

The 2009 AusIMM New Zealand Branch visiting lecturer is Cliff Stanley from Acadia University, Nova Scotia, Canada. Cliff will present a short course and lectures at several centres during May.

Cliff Stanley Biography

<http://ees.acadiau.ca/~cstanley/Home.html>

Cliff Stanley received his BA degree (1980) in earth sciences (Dartmouth College) and his M.Sc. (1984) and Ph.D. (1988) degrees in geological sciences (UBC). After a post-doctoral fellowship in numerical petrology (University of Calgary, 1989) and research associateship in applied geochemistry (Queen's University, 1990-1991), Cliff joined the Mineral Deposit Research Unit (UBC) as an adjunct professor (1992-1998) managing major porphyry Cu-Au and lithogeochemical exploration research projects. In 1999, Cliff became an assistant professor in applied geochemistry/economic geology at Acadia University (Wolfville, Nova Scotia), and is presently an associate professor in their Department of Earth and Environmental Science.

Cliff has published more than 40 refereed articles and presented over 150 talks/posters, but is best known for his development of frequency distribution modelling software (ProbPlot) for exploration geochemistry/ore reserve assay data, and for contributions to the development/application of molar element ratio analysis of lithogeochemistry data in mineral exploration. Recently, he has contributed to the development of unbiased measurement error assessment in ore resource datasets via several papers. In 2003-2004, Cliff served as distinguished lecturer for the Association of Applied Geochemists, and has won a number of professional presentation awards, including the Boldy Award from the Mineral Deposits Division (GAC). He also received a Distinguished Lecturer Award from CIM in 2008.

Programme

The following programme is tentative and may change. For specific dates, times and venues for events, please refer to notices that will be circulated locally.

Day	Location	Presentations
5 Tue	Visit Waihi mines	<i>Lecture B at Waihi mine</i>
6 Wed	University of Auckland	<i>Short course (2-day, day 1)</i> Evening lecture A in Auckland
7 Thur	University of Auckland	<i>Short course (2-day, day 2)</i>
8 Fri	GNS Science, Lower Hutt or VUW	<i>Late afternoon lecture A</i>
11 Mon	University of Otago, Dunedin	<i>Short course (one-day)</i> Evening lecture A in Dunedin
13 Wed	Visit Macraes mine	<i>Lecture B at Macraes mine</i>
14 Thur	Reefton	Evening lecture A at Reefton
15 Fri	Visit Globe-Progress mine	<i>Lecture B at mine</i>

Lecture A: Lithogeochemistry: What you Discover Depends on Where you Stand

Quantitative methods for evaluating rock chemistry typically have involved examination of simple scatterplots and the statistical evaluation of concentration data. Unfortunately, some characteristics of the lithogeochemical data make numerical evaluation in this way difficult, if not statistically or philosophically invalid. Rock compositions sum to 100%, and so are not independent. Furthermore, virtually all geochemical processes are at least partially deterministic (they follow a distinct and predictable pathway based on a quest for equilibrium). As a result, geochemical data are not random, and thus statistical treatment generally may not be appropriate. Modern alternative data analysis methods - molar element ratio analysis (MER) - that consider rocks as simple mixtures of minerals facilitate interpretation and provide opportunities for more refined and in-depth conclusions. These methods consider rock compositions on a molar basis and thus allow establishment of a more direct relationship between lithogeochemistry and mineralogy. Furthermore, these methods are founded on simple geometric principles, and employ hypothesis testing as a means to conclude information about a

rock's composition. Because geometric projections are possible, consequences of competing hypotheses can be examined independently, making geochemical complexities readily interpretable.

Several examples of MER analysis applied to datasets affected by a range of geochemical processes (hydrothermal alteration, diagenesis, igneous fractionation, etc.) illustrate the advantages of approaching lithogeochemical data analysis in this manner.

Lecture B: Quality Assessment and Control in Mining and Mineral Exploration: A Modern Day How-to

Historically, motivations to assess the magnitude of sampling and analysis error in exploration and mining samples were largely driven by exploration geologists seeking knowledge about how far they go with the interpretation of their geochemical data, and mine geologists looking to satisfy banks considering the risk associated with financing of a recently discovered ore deposit. In contrast, in our post-Bre-X world, security exchanges require far more rigorous and onerous analysis of measurement errors, largely because these efforts make detection of fraudulent practice easier to spot. Unfortunately, many of the statistical procedures presently used to undertake such assessments were developed in the pre-computer age and lack the advantages that statistical theory enhancements can offer. Modern statistical procedures afford geoscientists the ability to accurately and precisely assess and control the measurement errors in their geochemical determinations and assays. These new procedures thus offer significant advantages in mining industry applications. In this lecture, the use of these new data quality assessment techniques is described and illustrated in both mineral exploration and mining environments.

Short course: Molar Element Ratio Analysis: Applications to Lithogeochemical Exploration

This short course on lithogeochemistry is directed toward an economic geology-oriented audience with interests in using hydrothermal alteration and lithogeochemistry to explore for mineral deposits or in mineral deposit research. After taking the short course, the audience can be expected to have the background and insight necessary to undertake a lithogeochemical exploration survey using appropriate sampling and analytical procedures, and to interpret the results using simple molar element ratio analysis data evaluation procedures.

Background

Lithogeochemical exploration data have historically been evaluated using a variety of simple graphs and more complicated multivariate statistical procedures. Unfortunately, it is commonly difficult to relate results from these procedures to the actual petrology of the rocks under investigation because the empirical nature of these procedures and plots provides little interpretative guidance. However, a new data reduction methodology that uses scatterplots of linear combinations of molar element ratios facilitates proper interpretation of lithogeochemical exploration surveys. This is because the involvement of specific material transfer processes involving the addition or loss of elements, either in minerals or dissolved in solution, can be directly deduced from the slopes of data trends on the scatterplots. This methodology employs a data analysis philosophy that allows conclusive discovery of the nature and extent of material transfer processes responsible for observed compositional variations (e.g. - hydrothermal alteration). As a result, exploration-related decisions can be confidently made from results of this analysis because a strong petrochemical foundation is created during data evaluation.

This new data analysis methodology employs two complementary lithogeochemical data evaluation techniques: Pearce element ratio (PER) and general element ratio (GER) analysis (collectively referred to as molar element ratio - MER - analysis). Both utilize the 'essential' petrology of the rocks under investigation to direct data analysis, empowering the geologist to utilize geological or geochemical principles in the process. Specific petrologic and geochemical hypotheses explaining the cause for observed compositional variations in rocks can be formulated, formally tested, and accepted or rejected. To do this, the two MER techniques exploit the principles of projective geometry to identify the appropriate location(s) in geochemical space from which to examine lithogeochemical data (the appropriate MER diagram). As a result, specific MER diagrams can be constructed that isolate compositional variations related only to material transfer processes of interest (e.g. -

hydrothermal alteration), allowing unimpeded examination of the resulting compositional variations produced by those processes. In this way, the desired features within the data can be recognized and quantified.

Because the molar element ratio diagrams exhibit compositional variations that are proportional to the additions and losses of elements experienced by rocks during material transfer, quantitative, proportional estimates of mineral modes (including hydrothermal alteration mineral modes) can be determined for each rock. In addition, the compositions of solid solution minerals involved in material transfer and the coefficients of soluble species in geochemical reactions can be determined. This facilitates formulation of the net water-rock reactions responsible for hydrothermal alteration, ensuring proper recognition of different alteration styles, and accurate quantification of the extent of alteration. Molar element ratio analysis represents a superior lithogeochemical data analysis methodology to traditional mass- or volume-based techniques (e.g. - Gresens 1967; Grant 1986; MacLean 1990), which do not attempt or fail to discriminate between competing material transfer processes (e.g. - hydrothermal alteration and igneous fractionation). This produces more accurate lithogeochemical parameters for use in the exploration for hydrothermal orebodies.

Short Course:

The two-day Molar Element Ratio Analysis short course is presented in two parts. The first presents the theory of molar element ratio analysis using both first principles and graphical examples. The philosophical context and strategy of the techniques employed are explained and justified. The relationships and differences between the MER methods and conventional mass- or volume-based material transfer techniques are described to illustrate the advantages of MER analysis. Several simple case histories are then presented to familiarize the participants in the tactics, decision points and criteria to proceed through the analysis. Finally, the mechanics of making the molar element ratio diagrams are presented using a simple spreadsheet dataset exercise that participants undertake as a hands-on 'homework' problem.

After presentation of this background material, the short course concludes with presentations of a wide variety of case histories. These illustrate the use of the two material transfer evaluation techniques 'in action' and exploit the concepts presented in the first part of the short course. Those case histories that demonstrate the wide and comprehensive application of MER analysis that are of particular interest to a mineral exploration audience are presented. These include mineral deposit case histories from a wide variety of mineral deposit types, and involve host rocks with a range of sedimentary, igneous and metamorphic origins. During these presentations, logistical parameters involving lithogeochemical sampling and geochemical analysis are discussed so that the participants learn how to best collect lithogeochemical data in the proper format for subsequent MER analysis.

Part 1 - Theory (40 %)

- Underlying principles and graphical examples
- Philosophy and strategy of data analysis
- Differences with traditional approaches
- Example case histories illustrating tactics, decision points and criteria
- Hands-on spreadsheet homework problem

Part 2 - Mineral Exploration Applications (60 %) including:

- Orogenic or mesothermal Au deposits
- Epithermal Au-Ag deposit
- Cu-Mo porphyry deposits
- VHMS - Cu-Pb-Zn deposits
- Ultramafic-hosted Ni deposits

Contact

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