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A New Simplified Multivariate Approach to Defining Geochemical Exploration Targets from Regional Stream Sediment Data

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ABSTRACT

The interpretation of stream sediment data for mineral exploration is complicated by the influence of bedrock lithology, the effects of scavenging by secondary Fe and Mn hydroxides, clays and organic matter, and by dilution dependent on the size of the catchment area draining through the sample site. A number of ways have been proposed in the literature to correct for the effects of background variations in lithology, but most are driven by knowledge of the bedrock geology that may not always be available in reconnaissance exploration programs. We present a new approach for correcting for lithological and scavenging influences that is data-driven. Lithological controls on stream sediment geochemical data are identified by interpreting the results of principal component analysis. Values for elements strongly controlled by lithology are corrected by regression against the relevant component(s). Positive residuals represent elevated geochemical concentrations above what is defined by background bedrock geology. These positive residuals represent samples worthy of further investigation and allow regional data sets to be gridded to reveal trends in elevated metal concentrations above background. The residuals are incorporated in weighted sums models which define geochemical indices using element associations typical for a given mineral deposit type. These models are refined through validation against known mineral occurrences and then weighted by catchment area to define anomalous catchments for follow-up investigation. The selected catchments include not only those that have anomalous raw element values, but also highlight areas with more subtle raw data responses that may have been overlooked by previous exploration campaigns. Use of the approach is illustrated through selected examples of high quality geochemical analyses from British Columbia and the Yukon, and the results compared to other methods, including levelling of stream sediment data based on dominant catchment lithology, an estimated background value for catchments based on proportions of different lithologies within the catchment, and the presence or absence of particular lithologies in each catchment.

INTRODUCTION

Regional stream sediment geochemistry is an important 'layer' of data for companies conducting regional exploration and targeting in mountainous and hilly terrains globally. While simple point maps of unprocessed metal concentrations have led to discovery of a mineral occurrence or deposit, there are several processes that can mask signals related to bedrock mineralization. There are however, as will be described herein, data processing techniques that can be applied to regional geochemical data to subdue these masking effects and generate new meaningful geochemical targets that can be incorporated into district- or terrane-scale targeting endeavors.

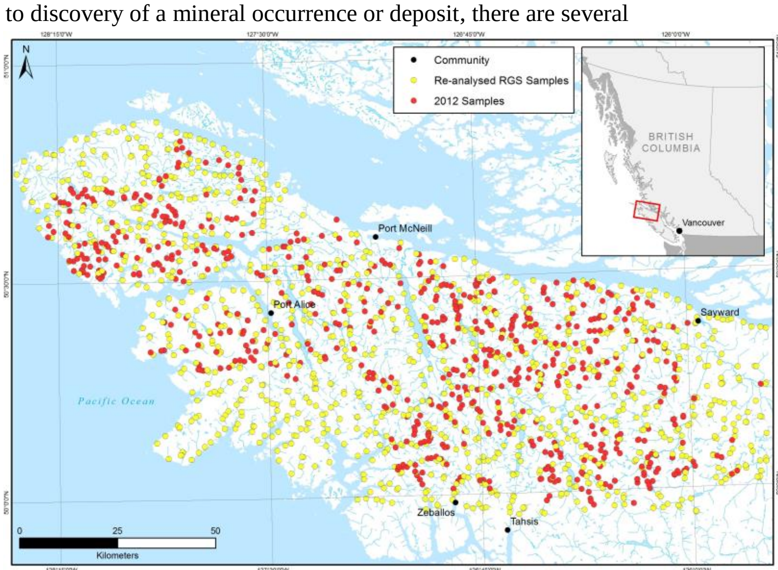

Figure 1: Distribution of RGS samples from northern Vancouver Island (from Arne and Brown, 2015)

CATCHMENT BASIN ANALYSIS

The application of catchment analysis for interpretation of stream sediment data is a well-established methodology (Carranza, 2009). Important aspects to be considered include the effects of dilution in catchment basins of differing areas, the influence of variable bedrock lithology on geochemical background values, the potential effects of scavenging of metals onto secondary Fe and Mn-oxides or organic matter, and the influence of stream water pH and Eh which control the solubilities of many metals (Hawkes, 1976; Bonham-Carter and Goodfellow, 1986; Pan and Harris, 1990; Carranza and Hale, 1997; Moon, 1999; Carranza, 2009). The main conclusion of many of these studies was recognition of the importance of bedrock geology as the main control on stream sediment geochemistry. An element such as Cu, which is elevated in mafic lithological units, may require

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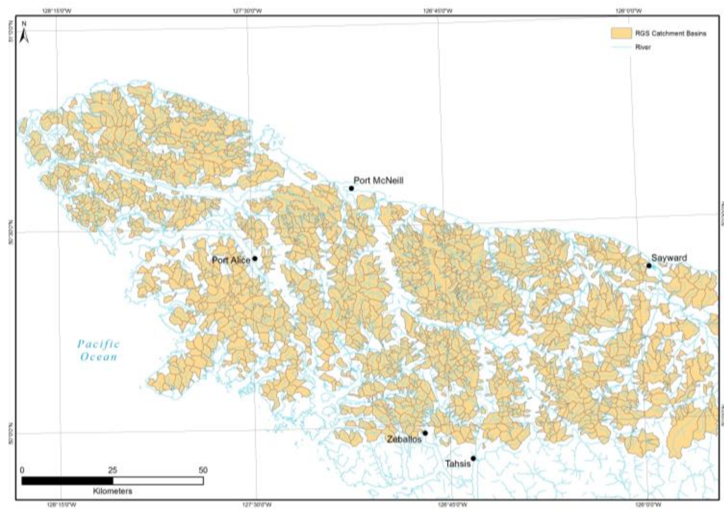

Figure 2: Catchment basins derived for the RGS samples by the GSBC from northern Vancouver Island.

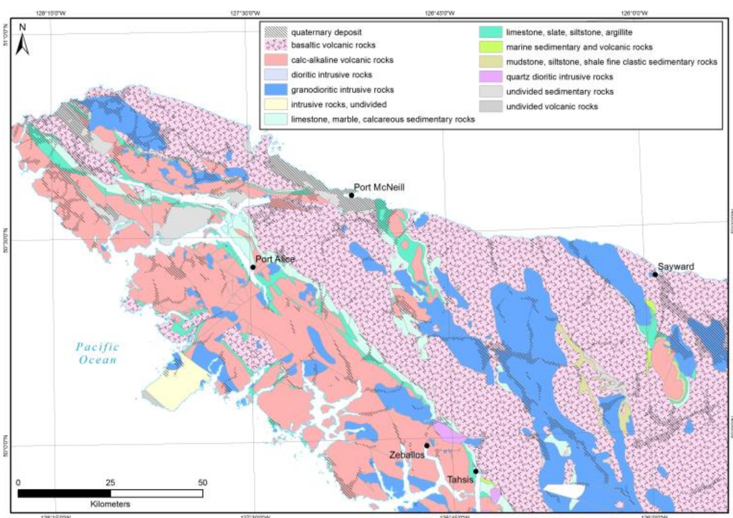

Figure 3: Bedrock geology plotted as lithology for northern Vancouver Island. Stippled pattern signifies basalt.

correction for bedrock effects in order to reveal subtle anomalies associated with Cu mineralization (e.g., Arne and Brown, 2015), whereas the precious metals show only minor variations between differing bedrock lithological units and correction for variable bedrock controls is less important. The effects of scavenging by secondary Fe or Mn oxides or organics will vary by geographical setting and stream pH is largely bedrock-controlled.

With increasing catchment size the likelihood that a mineralization signal will be diluted increases. This dilution is evident when plotting metal abundance against catchment area where commonly metal values drop with increasing catchment area and eventually reach a regional background value (Arne and Bluemel, 2011; Arne and Brown, 2015).

A case study is presented using data from northern Vancouver Island (Arne and Brown, 2015). Re-analysis of archived regional geochemical surveys (RGS) and new in-fill moss mat stream sediment samples were used for the study (Figure 1). Catchments were derived by the British Columbia Geological Survey (BCGS) using terrain resource information management (TRIM) topographical and hydrological data (Figure 2). These catchment polygons were used to query bedrock geology expressed in terms of lithology (Figure 3), which is often more meaningful geochemically than using stratigraphic nomenclature. Raw Cu data from northern Vancouver Island is strongly influenced by the distribution of Karmutsen Formation basalt (Figure 4), thus subduing Cu anomalies associated with porphyry Cu deposits.

ASSESSING COMPOSITIONAL CONTROLS

The main controls on chemical variation are assessed through exploratory data analysis (Grunsky, 2010). A useful tool in examining multi-element data is Principal Component Analysis (PCA) which is used to identify key element associations and determine the geochemical vectors that best describe the dataset. A centered-log ratio transformation is applied to the data prior to PCA to remove the effect of closure (Grunsky 2010). This procedure provides a statistically relevant means to assess the impact of lithological variation and scavenging of cations by secondary Fe and Mn oxides, clays and/or organic material. It is often evident that certain components are relatable to different lithological map units (Figure 5), or have element associations that are indicative of scavenging. In some instances, it can be shown that principal components can be directly related to mineral deposits. In this case a clear pathfinder element suite can be utilized.

PROCESSING OF GEOCHEMICAL DATA

Historically, various methods have been used to level background variation related to changes in lithology including levelling by the presence or absence of a particular lithologic unit, levelling by dominant mapped lithology and levelling based on the proportion of each lithologic unit within a catchment (Arne and Brown, 2015). Key shortcomings of these approaches are the reliance on the interpreted distribution of bedrock units and the assumption that all units within a given catchment have equal erosion rates. Instead of using mapped geology we use the geochemical data to define key vectors that relate to lithology or scavenging and use this information to level the data through regression analysis of key commodity or pathfinder elements against those principal components in which they are strongly represented (Figure 6).

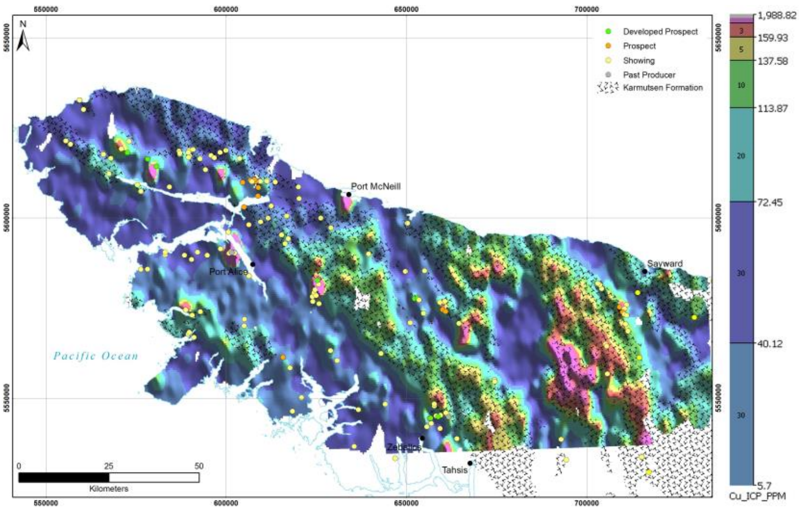

Figure 4: Gridded percentile image of raw Cu (in ppm) in regional stream sediments from northern Vancouver Island overlain by the distribution of the Karmutsen Formation basalts.

DEFINING GEOCHEMICAL TARGETS

The processed data are used to generate geochemical indices for different deposit types based on an understanding of which elements are most likely to be elevated in a given style of deposit. Rather than rely solely on published ideal element associations, signatures related to known deposits in the study region are used to define which elements are included. As described by Garret and Grunsky (2001) individual element values can be combined using weighted sums models. This technique allows for importance rankings to be assigned to each elements or ratios at the discretion of the modeler.

CONCLUSIONS

Recent work by the Authors (Arne and Brown, 2015; Mackie et al., 2015) has shown that PCA is effective in characterizing the distribution of geochemically distinct lithological units on a regional scale using data from RGS. Furthermore, for those principal components that contain commodity or pathfinder elements of interest, regression of those elements against one or more principal components that contain them is an effective way to correct for background variability in the data. These residuals can be combined in a weighted sums model to target various mineral deposit types more effectively than the use of raw geochemical data alone.

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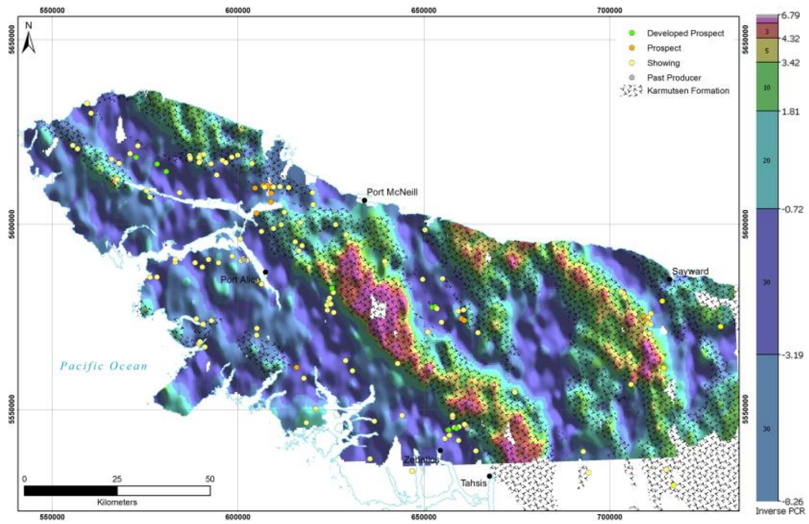

Figure 5: Gridded percentile image of inverse PC1 showing a good spatial match with the distribution of the Karmutsen Formation basalts (from Arne and Brown, 2015).

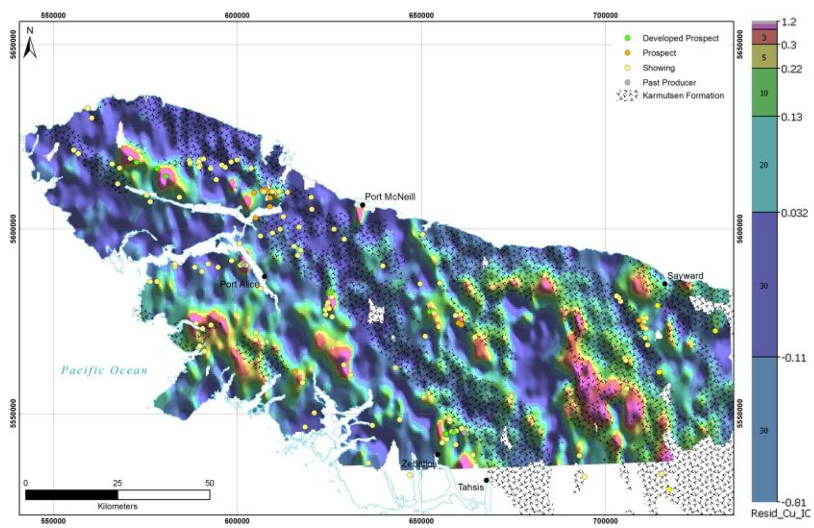

Figure 6: Gridded percentile image of Cu residuals following regression against PC1.