BIOGEOCHEMISTRY FOR MINERAL EXPLORATION IN CANADA & AUSTRALIA: A COMPARISON BASED ON INTERNATIONAL COLLABORATION

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INTRODUCTION

The application of biogeochemistry enables mineral explorationists to assess the economic potential and environmental status of an environment through determining whether trace elements within the environment are at anomalous or typical background levels. From a geochemical perspective, vegetation can be considered as the above ground extension of the concealed substrate. Australian mineral exploration companies are moving away from areas of outcrop, and into regions dominated by regolith where there is a burgeoning requirement for methods to 'see through' this obstructing cover. The chemical composition of living trees and shrubs can provide information for delineating local and regional geochemical dispersion patterns associated with mineralisation in regolith-dominated terrains.

During 2005, collaboration between some of CRC LEME's Australian biogeochemistry research workers and Canadian-based geoscientists (Colin Dunn and Steve Cook) involved working on a biogeochemical and soil sampling programme in western Canada. The study focussed on geochemical signatures associated with a range of mineral deposits typically found in central British Columbia (BC), including: (3Ts) a Au-Ag epithermal system; Au skarn (QR) and nearby Au/Mo mineralisation associated with gabbro; and Cu-Ag-Au porphyry (Mount Polley).

This paper outlines the mature application of biogeochemical sampling employed in Canada, and compares it with the emerging development of the application here in Australia.

HISTORY OF BIOGEOCHEMISTRY

The application of biogeochemistry for mineral exploration, and techniques employed in Canada are quite mature. From 1940-1966 the North American 'Father of Biogeochemistry' Harry Warren initiated a long progression of studies, which resulted in the rapid progress of biogeochemistry in British Colombia. He continued to augment these studies for another 30 years, long into his retirement, but it was during this earlier period that Warren and his associates undertook much of their most fundamental work in recognizing and documenting the relationship between plant chemistry and concealed mineralisation. This valuable research raised the credibility of biogeochemistry, as Professor Warren put it "from common scepticism, to a general belief that when employed correctly it can be a valuable tool for mineral exploration".

In Australia, however, the application of biogeochemical studies has been on a much smaller scale and with less co-ordination (Brooks 1972). The first reputable documentation of vegetation being implemented in mineral exploration programmes in Australia took place some 41 years ago by Monica Cole (1965). Over the following 25 years, the development of biogeochemical exploration in Australia was quite sporadic, with biogeochemical programmes taking place by PhD student Hall (1971), and some studies being undertaken by mining companies e.g. Pasminco (1970). An increasing acceptance of the application of biogeochemical exploration has taken place in the last decade with multiple papers published (Arne 1999; Lintern 1996; Cole 1991; Cruikshank & Pyke 1986). The resurgence of the application of biogeochemical exploration is a reflection of the shift in focus of mineral exploration towards areas predominately covered by a transported regolith. The Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) has recently been investigating the application of biogeochemistry for mineral exploration within these regions and a wide range of plants are being tested (Hulme 2006; Hill 2003; Hill & Hill, 2003; Dann 2001).

ENVIRONMENTAL/LANDSCAPE CHARACTERISTICS IN RELATION TO THE USE OF BIOGEOCHEMISTRY

In Central British Columbia (Nechako Plateau) and specifically at 3Ts, QR and Mount Polley, rolling hills, small lakes, ponds, and minor wetlands with elevations ranging between 1065-1250 m (3Ts), 1000-1100 m (Quesnel) and 920 – 1266 m (Mt Polley) characterise the landscape (Figure. 1). The average annual rainfall for Prince George is 418.8 mm with an average maximum 21.1°C and minimum 7.9°C in summer (June -

August) and –3.4°C and –11.7°C in winter (December - February) (Meteorology Canada 2006). Table 1, outlines the geology and mineralisation of the three survey areas.

	3Ts	QR	Mount Polley
Main lithologies	Rhyolitic lithic tuffs	Propylitized and carbonatized fragmental mafic volcanic rocks	Silica saturated intrusive complex
Prominent mineralisation	Au-Ag	Au, minor Ag	Cu-Ag-Au
Geochronology	Late Jurassic	Upper Triassic-Lower Jurassic	Late Triassic

Quaternary deposits and/or volcanic rocks cover a great deal of the bedrock in central British Columbia. These deposits are characterised by basal till with subordinate colluvial and glaciofluvial deposits. Lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) are the dominant trees across the area.

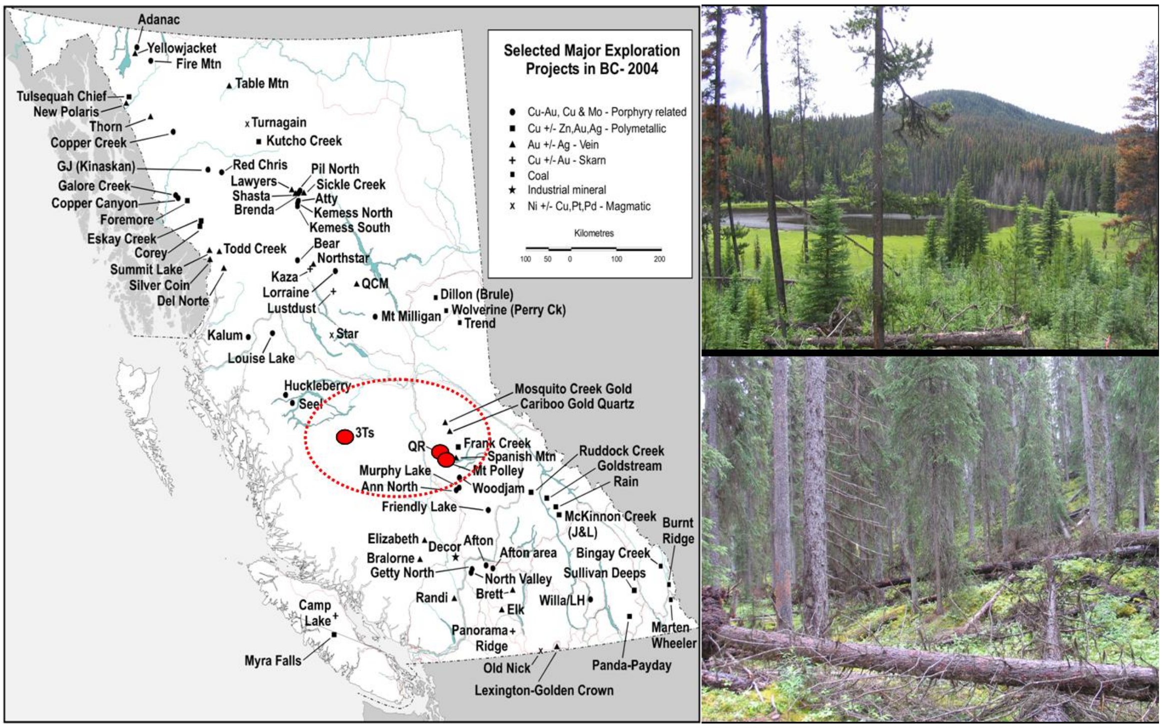

Figure 1. Location of the 3Ts Au-Ag epithermal prospect, QR Au-skarn prospect and Mt Polley Cu-Ag-Au porphyry mine, a typical pine and spruce forest.

The mineral exploration challenges of western New South Wales (NSW) are typical of much of Australia (Figure 2). The region comprises mostly undulating broad plains with elevations ranging between 60 and 200 m above sea level, with a few areas of higher relief hills and mountains rising up to 473 m in the Barrier Ranges (Hill 2005). The region has a semi-arid to arid climate, with an average annual rainfall of 240 mm, predominately in the summer. The average summer maximum is 31.9^{o} C, but can frequently exceed 38^{o} C, and the average winter minimum is 3.5^{O} C (Bureau of Meteorology 2006).

The geology consists of deformed late Palaeo-Proterozoic metasedimentary and metavolcanic rocks (Willyama Supergroup) with some meta-intrusives and early Meso-Proterozoic volcanics, sediments and granitoid intrusives. The region is famous for hosting the Broken Hill Ag-Pb-Zn orebody, but is also prospective for additional mineral commodities.

An all-important feature of Australia, and in particular far western NSW is a regolith blanket of varying depths, which obscures approximately 90% of the Australian prospective terrain (Hill 2002).

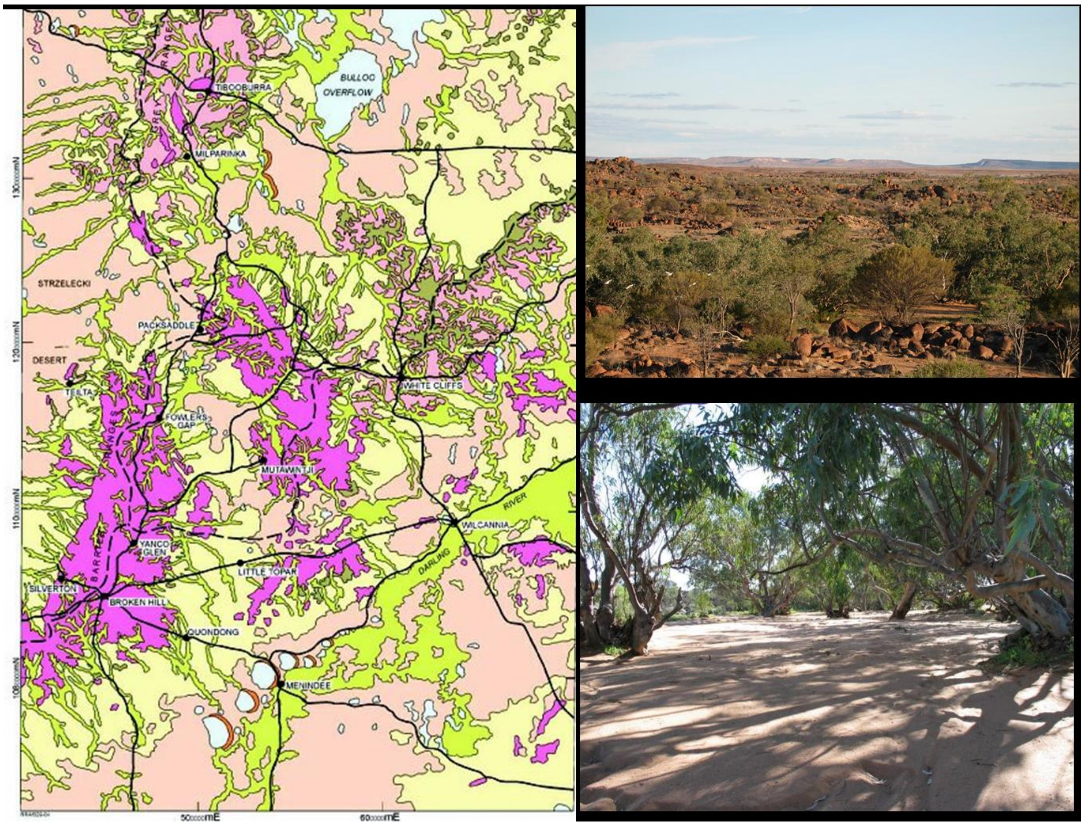

Figure 2. Regional regolith map of far western NSW, an important feature of the map is the narrow exposures of bedrock compared the extensive regolith dominated regions

EXAMPLE OF BIOGEOCHEMICAL APPROACH IN CANADA

During June 2005, an extensive biogeochemical investigation was undertaken in the Nechako Plateau 3Ts region. The survey involved the collection of appropriate vegetation samples along two traverses, which crossed the Au-Ag epithermal system evidenced by known mineralisation: the Tommy and Ted veins.

Fieldwork was conducted during a one-week period in late June (Summer). A total of 131 vegetation samples were collected along two west-east transects. The two most common plants across the survey area were white spruce and lodgepole pine. At 50 m intervals across the two traverses, white spruce foliage and lodgepole pine outer bark were collected. The method of sampling involved the collection of the most recent 5-7 years of growth for the white spruce foliage by leather-gloved hand. Foliage was cut with pruning shears and samples were placed into porous polypropylene bags ('Hubco' Sentry II). Lodgepole pine outer bark was collected by the use of a hardened steel paint scraper, and placed into a standard 'kraft' paper soil bag (Dunn *et al*. 2006). Samples were sent for analysis to investigate their multi-element chemical signature.

In the laboratory, the vegetation samples were dried at 70^{O} C for 24 hours to ensure all moisture was removed. Once dried, the white spruce needles were separated from their twigs and milled to a powder consistency in preparation for chemical analysis. Vegetation samples were sent to ACME Laboratories for the analysis of 53 elements by ICP-MS following nitric acid/aqua regia digestion.

EXAMPLE OF BIOGEOCHEMICAL APPROACH IN AUSTRALIA

During 2004, a biogeochemical survey was undertaken at the Pb-Ag-Zn Barrier Pinnacles Mine. The survey included the sampling of foliage from 215 River red gums (*Eucalpytus* camaldulensis) growing along an alluvial channel, along a traverse adjacent to the Barrier Pinnacles Mine.

Fieldwork was conducted during a two-week period in mid March (autumn). The method of sampling involved the removal of leaves while wearing non-powdered latex gloves. Gloves were changed between samples to minimise the risk of cross-contamination between different samples. The method of storage involved all samples being placed in individual brown paper bags (235 mm x 200 mm), that were then sealed by folding over the top and stored in a well-ventilated and dry area for the duration of the sampling period.

In the laboratory, the vegetation samples were dried at 60^{O} C for 48 hours to ensure all moisture was removed. Once dried, the foliage was milled to a powder consistency in preparation for chemical analysis. Vegetation samples were sent to Geoscience Australia for X-Ray Fluorescence (XRF) of vegetation pellets and (Hot plate, nitric acid/aqua regia digestion) ICP-MS analysis.

IMPLICATIONS FOR GEOCHEMICAL APPROACH/SAMPLING DESIGN IN CANADA AND AUSTRALIA

The procedures used in the biogeochemical surveys in Canada and Australia were different, but a large number of similarities in the procedures and precautions were adopted. Table 2 outlines the basic rules applied during the biogeochemical sampling survey and the rationale for adopting these.

Canada	Australia	Reasons
Collect, as much as is practically reasonable, from around the circumference of the tree	Subdivide the tree into 8 equal sectors (Reconnaissance)	To determine preferential translocation throughout the tree to allow for well developed conducting systems
Collect same species	Collect same species	Every species has different chemical composition, trace element tolerances and nutrient requirements
Use leather gloves	Use non-powdered latex gloves, or leather gloves for thorny species	Reduce contamination; also if survey is environmentally based, perspiration can induce elevated sodium and chloride concentrations
Collect same plant organ	Collect same plant organ	Each plant organ has different nutritional requirements and capacity to store trace elements
Collect same amount (age) of growth, from the same area of the tree (at chest height)	Collect same amount (age) of growth, from the same area of the tree (at chest height)	Chemical variations (e.g. in twig: wood ratio, see Dunn et al. 1995), to ensure homogeneous sampling should be taken from around the entire species
Collect samples of similar age and appearance, and don't mix live with dead tissue	Collect samples of similar age and appearance, and don't mix live with dead tissue	This ensures that all samples are repeatable, comparable and representative.
Collection of living material should be undertaken at the same time of the year (over a 2-3 week period), otherwise normalization of data to a common datum is required.	Collection of living material should be undertaken at the same time of the year (over a 2-3 week period), otherwise normalization of data to a common datum is required.	Significant temporal variations in plant chemistry may be observed.
Do not return to same tree previously sampled and expect to obtain exactly the same analysis	Do not return to same tree previously sampled and expect to obtain exactly the same analysis	This is unrealistic in view of the heterogeneity of element distributions and seasonal variations in composition.
Optimal sampling size no less than 20 g (desirable 100 g, depending on sample medium.)	Optimal sampling size no less than 20 g (desirable 300 g.)	Amount taken needs to be enough to ensure it is a true representative of the chemistry of the sampled medium
	Representative samples of surficial soils should be collected	Evaluate contributions of elements from soils to total concentration measured in plants
Eliminate adhering lichens as much as is practically reasonable	Samples collected should be free from fungi and faecal deposits.	Possibly results in fictitious anomalies
To wash or not to wash	To wash or not to wash	Will depend on the scope of the project: e.g. evaluation of airborne pollutants (don't wash), to define individual chemical composition due to soil interactions (wash). With rare exceptions 'washing' should only be gentle rinsing, otherwise some trace elements will be washed out of the plant structure.

TOWARDS A UNIVERSAL APPROACH?

In Australia over the last decade, we have witnessed the successful development of biogeochemistry as a means for mineral exploration. In order to fully understand the application of biogeochemistry, Australian researchers (CRC LEME) have been developing and modifying methods which are applicable from cool environments (Canada) to the more arid – semi arid Australian environment. Through liasing and working with our Canadian colleagues, we notice that at the heart of the application there are a number of procedures and precautions, which are transferable on an international arena.

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