QUANTITATIVE INTERPRETATION OF SOIL ORIENTATION SURVEYS

Chris Benn[1], Giancarlo A. Daroch[2], Martin Kral[2], Paul Lhotka[2]

[1]Chris Benn Consulting, 3424 West 1st Ave, Vancouver, V6R 1G7, BC, Canada; CJBenn@gmail.com

[2]Capstone Mining Corp., Suite 900-999 West Hastings St, Vancouver, BC, V6C 2W2, Canada

Introduction

Orientation surveys have the potential for generating a lot of data even though they comprise few samples. After analysing several sample types and/or several size fractions for many elements, it is easy to accumulate a lot of data.

Common interpretation aids such as dispersion profiles and symbol plots will adequately display the data from most orientation surveys. However, it is difficult to quantify the differences seen on these diagrams. For example, you may be able to see that one sample type is performing better than another, but by how much? Quantifying the differences will help when balancing out the relevant factors and deciding on the most cost effective methods.

The quantity most often used is the length (in the case of stream sediment sampling) or width of dispersion, as this can be related directly to the required sampling density. There are, however, problems with this due to the erratic nature of the geochemical data. The main problem is in deciding where the dispersion trail ends; that is, at which point do the anomalous samples become lost within the spread of background values. One or more threshold values are normally chosen to separate what is considered anomalous from what is considered background.

The choice of the threshold(s) will not present any problems in the unlikely event that the anomalous values are completely separate from the background values. Unfortunately one is commonly dealing with overlapping populations. The more they overlap, the more difficult it is to come up with sensible thresholds and hence determine dispersion distances.

Another problem with the more conventional methods of interpreting orientation surveys is that it is often not feasible to plot and interpret profiles and maps of every element and sample type combination.

The methods presented here allow all the combinations to be easily compared. This methodology is demonstrated with a set of data from an orientation soil survey that tested several analytical techniques and size fractions over known mineralisation in Chile.

Methodology

Outline

The basic idea underlying methods presented here is that an orientation survey allows you a priori to decide which samples should be anomalous and which should be background.

When interpreting normal orientation surveys, a lot of work is usually done in determining how to separate the anomalous population from the background population. A popular method of doing this involves plotting the data on a probability plot and separating the two populations by assuming that they follow a normal (Gaussian) or lognormal distribution.

With an orientation survey, no assumption about the form of the statistical distribution need be made. Instead you only have to decide that samples from over mineralisation are anomalous and other samples are background. The difficulty is to decide how far away from a direct projection of mineralisation to the surface a sample can be considered anomalous. The normal dispersion profiles should help with this. A refinement on this is to flag the samples as either highly anomalous, anomalous or background and capture this as a new “proximity classification”.

Orientation Area – Sierra Amarilla

Capstone Mining Corporation is exploring for base metal deposits in Central Chile through an option agreement with Sociedad Quimica y Minera S.A. (SQM). Before starting surface sampling programs, an orientation survey was carried over a small area of known oxide mineralisation in order to determine the most appropriate sampling method and analytical technique. An orientation area at a prospect called Sierra Amarilla was selected and is located 180 kms SE of Antofagasta. A number of trenches, shallow pits and drillholes have outlined a zone of Manto-type oxide copper mineralisation hosted in andesites of the Cretaceous Aeropuerto Fm (Figure 1a). Manto-type deposits are typically controlled by the permeability provided by faults, hydrothermal breccias, vesicular flow tops and flow breccias (Sillitoe, 2003). In addition to Cu, there are anomalous concentrations of Ag, Au, Zn and Pb (Tapia, 2011).

Three orientation lines were completed at line spacing of 150 meters and sample spacing of 10 meters. These lines were parallel to the trenches and care was taken to avoid contamination from the excavations and other surface work. A major objective of the work was to determine the type of geochemical response from known mineralisation through the gypcrete ± nitrate horizons that are present in this part of Chile. Previous studies have shown that there are distinct geochemical anomalies for Cu and other elements in these types of soils over deposits and also when they are covered by Miocene gravels (Cameron et al. 2010). Table 1 lists the types of samples collected at each site, and the type of analysis carried out.

Table 1. Types of Samples and Methods of Analysis

Sample	Collection Method	Analysis
A	Surface lag. Sieved < 2 mm coarse retained	Four acid "near-total" digestion method code (ALS) ME-MS61
B	Surface lag. < 2 mm	Analysed by pXRF
C	10 - 20 cm depth, reddish colour (due to Fe oxyhydroxides).	Ionic Leach. Selective leach. Static sodium cyanide leach method code (ALS) ME-MS23

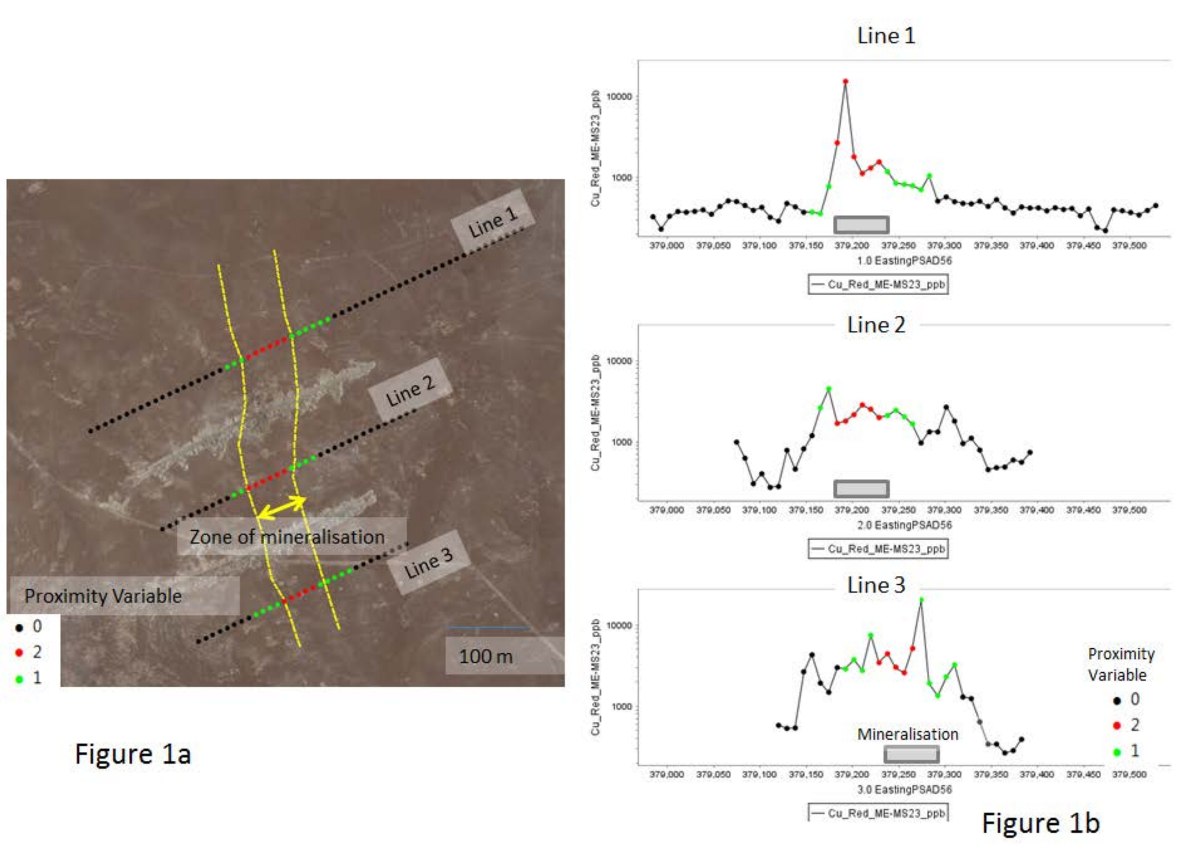

Figure 1. (a) Location of Orientation Lines. Zone of mineralization outlined from sampling of trenches and orientation samples classified according to this zone (a priori). (b) Example of dispersion profiles for Cu by Ionic Leach and coloured according to the proximity classification.

Results and Discussion

Dispersion profiles show if there is a response in elements along the orientation lines. Dispersion profiles together with a projection of the zone of mineralisation were constructed to assist with determining which samples were classified as anomalous and background. An example is given for Cu in Figure 1b.

The simplest and most direct way of displaying and comparing the anomalous and background samples, determined using dispersion profiles, is to draw probability plots of each on the same diagram. If a particular element and sample type combination is working well, the three probability plots should be well separated. There is no statistical distribution assumption made by using these plots, they are merely a convenient and familiar method of displaying the data distributions. It is only when you fit straight lines to probability plots that one assumes normal or lognormal distribution.

An example of split probability plots is presented in Figure 2 for Cu by the Ionic Leach digestion method. The probability scale is in units of the Standard Normal Deviate instead of percentage probability. The data axis is a log scale because the distributions are positively skewed. If the distributions are close to lognormal then the probability plot data should approximate straight lines.

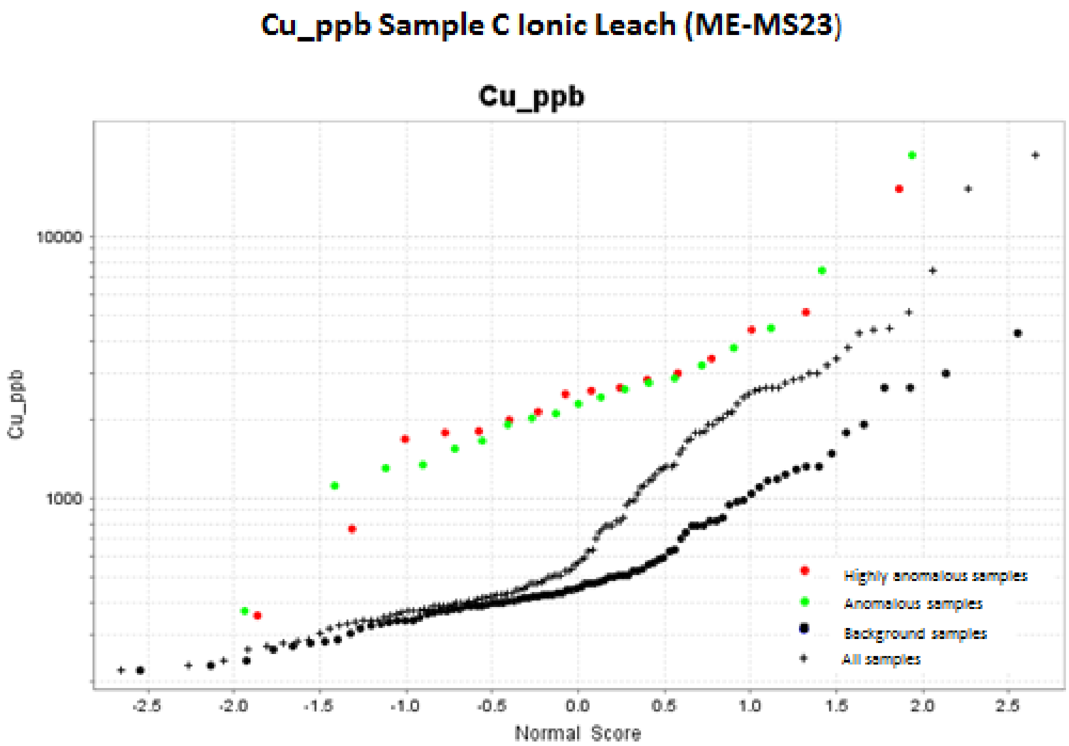

Figure 2. Example split probability plot for Cu by Ionic Leach, ME-MS23

These plots can be used to measure the reliability of a given threshold for a particular element and sample type combination. However these plots still require a subjective visual interpretation. What is needed is an overall measure of the separation that can be seen in these probability plots. The best way of doing this is to correlate the data values themselves with a proximity variable derived by ranking the samples in the following way:

- 0 for background samples (off the dispersion trail)
- 1 for anomalous samples (on the dispersion trail) but not directly over mineralisation
- 2 for anomalous samples close or over mineralisation.

The appropriate measure of correlation in this case is the Spearman's Rank Correlation Coefficient between the proximity variable and the analytical results. Results are presented in Table 2.

Table 2. Spearman Rank Correlation Coefficient for proximity variable and analytical results (target and pathfinder elements)

Sample	Type/Analysis	Cu	Ag	Au	Mo	Mn	Pb	Zn
A	Surface, 4 acid	0.67	0.66		-0.15	0.16	0.55	-0.16
B	Surface pXRF	0.61			0.06	0.02	0.067	0.01
C	20 cm depth Ionic Leach	0.71	0.61	0.43	0.43	0.51	0.57	-0.33

For the Sierra Amarilla orientation the target and pathfinder elements perform the best in Sample C, closely followed by Sample A. Sample B performed poorly for elements other than Cu but this is probably due more to the poor analytical quality of the pXRF for elements such as Mo.

This measure of proximity can be used in other statistical procedures. For example, multiple regression can be used to predict the proximity variable from several of the elements for a given sample type. This could result in an equation for a new variable that would highlight the mineralisation better than any single element alone.

The proximity variable was regressed against Cu, Ag, Au, Mn, and Pb, for Sample C. The Spearman correlation between this new variable and the proximity variable was 0.75, which is higher than that for Cu alone (0.71) suggesting that there is improvement in using this 'multielement' proximity variable. The effectiveness of this proximity variable would be increased if more elements were strongly anomalous.

Conclusions

This case study has shown the usefulness of assigning orientation samples to either a background or anomalous group prior to the analysis of data. Probability plots and Spearman correlations can then be used to determine the best elements and best sample types for detecting the type of mineralisation over which the survey was conducted.

Although this example is from a soil survey this methodology is particularly well suited to determining the optimum parameters from an orientation stream sediment survey. If the orientation survey is used to choose thresholds and lengths of dispersion trains, then the assumption must be made that the mineralisation and background characteristics found are typical of what will be encountered in a regional survey.

The results for Sierra Amarilla orientation show that Sample C is the best sample type for highlighting the known mineralisation. Sample A is the next best sample type and is close to the response of Sample C. There are other issues not discussed here that influence the choice of sample type and analytical method such as the poor reproducibility of the surface sample type (sample A) and limitations with pXRF analysis (Sample B)..

For Sample C the key elements in order of merit are Cu, Ag, Au, Mn, and Pb.

References

CAMERON, E, LEYBOURNE, M. REICH, M et al, 2010. Geochemical anomalies in northern Chile as a surface expression of the extended supergene metallogenesis of buried copper deposits. *Geochemistry: Exploration, Environment, Analysis* **10**;157-169

SILLITOE, R.H. 2003. Iron oxide –copper-gold deposits: an Andean view. *Mineralium Deposita*, **3**, 787-812.

TAPIA, JOSE. & VIDELA, MAURICIO 2011. Informe de Avance Geologia Basica Camapana 4 Ano 2011: Area de Interes Interior de Taltal GEDM Marzo, 2011. Internal report – SQM