Identifying Mineral Exploration Targets in the TREK Project Area, Central British Columbia (Parts of NTS 093B, C, F, G), Using a Multimedia and Multivariate Analysis of Geochemical Data and a Preliminary Method of Sediment Transport Modelling

D.A. Sacco, Palmer Environmental Consulting Group Inc., Vancouver, BC, david@pecg.ca

W. Jackaman, Noble Exploration Services Ltd., Jordan River, BC

R.E. Lett, Consultant, Victoria, BC

B. Elder, Consultant, Vancouver, BC

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Introduction

Geoscience BC's **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) project has produced a comprehensive collection of geoscience information for a highly prospective area in central British Columbia (BC). Up to this point, the surficial geochemistry component of the project has focused on new till and lake sediment sampling combined with a reanalysis and genetic interpretation of similar archived data, resulting in one of the largest, high-quality, and directly comparable raw exploration datasets in North America. This value-added project provides advanced processing of the TREK geochemical data that incorporates a bedrock and surficial context into the evaluation to better understand the complex nature of this information and promote its potential as a mineral exploration tool.

This project has two primary objectives: identify low-risk exploration targets within the TREK project area, and develop and test a method to delineate potential source regions for till and lake sediment samples. Exploration targets will be identified through a multimedia and multivariate analysis that highlights samples with geochemical signatures similar to specific common deposit types. Till and lake sediment samples are good candidates for the multimedia comparison as they have been shown to correlate (Cook et al., 1995). This correlation is likely a result of erosion and transport of the region's ubiquitous till cover by watercourses. Priority will be placed on targets that show spatially correlative dispersal in both till and lake sediment geochemistry.

Potential source areas, or areas of influence (AOI), for the two media are delineated using their unique transport mechanisms. Lake sediment samples are transported by watercourses, so a catchment basin analysis will be used that is similar to those used for stream sediment samples (e.g., Bonham-Carter and Goodfellow, 1986; Arne and Bluemel, 2011; Heberlein, 2013). Till samples are transported by glaciers, so their AOI will be delineated using ice-flow data, and will build on concepts related to provenance envelopes (Stea and Finck, 2001; Plouffe et al., 2011). Till AOI are designed to spatially link till samples to a dominant bedrock source unit. Contrasting rock types forming the bedrock geology within the TREK project area will be reflected in the till geochemistry. The till data will be levelled using the dominant bedrock source unit to mitigate the influence of these contrasting rock types on the regional dataset, which should improve anomaly identification.

Keywords: *British Columbia, TREK, regional geochemical survey, target generation, multivariate analysis, anomaly*

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Project Area

A summation and references for the known bedrock and surficial geology for the project area are provided in Sacco et al. (2014k). The project area is in the Interior Plateau (Mathews, 1986), south of Vanderhoof and approximately 60 km west of Quesnel. It occupies parts of NTS map areas 093B, C, F and G and covers more than 28 1:50 000 scale NTS map areas, and approximately 25 000 km^2 (Figure 1). Access is through a network of forest service roads in the Vanderhoof, Quesnel, Chilcotin and Central Cariboo forest districts.

The project area includes parts of the Nechako Plateau, Fraser Plateau and Fraser Basin physiographic regions (Holland, 1976). Thick surficial deposits composed dominantly of till and glacial lake sediments obscure most bedrock exposures. Higher relief features include the Nechako and Fawnie mountain ranges of the Nechako Plateau and the Ilgachuz and Itcha mountain ranges of the Fraser Plateau.

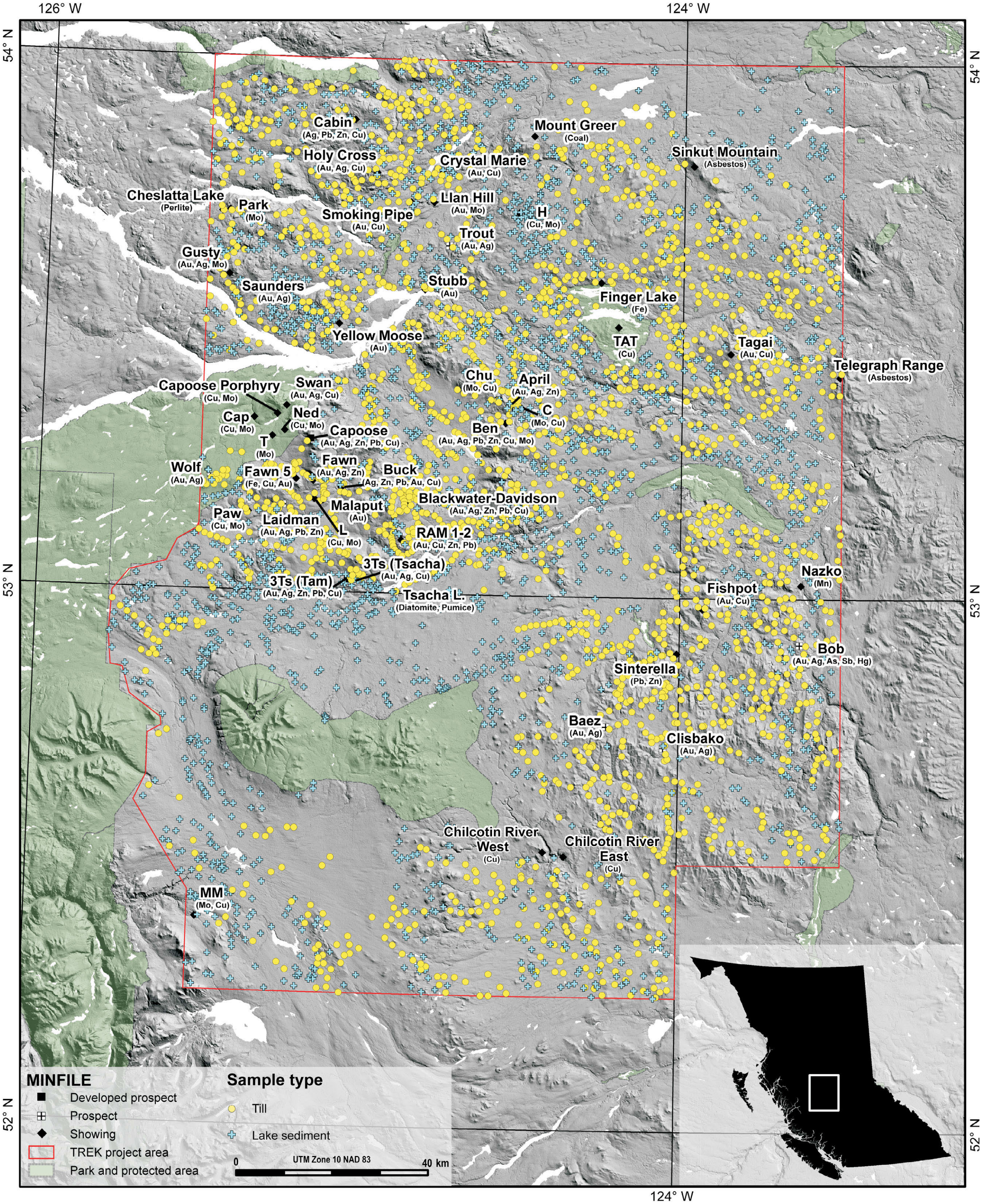

Figure 1. Location map showing the study area, till (yellow symbols) and lake sediment (blue symbols) sample locations, and MINFILE mineral occurrences (BC Geological Survey, 2016a). Digital elevation model from Canadian digital elevation data (GeoBase®, 2007).

Methods

This section outlines the proposed workflow and methods for the study (Figure 2). All procedures are carried out using a combination of ArcGIS™, Reflex® ioGAS and Microsoft® Excel® computer software.

Data

This project integrates data from multiple sources listed in Table 1. Due to the complex nature of this collection of information, inherent data discrepancies exist that may affect the results. Significant effort has gone into the assessment, compilation and processing of these data to ensure the best possible results. The specific procedures used are outlined in the appropriate method subsections below.

Bedrock Compilation and Simplification

The bedrock geology is an integral part of this study, so it is essential to have the most accurate and consistent mapping possible. The most continuous bedrock geology in the project area is compiled by Cui et al. (2015); however, more recent, higher resolution bedrock mapping conducted for parts of the project area by Mihalynuk et al. (2008), Angen et al. (2015) and Bordet (2016) is not in Cui et al. (2015). A new, uniform and continuous geology layer is being pro-

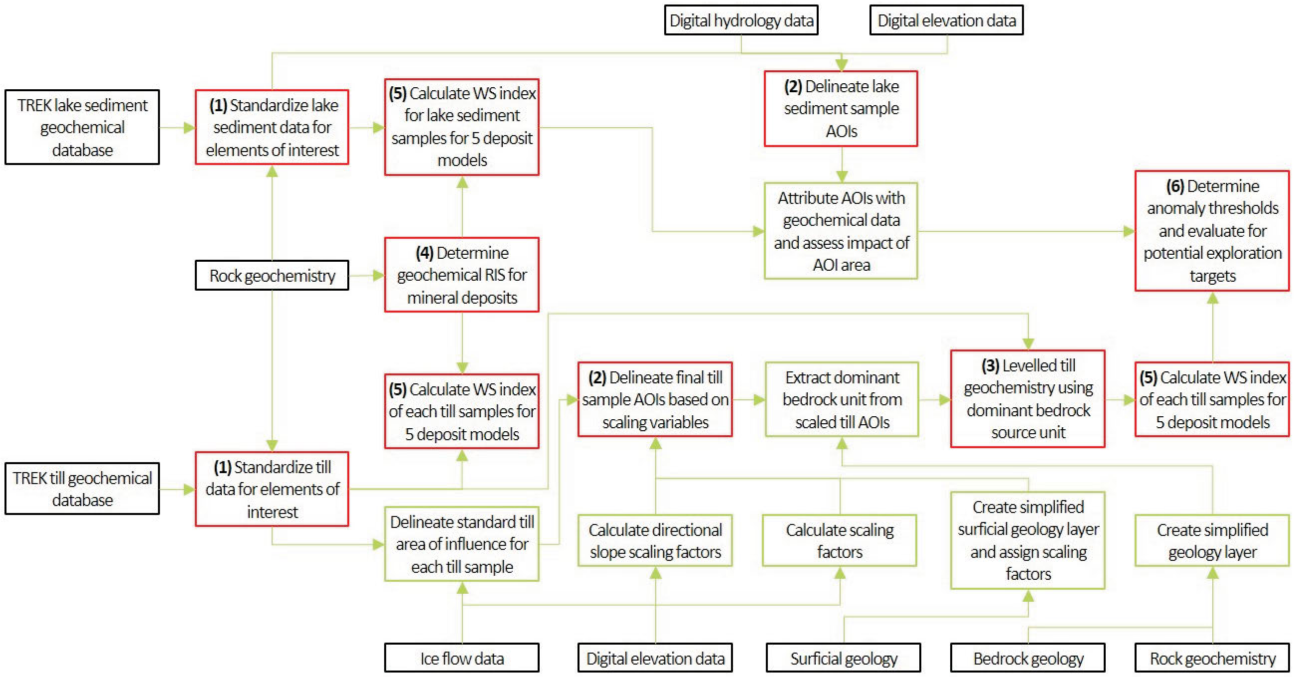

Figure 2. Flowchart illustrating the workflow for this study. Black boxes identify data sources, green boxes identify processing steps and red boxes identify final products. Bold bracketed numbers refer to the final product list in the conclusions section of this paper. Abbreviations: AOI, areas of interest; RIS, relative importance signature; TREK, Targeting Resources through Exploration and Knowledge; WS, weighted sums.

Table 1. Datasets and their references used in this study.

Data sets	Reference
TREK till geochemistry	Jackaman and Sacco (2014); Jackaman et al. (2015a)
Reanalyzed archive till geochemistry	Jackaman et al. (2015b)
TREK lake sediment geochemistry	Jackaman and Sacco (2014)
Archive lake sediment geochemistry	Jackaman (2006, 2008a, 2009a)
Reanalyzed archive lake geochemistry	Jackaman (2009a, 2009b)
Rock geochemistry	Mihalynuk et al. (2008a, b); Angen et al. (2016); additional data to be collected from MINFILE (BC Geological Survey, 2016) and ARIS (BC Ministry of Energy and Mines, 2016)
Geology	Cui et al. (2015); Bordet (2016); Mihalynuk (unpublished data)
Surficial geology	Kerr and Giles (1993); Plouffe et al. (2004); Sacco et al. (2014a–j)
Elevation data (SRTM, CDED)	Canadian Digital Elevation Data (CDED), GeoBase® (2007), Shuttle Radar Topography Mission (SRTM), NASA LP DAAC (2015)
Ice flow data	Ferbey and Arnold (2013); Plouffe and Sacco (unpublished data)
Hydrology	GeoBC (2016)

duced for this study that will combine these data sources. The data sources are first overlaid to assess the spatial comparability, unit designation and descriptions. From this assessment, the most suitable sources will be determined. The selected layers will then be converted to a comparable legend based on the most extensive data source (i.e., Cui et al., 2015), and spliced into the compilation. No attempts at edge matching will be made between the units as it is a complicated process that requires resources beyond the scope of this project. The new layer will then be simplified so that the geology is represented by major bedrock units that are most likely to influence the till geochemistry. Simplifications will be based largely on unit descriptions and supplemented with available rock geochemistry where possible.

TREK Geochemical Data Standardization

Data standardization refers to a series of processing steps required to create a genetically comparable, normally distributed and statistically equivalent dataset. Only sediments with similar genesis should be compared to eliminate variation associated with different transport and deposition mechanisms. Non-normal and censored data distributions can cause issues when applying mathematical or statistical analytical procedures (cf. Grunsky, 2010). Similarly, variation in analytical results from external factors can limit anomaly recognition within the dataset. A combination of filtering, data transformations and substitutions, and levelling techniques are applied to the raw data to improve its utility.

The geochemical data used for this study is a compilation of new till and lake sediment samples, and reanalyzed archive samples. Details for the datasets can be found in the references in Table 1 and sample locations in Figure 1. To ensure genetic continuity within the datasets, all till and lake sediment data were assessed separately. In addition, till samples that are not basal till are removed from the analysis based on genetic interpretations conducted earlier in the TREK surface sediment geochemistry program (Jackaman et al., 2015b). Basal till is well suited to assessing mineral potential of an area because it is a first derivative of bedrock (Shilts, 1993); therefore, it has a similar geochemical signature. It was eroded, transported and deposited under ice, thus its transport history is relatively simple and can be determined by reconstructing ice-flow histories. Furthermore, it produces a geochemical signature that is areally more extensive than the bedrock source and potentially easier to locate (Levson, 2001).

The data distribution of each element is assessed numerically and graphically to determine which data require the $\log_{10}$ transformation to produce more normal data distributions. Most data are positively skewed and require the transformation. Censored data distributions occur when enough data points fall below detection limits. A sufficient proportion of censored data artificially skews the data distribution. For elements with <1% of data points below the detection limit, the data below the detection limit are substituted with half of the lower detection limit. For elements with >1% of the data points below the detection limit, the data below the detection limit are substituted with predicted values based on linear regression coefficients of the data. This is accomplished by fitting a line by linear regression on a normal probability plot, and then replacing the censored data with their expected values.

The inductively induced neutron activation analysis (INAA) was conducted at Activation Laboratories Ltd. (Ancaster, Ontario) or Becquerel Laboratories Inc. (Mississauga, Ontario) laboratories, depending on the survey. An assessment of analytical results indicates there is minor variation in the analytical results from each lab. There is significant spatial overlap of the sampling regions for the two labs, thus it is unlikely the difference is related to geology. Instead, the variation is attributed to differences between the labs. To mitigate this variation, the data are levelled using a robust z-score method. The z-score levelling method was chosen because it does not change the shape of the data distribution and it preserves genuine outliers. This method converts each data point into a group-based z-score, expressing the data in units of standard deviation from the central tendency. The median is used as a robust estimate of the mean and the interquartile range (IQR) multiplied by 0.7413 as a robust estimate of standard deviation. It is defined by the equation

$$z = \frac{input\ value - median}{IQR \times 0.7413}.$$

Sample Areas of Influence

An AOI is designed to identify the potential source region for a sediment sample. Because till and lake sediments have different geneses, the AOI of each media is determined based on different transport mechanisms and represents a different source material. Basal till is eroded and transported by glacial ice and is dominantly derived from bedrock. The shape of each till sample AOI is dependent on variables related to ice-flow dynamics, and the AOI delineates a region of bedrock that has influenced the composition of the till sample. Lake sediment samples are transported through drainage networks; therefore, the AOI for lake sediment samples is defined by the catchment basin of the sampled lake.

Till Sample AOI

Till sample AOI represent the potential source region for a specific sample point, defined by a sector of a circle that is centred on the sample location. The angle of the sector is a function of the range of ice-flow directions that affected the location, and the length of the radii (arms) is a function of estimated sediment-transport distance (Figure 3). Delineation of a till sample AOI is an iterative process that begins with a standard till sample AOI that has a standard length and an arc length that is specific to the ice-flow history at each sample location. The standard AOI is used to extract scaling factors that reflect increased or decreased sediment transport distances. These scaling factors are then applied to the standard AOI to create the final till sample AOI that will be used to determine dominant bedrock influence (Figure 3).

Delineation of a Standard Till Sample AOI

The length of a standard AOI is determined based on average anomaly dispersion distances in till from known mineral deposits within the region. The dispersal distance is measured from the deposit to the location where associated element concentrations are below the 75th percentile. Based on the references listed in Table 2, the average dispersal length is approximately 2.5 km.

The angle of a standard AOI is based on the range of ice-flow directions that affected a sample location (Figure 2). Ice-flow directions were determined from the azimuth of small- and large-scale ice-flow indicators (see Table 1 for references). Ice-flow histories were determined where relative chronologies could be assigned to the indicators, and from regional ice-flow patterns. A 2 km buffer was created for each till sample location, and the maximum and minimum azimuth values from all ice-flow indicators were attributed to the sample point. The range for each sample location was assessed for the influence of spurious values and adjusted accordingly. During this assessment, modifications were made based on known ice-flow histories and topographic influences.

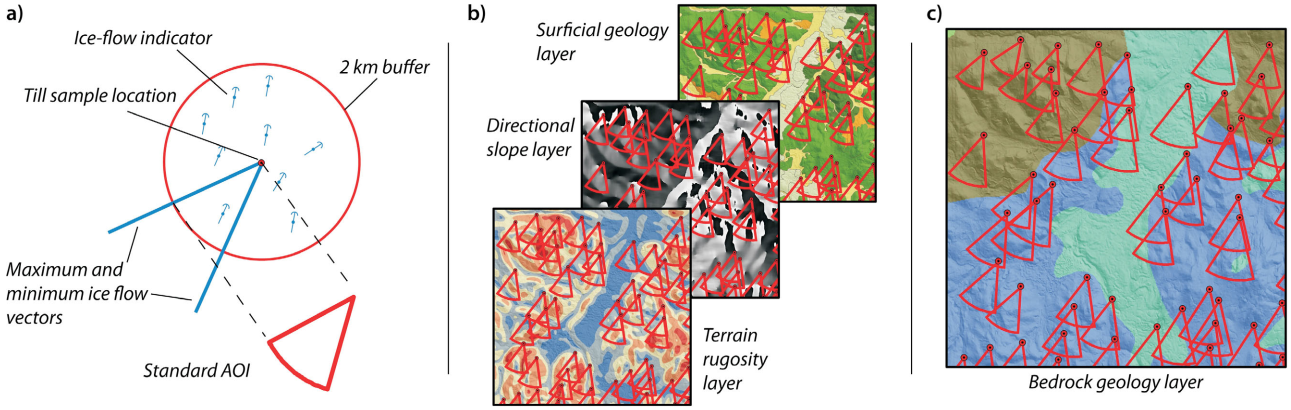

Figure 3. Conceptual diagram of till sample area of influence (AOI) delineation and utilization to extract the dominant bedrock source: **a)** standard till sample AOI are delineated based on sample locations and ice-flow vectors; **b)** length-scaling factors are extracted from layers that affect sediment transport distances using standard till AOI; **c)** the length of standard till sample AOI are multiplied by the scaling factors, and the dominant bedrock units affecting the samples are calculated.

Table 2. Geochemical dispersal distances in till to the 75th percentile from known mineral occurrences in central British Columbia.

Dispersal distance (km)	NTS 1:250 000 map area	Reference
2	093M, L	Ferbey et al. (2009)
5	093M, L	Ferbey et al. (2009)
1–3	93L	Stumpf (2012)
2.5–5	093F	Levson et al. (1994)
1–2	093F	Levson et al. (1994)
2	093F	Levson et al. (1994)
3–7	093F	O'Brien et al. (1997)
2–4	093F	O'Brien et al. (1997)
2	093F	O'Brien et al. (1997)
>1	093O	Plouffe (1997)
>1	082E	Lett et al. (2001)
2–4	093F	Sibbick et al. (1996)
1.6	093E	Ferbey et al. (2012)
1–2	O92P	Paulen et al. (2000a)
3	082M	Paulen et al. (2000b)
2–5	various	Weary et al. (1997)

Length-Scaling Variables and Factors

Length-scaling factors are used to modify the length of a till sample AOI based on the specific surface conditions to improve the accuracy of the estimated transport distance of each sample. It has been shown that transport distances increase with velocity of ice flow (Clark, 1987; Bouchard and Solonen, 1990; Aario and Peuraniemi, 1992). The ice velocity cannot be directly determined; thus, the scaling factors are based on three surface characteristics (i.e., scaling variables) that can affect ice velocity: slope, surface rugosity and surficial material. Transport distances can also be affected by the physical properties of the source (e.g., areal extent, erodibility, topographic position) and re-entrainment potential (Parent et al., 1996). The physical properties of the exploration targets are yet to be identified, and determining re-entrainment potential is not feasible across the study area so these factors will not be addressed here.

Glaciers generally accelerate downslope and decelerate upslope. Directional slope is measured using SRTM elevation data and the generalized ice-flow directions from the ice-flow indicator compilation. Thiessen polygons are created for the generalized ice-flow indicators. Spurious results are assessed and adjusted where necessary ensuring coordination with surrounding values. The polygon file is converted to an ice-flow direction raster with an equivalent cell size to the SRTM data. The ice-flow direction raster is smoothed using a roaming average of 10 cells to reduce sudden directional changes along polygon borders. The SRTM dataset is smoothed using a 25-cell roaming average to remove the influence of minor topographic features that are either too small to affect ice flow, or did not exist during glaciation (e.g., meltwater channels and postglacial landforms). Slope and aspect raster layers are calculated from the SRTM data, and the directional slope was calculated using the formula

$$S_D = \left(S\cos\left((D - A)\frac{\pi}{180} \right) \right),$$

where S_D = directional slope, S= slope raster, D = direction of ice-flow raster and A = aspect raster.

Increased surface rugosity increases basal drag and decreases ice velocity. Surface rugosity is calculated using a modified version of the terrain ruggedness index (TRI) by Riley et al. (1999). Several other methods of measuring rugosity were tested and were deemed unsuitable due to issues with scale and the resolution of the elevation data. For example, the true rugosity of a surface is probably best indicated by the 2-D area to 3-D area ratio. This method, however, could not produce accurate results at a scale that would affect a glacier and is better suited to higher resolution data.

The Riley et al. (1999) TRI is the difference between the value of a cell and the mean of a neighbourhood of surrounding cells. This calculation is performed on the SRTM dataset that is smoothed using a 10-cell roaming average to remove minor topographic irregularities from the calculation. Minimum and maximum 25 by 25–cell neighbourhood raster layers are derived from the smoothed DEM, then the TRI is calculated using the formula

$$TRI = \sqrt{\left(abs\left(\max^2 - \min^2 \right) \right)},$$

where max = maximum 25 by 25–cell neighbourhood raster and min = minimum 25 by 25–cell neighbourhood raster.

The surface expression and thickness of the surficial materials are used as qualitative proxies for ice-flow velocity and transport distance, respectively. Thicker till units are generally transported farther (e.g., Levson and Giles, 1995; Paulen, 2001) and streamlined landforms (notably with a length-to-width ratios of 10:1) suggest higher ice-flow velocities (Stokes and Clark, 2002; Briner, 2007; King et al., 2009). Sediment thickness and surface expressions were extracted from surficial mapping compiled from several sources (see Table 1). The mapping was combined using a common legend, with higher resolution mapping favoured where overlap occurred.

Quantifying the effects of the scaling variables on ice-flow velocity, and ultimately on sediment transport distance, is beyond the scope of this preliminary study. The scaling factors for this preliminary study are, therefore, relative rather than absolute. Each scaling variable is divided into five factor categories, with each representing a scaling factor of 0.1 (Table 3). The relative scaling factors are based on the average condition. For example, the average condition is scaled by a factor of 1; one below the average condition is scaled by a factor of 0.9; one above the average condition is scaled

Table 3. Length-scaling variables and factors used to adjust till sample areas of interest (AOI) based on surface characteristics that affect till transport distances.

Scaling factor	Category breaks	Slope value (°)	TRI index value	Surficial geology map unit description
0.8	> –1.5 standard deviation from mean	>5	<71	No surficial material (e.g., dominantly rock with lesser amounts of thin material; R.Tv)
0.9	–1.5 to –0.5 standard deviation from mean	5 to 2.1	72–263	Thin surficial material (e.g., veneers; Tv)
1	–0.5 to 0.5 standard deviation from mean	–2 to 2	264–454	Thick surficial material (e.g., blankets; Tb)
1.1	0.5 to 1.5 standard deviation from mean	–2.1 to –5	455–646	Thick material with some streamlining (e.g., till blanket with some streamlining; Tb.Ts)
1.2	>1.5 standard deviation from mean	<–5	>646	All material is streamlined (Ts)

Note: Thin and thick material categories are based on material thickness and not genesis, thus can include all material types.

by a factor of 1.1. Directional slope and rugosity variables are numerical indices. The average condition for these indices will be determined by the mean, and the scaling-factor divisions measured in units of standard deviation (Table 3). Surficial material characteristics are more qualitative and require a different approach. Based on areal distribution, thick material is the average condition and is assigned a scaling factor of 1. The scaling factors increase as the amount of streamlining increases, and decrease as the material becomes thinner.

The percent coverage of the scaling factors for each scaling variable are measured from within the standard AOI. A final scaling factor for each variable is determined by weighting each category based on the percent coverage. The standard AOI length is then multiplied by each variable's weighted scaling factor and the final till sample AOI are delineated using those lengths.

Levelling Geochemical Data Based on Bedrock

The final till sample AOI spatially link each till sample to a probable source region. The dominant bedrock source unit can be determined by extracting the dominant bedrock unit within the AOI. The efficacy of the bedrock attribution will be measured by examining the pebble lithologies of till samples, and by comparing the geochemistry of till samples with that of the bedrock source. Till samples collected in 2013 and 2014, in association with the TREK project, included the collection of 50 clasts (Jackaman and Sacco, 2014; Jackaman et al., 2015a). The proportion of clasts collected will be compared to the source area bedrock attribution and assessed for consistency. Similarly, the geochemical concentrations of till samples will be compared with those of the bedrock source regions to determine if they match. These quality-control measures are limited by the fact that not all samples have pebble data and not all rock units have available geochemical data that are comparable to the till geochemical data.

If the bedrock attributions are found suitable, the till geochemical data will be levelled to mitigate the variance in geochemical concentrations related to bedrock source. The levelling procedure will use the same methods outlined in the data standardization section because it does not change the shape of the data distribution and it preserves genuine outliers.

Lake Sediment Sample AOI

Lake sediment sample AOI represent the potential area from which lake sediment was derived, and are delineated in the same manner as a catchment basin. For the purposes of this study, a lake catchment is defined as the drainage area from the outlet of the sampled lake to the outlet of the next upstream sampled lake. Lake sediment sample AOI are delineated by computing the catchments of sampled lakes using Canadian digital elevation data (CDED; GeoBase®, 2007). The CDED was chosen because it was created using hydrographic elements, and more accurately represents the hydrological system compared with the SRTM elevation data.

The CDED is processed to remove linear artifacts that affect the drainage system modelling. The data are resampled to a resolution of 10 m and smoothed using the minimum value of the surrounding eight cells. The minimum value is used to ensure lower elevation areas representing drainage networks are not artificially raised, resulting in disconnected upstream areas.

Preliminary catchments are delineated for all sampled lakes by using the Arc Hydro tool set, and generally following the method for modelling deranged drainage systems (Djokie, 2008). The elevation values under the sampled lakes are reduced to below the minimum value of the elevation dataset to ensure the modelling does not allow for water flow through the lake. A flow direction raster is created specifying the sampled lakes as sinks. During this process, each cell that would eventually drain into an identified sink was defined, which delineated the possible sediment source area for each sampled lake.

Errors can occur in the catchment delineation for lakes with upstream, adjacent wetlands. If the upstream wetland is flat in the elevation model, no flow direction can be computed and the upstream area is cut off from the lake catchment. All wetlands that are adjacent to lakes are identified and screened for potential impact on catchment delineation. Upstream wetlands that impact the preliminary catchment delineation are merged into the lake, and the process is rerun using the modified lakes.

Lake sediment sample AOI represent the potential source region for a sample; therefore, they represent the source for geochemical anomalies within that sample. The geochemistry of the lake sediment samples is attributed to the AOI to indicate the ground coverage of the sampling, and an area to focus exploration efforts.

In several large lakes, sediment samples were collected from what was interpreted as different basins (Jackaman, 2006, 2008a; Jackaman and Sacco, 2014). The geochemical concentrations of lake sediment samples collected from the same lake are compared for variation prior to attribution to the AOI. If the variation between key mineralization pathfinder elements (e.g., Cu, Zn) are within 25%, estimated as percent relative standard deviation, the values are averaged and applied to the AOI. If significant variation is observed, the catchment is manually modified based on topographic and hydrological considerations to best represent input into the sampled basins within the lake (Figure 4).

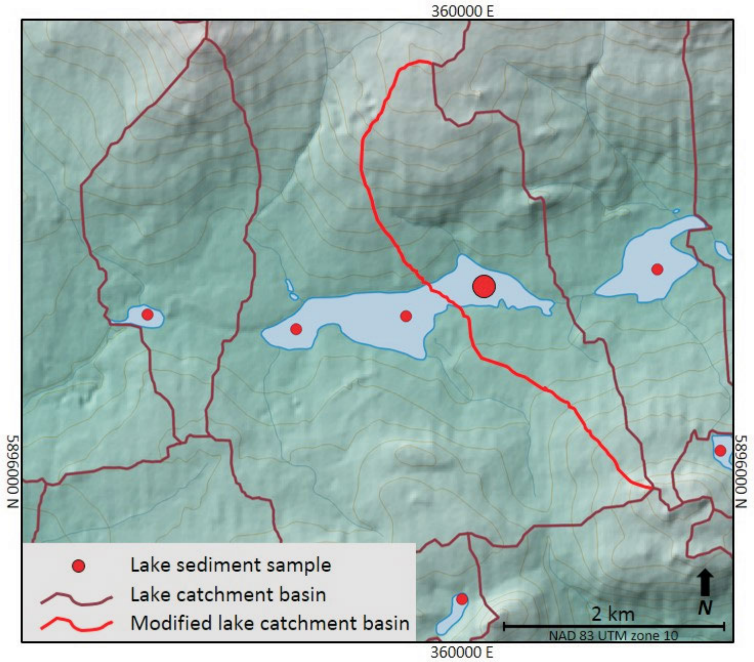

Figure 4. Example of catchment basin delineations for lake sediment samples (burgundy lines). Catchments are manually modified based on topographic and hydrological considerations where samples within the same lake have percent relative standard deviations that are greater than 25% (red lines).

Evaluation of the lake sediment geochemistry will include consideration for AOI size. It is expected that samples with larger AOI will have geochemical values that are closer to background levels due to dilution. The effect of dilution will be assessed empirically using concentration versus AOI area scatterplots to identify samples from large catchments that are above the mean concentrations. If AOI are prohibitively large, the sample may be removed from the dataset or evaluated separately.

Data Evaluation

Deposit Types and Relative Importance Signatures

The deposit types used in this study will be based on nomenclature from the BC mineral deposit profiles (BC Geological Survey, 2016b). The weighted sums (WS) analysis uses elements that are diagnostic of mineral deposit types common to the region (Table 4). Preliminary elements of interest were determined through a review of available rock geochemistry from those mineral deposit types and information in MINFILE (BC Geological Survey, 2016a). A specific relative importance signature (RIS) will be determined for each deposit type through factor analysis and correlation matrices of surface sediment and rock geochemistry. Positive values in the RIS indicate that elevated concentrations of pathfinder elements are significant and negative values indicate that depleted concentrations are significant. Preliminary experiments will be carried out to determine which deposit types will be used in the final analysis.

Weighted Sums Analysis

A weighted sums (WS) analysis creates a single index that considers multiple elements and is specific to the geochemical signature of the exploration targets. The WS analysis uses a priori knowledge of mineralization to reduce its multi-element signature to a single linear function (see Garrett and Grunsky [2001] for a description of the calculation). The specific RIS will be used to calculate the WS index for each deposit type. The relative importance values are converted to weights by dividing each importance by

Table 4. British Columbia Geological Survey mineral deposit profiles (BC Geological Survey, 2016b) with examples from MINFILE (BC Geological Survey, 2016a) in the **T**argeting **R**esources through **E**xploration and **K**nowledge (TREK) project area, and preliminary mineralization pathfinder elements that will be used for the relative importance signatures. Preliminary experiments will be carried out to determine deposit types used in final analysis.

Deposit profile	Au	Ag	As	Ba	Cu	Bi	Co	F	Fe	Hg	Mn	Mo	Ni	Pb	S	Sb	Te	V	W	Zn
L04: Porphyry Cu±Mo±Au, e.g., Capoose (MINFILE 093F 022)	x	x	x	x	x		x		x			x		x		x	x	x		x
L05: Porphyry Mo, e.g., Nithi (MINFILE 093F 014)					x			x	x			x							x	x
H04: Epithermal Au-Ag-Cu: high sulphidation, e.g., CH (MINFILE 093F 085)	x	x	x		x					x				x	x	x	x		x	x
H05: Epithermal Au-Ag: low sulphidation, e.g., Blackwater Davidson (MINFILE 093F 037)	x	x	x	x	x			x		x	x			x	x		x			x
H02: Hot spring: Hg (no known examples in TREK area)	x		x							x						x				
D03: Redbed volcanic copper, e.g., Pickle (Angen et al., 2016)	x	x			x															x
E03: Carbonate-hosted disseminated Au-Ag, e.g., Bob (MINFILE 093B 054)	x	x	x							x		x				x	x			
K04: Au skarn, e.g., Fawn 5 (MINFILE 093F 053)	x		x		x	x	x		x				x				x			
I01: Au-quartz veins, e.g., Laidman (MINFILE 093F 067)	x	x	x													x	x		x	
I05: Polymetallic veins Ag–Pb–Zn±Au, e.g., 3Ts (MINFILE 093F 068)	x	x	x	x	x					x	x			x						x

Note: Fluorine (F) only determined for lake sediment samples.

the square root of the sum of the squares of all the importance values, resulting in the sum of squares of the weights equating to 1. The WS analysis will be carried out on the standardized geochemical datasets for the till and lake sediment, and again on the till dataset that has been levelled using dominant bedrock source.

Anomaly Evaluation

Specific anomaly thresholds will be determined for each element of interest and WS indices by assessing data distributions on probability graphs (cf. Sinclair, 1981; Grunsky, 2010). Once the anomaly thresholds are determined, the data will be symbolized in a GIS and assessed to identify the locations of anomalies and spatially correlate anomalies between the different media. Clustered anomalous samples and spatially correlative anomalies between the two media will be identified as high-priority exploration targets.

Discussion

The aim of this project is to identify exploration targets through the multivariate analysis of both till and lake sediment samples. Efficacy of the study relies heavily on the quality of the data, the accurate delineation of sample AOI and the RIS. Geochemical data quality has been improved through recent reanalysis and genetic interpretations. Further improvements are made in this study through data standardization to create a genetically comparable, normally distributed and statistically equivalent dataset.

Areas of influence are delineated for till and lake sediment samples to assist in the evaluation of the TREK geochemical dataset. This method is based on catchment analysis that is typically applied to stream sediment samples (e.g., Arne and Bluemel, 2011; Heberlein, 2013). Provided here are preliminary methods to delineate the AOI for till and lake sediment samples, which can be built upon and improved in future studies. Till sample AOI are meant to spatially link each sample to a dominant bedrock source so that the influence of varying bedrock geology can be removed from the regional geochemical dataset. In this study, the determination of till transport distances (i.e., length of till sample AOI) is relative and based on factors that influence glacier velocity. Future efforts to delineate till sample AOI could also use the length of streamlined bedforms as a proxy for ice-flow velocity. Attempts to apply more absolute scaling values based on sediment transport studies (e.g., Clark, 1987; Parent et al., 1996) may also improve the accuracy of the delineation. The accuracy of the bedrock mapping and simplifications are also very important. Inaccurate mapping will result in the incorrect attribution of bedrock source units and cause spurious data levelling results. Efforts are made to incorporate the highest resolution, comparable bedrock mapping into one layer and to create accurate simplifications. Future work should concentrate on improving the assimilation of bedrock data from different sources and the acquisition of extensive geochemical data, which will improve the simplification process.

Lake sediment sample AOI are delineated from the outlet of the sampled lake to the outlet of the next upstream sampled lake. This definition assumes that there is minimal sediment transfer through the sampled lakes; however, the catchments of upstream lakes that were not sampled are included in the delineation in order to not exclude potential source areas. A comparative analysis of geochemical data using nested and non-nested catchments may provide empirical evidence to inform whether upstream catchments should be included in the AOI delineation.

Using catchment basins as lake sediment sample AOI presumes that any sediment within the catchment is available for erosion and transport to the lake. In reality, soil erosion in most areas is limited by vegetation, and likely only occurs in significant amounts near the stream networks. Incorporating a buffer around active watercourses may provide a more precise delineation of the major contributing sediment sources to the lakes. This delineation would reduce the size of the exploration target, and may provide a better estimate of catchment area, which can be used to determine dilution during data evaluation.

Conclusions

This paper presents the methods that will be used to identify mineral exploration targets in the TREK project area using multivariate and multimedia geochemical data analysis, and a preliminary method of sediment transport modelling. These methods are suitable for the evaluation of surficial exploration data in most regions, particularly in other areas of BC where there is a large collection of geochemical data. The completed study will produce (numbers in parentheses are referenced in Figure 2)

- a database of standardized till and lake sediment geochemical data for elements of interest (1);
- polygon shapefiles of AOI for all till and lake sediment samples (2);
- levelled till geochemistry using dominant bedrock source (3);
- RIS of geochemistry for six common mineral deposits in central BC (4);
- WS indices for deposit models calculated with standardized till and lake sediment geochemistry, and levelled till geochemistry (5);
- potential exploration targets (6); and
- georeferenced maps (e.g., eight 1:100 000 scale maps in PDF) to display WS indices using proportional dot symbols, and gridded data if the sample spacing allows.

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