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Quantitative Interpretation of Orientation Surveys

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Introduction

When exploring in new areas, preliminary field and laboratory investigations are accomplished by carrying out orientation surveys. These surveys determine: (a) the nature and extent of dispersion patterns related to mineralization, and (b) the distribution and behaviour of elements of potential interest in unmineralised areas.The parameter most often sought is the length (in the case of stream sediment sampling) or areal extent (in the case of soil sampling) of dispersion trails, as these can be related directly to the required sampling density. There are, however, problems with these quantities due to the erratic nature of 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.

Orientation surveys have the potential for generating abundant 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, one may be able to see that a particular sample type is performing better than another, but by how much? Quantifying these differences will help when balancing out the relevant factors and deciding on the most cost effective methods.

When interpreting orientation surveys a popular method of separating anomalous from background populations is to analyse the data on a probability plot and then separate the two, or more, populations by assuming that they follow a normal (Gaussian) or lognormal distribution (Sinclair 1976). The choice of the threshold(s) will not present any problems in the unlikely event that anomalous and background values are completely separated. Unfortunately overlapping populations are the norm. The more they overlap, the more difficult it is to establish sensible thresholds and hence determine dispersion distances. Stanley (2003) described a method of determining the effectiveness of any new exploration method using hypergeometric probability. The study reported here describes an additional approach acting on the suggestion by Stanley (2003) that an orientation survey allows the operator a method of deciding, *a priori*, which samples are anomalous and which are background. With an orientation survey, no assumption about the form of the statistical distribution need be made. Instead one only has to break the populations into the two, or more, groups, anomalous and background. There could be more than one background population if there are geochemically different bedrock units in the survey area. The difficulty lies in deciding how far away from a direct projection of mineralization to the surface a sample can be considered anomalous. A refinement on the above binary method is to use a threefold categorization of (1) highly anomalous, (2) anomalous, or (3) background, which provides a new "proximity indication".

The simplest and most direct way of displaying and comparing the anomalous and background samples, determined using dispersion profiles, is to construct a probability plots of each on the same diagram. If a particular element and sample type combination is working well, the different probability plots should be well separated. No statistical distribution assumption is made by using these plots; they are merely a convenient and familiar method of displaying the data distributions.

This methodology is demonstrated with two examples. The first is an orientation soil survey that tested several analytical techniques and size fractions over known mineralization in Chile, and the second a stream sediment orientation survey in Australia.

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Example 1 – Sierra Amarilla area, III Region, Chile

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 out over a small area of known oxide mineralization in order to determine the most appropriate sampling method and analytical technique. An orientation area at a prospect called Sierra Amarilla was selected that is located 50 km east of the city of Taltal in Region II, at a mean elevation of 1,800 m above sea level, with mostly gentle topography. The Pan-American Highway cuts through the centre of the block (Fig. 1). The region has a hyper-arid climate and is almost devoid of plant growth.

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In addition to the technical article, authors are asked to submit a separate 250 word abstract that summarizes the content of their article. This abstract will be published in the journal **ELEMENTS** on the 'AAG News' page.

Submissions should be sent to the Editor of **EXPLORE**:

Beth McClenaghan
Email: beth.mcclenaghan@canada.ca

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Notes from the Editor

EXPLORE issue 177 includes two articles. The first one is written by Chris Benn, Giancarlo Daroch, Martin Kral, and Paul Lhotka and describes the interpretation of geochemical data from orientation surveys in Chile and Australia. The second article by Charlie Moon provides insights into the teaching of exploration geochemistry and future demands for education. **EXPLORE** thanks all those who contributed to the writing and/or editing of this issue: Steve Amor, Dennis Arne, Al Arsenault, Chris Benn, David Cohen, Giancarlo Daroch, Bob Garrett, Martin Kral, Arthur Lang, Dan Layton-Matthews, Ray Lett, David Leng, Matt Leybourne, Paul Lhotka, Charlie Moon, Paul Morris, and Ryan Noble.

In this last issue of 2017, **EXPLORE** gratefully acknowledges our two corporate sponsors for the year, ALS Minerals and SciApps, as well as our advertizers, for their continuing financial support. Below is the team that has provided readers with four excellent issues this year. We wish all AAG members and other readers of **EXPLORE** a successful upcoming 2018.

Beth McClenaghan, Editor
Pim van Geffen, Business Manager
Steve Amor, Calendar of Events
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Ryan Noble, President's Letter
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Editor

President's Message

My two-year tenure at the AAG helm has come and nearly gone. It went fast and was an enjoyable experience. During my tenure, I have greatly benefited from the help of the others that contribute to the running of the AAG and I would like to take this time to mention them. In the Executive, the stalwarts Gwendy Hall (Treasurer) and Dave Smith (Secretary) along with Steve Cook (Vice President) keep things running smoothly. Al Arsenault in the AAG Business Office is essential to the day to day business operations. Our Councillors make a significant service commitment both in regional and term positions, particularly those that chair committees and I single out Paul Morris and David Cohen in particular for their efforts. Finally, thank you to Beth McClenaghan and Pim van Geffen for managing our newsletter **EXPLORE** and to Dennis Arne for overseeing contributions to Elements. These people have made sure our Association publications get out on time, have relevant and interesting content and look great. The AAG outputs continue to improve and I appreciate these efforts of the real doers that make the AAG successful. There are always other contributors that are left off lists like this and I apologize in advance, but thank you for your contributions. I welcome our new and returning councillors, and wish the very best to Steve Cook as he takes over as President of the AAG for 2018-2019.

2018 should get off to a good start for the Association. Our finances and membership are solid and the structure and strategic direction are in place to support future efforts of the AAG. I am excited to see the new website and thanks to Gemma, Gwendy, Tom, and others that are working behind the scenes to improve our website. The RFG2018 conference and our 28th IAGS (http://rfg2018.org/) is well planned and by now hopefully many of you are submitting abstracts for our AAG affiliated sessions. If you need a reminder of these specific sessions, check my past few emails or the AAG website. An AAG awards banquet, field trips and short courses will be held during the RFG conference.

A few other positive changes are happening behind the scenes and I hope to be able to announce some new winners of our Association medals at the Vancouver event as well as a new AAG Distinguished Lecturer. We will be making this position more accessible in the future by recording a presentation or two and posting the lectures on our website. Thanks to Dan Layton-Matthews for his past work as the AAG Distinguished Lecturer.

Finally, we have lost a number of important geochemists in the past two years and they will be missed. For me, Professors Kurt Kyser and Xie Xuejing are the most notable, but there are others that are equally important that are perhaps less well known. It is unfortunate that unlike life, we do not celebrate the "births" of new geochemists, they just emerge over time. If you are reading this message and are at the start of your career, welcome to the AAG! I hope to see many of you presenting results at the RFG event.

Thank you to all our members for continuing to be a part of our AAG. Over to you, Steve.

Warm regards,

Ryan Noble
AAG President
Email: ryan.noble@csiro.au

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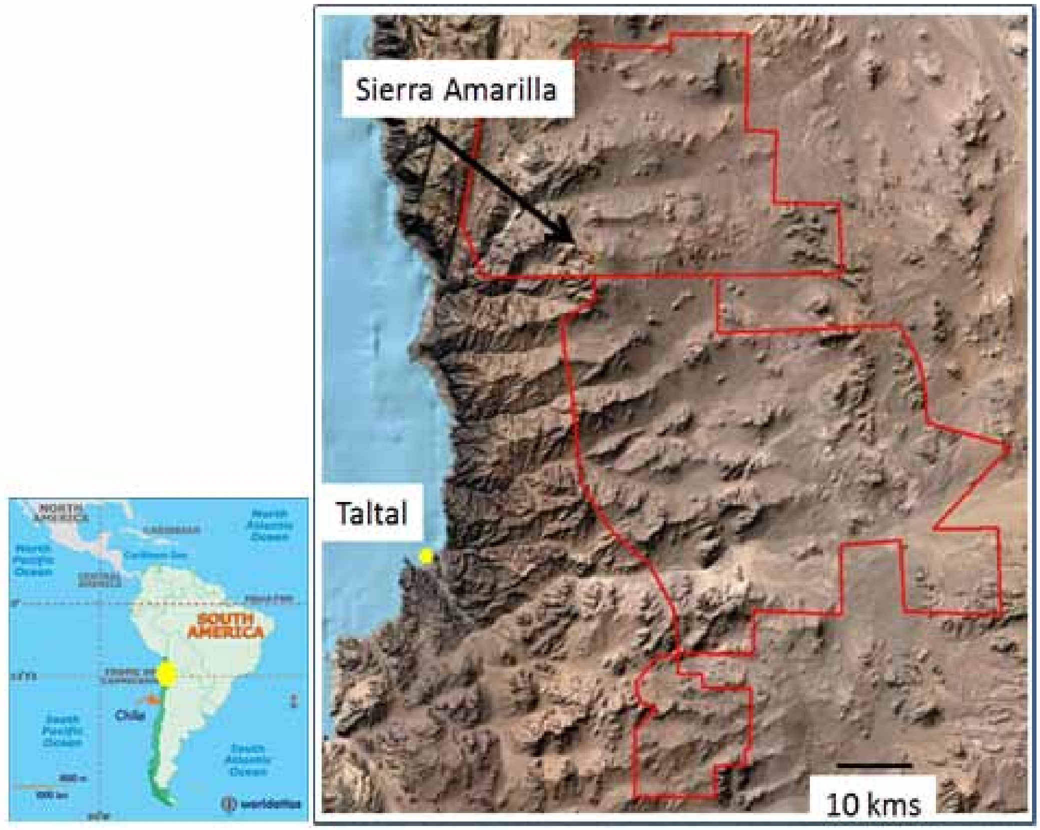
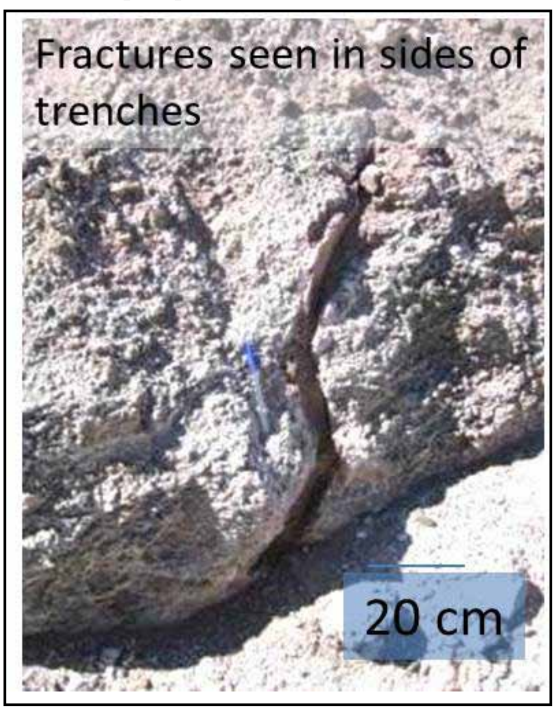


Figure 1. Location of the Sierra Amarilla orientation area, Chile.

Information from a number of trenches, shallow pits, and drillholes was used to outline a zone of manto-type oxide Cu mineralization hosted in andesites of the Cretaceous Aeropuerto Formation. 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 and Videla 2011) at the prospect. The area is covered by 5 to10 m of Tertiary gravels.

Previous work has shown that certain analytical techniques and sample types reveal geochemical anomalies at the surface of transported gravels in the Atacama region of Chile (Cameron *et al*. 2010). One possible mechanism for the formation of surface geochemical anomalies in the region is seismic pumping of groundwater from depth to the surface through the gravels. The pH of the groundwater is slightly alkaline and elements such as Mo and As can be transported as oxyanions. Support for the seismic pumping theory comes from significant seismic activity in the region and evidence of fault scarps and fractures that cut through the post mineral cover (Kelley *et al*. 2003). Recent fracturing with secondary Cu oxides forming part of the infill material can be seen in the sides of the trenches (Fig. 2a) and these could be possible conduits for the groundwater. These fractures also postdated a cemented layer of caliche developed in places within the pediment gravels (Fig. 2b).



2a

Figure 2. (a) Fractures cutting through surface material; (b) caliche developed on gravels that postdate mineralisation.

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Although generally weak anomalies form at the surface, the anomaly to background contrasts can be improved by using selective leach extractions. The aim of the orientation study was to investigate the effectiveness of several surface sampling and analytical techniques in areas of transported gravel.

Three orientation lines were completed at a spacing of 150 m with samples collected every 10 m. These sampling lines were parallel to the trenches and care was taken to avoid contamination from these surface disturbances. 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 (see Figure 3)

Sample	Collection Method	Analysis
A	Surface lag: 500 g of surface material sieved <2 mm, coarse retained	Pulverised and four acid "near-total" digestion method code (ALS) ME-MS61
B	Surface lag: 100 g split of <2 mm from above	Analysed by portable XRF
C	10 - 20 cm depth: thin brownish layer scraped away so reddish colour visible (due to Fe oxy-hydroxides), 1.5 kg of <2mm material collected.	Ionic Leach. Static sodium cyanide leach method code (ALS) ME-MS23. Preferentially attacks weakly adsorbed metal ions; metals associated with carbonate minerals and to some extent metals associated with amorphous Mn and Fe oxyhydroxides.

Figure 3. Methods for collecting samples A, B, and C.

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Field duplicates were taken and good reproducibility was shown for all elements (RSD <15%) except for Au determined by Ionic Leach, which had a RSD of 47%. Results of the orientation sampling were plotted as dispersion profiles and these are useful for showing if there is a response along the orientation lines (Fig. 4).

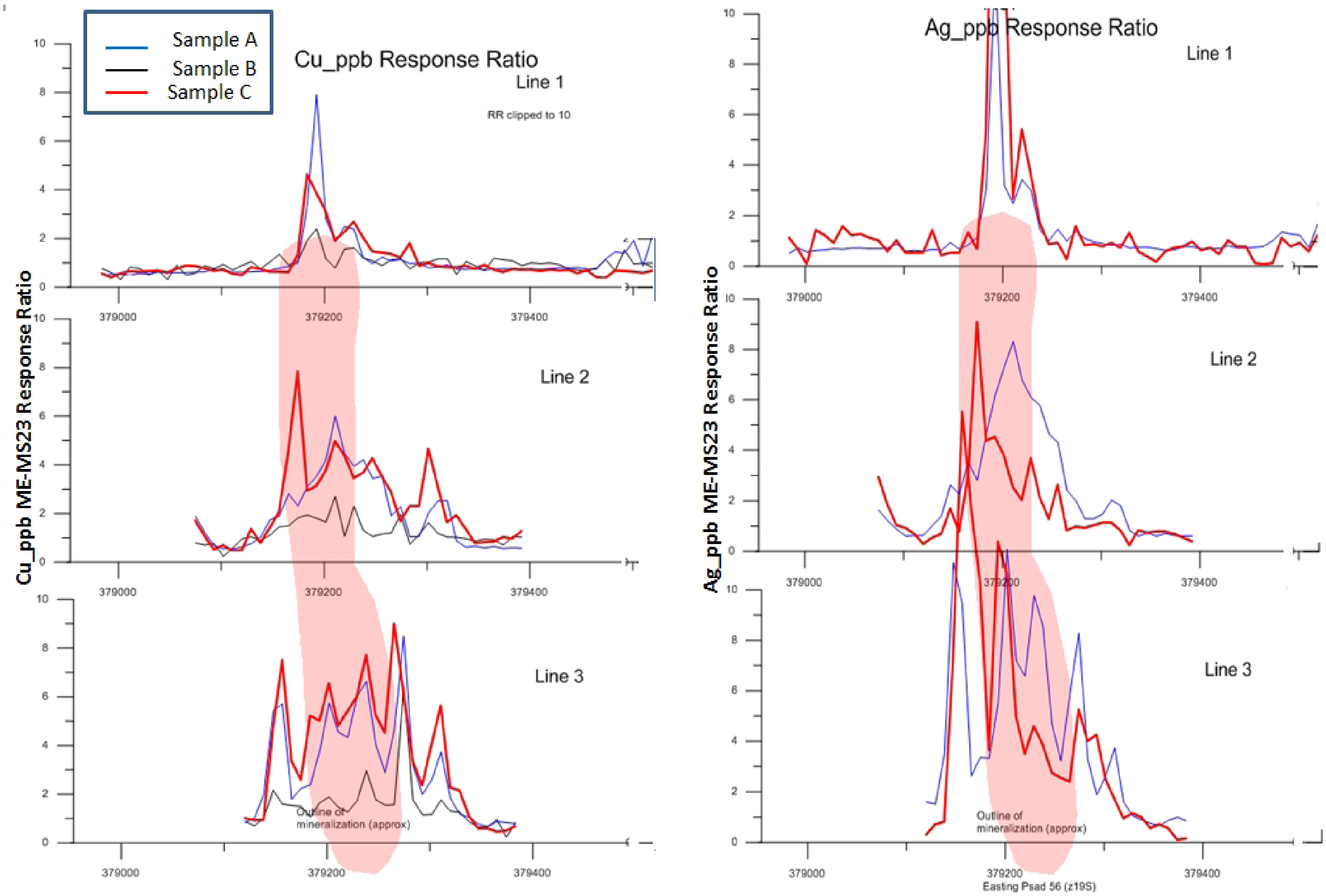
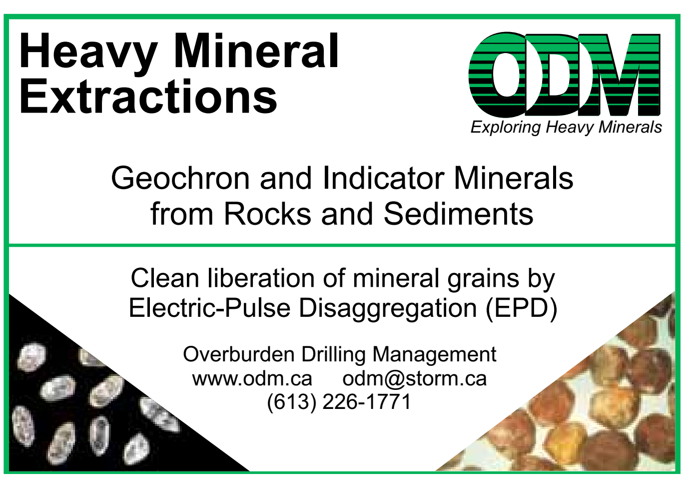


Figure 4. Dispersion Profiles for Cu and Ag for different types of samples

The outline of mineralization is shown in light red and the Y axis shows the response ratio which is the actual value divided by the first quartile. A positive response from the A (surface lag) and C (Ionic Leach) samples for Cu and Ag is apparent on all three lines, although it is difficult to determine which sample type is the best.

These dispersion profiles together with a projection of mineralization can assist in determining which samples are anomalous versus background. Figure 5 uses the profiles for Sample C to demonstrate that it is reasonably easy to distinguish between coincident samples overlying mineralization (red dots) versus flanking samples (more distal) from mineralization (green dots).



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The simplest and most direct way of displaying and comparing this a priori classification of proximal mineralization and background samples is to draw probability plots for this classification for each element of interest on the same diagram.

If a particular element and sample type is suitable, then the three probability plots should show clear separation between data for sample sites coincident to mineralization that are higher than those flanking to mineralization and both higher than the background samples. There is no statistical distribution assumption made by these plots. It is only when a straight line is fitted to probability plots that there is an underlying assumption of normal or lognormal distribution. These plots can be used to measure the reliability of any given threshold for a particular element and sample type combination. Figure 6 is an example

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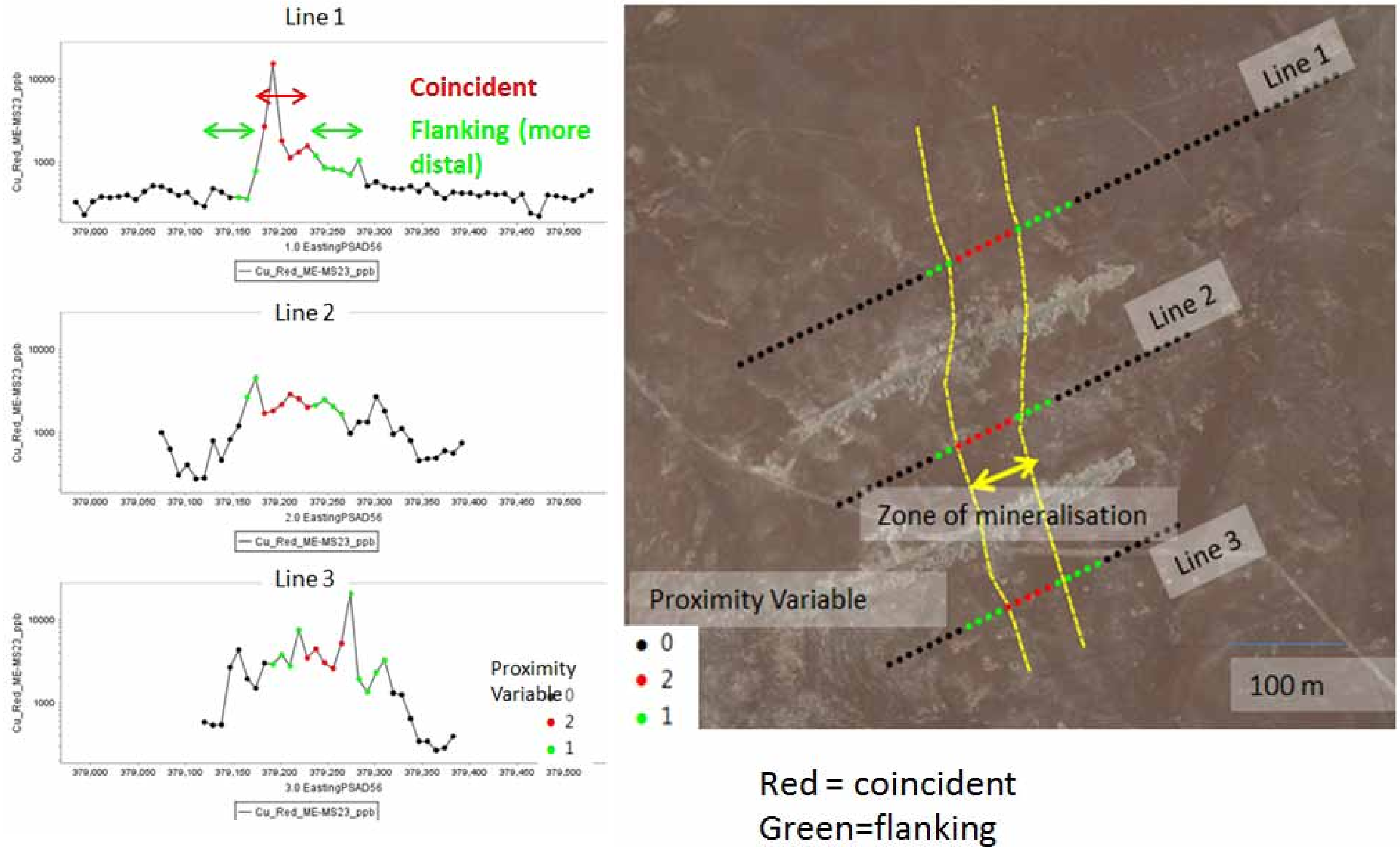

Figure 5. Profiles showing selection of samples as highly anomalous, anomalous, and background.

of probability plots for Cu content in Sample C (ionic leach analysis). Although the flanking and coincident samples are well separated from the background population, they are similar to each other suggesting little difference between the two. A probability plot for all the samples is also shown for reference.

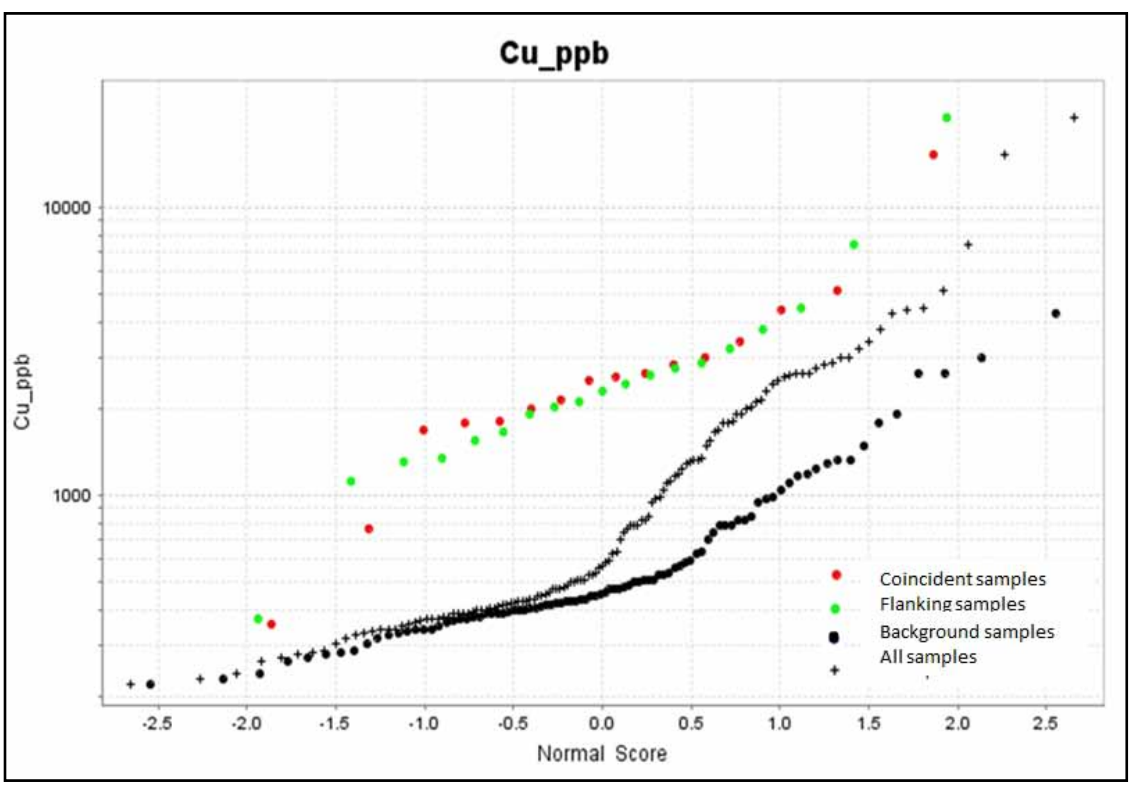

Figure 6.
Split probability plot for Sample C (ionic leach) showing the difference between coincident, flanking and background samples.

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An additional feature of this type of plot is that one can measure the proportion of samples below the threshold (anomalies missed) and proportion of samples above the threshold (false anomalies). These probability plots require a subjective visual interpretation such as determining an inflection point between two different plot gradient segments. Hence, an overall measure of the separation revealed by these probability plots is needed. This can be achieved by correlating the data values with a proximity variable derived by ranking the samples using the a priori method just described. A numerical ranking system is required:

- 0 for background samples (off the dispersion tail);
- 1 for flanking samples (on the dispersion trail) but not directly over mineralisation; and,
- 2 for coincident samples close or over mineralisation

The most appropriate correlation measure is the Spearman rank correlation coefficient. This is a non-parametric statistic that quantifies the association between two variables. The higher the correlation, the better the element and sample type is at defining the mineralization. Using the Spearman rank correlation, it is possible to simultaneously compare all the elements and sample types. Table 2 shows the Spearman rank correlation coefficients for proximity variable with target (Cu, Au, Ag) and pathfinder elements (Mo, Mn, Pb, Zn), and different sample types.

Table 2. Spearman rank correlation between proximity variable and target/pathfinder elements for different sample types.

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	20cm depth Ionic Leach	0.71	0.61	0.43	0.43	0.51	0.57	-0.33

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 to the poor analytical quality of the pXRF for some elements – an example being Pb.

This measure of proximity can be used in other statistical procedures such as multiple regression 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 mineralization better than any single element alone. In this case, the proximity variable was regressed against Cu, Ag, Au, Mn, Pb for Sample C (Ionic Leach sample). The Spearman rank correlation between this new variable and the proximity variable was 0.75, which was higher than that for Cu alone (0.71) suggesting there is a small improvement using this multielement proximity variable.

Dispersion profiles for Cu and the new proximity variable composed of Cu and Ag are shown in Figure 7.

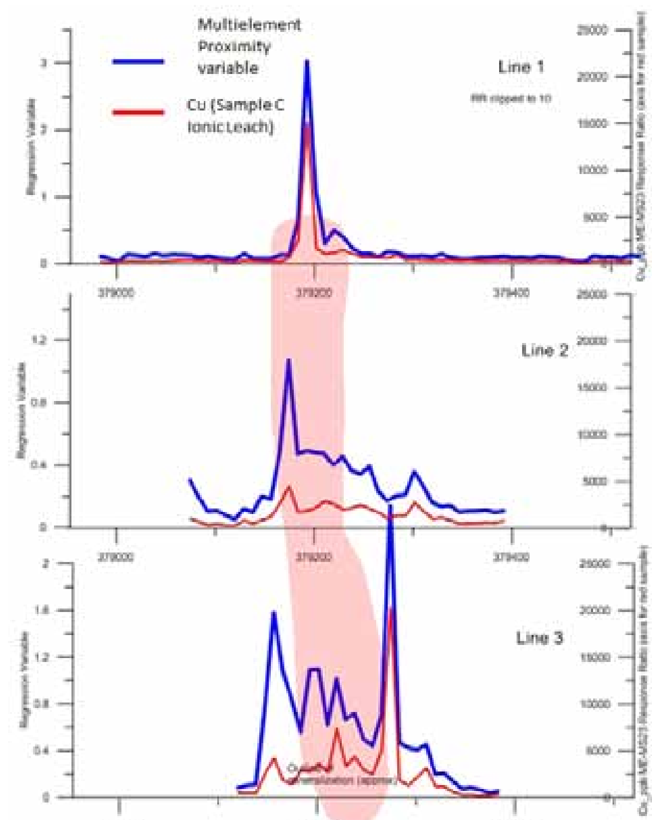

Figure 7. Dispersion profiles for Cu content in Sample C and new proximity variable (Cu +Ag).

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Copper and Ag make by far the largest contribution to the regression model, and it is possible that the regression estimating the multivariate proximity variable could show an improvement if more elements were included in the correlation.

This case study has shown the usefulness of assigning orientation samples to background, flanking, or coincident groups prior to the analysis of data. Probability plots and Spearman correlation coefficients can then be used to determine the best elements and sample types for detecting the type of mineralization over which the survey was conducted.

Example 2 – Stream sediment orientation survey, Rhyolite Creek Au-base metal prospect, Victoria, Australia

The Rhyolite Creek Au-base metal prospect is located about 145 km ENE of Melbourne in central eastern Victoria (Fig. 8). Weak Au mineralization was explored by BHP in the 1980s. The prospect lies within a fault bounded structural window that exposes Cambrian rocks within the Palaeozoic Mount Useful Slate Belt. Mineralization is hosted by volcaniclastic units interbedded with intermediate to felsic volcanic flows and intrusives. Significant Cu-Au sulphide mineralization was discovered at Hill 800 6 km to the north.

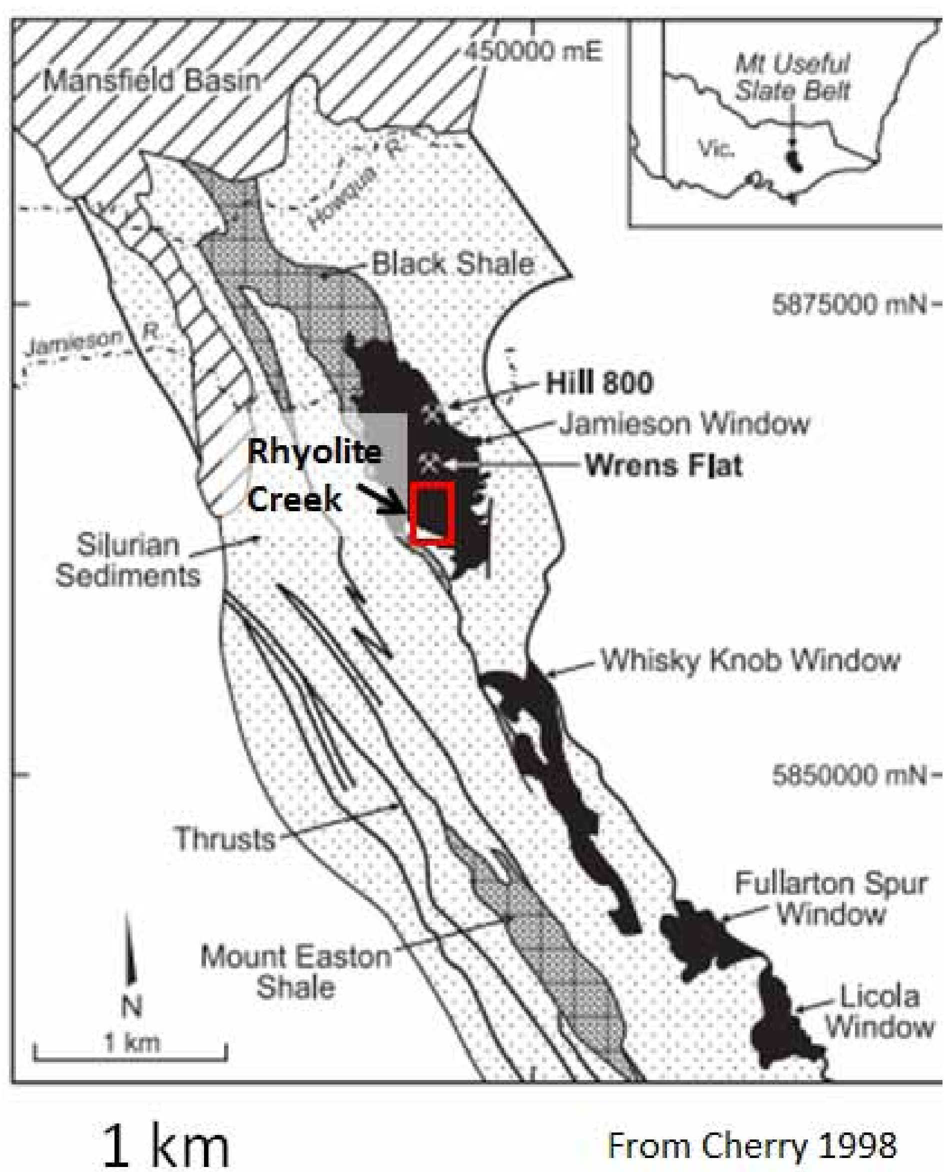

Figure 8.
Location of Rhyolite Creek Au base metal prospect Victoria. Australia

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A stream sediment orientation survey consisting of 36 samples and 5 field duplicates was carried out downstream from known mineralization. Two types of samples were collected and analyzed:

~ 1 kg Bleg sample (cyanide active), analysis for Au.

~ 1 kg sample sieved to <200 mesh, <20+40 mesh, <40+60 mesh, <60+80 mesh, <80+200 mesh, analysis for Au (fire assay), Pb, As, Zn, Cu by 3-acid (HNO_3, HCl, $HClO_4$) digestion and AAS.

The survey was carried out in 1984 and only atomic absorption spectrometry (AAS) was available for the sample analysis at that time.

As described before in example 1, probability plots were used to display and compare anomalous and background samples. These plots still require a subjective visual interpretation to establish the overall measure of population separation. Figure 9 shows the distribution of stream sediment samples. There was evidence in dispersion profiles that samples as far as 7 km downstream reflect the Cu-Au mineralisation.

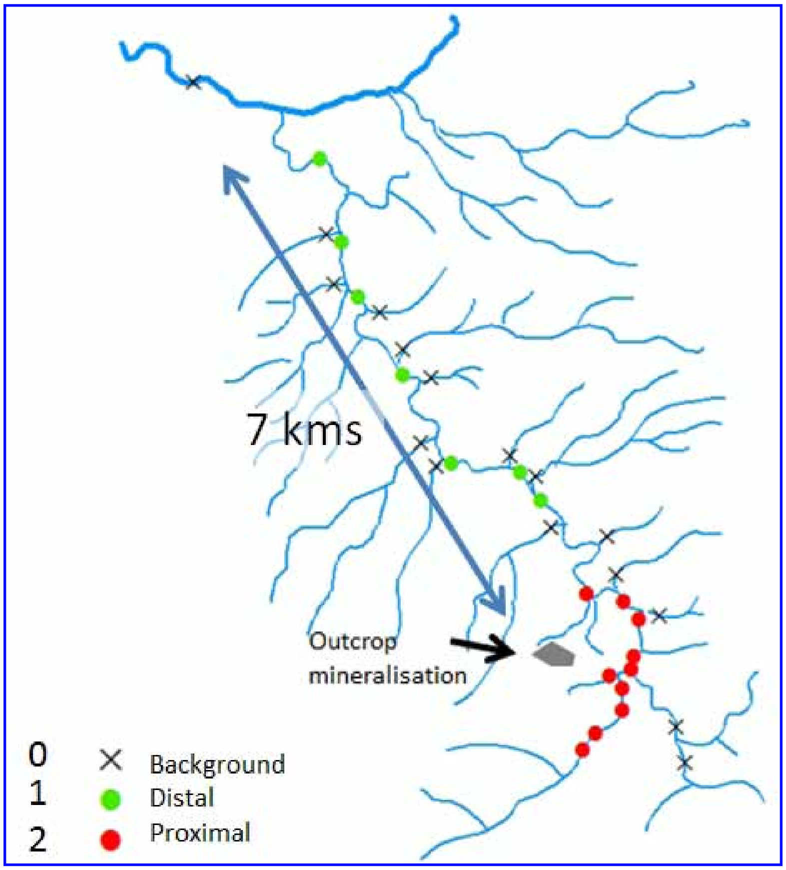

Figure 9. Distribution of orientation samples

For the orientation study, the proximity variable was given by:
0=off dispersion (background)
1=on dispersion trail 3-7 km away (distal)
2=on dispersion trail 0-2 km away (proximal)
A measure of how well a particular element and sample type identified the Cu-Au mineralization is revealed by the Spearman rank correlation coefficient between the proximity variable and analytical results (Table 3).

Table 3 Spearman rank correlations with proximity variable

	Au	Pb	As	Zn	Cu
BLEG	0.47				
<200#	0.55	0.38	0.36	0.55	0.04
<80>200#	0.04	0.34	0.21	0.49	-0.06
<60>80#	0.16	0.23	0.12	0.49	-0.07
<40>60#	0.43	0.21	0.12	0.45	-0.2
<20>40#	0.02	0.32	0.17	0.37	-0.14

For Au, the <200 mesh samples performed the best, followed by Bleg, and then <40+60 mesh. Correlations of Zn are all significant and were highest for each sample type. Lead gave the second best correlations in all sample types except <200 mesh and <40+60 mesh. The <200 mesh fraction performed well for every element except Cu.

Arsenic gave significant correlations in only <200 mesh and this poor response is explained by examining the between-element correlations. Arsenic shows a Pb-Zn-As-Au association related to the Cu-Au mineralization whereas the Cu-As association is un-related to Cu-Au mineralisation.

These elements can be combined into an equation that better highlights the Cu-Au mineralisation. This was accomplished by regressing the proximity variable against the analytical results for the <200 mesh samples. Results for each element were first log transformed because the frequency distributions are highly positively skewed. Stepwise multiple regression analysis was carried out which showed that only Au and Zn are needed in the equation. The resulting equation is:

$Y = 2.5\log(Zn) + 1.0\log(Au)$

The Spearman rank correlation between this new variable and the proximity variable is 0.71, which is higher than either Au or Zn alone (0.55). The probability plot of the regression variable is shown in Figure 10, and the map of posted values spatially shows how well the technique works.

Results for the Rhyolite Creek orientation survey show that the <200 mesh sample was the most suitable size fraction for highlighting the known Cu-Au mineralisation and the elements in order response are Au > Zn > Pb> As > Cu. For Au alone, the Bleg technique also indicated the presence of the Cu-Au mineralisation.

Conclusions

These case studies have shown the usefulness of *a priori* assigning orientation samples to either background or anomalous groups based on their spatial relationships to known mineralization before further interpreting the data. Probability plots and

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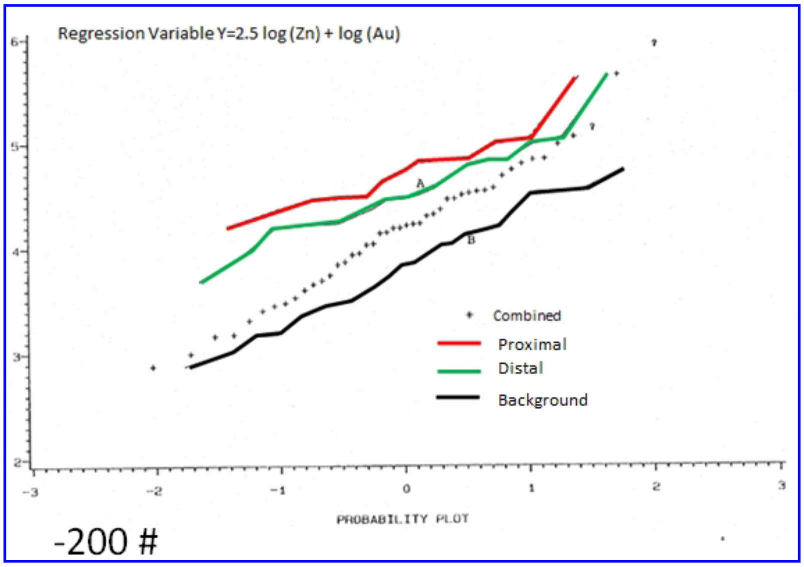

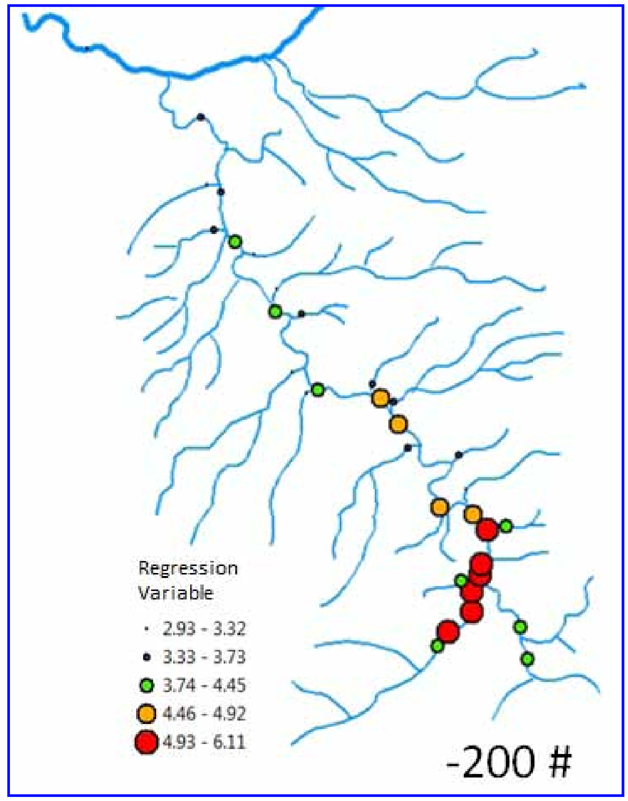

Figure 10. Split probability plot for the regression variable and location of values for the regression variable for the -200 mesh fraction of stream sediment samples.

Spearman rank correlations can then be used to determine the most suitable elements and sample types for detecting the type of mineralisation over which the surveys were conducted. The method can be applied to most types of orientation survey data and mineralisation as long as the spatial location of bedrock mineralisation is well constrained.

Acknowledgements

Capstone Mining is thanked for allowing the Sierra Amarilla case history to be published. Colin Farrelly is thanked for the developing the initial methodology and providing inspiration. Bob Garrett, Ray Lett, Graeme Bonham-Carter, Rael Lipson and Matt Eckfeldt are thanked for reviewing the article and making significant improvements.

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Teaching Exploration Geochemistry — A View From Europe

Charlie Moon *Consulting Geologist and Part-time Lecturer, United Kingdom*

Introduction

In his president's message of June 2017 (EXPLORE, 175), Ryan Noble commented on the state of applied geochemistry in tertiary education. As he rightly pointed out, major centres are limited, as they require access to expensive equipment and collaboration with industry or government organisations. Smaller scale combined teaching and research centres are more widespread. In this article, I review the content of courses which I have been involved in over the last 35 years (mainly in the UK) and some of the opportunities I see in the future. Most of these courses have focussed on mining and exploration, with occasional forays into environmental issues.

The courses or modules have mainly involved applied geology at undergraduate level (3rd year in UK), with a one-year course at master's level in either mineral exploration or mining geology. However, in addition, applied geochemistry can be a large component of 2-3 month student projects at master's level, usually in collaboration with industry.

The key driver for such courses is employment; there is no point devising expensive courses if there are few jobs. Europe has seen a distinct decline in home-base mineral exploration and mining, but the better students have found employment, at least in boom years, in Africa and Australia. If they choose to be based in Europe, there is employment in consulting companies or more recently as fly-in fly-out employees in Africa or Asia. Others have gravitated towards environmental projects. Some students have gone on to become fully fledged geochemists, through the Ph.D. route, or via training in industry or government. To date, the positive attitude of university administrators in the UK combined with the interest of students has kept courses going through industry low-points, unlike the less tolerant approach shown in North America and Australia.

Courses

Typically, exploration geochemistry modules have involved lectures and workshops integrated with field sampling, laboratory analysis and data interpretation exercises. These have usually built on student's knowledge of mineral deposit geology and chemistry, but the extent of this latter knowledge seems to have become more limited in recent years. The lecture topics covered include distribution of elements, chemical analysis, weathering, soil, water, and rock geochemistry as well as some case studies and special cases, particularly gold and diamond exploration.

Workshop sessions commenced with some exercises from Levinson *et al*. (1987) and plotting simple single element maps of element distributions. I found the Daisy Creek copper data useful as it is well described in the literature (Stanley 1988). Of the remaining sessions most are devoted to data from a field area, often using public domain data e.g. TellusSW (TellusSW 2017) and getting students familiar with software discussed below. I have successfully used the AAG 'Writing Geochemical Reports' as a template for the final report (Bloom 2001).

One of the problems in training students is the lack of a good current textbook in exploration geochemistry. Since the publication of Rose *et al* (1979) and Levinson (1980), there have been few textbooks addressing exploration geochemistry, although Evans (1995) and Moon *et al*. (2006) offer some coverage of this topic. The contents were to some extent determined by the opinion of a commercial publisher as to future sales and pricing point. This has proved correct, at least until the advent of the internet and mass scanning of texts. Recently there have been other texts published on mineral exploration (Haldar 2013; Gandhi & Sarkar 2016; Bustillo Revuelta 2018) but none on applied geochemistry.

Fieldwork

One of the key features of any programme is fieldwork (Fig. 1). The most rewarding fieldwork for the students has been the reconnaissance phase of stream sediments sampling, including a demonstration of panning, with a follow-up soil sampling exercise. For universities that are distant from suitable field areas, these exercises are carried out as field camps (i.e. are residential). The best field areas in my experience are of sub-economic base metal deposits in areas of little past mining.

For residential courses, chemical analysis of samples on site is preferable so that anomalies can be followed up in the field and investigated by further sampling, mapping and geophysics. However, this can be expensive. In the days of AAS, we set up an instrument in a self-catering establishment, but ICP analysis requires analysis in the laboratory. Field-based analysis is now again possible with the low detection limits for portable XRF instruments. The advent of field data collection on mobile phone and tablets has also enabled much more accurate positioning and reduced field errors, although not all apps are yet student proof.

Figure 1. Students collecting soil samples over the Coed-Brenin porphyry Cu-Au prospect, Wales.

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Teaching Exploration Geochemistry — A View From Europe... *continued from page 15*

Another type of fieldwork involves visits to mining and exploration operations. We have been fortunate to do this on a worldwide basis. Students can really see a way forward and the use of what they have learnt in the classroom. Although these take up valuable time for the organisations that have accommodated us, they are much appreciated.

Laboratory

Getting students to understand how chemical analysis is undertaken is best done with some time in the laboratory (Fig. 2). However, increased concern for health and safety associated with the use of strong acids has resulted in far fewer students having exposure to wet chemistry. Sharing of instruments with other researchers, especially laser-ablation research, has enabled students to continue with some access, particularly for projects. However, scheduling for larger batches of samples for teaching is difficult and expensive. Use of portable XRF instruments is permitted for students in the UK after a short training, and can enable students to get a good understanding of hands-on data acquisition, including precision and accuracy at limited cost.

Figure 2. Student digesting the Coed-y-Brenin soil samples in the university laboratory.

Statistics and Worksheets

It soon becomes obvious to students that geochemical data sets are large, requiring a knowledge of computer based statistics. The initial stages are usually involve reviewing the data in a spreadsheet, such as Microsoft Excel. Over the years we have used a variety of computer-based statistics packages including Minitab, SPSS and recently the public domain R, largely dependent on the site licence of the university and preferences of other university departments (Minitab 2017; SPSS 2017; R 2017). More recently we have moved to ioGAS, which is more suitable for geologists.

GIS and Simulation

GIS proficiency is, at least in the UK, mandatory for professional accreditation in geology courses, whereas in exploration or environmental geochemistry it is optional (Fig. 3). Most of the recent GIS work has been in ArcGIS, as UK universities have access to reasonably priced site licences. Some students have also used Mapinfo and recently the public domain software QGIS (ArcGIS 2017; Mapinfo 2017; Qgis 2017). We have used a number of examples to teach GIS, such as the Cabo de Gata area in Spain where Au mineralisation is well documented and is easily accessible for fieldwork from the UK (e.g., Carranza *et al.* 2008). Another suitable dataset is the western part of the Bushveld Igneous Complex in South Africa where airborne geophysics and widely spaced government soil geochemistry were made available under an initiative of the South African Geophysical Association (SAGA 2017). Other sets used by colleagues are from Leinster in Tellus Ireland (Tellus Ireland 2017) and northern Finland (GTK 2017).

A number of large multi-method datasets,

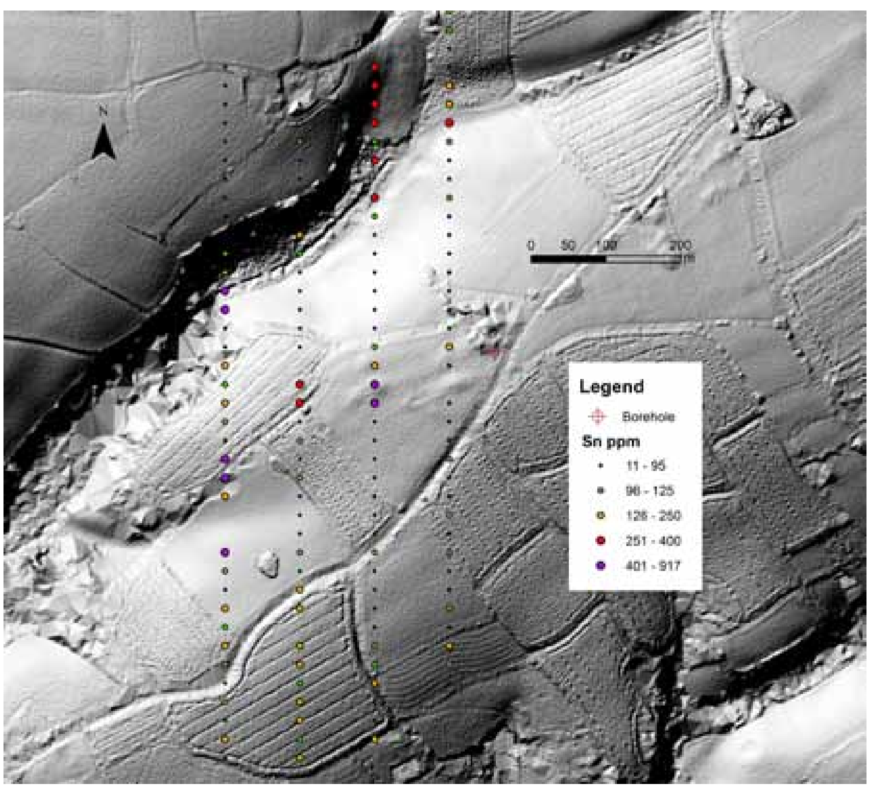

Figure 3. Results of typical student soil sampling exercise: Sn (ppm) soil, SW Cornwall plotted in ArcGIS. The base map is a hill-shaded Lidar DTM from Ferraccioli et al. (2014). Samples were analysed by pXRF on disaggregated soil samples: N= 143 samples, ~50, 75, 90, 95 percentiles plotted. Lumpy features on the ground surface associated with Sn anomalies are old tin mine workings.

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Teaching Exploration Geochemistry — A View From Europe... continued from page 16

including geochemistry, are now being made available for this type of work, conspicuously under the Frank Arnott competitive initiative (Frank Arnott 2017) and can be also used for teaching. The results of initial interpretation of the top four entire were presented at the Exploration '17 decennial conference in Toronto, Canada in October 2017. One danger of this GIS approach is that exploration geochemistry is now often seen as only another layer in the GIS (notably by exploration managers) and insufficient emphasis is put on understanding how anomalies have formed, rather than looking at the immediate high concentrations that link with geophysics or geology.

Handling data from drillholes and 3D modelling is more problematic as few universities, particularly geology departments, regard this as a priority area and the software is complex and not easily learnt. We have used Micromine, Datamine, and Leapfrog, but students have been mainly taught by professional trainers from software providers and the training has been oriented to deriving a geological model and a resource estimate, usually on simulated data (Datamine 2017; Leapfrog 2017; Micromine 2017).

One method of teaching which we found particularly useful for a number of years was running a module based around a sophisticated exploration model of the Central African Copperbelt (Bachau *et al*. 1993). Students were able to soil sample and drill anywhere in the model (20 x 20 km). The location of the deposits and grade could be varied before the simulation started. Unfortunately the model has not been updated with changes in computer operating systems and is not now available (18software 2017).

The Future

The demand for education and training in geochemistry of mineral exploration geologists will continue as they are responsible for most geochemical surveys. AAG can help in this

(i) by updating case histories of exploration discovery, if possible, with digital supplements of original datasets and short videos by discovers
(ii) collating datasets, with discussions, for different methods e.g. bulk leach gold, heavy minerals, laser ablation on minerals
(iii) organising an update of Rose, Hawkes and Webb or new textbook
(iv) continuing with publications, symposia and fieldtrips

Acknowledgements

Staff, particularly technical staff, and students at the universities of Exeter (Camborne School of Mines) and Leicester provided help and constructive criticism of the courses discussed. Paul Morris and Beth McClenaghan are thanked for helpful reviews.

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A Strange Cocktail or a Great Conversation? Defining the Resources for Future Generations 2018 Audience

What happens when you bring industry, government, First Nations representatives, policy-makers, academics, scientists, and members of civil society together? It may sound like a strange mix, but Resources for Future Generations 2018 (RFG2018) recognizes that in order to have a meaningful conversation about the use of Earth¹s resources in the future, all these groups must be in the room. In order to enrich the conversation, RFG2018 has unveiled a robust, comprehensive list of sessions structured around six central themes: The Earth, Water, Minerals, Energy, Resources & Society, and Education & Knowledge. You can review a full list of Theme Sessions at the following link: http://ow.ly/teFv30g7HP8

The Call for Abstracts to RFG2018 sessions is now open. Abstracts will be accepted until January 15, 2018, and we encourage you to add your voice to this event. Visit rfg2018.org for details.

AAG Member Survey

The results of the AAG member survey conducted in the first quarter of 2017 have now been compiled and a summary of the results is found below. We received 110 responses (33% of current membership) which was topped up with a further 48 responses (10% response) from past members. This provides us with a reasonable representation of the views of members past and present. Most respondents were from Australia followed by Canada and USA, which, collectively, account for 71% of the total respondents and reflects the actual membership mix (71%). Females were slightly over represented (15%) in the survey compared with actual membership (11%).

An initial assessment was done on the surveys separately, but the demographic was similar in a number of categories between present and past members and so was combined (Fig. 1). Age was deemed an important variable as the AAG looks to build membership and, critically, attract younger members (19% under 40 for respondents).

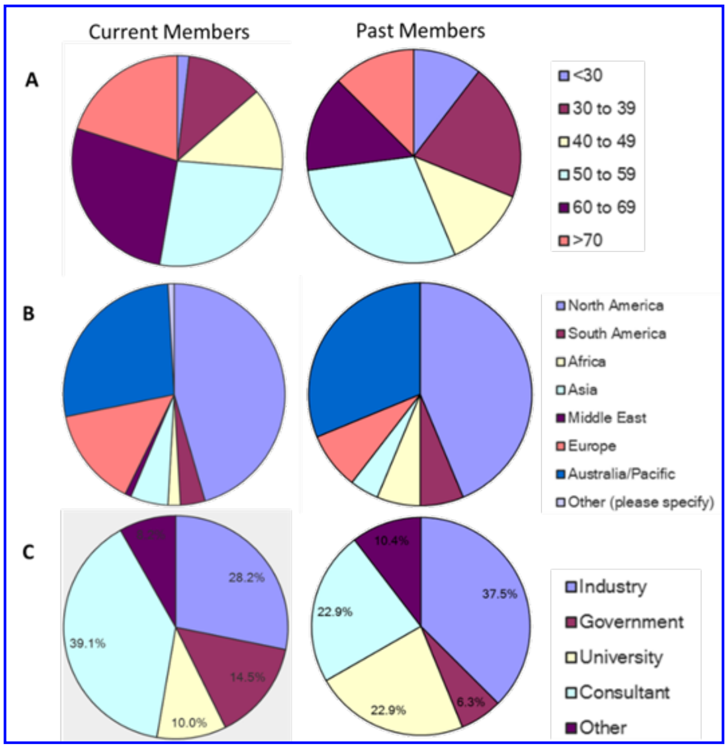


Figure 1. Comparison of key AAG survey demographics. A) Age, B) Primary location, C) Employment sector.

Not surprisingly, most of the respondents are involved in exploration (71%) with environment (19%) and analytical (7%) following second and third, respectively. The AAG should gain members from the more expansive environmental geochemistry sector. Member retention recognizes that it is not only important to attract new members to the AAG but also to keep them. Respondents told us that access to news and information, publications such as **EXPLORE**, supporting the profession and networking were the most important factors with discount fees for IAGS rating lowest benefit across the membership. Worryingly, it was shown that more than 20% of the respondents under 30 years of age had no intention to retain their membership. This may be related to communication channels used by the AAG which the respondents told us, not surprisingly, that younger members would like to see more communication from the AAG via social media such as LinkedIn (which we currently don't use much) compared to the older membership; the older members will be relieved to find that Twitter and Facebook received lower ratings for future AAG communications across the age demographic.

The response to questions about the IAGS showed fairly equal importance to factors such as hearing about current advances, networking, presentation of work and less so around the actual venue. Few differences were seen between age groups, although presenting papers was more important to the younger respondents. The take home message here was interpreted as encouraging less spectacular and expensive IAGS bids and piggy-backing on other popular but related events.

GEEA continues to be a popular avenue to publish members work with Applied Geochemistry, JGE and Economic Geology following. Impact factors are important for the younger respondents for career progression; note that GEEA is nearly pushing through IF 2.

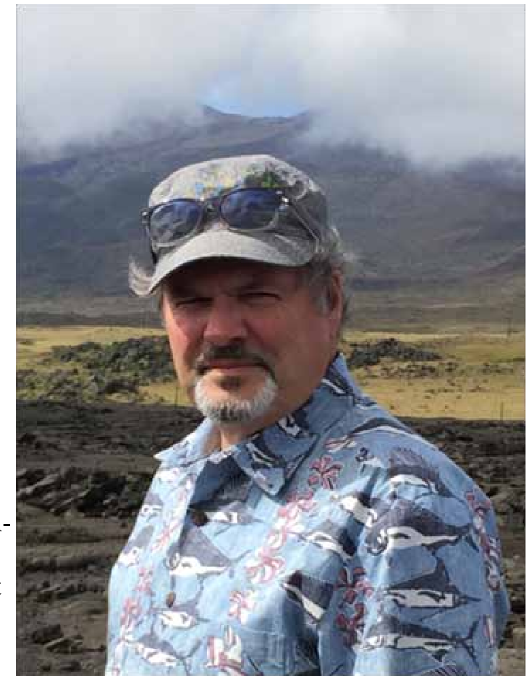
Other findings include:

- Education opportunities were continually emphasized, including short courses, visiting lecturers and webinars,
- Better use of web site for interaction between members and a repository of cases studies and databases as well as dissemination of educational materials,
- Student support is needed – both financial and mentoring,
- Stronger links with universities are also needed and marketing of AAG within them.

The Council and Committee have used insights from the survey to compile a decadal strategy document for the AAG that is up for endorsement by Council at the next meeting. It is hoped a number of the potential action items will spawn some new initiatives within the AAG and reinvigorate the membership. All the respondents are thanked for their input into the current running and future directions for the AAG. The full report and results of the survey can be found on the AAG website (https://www.appliedgeochemists.org) after logging into the "Members" area.

Mel Lintern
Email: Mel.Lintern@csiro.au
CSIRO Mineral Resources

Obituary



T. Kurtis Kyser (1951 - 2017)

The Association of Applied Geochemists (AAG) recently lost one of its most well-known, charismatic scientific leaders and educators, Professor T. Kurt Kyser. He died on August 29 while co-leading a graduate and undergraduate fieldtrip on carbonates in Bermuda.

Kurt was the Editor-in-Chief of the Association's journal, *Geochemistry: Exploration, Environment, Analysis* (GEEA) for the past few years, where he had led the journal to a significant increase in impact factor and set up future directions and a structure for GEEA that should see it well placed for the next decade. His editorial accomplishments were well defined through his extensive publication history. Kurt was an author on more than 400 peer-reviewed journal papers, more than 200 refereed conference proceedings, a couple of books and several more book chapters, along with a host of technical reports and educational notes.

His most prominent research was in the application of isotopes to mineral exploration and environmental geochemistry, with a strong focus on uranium. However, when reviewing Kurt's publications it is clearly evident that he was hugely influential on a diversity of science disciplines.

Kurt was at the forefront of geochemical isotopic research. He developed and directed the Queen's Facility for Isotope Research (QFIR), a leading geochemistry and isotope laboratory in North America, which examines element cycling at the geosphere-biosphere interface. Through QFIR, he initiated many projects that totalled in excess of $12 M CAN.

As an educator, he was active and enthusiastic in teaching courses at the undergraduate, graduate and professional level. Kurt had a strong commitment to training the next generation of geochemists, having supervised ~50 MSc and ~50 PhD students, not to mention the many more he influenced as undergrads or co-supervised post grads or colleagues. Over the last six years he had directly supervised 15 undergraduate theses, 26 M.Sc. theses, 17 Ph.D. theses and 10 Post-doctoral researchers. Through these graduate and undergraduate student interactions, Kurt had grown and raised a large geochemistry family.

The sheer volume, significance and influence of Kurt's research and teaching ensured he was world renowned and the recipient of many honours. His numerous awards include the Duncan R. Derry Medal, Hawley Medal, Willet G. Miller Medal, Past President's Medal of the Mineralogical Association of Canada, and Past President's Medal of the Geological Association of Canada. In addition to these honours, he was a Fellow of the Royal Society of Canada, a Queen's Research Chair, a Queen's National Scholar, a NSERC Killam Research Fellow, a Fellow of the Mineralogical Society of America, and recipient of the NSERC E.W.R. Steacie Memorial Fellowship. For the AAG (in addition to his GEEA role), Kurt was a Fellow and the AAG Distinguished Lecturer in 2008-2009.

He was also active in other groups as a member of the Mineralogical Society of America, American Geophysical Union, Geochemical Society of America and the Mineralogical Association of Canada. He was a Past President of the Mineralogical Association of Canada.

Kurt's early years were in California, although he was born in Montana, U.S.A. When he was six years old growing up in San Diego, CA, he was fascinated with insects. He thought that entomology was surely in his future, catching Monarch and Yellowtail butterflies in mason jars. He would use a nail and hammer to perforate the lids, but little did he realize then that the hammer was his future, not what was in the jar. With time, isotopes became his focus and their application to understanding processes in the geosphere has allowed his research group not only to examine ore deposits, but also the geosphere-biosphere interface. In fact, he recently returned to entomology applying isotopes to butterflies and their challenging migration habits. In a recent acceptance speech, he said "Realize your passions—real ones don't diminish with time, they only hibernate and then return again full circle".

He completed his B.Sc. at the University of California, San Diego in 1974, before completing his M.A. and Ph.D. in Geology from the University of California, Berkley in 1976 and 1980, respectively. Following post-doctoral positions at the U.S. Geological Survey in Denver and a NATO post-doctoral fellowship at the University of Paris in 1980, Kurt joined the University of Saskatchewan as an Assistant professor, progressing through to full Professor in 1989. In 1995 he joined the Department of Geological Sciences and Geological Engineering at Queen's University in Kingston where he remained.

Kurt always stood out at any event, partly through his knowledge, charisma and laugh, but also because of the brightly coloured Hawaiian shirts and sandals that were his uniform more often than not. It was his uniform and genuine personality that made everyone who talked with him, be it a Nobel laureate or a person on the street, feel welcomed and appreciated. Despite his stature in the field and incredible knowledge, Kurt had an incredible ability to

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T. Kurtis Kyser ... *continued from page 20*

make you feel that your ideas were interesting, and even at times, important. The fondest memories, other than all the times debating science and life over wine, was spending time with Kurt in the field. Some of us were lucky enough to spend eight days with Kurt floating down the Colorado River through the Grand Canyon, prior to the IAGS meeting in Tucson, in 2015. It was a magical trip of geology, comradery, sipping scotch on the small beaches at the side of the river, and sleeping under the stars. This was a trip that Kurt had always wanted to do since he was a graduate student sampling volcanic-hosted mantle xenoliths at the north canyon rim. It was one of many truly extraordinary experiences that Kurt managed in his career.

Kurt was 65 and is survived by his wife and partner in science and life, April Vuletich. He is also survived by a truly incredible number of former students, post-doctoral fellows and research collaborators in all corners of the globe that will ensure his legacy of research, education and love for living-life-large will continue. As Kurt would have liked, many have raised a glass of red or white in his honour. Cheers to an exceptional life, lived well.

Ryan Noble, Dan Layton-Matthews and Matt Leybourne

The AAG-SGS Student Presentation Prize

The Association of Applied Geochemists, through the support of SGS Mineral Services, awards a prize for the

Best oral presentation by a student at the biannual International Applied Geochemistry Symposium (IAGS)

Next IAGS will be part of the RFG2018 Conference, Vancouver, June 16-21, 2018 (rfg2018.org)

The intent of this prize is to encourage the presentation of high quality research by students at an International Applied Geochemistry Symposium (IAGS) and provide further incentive to publish the results of the research in the Association's journal, Geochemistry: Exploration, Environment, Analysis (GEEA). The winner is determined based on feedback from a group of judges that includes Fellows and Members of the Association. Criteria for judging the presentations include excellence and originality in research design, research execution, interpretation, and the oral presentation itself. Honours, Masters, and Doctoral students are all eligible. The format of the presentation may vary between IAGS.

The Rules

1. The paper must be presented by the student at an IAGS as an oral paper, in the format specified by the IAGS organizing committee.
2. The conference presentation and paper must be largely based on research performed as a student. The student's supervisor or Head of Department may be asked to verify this condition.
3. The decision of the AAG Symposium Co-ordinator (in consultation with a representative from SGS) is final and no correspondence will be entered into.
4. Entry in the competition is automatic for students (but students may elect to "opt out").
5. The detailed criteria and process for assessing the best paper will be determined by the AAG Symposium Co-ordinator in consultation with the AAG Council and the LOC.
6. A paper substantially derived from the material presented at the IAGS and submitted for publication in the Association's journal *Geochemistry: Exploration, Environment, Analysis* within the timeframe specified by the AAG (normally 12 months) will be eligible for the increased value of the prize.

The Prize

1. $700 CAD from SGS Minerals Services (normally presented to the winner at the end of the relevant IAGS) with a further $300 CAD from AAG if a paper related to the oral presentation is submitted to GEEA within the nominated time frame after the IAGS;
2. A 2-year membership of the Association, including subscription to GEEA and EXPLORE; and
3. A certificate of recognition.

David Cohen
Chair of Student Prize Committee
University of New South Wales
Email: d.cohen@unsw.edu.au

PDAC short course, March 2-3, 2018

Exploration Geochemistry: Fundamentals and Case Histories

This short course will review principles, methods, and developments in the application of low temperature exploration geochemistry for surficial media by providing presentations by some of the most experienced practitioners in the field. This course will be of interest to young geoscientists and students just starting their careers as well as experienced geologists that would like to update their exploration geochemistry knowledge. Much of the course content is not taught at Canadian universities. Day 1 will review the fundamentals of exploration geochemistry. Day 2 will present case studies for different deposit types and exploration methods in various parts of the world.

Conveners:
Beth McClenaghan (Geological Survey of Canada)
Lynda Bloom (Analytical Solutions)

March 2 Exploration Geochemistry Basics

Introduction to exploration geochemistry
Lynda Bloom, Analytical Solutions Ltd.

Design of a successful geochemical survey
Lynda Bloom, Analytical Solutions Ltd.

Stream sediments, lake sediments, aqueous geochemical methods
Matt Leybourne, Queen's University

Indicator mineral methods
Beth McClenaghan, Geological Survey of Canada

Geochemistry data validation
Pim van Geffen, Vancouver Geochemistry

Exploratory data analysis
Pim van Geffen, Vancouver Geochemistry

March 3 Case Histories

Exploration targeting using stream sediments in British Columbia and Yukon, Canada
Dennis Arne, CSA Global PTY Ltd

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Colin Dunn, Colin Dunn Consulting Inc.

Geochemistry: Exploration, Environment, Analysis

Geochemistry

EXPLORATION, ENVIRONMENT, ANALYSIS

The journal is abstracted and/or indexed in *AGI's Bibliography and Index of Geology, Chemical Abstracts, Current Contents, Engineering Index, GEOBASE, GeoRef, Mineralogical Abstracts, PASCAL/CNRS, GeoArchive, Thomson ISI database (SCIE, CC/PC & ES)*

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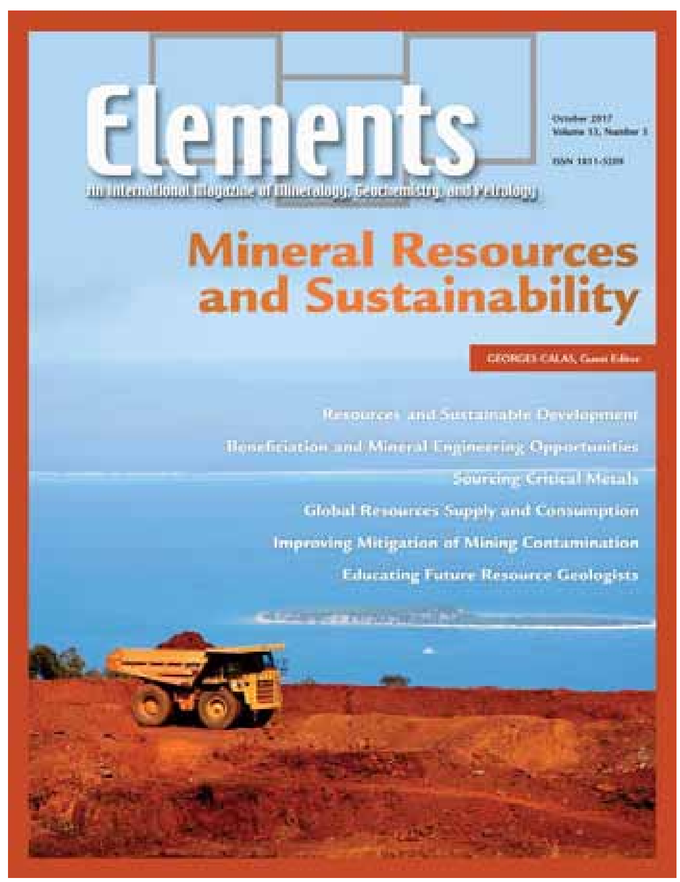
Recently Published in Elements

Volume 13, no. 5

Mineral Resources and Sustainability

The October issue of Elements deals with issues of sustainability in the mineral resources industry. The AAG news in this issue contains a Message from the President and a summary of sessions and short courses for IAGS 2018 that have been accepted as part of the RFG2018 mega-geoscience conference in Vancouver next June.

Dennis Arne



Elements

An International Magazine of Mineralogy, Geochemistry, and Petrology

Volume 13, Number 5 • October 2017

COVER IMAGE: The nickel mine of Tiebaghi is developed on an ultrabasic massif in Northern New Caledonia. A former chromium mine, it is now mined for nickel silicate ores. Its mountaintop location overlooks the New Caledonian lagoon listed by UNESCO on the World Heritage List. This illustrates the development of a mining activity in an environmentally vulnerable situation. In the background, the Barrier Reef makes a clear boundary between the lagoon and the open Pacific Ocean. PHOTO CREDIT: SOCIÉTÉ LE NICKEL, NOUMÉA (NEW CALEDONIA)

Mineral Resources and Sustainability

Guest Editor: **Georges Calas**

DEPARTMENTS

Elements is published jointly by the Mineralogical Society of America, the Mineralogical Society of Great Britain and Ireland, the Mineralogical Association of Canada, the Geochemical Society, the Clay Minerals Society, the European Association of Geochemistry, the International Association of GeoChemistry, the Société Française de Minéralogie et de Cristallographie, the Association of Applied Geochemists, the Deutsche Mineralogische Gesellschaft, the Società Italiana di Mineralogia e Petrologia, the International Association of Geoanalysts, the Polskie Towarzystwo Mineralogiczne (Mineralogical Society of Poland), the Sociedad Española de Mineralogía, the Swiss Society of Mineralogy and Petrology, the Meteoritical Society, and the Japan Association of Mineralogical Sciences. It is provided as a benefit to members of these societies.

Elements is published six times a year. Individuals are encouraged to join any one of the participating societies to receive *Elements*. Institutional subscribers to any of the following journals—*American Mineralogist*, *Clay Minerals*, *Clays and Clay Minerals*, *Mineralogical Magazine*, and *The Canadian Mineralogist*—also receive one copy of *Elements* as part of their 2017 subscription. Institutional subscriptions are available for US$165 (US$180 non-US addresses) a year in 2017. Contact the executive editor (jrosso.elements@gmail.com) for information.

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From the Archives...

Camels in the Cariboo Gold District, Canada

This story was recently found in the archived files of Arthur Lang in the Geological Survey of Canada Archive Collection.

Camels were used as pack animals for one year in the early days of the province of British Columbia, Canada and for many years thereafter a few survivors lingered in the interior of the province, to the wonderment of those who encountered them. The writer first became interested in this curious sidelight on the early development of the Canadian West when he was told about it by the early pioneers. He once saw a photograph of one of the camels, but could not persuade the owner to part with it. He has since found more information on the subject in an entertaining article by W.T. Hayhurst in the report of the Okanagan Historical Society for 1935. Other references corroborate the story and add to the details. As none of the accounts are widely available it may be of interest to give the facts briefly, as they have been pieced together.

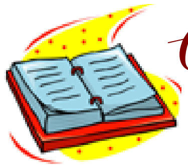
When rich gold-bearing gravels were found in the Cariboo region of what is now British Columbia in 1860, thousands of miners and adventures flocked to the scene from many parts of the world, causing the celebrated Cariboo rush which was the turning point in the opening up of the far west. Most of these gold seekers arrived at the coast by boat, and proceeded in smaller boats up the lower reaches of the Fraser River and up Harrison Lake. Then, since there were no roads or railways at the time, they made the long and arduous trip to the gold fields on foot or horseback, by way of the hastily constructed Cariboo Trail.

Until a road was completed to the Cariboo in 1885 supplies were freighted on the backs of horses and mules. A merchant named Frank Laumeister conceived the idea of using camels for this purpose because part of the route lay through what is called the ‘Dry Belt’, where water and forage is scarce, and because he thought that camels could go farther in a day and carry larger loads than horses or mules were capable of doing. Accordingly, he arranged for the purchase of twenty-two ‘ships of the desert’ in California and had them sent from San Francisco to Victoria, where they arrived in April, 1862, much to the surprise of the inhabitants.

In 1886 the United States Government brought a shipload of camels from North Africa to Texas as an experiment for army transport. Some of these animals were taken overland to California, where a boom was in progress as a result of the gold discoveries of ’49. This gave the idea of using camels for packing in California to a local businessman who imported three shipments for two-humped Bactrian camels from China. The camels brought to Canada were selected from these.

Mr. Laumeister had his animals taken by boat from Victoria to New Westminster, then by scow to the beginning of the Cariboo Trail. At first they seemed to fulfill all expectations, for they were docile and carried twice the load of a mule; but the men in charge soon found that two important considerations had been overlooked. The animals were accustomed to travelling on sand, and their feet were badly cut by the sharp rocks of the trail, therefore boots of canvas and leather had to be improvised for them. The deciding factor was, however, the marked resentment shown by the horses and mules, who stampeded with their packs as soon as they smelled or saw the camels on the trail. The owners of the more orthodox packs trains were greatly in the majority and they made such strong protests to the government that the camels were banned from the trail within a year. Some were sent back to California and others were turned loose or kept as curiosities on ranches, where they lived out their days far from their native land. Mr. Hayhurst states that the last survivor was shot for reasons of old age, probably in 1896.

A.H. Lang (1905-1990)
Geological Survey of Canada



CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry. These events also appear on the AAG web page at: www.appliedgeochemists.org.

Please let us know of your events by sending details to:
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Or Tom Meuzelaar, AAG Webmaster,
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2018

8-13 JANUARY	2018 Winter Conference on Plasma Spectrochemistry. Amelia Island FL USA. Website: tinyurl.com/mrvbqwa
20-21 JANUARY	Gordon Research Seminar – Geobiology. Galveston TX USA. Website: tinyurl.com/ybnd3xch
22-25 JANUARY	Mineral Exploration Roundup 2014. Vancouver BC Canada. Website: roundup.amebc.ca
2-3 FEBRUARY	Atlantic Geoscience Society Annual Colloquium. Truro NS Canada. Website: tinyurl.com/ydy5yfmm
3-4 FEBRUARY	Short Course on Orogenic Gold in Africa and Worldwide. Rondebosch South Africa. Website: tinyurl.com/y9929kge
8-10 FEBRUARY	9th International Congress of Environmental Research. Gwalior India. Website: www.icer18.jerad.org/
11-16 FEBRUARY	Ocean Sciences Meeting. Portland OR USA. Website: osm.agu.org/2018
18-21 FEBRUARY	Australian Exploration Geoscience Conference. Sydney NSW Australia. Website: www.aegc2018.com.au
4-7 MARCH	Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/convention
11-15 MARCH	The Minerals Metals & Materials Society 145th Annual Meeting & Exhibition. Phoenix AZ USA. Website: www.tms.org/tms2018
8-13 APRIL	European Geosciences Union General Assembly 2018. Vienna Austria. Website: www.egu2018.eu
2-4 MAY	International Conference on Geology & Earth Science. Rome Italy. Website: http://geoscience.madridge.com
16-21 JUNE	Resources for Future Generations (Energy, Minerals, Water and the Earth). Vancouver BC Canada. Website: rfg2018.org. **See announcement in current issue of Explore**.
16-21 JUNE	GAC/MAC Annual Meeting. Vancouver BC Canada. Website: rfg2018.org
30 JUNE – 6 JULY	13th International Platinum Symposium. Polokwane South Africa. Website: 13ips.com
1-6 JULY	7th International Congress on Arsenic in the Environment. Beijing, China. Website: www.as2018.org
7-8 JULY	Gordon Research Seminar — Ocean Biogeochemistry. Hong Kong China. Website: tinyurl.com/y98s7dwe
8-13 JULY	Geoanalysis 2018. Sydney NSW Australia. Website: 2018.geoanalysis.info
5-10 AUGUST	Gordon Research Conference - Gordon Research Conference - Geochemistry of Mineral Deposits. Waterville Valley NH US. Website: tinyurl.com/ybnhv8mv
5-9 AUGUST	Microscopy & Microanalysis 2018 Meeting. Baltimore MD USA. Website: tinyurl.com/yc9alqdk
12-17 AUGUST	Goldschmidt 2018. Boston MA USA. Website: goldschmidt.info/2018
12-17 AUGUST	21st World Congress of Soil Science. Website:www.21wcss.org
13-17 AUGUST	22nd General Meeting of the International Mineralogical Association. Melbourne VIC Australia. Website: www.ima2018.com
28-31 AUGUST	15th Quadrennial IAGOD Symposium. Salta Argentina. Website: www.iagod.org/node/76
2-8 SEPTEMBER	19th Annual Conference of International Association for Mathematical Geosciences. Olomouc Czech Republic. Website: www.iamg2018.org/
10-13 SEPTEMBER	XXI Congress of Carpathian Balkan Geological Association. Vienna Austria. Website: cbga.sbg.ac.at
13-15 SEPTEMBER	SIAM Conference on Mathematics of Planet Earth (MPE18). Philadelphia PA USA. Website: www.siam.org/meetings/mpe18
16-21 SEPTEMBER	IWA World Water Congress & Exhibition 2018. Tokyo Japan. Website: tinyurl.com/ybpmakrc
22-25 SEPTEMBER	SEG 2018. Keystone CO USA. Website: www.seg2018.org
14-18 OCTOBER	Australian Geoscience Council Convention. Adelaide SA Australia. Website: tinyurl.com/zqxc6n2
25-26 OCTOBER	Sampling 2018. Lima Peru. Website: www.encuentrometalurgia.com/Sampling-2018

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4-7 NOVEMBER GSA 2018 Annual Meeting. Indianapolis IN USA. Website: tinyurl.com/yb859e9n

12-15 NOVEMBER XIII Latin American Symposium on Environmental Analytical Chemistry. La Serena Chile. Website: tinyurl.com/yc92c5jk

10-14 DECEMBER AGU Fall Meeting. Washington DC USA. Website: tinyurl.com/yclg7sut

Geochemistry in the News

October 16, 2017. For the first time, scientists have caught two neutron stars in the act of colliding, revealing that these collisions are the source of heavy elements such as gold and platinum. To read more about this exciting topic, use the link below.

https://www.npr.org/sections/thetwo-way/2017/10/16/557557544/astronomers-strike-gravitational-gold-in-colliding-neutron-stars

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