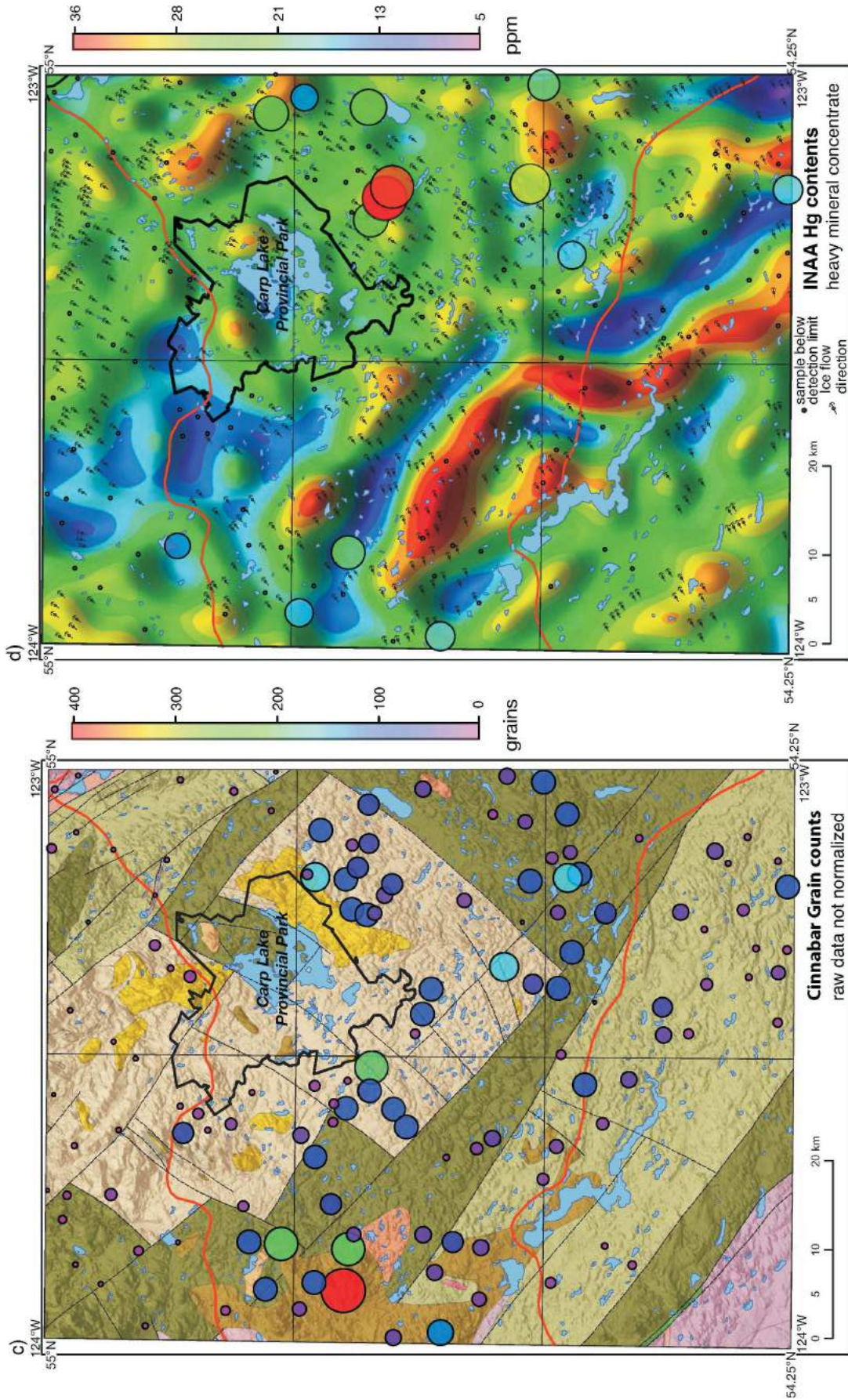


Figure 3 (continued). Proportional dot maps of selected elements in heavy mineral separates from till samples: **c)** cinnabar grain counts, with data overlain on the bedrock geology map presented in Figure 1, and **d)** Hg contents by instrumental neutron activation analysis (INAA), with data overlain on a gravity geophysical map (gravity highs in red; lows in blue) modified from Sanders Geophysical Limited (2008) with ice flow from Tipper (1971).

analyzed for Hg by INAA (Figure 3d); unfortunately, because of detection limit issues, due to interference with other elements, only 14 samples have values above detection limit. These samples are on the western and eastern sides of the study area and do mimic highs in the cinnabar grain counts. Also plotted are Sb contents as Sb is commonly associated with Hg (Figure 3b). Antimony is also a common pathfinder element of porphyry Cu-Au and VMS mineralization. The two highest values are to the southeast and northeast of Carp Lake, with intermediate values in the northwest, the zone of potential porphyry Cu-Au-style mineralization.

Ce, Th, Cr and Ta Contents

The basal till geochemical results presented by Ward et al. (2011) show that values for rare earth elements (REE), U, Th, K, Ca, Mg, Na, Ni and Cr have spatial relationships that are consistent with changes in the dominant underlying bedrock lithology. Thus, incompatible elements that are enriched in felsic rocks (i.e., REE, U, Th, K and Hf) are elevated in the northern part of the study area coincident with the Wolverine metamorphic complex, which contains felsic rocks such as granitic pegmatite, granite, granodiorite and rhyolite (Struik, 1994). Ni and Cr contents are highest in the south-southwestern portion of the study area where mafic and volcanoclastic rocks of the Quesnel terrane occur (Struik, 1994). The INAA determinations on the heavy mineral fraction presented here show a similar spatial distribution of elements. High Ce, Th and Ta contents in the north to northwest suggest more felsic rocks, likely the granitic pegmatite, granite, granodiorite and rhyolite and/or more enriched mafic rocks; whereas high Cr contents in the south indicates more primitive mafic rocks (Figure 4a-d). There is the possibility that the Cr could be derived from ultramafic rocks to the southwest in the Cache Creek terrane (Struik, 1994; Logan et al., 2010). If the Cr contents were derived from these ultramafic rocks, this would represent the longer distance of glacial transport associated with the thicker till in this area. The thinner till in the northern portion of the study area is thought to have a more local signature, reflecting local bedrock with a shorter distance of glacial transport.

Till Geochemical Exploration

The INAA determinations on heavy mineral concentrates presented here add to the previously published data and begin to build a coherent story on the potential for metallic mineralization in the study area. The spatial distribution of Au, As and Sb contents confirm the potential for epigenetic Au-Cu mineralization and to a lesser extent porphyry Cu-Au in the northeastern and northwestern areas of the study area, respectively. With >30 samples having Au contents >400 ppb, there is the potential for mineralized bedrock to occur there. Gold anomalies commonly coincide with

anomalies in other pathfinder elements, such as As and Sb. Although only a limited number of values are above detection limit, the spatial distribution of Hg values from the heavy mineral concentrate does mimic the distribution of cinnabar grains. Areas with elevated INAA values and grain counts may be associated with faults similar to the Pinchi Lake fault.

Elevated light REE and Th in the northern part of the study area are coincident with, and located down-ice from, granite pegmatite, granite and granodiorite suggesting the possibility of REE mineralization being associated with felsic porphyry bodies in the area, especially in the zone of gravity lows in the northwestern portion of the study area. Previous studies by the authors on the clay+silt and clay fractions of tills in the study area and the presence of large numbers of pyrite/marcasite grains in some of the heavy mineral concentrate samples suggest possible VMS mineralization (Ward et al., 2011). However, the inherent limitations of the INAA method (e.g., lack of Cu and Pb determinations and high detection limits for Zn, Cd and Ag) mean that INAA determinations presented here on heavy mineral concentrates do not add any insight into the potential for VMS-style mineralization within the study area.

Conclusions

The INAA of the <0.25 mm fraction of the heavy mineral concentrate of till samples adds insight into the interpretation of regional till geochemistry for the McLeod Lake map area. The potential for epigenetic Au-Cu mineralization, and to a lesser extent porphyry Cu-Au mineralization, in the northeastern and northwestern areas of the study area, respectively, is confirmed by the distribution of Au, As and Sb contents presented here. The few samples with Hg contents above detection limit mimic the distribution of cinnabar grains, implying there could be mineralization along faults in the area. Elevated Th and light REE in the northern part of the study area suggest the possibility of REE mineralization in association with felsic intrusions. The INAA data from heavy mineral concentrates does not add any insight in to potential VMS mineralization in the study area due to inherent limitations of the INAA method. All geochemical data from the Quaternary project will be released in early 2012 as a Geoscience BC report.

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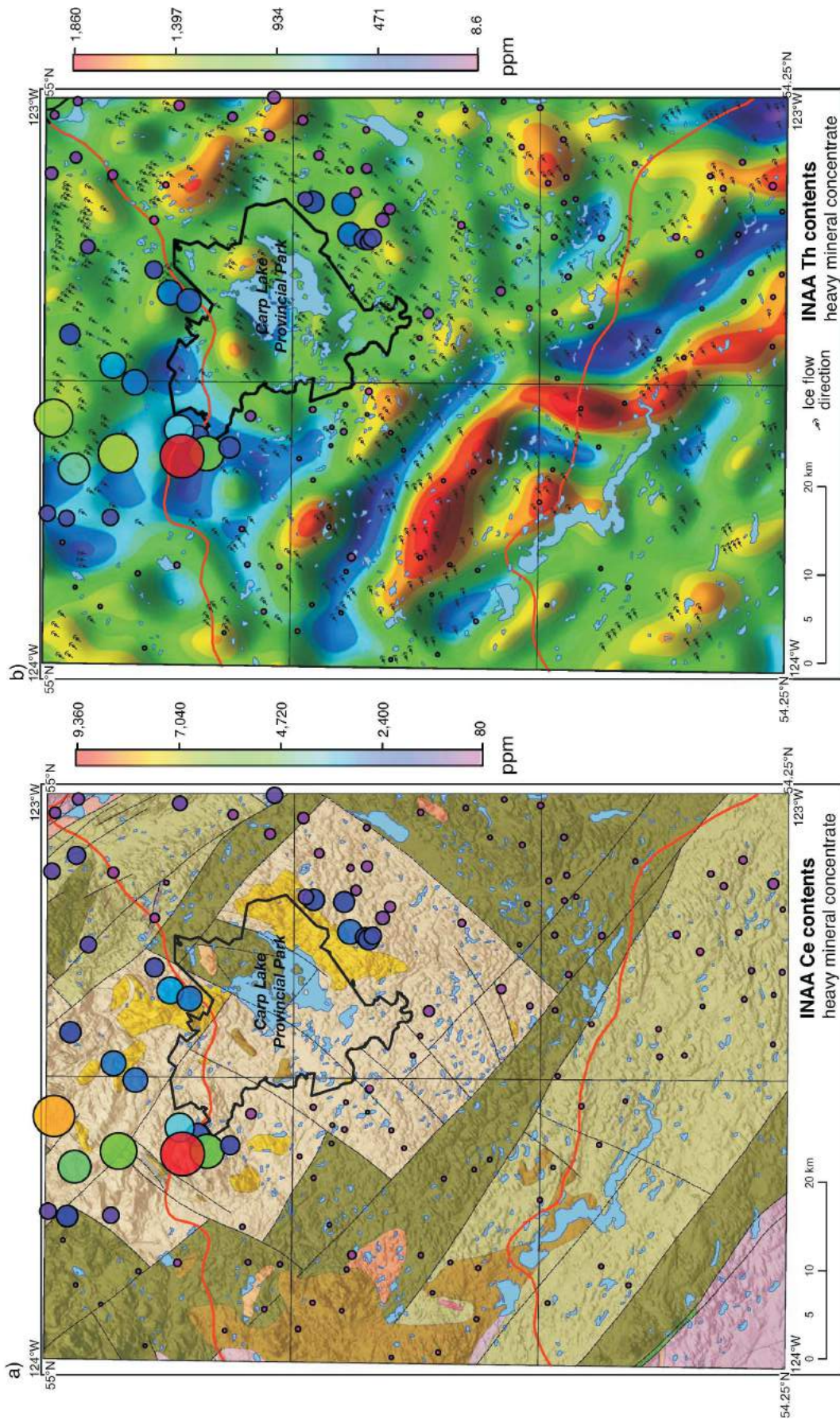


Figure 4. Proportional dot maps of selected elements in heavy mineral separates from till samples: **a)** Ce contents by instrumental neutron activation analysis (INAA), with data overlain on the bedrock geology map presented in Figure 1, and **b)** Th contents by INAA, with data overlain on a gravity geophysical map (gravity highs in red; lows in blue) modified from Sanders Geophysical Limited (2008) with ice flow from Tipper (1971).

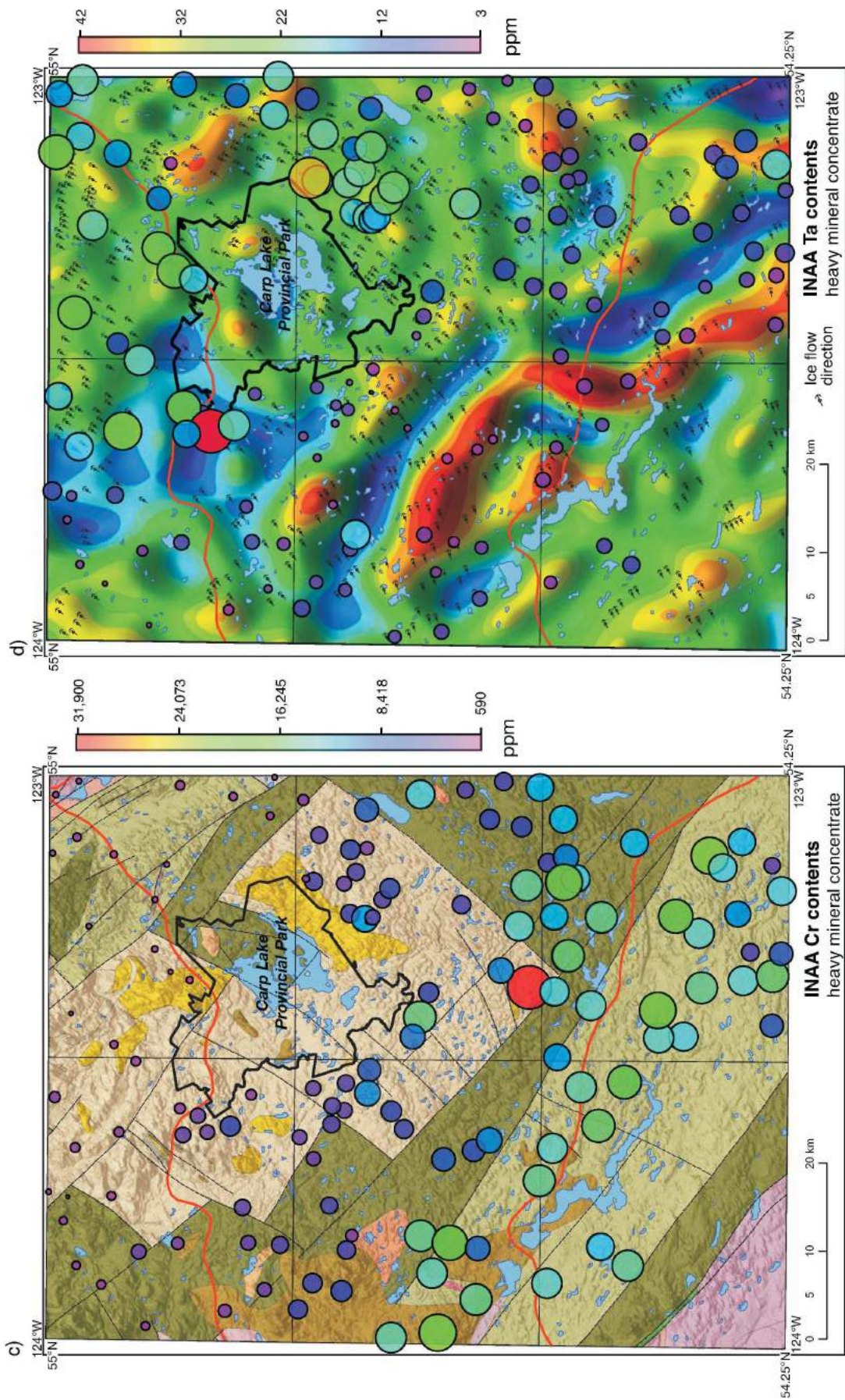


Figure 4 (continued). Proportional dot maps of selected elements in heavy mineral separates from till samples: **c)** Cr contents by instrumental neutron activation analysis (INAA), with data overlain on the bedrock geology map presented in Figure 1, and **d)** Ta contents by INAA, with data overlain on a gravity geophysical map (gravity highs in red; lows in blue) modified from Sanders Geophysical Limited (2008) with ice flow from Tipper (1971).

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