SOME IMPORTANT PLANT CHARACTERISTICS AND ASSAY OVERVIEWS FOR BIOGEOCHEMICAL SURVEYS IN WESTERN NEW SOUTH WALES

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INTRODUCTION

Plants are a significant component of regolith and landscapes across most terrestrial settings. Their use as mineral exploration and environmental chemistry sampling media has previously gained mixed support in Australian regolith studies, however they have numerous advantages for use due to:

- Widespread cover across the landscape;
- Easy access to samples that in many cases are easy to take;
- An ability to construct chemical pathways that penetrate regolith (especially transported cover) to the underlying bedrock;
- An ability to selectively extract and concentrate some elements;
- An ability to amalgamate a chemical signature from an enlarged sampling area (potentially achieving greater site representation and reducing potential problems with heterogeneous sample media, leading to 'nugget effects')
- Minimal site disturbance and remediation costs associated with sampling; and,
- Some proven exploration success for a wide range of elements, regolith-landform settings and mineralisation styles.

In recent years a small and emerging biogeochemistry research program has been undertaken in Western NSW. This data are now being compiled, and some preliminary results and background information are presented here. The research approach has been to target trees and shrubs that are widespread across the region, or else are locally significant to areas hosting regolith geochemistry case and pilot studies (Hill, 2003). Honours and PhD student research projects have been one of the main ways of accommodating this research, when greater funding and support has not been particularly forth-coming at the larger project level.

Unless otherwise stated, sampling and sample preparation are according to Hill (2002). Names and botanical descriptions are after Cunningham *et al.* (1992) and Ross (1996). Analytical suites and techniques are described in Appendix 1 at the end of this manuscript.

SPECIES INFORMATION - TREES

Mulga (*Acacia aneura* var. *aneura*)

Mulga is abundant and widespread, particularly in the northern half of the region. It is most abundant in well drained sites with neutral-acidic regolith, particularly associated with bedrock exposures on erosional hills and rises and aeolian sand plains. It is estimated to be 100-200 years old at maturity (Slatyer 1961). Juvenile trees are rare in the district, with most trees at maturity or senescence. Evidence from over-turned dead trees suggests that the root system is mostly shallow and branching. Two main habit forms occur in the region: a bushy; and, an elongate form, however both have ascending to near horizontal branches. Flowering and phyllode generation is generally determined by proximity to variable rainfall events.

A total of 59 mulga trees have been sampled from the region. Nine of these have included samples of phyllodes, twigs and bark analysed by ICP-MS[1] and INAA for Au from near Tibooburra (Hill in prep.). Near Broken Hill phyllode samples were taken from 17 trees in areas of ultramafic bedrock and adjacent Willyama Supergroup rocks (Hill & Barratt 2003) and from 33 trees from the Flying Doctor prospect (Thomas *et al.* 2002, Hill *et al.* 2003), and analysed by XRF and ICP-MS[2]. Phyllodes are generally easy to sample and detach from twigs relatively easily, although some trees without low branches can be difficult to reach. In general, the chemistry of the phyllodes and twigs is not significantly different. Biogeochemistry results typically provide a strong bedrock signature when growing on erosional rises and hills. Near Broken Hill, in sites where transported cover is thicker (e.g., up to 2 m of aeolian sediments), the phyllode chemistry tended to represent bedrock chemistry when growing near ultramafic rocks, rather than the overlying sediments (Barratt & Hill 2003).

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Prickly Wattle (*Acacia victoriae*)
The prickly wattle is one of the most widespread small trees – large bushes in the region, where it mostly grows in areas closely associated with alluvial regolith, such as along small channels and drainage depressions and across alluvial plains and floodout fans. It has a large tap-root that penetrates the regolith for depths of at least 3 metres (observed in gully sections), and it is generally short-lived (10-15 years, Cunningham *et al.* 1992). Although samples are generally easy to access, the spiny branches can make sampling very uncomfortable. Sampling by closing fingers around stems and running fingers down the stem avoids most prickles, although can tear sampling gloves.

62 prickly wattle phyllode samples were taken from the Flying Doctor prospect near Broken Hill, and assayed by XRF and ICP-MS[2] (Thomas *et al.* 2002, Hill *et al.* 2003). The results from this program were extremely exciting, suggesting that the trace metal biogeochemistry was more closely related to bedrock buried by shallow transported regolith, rather than to surface soils.

Bastard Mulga (*Acacia clivicola*)
Bastard Mulga is limited to the far north-west of the region. It is abundant on aeolian sand plains, but is also associated with bedrock exposures on erosional hills and rises, particularly those with silicified regolith. Flowering and phyllode generation is typically in spring-early summer. No information has been able to be obtained on the longevity of this species, although it is likely to be equivalent to the mulga.

24 individuals have been sampled at Tibooburra, with leaves and twigs analysed by ICP-MS[1] and INAA for Au (Hill in prep.). Twigs and phyllodes are generally easy to detach from the branches, however, they can be sticky and covered in ants. Although similarly named, the concentrations of trace metals in bastard mulga are generally lower than the mulga. The exceptions are Ni and Zn, which accumulate in relatively high concentrations in this plant. As with mulga, their restricted distribution on thick transported regolith makes it difficult to assess their ability to provide a bedrock signature from beneath the cover.

Cabbage Tree Wattle (*Acacia cana*)
The cabbage tree wattle is widespread in the northern half of the region, in particularly in the White Cliffs-Milparinka area, where it mostly grows across sheetwash plains and alluvial plains, and in some cases across erosional rises of weathered bedrock. They grow to 4 m high and have distinctive silvery-grey phyllodes and a gnarled, stunted habit which makes them easy to identify in the field. Phyllodes and twigs are difficult to detach from the branches without clippers, however, they can be removed by pulling branchlets upwards, towards the tree trunk. The tip of the phyllodes are sharp and care is needed to ensure that gloves and bags are not torn during the sampling process. A strong, festering 'cabbage-like' smell is produced from the leaves when they are drying, and can become quite unpleasant.

52 samples of phyllodes have been collected from the Milparinka-Kayrunnera region, and analysed by INAA (Au+31). These samples were taken to test a reported associated between these trees and elevated Se contents giving stock the staggers (McBarron 1977). Only one sample contained detectable Se (and also detectable Au), and this came from the vicinity of the Williams Peak Au-field.

Western Rosewood (*Alectryon oleifolius***)**
Western Rosewood is widespread and abundant throughout the region, most typically occurring in association with belah. It is generally associated with sandy soils containing regolith carbonates, but is rare on mid-slope settings. Leaves are olive-grey with a prominent vein and the habit is characteristically gnarled. Root systems appear to be very deep, exceeding 5 m in gully sections. Flowering and leaf generation is mostly in late spring-summer, with a high rate of leaf shedding in summer. Cyanogenetic foliage production is suspected in some instances following summer rains (Cunningham *et al.* 1992).

15 samples of leaves have been taken at Thackaringa, near Broken Hill (Hill 1998). Leaves were analysed by AAS and Flame Photometer. Leaves are generally easy to sample, however, individuals may be heavily infested with mistletoe and care is needed to ensure that only host material is collected. Biogeochemical results typically provide a strong bedrock signature, however, concentrations are relatively low for most trace elements including Cu, Fe, Zn, Mn and Pb when compared to mulga.

White Cypress Pine (*Callitris columellaris*)
White Cyress Pine is abundant in southern and eastern parts of the region, although it becomes less abundant in the Broken Hill region and the far north-west, although this is possibly due to timber harvesting. It is

typically associated with aeolian sand plains and dune fields and colluvial hills and rises, with rare occurrences on slightly weathered bedrock rises (e.g., Pyrite Hill, Thackaringa Station). Branchlets are typically aromatic and have a scaly texture. Flowering and leaf generation is generally in spring-early summer. It is a long-lived tree, although longevity data was not able to be obtained. Sampling is relatively easy, with branchlets and shoots easily ripped off by hand, although they appear to hold a considerable amount of dust and variable amounts of pollen in some cases.

Approximately 70 branchlet - shoot tip samples have been obtained from the dunefields of the Teilta 1:100k mapsheet area, and assayed using INAA (Au+31), ICP-MS[3] and ICP-OES. Results are yet to have been fully investigated.

Belah (*Casuarina pauper*)
Belah is common throughout the region, occurring as relatively dense woodlands in association with other tree species such as western rosewood to the south and as isolated clumps or individuals to the north. It is found in association with a variety of regolith materials and landscape settings, however, appears to be strongly controlled by hydromorphic characteristics of substrates sometimes growing over saprolite or bedrock, or sometimes lacustrine sediments, typically with an associated hardpan regolith carbonate coating. Reported to live for up to 100 years (Irons & Quinlan 1988). The leaves are small pointed scales sheathing the joints between sections of branchlets. Flowering and foliage generation typically occurs in summer-autumn, but has been observed in other seasons after suitable rains. This species of belah is smaller, more gaunt and more widespread than *Casuarina cristata* which may also be referred to as belah. Branchlets are relatively easily sampled.

Branchlets from 20 trees have been collected from Thackaringa, near Broken Hill (Hill 1998) and analysed using AAS and Flame Photometer. Biogeochemical results provide a strong bedrock signature for individuals on serpentinites, in particular exhibiting a markedly higher concentration of Cu compared to individuals on an adjacent pegmatite.

River Red Gum (*Eucalyptus camaldulensis*)
River red gums are widespread in the region, mostly confined to the riparian fringes of large alluvial channels, particularly within and flanking upland areas. They are generally large (15-30 m high) gnarled trees with a spreading canopy. Flowering periods are variable due to the variable availability of water, however it generally takes place in spring. River red gums have an extensive and deep taproot system that may extend over 100 m horizontally and at least 20 m deep (Hulme & Hill 2003a & b). They are reported to live for at least 400 years (Ogden 1978). Leaf samples tear off branches relatively easily, however some specimens without low branches can be difficult to sample. Twigs and bark are more time consuming to sample however can be readily obtained, roots are variably exposed, and fruits are susceptible to seasonal variations in availability and maturity.

Dann (2001) conducted a pilot study of river red gum organ chemistry and sampling along Stephens Ck. He found that leaves and twigs tended to accumulate higher concentrations of most trace metals than fruit, roots, wood and bark, and recommended leaves as the better regional sampling media for most trace elements. Leaf samples from 37 trees along Stephens Creek were analysed by ICP-MS[1] and showed that Pb contents were greater nearer Pb mineralisation such as at the Parnell Mine, although most other trace metals gave variable results. Barratt & Hill (2003) showed extremely elevated Pb contents (over 300 ppm) from near the Pinnacles Mine for leaves from 51 trees in Pine Creek that were analysed by INAA (Au+31), ICP-MS[3] and ICP-OES. Ongoing research is further characterising the biogeochemistry of these trees in the region (Hulme & Hill 2003a & b).

Curly Mallee (*Eucalptus gillii*)
Curly Mallee has a very restricted distribution, with only a few isolated stands along the Barrier Range. It has been previously described from Corona and Fowlers Gap districts (Cunningham *et al.* 1992), but also recently found at the Thackaringa Serpentinite (Hill 1998, Hill 2000), and in the Mt Darling Ranges (Avondale, Rupee and K-Tank stations). Typically associated with calcareous and carbonate-rich regolith, in particular more Mg-rich substrates. It is a multi-stemmed, small to medium-sized tree (2-6 m high) with crooked stems giving a gnarled or 'curly' habit. Flowering and leaf generation is typically in late winter-early spring.

Leaves were collected from 10 trees by Hill (1998) at the Thackaringa serpentinite and analysed by AAS and Flame Photometer. Leaves are easily collected from trees, although many exhibit microbial infestation and care is required to avoid these. Biogeochemical results suggest that curly mallee has developed chemical tolerances which limit its ability to provide a strong bedrock signature, although more work is needed on this species.

SPECIES INFORMATION - SHRUBS

Bladder Salt-bush (*Atriplex vesicaria*)
This perennial is widespread throughout the region. Although found in association with most regolith types and landscape settings, bladder saltbush is most typically associated with clay-rich alluvial and sheetwash plains, particularly with distinctive 'contour-band' micro-topography. It is reported to live for 20 to 30 years (Cunningham *et al*. 1992). The root system is shallow, mostly penetrating to 30 cm depth (Eldridge 1988), although it may extend up to about 1 m. Flowering and leaf generation generally occurs in spring and summer, but it may also flower at other times following adequate rainfall. Its recently observed susceptibility to drought mortality, plus the high and variable salt content of leaves, have favoured twig sampling for biogeochemical surveys (Brown in prep.).

Leaf and twig samples from 28 individuals from near Tibooburra have been sampled and analysed by ICP-MS[1] and INAA for Au (Hill in prep.). The results showed higher Na, Cl and Zn contents in bladder salt-bush leaves and twigs than other chenopods in the area, however most other elements are in significantly lower abundance than in blue-bushes. A comparison of the biogeochemical characteristics of leaves and twigs suggest that most trace elements are accumulated in the leaves, except for Pb which was below detection limit in the leaves. Leaves from 26 bladder salt-bush individuals on Thackaringa station were sampled and assayed by ICP-MS[1] (Debenham 2000). The assay results in this low-order stream catchment study suggest that bladder salt-bush leaf chemistry is influenced by landscape setting, and regolith substrate chemistry. Notable here was that all leaf samples had Pb contents below detection limit, even though adjacent black blue-bush and soil samples had detectable Pb contents and that Zn contents in bladder salt-bush were greater than in black blue-bush. A nearby study at the White Dam prospect (Brown in prep.) has sampled about 100 bladder salt-bush dead twig samples, for assays by INAA (Au+31), ICP-MS and ICP-OES which are soon to be completed.

Black Blue-bush (*Maireana pyramidata*)
Black bluebush is a widespread perennial throughout the region, where it is generally associated with friable substrates, typically with regolith carbonate accumulations. A tap-root system may penetrate to >3 m observed from creek sections and costeans in the region. Flowering and leaf generation is generally in spring. It is reported to be a long-lived shrub (Cunningham *et al.* 1992). It is relatively easy to sample, with the aid of clippers, although when heavily grazed care is needed to ensure that twigs do not tear sampling bags and gloves. These shrubs also appear to trap large amounts of dust.

23 individuals have been sampled, with the leaves and twigs analysed by ICP-MS[1] and Neutron Activation for Au (Hill in prep.). The assay results show an ability of the shrub to accumulate high concentrations of trace metals (particularly in leaf tissues) compared to other chenopods growing in the sampling areas. Leaves collected from 20 individuals near the Thackaringa serpentinite (Hill 1998) were analysed using AAS and Flame Photometer. In general, these results suggest that there is an ability for these shrubs to process or exclude many trace elements when on ultramafic bedrock, however, Cu was significantly higher in the leaves of individuals on serpentinite compared to adjacent substrates. Senior (2000) and Senior & Hill (2002) found that Cu, Pb and Zn contents from a data set of 34 samples of black blue-bush leaves from near North Tank were able to detect a partially buried mineralised quartz-gahnite lode. Debenham (2000) compared the assays of leaf samples from 15 black blue-bush shrubs with leaf samples from adjacent bladder salt-bush shrubs and found that the black blue-bush samples generally had greater Cu, Fe, Mn and Pb contents and lower Bi and Zn contents. Leaves from 71 shrubs at the Flying Doctor prospect were analysed by ICP-MS[2] and XRF and showed a notable increase in Pb over mineralisation (Thomas *et al*. 2002, Hill *et al*. 2003).

Pearl Blue-bush (*Maireana sedifolia*)
Pearl bluebush is a common perennial throughout the region. It is associated with friable regolith substrates that allow great root penetration, such as fractured bedrock or most typically sites with regolith carbonate accumulations within 60 cm depth (Cunningham *et al*. 1992). Reported to live at least 150-300 years (Irons & Quinlan 1988). They have a relatively deep tap-root system (up to 3 m) with shallow deciduous feeding roots (Cunningham *et al*. 1992). Flowering and leaf generation is generally in summer. Leaf sampling is relatively simple, especially with the aid of clippers, where mixed leaf and twig samples can be further

separated after they fall apart during drying. Care needs to be taken not to confuse this species with *M.astrotricha*, which has stalked leaves (*M. sedifolia* leaves are stalkless).

Leaves and twigs from 32 individuals were analysed by ICP-MS[1] and Neutron Activation for Au (Hill in prep.). Assays showed similar biochemical patterns to black blue-bush, however, trace element concentrations were generally lower except for Cl and Zn. A few specimens were sampled from near the Great Goulburn mineralisation Jones (1999), however the sample number was not great enough to make any significant conclusions.

Rock Sida (*Sida petrophila*)
Rock sida, is typically abundant in the region where bedrock is close to the surface (subcropping), where it typically grows across erosional rises and along drainage depressions, particularly on south- and east-facing slopes. It is an erect and twiggy, perennial forb, mostly up to about 1 m high. Following rains it has greyish-green felty leaves and its yellow flowers may form at most times of the year. Twigs are relatively easily sampled, either by breaking by hand or else with clippers. The availability of abundant foliage limits the application of leaf sampling.

38 living twig samples were collected from the Flying Doctor prospect area (Thomas *et al*. 2002, Hill *et al*. 2003), and assayed by XRF and ICP-MS[2]. The results did not show a strong reflection of mineralisation mainly because samples were scarce in mineralised sites.

Velvet Potato Bush (*Solanum ellipticum*)
Velvet Potato-bush is widespread throughout the region in a wide range of regolith and landscape settings, particularly within drainage depressions, channels and alluvial outwash areas, and at the base of trees within aeolian sand plains. This perennial forb has blue or purple flowers followed by globular berries up to 20 mm, at most times of the year. Leaves are easy to access, however, their fine surface hairs makes them very susceptible to detrital contamination. Avoiding the slender prickles on branches and along the stems of many leaves can also be challenging.

The leaves from 14 specimens were sampled near Tibooburra and analysed using ICP-MS[1] and Neutron Activation for Au (Hill in prep.), and from 20 specimens near the Thackaringa serpentinite (Hill 1998) and assayed using AAS. The later results showed significantly higher Zn, Pb and Ni concentrations in the leaves for individuals growing over serpentinite compared to those over adjacent rock types.

CONCLUSIONS

Preliminary results are very promising however, particularly for the ability of many of these plants to ‘penetrate’ transported cover. Some of the data sets are now becoming significant enough for preliminary results to be presented and compiled. So far there has been a lot of scepticism and unfounded negativity towards developing these approaches, specifically in this region. It must be remembered that it is difficult to present supportive results for a new technique before the research has ever been conducted in a region! Hopefully this abstracts shows the development of some of the potential of this research.

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APPENDIX 1: Laboratories and analytical suites

ICP-MS[1]: Ecochemistry Laboratory, University of Canberra: Al, As, B, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cu, Fe, Ga, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Rb, S, Sc, Se, Si, Sr, Ti, V, Y, Yb and Zn.
ICP-MS[2]: Geoscience Australia Laboratories, Canberra: Ag, As, Be, Bi, Cd, Ce, Cs, Dy, Er, Eu, Ga, Gd, Ge, Hf, Ho, La, Lu, Mo, Nb, Nd, Pr, Sb, Sm, Sn, Ta, Tb, Th, U, Y, and Yb.
ICP-MS[3]: Becquerel Laboratories, Lucas Heights: Be, Bi, Cd, Ga, In, Nb, Nd, Pb, Sn, and Sr.
ICP-OES: Becquerel Laboratories, Lucas Heights: Al, Cu, Mg, Mn, Ni, P, S, Ti, and V.
XRF: Geoscience Australia Laboratories, Canberra: Al, Ba, Ca, Cl, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Rb, S, Si, Sr, Zn, and Zr.
INAA Au: Becquerel Laboratories, Lucas Heights: Au.
INAA Au + 31: Becquerel Laboratories, Lucas Heights: Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Ir, K, La, Lu, Mo, Na, Rb, Sb, Sc, Se, Sm, Ta, Te, Th, W, U, Yb, Zn, and Zr.
AAS: Melbourne University Geography Department, Atomic Absorption Spectrometry: Ca, Cu, Fe, Mg, Mn, Ni, Pb and Zn; and, Flame Photometer: K and Na.