EXPLORATION TARGETING USING STREAM SEDIMENTS IN BRITISH COLUMBIA AND YUKON, CANADA

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TELE GEO

OUTLINE

- Statement of problem
- Background to catchment analysis
- Case studies
  - British Columbia
  - Yukon Territory
- Conclusions

ACKNOWLEDGEMENTS

Rob Mackie & Chris Pennimpede, CSA Global

Yao Cui, British Columbia Geological Survey

Eric Grunsky

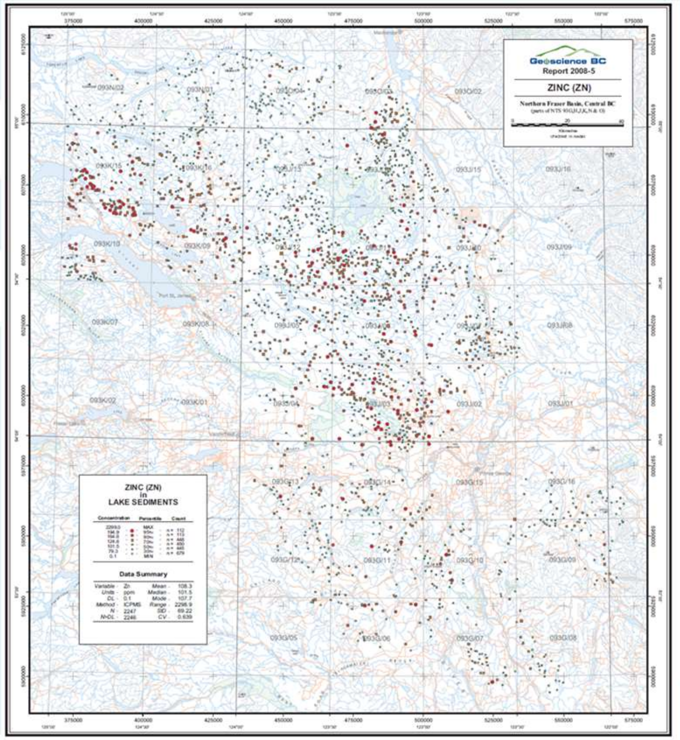
Funding from Geoscience BC

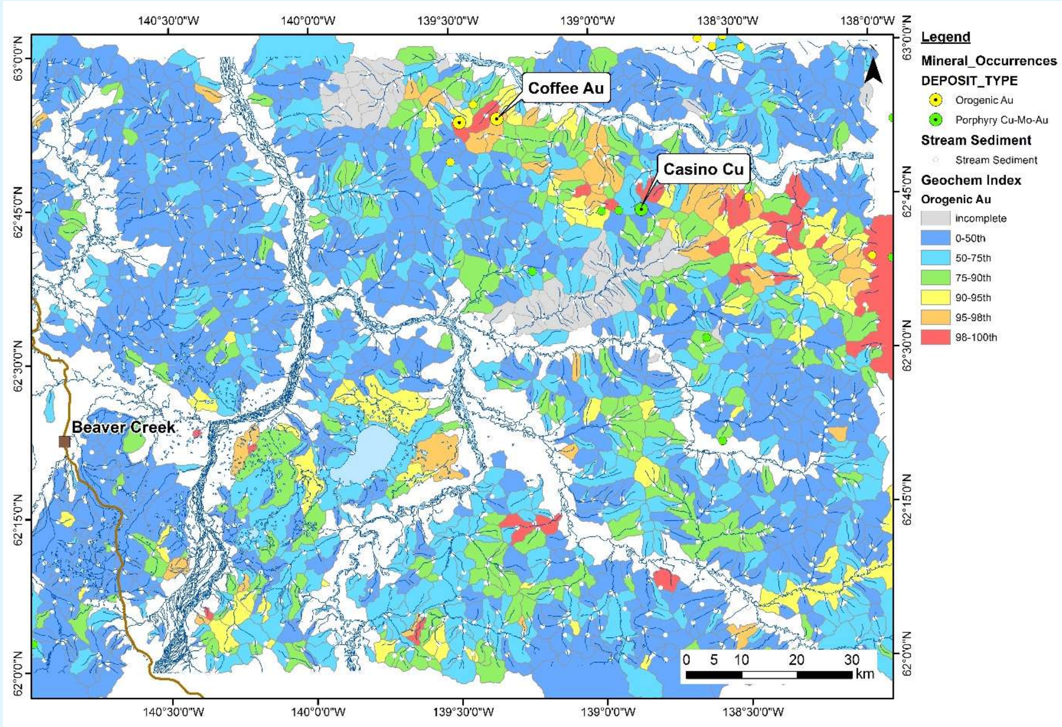
Funding from Yukon Geological Survey

STATEMENT OF PROBLEM

- How do we correct stream sediment data for the effects of variable geochemical background due to different lithological units?
- How do we take into account surficial processes such as scavenging of metals onto secondary Fe and Mn oxides, clay minerals or organics?
- How do we correct for the differential effects of dilution in catchment basins of differing area?
- How do we collect a representative and repeatable sample for analysis of particulate phases such as Au?

THEMATIC VS TARGETING PRODUCTS





How do we get from this ….

To this?

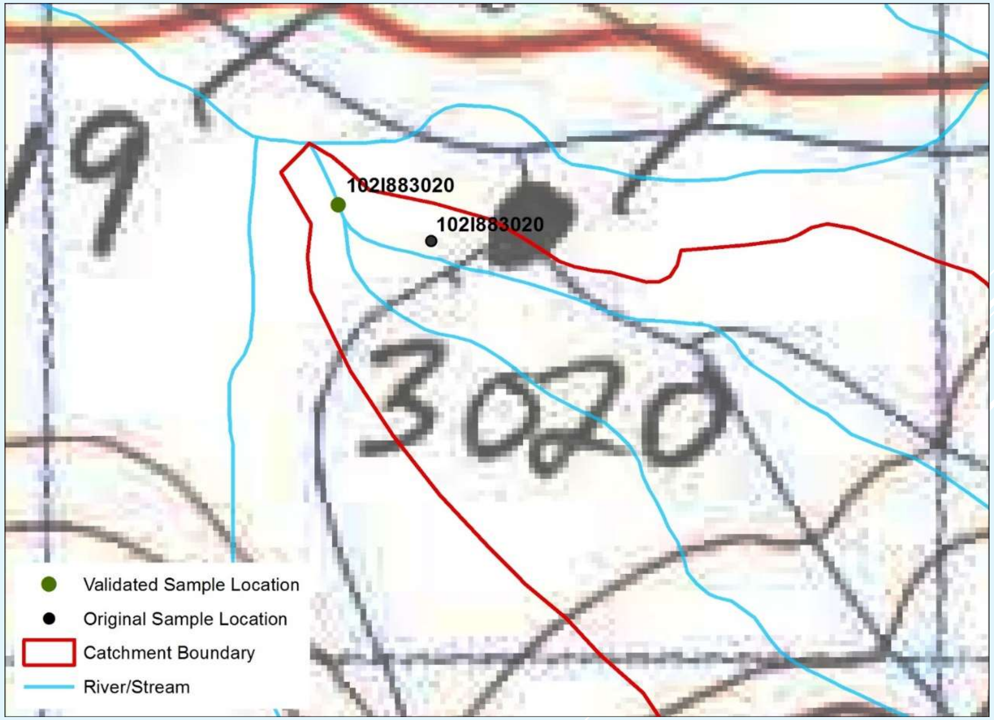
CATCHMENT ANALYSIS APPROACH

- Stream sediments represent geochemical data from an area, rather than a point source.
- Catchment basin lithologies are the main influence on stream sediment geochemistry; these can be corrected by:
  - Productivity analysis
  - Levelling by dominant lithology
  - Levelling by presence/absence of significant unit (i.e. basalt or black shale)
  - Weighted average background of lithologies in catchment
  - Multiple regression analysis of lithologies in catchment
  - Principal component analysis & regression analysis

SAMPLE LOCATION VALIDATION

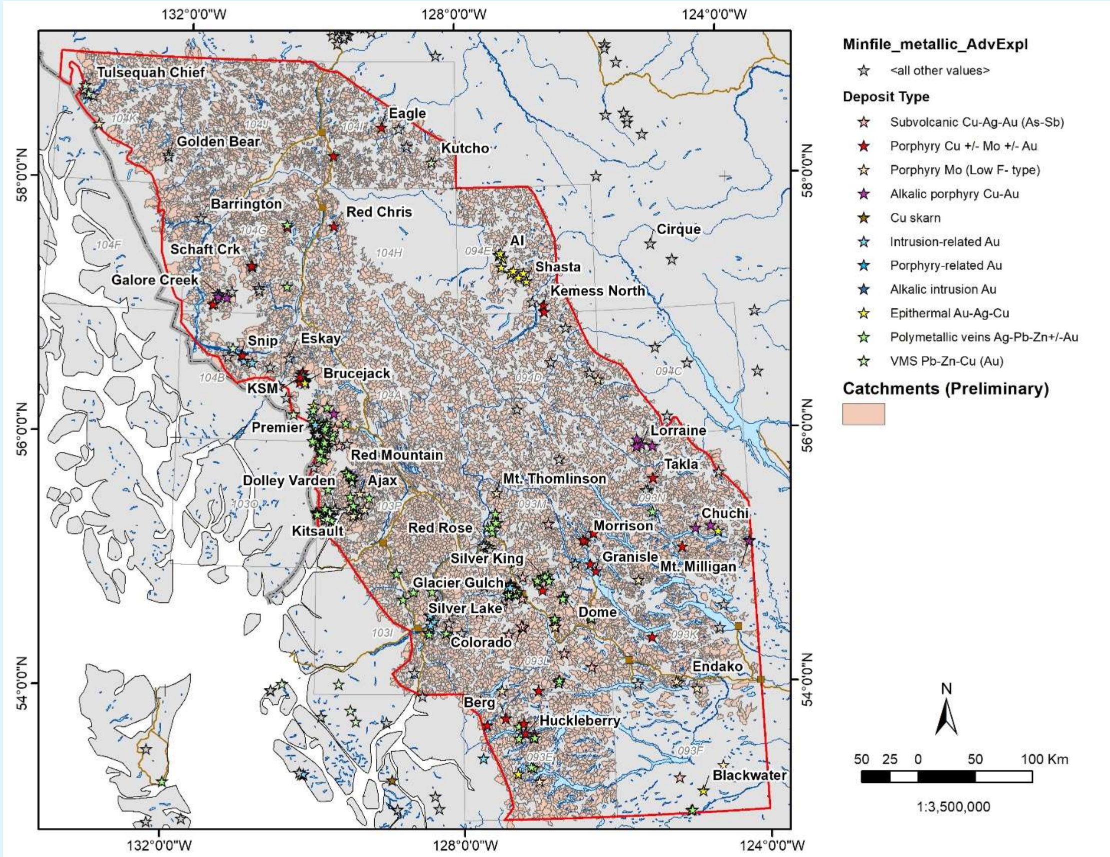
- Regional Geochemistry Survey samples were mainly collected prior to the widespread use of GPS.
  - i.e. physical transcription of data from paper maps and manual entry into GSC database (scope for error!)
- Original topographical maps used to locate samples may have been inaccurate compared to present day terrain data.
- Sample locations must be adjusted to lie on correct drainage, based on original topographic maps.

Sample location from Vancouver Island
re-located onto TRIM hydrology layer



DERIVATION OF CATCHMENTS

- Derived from digital elevation model (DEM).
- Previously done by tracing out the heights of land surrounding the catchment basin by hand.
- Now automated using a number of software packages – note that not all allow determination of a catchment from an arbitrarily located sample point rather than a stream outlet.

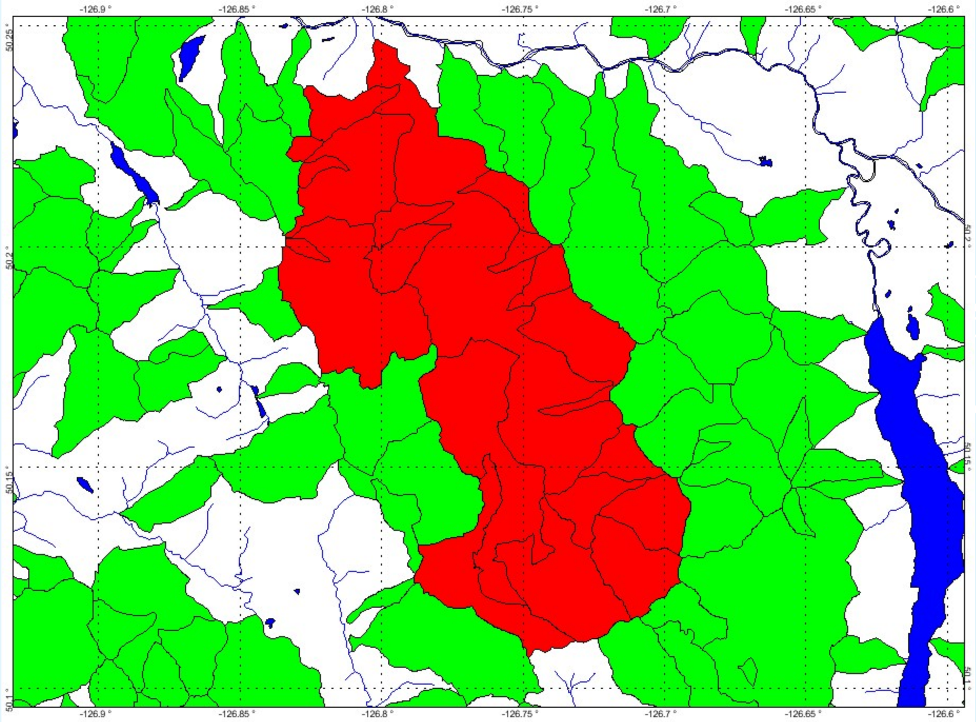


Preliminary catchment basins from northwest BC (From Mackie et al., 2018).

NESTED CATCHMENTS

- Catchment basins on lower order streams may be included within larger catchment basins.
- A stream sediment sample is influenced by all material upstream of the sample location.
- Catchment analysis may require the construction of overlapping (nested catchments) to adequately represent the source regions draining through each sample point.

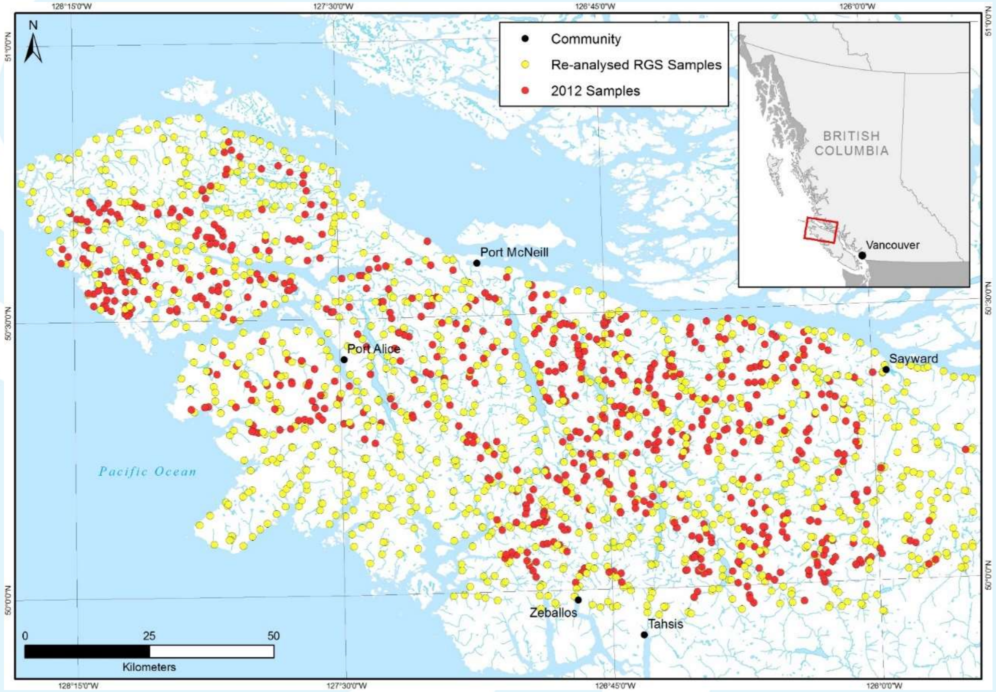
Large catchment basin in red containing multiple nested catchments within it.

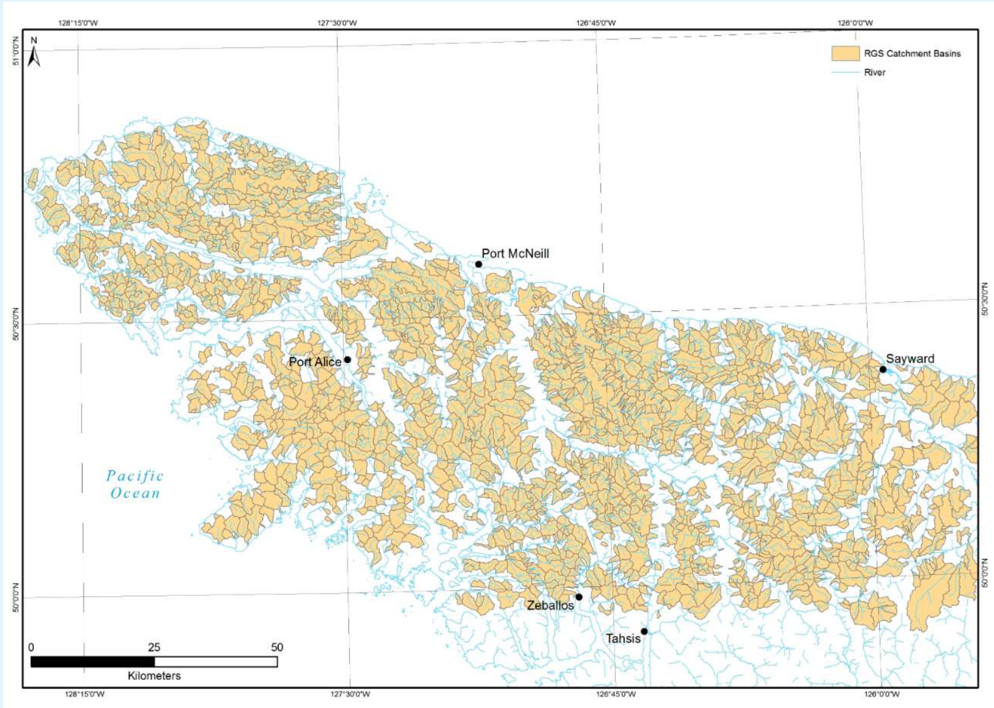


CASE STUDY 1 – NORTHERN VANCOUVER ISLAND

Arne, D.C. and Brown, O. (2015): Catchment analysis applied to the interpretation of new stream sediment data from northern Vancouver Island, Canada (NTS 102I and 92L). Geoscience BC Report 2015-4, 41 p., URL <http://www.geosciencebc.com/s/Report2015-04.asp> [October 2017]

NORTH VANCOUVER ISLAND CATCHMENTS





- Data compiled for 1835 samples in total
- Catchment basins delineated for 1725 samples

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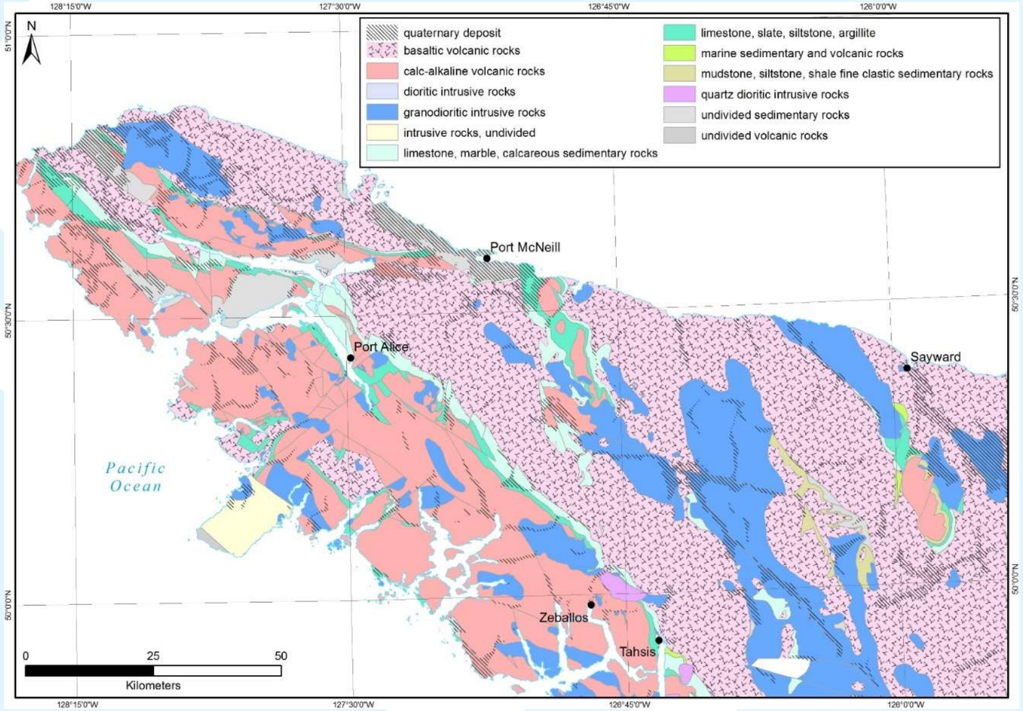
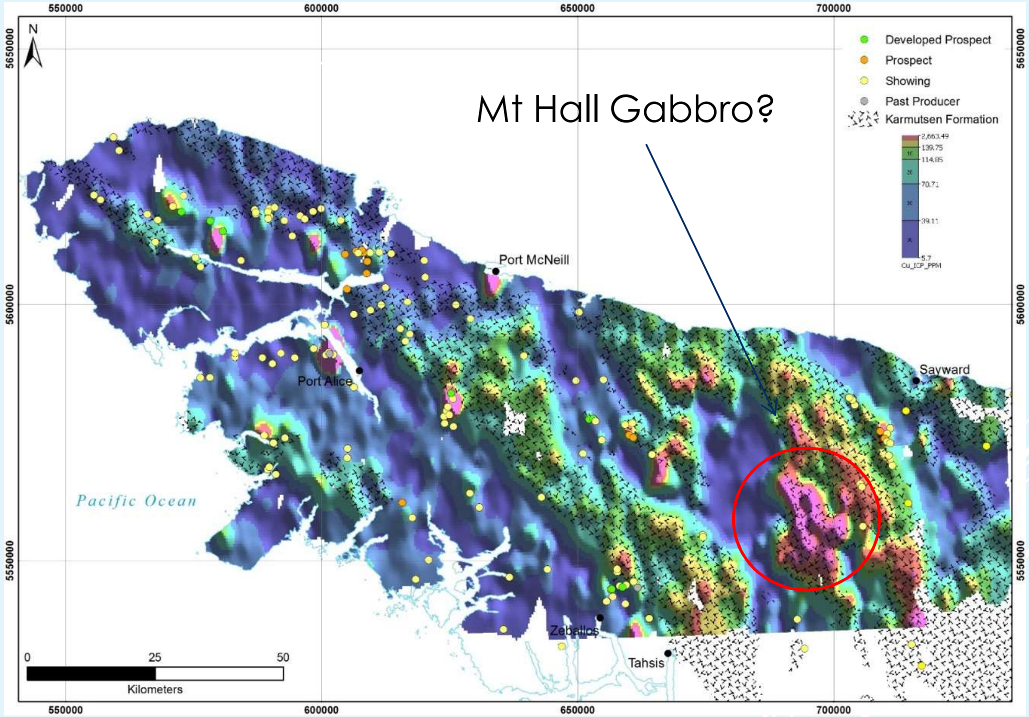
IMPORTANCE OF LITHOLOGY





- Geology is interpreted in terms of lithology, rather than map units.
- The distribution of Cu is clearly influenced by the Karmutsen basalt; difficult to distinguish Cu anomalies associated with porphyry Cu deposits.

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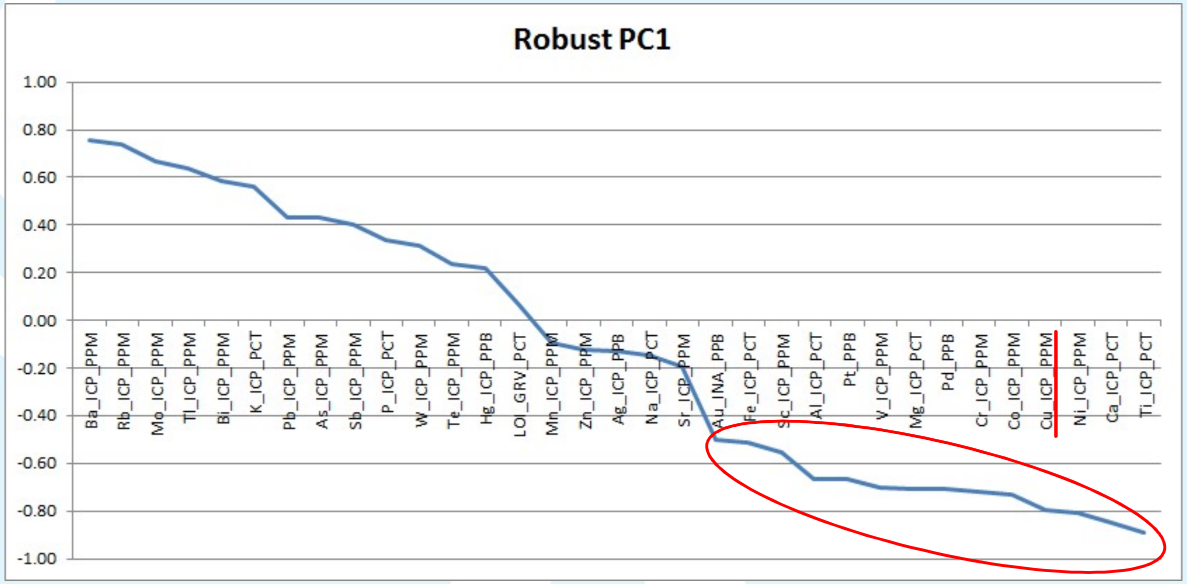
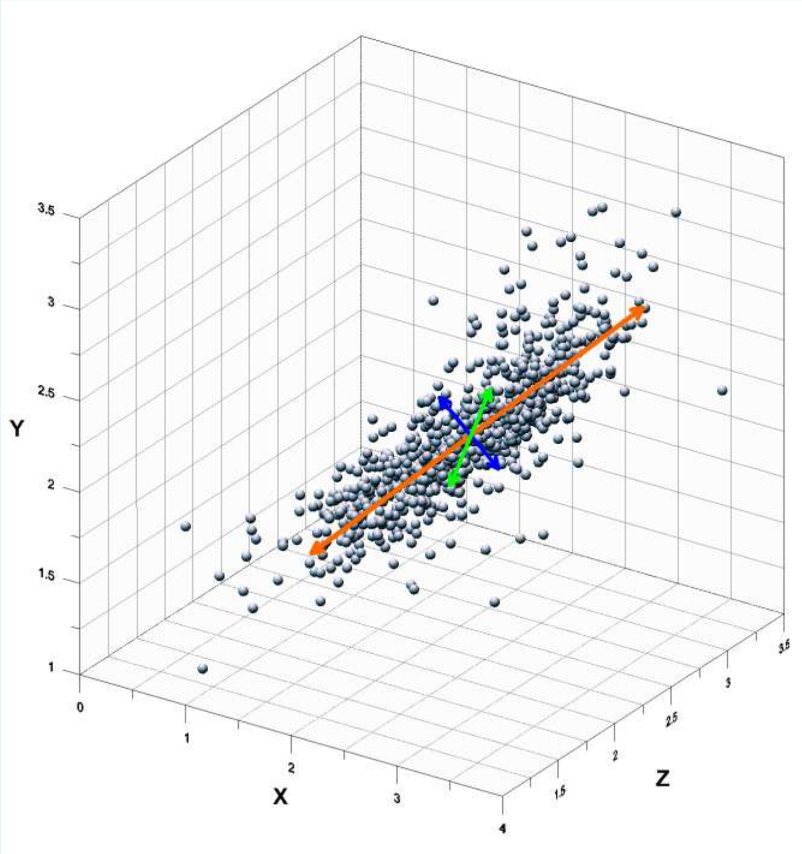
PRINCIPAL COMPONENT ANALYSIS





- The most important principal components from regional stream sediment geochemical data usually reflect bedrock lithology
- PC1 from northern Vancouver Island separates felsic and mafic lithologies

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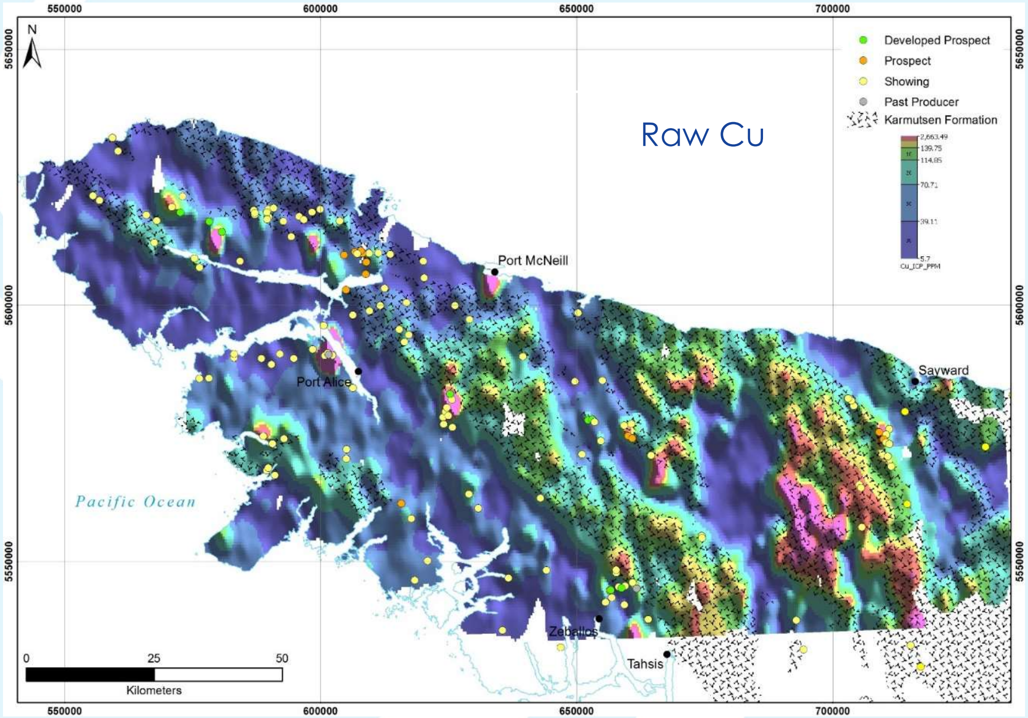
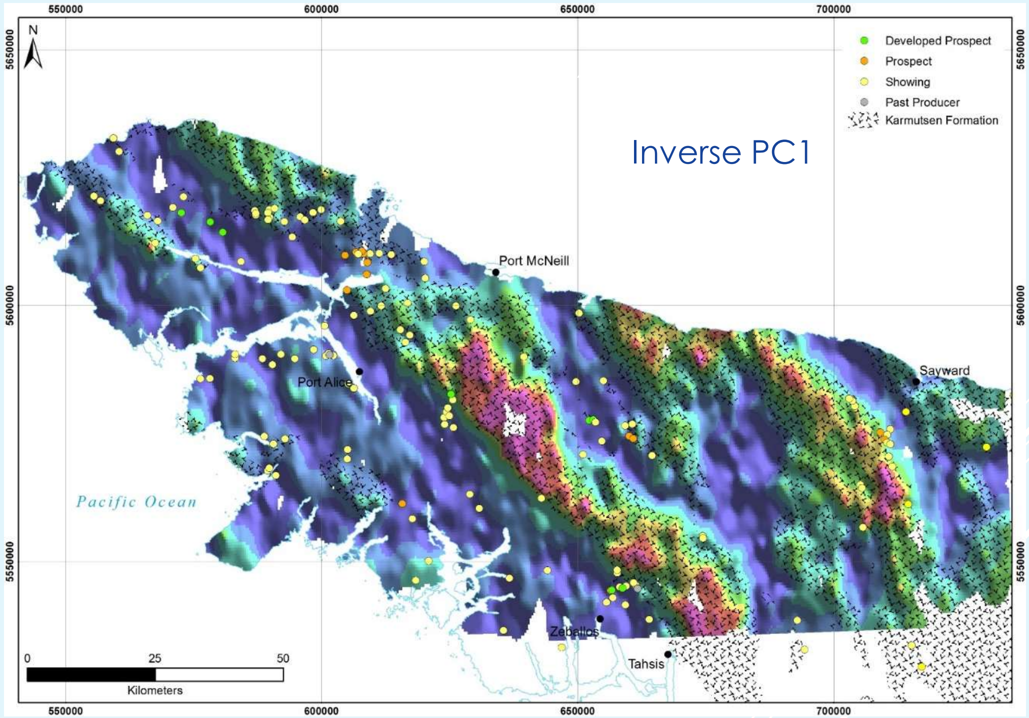
PC1 VS RAW CU DATA



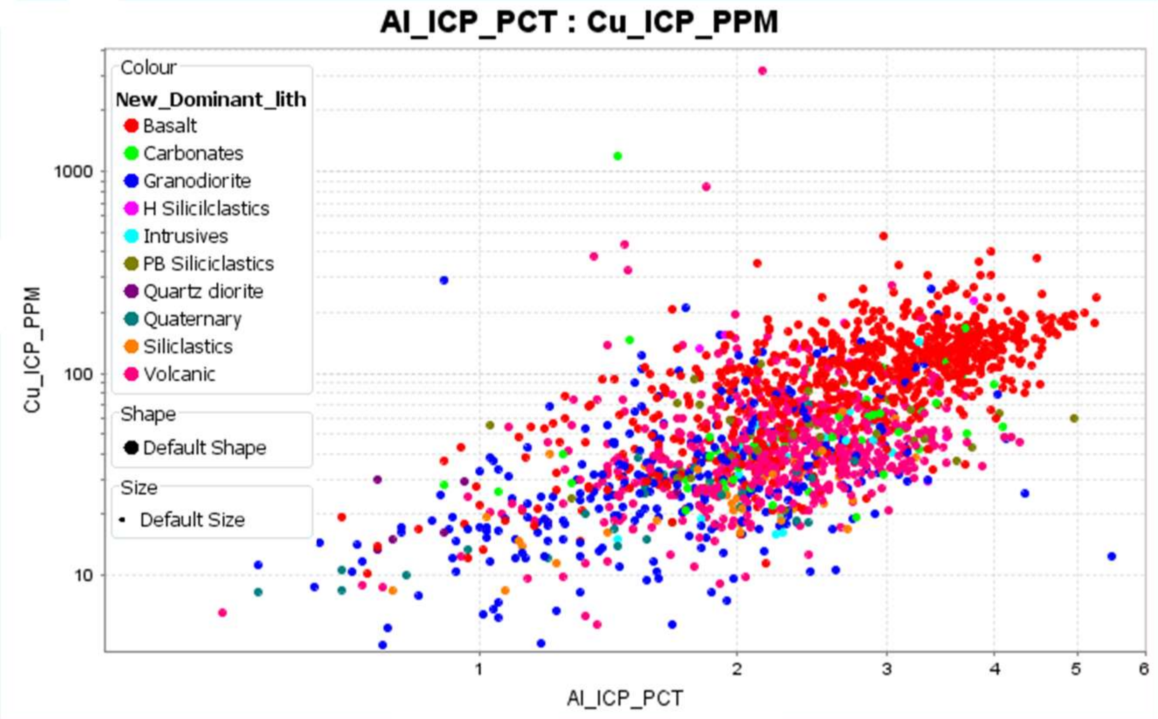


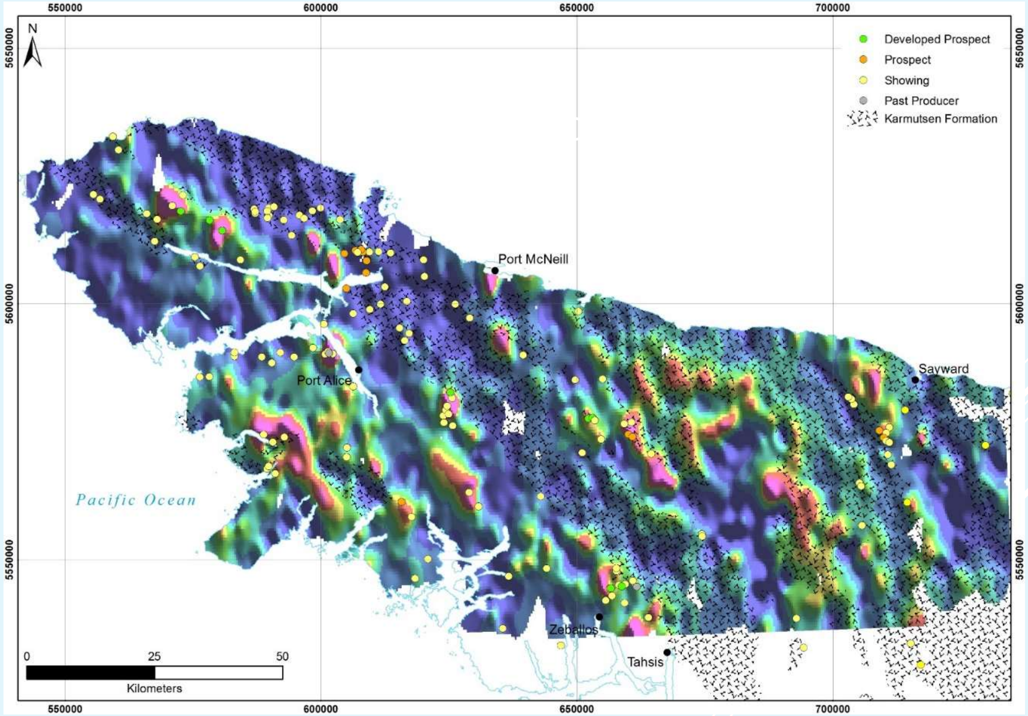
- PC1 provides a better discriminator for the Karmutsen basalt than raw Cu, which is influenced by the Mt. Hall Gabbro

DATA PROCESSING APPROACHES

- Raw data
- Residuals following regression against control elements
- Data levelled by dominant catchment lithology
- Data levelled by presence/absence of basalt
- Data levelled by catchment weighted background value
- Multiple regression analysis using catchment geology
- Residuals following regression against principal components
- Productivity analysis
- Weighted sums model
- Weighted sums model adjusted for catchment area size

RELATIONSHIP BETWEEN Cu AND Al



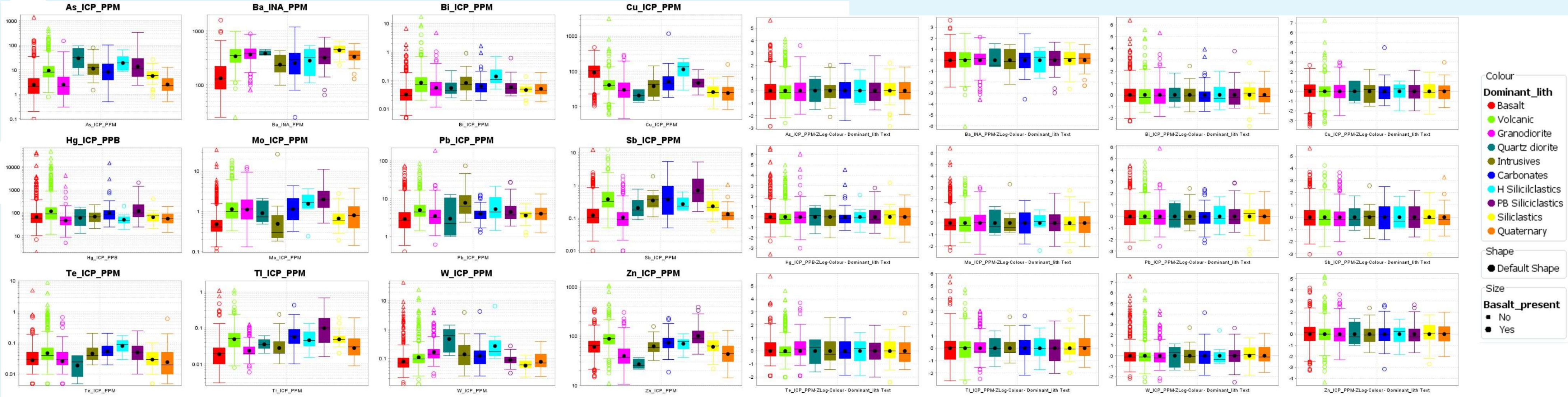


- Cu shows a positive correlation with Al
- Regression against Al removes some of the lithological effects

LEVELLING BY DOMINANT LITHOLOGY

Raw Data

Levelled Data



- Many potential pathfinder elements show lithological control
- Statistical outliers are preserved during Z-score levelling by grouped lithology

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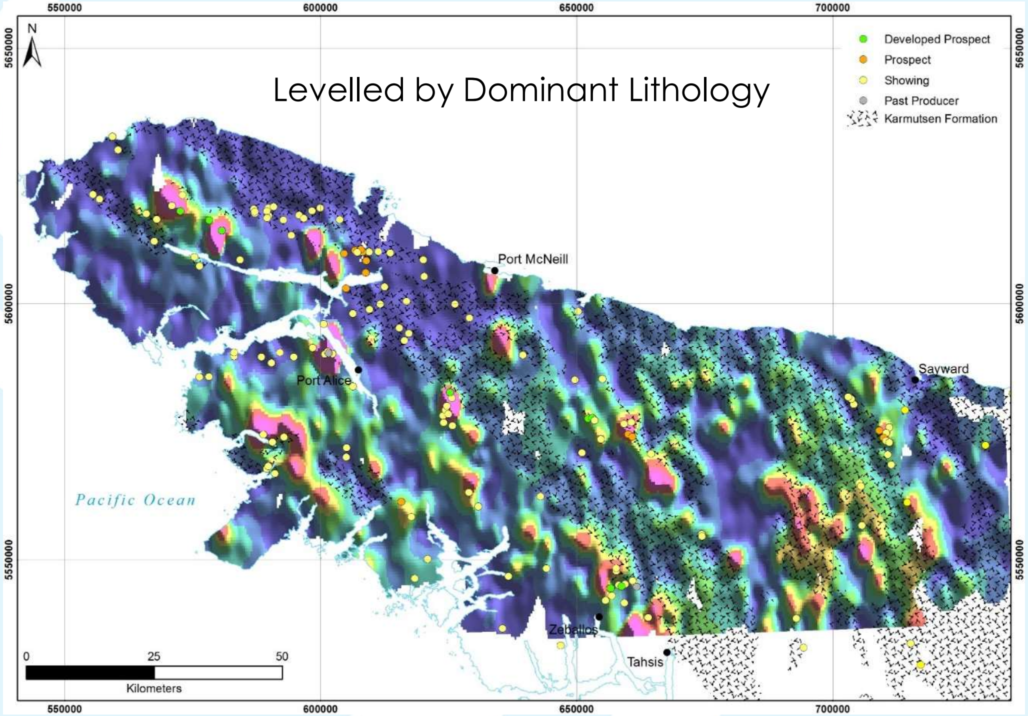
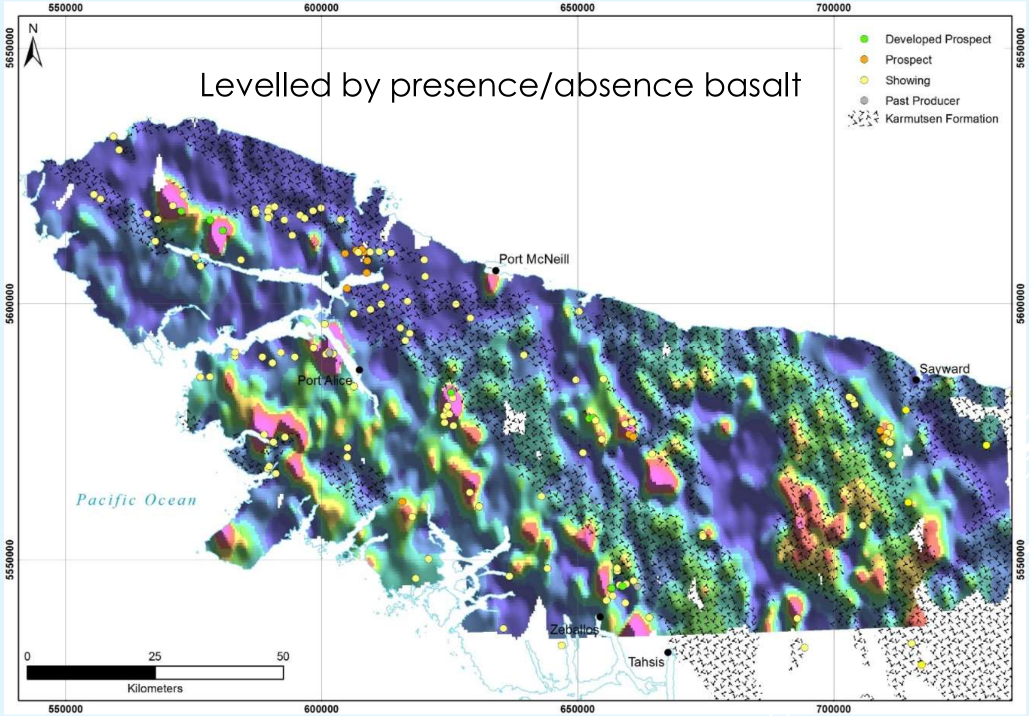
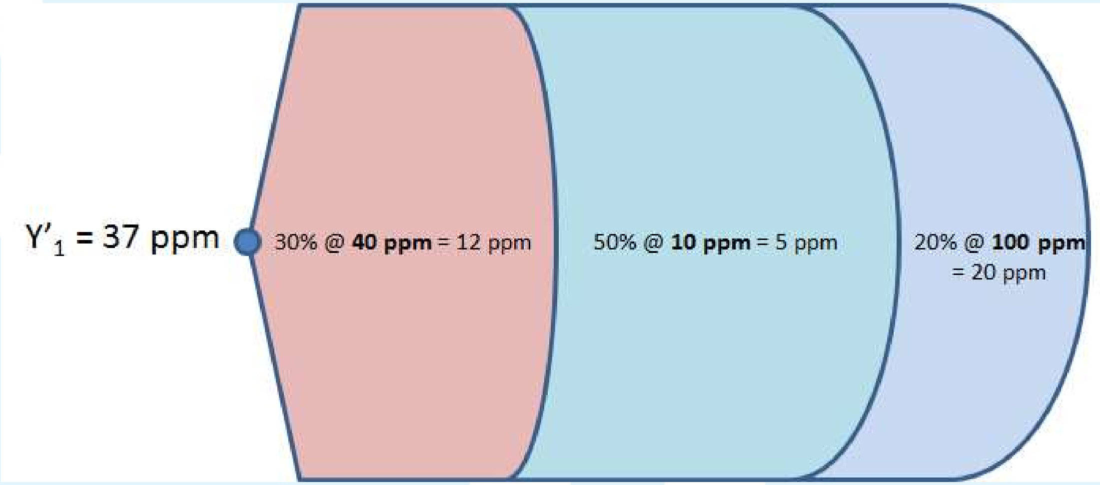
LEVELLING Cu DATA FOR LITHOLOGY

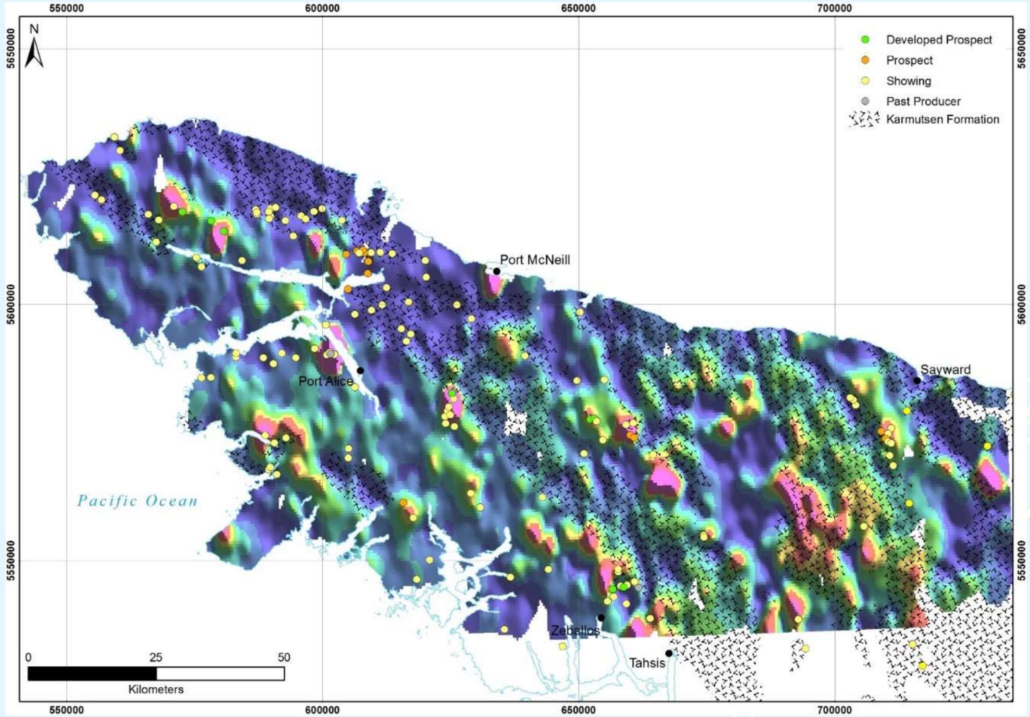




- Levelling by dominant lithology or presence/absence of basalt both reduce lithological effects

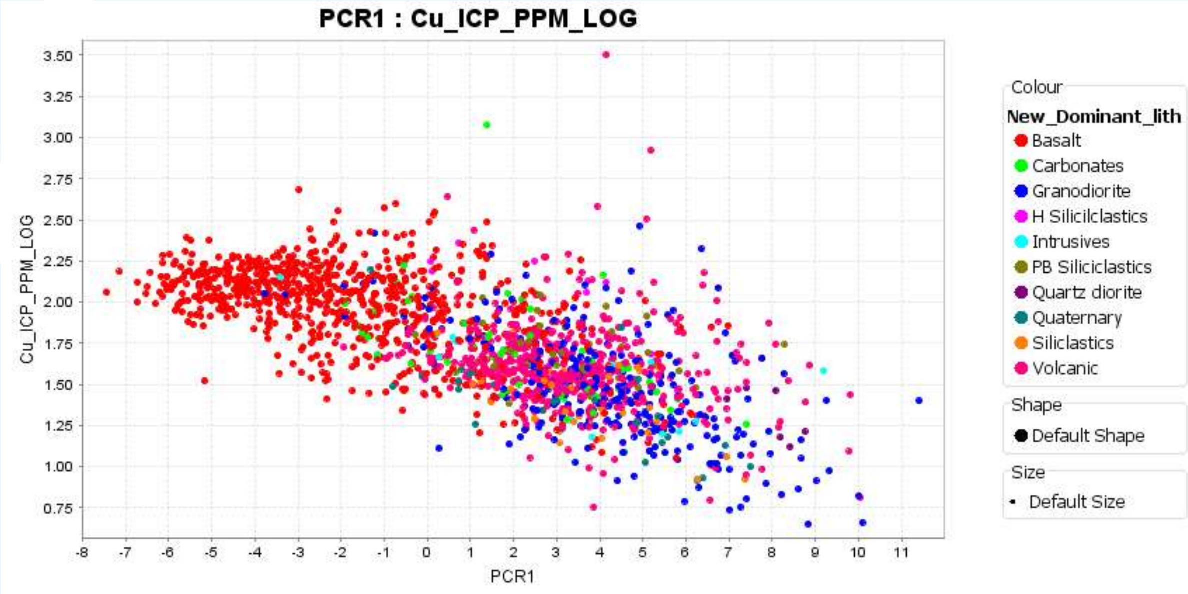
WEIGHTED BACKGROUND VALUES

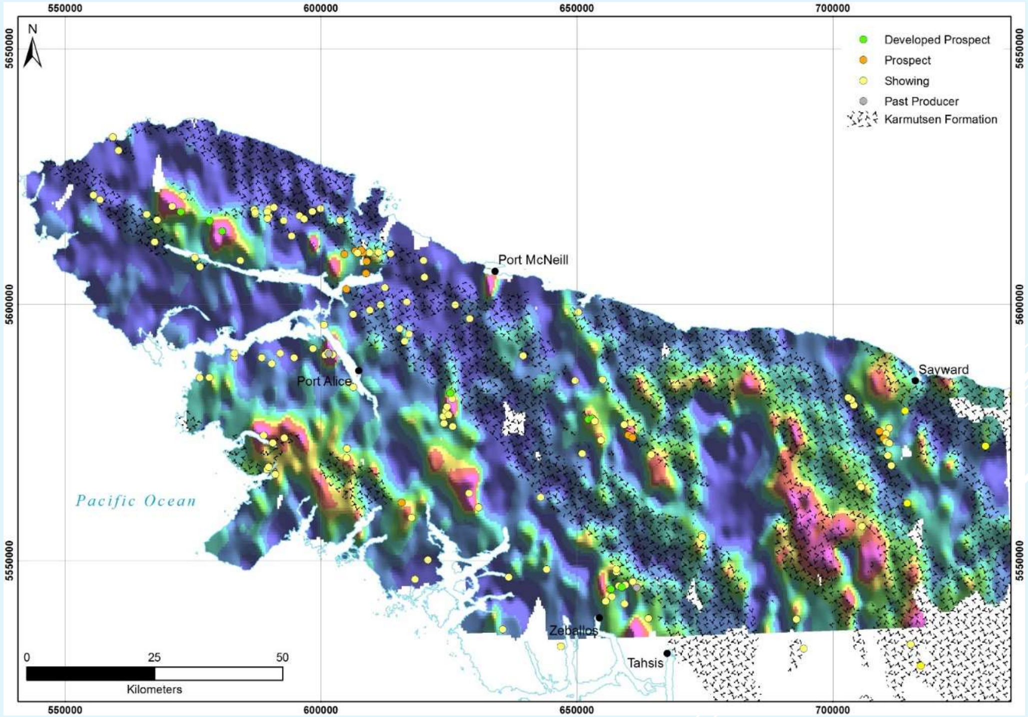




- Average background values have been estimated for most lithologies
- These have been used to calculate weighted average background values, which were used to calculate Z-scores

REGRESSION AGAINST PC1





- Cu can be regressed against PC1 (lithological control)
- High positive residuals represent Cu above predicted background

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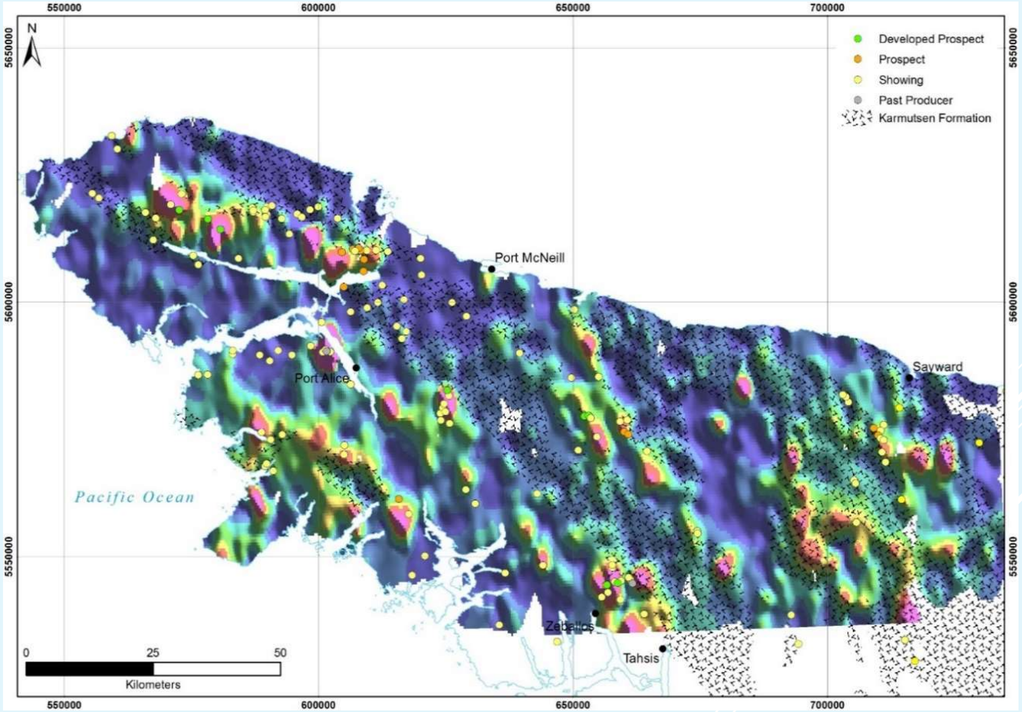
WEIGHTED SUMS MODEL (From Garrett & Grunsky, 2001)

- The user assigns importance rankings (positive or negative) to selected variables based on a-priori knowledge of the mineralogy/chemistry of a target mineral deposit type
- For a porphyry Cu example, using levelled data:

Cu	Mo	Ag	Au*	Zn
3	2	1	1	1

*raw data



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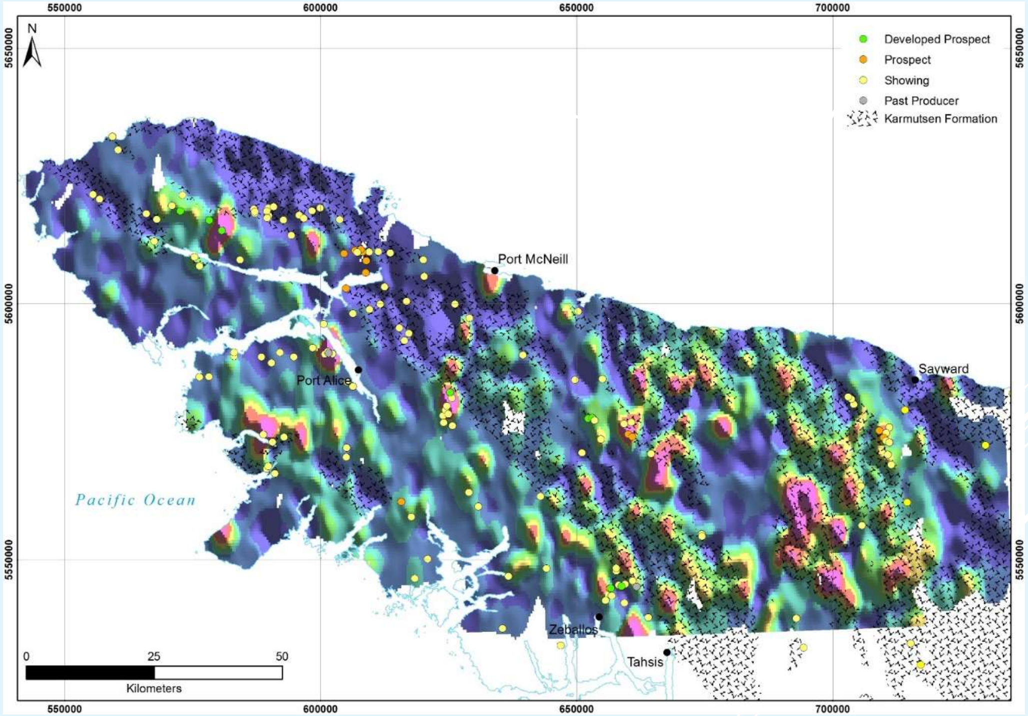
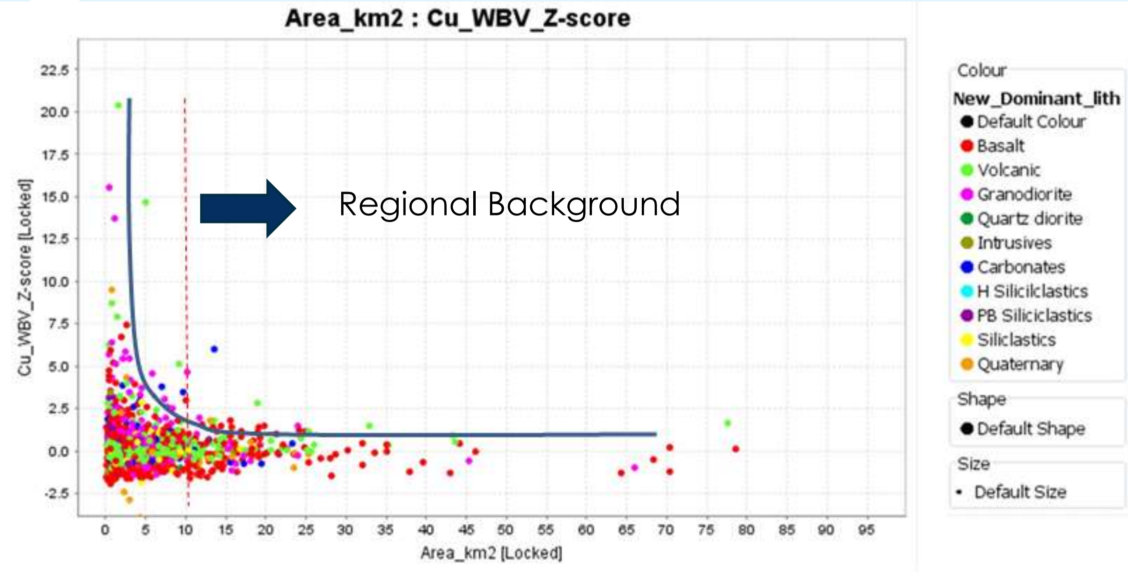
PRODUCTIVITY ANALYSIS

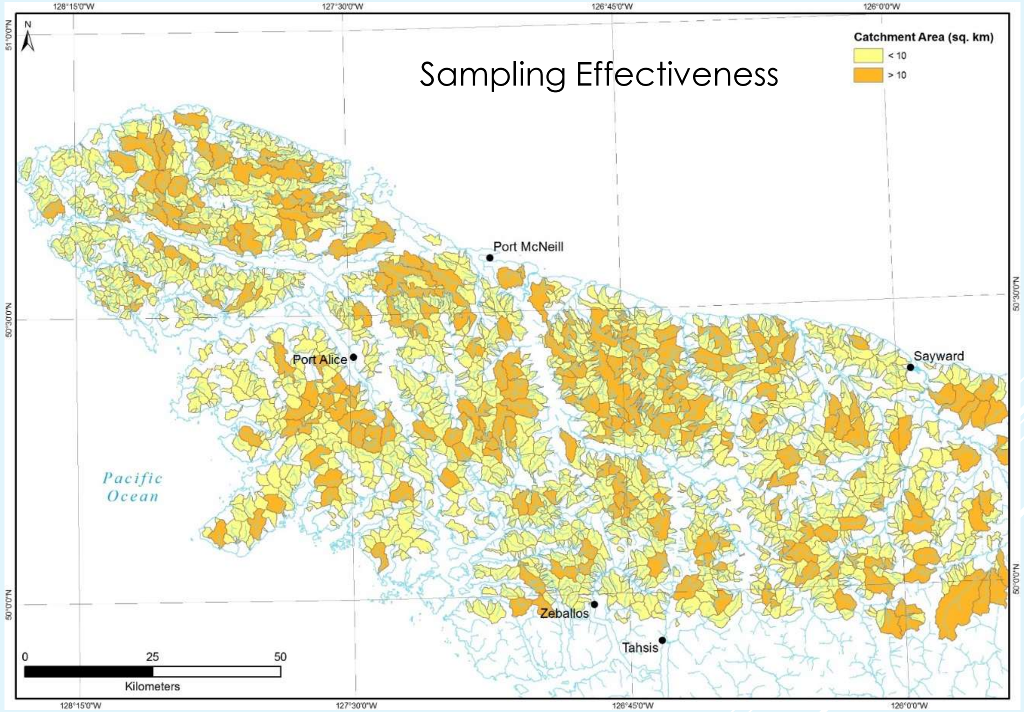
(From Rose *et al.*, 1979)

- Introduced to account for the downstream dilution of the geochemical signature from a mineral deposit exposed within a catchment basin:
  - $Me_m A_m = (Me_a - Me_b)A_a + Me_b A_m$ where
    - Me_a = the metal content at the mouth of catchment
    - A_a = the total area of the catchment
  - Me_m = the metal content of the eroding mineral deposit
  - A_m = the area of the target exposed at surface
    - Me_b = background metal content in the catchment
- However, for a small deposit size relative to the area of the catchment: $Me_m A_m = (Me_a - Me_b)A_a$
  - This is also known as the Productivity



DILUTION EFFECTS

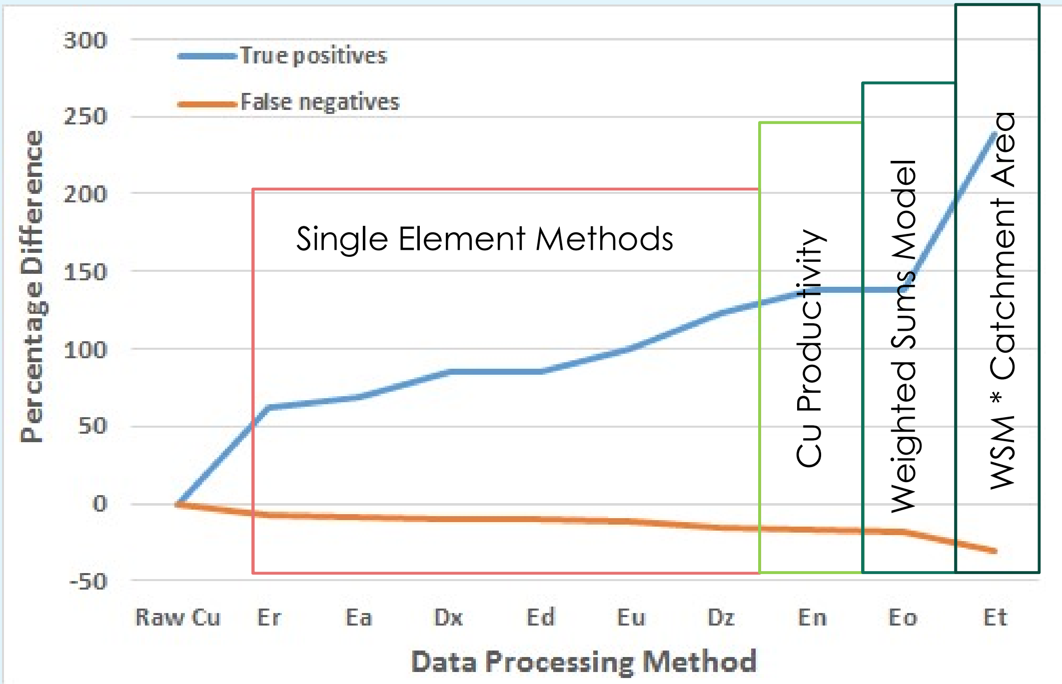




- Geochemistry in catchment areas >10 km^2 mainly reflects regional background
- Catchments > 10 km^2 have not been effectively sampled

METHOD VALIDATION

	Cu Occurrences	No Cu Occurrences
>90th Percentile	True Positives	False Positives
<90th Percentile	False Negatives	True Negatives

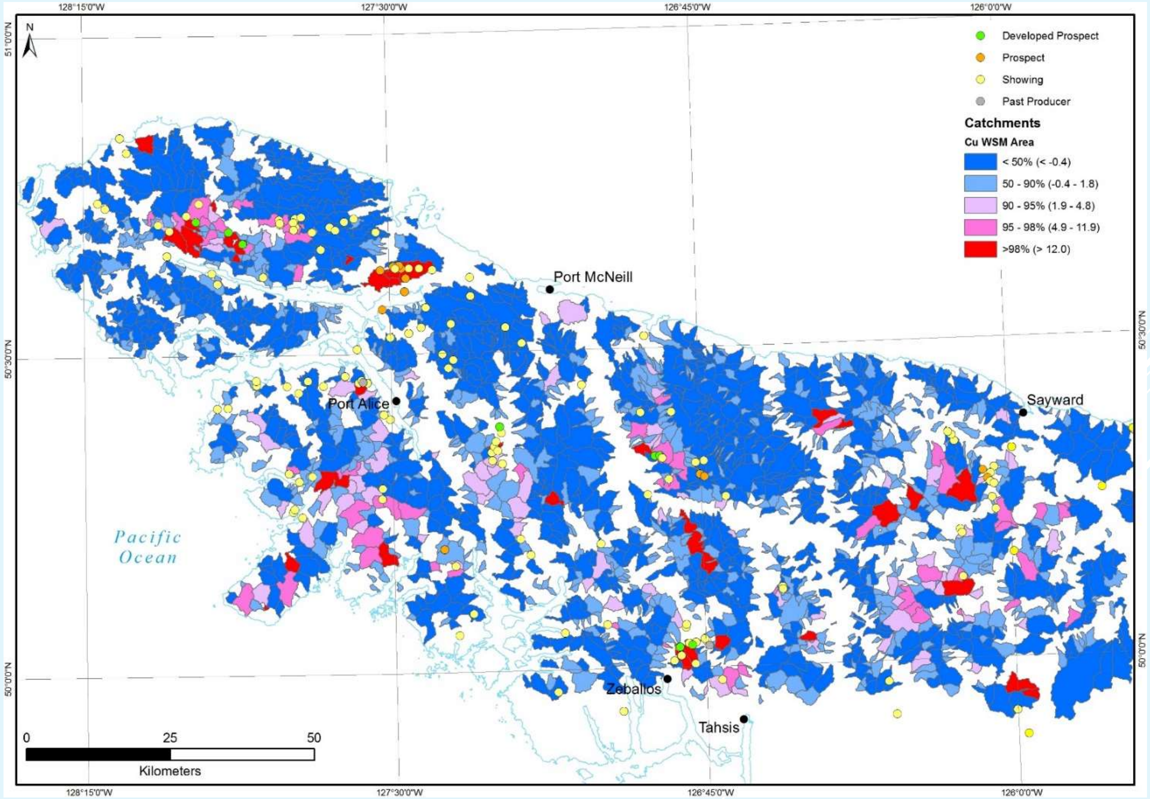


- Data processing methods were validated against known occurrences

FINAL PRODUCTS

- 41 page report.
- Compiled data file with geochemistry.
- Shapefile of catchments attributed with derived values.
- PDF copies of report figures and catchment maps.

Example of thematic catchment basin map



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CASE STUDY 1 CONCLUSIONS

- The effects of elevated background Cu are easily filtered using a variety of methods of varying sophistication.
- Processing methods using several commodity and pathfinder elements weighted for the effects of dilution work best.
- Existing Cu occurrences & deposits on NVI are more readily apparent and new targets evident in the processed data.
- An empirical assessment of sampling effectiveness indicates there are still exploration opportunities in under-sampled areas.
- There is still much value to be obtained from the processing of RGS data, especially where archived material has been re-analyzed by ICP-MS.

CASE STUDY 2 – YUKON TERRITORY

Mackie, R.A., Arne, D.C. and Brown, O., (2015): Enhanced interpretation of regional stream sediment geochemistry from Yukon: catchment basin analysis and weighted sums modelling; Yukon Geological Survey, Open File 2015-10. URL <URL http://data.geology.gov.yk.ca/Reference/69462 [November 2017].>

Mackie, R.A., Arne, D.C. and Pennimpede, C. (2017): Assessment of Yukon regional stream sediment catchment basin and geochemical data quality; Yukon Geological Survey, Open File 2017-4, 36 p., URL <http://data.geology.gov.yk.ca/Reference/79430> [October 2017]

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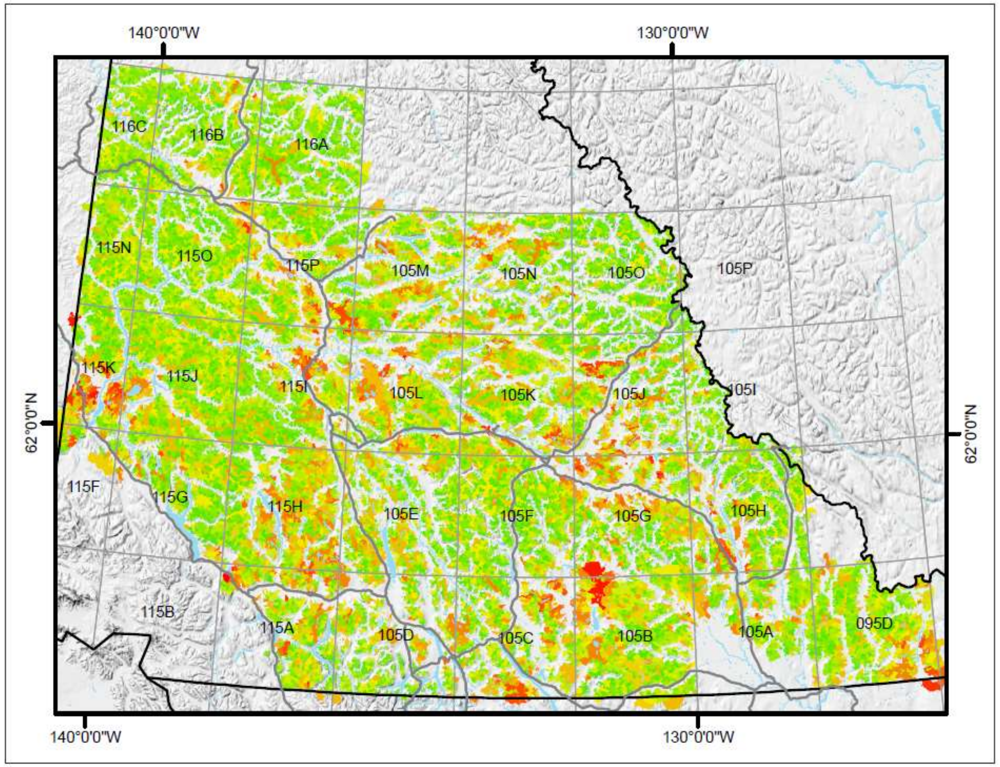
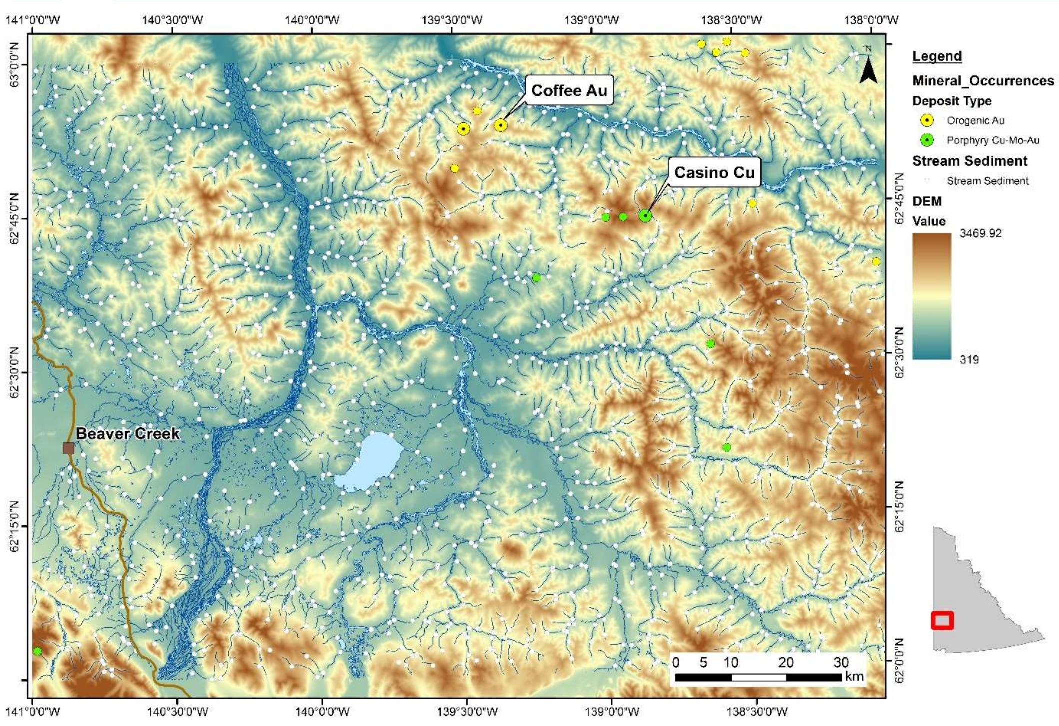
YUKON TERRITORY PROJECT (2015-2017)

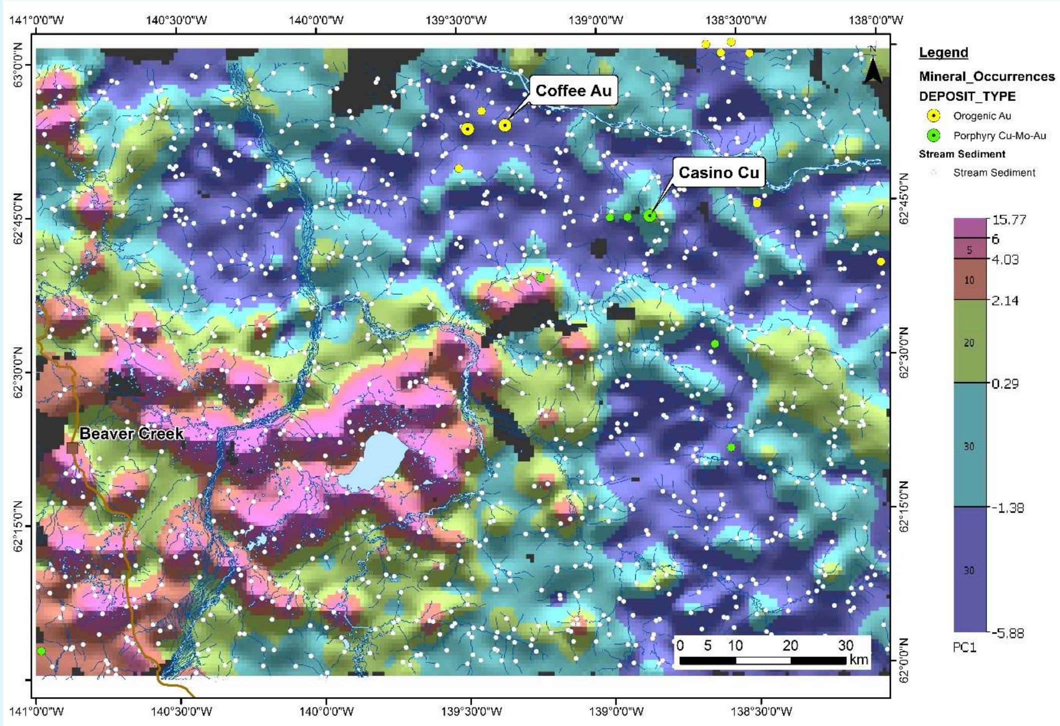
- A total of 24,279 original RGS sample pulps re-analysed by ICP-ES/MS by Yukon Territory.
- 29 entire or partial NTS 1:250,000 map sheets evaluated.
- Catchments also assessed for sample location accuracy, slope angle, slope aspect, area and dominant material type.
- Levelled by dominant catchment lithology and by principal component analysis.

Thematic map of overall catchment quality



SCAVENGING EFFECTS





- PCA component 1 is characterized by high loadings in LOI, Ca, Sr, As, Cu, Co, Fe, Zn.
  - Note the correspondence of high PC1 with a topographically subdued region.

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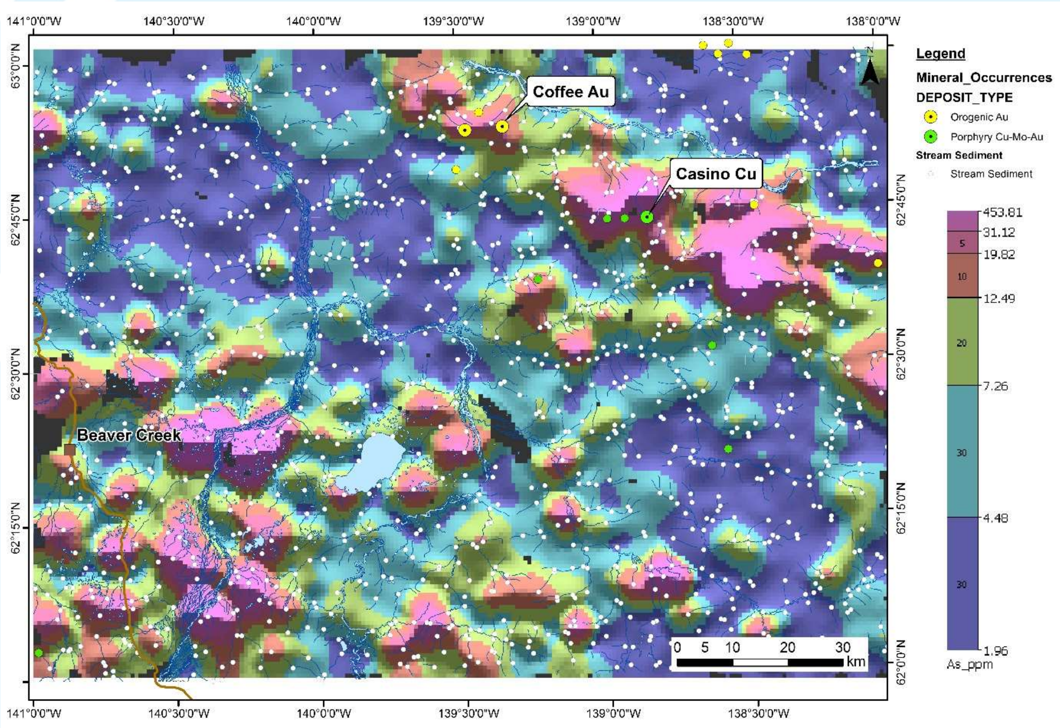
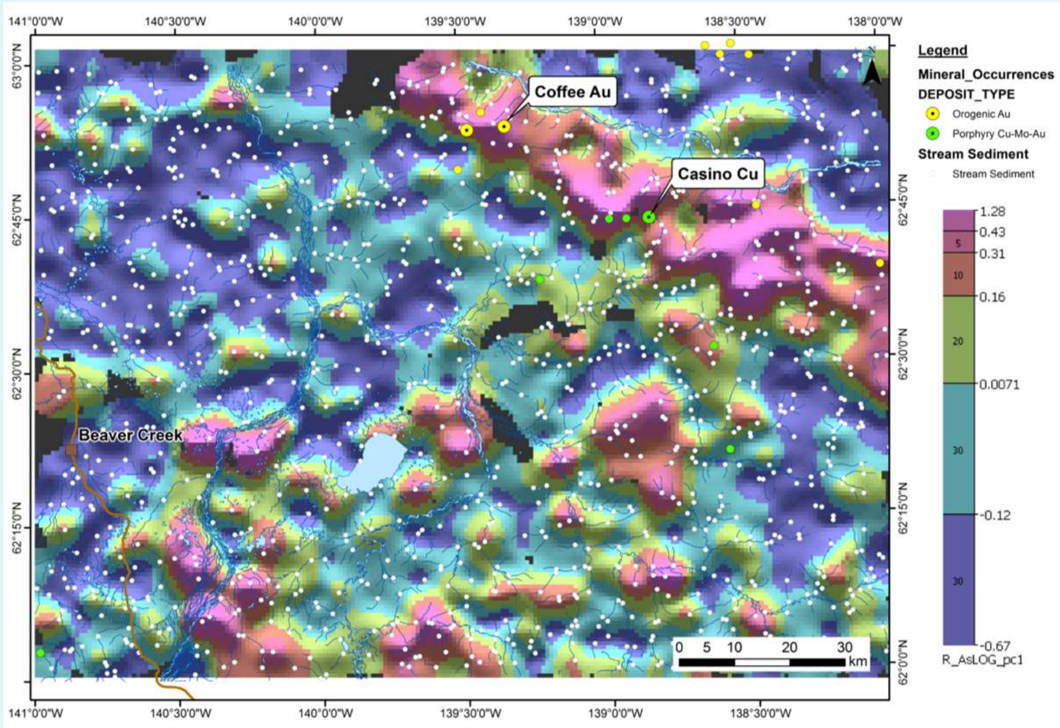
REGRESSION OF As AGAINST PC1





- Regression of As against PC1 reduces (but does not eliminate) the scavenging influence of organics and secondary Fe oxides in the sediments.

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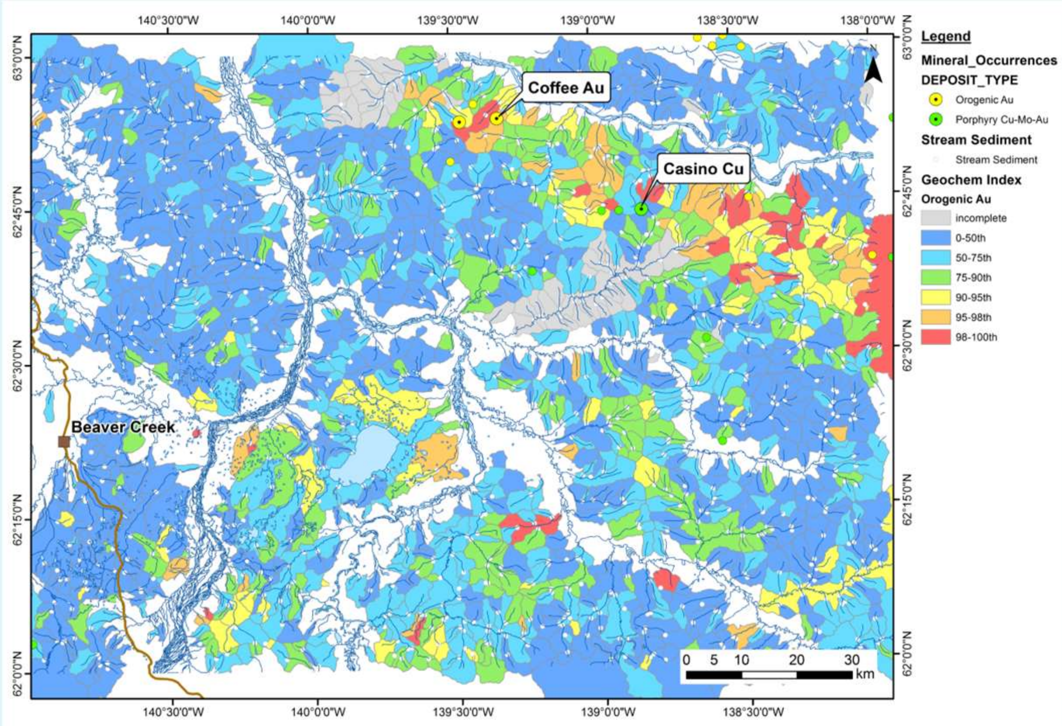
OROGENIC GOLD GEOCHEMISTRY MAP

- Weighted sums model calculated using As, Au, Sb & Te to enhance orogenic Au.
- Cu negatively weighted in the model to reduce the response of Cu-Au mineralization along the Casino trend.
- Catchments thematically coloured based on percentile weighted sums scores.
- Models also generated for a variety of different deposit types.



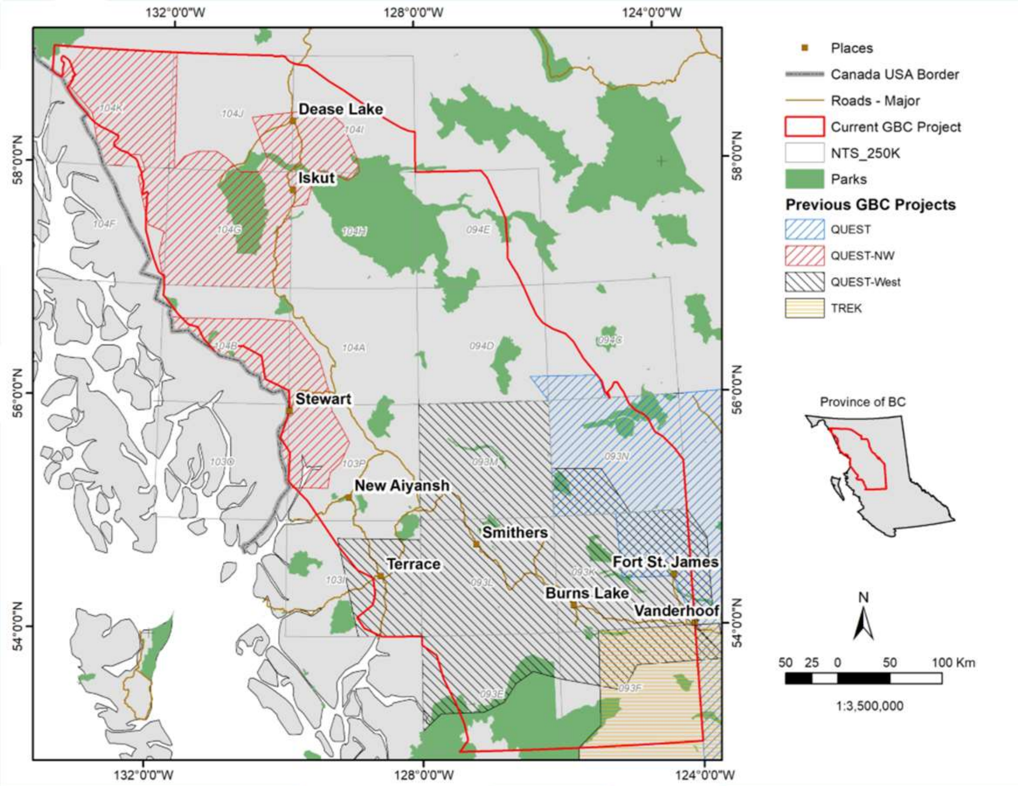
CASE STUDY 2 CONCLUSIONS

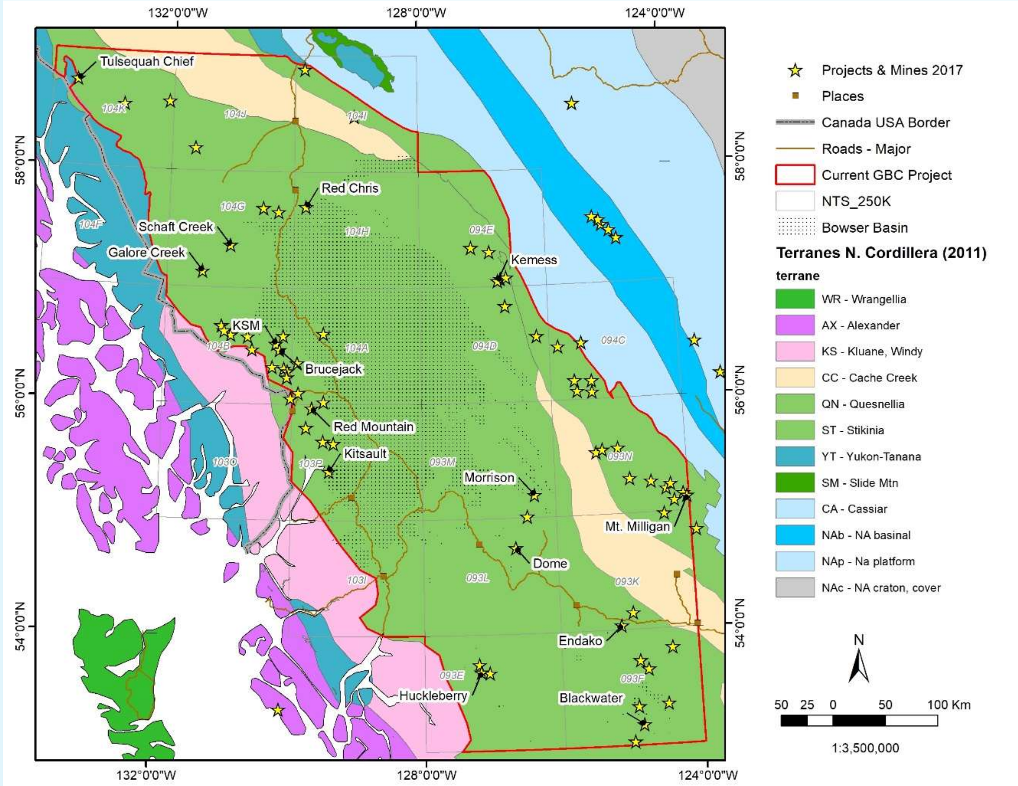
- The use of catchment basins to level stream sediment data assumes:
  - That the sample location is correct and the defined catchment basin is accurate;
  - That the bedrock geology map is an accurate representation of lithological variation in the catchment; and
  - That all areas of the catchment are contributing equally to the sediment load sampled at the stream sediment sample location.
- The use of principal components for data levelling assumes:
  - That the principal components can reliably be related to either lithology or the effects of scavenging.
  - This approach is divorced from the physical location of the data and is entirely "data-driven".

CASE STUDY 3 – NORTHWESTERN BRITISH COLUMBIA

Arne, D.C., Mackie, R., Pennimpede, C. and Grunsky, E. (2018): Integrated assessment of regional stream-sediment geochemistry for metallic deposits in northwestern British Columbia (parts of NTS 093, 094, 103, 104); *in* Geoscience BC Summary of Activities 2017: Mineral and Mining, Geoscience BC, Report 2018-1, p. 23–30. URLhttp://cdn.geosciencebc.com/pdf/SummaryofActivities2017/MM/SoA2017_MM_Arne.pdf (February, 2018)

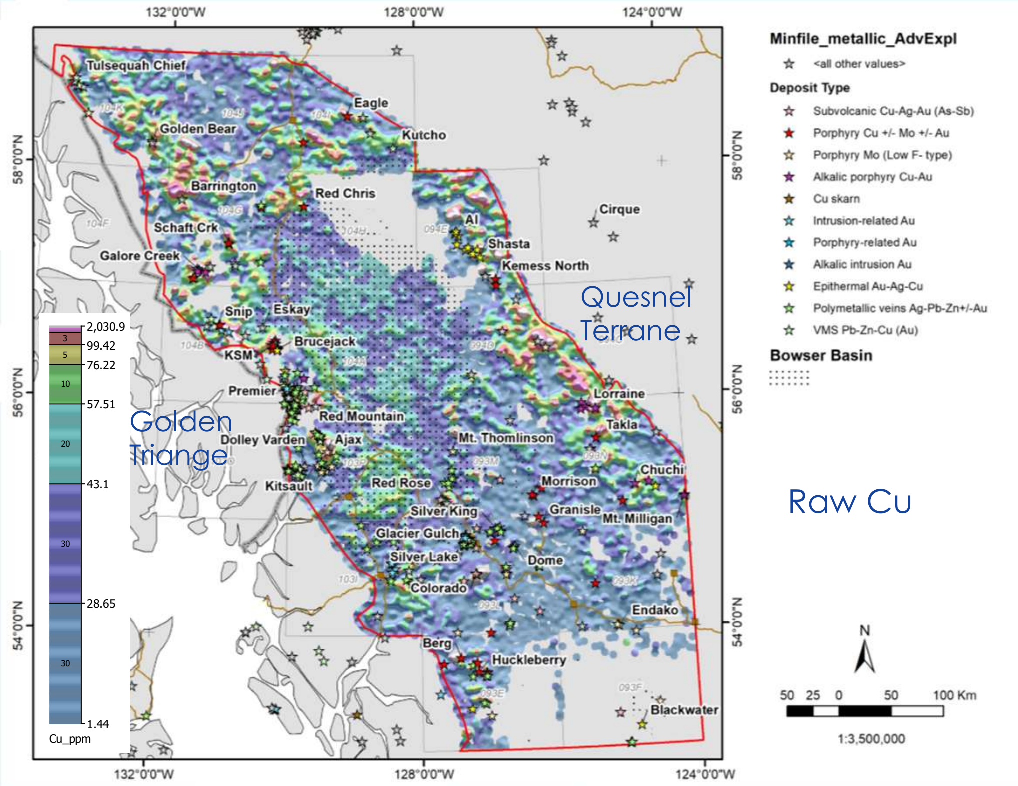
PROJECT LOCATION & GEOLOGY

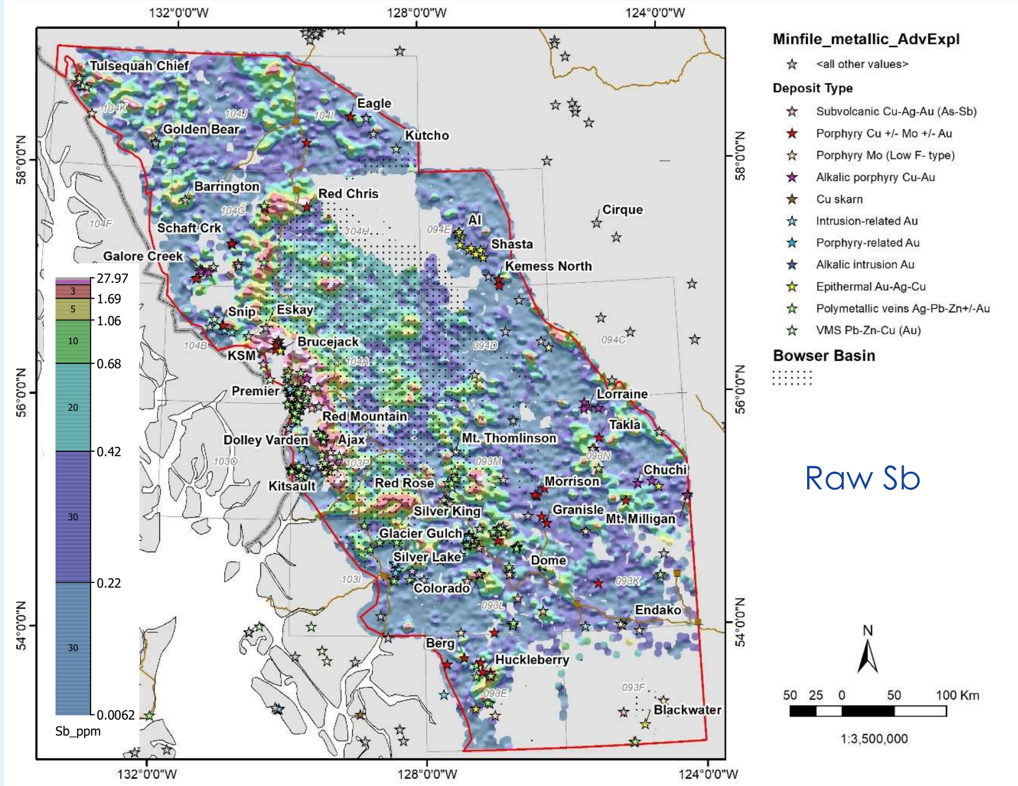




- Project focused on Stikine Terrane with some Cache Creek and Quesnel.
- Re-analysis of archived RGS pulps undertaken over a 10-year period.

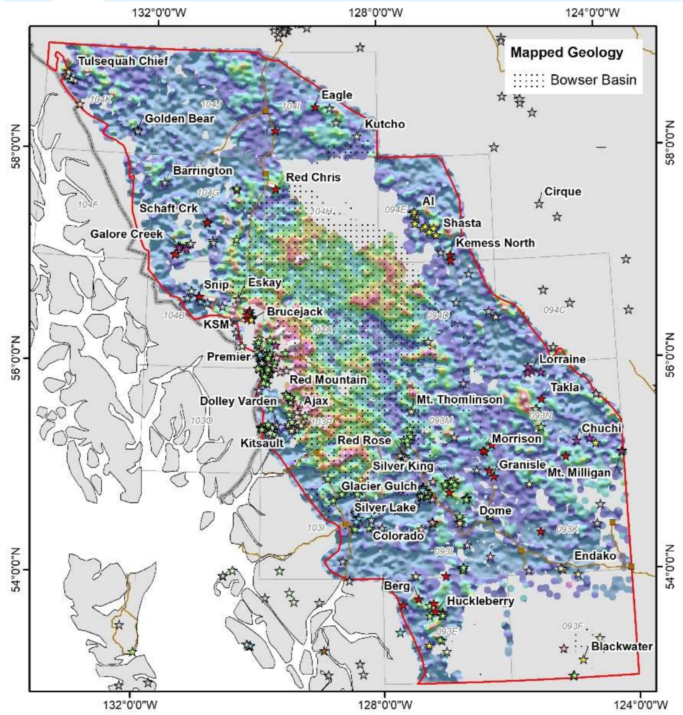
RAW ELEMENT PLOTS

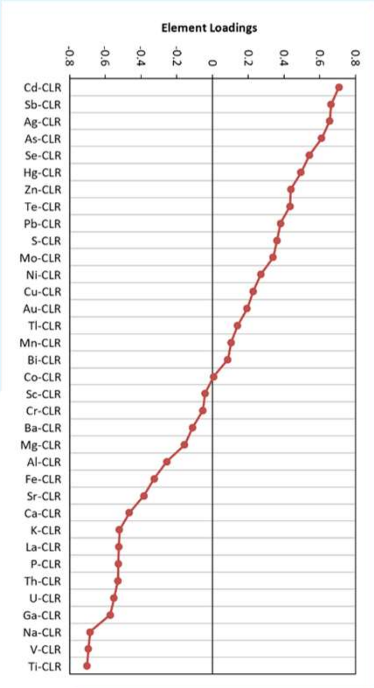


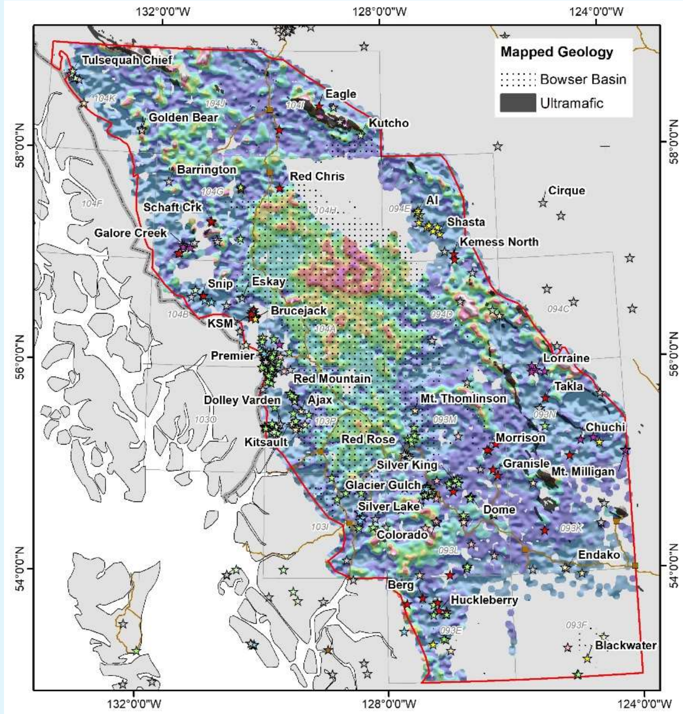


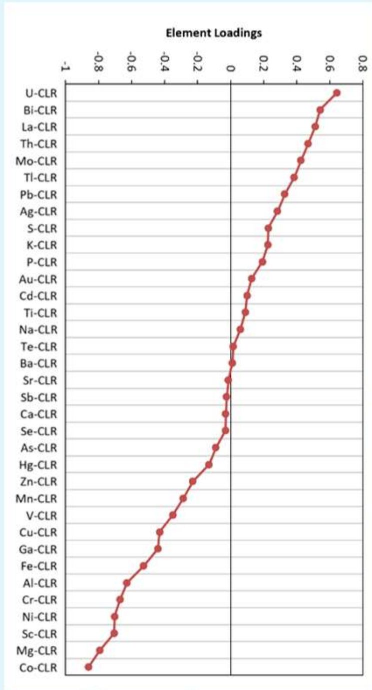
- Raw element plots for Cu and Sb define the Cu-Au porphyry belt in the Quesnel Terrane and the Golden Triangle region, respectively, but with elevated Sb in the overlying Bowser Basin

PRINCIPAL COMPONENT ANALYSIS





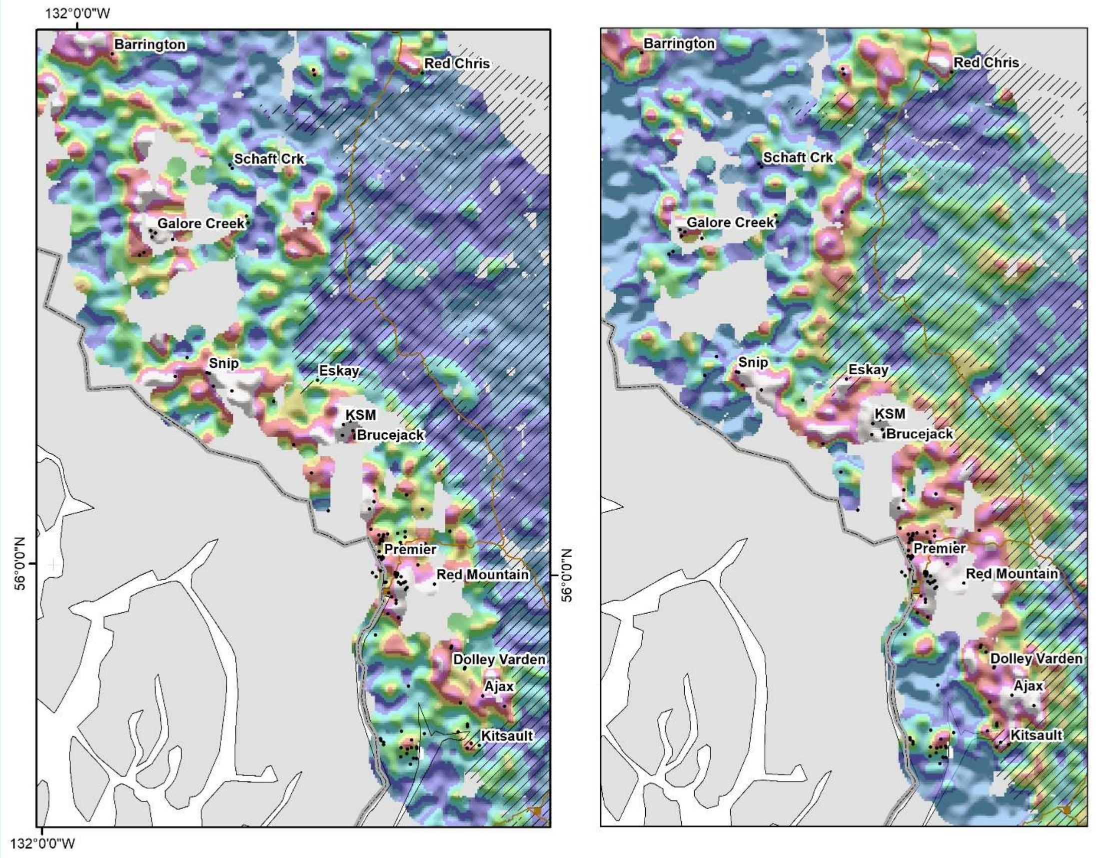




- PC1 (left) shows the Golden Triangle trace element suite
- PC2 (right) highlights the Bowser Basin sediments, which is the response we want to mask.

GOLDEN TRIANGLE

- A weighted sums model for mineralization in the Golden Triangle (right) using raw element data shows weak anomalism into the overlying Bowser Basin sedimentary basin.
- Using principal components in the weighted sums model (left) allows the Bowser Basin signal (PC2) to be filtered.



PC WSM

Raw element WSM

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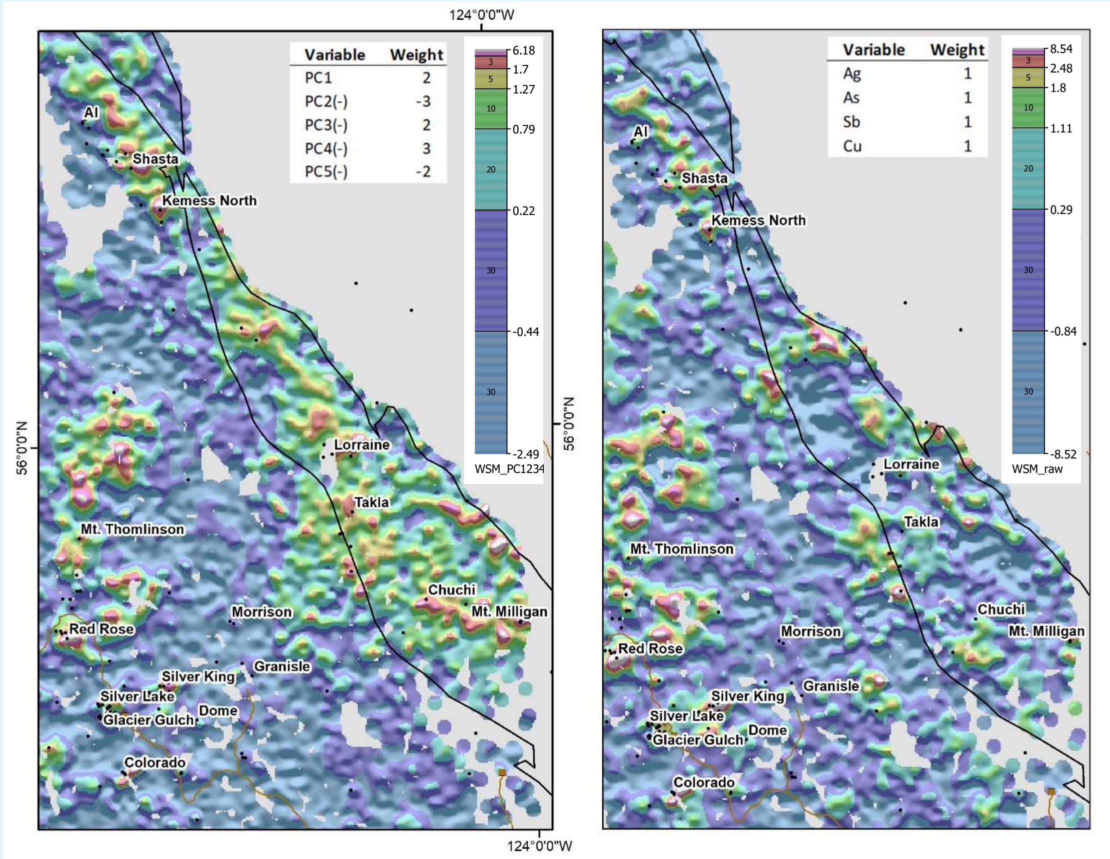
QUESNEL TERRANE

- A weighted sums model using raw element data (right) fails to define the main porphyry Cu-Au deposits with any consistency.
- The use of principal components in the weighted sums model (left) not only highlights the known porphyry Cu-Au occurrences, but also defines the prospective areas of the Quesnel and Stikine terranes.



PC WSM

Raw element WSM

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CASE STUDY 3 CONCLUSIONS

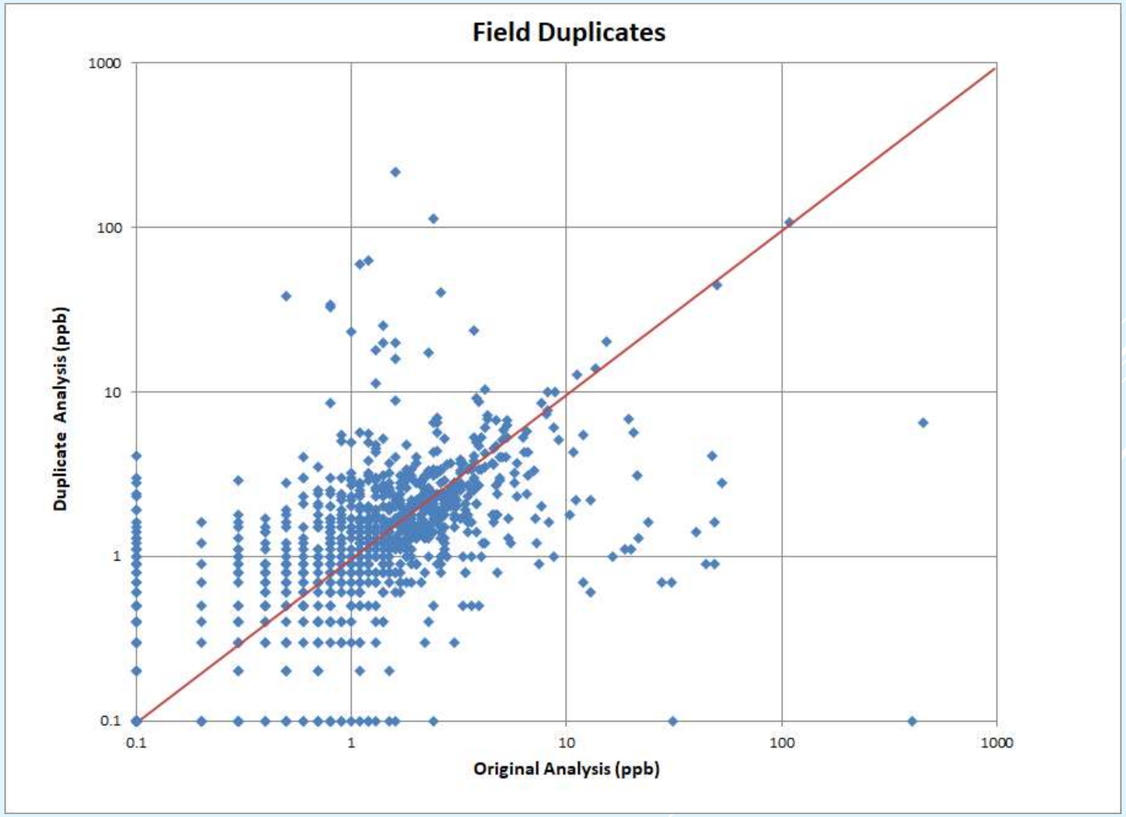
- Principal components in well mineralized areas may directly indicate the presence of mineralization.
- Principal components, rather than raw element data, can be used to construct weighted sums models for specific mineral deposit types.
- The use of negative weightings in a weighted sums model can be used to filter out overlapping geochemical signals that may interfere with the targeted mineral deposit signature.
- There can be no set approach to the interpretation of regional geochemical data – data processing approaches must be driven by the data rather than convention/habit.

CASE STUDY 4 – ANALYSIS OF GOLD IN STREAM SEDIMENT SAMPLES

Arne, D. and MacFarlane, B., 2014. Reproducibility of gold analyses in stream sediment samples from the White Gold District and Dawson Range, Yukon Territory, Canada. Explore, No. 164, p. 1-10. URL <https://www.appliedgeochemists.org/explore-newsletter/explore-issues>

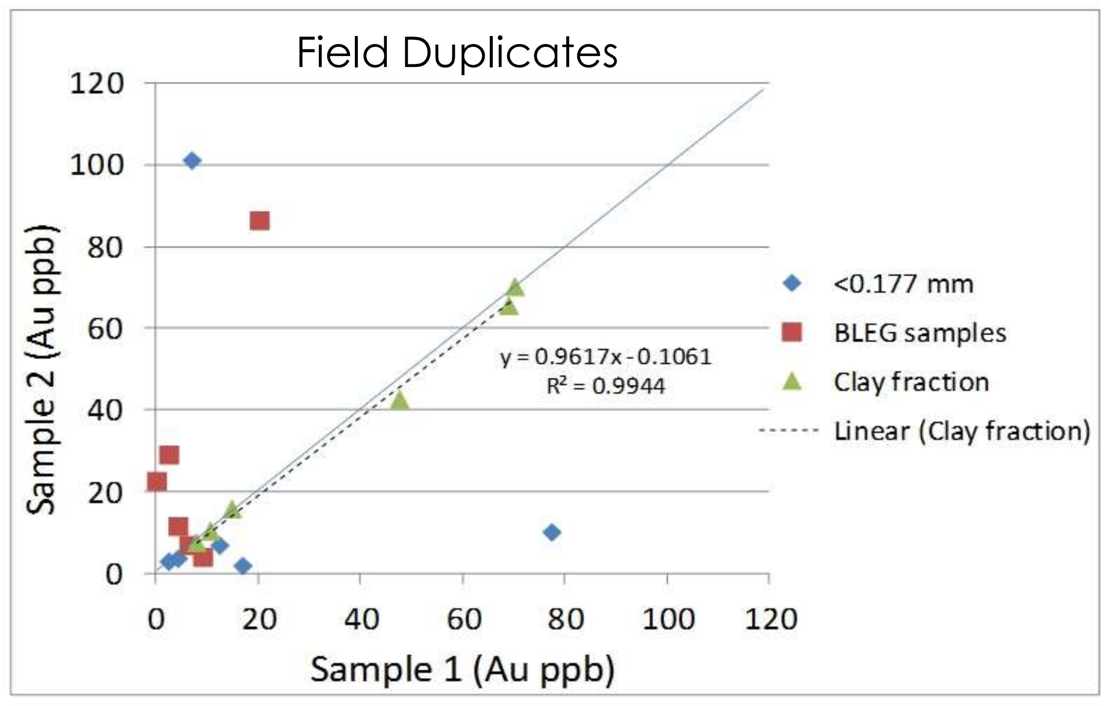
RECENT ICP-MS GOLD DATA

- Re-analyses of archived RGS stream sediment data using an aqua regia digestion followed by ICP-MS instrumental finish include new Au data.
- However, the original samples are -177 μm grain size and the sample aliquot used is 0.5 g.
- Sampling theory indicates that this sample mass is too low to obtain representative Au data, and this is borne out by data from field duplicates.



USE OF CLAY SEPARATES

- Duplicate orientation stream sediment samples analysed by:
  - 30 g -177 µm (#80) aqua regia digest
  - 1 kg -177 µm conventional BLEG
  - 0.5 g <10 µm clay fraction aqua regia digest
- Only the clay fraction separates gave good field reproducibility (i.e., no nugget effect)



SUMMARY

- Regional geochemical data should be processed in a similar manner as raw geophysical data in order to enhance specific geochemical responses.
- There is still value to be obtained from processing historical, open-file geochemical data, particularly if new high-quality analytical data are provided.
- A catchment analysis approach not only attributes a catchment basin with geochemical responses, but also highlights areas that have been under-sampled.
- Obtaining representative Au data from stream sediment samples remains challenging – most publicly available data are of poor quality.