Catching the tail of a golden dragon plus 60 elements in British Columbia

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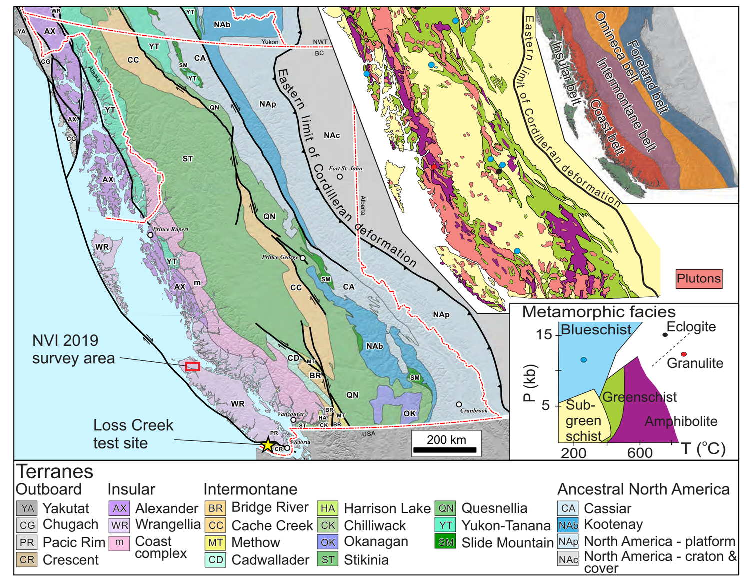
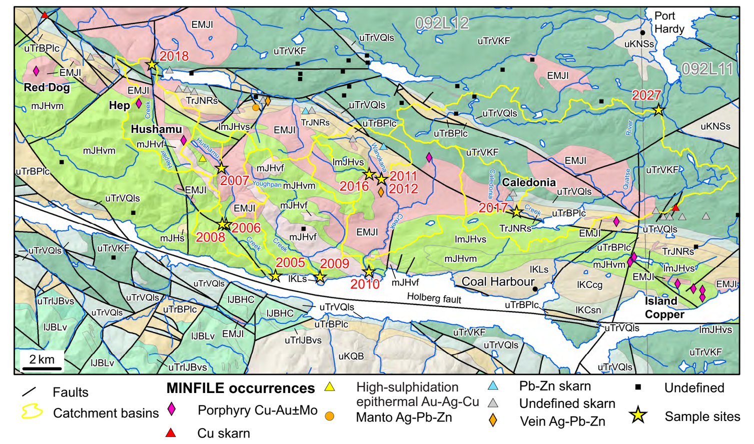
Introduction

Regional geochemical surveys support the societal resource base by identifying prospective areas for large-tonnage economic deposits of a wide range of commodities, including non-traditional deposit-types in undeveloped and underexplored regions. With the objective of developing geochemical exploration methods that are both effective and inexpensive, herein we use the <1 mm fraction of heavy mineral concentrate (HMC) samples (200-400 g) from several Vancouver Island drainages recovered by sluicing and panning of 11-16 kg of the <2 mm fraction of bulk alluvium in the field. Analysis of the field-processed HMC samples greatly enhanced the geochemical anomaly contrast and confidently identified visually confirmed mineralization even at the mouths of third- to fifth-order streams, many km downstream from known mineralization. In contrast, analysis of the conventional stream and moss-capturing sediments commonly failed to detect even proximal mineralization. The prognostic geochemical resources not only confirm known base and precious metal deposits, but also indicate a large, unconventional type of a placer garnet-hosted HREE-Y-Sc-Mn deposit and other 'critical' commodities. We propose a three-stage method for drainage geochemical surveys that is rapid, inexpensive, and effective (see Rukhlov et al., 2020).

Location of survey areas



Northern Vancouver Island area



Sampling

HMC samples were recovered from the wet-sieved <2 mm fraction of alluvium (11-16 kg) using a portable, gas-powered, 2.5 cm-diameter water pump.

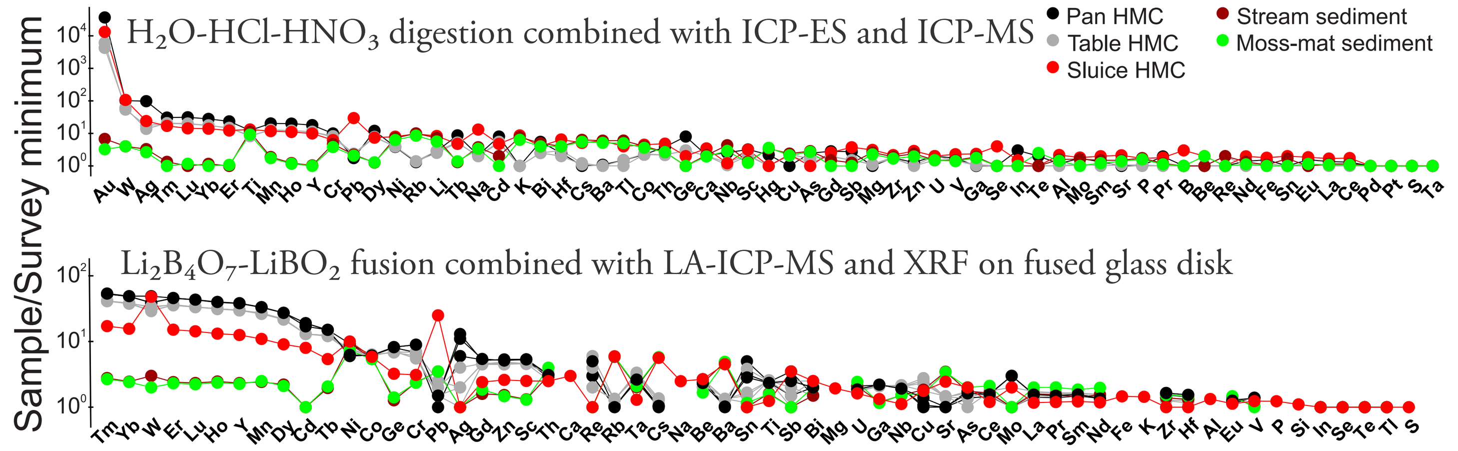
We used a mini-sluice box (25.5 x 91.4 x 11.4 cm), lined with a grooved rubber matting and coupled with a hopper fitting a garden hose. The sluice operated at a consistent forward slope of 10-11° and water flow of 33-35 L/min, supplied by a 2.5 cm-diameter pump.

The sluice concentrate was then refined by quick panning to wash off coarse low-density minerals, yielding 200-500 g (wet mass) HMC samples, which retain sulphides and other heavy minerals as opposed to hard-panned 'black sand' with specific gravity >5 g/cm³.

Preparation, analysis and results

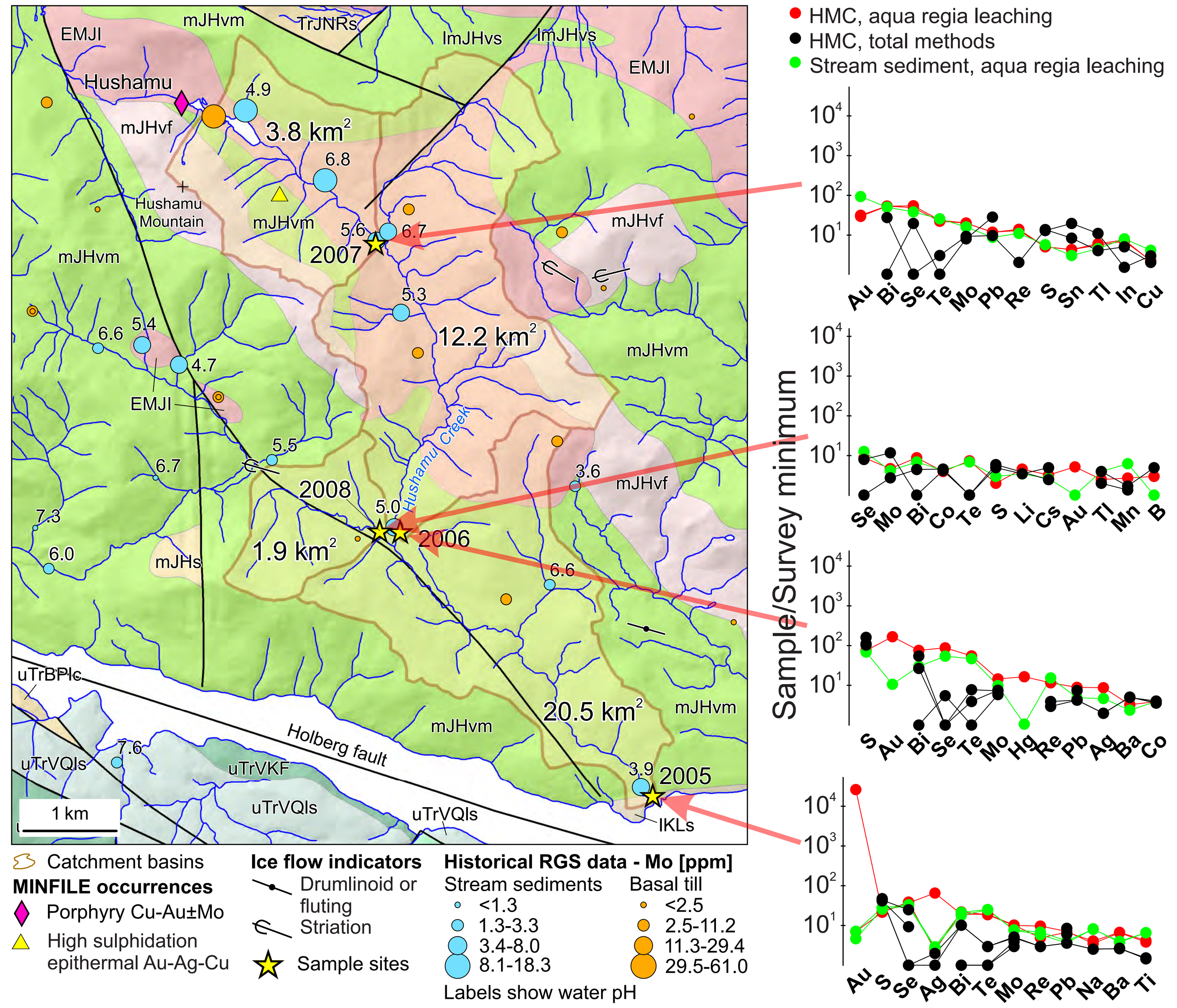
Samples were oven dried at 36°C, sieved through stainless-steel sieves, and then split using a Jones splitter. The whole 1-2 mm and 1/8th split of 0.5-1.0 mm, sieved fractions were kept for mineralogical examination. Splits of the <1 mm, sieved fraction were pulverized for geochemical analysis using several standard methods, including acid and total digestions, combined with inductively coupled plasma emission spectrometry (ICP-ES), inductively coupled plasma mass spectrometry (ICP-MS), and X-ray fluorescence (XRF) for as many elements as possible (currently 65).

Examples of ranked element contrast (REC) plots for Loss Creek samples



REC plots are sorted (maximum to minimum) analytical results normalized to survey minimum values. Contrast leaders Au-Ag-W-Mn-HREE-Y reveal the anomalous element association, which reflects the occurrence of placer Au from orogenic Au veins and garnet-hosted Mn-Sc-Y-HREE. Conventional RGS bulk stream and moss-mat sediment materials missed the Au-Ag-W-HREE-Y anomaly.

REC leaders for Hushamu Creek catchment area, northern Vancouver Island

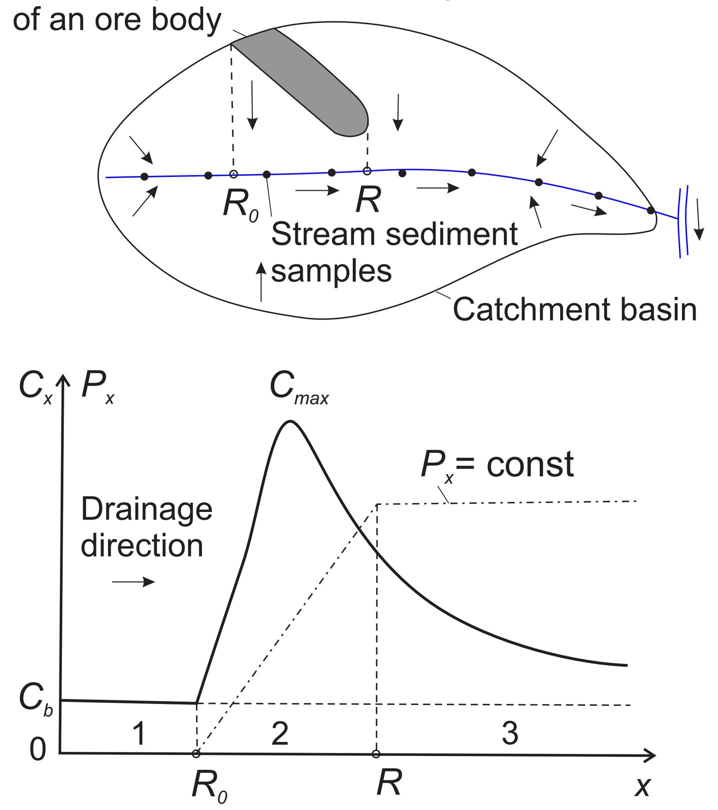


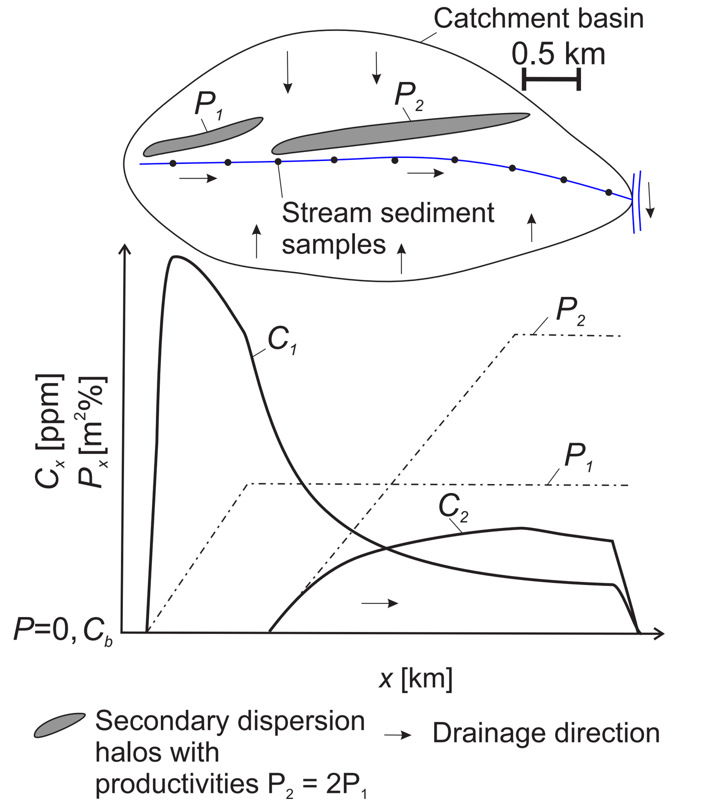
The anomalous element association confirms not only epithermal Au-Ag-Cu and porphyry Cu-Mo±Au mineralization, but also suggests shallow erosion of the mineralization.

Lithochemical dispersion stream

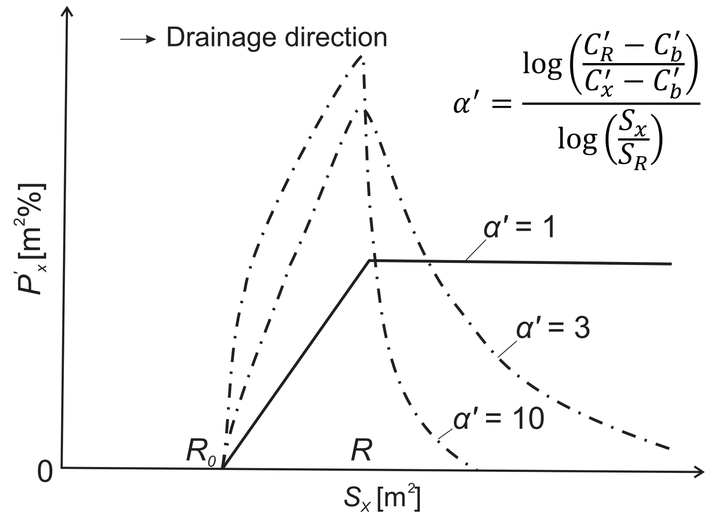
Geochemical anomaly in a catchment basin and plots of element concentration (C_x) and productivity (P_x) of the ideal dispersion stream

Secondary dispersion anomaly of an ore body





Plots of true (α' =1) and apparent (α' = 3 and α' = 10) productivity (P_x) of dispersion streams



Productivity, P, of secondary dispersion anomaly (in m²%):

$$P = S \cdot (C - C_b),$$

where S is area of the secondary anomaly (in m²) with concentrations of an ore element above the anomaly threshold, C_a (in wt%):

$$C_a = C_b \cdot \varepsilon^3,$$

where C_b is the average local background concentration of ore element (in wt%), C is the average concentration of ore element (in wt%) within the anomaly contour, and ε is standard multiplier:

$$\varepsilon = \text{antilog } s_{\log},$$

where s is standard deviation. Productivity of dispersion stream, P_x (in m²%), relates to the productivity of secondary dispersion anomaly, P:

$$P_x = S_x \cdot (C_x - C_b) = k' \cdot P = \text{const},$$

where C_x is concentration of element in stream sediment (in wt%), S_x is catchment area of stream basin at the sampling site (in m²), and $k' <> 1$ is the local proportionality coefficient, between the productivity of the dispersion stream and that of the secondary dispersion anomaly, which depends on hydrography and individual properties of elements resulting in their supergene enrichment or leaching (after Matveev, 2003).

Characteristics of the ideal dispersion stream (upper left diagram; after Solovov, 1985)

Interval of x values	Concentration of element (C_x) in dispersion stream $C_x = f(x) = f(P, S_x)$	Productivity (P_x) of dispersion stream
1) $0 < x \le R_0$	$C_x = C_b$ (background)	$P_x = 0$
2) $R_0 \le x \le R$	$C_x = \dfrac{P \cdot (x - R_0)}{S_x \cdot (R - R_0)} + C_b$ (anomalous - increases & decreases)	P_x increases
3) $x \ge R$	$C_x = P/S_x + C_b$ (anomalous - decreases)	$P_x = k' \cdot P$ = const

The prognostic geochemical resources (Q_H) or quantity of metal above background (in tonnes of metal) for n streams draining the secondary dispersion anomaly of an ore deposit is:

$$Q_H = \frac{1}{40k'k} \cdot \sum_{i=1}^{n} P_i' \cdot H$$

where $k <> 1$ is the proportionality coefficient between the productivity of secondary dispersion halo and that of ore body, P_i' is the productivity of dispersion stream, and H is the calculation depth. Non-ideal dispersion streams (i.e. 2nd- or higher-order) obey the differential equation of process (after Matveev, 2003):

$$S_x \cdot \frac{dC_x'}{dS_x} + \alpha' \cdot C_x' - \alpha' \cdot \frac{dP_x}{dS_x} = 0$$

where P_x is the productivity of secondary dispersion halo, C_x' is concentration of an element in alluvium, and $\alpha' > 1$ is a local coefficient for the material from the nearest slopes of stream basin, which is α' times that in the average alluvium of the stream basin.

Summary

We propose a simplified approach for evaluating drainage lithochemical results in terms of prognostic geochemical resources per element based on near-mouth alluvial HMC samples. Assuming $k' = k = 1$ and H = 1 m, prognostic geochemical resources of lithochemical anomaly in a drainage system, q (in tonnes per 1 m depth), are calculated as

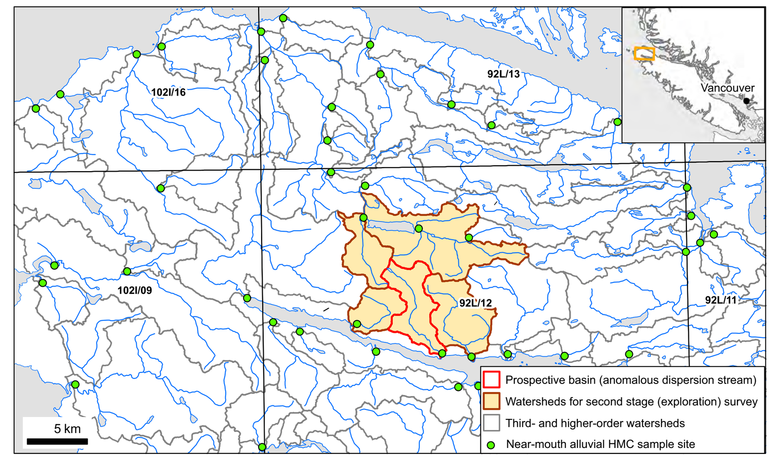
$$q = S \cdot (C - C_b)/40$$

where S is the catchment area of stream basin at the sampling site (in m²), C is the above-background concentration of an element in the HMC sample (in wt.%), and C_b is the average background concentration of an element (in wt.%). Background per element can be estimated as the average of survey values within the range of 10 times the minimum value (e.g., 1.5-15).

Prognostic geochemical resources (tonnes/m) of 315 Au, 24 Ag, 325 Cu, 161 Mo, 1146 Zn, 247 Pb, 569 Se, 75 Sn, 52 Co, 49 Bi, 34 Te, 16 Sb, 9 Hg, 8 Tl, and 2 In confirm epithermal Au-Ag-Cu and the uppermost dispersion halo of the blind porphyry Cu-Mo-Au system in the Hushamu watershed.

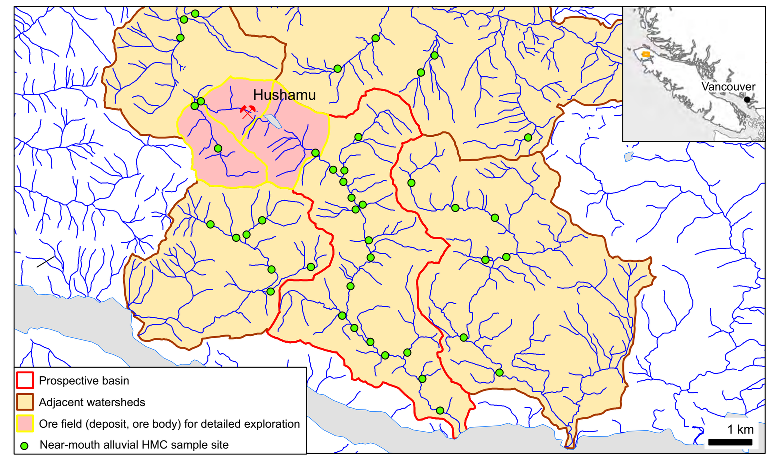
HMC samples at Loss Creek indicate (tonnes/m): 3066533 Mn, 86132 Y, 41516 ΣHREE (Gd to Lu), 38542 Cr, 28724 Zn, 14377 Li, 5553 Sc, 2873 ΣLREE (La to Eu), 2568 W, 2182 Ni, 1640 Ga, 1532 Se, 871 Co, 833 Au, 753 Ge, 621 Pb, 613 Cd, 594 Nb, 235 Hf, 207 Th, 78 Ag, and 76 Ta, which indicate a large, unconventional type of garnet-hosted HREE-Y-Sc-Mn deposit and other 'critical' commodities.

Reconnaissance stage drainage HMC geochemical survey identifies prospective basin



- We propose a three-fold drainage geochemical survey program that consists of reconnaissance, exploration, and detailed stages.
- The objective of the reconnaissance stage is to identify prospective basins based on collecting one near-mouth HMC sample (200-400 g) per 3rd-roder or higher stream.

Exploration stage drainage HMC geochemical survey identifies the area for the detailed study



- In the second stage, one near-mouth HMC sample is taken from each tributary of the prospective basin and the adjacent watersheds identified during reconnaissance.
- The purpose of this stage is to identify the area for the final, detailed study of the ore field, deposit, or ore body.

Conclusions

The revised three-stage method is fast, effective, and inexpensive. We recommend it to prospectors. For interpretation of the data and cited references please see Rukhlov et al., 2020. In: Geological Fieldwork 2019, BCGS Paper 2020-1.