Biogeochemistry in Mineral Exploration

Photos courtesy of Colin Dunn

Biogeochemistry, or more precisely, phytogeochemistry, uses plants as the sample medium for exploration, **in particular when soil samples cannot be taken due to inaccessibility or in areas of transported overburden.** Vascular plants have evolved over 400 Ma to survive a wide range of physical and chemical conditions, and have developed mechanisms to absorb and scavenge elements and translocate them to foliage, twigs, bark, flowers and seeds. **Some plants are able to solubilise Au** by releasing such ligands as cyanide (observed in Acacia and Eucalyptus (Ma et al. 2009).

Biogeochemistry is particularly useful as a guide to the underlying geology in areas of transported cover, where the signature in the vegetation can be better than the soils (Anand et al. 2007). In arid and semi-arid conditions (Canadell et al. 1996) roots can penetrate several meters to reach permanent water source (Table 1), for example **roots of Spinifex have been observed in mine pits at depths to 30 m and below** (Reid et al. 2008).

Table 1. Maximum rooting depths, in various ecosystems (Canadell et al. 1996)

Ecosystem type	Range of rooting depths (m)
Boreal Forests	1.2-3.3
Desert	1.8-53
Coniferous forest	2.0-7.5
Tropical forests	2.0-18
Tropical grassland and savannah	1.6-68

Vegetation is widespread and **samples are easy and cheap to collect, with a low environmental impact**, compared with more invasive exploration sampling techniques. The levels of metals in plants are low, compared with soils, so care must be exercised to minimise contamination during when sampling.

Sampling

Where? Sample around a tree or shrub at about the same height, taking samples of approximately the same age. The site should away from areas of anthropogenic impact. Collect enough to fill a large soil sample packet or a small calico bag and air dry in the field if possible. To prevent mould, do not store samples in plastic bags for long periods.

Which species? One or several targeted species, typically the most widespread with high chance of being deep-rooted (Hulme et al. 2006). If there is existing knowledge on particular plant species in your area this may also influence the choice of target species. Out of 138 scientific studies, which were analysed at Intertek Genalysis, the most popular species successfully used in exploration studies in Australia are **Acacia** and **Eucalyptus, Spinifex, Tea tree**, Fuschia bush, Monterey pine, Black oak and Cassinia. Some plants hyperaccumulate certain elements to very high levels, to name a few Australian plants (Fig.1): Shrub Violet (*Hybanthus floribundus*, **Ni and Co accumulator)**, Black Nightshade (*Solanum nigrum*, **accumulator of Cd**), Flat-topped saltbush (*Atriplex codonocarpa*, **accumulator of Hg**), Dysentery Bush (*Alyxia buxifolia* accumulator of Cr and Cu). *Polycarpaea spirostylis* is known to grow on soils rich with Ag, Pb and Cu however this species is endangered in Australia and should be used only as an indicator. Among unusual, but very successful media to sample are kangaroo scats and termites.

What part of plant tissue? Uniform plant tissue (foliage of uniform age/maturity, twigs of similar diameter, bark, flowers, seeds, litter) can be analysed and a small orientation study is recommended to determine the most useful species and the tissue types. **Foliage and bark often give the strongest geochemical signatur**e.

When? Limitted time period (2-3 weeks) as live plant tissue exhibit seasonal variations, but this is generally less than 20%. Dead tissues such as outer bark or litter yield small or no change in composition during seasons (Dunn, C., 2007).

How much? Optimal size from 20g to 100-300g.

Other media to sample? Biogeochemistry has been proven to be a successful exploration tool on its own, however, for a comprehensive program it is recommended to sample other media together with plant tissue such as soil for Partial Digest (Intertek Genalysis Code TL/) and, if samples are accessible, surface water/groundwater or stream sediments for Hydrogeochemical analysis (Intertek Genalysis code SO/).

Analysis

Samples are prepared in dedicated facilities in the laboratory. Samples are dried, the foliage is separated from twigs and extraneous material removed from litter, as required, before being milled in specialised equipment. Soft leaves and bark usually is easy to prepare, whereas thick twigs require more work.

The pulped sample is digested using a modified aqua regia digest and analysed by ICP-OES, ICP-MS and AAS. Multielement analyses are the most useful for biogeochemical interpretation and depending on the project budget Intertek Genalysis offers various packages (BG/), however, for an initial small orientation study the full suite of elements is recommended (BG/OM20). Detection limits for salt bush leaves (not twigs) and other samples that are particularly enriched may be higher if extra dilutions are required, however, most of popular plants used in biogeochemistry do not require this. For quality control we have a wide range of Australian vegetation standards to match the sample matrix.

Figure. 1. Gold in soil and vegetation at Moolart well gold deposit (Anand et al. 2007).

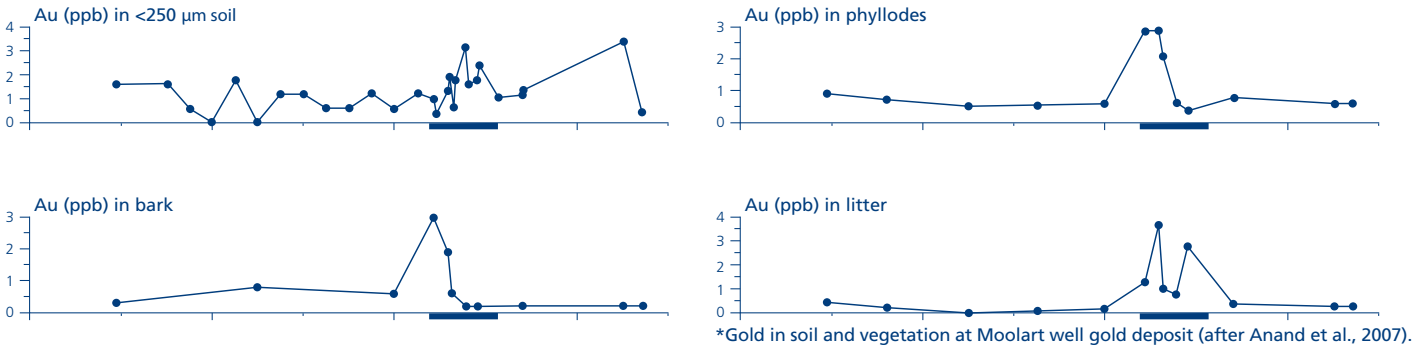
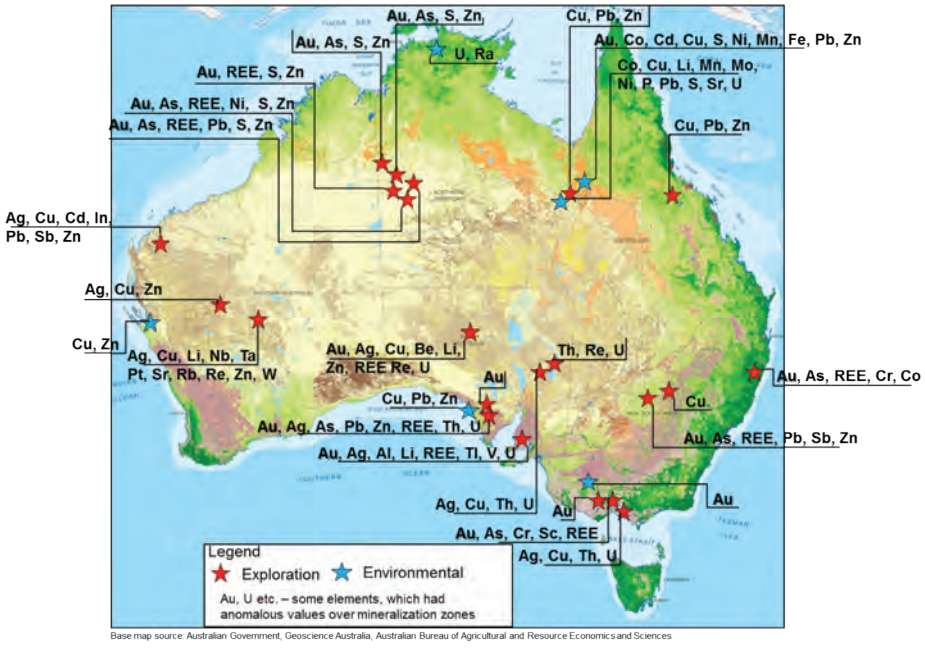


Figure 2. Geography of successful research studies on biogeochemistry over various mineralization zones in Australia.



The map on Figure 2 shows the geography of only a few successful scientific studies of biogeochemistry expression over various mineralization zones in Australia and some elements, which had anomalous values over those zones. Majority of studies (46 %) were devoted to identify Au mineralization. In studies for Au mineralisation the major plant tissue were leaves and leaflet branchlets (87%), bark (7.8%), twigs (3.1%) and litter (1.6%). Bark and leaves on average gave the highest values for gold anomalies. In **86% of cases anomalous Au values were present in plant tissue over mineralisation zone.**

The map highlights **applicability of biogeochemistry method for exploration in a wide range of arid environments.**

Biogeochemistry Sample Preparation

Various preparation options are available in combination with either the basic, standard or comprehensive biogeochemistry packages.

Description	Code
Sorting and stripping of twigs and leaves per 100g	BGSS
Single milling and drying of soft plant tissue (Retsch Mill Type Grindomix GM 200)	BGMD01
Double milling and drying of hard plant tissue	BGMD02

Biogeochemistry Analysis Options

Various preparation options are available in combination with either the basic, advanced or comprehensive biogeochemistry analysis packages.

Basic Package

Element	Range ppm	Element	Range ppm	Element	Range ppm
Ag	5ppb - 10	Hg	2ppb - 50	S	5 - 1%
Al	5 - 2%	K	10 - 5%	Sb	5ppb - 500
As	0.1 - 1000	La	2ppb - 200	Se	0.02 - 50
Au	0.5ppb - 10	Li	0.02 - 500	Sn	0.02 - 50
Bi	2ppb - 100	Mg	10 - 2%	Sr	0.05 - 2000
Ca	20 - 5%	Mn	0.5 - 2000	Th	5ppb - 200
Ce	5ppb - 200	Mo	0.02 - 200	U	0.5ppb - 2000
Co	0.02 - 200	Na	20 - 5%	V	0.2 - 500
Cr	0.2 - 500	Ni	0.1 - 2000	Zn	0.2 - 2000
Cu	0.1 - 5000	P	5 - 5000		
Fe	5 - 5%	Pb	0.02 - 1000		

Biogeochemistry basic package
Modified aqua regia digest / ICP-OES & ICP-MS — BG/OM02

Standard Package

Element	Range ppm	Element	Range ppm	Element	Range ppm
Ag	5ppb - 10	Gd	0.5ppb - 50	Pt	1ppb - 10
Al	5 - 2%	Hf	2ppb - 50	Rb	0.01 - 500
As	0.1 - 1000	Hg	2ppb - 50	Re	0.5ppb - 50
Au	0.5ppb - 10	In	1ppb - 50	S	5 - 1%
B	2 - 1000	K	10 - 5%	Sn	0.02 - 50
Ba	0.05 - 1%	La	2ppb - 200	Sr	0.05 - 2000
Be	5ppb - 50	Li	0.02 - 500	Te	5ppb - 50
Bi	2ppb - 100	Mg	10 - 2%	Th	5ppb - 200
Ca	20 - 5%	Mn	0.5 - 2000	Ti	0.5 - 500
Cd	2ppb - 50	Mo	0.02 - 200	Tl	2ppb - 50
Ce	5ppb - 200	Na	20 - 5%	U	0.5ppb - 2000
Co	0.02 - 200	Nb	5ppb - 50	V	0.2 - 500
Cr	0.2 - 500	Nd	2ppb - 200	W	0.02 - 50
Cs	1ppb - 50	Ni	0.1 - 2000	Y	5ppb - 50
Cu	0.1 - 5000	P	5 - 5000	Zn	0.2 - 2000
Fe	5 - 5%	Pb	0.02 - 1000	Zr	0.05 - 50
Ga	0.01 - 200	Pd	2ppb - 10		

Biogeochemistry standard package
Modified aqua regia digest / ICP-OES & ICP-MS — BG/OM10

Comprehensive Package

Element	Range ppm	Element	Range ppm	Element	Range ppm
Ag	5ppb - 10	Hg	2ppb - 50	Sb	5ppb - 500
Al	5 - 2%	Ho	0.1ppb - 50	Sc	0.01 - 200
As	0.1 - 1000	In	1ppb - 50	Se	0.02 - 50
Au	0.5ppb - 10	K	10 - 5%	Sm	1ppb - 200
B	2 - 1000	La	2ppb - 200	Sn	0.02 - 50
Ba	0.05 - 1%	Li	0.02 - 500	Sr	0.05 - 2000
Be	5ppb - 50	Lu	0.1ppb - 50	Ta	2ppb - 50
Bi	2ppb - 100	Mg	10 - 2%	Tb	0.5ppb - 50
Ca	20 - 5%	Mn	0.5 - 2000	Te	5ppb - 50
Cd	2ppb - 50	Mo	0.02 - 200	Th	5ppb - 200
Ce	5ppb - 200	Na	20 - 5%	Ti	0.5 - 500
Co	0.02 - 200	Nb	5ppb - 50	Tl	2ppb - 50
Cr	0.2 - 500	Nd	2ppb - 200	Tm	0.5ppb - 50
Cs	1ppb - 50	Ni	0.1 - 2000	U	0.5ppb - 2000
Cu	0.1 - 5000	P	5 - 5000	V	0.2 - 500
Dy	0.5ppb - 50	Pb	0.02 - 1000	W	0.02 - 50
Er	0.5ppb - 50	Pd	2ppb - 10	Y	5ppb - 50
Eu	0.2ppb - 50	Pr	1ppb - 200	Yb	0.5ppb - 50
Fe	5 - 5%	Pt	1ppb - 10	Zn	0.2 - 2000
Ga	0.01 - 200	Rb	0.01 - 500	Zr	0.05 - 50
Gd	0.5ppb - 50	Re	0.5ppb - 50		
Hf	2ppb - 50	S	5 - 1%		

Biogeochemistry Comprehensive package
Modified aqua regia digest / ICP-OES & ICP-MS BG/OM20

Biogeochemistry ICP OES and MS Individual Elements

All ICP-OES and ICP-MS elements are available individually. Please see tables above for elements and detection limits.

Biogeochemistry AAS Individual Elements

Element	Range ppm	Finish	Element	Range ppm	Finish	Element	Range ppm	Finish
Au	0.2ppb	GF AAS	Ni	0.2 - 2000	AAS	Zn	0.2 - 2000	AAS
Cu	0.1 - 5000	AAS	Hg	1ppb	AAS	Mn	0.2 - 2000	AAS

Modified aqua regia digest / AAS first element BG/AA
/Hg BG/AA11

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