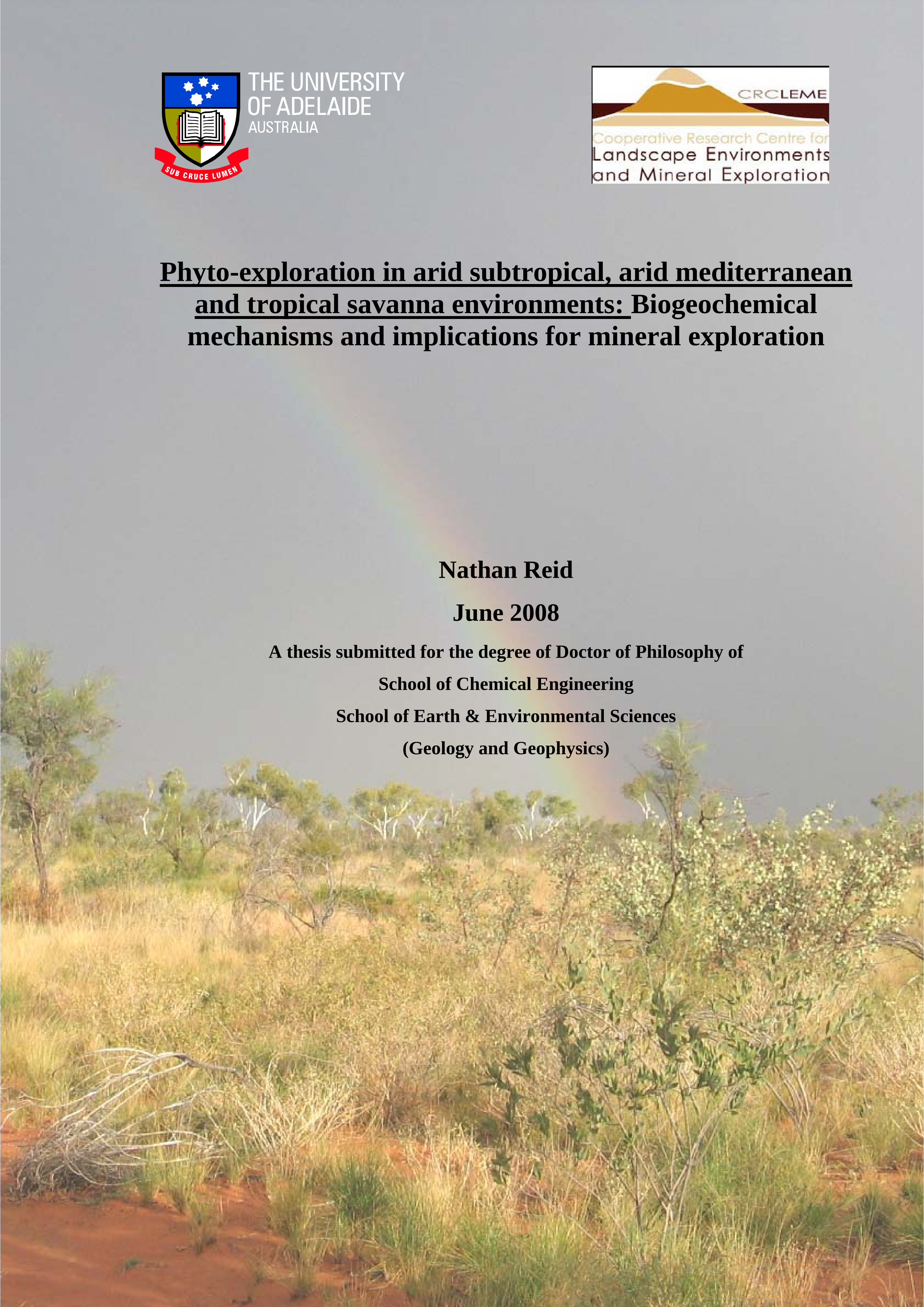

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# Phyto-exploration in arid subtropical, arid mediterranean and tropical savanna environments: Biogeochemical mechanisms and implications for mineral exploration

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# 6 Tanami Region – Regional Summary and Discussion

## 6.1 Interpretation of spatial patterns

In each of the field sites a major challenge is the distinction between surface expression of buried mineralisation and lateral transport and deposition. A combination of recognising the surficial regolith-landform assemblage and utilising the multi-element chemical assays seem to be the best ways to discern this. For instance, depositional landforms such as drainage channels will have a greater tendency towards hosting transported responses, whereas erosional rises will have more locally derived responses. 'Gold-only' responses appear to be variable and are subjected to strong 'nugget' effects. Supportive high responses in other mineralisation-related elements, in particular As, REE, Zn and S, appear to be valuable for interpreting less transported material and anomalies.

### 6.1.1 Coyote

At the Coyote Prospect, spinifex, snappy gum, desert bloodwood and silver box were all able to express the buried mineralisation or associated dispersion haloes with either all or some of Au, As, S, Zn and REE. Soft spinifex was the most widely distributed species and gave the best 'direct' footprint of the mineralisation zone. This zone varied in length based upon the mobility of each element examined. The original geochemical data at the site showed that there was only a surface As anomaly and the geochemistry of the regolith profile showed barren saprolite to 80 m depth.

Since *Triodia pungens* is a deep-rooted species it is able to give localised chemical signatures for the *in-situ* regolith materials that may underlies 5-15 m of surface sediment (Burbidge 1953; Reid *et al.* 2008; Grigg *et al.* 2008b). In the Tanami region, and possibly many other parts of arid Australia, the spinifex is an excellent biogeochemical exploration sampling medium, especially compared to soils, which are typically influenced by complexities of sheetflow and aeolian dispersion and dilution. The vegetation results have very sharp cut-offs to the generated anomalies in this system. There are high values next to values that are below the detection limit of the analysis technique. This makes it less useful in a regional sampling program, but spinifex would be an ideal sampling medium for closely spaced, detailed ore body delineation in the Tanami region and most likely in other hummock grass-dominated parts of the continent and grasslands world-wide.

*Eucalyptus brevifolia* had a distinct geobotanical anomaly related to the Coyote Fault. This means that botanical mapping of the distribution of this species could be used as a surrogate for interpretive structural geology maps. However, the elemental distributions showed a widely dispersed halo within Zn and S that decreased gradually to the south of the transect.

The implications of this are that finding an anomaly within the biogeochemistry of this species could reflect proximity to a mineralised body. Hence it would be possible to conduct regional style sampling of this species and then move into detailed sampling based upon the anomalies generated. This is possible because of the snappy gum's broad lateral root system (similar to *Corymbia chippendalei* Grigg *et al.* 2008a) that gives a broad chemical signature that may be related to the hydrogeochemical signatures in the area.

*Corymbia opaca* results are less distinctive due to the lack of plants growing over the prospect. The results seem to be of comparable values to the snappy gum results where the two species overlap in distribution. Therefore it could be possible to use this species as a surrogate sampling medium if snappy gums are not available such as over the Coyote Fault Zone. Even though the snappy gum and desert bloodwood are different species, their root structures seem to be similar.

*Eucalyptus pruinosa* also has a restricted distribution across the prospect, but that may have a potential geobotanical application. Since the species is growing directly over areas of vein quartz, it would be possible to use remote sensing data to identify areas of the species (silvery-grey leaves would be easily detected in hyperspectral imagery), once these areas are detected it would be possible to rank these areas as higher priority for drilling or more detailed biogeochemical sampling with spinifex.

Overall, silver box could be used to detect potential sites from remotely sensed data, snappy gum (supplemented with desert bloodwood) could be used for regional to tenement scale sampling programs and spinifex could be used for detailed ore body delineation at tenement/prospect scale.

### 6.1.2 Larranganni

Snappy gum leaf samples were able to express the areas of mineralisation along the transect and other prospects within a multi-elemental suite. The dispersion of these elements is not as extensive as at the Coyote Prospect, due to the thinner transported caver and therefore greater and more direct interaction between plant roots and bedrock at Larranganni. The highest Au assay (2.5 ppb) is generated by a plant growing directly out of the quartz vein hosting the Kookaburra mineralisation, which is a saddle reef of quartz with pyrite and arsenopyrite (Bagas *et al.* 2007). This suggests that greater cover is required to generate a more dispersed halo over mineralisation. The implications of this are that plants can be used to find primary mineralisation when they are growing on it, but if there is a significant amount of cover material then dispersion haloes and pathfinder elements (Au, As, REE, Zn, S) are of greater importance.

The elevated Al over the mineralisation is possibly likely related to some of the clearing around the sites generating dust that would contaminate the leaves. This contamination is deemed insignificant due to a lack of correlation with the pathfinder elements (Au, As, Cu, Pb, and REE). Another possibility is that high Al could be related to the oxidation of primary sulphides (Bagas *et al.* 2007) that releases acid, lowering the pH, and increasing the mobility of Al in the system.

The elevated Pb at the Cuckoo mineralisation is unique suggesting that there is a higher percentage of Pb in the substrate than any of the other sites, which were below detection; this includes the one plant at the Kookaburra site where the snappy gum was growing in a quartz vein. Hence it is possible that the mineralisation hosted at the Cuckoo mineralisation is of a different origin than the other sites, and may include galena. The elevated Ni over the Pelican mineralisation is likely due to the presence of dolerite in that area (Bagas *et al.* 2007).

### 6.1.3 Hyperion

One of the greatest problems with this field site has been the lack of background information. It is known that there is Au mineralisation along the transect, it is approximately in the centre, there is a change in magnetic intensity around this area as well as a colour change in the SPOT imagery, and the bedrock is mostly dolerite. From that, the *Eucalyptus* species and dogwood detect the mineralisation through a multi-element dispersion halo towards the east of the transect. The soft spinifex provided irregular results, within a multi-element suite, which may not have direct bearing upon mineralisation, or could be linked to the form and structure of the ore deposit. The results from turpentine show a trend in elemental concentration opposite to the other plant species which is most likely due to the influence of wind bourne dust sticking to the phyllodes of the plant.

The implications of this are that either of the *Eucalyptus* species would be good phyto-exploration sampling media within this terrain, providing expression of dispersion haloes to mineralisation. More information is needed about the style of the ore deposit to determine if the soft spinifex results have any direct link to mineralisation. Finally, turpentine would be unsuitable to use as a sampling medium because of the adherence of dust particles to the phyllodes.

A full suite of REE can be analysed on vegetation to provide some background information about the underlying sediments, groundwaters or bedrock. This study was limited in that it is difficult to determine what substrate the REE are derived from. However, since the REE are generally of a similar size and charge, it seems that the plants will uptake them in amounts proportional to the underlying substrate with no mechanisms affecting one element different from the others. This suggests a passive mechanism of uptake for all the REE as there seems to be no fractionation taking place.

### 6.1.4 Titania

#### Biogeochemical Pathways for different plant species

The mineralisation at the Titania prospect is most consistently biogeochemically expressed by four of the eight plant species within several elements (Au, As, Zn, S, Cu, Pb and REE). The difference in spatial scale and magnitude of expression for these elements is largely due to: the different chemical mobilities of the individual element; primary dispersion from mineralisation; and secondary dispersion of elements and as a result of the regolith-landform context. The original geochemical data at the site showed that there was a surface Au, As , Sb and Zn anomaly and the geochemistry of the regolith profile showed barren saprolite to depth.

*Triodia pungens, Melaleuca glomerata* and *Melaleuca lasiandra* express the mineralisation as a zone of Au and As directly over the mineralisation, but the Zn and S halos are dispersed towards the south-east in the direction of groundwater flow towards major palaeodrainage systems. This indicates that these species are being influenced both by the elements relating to the primary mineralisation and dispersion towards the palaeodrainage system, most likely as groundwater dispersion.

*Acacia bivenosa* represents the mineralisation within the Au and As results in a similar manner to the other two species, however, it shows a different dispersion pattern within the

Zn and S results. These elements disperse evenly in all directions away from the mineralisation zone, indicating that these results are not influenced by the dispersion towards the palaeodrainage system. This dispersion pattern is more closely linked to the surface flow patterns and the generation of gypsum at the surface of the soil. If the elevated Au and As assays of this species are linked to a surface dispersion pattern then this anomaly must be from either drill spoil or a naturally occurring surficial expression possibly related to biogeochemical element cycling from depth and to the surface. This surficial signature is supported by this species having many surface lateral roots. If *Acacia bivenosa* is detecting a near surface chemical expression, then the different characteristics of the assays for *Triodia pungens, Melaleuca glomerata* and *Melaleuca lasiandra* reflect their detection of a chemical signature from depth.

*Acacia coriacea* and *Hakea macrocarpa* are intermediate between the two extremes of surficial vs. depth signatures. Neither delineates the mineralisation very well. Unfortunately *Eucalyptus pachyphylla, Corymbia opaca* and *Grevillea striata* were all too sparse over the prospect to give highly significant information, but they each warrant further investigation if there was a site where they were more abundant.

### Multi-element Biogeochemical Dispersion Haloes

The mineralisation at Titania is represented by varying sized multi-element haloes within all plant species examined. The elements most closely related to the mineralisation are Au, As, REE, Zn and S, with related haloes within Cu and Pb results. These haloes vary in magnitude from only a few hundred metres to over 1.5 km, all of which exceed the sample spacings used in this study. The different spatial extension of elemental expressions represents the different dispersion potentials of each element in this system, how each element is dispersed from the primary mineralisation, moves up through the profile and interacts with the hydrological and biological systems.

### Implications for Mineral Exploration Strategies

All plant species examined were able to provide a variably focussed expression of the mineralisation using the multi-element haloes discussed above. However, *Acacia bivenosa* is shallow rooted and displayed an obvious surface dispersion pattern that may be correlated with the drill spoil seen in the area. Hence this species would not be an ideal sampling medium for penetrative mineral exploration in this area.

*Triodia pungens, Melaleuca glomerata* and *Melaleuca lasiandra* were able to detect primary mineralisation through 15-30 m of transported cover materials with a sample spacing of 250 m. While they have proven to be most effective at detecting the known mineralisation extents in this area, *Melaleuca lasiandra* and *M. glomerata* have a more restricted distribution due to their growth preferences. Therefore the implication is to use spinifex as a biogeochemical sampling medium in areas of thick transported cover and this can be used at spacings of 50 to 250 m without loss of detection.

## 6.2 Biogeochemical exploration model and recommended applications

By sampling a variety of media at a variety of sites several exploration recommendations can be made from this study. Firstly all of the media show some potential for strongly expressing shallow buried as well as more subtly expressing more deeply buried (up to 10s of metres) mineralisation. The application of any of these media will largely depend on the following criteria:

- Ease of collection and sample preparation;
- Widespread and abundant distribution; and,

- Strong chemical distinction between mineralisation and background in a range of elements.

All media could be considered relatively easy and convenient to sample and prepare (except for spinifex). Distributions of media varied considerably, particular between species assemblages on areas of thin cover compared to those in thick cover on the margins of palaeo-drainage systems. The grass *Triodia pungens* was the most abundant and widespread media, followed by *Eucalyptus brevifolia*, and *Acacia coriacea*. *Melaleuca lasiandra* and *Acacia bivenosa* were more locally abundant at the Titania Prospect. All of the species tested appear to provide a suitable distinction between mineralised and 'background' sites, however, the magnitude and spatial distribution of elevated values varied greatly between species. In particular a combination of *Triodia pungens,* and either *Melaleuca lasiandra* or *Eucalyptus brevifolia* would be very useful in identifying areas of potential mineralisation before pattern drilling could be applied. These plants appear to provide expressions of mineralisation consistent with previous soil and drill results and can be more efficiently sampled at less cost and environmental impact that pattern drilling. Drilling costs can be anything up to $AUD200/m with diamond drilling, whereas any geochemical analysis (vegetation, soils, calcrete or stream sediments) are roughly $AUD25 per sample. However, the time required to sample vegetation is much less than most of the other methods which means less time is required in the field, reducing the costs. Soil sampling takes a similar amount of time as vegetation, however the signal generated from soils will not penetrate into the substrate as deeply as plants.

## 6.3 Conclusions

The sampling at each of the study sites show that the region is suitable for hosting biogeochemical sampling media that could be suitable for regional exploration programs across the transported regolith of the Tanami Desert. All media were successful at expressing known mineralisation, to a greater or lesser extent dependent upon the plants root structure and uptake mechanisms. Constraint of the regolith-landform setting, the use of multi-element assay suites and consistent and robust sample collection and preparation techniques are critical ingredients for further application of these techniques.

Since each of the 4 field sites have different subsurface properties (Figure 6.1), the biogeochemical responses will be different for each scenario. At the Larranganni Prospects there are minimal transported cover materials and a deep water table within fractured rock aquifers. Chemical dispersion is very low in this situation, which leads to closely spaced sampling being required to accurately delineate mineralisation.

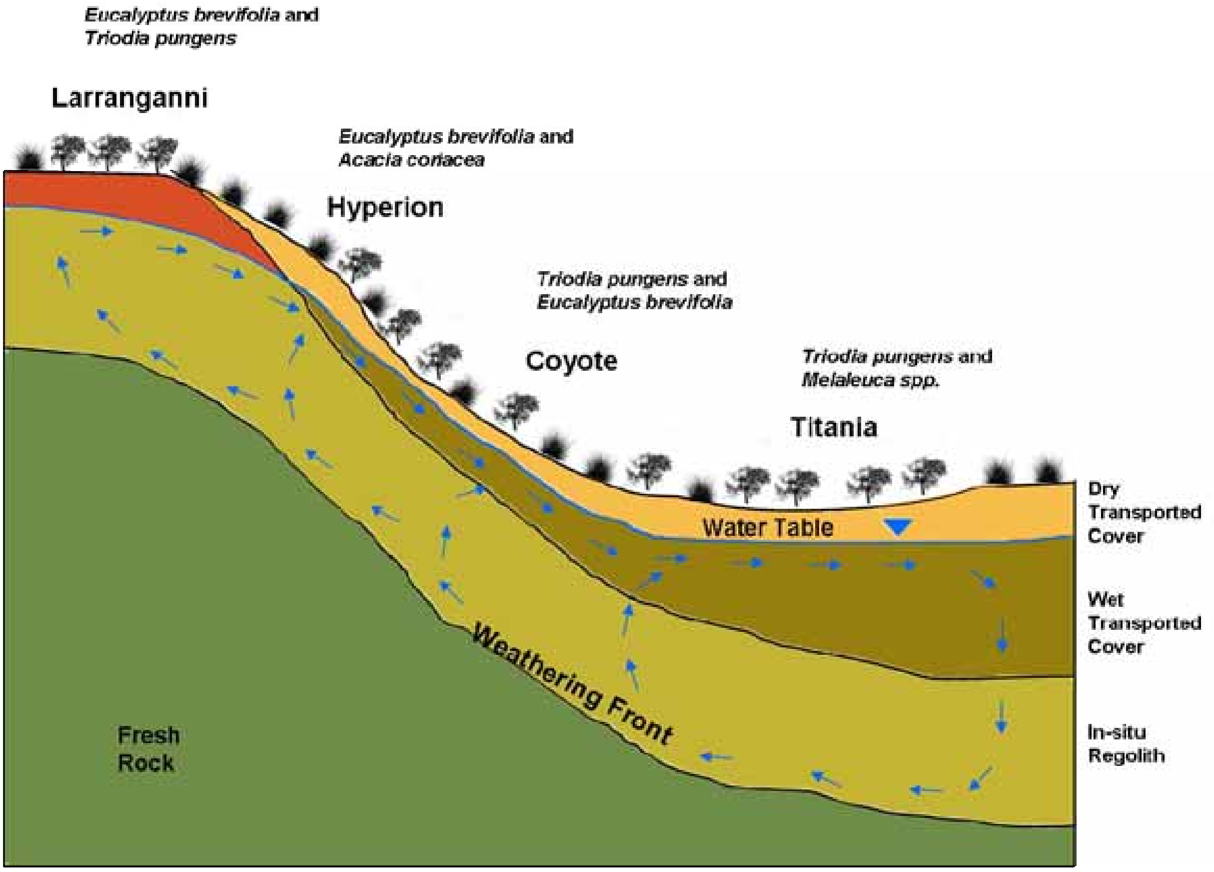

**Figure 6.1: Stylised cross section of the Tanami showing materials beneath each field site and recommended sampling species.**

At the Hyperion Prospect there is thin (7-8 m) of transported cover materials but would still have a relatively deep water table since the prospect is locally elevated. Chemical dispersion in this situation is low but greater than that seen at the Larranganni Prospects. Therefore, species that are able to amalgamate a large signal and penetrate the thin cover would be best for biogeochemical sampling.

The Coyote Prospect has thicker transported cover materials (ranging from 5-15 m) and the water table is much higher than at the previous 2 sites because it is near a palaeo-drainage system. Chemical dispersion in this environment is moderate with signatures from mineralisation able to disperse several kilometres from the source. This implies that broadly spaced sampling of a plant species which amalgamates a chemical signature from a large root system (snappy gum) would highlight areas which could be followed up with close spaced spinifex sampling. The soft spinifex provides a point source signature which would allow delineation of the mineralisation for follow-up drilling.

The Titania Prospect, which is on the margins of a large, palaeo-drainage system has thicker transported cover materials than the other sites (15-30 m). The water table is also relatively shallow (4 m before flooding and 2 m after), which implies that chemical dispersion in this environment will be great. Even point source, penetrating species like spinifex will show a dispersed mineralisation signature. Therefore, any species which can accurately show the dispersion as well as primary mineralisation (*Triodia pungens* and *Melaleuca spp.*) would be ideal for either: broad sampling to highlight target areas for follow-up work; or closely spaced, ore-delineation sampling.

# 7 Other Field Sites

## 7.1 Pine Creek Orogen – Background

### 7.1.1 Introduction

The Pine Creek Orogen hosts significant gold mineralisation, most of which is found within or adjacent to areas of exposed bedrock (T. Ireland, pers. comm., 2007). There are large areas that have been under-explored in this region due to the significant cover materials generated in subtropical and tropical environments. The areas with transported cover have been the focus of this study, in particular the shallow 'black-soil plains' which have been a major impediment for previous mineral exploration programs due to their heterogeneous, geochemical fingerprint. The aims were to determine if properties of plants found from the studies in the Tanami region could be applied to this area to aid phyto-exploration over the 'black-soil plains'. Due to time constraints this was employed as sampling multiple species over single transects over 4 green field sites which may host extensions of known ore bodies (Johns hill, Great Northern, Glencoe and Mckinlay).

### 7.1.2 Previous work

The closest areas that have had biogeochemical studies carried out were looking at U mineralisation in the far north of Northern Territory (Debnam 1955; Cruickshank & Pyke 1986). None of these studies looked at the Pine Creek Orogen in particular but the species studied were seen within the field sites. The Debnam (1955) study sampled a large range of species and different plant organs from known U mineralisation sites. Samples were ashed and assay by fluorescence techniques for U only. The highlight of that study was the discovery that *Xanthostemon paradoxus* was a U accumulator. It was also found that leaves were the most useful biogeochemical sampling organ, however in final conclusion decided that soil sampling was more useful in mineral exploration programs (Debnam 1955). In the Ranger study by (Cruickshank & Pyke 1986), *Eucalyptus miniata* and *Melaleuca viridiflora* were included in the sample suite of species and are common to both the Ranger area and the study sites in this study. Of these two species only *E. miniata* was considered to provide a suitable distinction between 'background' and mineralisation based on U content of plant tissue.

Previous work on regolith studies in the Northern Territory have culminated in the *Atlas of regolith materials of the Northern Territory* (Robertson *et al.* 2006) which provides a territory-wide regolith / landform map that includes detailed regolith lithology descriptions from the 'Pine Creek Terrain'. This map and associated report are limited in application to this study due to the differences in scale of the two studies. The regolith map shows all of the study sites as "*Saprolith: weathered bedrock (saprock/saprolith) on erosional plains, rises, low hills, hills, mountains and plateau surfaces*", yet the major exploration challenges in these areas mostly relate to the extensive transported cover of the 'black-soil plains'.

Although the Pine Creek Orogen has not been the subject of a detailed regional regolith and landscape evolution study, numerous previous studies provide some background information. Most of these studies are small components of larger geological or geomorphological studies of the region or neighbouring areas. The most relevant previously completed landscape studies of the study area are associated with the CSIRO Land Research Series report on the

Adelaide-Alligator region (CSIRO 1969) and associated papers derived from that (Williams 1973; Williams 1978). The initial report provides regional accounts of the landuse, climate, geology, geomorphology, soils, vegetation (especially pasture grasses). A soils and geomorphology map broadly shows the distribution of "flood-plains of dominantly silty alluvium" and the "low hills and alluvial plains on slightly weathered metasediments" for the study sites. The 'black-soil plains' of the region are included in the 'McKinlay' land system, with the flanking bedrock rises within the 'Rumwaggon' land system. Descriptions of these land systems are:

- ***McKinlay (M):*** *channels and flood-plains; uniform sands and silts, gradational acid loamy and sandy soils, gradational alkaline loamy soils, and alkaline texture-contrast soils; paperbark forest or savannah, very variable*; and,
- ***Rumwaggon (Rw)****: hills or raised gravel patches and intervening alluvial flats; skeletal soils and gradational yellow loamy soils on hillslopes, texture-contrast alkaline soils on flats; woodland (semi-deciduous eucalypt) or stunted woodland (mixed) on hill slopes, savannah on flats.*

### 7.1.3 Regional setting

#### Location and geology

The 4 study sites were in the Adelaide River – Pine Creek region of the Northern Territory, 150 km southeast of Darwin. Bedrock around the study sites mostly consisted of Early Proterozoic, Burrell Creek Formation of the Finniss River Group. This was typically interbedded shale, slate, phyllite, siltstone, greywacke, volcani-lithic conglomerate and rare altered felsic to intermediate volcanics (Stuart-Smith *et al.* 1993).

There are over 250 known gold occurrences in the Pine Creek Orogen (Ahmad *et al.* 1999). There seems to be confusion about when Au was discovered in this region; either 1864 (Nicholson & Eupene 1990); 1865 (Ahmad *et al.* 1999), or 1872 (Stuart-Smith *et al.* 1993). This fuelled the mineral exploration in this region and was soon followed by discoveries of copper, tin, silver and lead. There are 4 main styles of mineralisation in the region (Stuart-Smith *et al.* 1993):

1. Hydrothermal veins or stockworks associated with granitoid intrusions (Sn, W, Au, Ag, Pb, Zn, Cd, Cu, Bi, As, U, and Mo);
2. Stratabound massive sulphide deposits within the South Alligator Group (Au, Ag, Cu, Pb, and Zn);
3. Residual massive oxide deposits (Fe and Mn); and,
4. Alluvial deposits (Au and Sn).

Most mineral deposits in the region are vein-type, with only minor placer Au and Sn. All of the study sites examined here are most prospective for Au-rich (± Ag, Cu, Pb, Zn) hydrothermal veins, associated with quartz reefs. The Au occurs as disseminated sulphides, including pyrite and arsenopyrite with minor chalcopyrite, galena, pyrrhotite, marcasite, sphalerite, tetrahedrite and native bismuth (Stuart-Smith *et al.* 1993). Most lodes were originally worked within the oxidised zone, typically within the first 30 m, with more recent open cuts extending deeper to the primary sulphide ore. The main structural settings for Au-mineralisation include: saddle reefs, quartz-filled fault, en echelon lodes in shear zones, parallel veins in shear zones, dilation structures in faults, and stockworks controlled by bedding and joint planes (Stuart-Smith *et al.* 1993).

### Landscape and landuse

The region is monsoonal with an annual rainfall of approximately 1500 mm, mostly falling between November and April. The study sites consist of:

- Erosional rises and low hills consisting of weathered bedrock and flanking colluvial cover grading down to plains; and,
- Alluvial plains, including flood plains, incised channels, levees and swamps, dominated by ‘black soil’ consisting of grey-brown fine sands, silts and clays. These plains are associated with the Margaret River and McKinlay River drainage systems and extend northwards towards the coast.

The area is sparsely populated with Pine Creek and Adelaide River being the main towns. Most of the land is used for cattle grazing, with some limited agriculture (mostly tropical fruits such as mangoes). Access to the site is from mostly unsealed roads that extend from the Stuart Highway.

## 7.1.4 Vegetation

The dominant vegetation of the region was an open *Eucalyptus* / *Corymbia* woodland with a grassy understorey. Erosional rises and low hills were typically dominated by the greatest diversity of tree species, with *Eucalyptus miniata* being dominant in most areas. The flanking alluvial plains were mostly colonised by *Eucalyptus – Corymbia spp.* across floodplains and outwash from erosional rises and *Melaleuca viridiflora* woodland dominated the poorly drained sites, such as alluvial swamps and riparian margins.

### ***Brachychiton paradoxum*** **(red-flowered kurrajong)**

The red-flowered kurrajong is a straggly, small, deciduous tree, with large hairy, broad, circular 3-5 lobed, 11-30 x 13.5-25 cm leaves (Figure 7.1). It is an abundant understorey plant in open forest and woodland, particularly on well-drained rises with bedrock exposure (Brock 2001). Its limitation to areas of bedrock exposure, reduce its potential as a regional sampling media across the black soil plains. This plant was sampled over known mineralisation at Johns Hill, Great Northern, Great Western, and McKinlay.

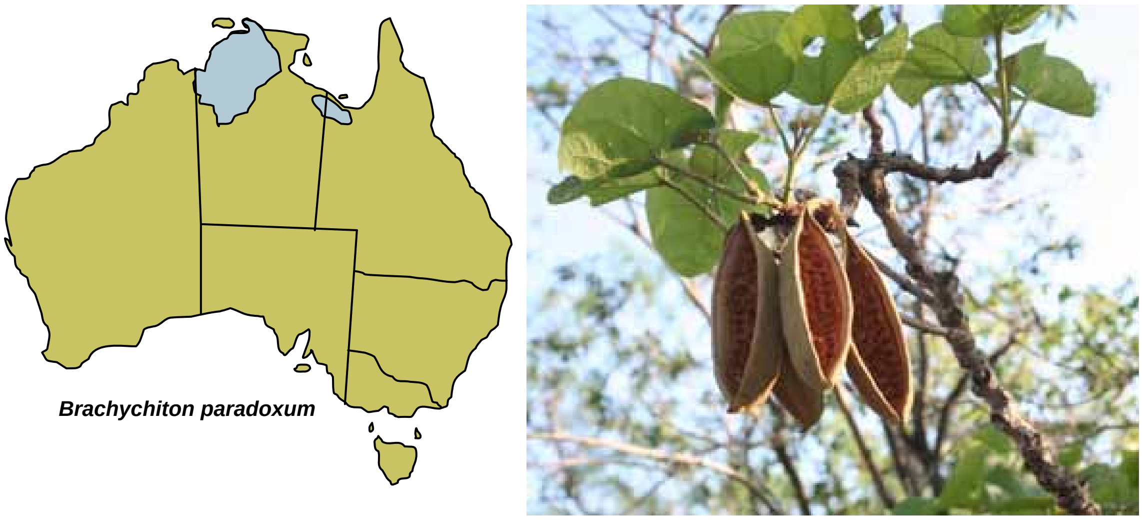

**Figure 7.1 Leaves, fruit and distribution of *Brachychiton paradoxum* adapted from Brock 2001**

### *Calytrix achaeta* (turkey bush)

*Calytrix achaeta* is a slender straggly shrub with pendulous branches (Figure 7.2). Leaves are tiny, hairy and crowded along slender branchlets. It grows in shrubland and woodland in rises with bedrock exposure across northern Australia (Brock 2001). Its limitation to areas of bedrock exposure, reduce its potential as a regional sampling medium across the black soil plains. This shrub was sampled at Glencoe and over known mineralisation at Great Northern, Glencoe and Johns Hill.

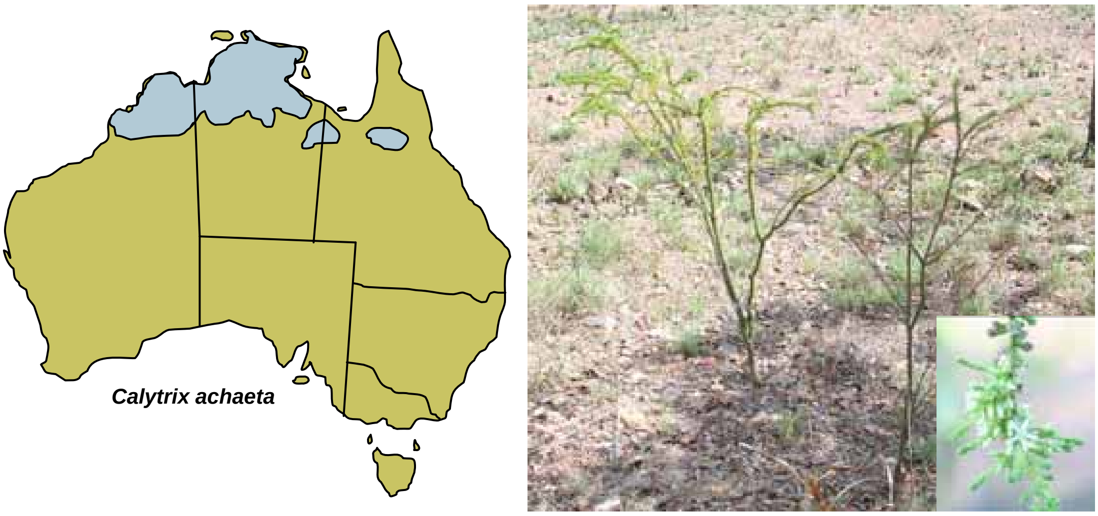

**Figure 7.2: Form, flowers and distribution of *Calytrix achaeta* adapted from Brock 2001**

### *Cochlospermum fraseri* (kapok bush)

The kapok bush is a slender shrub to small tree, with deciduous leaves that are hairy with 3-7 broad variable lobes (Figure 7.3). Fruiting plants produce woody brown capsules that split to reveal masses of cotton fibre (kapok). This is a common understorey plant in open forest and woodland, mostly on well-drained soils through the Kimberley, northern Tanami and central northern Arnhem Land (Brock 2001). Its regionally widespread distribution makes this plant an interesting sampling medium, but its limitation to areas of bedrock exposure or shallow cover limit its application to exploring under black soil plains. This was sampled at sites of known mineralisation at Johns Hill, Great Northern, Great Western and McKinlay.

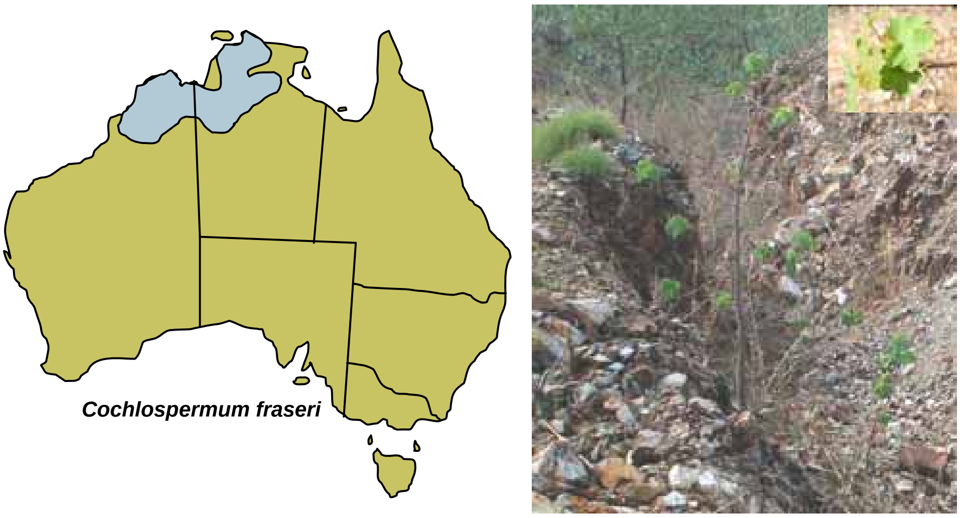

**Figure 7.3: Form, leaves and distribution of *Cochlospermum fraseri* adapted from Brock 2001**

### *Corymbia polycarpa* (long-fruited bloodwood)

*Corymbia polycarpa* is a medium-sized tree with rough tessellated bark over trunk and branches (Figure 7.4). Elongated, ovoid, up to 3.2 x 1.7 cm fruit are distinctive and typically found in litter under tree if not readily seen on the tree. It is widespread across northern Australia from Derby in Western Australia, through the northern third of Northern Territory, to Chillagoe in Queensland (Brock 2001). This species was sampled at Johns Hill and McKinlay.

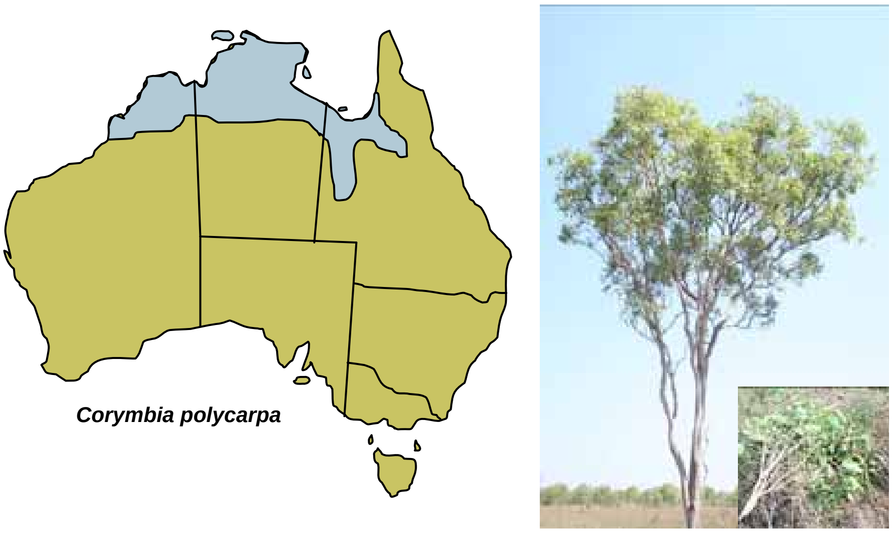

**Figure 7.4: Form, leaves and distribution of *Corymbia polycarpa* adapted from Brock 2001**

### *Eucalyptus foelscheana* (broad-leaved bloodwood)

This species is a small to medium-sized tree with rough flaky grey over orange, coppery bark over at least the lower trunk and cream, white smooth bark above (Figure 7.5). Adult leaves are mostly ovate to orbicular, 20 x 12 cm, although juvenile leaves can up to 35 x 25 cm. It is widespread on plains and low slopes across north-western Northern Territory (Brock 2001). This species was sampled at Johns Hill, Great Northern and McKinlay.

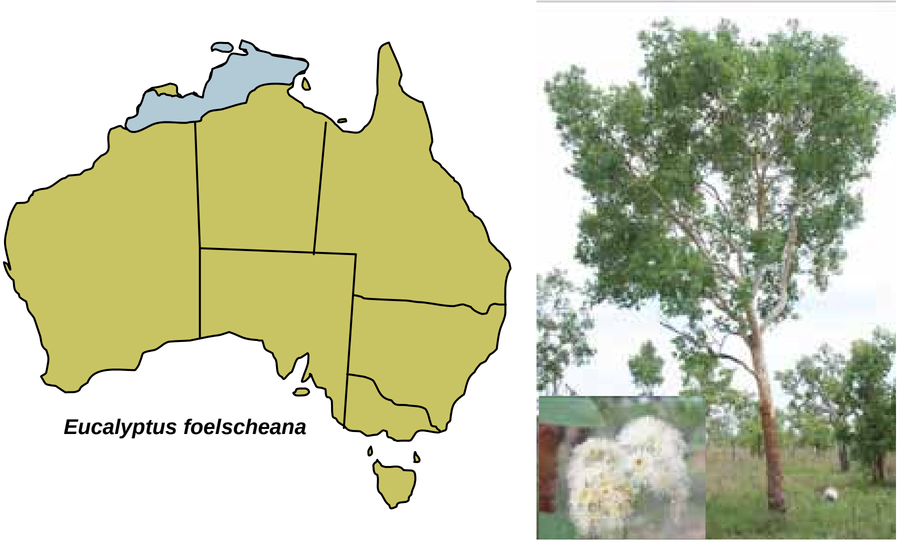

**Figure 7.5: Form, flowers and distribution of *Eucalyptus foelscheana* adapted from Brock 2001**

### *Eucalyptus miniata* (Darwin woolybutt)

*Eucalyptus miniata* is a small to medium-sized tree with rough, thick, loose, dark brown bark on lower trunk and smooth white bark on upper trunk and branches (Figure 7.6). Adult leaves are typically lanceolate up to 16 x 3.5 cm, and juvenile leaves tend to be more ovate. It is widespread and abundant across plains and low rises across northern Australia from the Kimberley to the Gulf of Carpentaria, as well as populations in the lower Cape York

Peninsula near Georgetown and a small area in central-west Queensland (Brooker & Kleinig 1994; Brock 2001). This is one of the most widespread tREE in the region both over sites of known mineralisation and along the orientation transects across the black soil plains. Exposures of its root systems within some of the southern pits at Glencoe show that as well as extensive spreading lateral roots it also has a set of sinker roots that penetrate at least 5 m through transported regolith. This was sampled at McKinlay and Glencoe, as well as over known mineralisation at Johns Hill, Great Northern, Great Western, McKinlay and Glencoe.

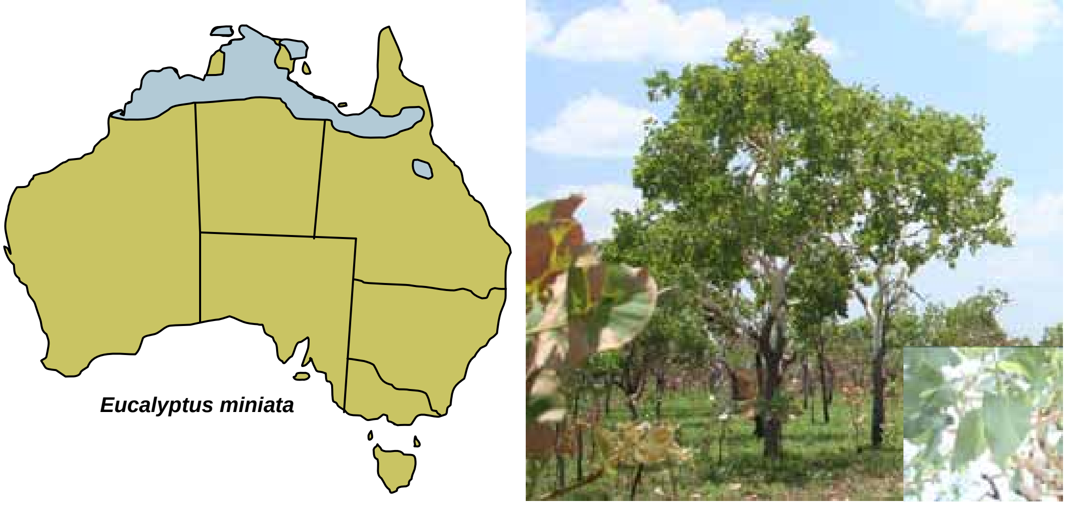

**Figure 7.6: Form, leaves and distribution of *Eucalyptus miniata* adapted from Brock 2001**

### *Heteropogon triticeus* (tall spear grass)

Spear grasses are perennial, tufted grass, 100-160 cm tall (when not grazed, Figure 7.7). Leaf blades are 20-80 cm long and 3-16 mm wide with a prominent midrib. It is a widespread and abundant grass of *Eucalyptus* forests and woodlands in the Northern Territory and Queensland, it is also present in temperate and tropical Asia (Moore 1975; Sharp & Simon 2002; Williams *et al.* 2003). Heteropogon is a C4 species making them more adaptable to aridity (Hattersley & Watson 1976). This grass was the most dominant over all studied sites and was sampled at each site along all transects and across the mineralisation zones.

NOTE:
This figure is included on page 156
of the print copy of the thesis held in
the University of Adelaide Library.

**Figure 7.7: Form, roots and distribution of *Heteropogon triticeus* adapted from Sharp & Simon 2002**

### *Melaleuca viridiflora* (broad-leaved paperbark)

*Melaleuca viridiflora* is a small erect or straggly tree with an open canopy and brownish white or grey, papery bark (Figure 7.8). Leaves are elliptic, ovate or obovate, thick and leathery, spirally arranged 6-19.5 x 2-7.5 cm, with 5-9 longitudinal conspicuous veins. It is widespread on poorly drained plains and alluvial flats around coastal regions of northern Australia from Maryborough in Queensland, through Arnhem Land to the Kimberley in

Western Australia (Holliday 2004), although Brock (2001) shows more extensive distribution down the east coast of Australia to Sydney. This is a very widespread species across the parts of the blacksoil plains where transported cover is more extensive. Some creek exposures near Johns Hill show extensive spreading lateral roots and a set of sinker roots that penetrate transported cover. The distribution and root habit of this species make it of interest for development as a regional exploration sampling medium. This species was sampled at Johns Hill and Great Northern.

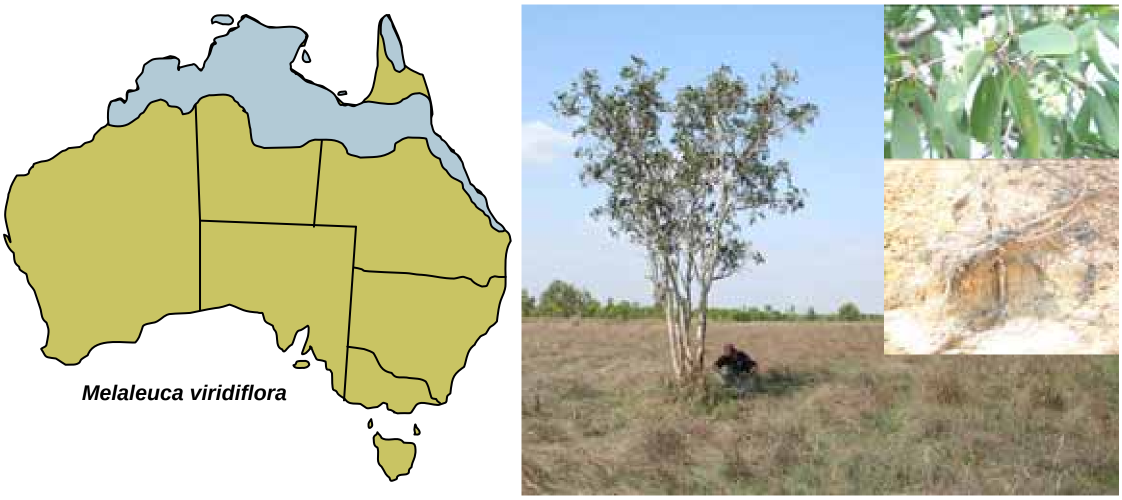

**Figure 7.8: Form, flowers, roots and distribution of *Melaleuca viridiflora* adapted from Brock 2001**

## *Xanthostemon paradoxus*

*Xanthostemon paradoxus* is a small scraggly tree, with large, crowded, smooth, shiny dark green or glaucous grey-green, 7.5-20 x 3.5-10 cm leaves (Figure 7.9). It has bright yellow flowers with numerous stamens. It is a common understorey tree in open forest, woodland and shrubland, often on low ridges with outcrops or shallow soils (Brock 2001). Its limitation to areas of bedrock exposure, reduce its potential as a regional sampling media across the black soil plains. However it is documented as being a U accumulator species, which could indicate whether U sources are present in the area (Debnam 1955). This plant was sampled over known mineralisation at Great Northern, Great Western, and McKinlay.

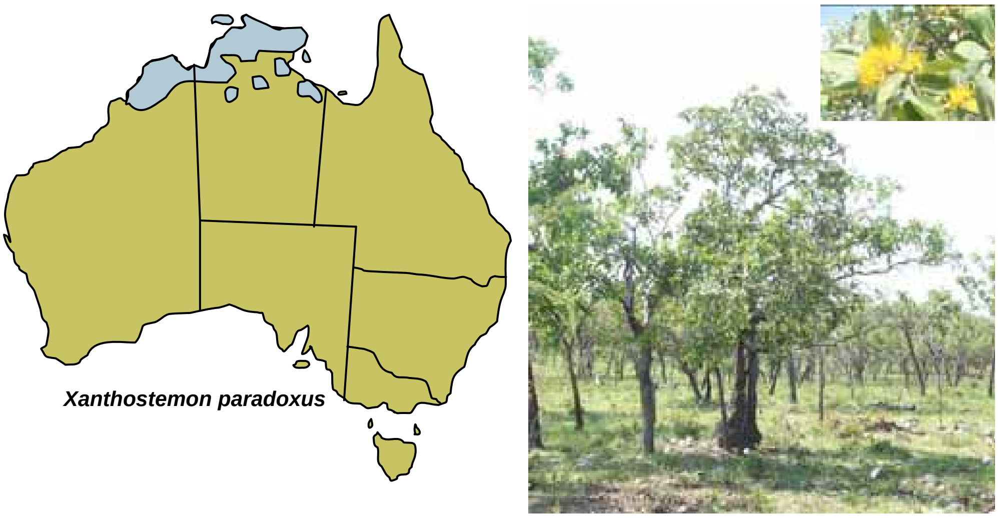

**Figure 7.9: Form, flowers and distribution of *Xanthostemon paradoxus* adapted from Brock 2001**

### 7.1.5 Study sites

The 4 Pine Creek field sites, Johns Hill, Great Northern, Glencoe and McKinlay can be seen in Figure 7.10. There is no specific geological or regolith information about each site as these are all green fields sites where nothing is known about the substrate below the transects at this stage.

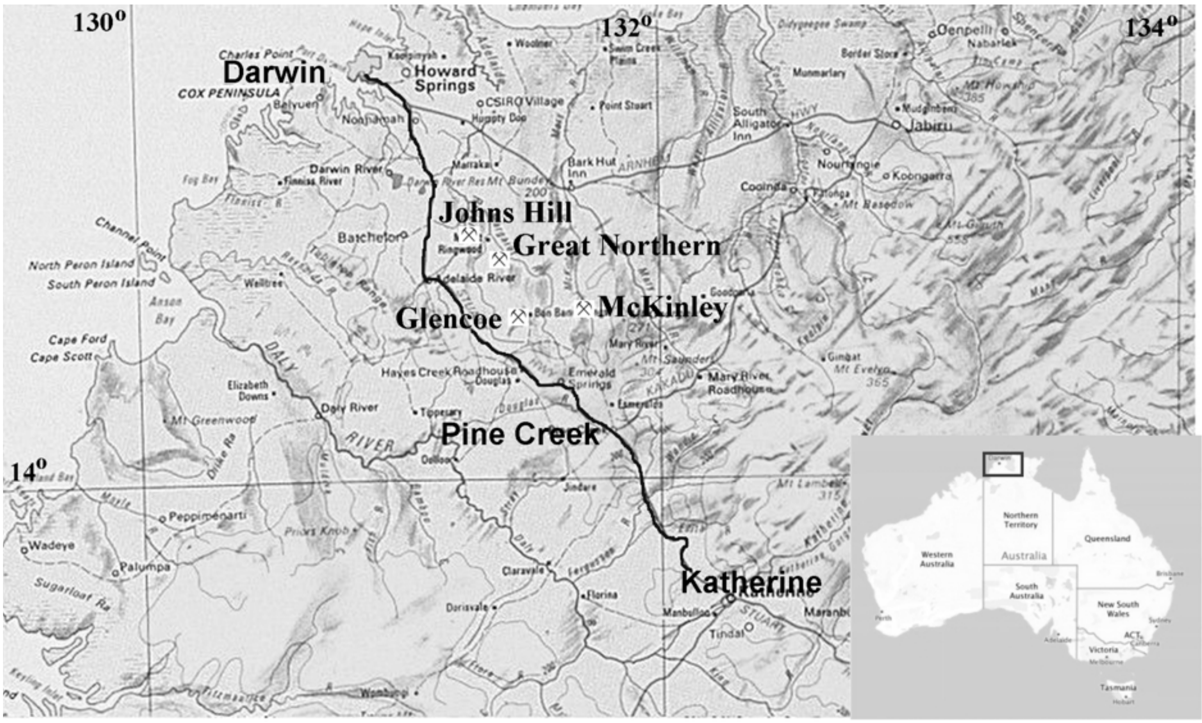

**Figure 7.10: Location of the Pine Creek field sites with respect to major towns (http://www.ga.gov.au/ 2006).**

### John’s Hill

The sampling transect at Johns Hill was approximately 1 km long trending E-W and was north of the main road past Johns Hill. This transect crossed the plain to the north of the known mineralisation, which was comprised of N-S trending quartz veins subcropping along the summit of the Johns Hill ridge. This included the discharge area of the now incised creek that flowed northwards off the Johns Hill ridge. The area had been largely cleared for grazing, although a few remnant large trees (mostly *E. polycarpa*) and smaller regrowth (mostly *M. viridiflora*) were sampled.

### Great Northern

The Great Northern area hosted extensive mining and ore processing in the late 1800s. The sampling transect here is approximately 1.5 km long trending E-W, north of the ridge hosting the Great Northern mineralisation. This area potentially contained alluvial and colluvial outwash from the Great Northern ridge overlying potentially mineralised bedrock. The eastern end of the transect appeared to contain the greatest amount of alluvial input from the ridge. The sample sites along the western end of this transect closely corresponded with a previous drilling program. The area contained widespread and abundant trees (mostly *M. viridiflora* and *E. foelscheana*).

### Glencoe

The known mineralisation at this site was discovered from a rock-chip exploration program by Magnum Exploration Ltd in 1985. It was thought to conform to a 300-340$^{o}$ trending, southeast plunging asymmetrical anticline (Ahmad *et al.* 1999). Three styles of gold mineralisation were recognised (Ahmad *et al.* 1999):

- subvertical quartz-filled fractures parallel to the axial plane of the anticline;
- lenticular, subvertical quartz veins at a considerable distance from the axial plane; and,
- stratabound concentrations within carbonaceous metapelite.

The first style of mineralisation was most important economically. Ore assemblages included arsenopyrite and traces of chalcopyrite. Gangue minerals were chlorite, quartz, tourmaline and carbonaceous matter (Ahmad *et al.* 1999). The estimated resource was 1.5 Mt at 1.9 g/t Au (Ahmad *et al.* 1999).

The 1 km long, sampling transect was N-S parallel to a fence-line track to the east of the known mineralisation. This closely followed a topo-sequence from a subdued ridge crest (erosional plain) with sub-cropping gravels overlying weathered bedrock, southwards down-slope across sheetwash sediments towards an alluvial depositional plain with thicker transported cover. The sampling transect contains abundant tree cover of mostly *E. miniata*. Recent fires burnt most of the area, leaving desiccated leaves on the trees, with only small patches of unburnt vegetation. Burnt and unburnt leaves were collected from 6 individual trees to test for the significance of fire desiccation to plant biogeochemical assay results.

### McKinlay

The sampling transect at this site was 1 km long, trending E-W and south of the N-S trending mineralised quartz veins exposed on the ridge. This crossed the McKinlay River and the central and western parts extend across outwash from the ridge hosting known mineralisation. The transect had a slight ‘dog-leg’ on its western end in order to target consistent vegetation types. Parts of the sampling transect had sparse tree availability, although *E. miniata* and *E. polycarpa* were more abundant towards the eastern end, where quartz vein detritus was more apparent in termitaria and surface.

## 7.2 Pine Creek – Species Results and Discussions

### 7.2.1 Site specific methods

The sampling program consisted of sampling along approximately 1 km long transects across the buried margins of sites of known mineralisation. Sample spacing was approximately 50 m, although this ultimately was influenced by the distribution and availability of target media, which included leaves from dominant trees and the dominant grass species (leaves shown to be the best medium from the Tanami study). Several samples of target media were taken from directly over the sites of known mineralisation (Johns Hill, Great Northern, Great Western, McKinlay and Glencoe) in order to gain a potentially strong expression of mineralisation and associated pathfinder elements. These results may not directly relate to regional exploration across the black soil plains, however they may be of value in regional sampling programs to test for the ‘chemical fertility’ of exposed and sub-cropping quartz vein systems.

### 7.2.2 John's Hill

Mineralisation at Johns Hill has a broad biogeochemical association with As, Au, Cu, La, Mo, and Zn, and more variably Ag. The grass *Heteropogon triticeus* provides the most consistent multi-element expression of mineralisation, which also includes an extremely high Cr assay (14.7 ppm). The *Brachychiton paradoxum* sample produced the highest Cu assay of the entire data set (13.17 ppm).

#### *Heteropogon triticeus* (tall spear grass)

*Heteropogon triticeus* was widespread across the field site and the results show 3 distinct elemental patterns:

1. Elements that are elevated over the east (As, Au, B, Ce, Cr, Hf, Hg, La, Mg, Nb, Ni, Sc, Sr, U, Y and Zr); (Figure 7.11)
2. Elements elevated to the west (Cs, Cu, Mn, Na, and Se); and,
3. Elements elevated to the centre (Ba, Ca, Cd, Co, Ge, Mo, S, Sb and Zn).

There are also elements that are irregularly distributed (Ag, Al, Fe, Ga, K, Li, P, Pb, Rb, Sn, Th and Ti). Elements that were below analytical detection limit were Be, Bi, In, Pd, Pt, Re, Te, Tl, V and W.

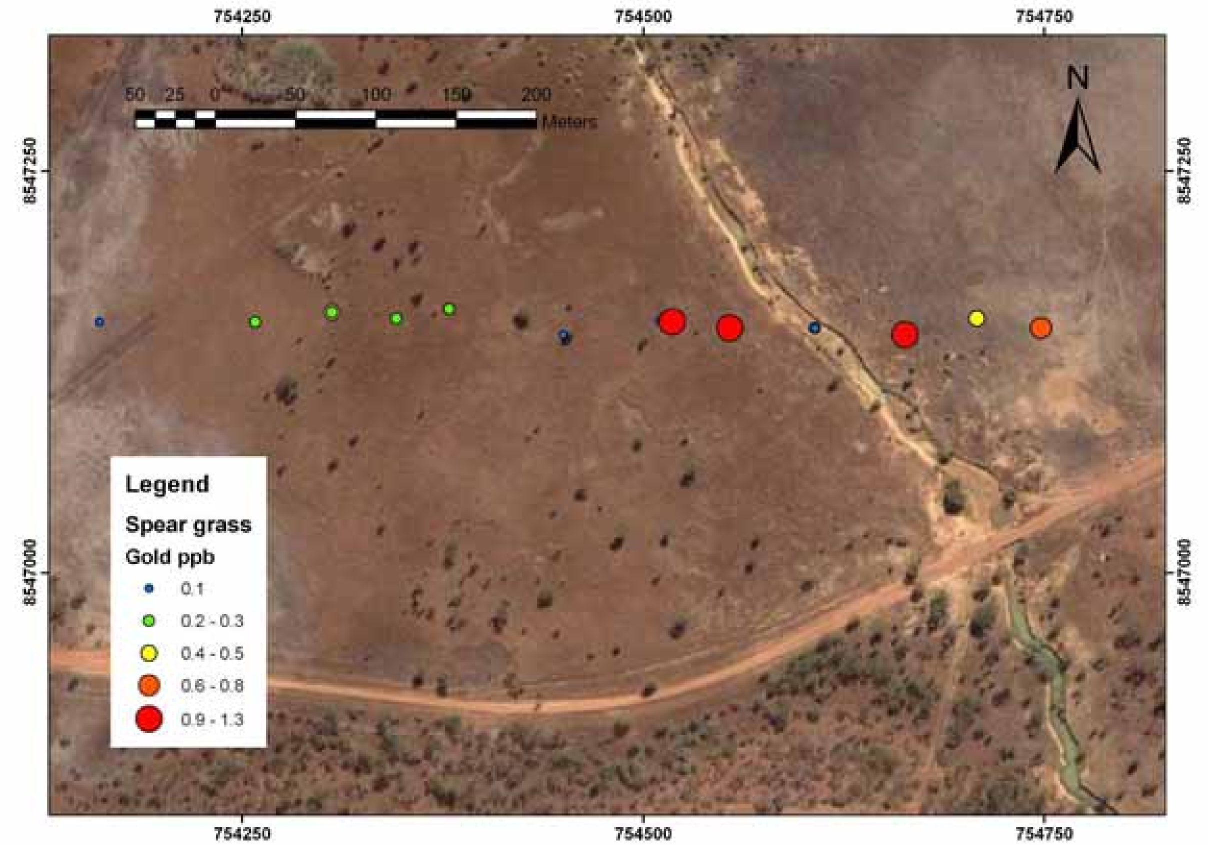

**Figure 7.11: Spatial distribution of Au assay results for *Heteropogon triticeus* along the Johns Hill transect overlying the satellite imagery.**

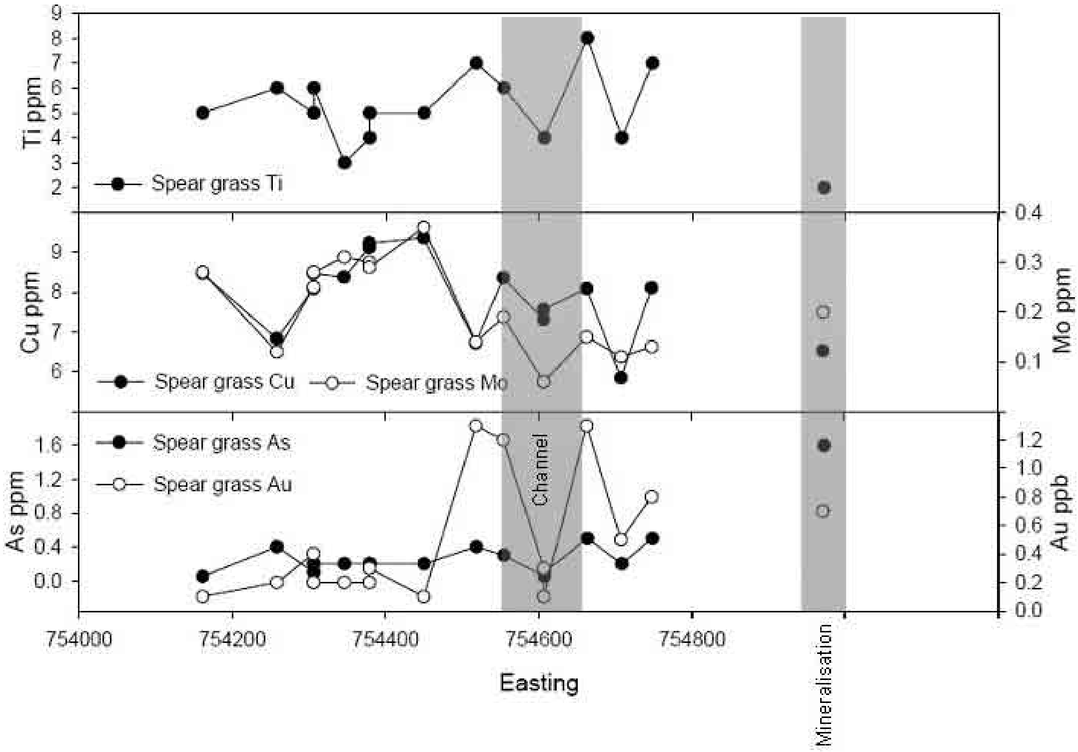

**Figure 7.12: *Heteropogon triticeus* elemental cross section across the Johns Hill transect**

## Discussion

These results mainly highlight the effect of drainage upon the chemistry of this species (Figure 7.12). In general most of the elements have their highest values towards the east of the transect which is where the major drainage for this area is. This means that these values should be regarded suspiciously and may not represent mineralisation but elements washing off the mineralisation to the south. The elements which have higher values towards the centre or the west of the transect are more likely to represent a buried signature than those towards the east. In particular the Mo and Cu results show a peak near the centre which correspond, and the samples collected from the known mineralisation show that these elements could be important path-finder elements for the Au mineralisation. This species has a greater contamination potential than the others sampled at this site, shown by the Ti results (Figure 7.12) which show low concentrations which are aligned with the modern drainage. This is due to this species being much lower to the ground and hence being able to collect more dust than the tree species.

### *Corymbia polycarpa* (long-fruited bloodwood)

*Corymbia polycarpa* had a patchy distribution across the field site and the results show 3 distinct elemental patterns:

1. Elements that are elevated over the east (Au, Fe, Mn and Th);
2. Elements elevated to the west (B, Ba, Ca, Ce, Co, Cr, Cu, Hf, Hg, La, Li, Mo, Na, Ni, P, Pb, S, Se, Sr, Y and Zn); and, (Figure 7.13)
3. Elements elevated to the centre (Cd, K, Mg and Rb).

There are also elements that are irregularly distributed (Cs, Ge, Ti, U and Zr). Elements that were below analytical detection limit were Ag, Al, As, Be, Bi, Ga, In, Nb, Pd, Pt, Re, Sb, Sc, Sn, Te, Tl, V and W.

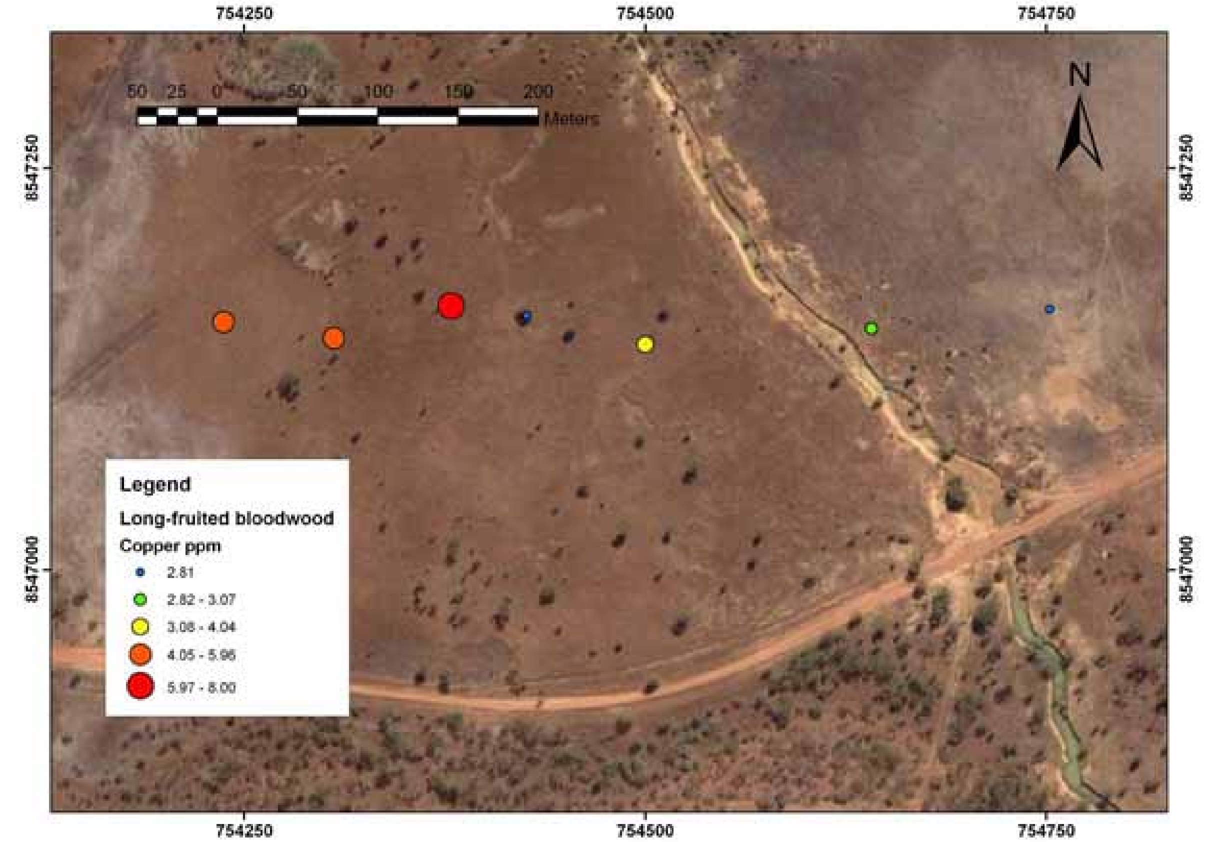

**Figure 7.13: Spatial distribution of Cu assay results for *Corymbia polycarpa* along the Johns Hill transect overlying the satellite imagery.**

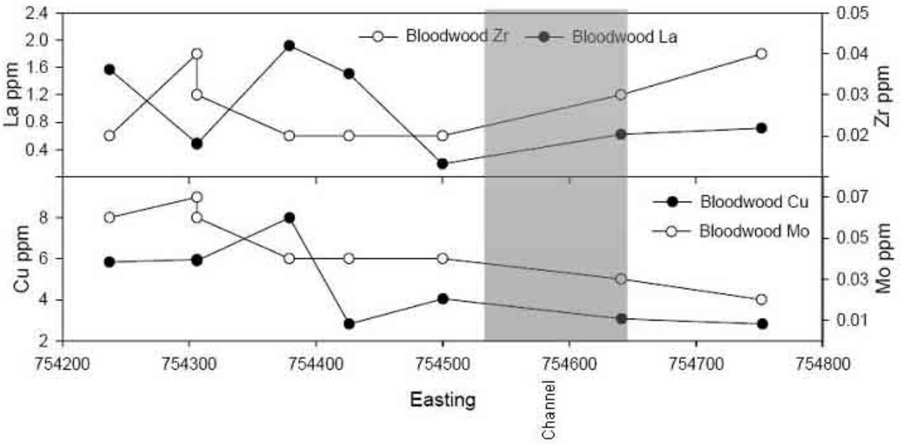

**Figure 7.14: *Corymbia polycarpa* elemental cross section across the Johns Hill transect**

## Discussion

The results from this species appear to be the opposite of the trends observed from *Heteropogon triticeus* (Figure 7.14). This could be explained by the species sampling from different depths and hence sourcing elements from different horizons. The spear grass appears to show the modern drainage signals, whereas the bloodwood does not show this trend but possibly where the channel used to flow. However, the Cu and Mo results do correlate between the two species which reinforce the thought that the centre and right of the transect would be the most prospective area for follow-up work. There is also little contamination issue within the samples as shown by the Zr results (Figure 7.14) which show low values which are irregularly distributed.

### *Melaleuca viridiflora* (broad-leaved paperbark)

*Melaleuca viridiflora* had a patchy distribution across the field site and the results show 3 distinct elemental patterns:

1. Elements that are elevated over the east (Re);
2. Elements elevated to the west (As, B, Ba, Ca, Ce, Cs, Cu, K, La, Li, Mn, Mo, Na, Ni, Rb, Sr, Tl and Y); and, (Figure 7.15)
3. Elements elevated to the centre (Au, Hg, P and Zn).

There are also elements that are irregularly distributed (Co, Cr, Fe, Ge, Hf, Mg, Pb, S, Se, Th and Zr). Elements that were below analytical detection limit were Ag, Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V and W.

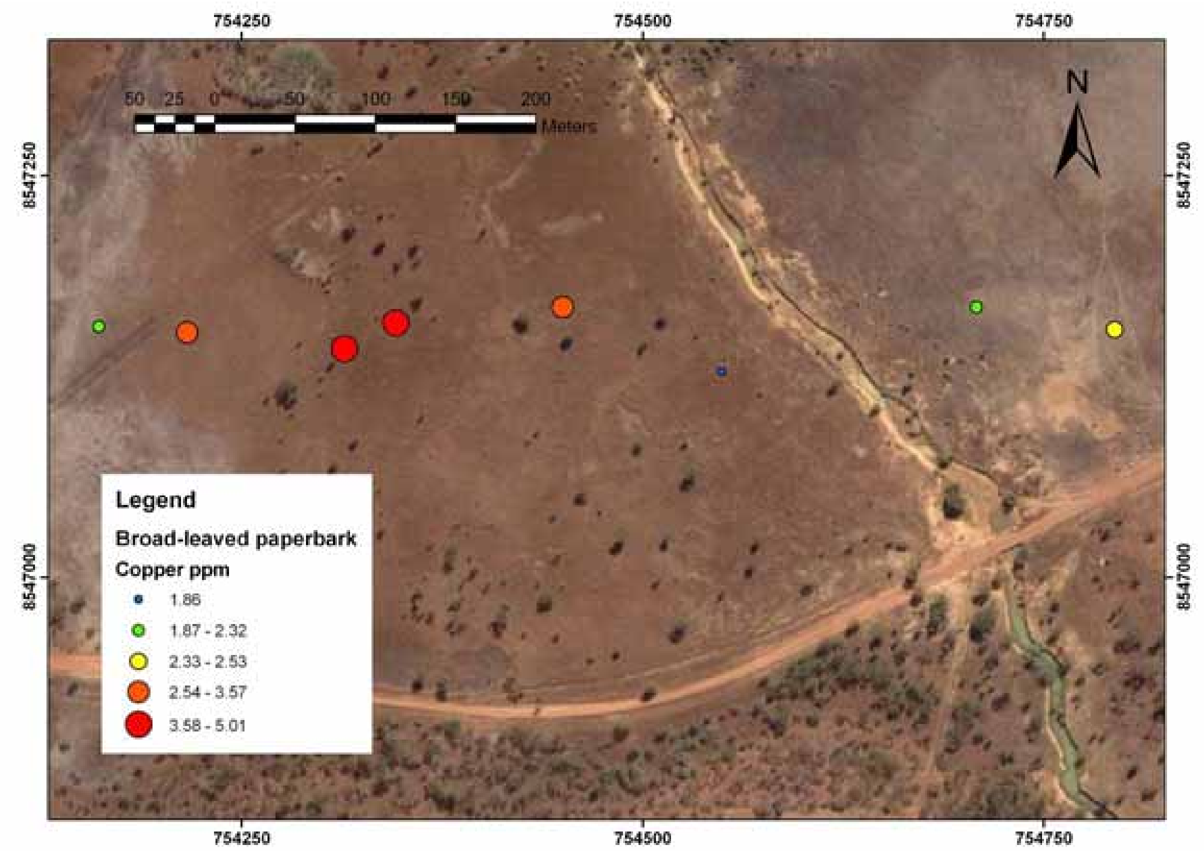

**Figure 7.15: Spatial distribution of Cu assay results for *Melaleuca viridiflora* along the Johns Hill transect overlying the satellite imagery.**

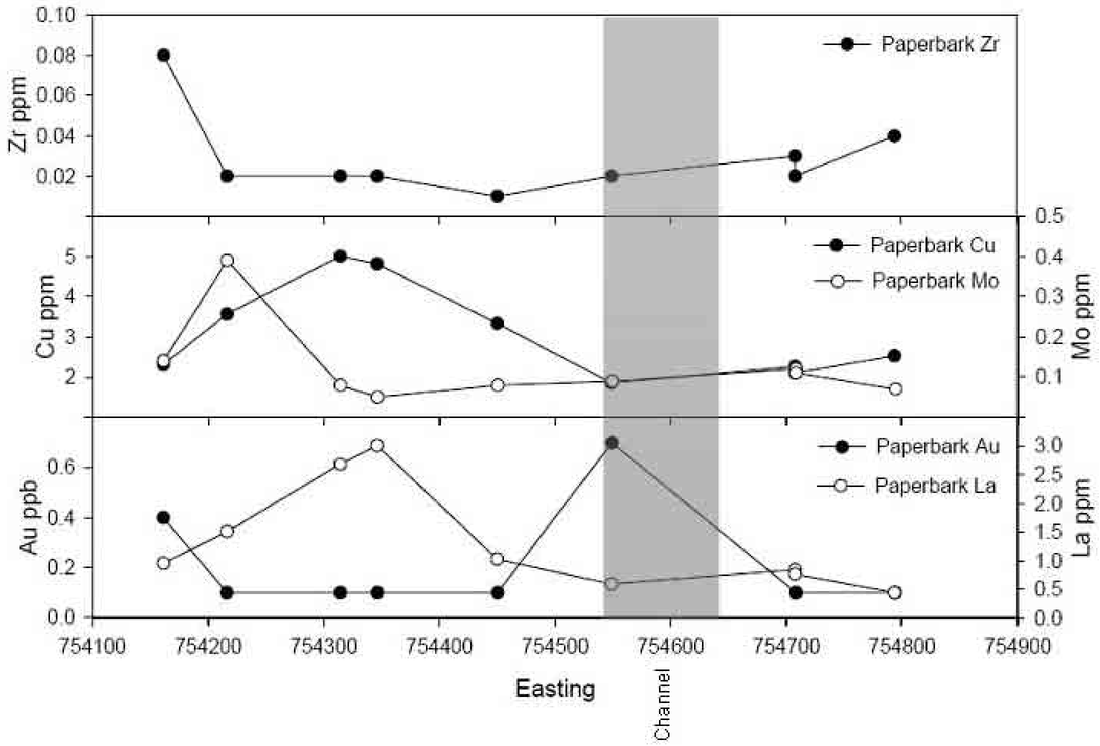

**Figure 7.16:** ***Melaleuca viridiflora*** **elemental cross section across the Johns Hill transect**

**Discussion**

The results for this species are similar to that produced by *Corymbia polycarpa* (Figure 7.16) which suggests that the rooting depth and habit of the two plants are similar. Same as the other species at this site there is a consistent small magnitude Mo and Cu anomaly from the centre of the transect heading to the west. There is little contamination of the samples as shown by the low Zr results (Figure 7.16), which is similar to the other plants.

### 7.2.3 Great Northern

The mineralisation at Great Northern is a more irregular and therefore inconsistently biogeochemically expressed site. The mineralisation is best biogeochemically expressed by Au contents although there are some moderately high Zn assays (up to 33.7 ppm) and a *Xanthostemon paradoxus* sample with 7 ppm Ag (GN X 025B). The highest Au-bearing *Eucalyptus miniata* sample (5.2 ppb in GN WB 025A) was obtained from a site along an old costean that previously provided high Au assays from rock chips, although another 2 *Eucalyptus miniata* trees sampled approximately 10 m (GN WB 025B) and 25 m away provided below detection Au.

The mineralisation at Great Western is best expressed by very high Ag (28 ppm) and Au (8.7 ppb) assays in a *Xanthostemon paradoxus* sample (GW X001) and very high Zn contents (53.9-119.3 ppm) in all species assayed at this site. The *Brachychiton paradoxum* sample (GW KURRAJ 001) had the second highest Cu assay (12.81 ppm) for all biogeochemical samples in this study.

### *Heteropogon triticeus* (tall spear grass)

*Heteropogon triticeus* had a wide distribution across the field site and the results show 4 distinct elemental patterns:

1. Elements that are elevated over the east (Al, Ba, Ca, Ce, Co, Ga, Ge, Hf, Hg, La, Pb, U, V, Y and Zr);
2. Elements elevated to the west (B, Cs, Mg, Na, P, Rb and S);
3. Elements showing elevated values in a 'rabbit ears' pattern (Ag, Au, Fe and Sr); and,
4. Elements elevated to the centre (As, Cr, Cu, K, Mn, Mo, Ni, Se and Zn). (Figures 7.17 and 7.18)

There are also elements that are irregularly distributed (Li, Nb, Sn, Th, Ti and Tl). Elements that were below analytical detection limit were Be, Bi, In, Pd, Pt, Sb, Sc, Te and W.

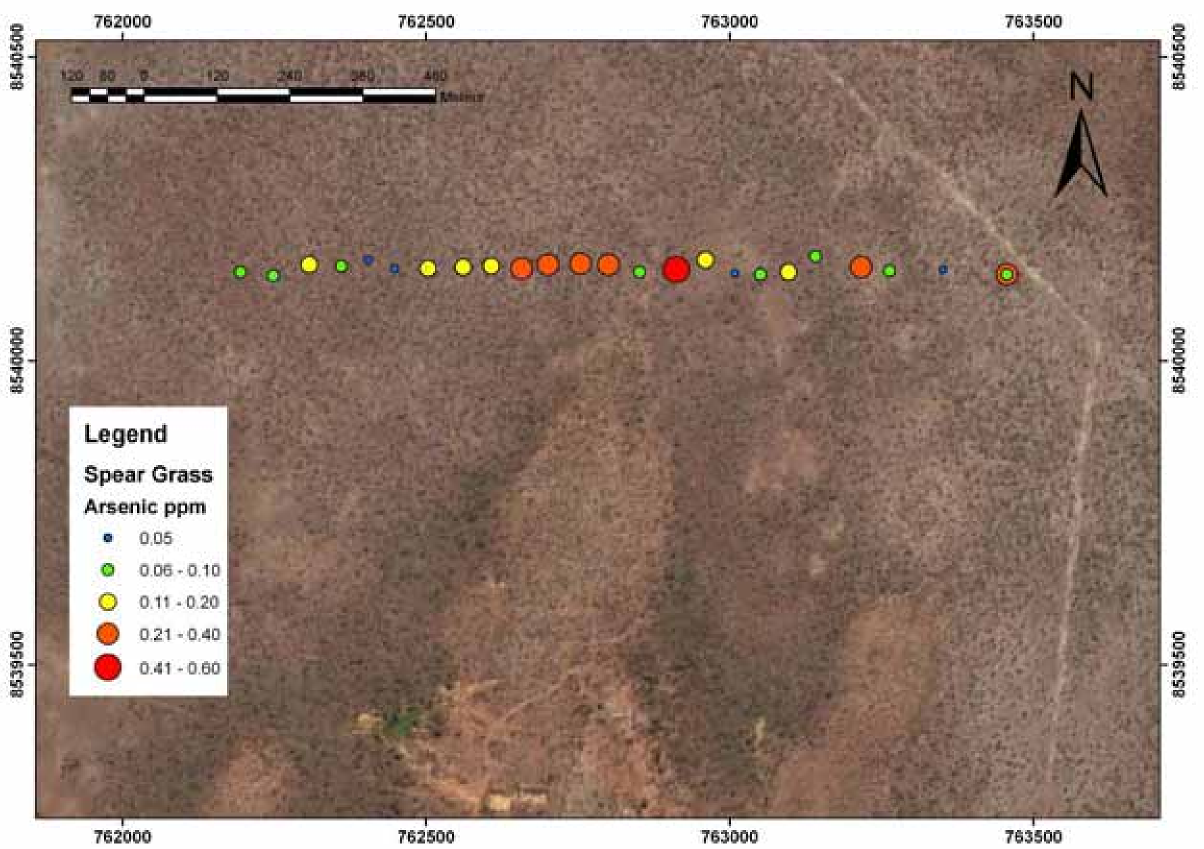

**Figure 7.17: Spatial distribution of As assay results for *Heteropogon triticeus* along the Great Northern transect overlying the satellite imagery.**

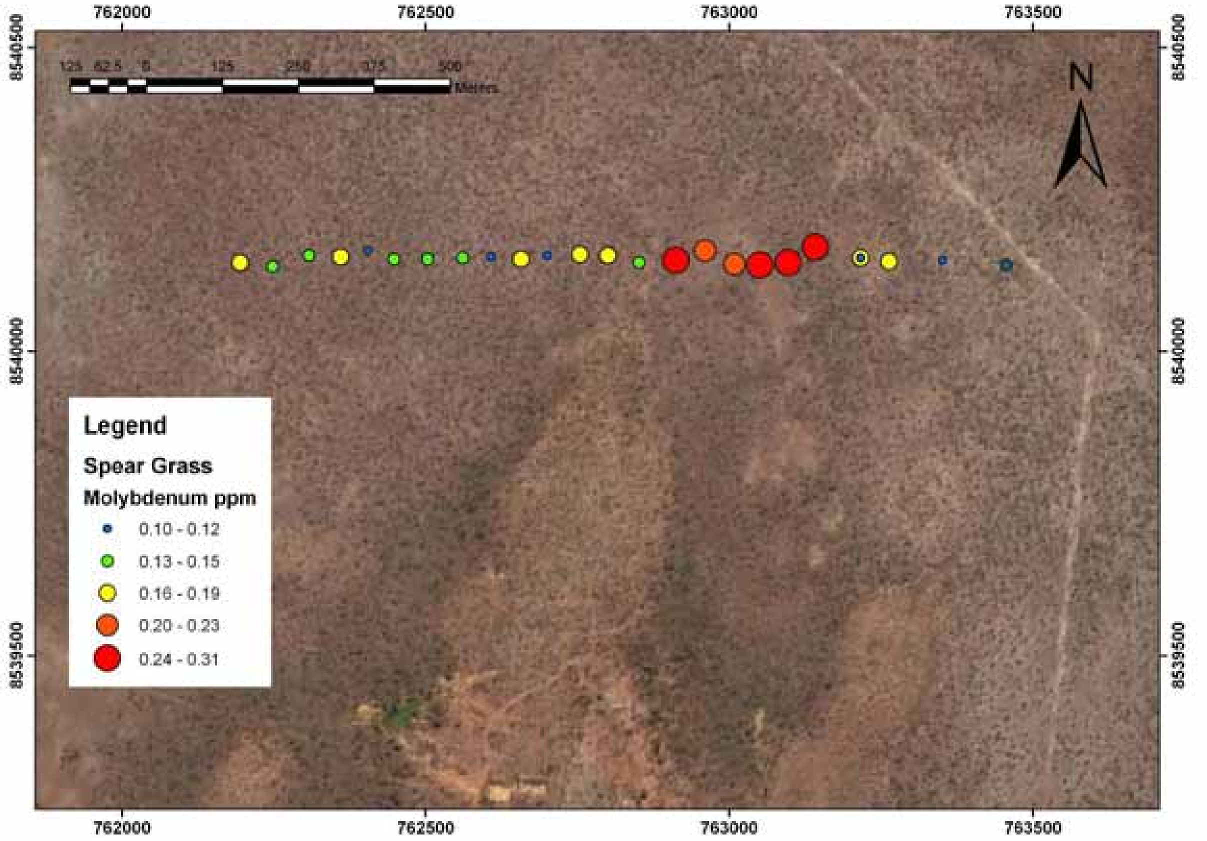

**Figure 7.18: Spatial distribution of Mo assay results for *Heteropogon triticeus* along the Great Northern transect overlying the satellite imagery.**

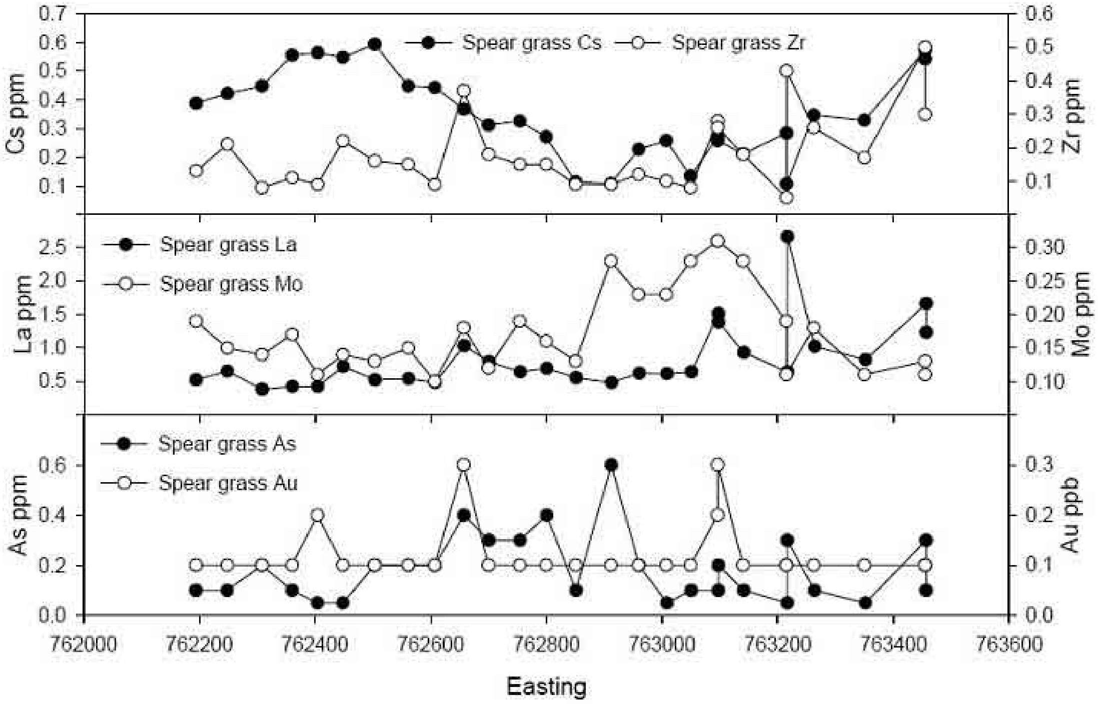

**Figure 7.19: *Heteropogon triticeus* elemental cross section across the Great Northern transect**

## Discussion

The results from this speices indicate that it is influenced by surficial processes at this site (Figure 7.19). The higher concentrations of the usual contamination elements to the east (Al, Hf and Zr) show that dust from the track blows over the grass to the east and is caught on the leaves. However, the elements to the west (Cs, Mg, Na, P and S) show that water movement is greater towards the western end of the transect as these elements tend to be associated with normal plant growth and are increased with greater biological activity which is stimulated by increased water. One problem with this site is that there is little background knowledge about this site. Regolith and geological mapping have not been done so it is difficult to say if the changes are all linked to surficial processes or whether lithological controls are of importance.

The high concentrations over the centre and the ‘rabbit ears’ anomalies show the greatest potential for representing buried mineralisation. The ‘rabbit ears’ could be either a vein or layer that is on either side of the slight ridge through the centre or could equally be from transported materials shedding off the mineralised ridge to the south. The As and Mo anomalies (Figures 7.25 and 7.29) are the most promising at representing shallower cover over mineralisation as they are around where the mineralised ridge is expected to continue under the ‘black-soil plains’.

### *Eucalyptus foelscheana* (broad-leaved bloodwood)

*Eucalyptus foelscheana* had a wide distribution across the field site and the results show 4 distinct elemental patterns:

1. Elements that are elevated over the east (Ag, Cu, K, P, Rb, S and Ti);
2. Elements elevated to the west (B, Co, Cr, Hg, Li, Mn, Na, Ni, Re, Tl, U and Zr);
3. Elements showing elevated values in a ‘rabbit ears’ pattern (Ba, Cs, Hf and Mo); (Figure 7.21) and,
4. Elements elevated to the centre (As, Au, Cd, Ce, Ge, La, Mg, Sb, Se and Y) (Figure 7.20).

There are also elements that are irregularly distributed (Ca, Fe, Pb, Sr and Zn). Elements that were below analytical detection limit were Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sc, Sn, Te, V and W.

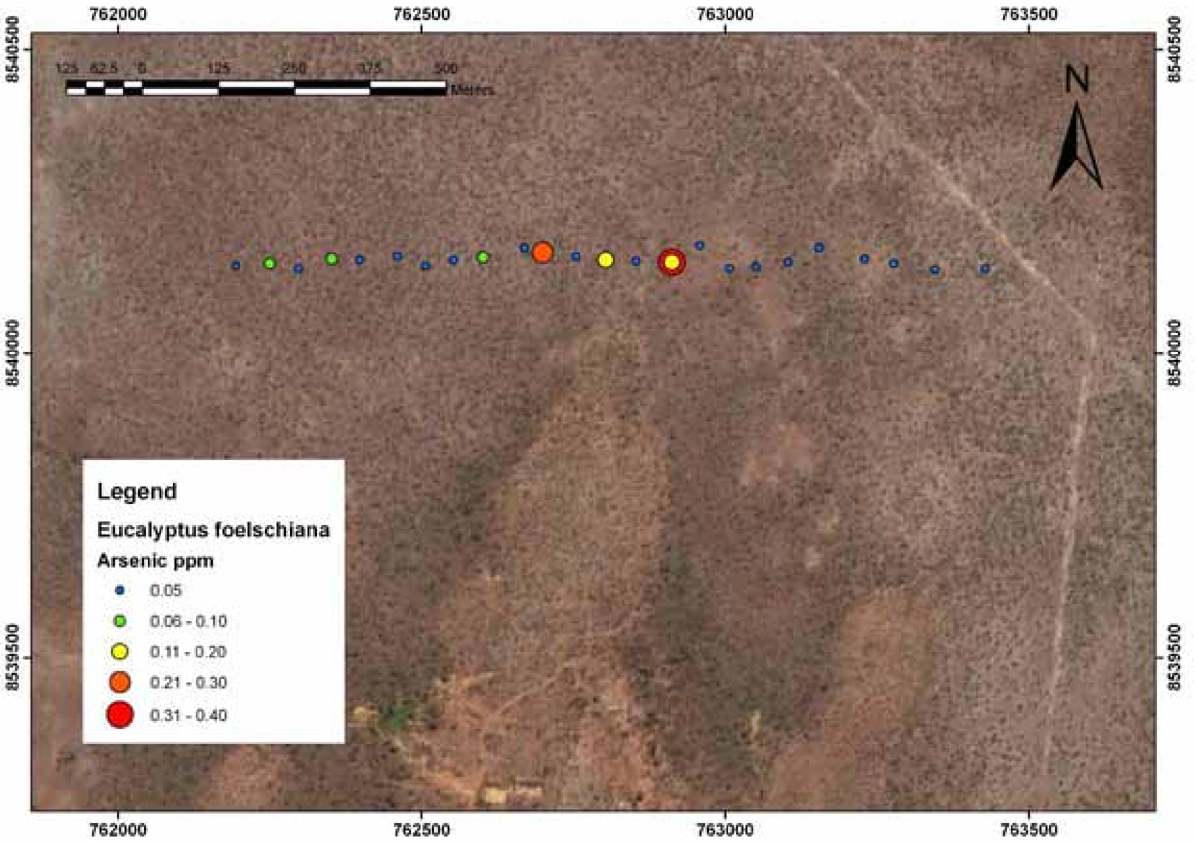

Figure 7.20: Spatial distribution of As assay results for *Eucalyptus foelscheana* along the Great Northern transect overlying the satellite imagery.

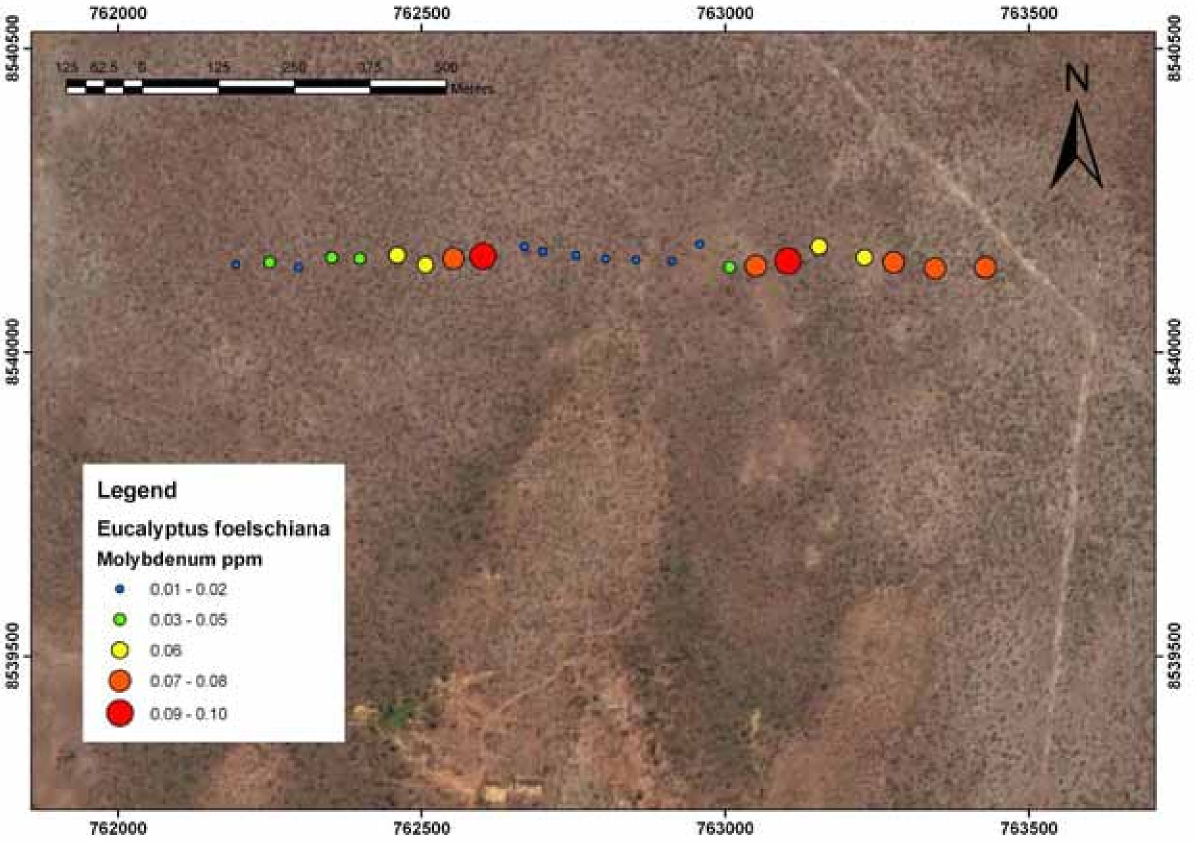

Figure 7.21: Spatial distribution of Mo assay results for *Eucalyptus foelscheana* along the Great Northern transect overlying the satellite imagery.

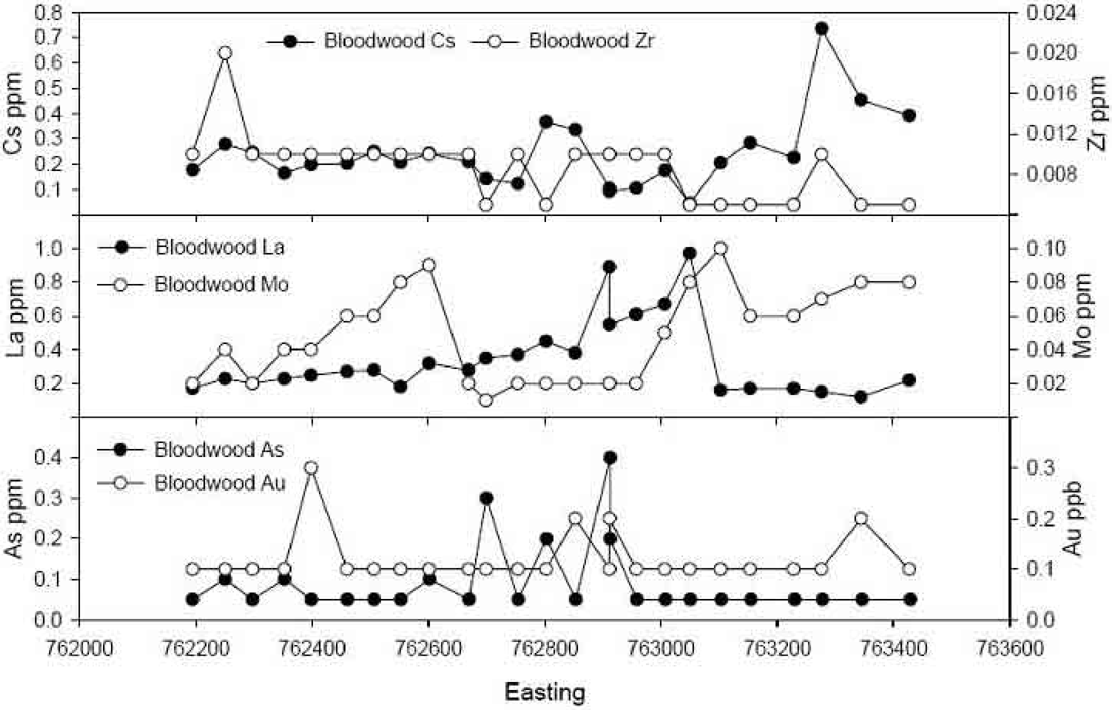

**Figure 7.22: *Eucalyptus foelscheana* elemental cross section across the Great Northern transect**

## Discussion

The results from this species show that *Eucalyptus foelscheana* is not as affected by the surficial processes as the spear grass was (Figure 7.22). In this case the common detrital contamination elements are not aligned together in any meaningful way, and since all the concentrations are low, the results are insignificant. The high As and Au concentrations over the centre of the transect combined with a low within the Mo results highlight this area as being of interest for mineral exploration, this 'rabbit ear' could be related to a bedrock high since the area is topographically flat over this distance. This area also corresponds with the significant areas presented in the *Heteropogon* results which reinforces the anomaly.

### *Melaleuca viridiflora* (broad-leaved paperbark)

*Melaleuca viridiflora* had a wide distribution across the field site and the results show 4 distinct elemental patterns:

1. Elements that are elevated over the east (Hg, Li and Se);
2. Elements elevated to the west (Co, Cs, Mn, Na, Ni, Rb, Re, Tl and Zn);
3. Elements showing elevated values in a 'rabbit ears' pattern (Ba, Ce, Hf, La, Mo and S); and,
4. Elements elevated to the centre (As, Au, Cr, Ge and Y). (Figure 7.23)

There are also elements that are irregularly distributed (B, Ca, Cu, Fe, K, Mg, P, Pb, Sr, Ti and U). Elements that were below analytical detection limit were Ag, Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V, W and Zr.

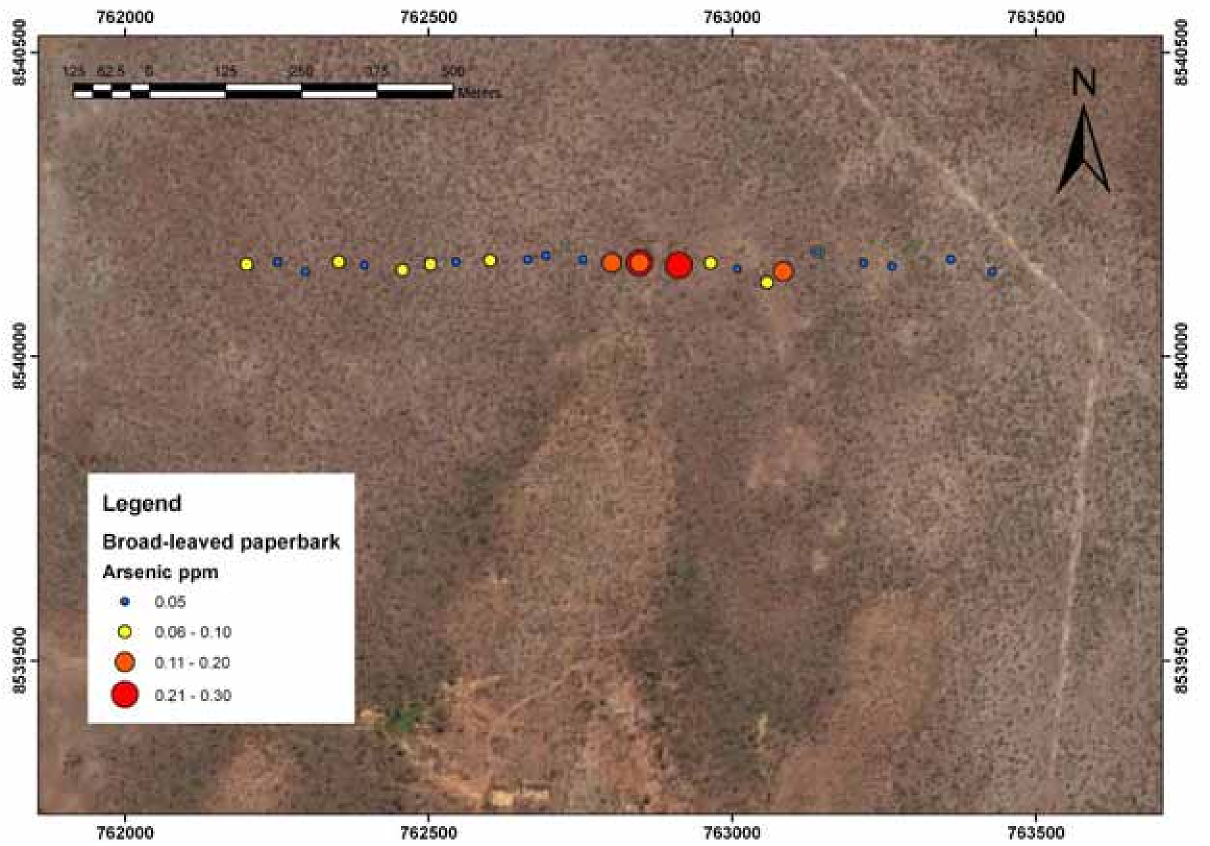

**Figure 7.23: Spatial distribution of As assay results for *Melaleuca viridiflora* along the Great Northern transect overlying the satellite imagery.**

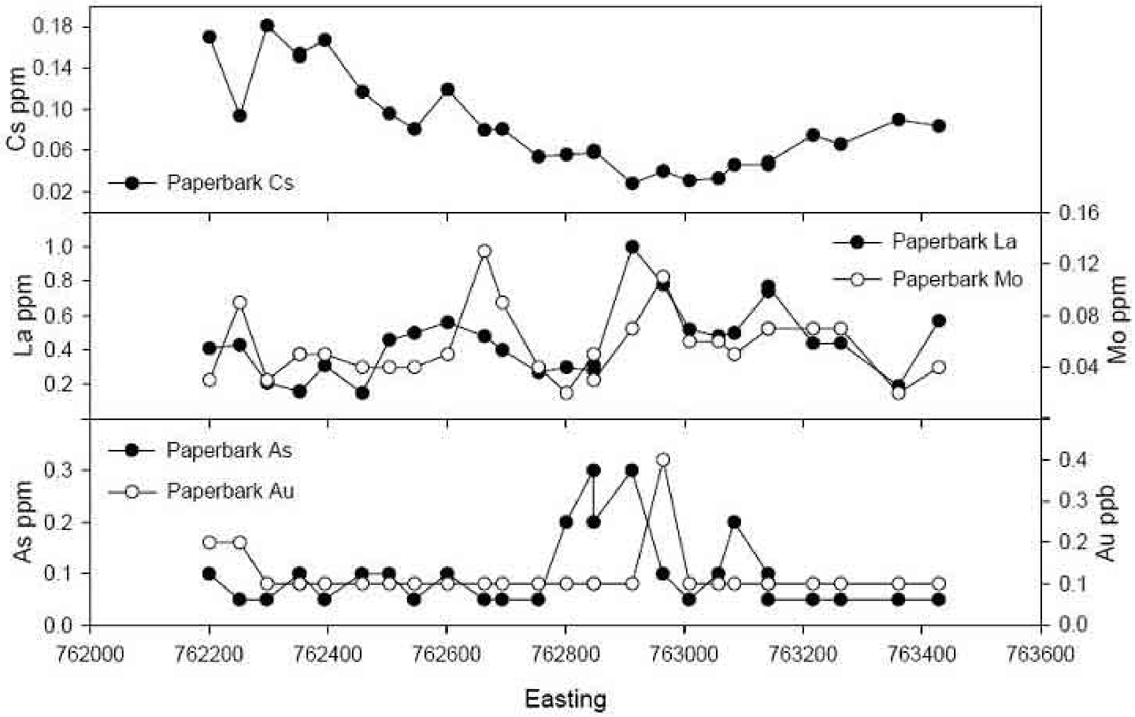

**Figure 7.24: *Melaleuca viridiflora* elemental cross section across the Great Northern transect**

## Discussion

The results from the *Melaleuca viridiflora* assays showed similar results to the *Eucalyptus foelscheana* assays (Figure 7.24). This indicates that the two species are sampling from similar depths and from similar materials. The elevated As and Au over the centre of the transect as well as the low Mo concentration reinforce the centre of the transect being rated as the highest likelihood of being over buried mineralisation.

### 7.2.4 Glencoe

The mineralisation at Glencoe is most consistently and broadly expressed by As, Au, Mo and Zn. The larger variability of assay results near mineralisation however is likely to mostly reflect the variability of sample site locations with respect to their proximity to mineralisation. For instance the two samples from over the axis of the mineralised antiform on the margins of the main mineralisation pit at Glencoe (GL CALIT A021 and GLGA021) provided the highest Ag, As, Au, La assays for the entire site. The grass *Heteropogon triticeus* appears the strongest and most consistent multi-element expression of mineralisation, in particular the GLGA021 sample from the main pit margin.

#### *Heteropogon triticeus* (tall spear grass)

*Heteropogon triticeus* had a wide distribution across the field site and the results show 4 distinct elemental patterns:

1. Elements that are elevated over the south (As, Ba, Cs, Ge, K, Li, Mg, Mo, Na, Nb, Pb, Rb and Sb); (Figure 7.25)
2. Elements elevated to the north (Ce, Cr, Hg, Se, Th and U);
3. Elements showing elevated values to the centre and south (Ca, Cu, S and Sr); (Figure 7.25) and,
4. Elements elevated to the centre (Au, La, Tl and Y).

There are also elements that are irregularly distributed (Al, B, Co, Fe, Hf, Mn, P, Sc, Sn, Ti, Zn and Zr). Elements that were below analytical detection limit were Ag, Be, Bi, Ga, In, Pd, Pt, Te, V and W.

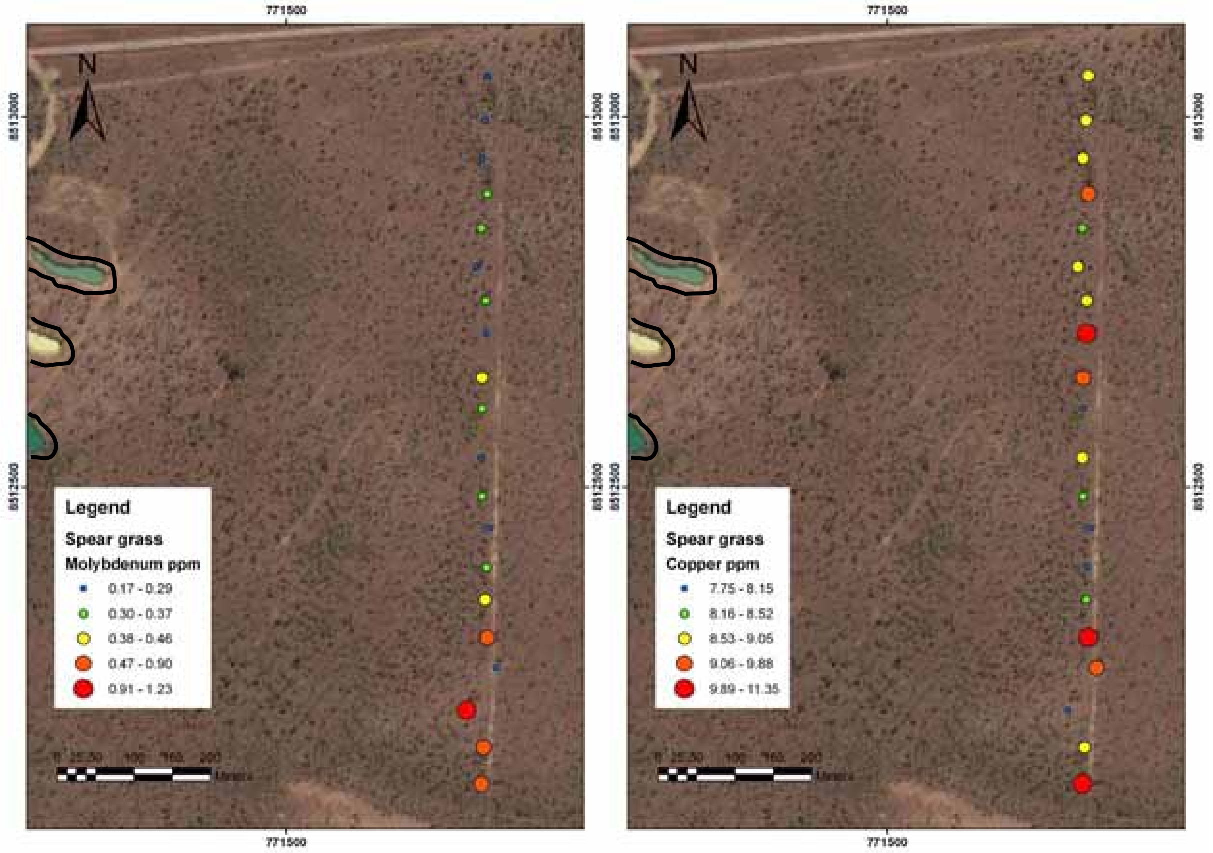

**Figure 7.25: Spatial distribution of Au and Cu assay results for *Heteropogon triticeus* along the Glencoe transect overlying the satellite imagery. Known mineralisation within the black lines.**

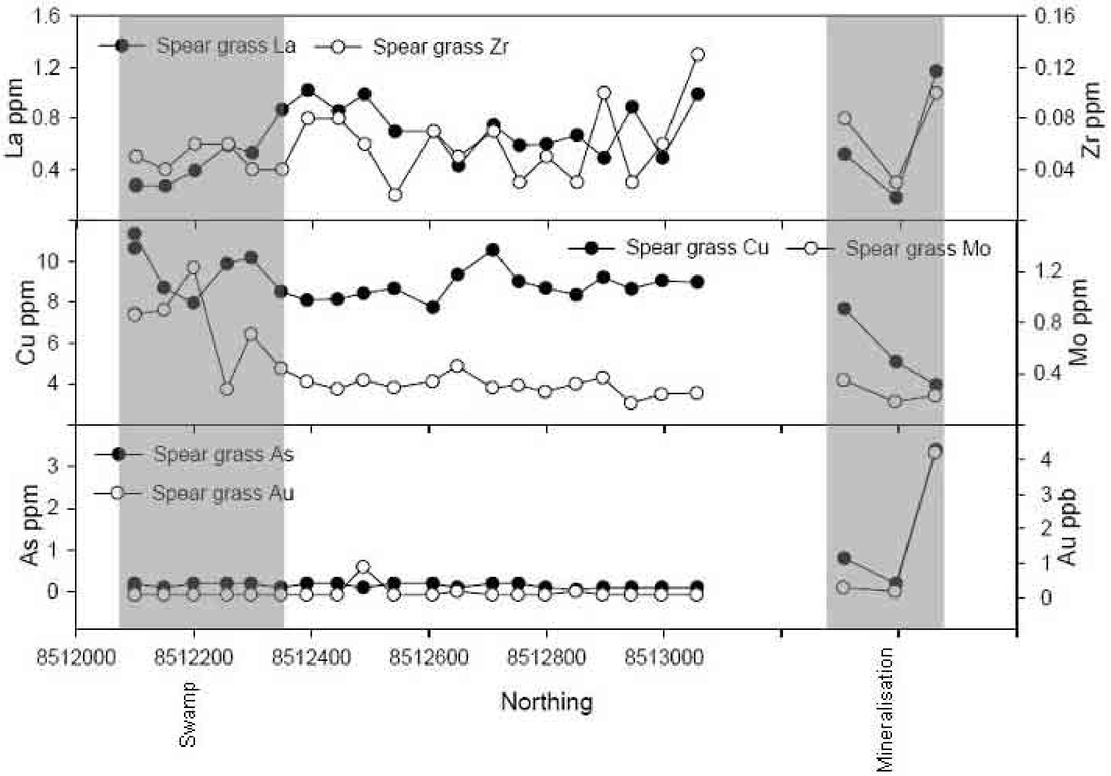

**Figure 7.26: *Heteropogon triticeus* elemental cross section across the Glencoe transect**

## Discussion

The results from this species highlight many elements with high values towards the south of the transect, which corresponds to a swampy region (Figure 7.26). This means that any high value from this region should be ranked lower than other highs. Most of the detrital contaminant elements have no recognisable association which means that there is little influence from detrital sources. The area that would be ranked higher for exploration potential is near the centre of the transect where some elements have a secondary elevated area, this secondary peak could relate to a slight bedrock high in that area which may be the under cover extension of the mineralisation to the west.

### *Eucalyptus miniata* (woolybutt – burnt leaves)

*Eucalyptus miniata* had a wide distribution across the field site and the results from the burnt leaves show 4 distinct elemental patterns:

1. Elements that are elevated over the south (As, Au, Mo and Rb); (Figure 7.27)
2. Elements elevated to the north (Cr, Mn, Na, Ni, P, S and U);
3. Elements showing elevated values to the centre and south (Ce, Cu, La and Y); and,
4. Elements elevated to the centre (Cs, Hg and Tl).

There are also elements that are irregularly distributed (Ag, B, Ba, Ca, Cd, Co, Fe, Ge, Hf, K, Li, Mg, Pb, Se, Sr, Ti and Zn). Elements that were below analytical detection limit were Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V, W and Zr.

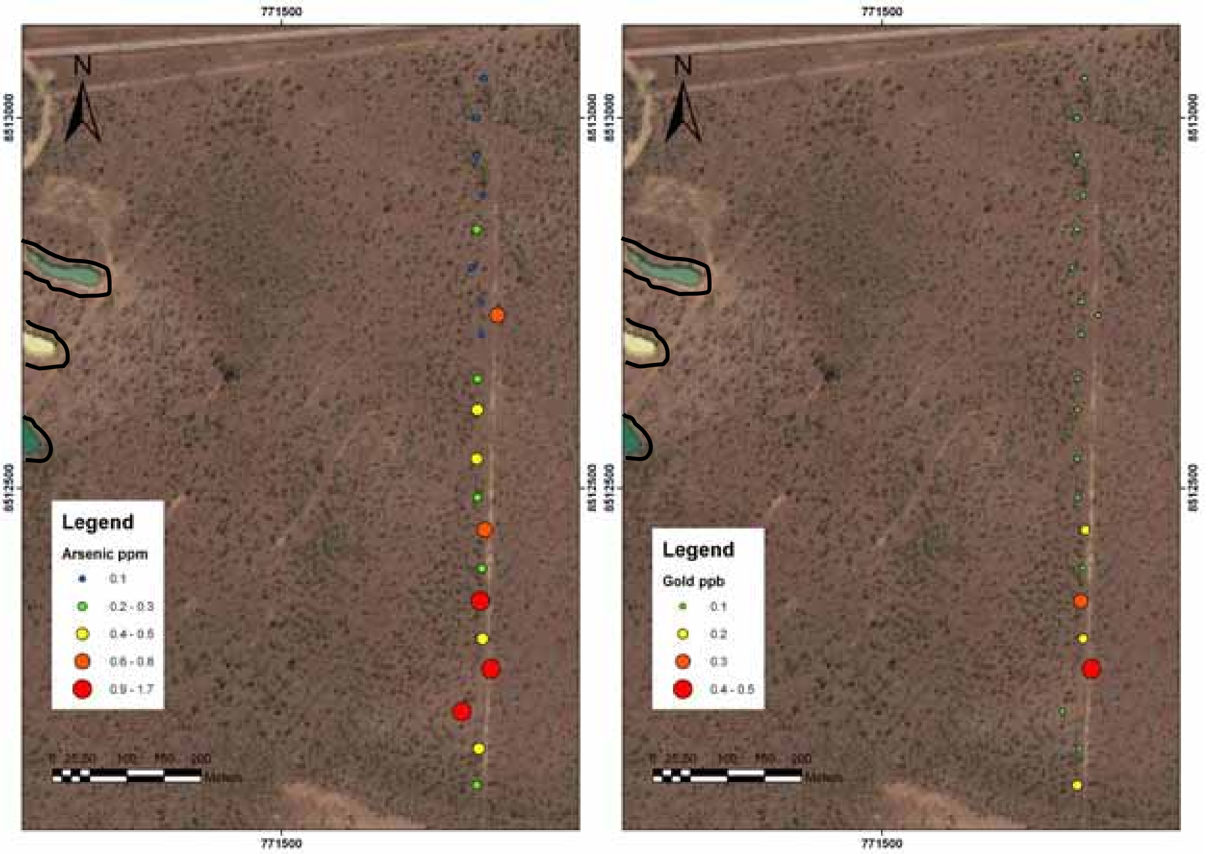

**Figure 7.27: Spatial distribution of As and Au assay results for *Eucalyptus miniata* along the Glencoe transect overlying the satellite imagery. Known mineralisation within the black lines.**

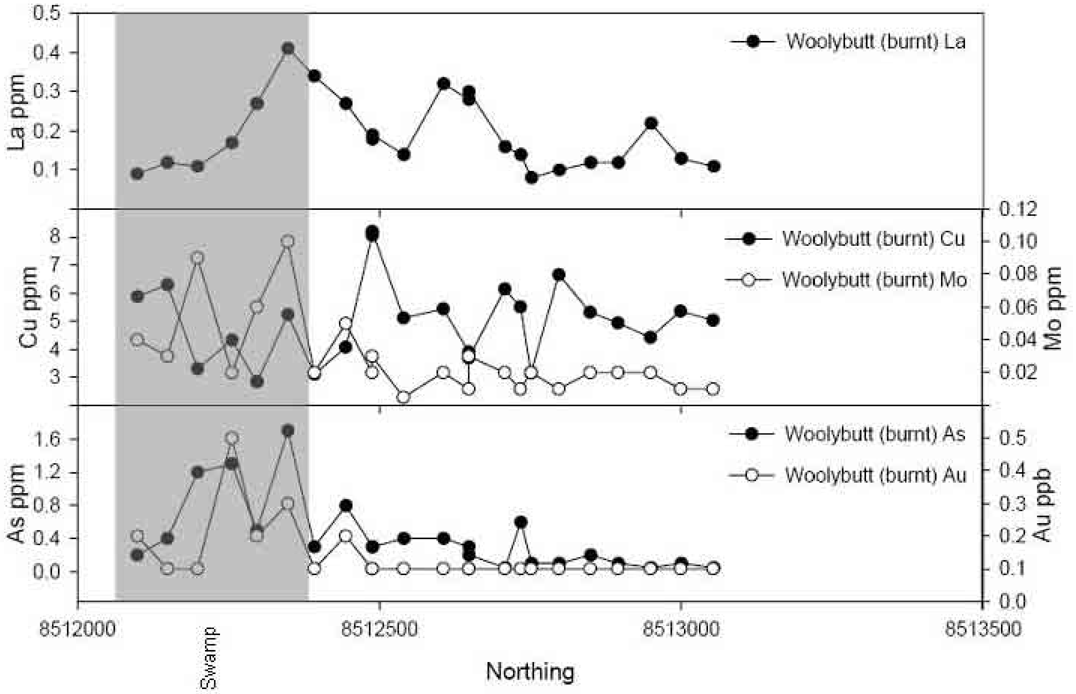

**Figure 7.28:** ***Eucalyptus miniata*** **(burnt) elemental cross section across the Glencoe transect**

### Discussion

The results from this species seem to be even more pronounced than the spear grass results (Figure 7.28). The normal pathfinder elements have very strong elevated values towards the south swampy area, however, there are still very small magnitude high values over the centre of the transect in both As and Mo (Figure 7.27). This corresponds with the Cu and REE and the results from the spear grass highlighting this region as being of greater potential than the southern region.

### *Eucalyptus miniata* (woolybutt – green leaves)

*Eucalyptus miniata* had a wide distribution across the field site and the results from the green leaves show 3 distinct elemental patterns:

1. Elements elevated to the north (Cr, Li, Ni, P, S and Ti);
2. Elements showing elevated values to the centre and south (Au, Mo and Pb); (Figure 7.29) and,
3. Elements elevated to the centre (As, Ba, Ca, Ce, Co, Cs, La, Mg, Mn, Na, Rb, Sr, Tl, Y and Zn). (Figure 7.29)

There are also elements that are irregularly distributed (B, Cd, Cu, Ge, Hf, Hg and K). Elements that were below analytical detection limit were Ag, Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V and W.

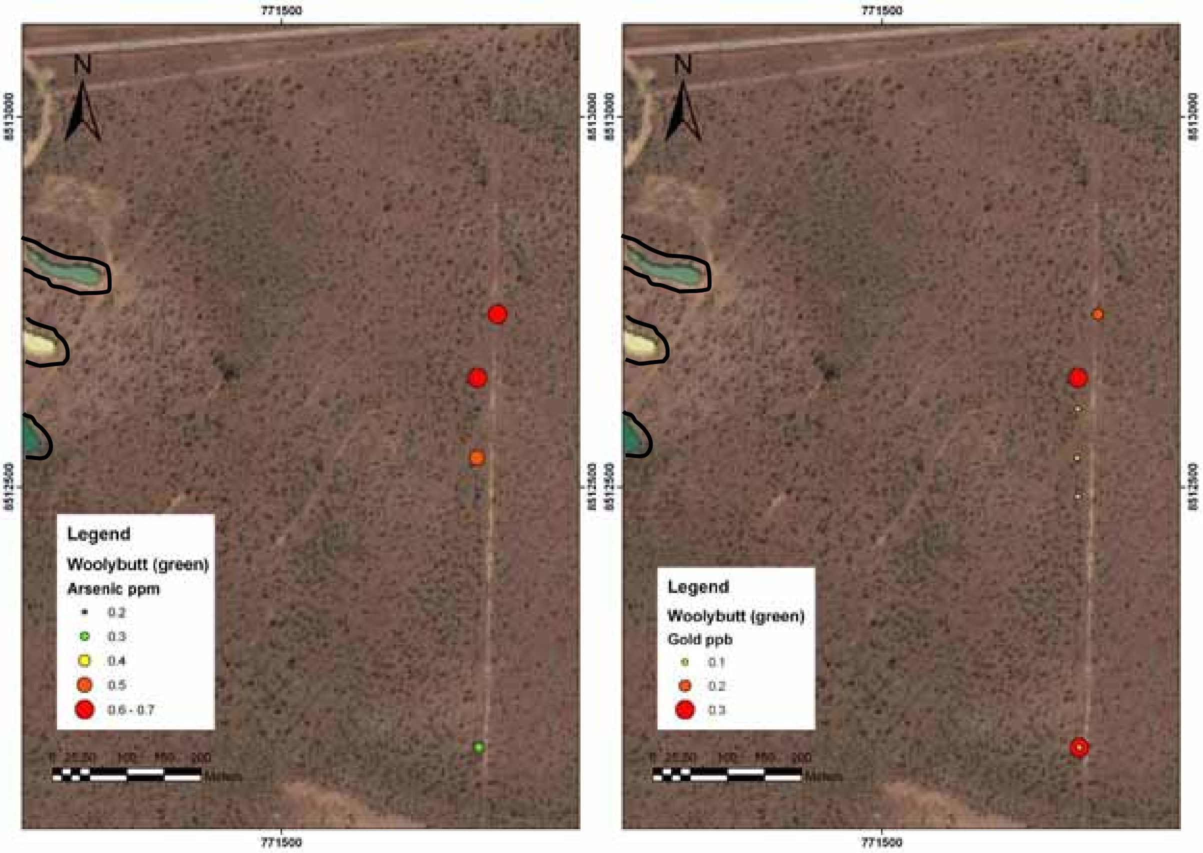

**Figure 7.29: Spatial distribution of As and Au assay results for *Eucalyptus miniata* along the Glencoe transect overlying the satellite imagery. Known mineralisation within the black lines.**

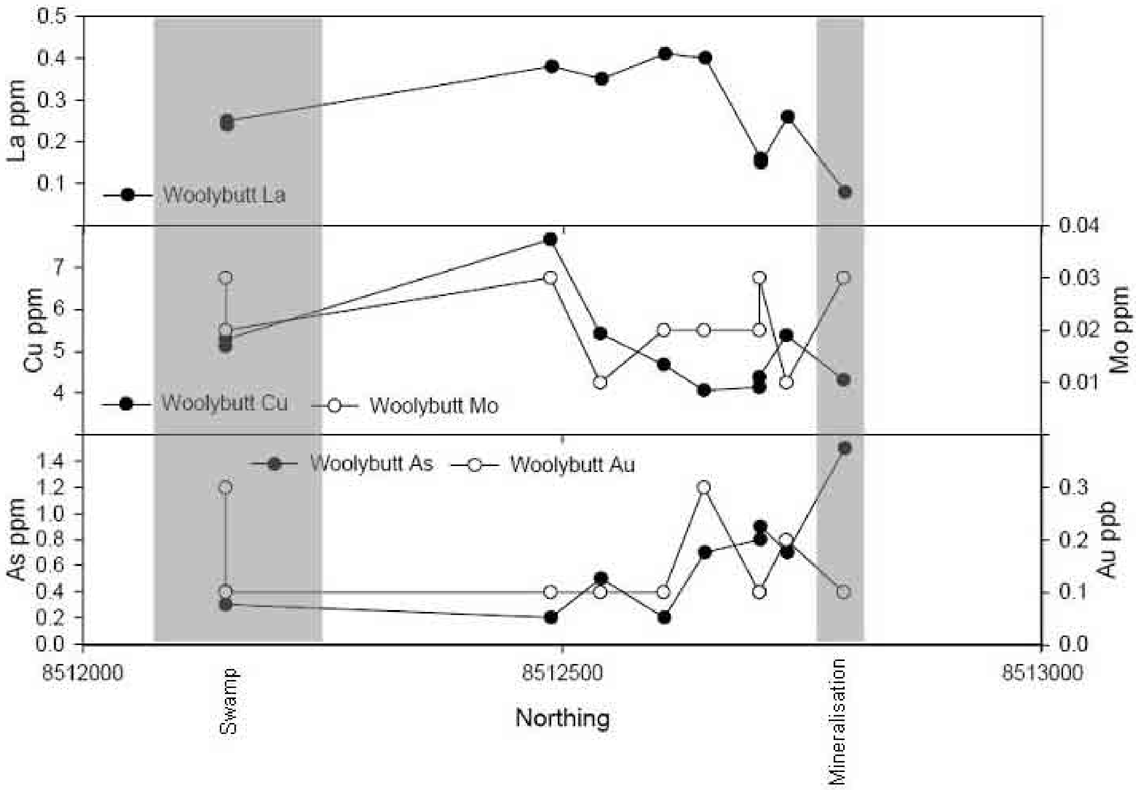

**Figure 7.30: *Eucalyptus miniata* (green) elemental cross section across the Glencoe transect**

## Discussion

Several of the *E. miniata* trees had both green and burnt leaves on them, so both types were collected off these trees. In general the elements behaved in similar fashions but with fewer points for the green leaves (Figure 7.30). This meant that without the previous results from the burnt leaves it would be difficult to gain meaning from these assays. However, since the samples collected from the mineralisation were all of green leaves, this data needed to be presented as a comparison for the burnt leaves.

### 7.2.5 McKinlay

The biogeochemical expression of mineralisation at McKinlay has consistently detectable and in some cases high Ag contents (3-24 ppm Ag), low but consistently detectable Au (detection limit to 0.4 ppb Au), as well as consistently moderately high Zn contents (25.5-58.1 ppm Zn), and variable but high La (up to 1.67 ppm La) and As (up to 1.1 ppm As) contents. Although mostly detectable in samples, the Au contents were not particularly high (detection limit – 0.4 ppb Au). The *Cochlospermum fraseri* samples (MC KAPOK A and MC KAPOK B) from the pit walls had the highest Ag contents (22 and 24 ppm Ag) with the sample MC KAPOK A also having the highest As (1.1 ppm), La (1.67 ppm) and Zn (58.1 ppm) contents.

#### *Heteropogon triticeus* (tall spear grass)

*Heteropogon triticeus* had a wide distribution across the field site and the results show 5 distinct elemental patterns:

1. Elements elevated to the east (Ca, Co, Cr, Li, Mo, Na, Nb, Pb, Sb and Sr);
2. Elements elevated to the west (P and Ti);
3. Elements showing elevated values to the east and centre (Al, Ba, Ce, Fe, Hf, La, Th, U, Y, Zn and Zr);
4. Elements elevated to the centre (Ag, As, Au, Cd, Cu, Mg, Ni, S and Tl); (Figure 7.31) and,
5. Elements lower over the centre (Cs and Se).

There are also elements that are irregularly distributed (B, Ge, Hg, K, Mn, Rb and Re). Elements that were below analytical detection limit were Be, Bi, Ga, In, Pd, Pt, Sc, Sn, Te, V and W.

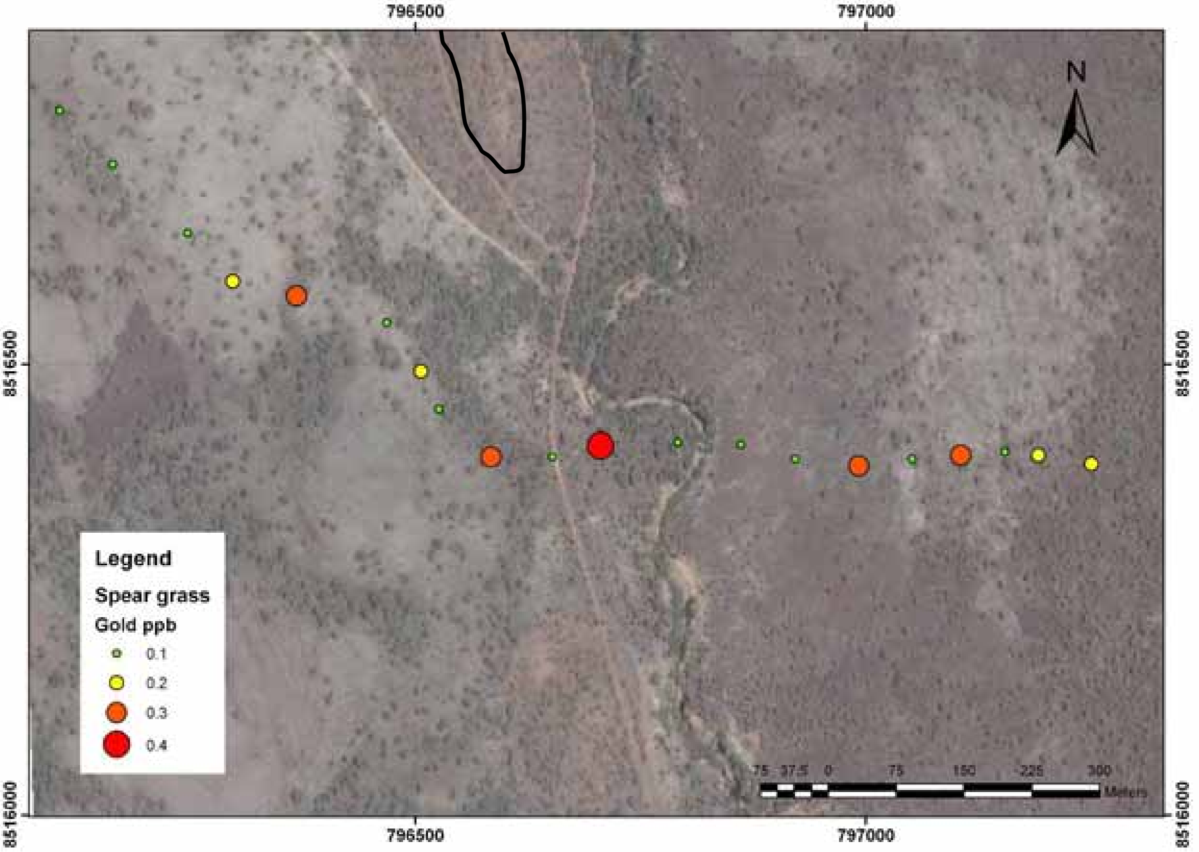

**Figure 7.31: Spatial distribution of Au assay results for *Heteropogon triticeus* along the McKinlay transect overlying the satellite imagery. Known mineralisation is within the black line.**

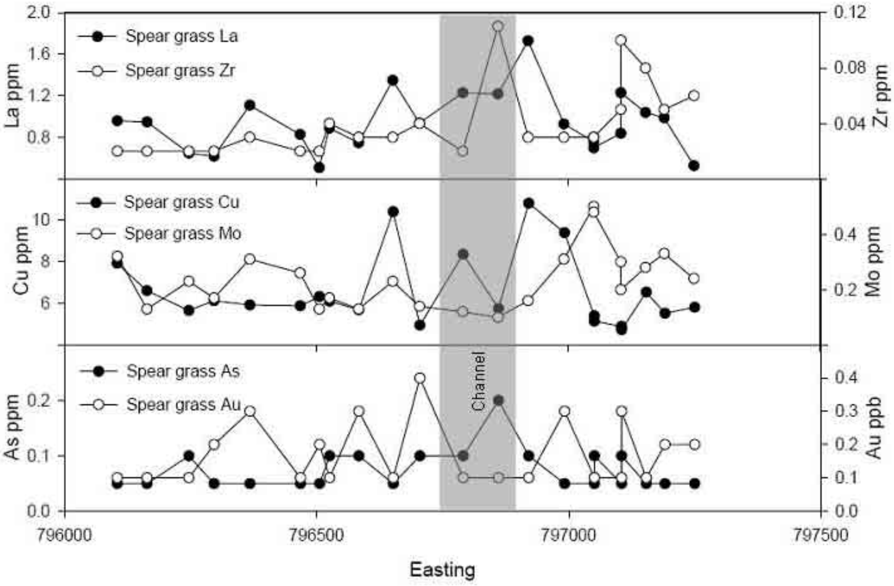

**Figure 7.32: *Heteropogon triticeus* elemental cross section across the McKinlay transect**

## Discussion

The results from this species shows high values around the centre of the transect within all the usual pathfinder elements (Figure 7.32). This is problematic as this is also the location of the major creek running through the area and hence should contain the most transported material. However, the area with the most detrital component is towards the east with some over the central area which suggests transport is heading south with the creek flow and east with lateral wash outs. The benefit of this is that anomalism found on the western bank of the creek (Au and Cu, Figure 7.32) are more likely to be derived from buried mineralisation which would continue from the bedrock ridge to the north.

**_Corymbia polycarpa_ (long-fruited bloodwood)**

*Corymbia polycarpa* had a patchy distribution across the field site and the results show 5 distinct elemental patterns:

1. Elements elevated to the east (Ba);
2. Elements elevated to the west (As, Cs, Cu, Pb and Rb); (Figure 7.33)
3. Elements showing elevated values to the east and centre (Ca, Ce, La, Tl, U, Y and Zn);
4. Elements elevated to the centre (Cd, Cr, Ni, P, S and Se); and,
5. Elements lower over the centre (Co and Na).

There are also elements that are irregularly distributed (Au, B, Fe, Ge, Hf, Hg, K, Li, Mg, Mn, Mo, Sr, Ti and Zr). Elements that were below analytical detection limit were Ag, Al, Be, Bi, Ga, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V and W.

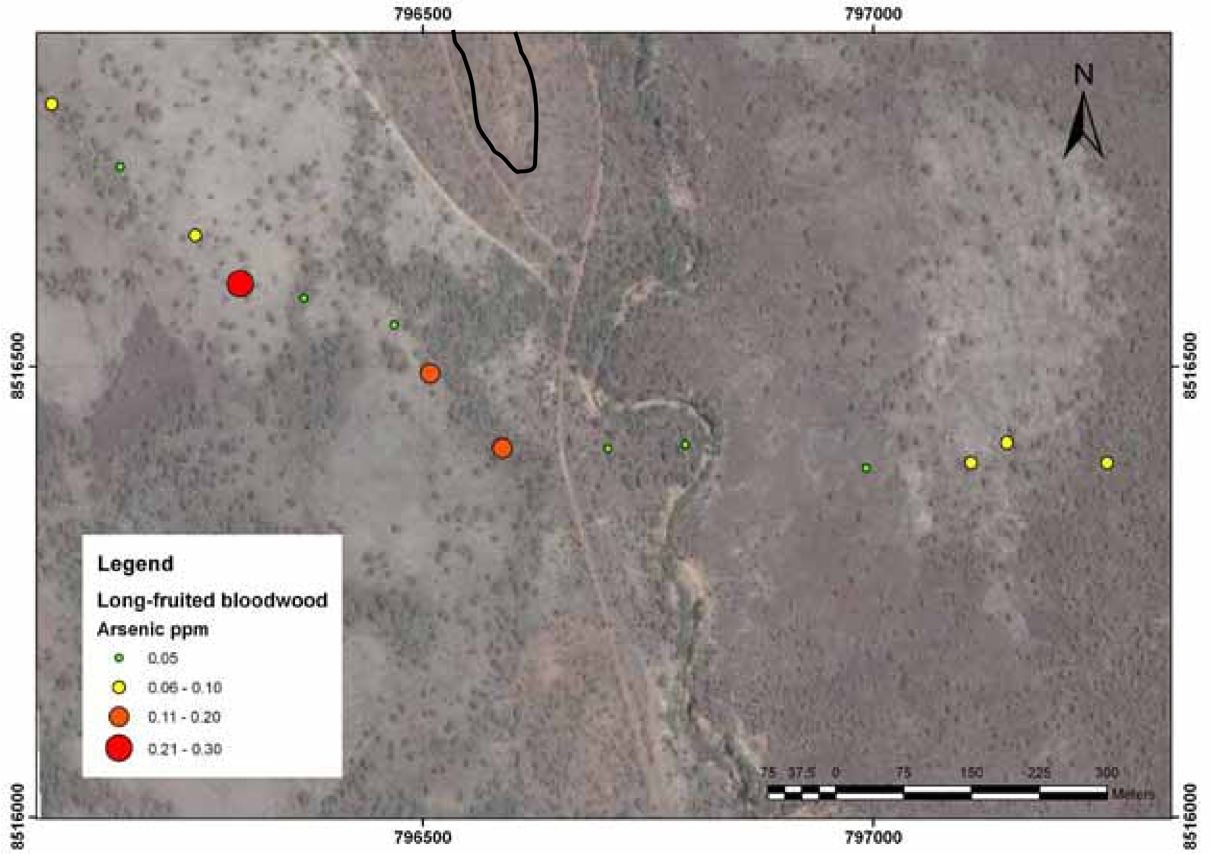

**Figure 7.33: Spatial distribution of As assay results for *Corymbia polycarpa* along the McKinlay transect overlying the satellite imagery. Known mineralisation is within the black line.**

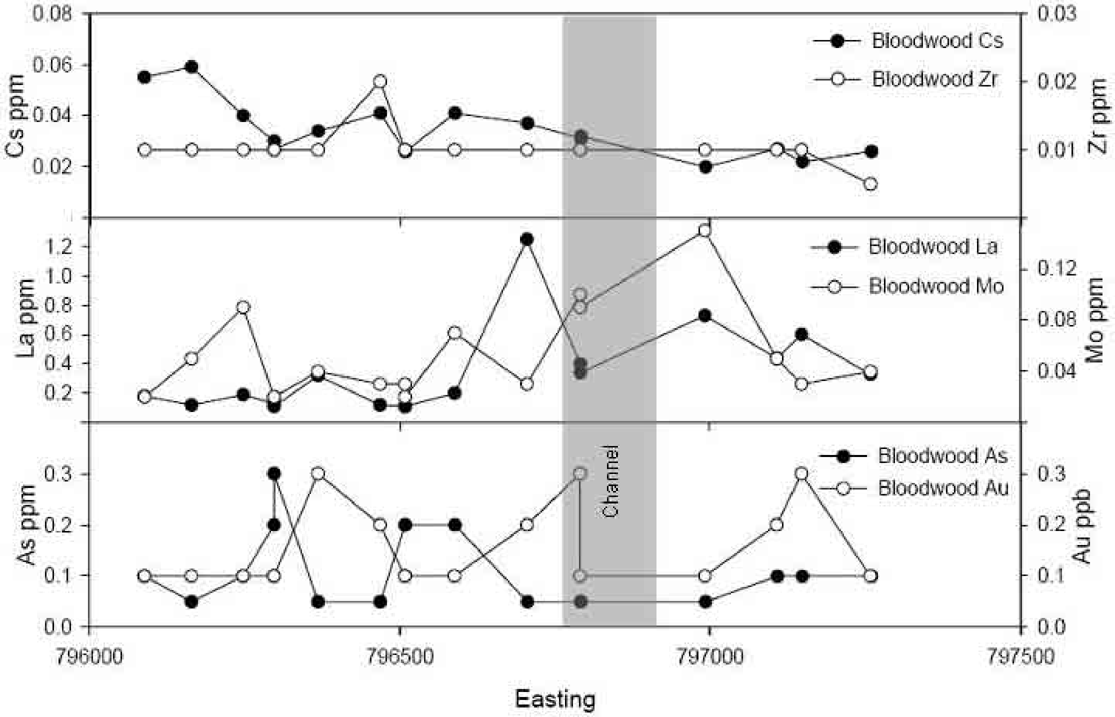

**Figure 7.34:** ***Corymbia polycarpa*** **elemental cross section across the McKinlay transect**

## Discussion

The results from this species are different from that seen with the spear grass (Figure 7.34). The Au results show 3 areas of higher values: to the east, the centre and the west of the transect. The spear grass results highlight the east as being higher in detrital contaminants so the eastern anomaly is less likely to be from mineralisation. The central anomaly would correspond with the previous results and do correspond with REE, S and Zn results, but the western anomaly is different. This anomaly also has a corresponding region of higher concentration of As, which could lead to this area being potentailly prospective for Au.

### *Eucalyptus foelscheana* (broad-leaved bloodwood)

*Eucalyptus foelscheana* had a patchy distribution across the field site and the results show 3 distinct elemental patterns:

1. Elements elevated to the east (Na and Tl);
2. Elements showing elevated values to the east and centre (Co, Cs, Cu, Ni, Rb, U and Zn);
3. Elements elevated to the centre (Ag, As, Au, B, Ba, Cd, Ce, Cr, Fe, La, Mg, Mn, Mo, P, Pb, S, Se, Ti and Y); (Figure 7.35) and,

There are also elements that are irregularly distributed (Ca, Ge, Hg, K, Li, Sr, Te and Zr). Elements that were below analytical detection limit were Al, Be, Bi, Ga, Hf, In, Nb, Pd, Pt, Sb, Sc, Sn, Te, V and W.

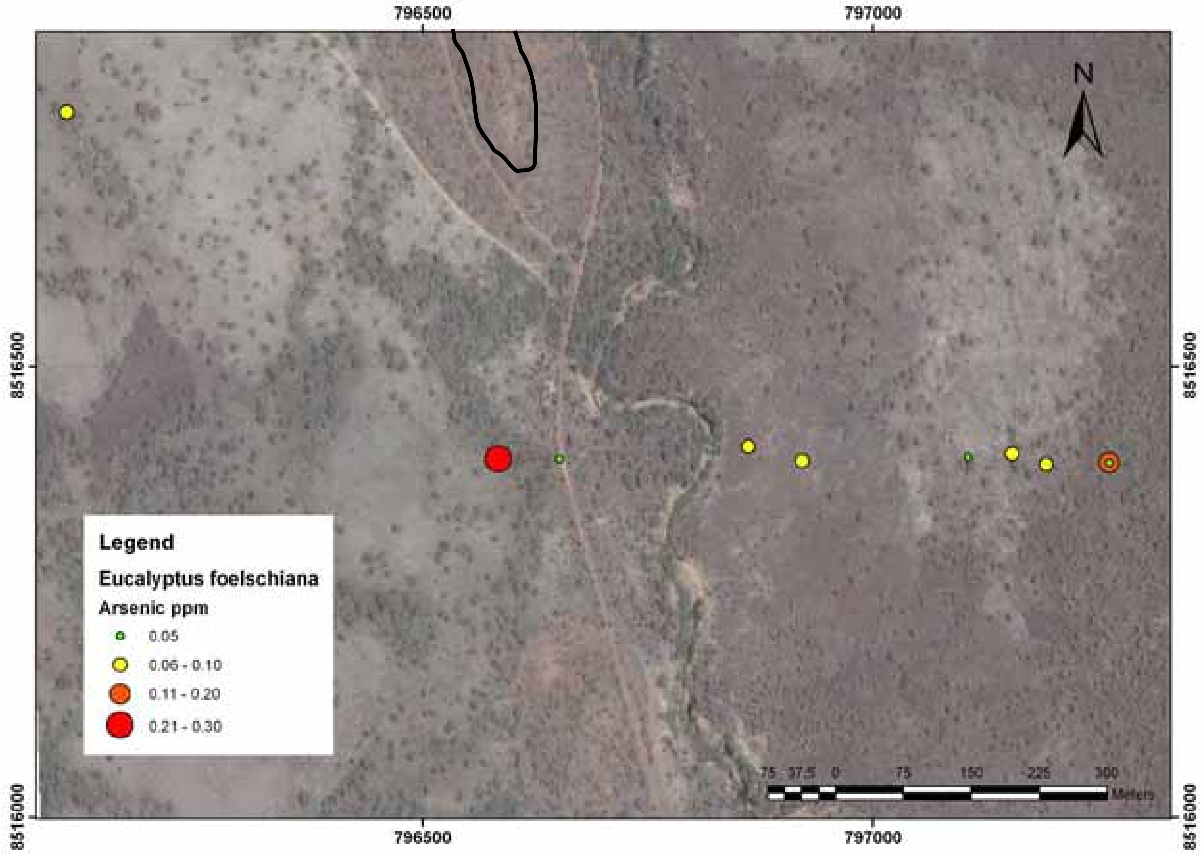

**Figure 7.35: Spatial distribution of As assay results for *Eucalyptus foelscheana* along the McKinlay transect overlying the satellite imagery. Known mineralisation is within the black line.**

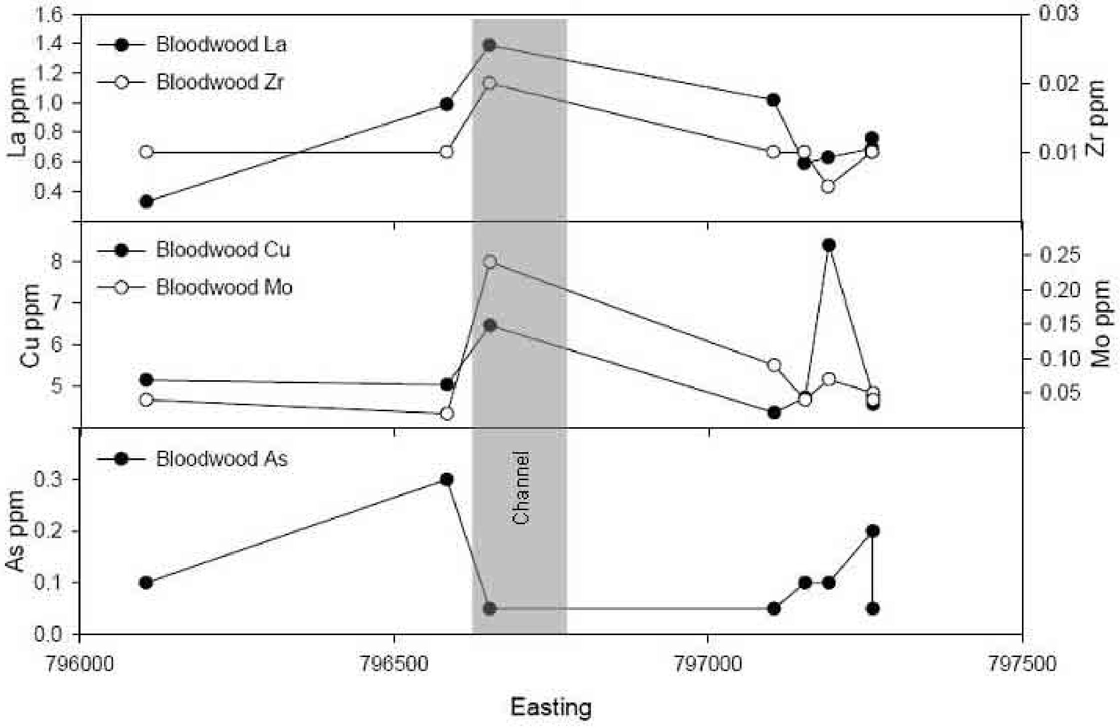

**Figure 7.36: *Eucalyptus foelscheana* elemental cross section across the McKinlay transect**

## Discussion

The results shown by this species were hampered by the small sample size (Figure 7.36). Most of the samples were near the centre of the transect so most of the high values are over this area. However, combined with the other species the spatial plots do correlate with respect to the pathfinder elements (As, Cu, REE and Mo) which reinforces the centre of the transect as being the region most likely to host an extension to known mineralisation. This signal would be greatly influenced by the channel sediments and would need to be further investigated to determine whether there was a true mineralisation signature or (more likely) that the signature is from materials flowing off of the known mineralisation (bedrock high). There were no samples collected over the western area shown as prospective in the *Corymbia polycarpa* results.

### *Eucalyptus miniata* (woolybutt)

*Eucalyptus miniata* had a patchy distribution across the field site and the results show 4 distinct elemental patterns:

1. Elements elevated to the east (Ce, Co, La, Ni, Te, U and Y);
2. Elements elevated to the west (As, Cr, Cs, K, Mn, Na, Rb, S, Sr and Tl); (Figure 7.37)
3. Elements showing elevated values to the east and centre (Ca, Cu, Mo, Pb and Zn);
4. Elements elevated to the centre (Cd and Mg); and,

There are also elements that are irregularly distributed (Au, B, Ba, Fe, Ge, Hg, Li, P and Ti). Elements that were below analytical detection limit were Ag, Al, Be, Bi, Ga, Hf, In, Nb, Pd, Pt, Sb, Sc, Se, Sn, Te, V, W and Zr.

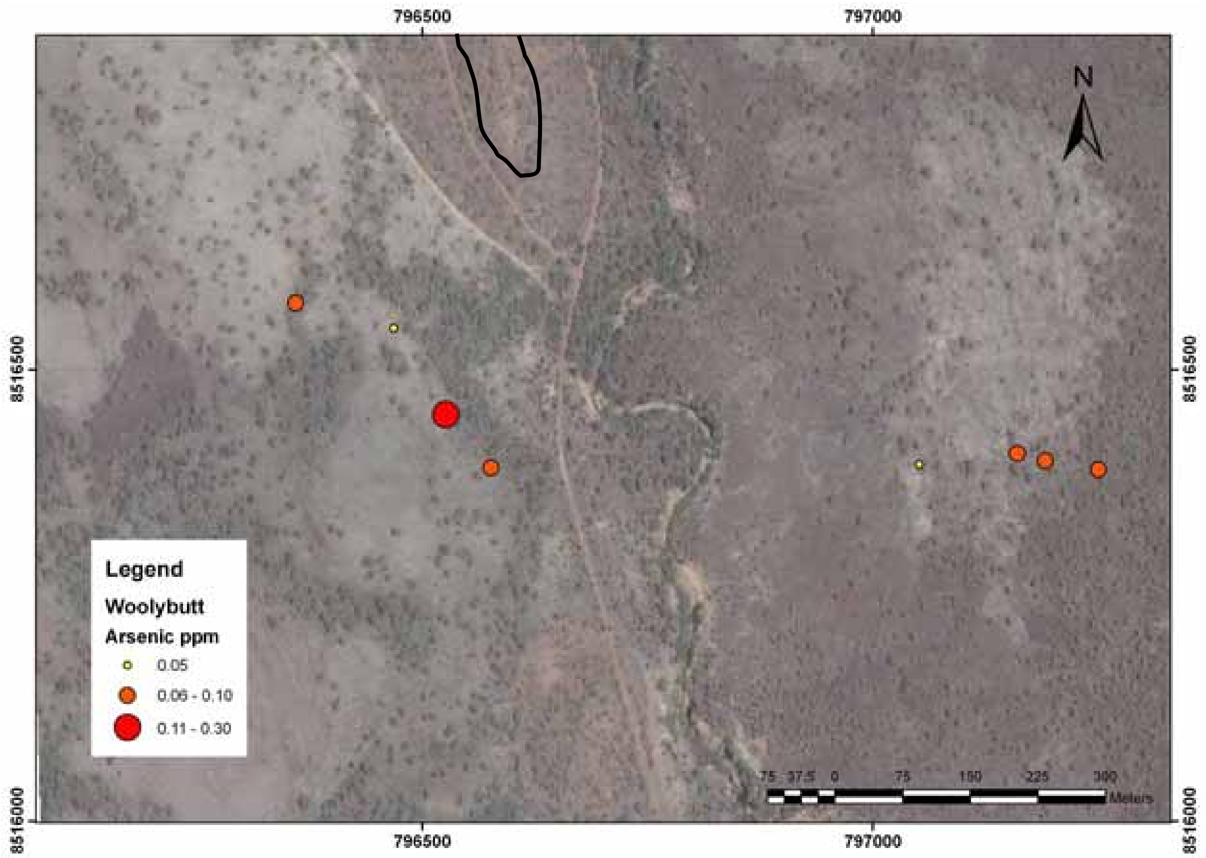

**Figure 7.37: Spatial distribution of As assay results for *Eucalyptus miniata* along the McKinlay transect overlying the satellite imagery. Known mineralisation is within the black line.**

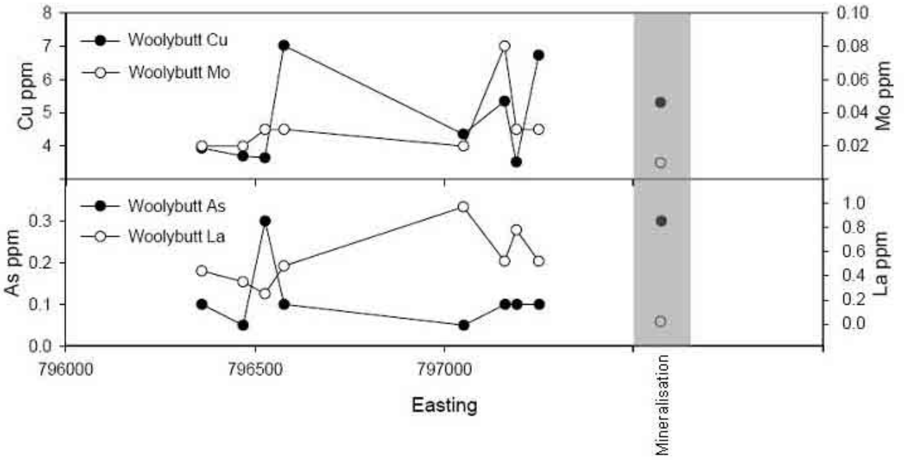

**Figure 7.38: *Eucalyptus miniata* elemental cross section across the McKinlay transect**

## Discussion

The results for *Eucalyptus miniata* are similar to the *Eucalyptus foelscheana* in that they are hampered by having a smaller sample size (Figure 7.38). There were no trees growing over the creek area so extrapolation of the data is required to determine if the concentrations of pathfiner elements correspond with the results found in the other species. Without including the direct pathfinders, As and Au, the more dispersed pathfinder elements (Cu, Mo, Pb, S and Zn) all correspond to the areas shown in the other species.

### 7.2.6 Species Differences

In general *Heteropogon triticeus* had the highest contamination levels of all the plants sampled in this region. However, these levels were low and deemed to have little significance since none of the pathfinder elements followed the same trend as the contaminant elements (Al, Fe, Hf, Th, Ti and Zr). Summaries of some for the important differences can be seen visually in Figures 7.39 – 7.47.

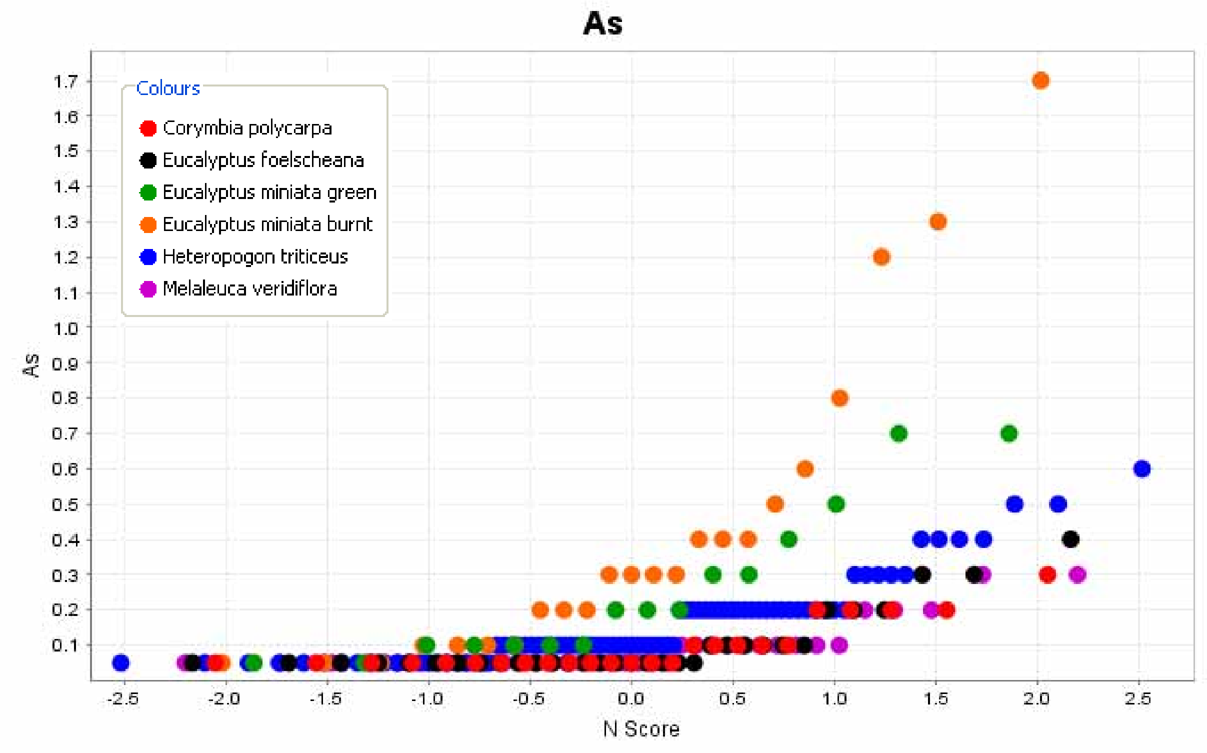

**Figure 7.39: As results split by species at the Pine Creek Prospects.**

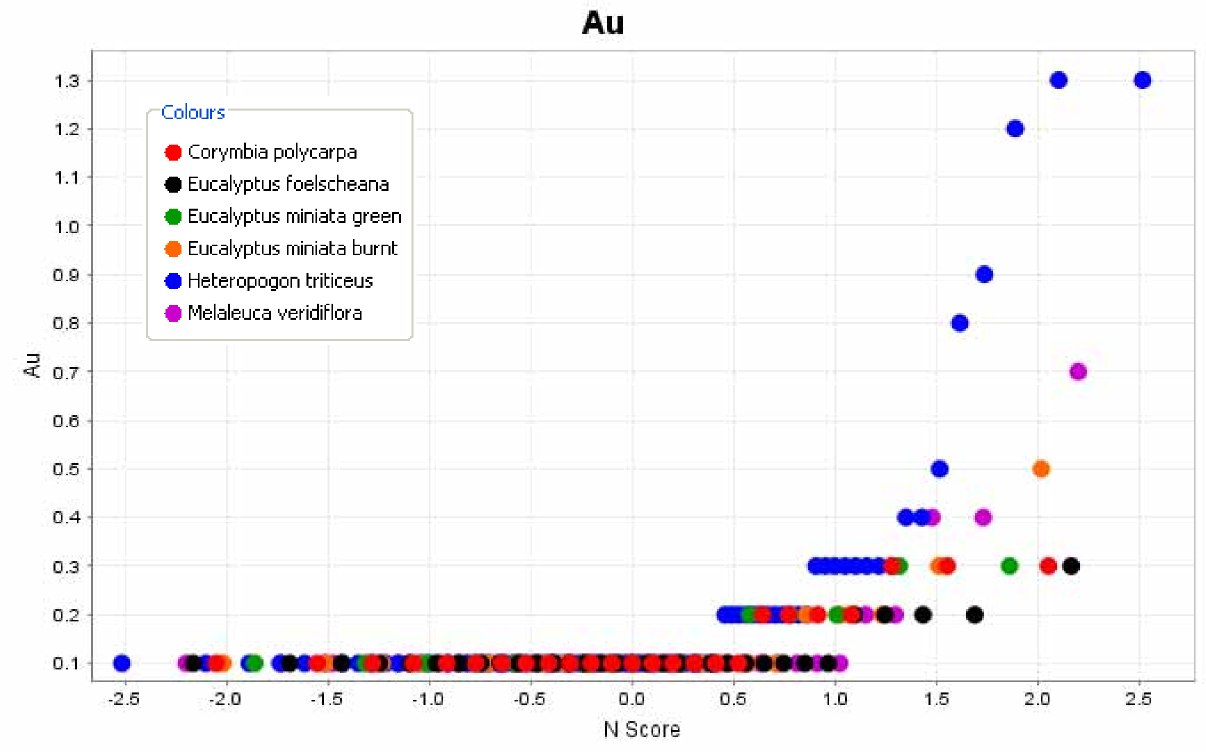

**Figure 7.40: Au results split by species at the Pine Creek Prospects.**

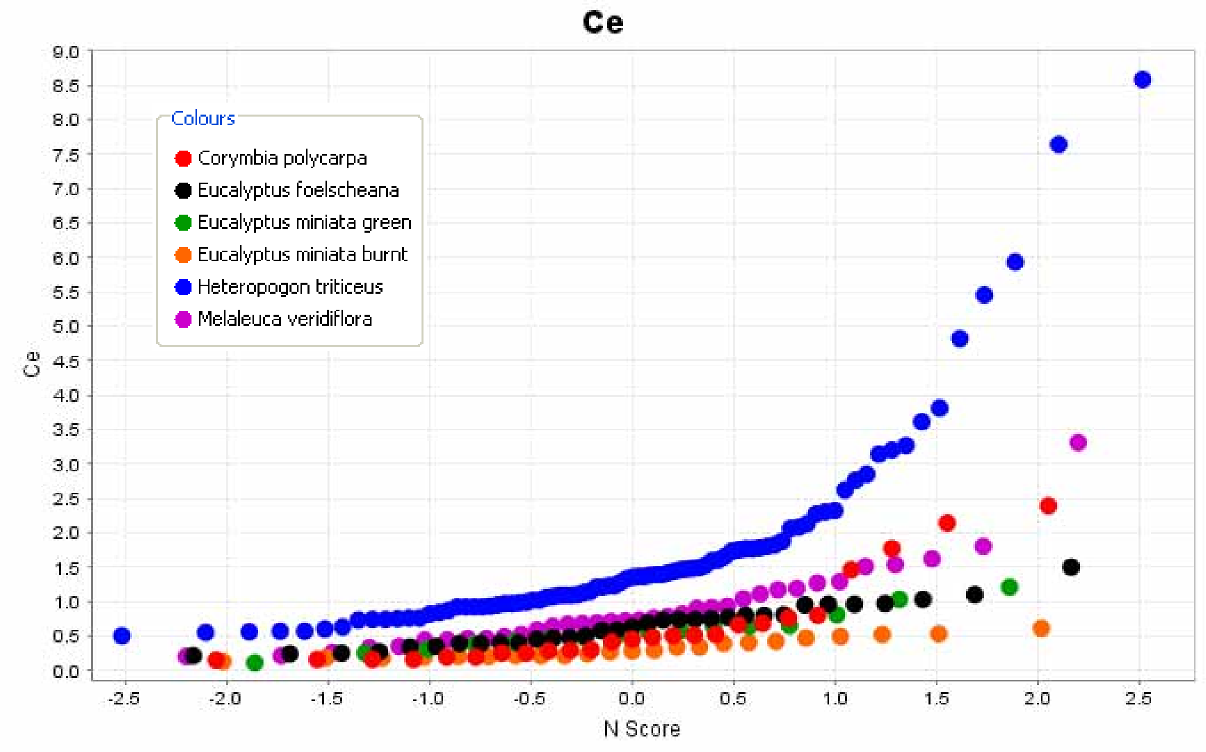

**Figure 7.41: Ce results split by species at the Pine Creek Prospects.**

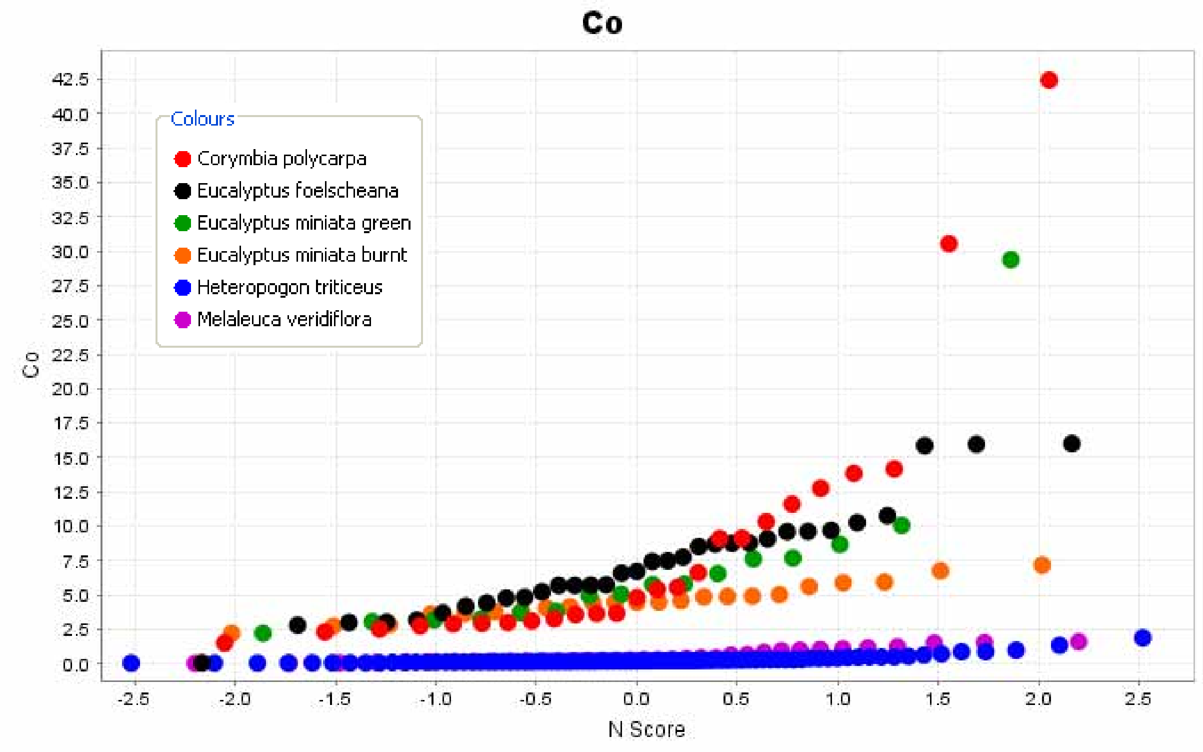

Figure 7.42: Co results split by species at the Pine Creek Prospects.

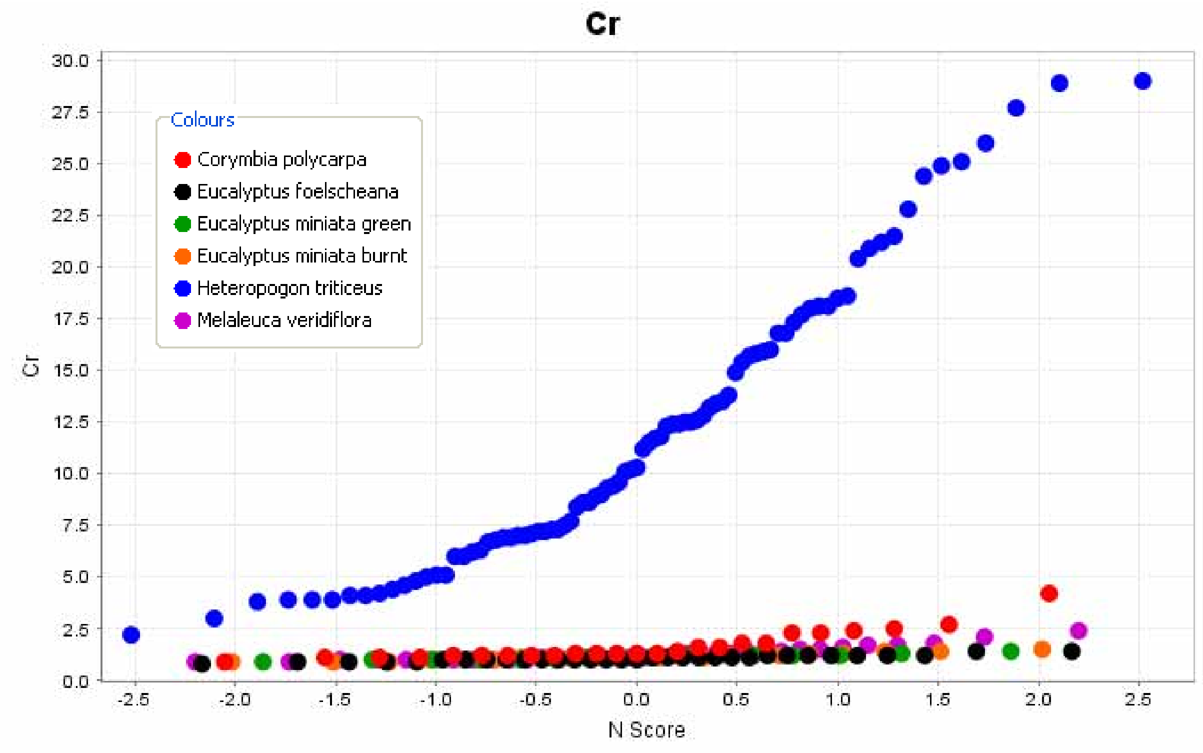

Figure 7.43: Cr results split by species at the Pine Creek Prospects.

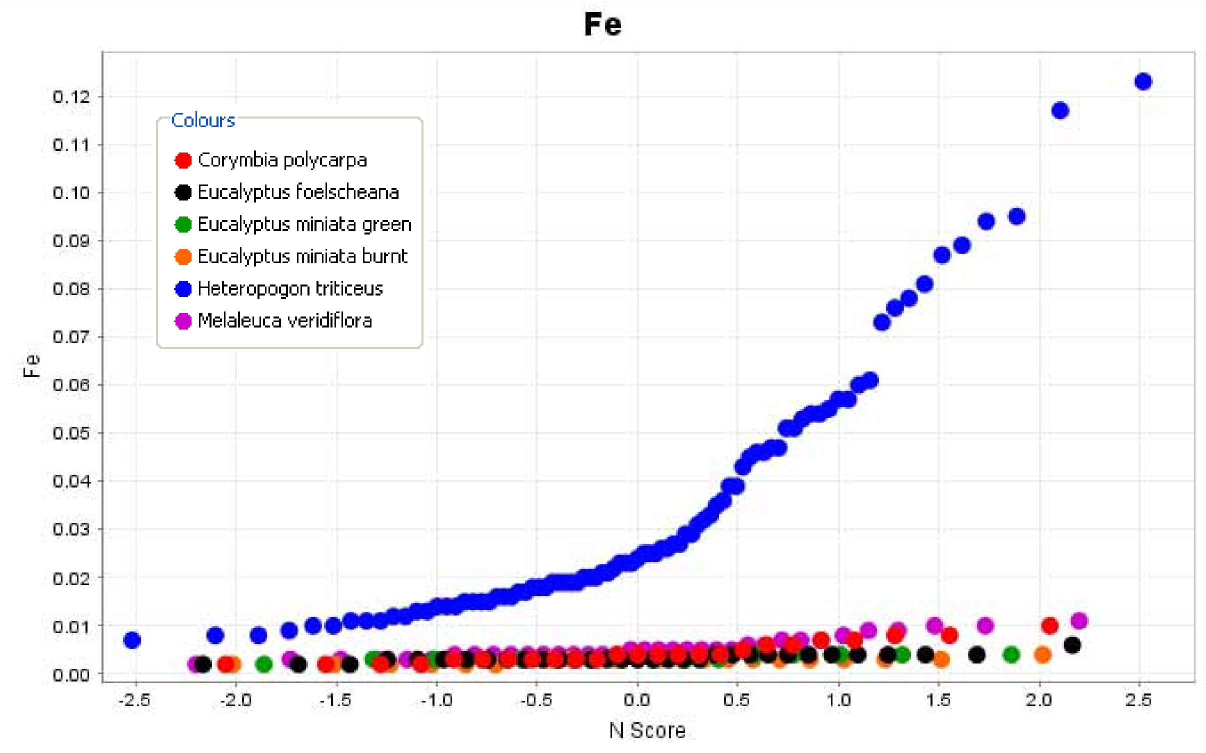

Figure 7.44: Fe results split by species at the Pine Creek Prospects.

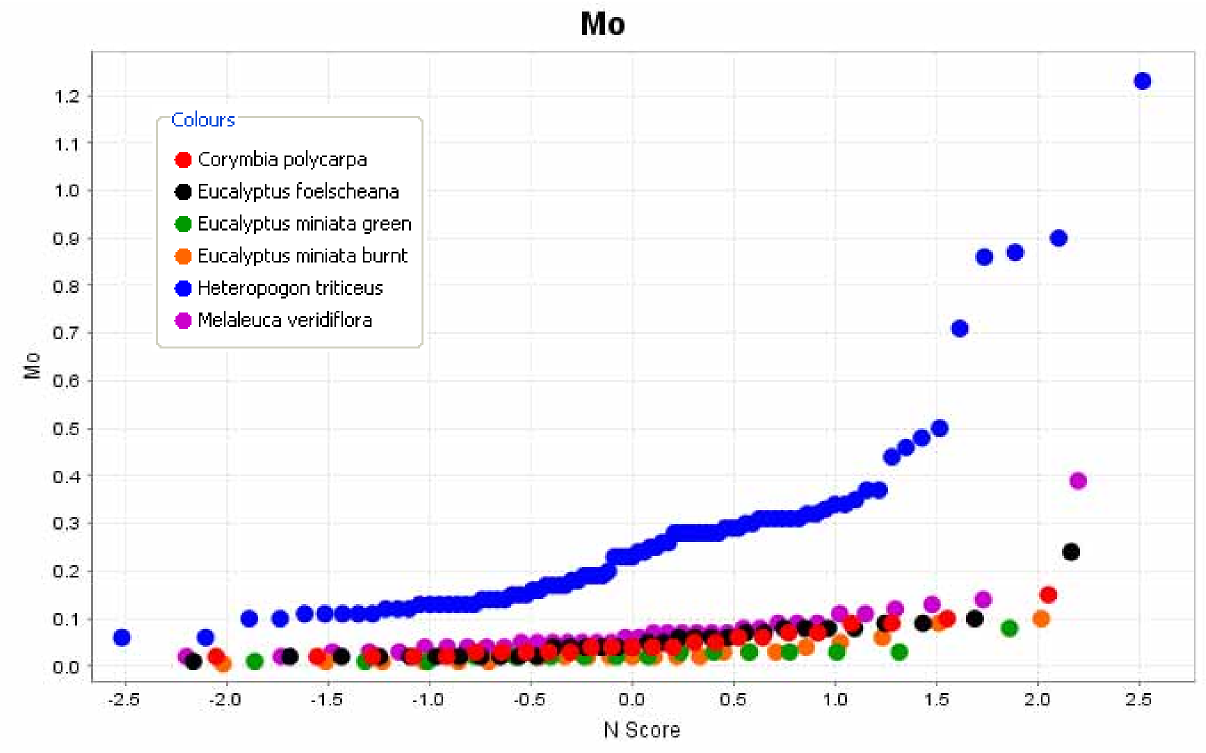

Figure 7.45: Mo results split by species at the Pine Creek Prospects.

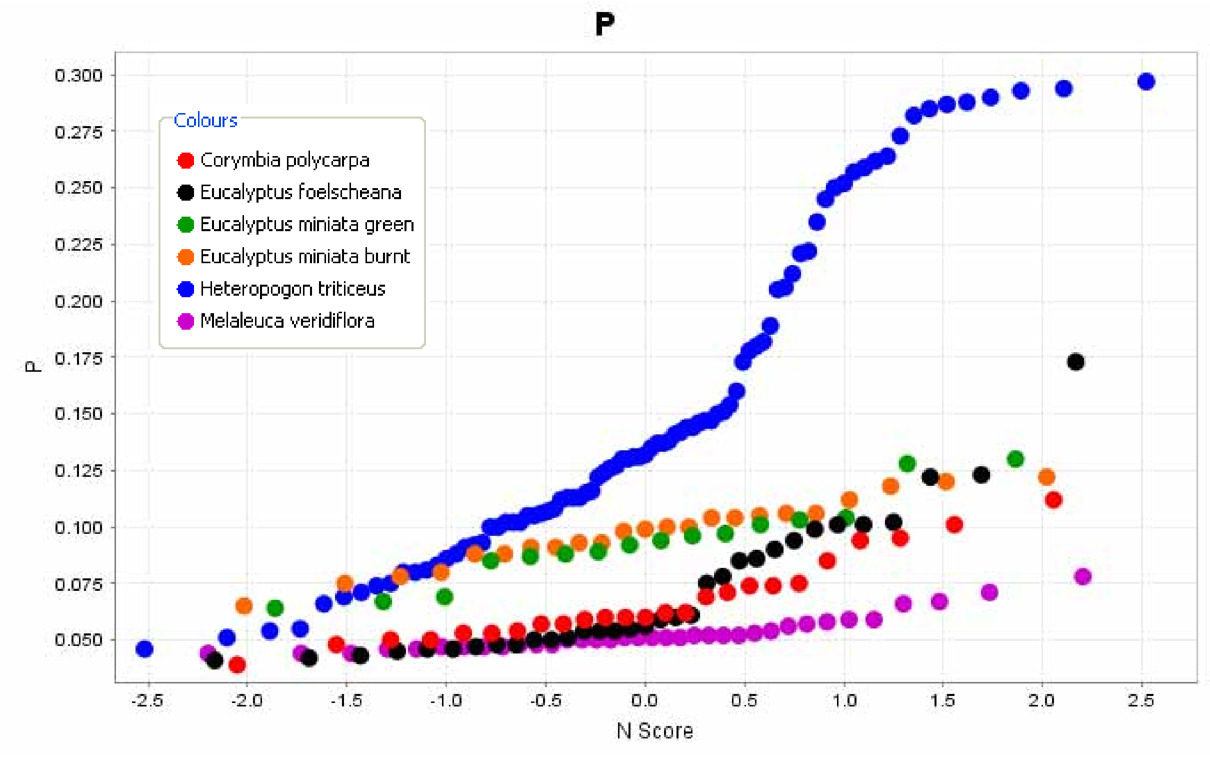

**Figure 7.46: P results split by species at the Pine Creek Prospects.**

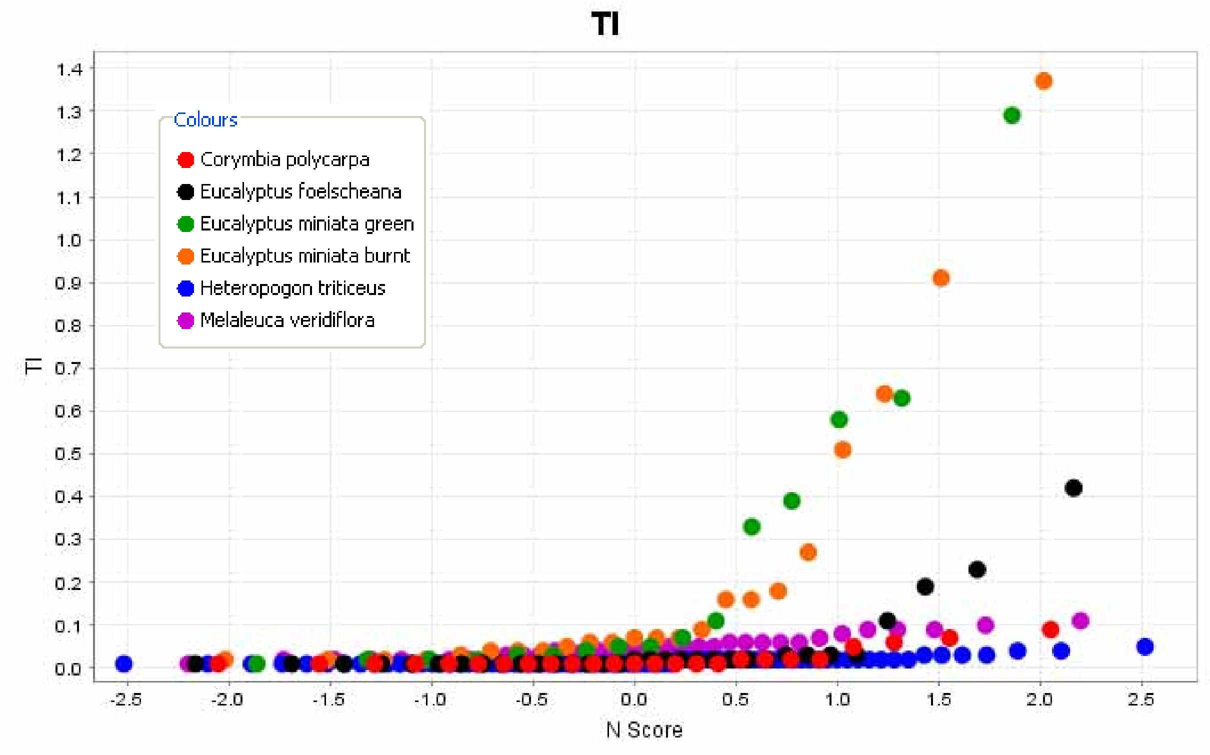

**Figure 7.47: Tl results split by species at the Pine Creek Prospects.**

Elements that are considered to be uptaken by passive mechanisms (As, Au) appear to be relatively consistent between species where there is a gentle anomaly to background contrast. The trend in the REE (Ce, La, Y) show the same trend for all plant species, however, the magnitude of the anomalism is different. This is much greater in the *Heteropogon* results as this species seemed to have greater influence from the surficial dispersion of elements and so was able to uptake elements from dissolved detrital monazites. Molybdenum is also higher within the spear grass results, but it is does not seem to be related to the contamination or dispersion of elements, which indicates that Mo results could be linked to mineralisation.

Phosphorous results are very different in this region than was seen in the Tanami Desert. The spear grass is able to uptake much greater concentrations than the other plants in the area. This suggests that unlike in the arid regions, P is not limited in the Australian tropical savanna region. Therefore, plant growth is not limited by this factor.

An interesting result from the Pine Creek samples is that the Tl concentrations in all the sites are much greater than in any of the other sites studied, and Glencoe has the greatest concentrations of all. Of greater interest is that both burnt and unburnt leaves from the Glencoe site show the same concentrations within most of the elements.

### 7.2.7 Elemental Correlations

Correlation coefficients were calculated using Excel for all the vegetation samples and for each individual species shown visually in Figures 7.48 – 7.54. The general trends for each species were very similar. All the contaminant elements in the data set correlate strongly with each other, shown by Fe and Zr (0.96). One interesting difference from the trends seen at the Tanami sites is that Th is not correlated with the contaminant elements but with U, which suggests that in the Pine Creek area Th is not bound with Fe-oxides but with U minerals which are prevalent in the region.

All the REE correlated very well with each other (Figure 7.48), which is to be expected as the main source of REE is monazite which has all the elements in fixed concentrations. The REE positively correlate with the contaminant elements (Al, Hf, Fe, Ti and Zr) indicating that the monazite hosts for the REE are in a detrital situation. However, *Heteropogon triticeus* appears to have a bimodal correlation which suggests two sources of monazites contributing to the concentration. One source would have moved further and hence be more contaminated, and the other would have moved less distance and would be more related to a primary monazite source. Since there was no correlation between REE and U there was likely no REE sourced from U minerals, or that since U is much more mobile than REE the relationships between these elements would have been destroyed due to movement throughout the profile.

*Heteropogon triticeus* has a strong positive correlation with Cr and Ni (0.86), the other plants have no distinct correlation with these elements. This is most likely relating to a barrier mechanism effect with respect to Cr from the other plants rather than accumulation of the spear grass. Since P was shown not to be limited in this environment there are strong correlations between P and other essential plant nutrients, in particular K (0.87) and S (except for *Melaleuca viridiflora*).

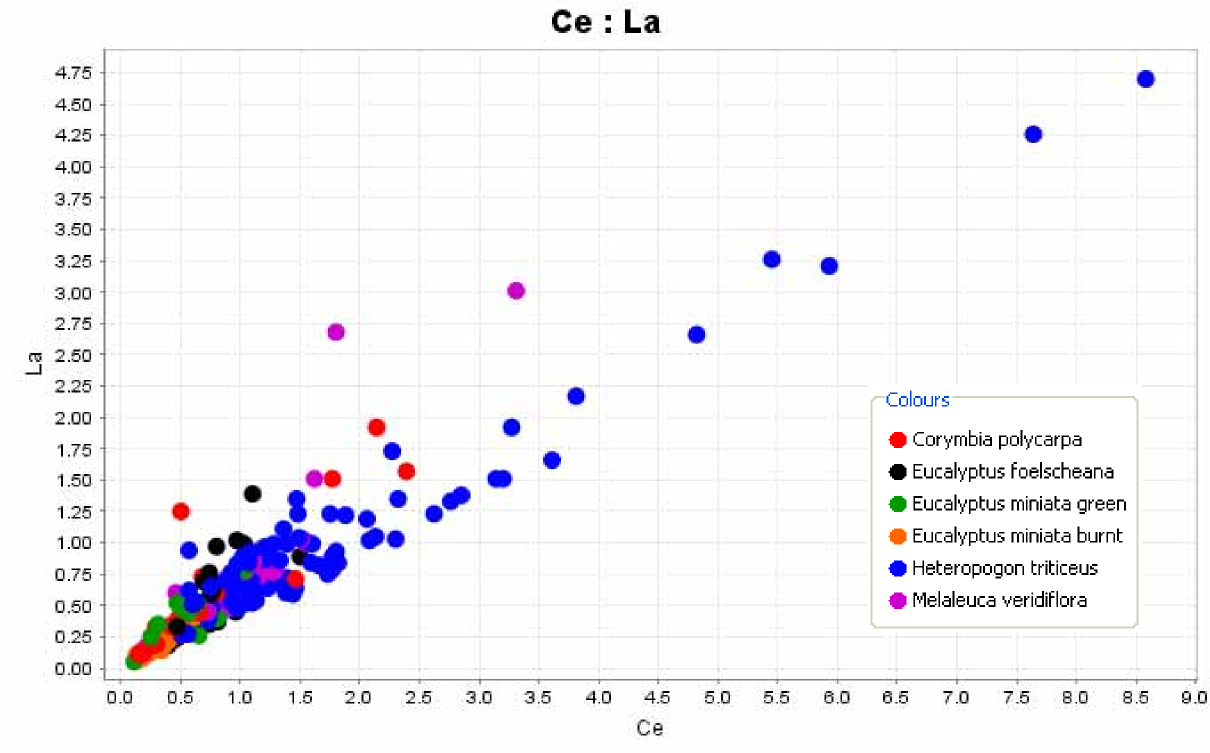

Figure 7.48: Ce and La visual correlation split by species at the Pine Creek Prospects.

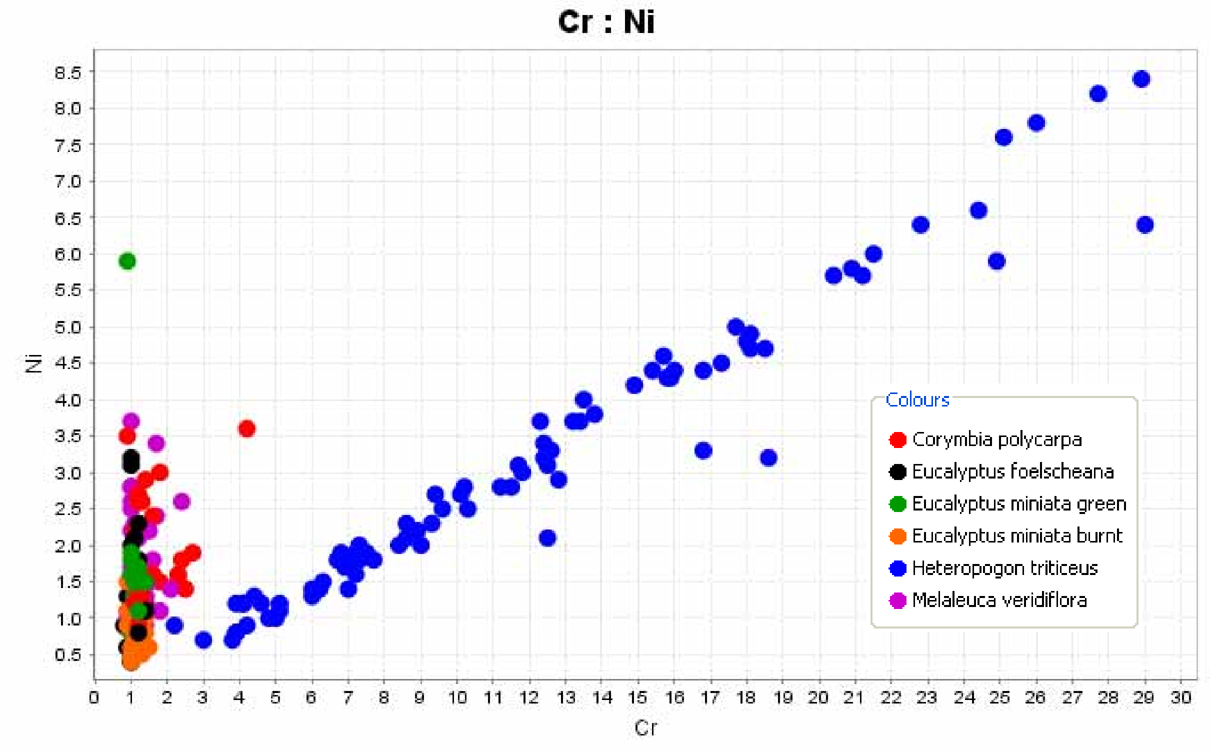

Figure 7.49: Cr and Ni visual correlation split by species at the Pine Creek Prospects.

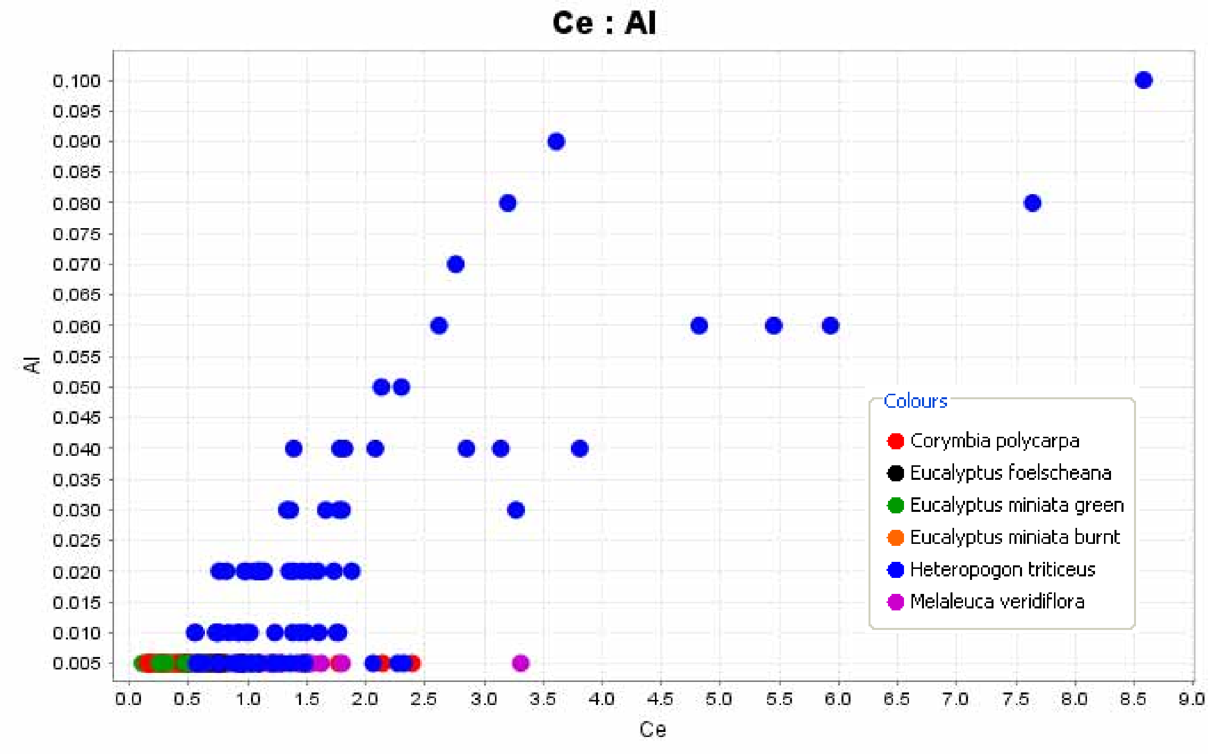

Figure 7.50: Ce and Al visual correlation split by species at the Pine Creek Prospects.

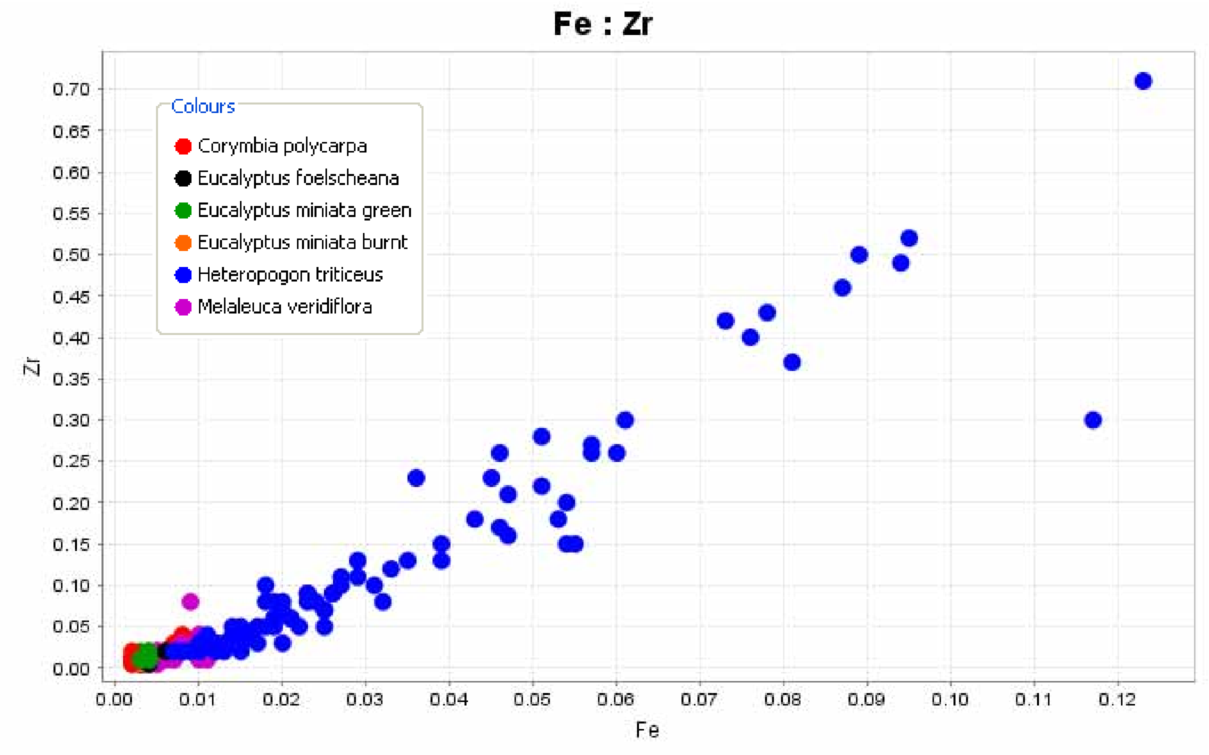

Figure 7.51: Fe and Zr visual correlation split by species at the Pine Creek Prospects.

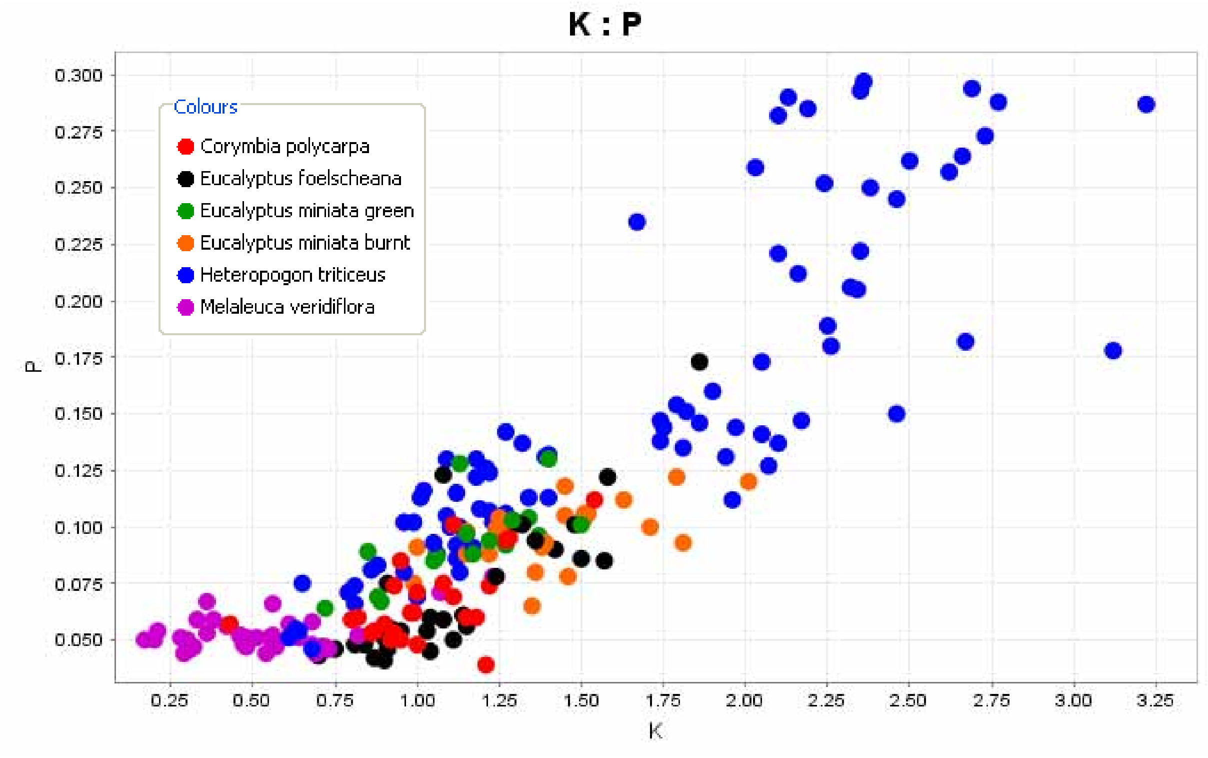

Figure 7.52: K and P visual correlation split by species at the Pine Creek Prospects.

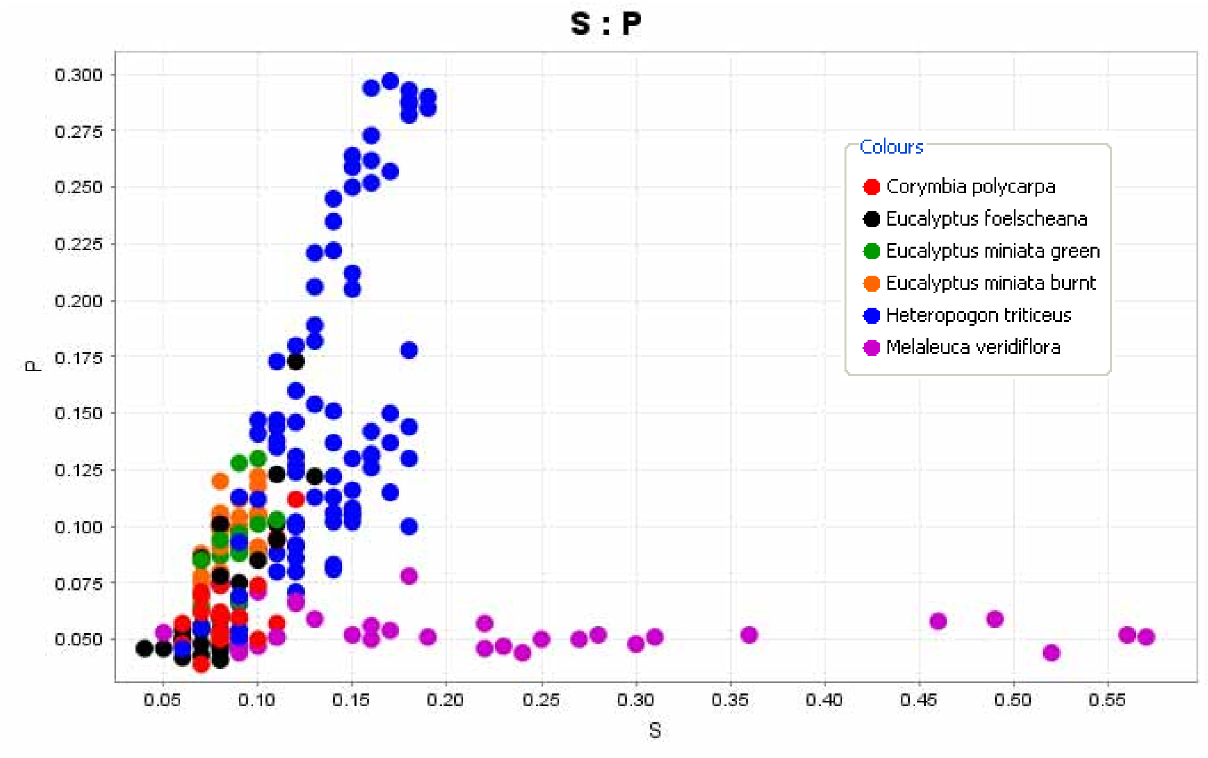

Figure 7.53: S and P visual correlation split by species at the Pine Creek Prospects.

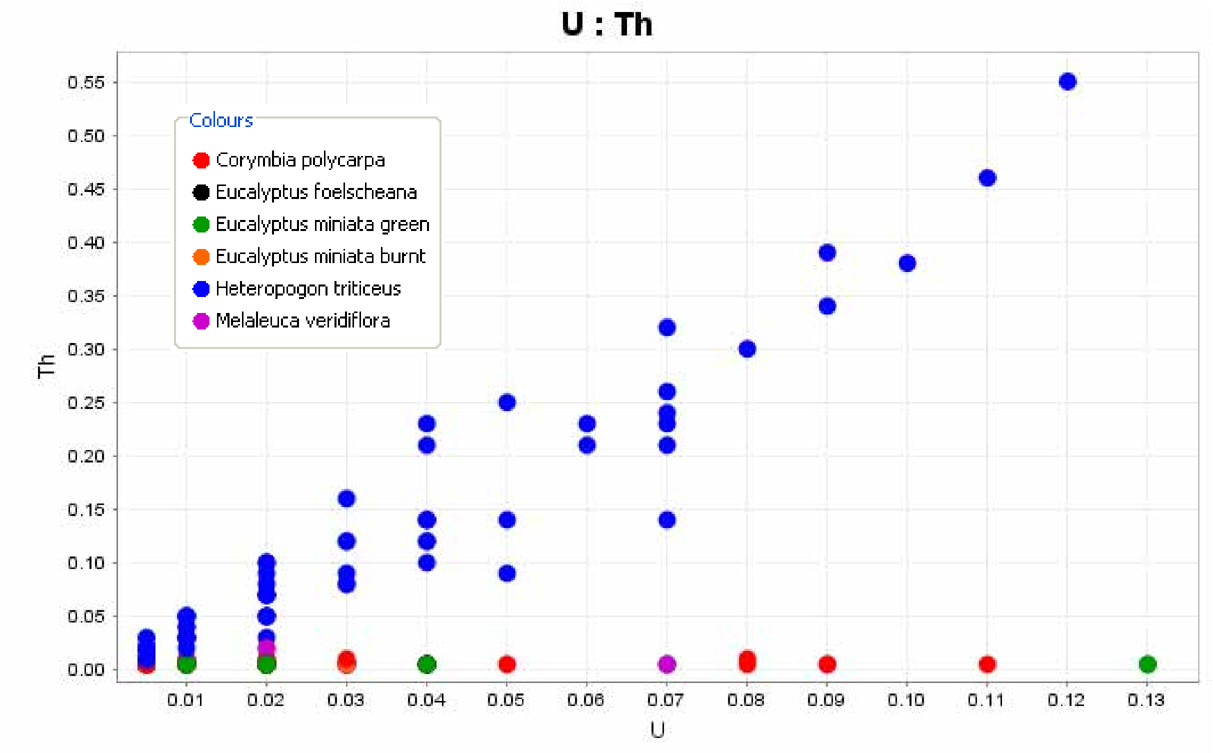

**Figure 7.54: U and Th visual correlation split by species at the Pine Creek Prospects.**

### 7.2.8 Pine Creek Orogen – Regional Summary and Discussion

#### Johns Hill

The Johns Hill transect was limited in its tree availability due to land clearance. Most of the mineralisation-related elements (especially Au and As) were best expressed in the east of the transect. This end of the transect features a drainage channel derived from the erosional rise with known mineralisation, therefore increasing the likelihood of these responses being a laterally transported expression of mineralisation upslope. The high elemental contents from the centre and west of the transect were from elements less related to mineralisation, however the generally high Mo and Cu contents (in *Heteropogon triticeus*, *Corymbia polycarpa*, and *Melaleuca viridiflora*) in these parts of the transect warrant some consideration, since they do not have a direct link to mineralisation from the samples collected over the known ore body the reasons for being elevated are due to other factors which should be investigated.

#### Great Northern

This transect provided encouragingly strong and consistent elevated assays for mineralisation-related elements near the centre of the transect. For example, elevated assays were detected from the centre of the transect for:

- *Heteropogon triticeus* had elevated Ag, As, Au, Cr, Cu and Zn;
- *Eucalyptus foelscheana* had elevated As, Cr, Zn, La, as well as relatively high Co (16.01 ppm) and detectable Au; and,
- *Melaleuca viridiflora* had elevated As, Au, Cr, La, Mo and Zn.

It is particularly encouraging that high Au contents in this part of the transect are supported by elevated assays for other elements such as As, in a range of sampling media. Some elements showed lowest concentrations over the centre of the transect (e.g. Ag, Cu and Mo in *Eucalyptus foelscheana*, and Cu and S in *Melaleuca viridiflora*), and although these may be interpreted as an encouraging ‘negative anomalism’, it is preferable here to instead emphasise the strong ‘positive’ responses from this part of the transect. The central part of this transect is also consistent with an expected extension of known mineralisation as seen in the exposures on the rise to the south. Also since Cu and Mo seem to be of low concentrations in the plants over the mineralisation, having a negative anomaly in these elements and a positive in As or Au is an indication of potential mineralisation.

### Glencoe

The strongest feature of these transect results is the large accumulation of mineralisation-related elements to the south, within the depositional swamp at that end of the transect. This strongly suggests that there has been considerable lateral transport and re-accumulation of many of the elements in this area. This is particularly noticeable for As and Mo in *Heteropogon triticeus,* and As, Au and Mo in *Eucalyptus miniata*. A more subtle high elemental response occurs near the centre of the transect, which more closely corresponds to an expected trend for an extension of mineralisation. *Heteropogon triticeus* had elevated Au, Cr, Zn and La near the centre of the transect, where *Eucalyptus miniata* also had elevated Ag, Zn, Cu (and Co and Pb).

### McKinlay

The responses from the sampling media here were very irregular and inconsistent between the different sampling media. The most encouraging results were obtained from the centre of the transect with moderate Ag, Au, Cu, La and Zn in *Heteropogon triticeus*. The elevated Au contents are not generally supported by many other elevated trace elements such as As. Other media such as *Corymbia polycarpa* and *Eucalyptus miniata* have elevated responses to the east and northwest. A further complication is that this transect has variable thickness and type of transported cover. The McKinlay River channel and floodplain dominate the centre of the transect and would act as an important repository for transported trace elements, while the eastern end of the transect appears to have a shallow transported regolith cover, based on quartz vein fragments in termitaria (A. Petts, pers. comm. 2007).

### Areas of known mineralisation

The elemental suite of Ag, As, Au, Cu, La, Mo and Zn were useful for expressing mineralisation in all species. Most species provided at least some Au and multi-element expression of the known mineralisation, with variations related to local differences in proximity to vein-type mineralisation.

*Heteropogon triticeus* was able to provide a strong and consistent expression of mineralisation and is widespread across the region. This grass expressed high Au contents (particularly 4.2 ppb in GLGA021, which was sampled from a grass growing in a quartz vein on the pit edge directly over the Glencoe anticline) and surprisingly high Cr contents (up to 29 ppm, which is significantly higher than the other species). These results suggest that *Heteropogon triticeus* is an accumulator of Cr.

*Eucalyptus miniata* is widespread in the region and provided expression of known mineralisation. It may be useful as a sampling medium on erosional rises and their immediate margins (such as near Glencoe). Species such as *Brachychiton paradoxum* and *Cochlospermum fraseri* provided strong expressions of mineralisation where they were available; however their restricted distribution and limitation to erosional rises reduced their usefulness for regional mineral exploration under cover.

Although Au contents were variable at sites of known mineralisation (possibly reflecting local proximity to mineralisation) the inclusion of a multi-element suite appears to be very important. Firstly, elements such as Ag, As, Cu, La, Mo and Zn can be used to reinforce the Au results. Secondly, many of these elements are able to express a larger mineralisation halo than the zone of elevated Au concentrations. In particular, elements such as Cu and Zn were relatively high in most samples broadly from the areas of known mineralisation, even though other elements showed more extreme values but with greater variability. A disadvantage with the elements that can express larger halos is that they are readily dispersed throughout the landscape, making it difficult to isolate a potential mineralisation source. This problem however, can be overcome by examining the multi-element suite.

### Interpretation of spatial patterns along 'black-soil plains'

In each of the transects a major challenge is the distinction between surface expression of buried mineralisation and lateral transport and deposition from adjacent mineralised rises. A combination of recognising the surficial regolith-landform assemblage and utilising the multi-element chemical assays seem to be the best ways to discern this. Depositional landforms, such as drainage channels, will have a greater likelihood to host transported responses, whereas, erosional rises will have more locally derived responses. High responses in Au and other mineralisation-related elements (in particular As) appear to be valuable for interpreting less transported responses. Examples of potential *in-situ* responses through transported cover that may warrant further investigation are the centres of the Glencoe and Great Northern transects, the eastern end of Johns Hill transect and the centre of the McKinlay transect.

### Biogeochemical exploration model and recommended applications

Sampling a variety of media at various sites can lead to several mineral exploration recommendations. Firstly all the media show some potential for expressing shallow buried, as well as subtly expressing deeply buried (up to 10s of metres) mineralisation. The application of any of these media will largely depend on the following criteria:

- Ease of collection and sample preparation;
- Widespread and abundant distribution; and,
- Strong chemical distinction between mineralisation and background in a wide range of elements.

All media were easy to sample and prepare, but the distributions of each species varied considerably, particular between vegetation assemblages on erosional rises compared with the depositional settings of the 'black-soil plains'. *Heteropogon triticeus* was the most abundant and widespread medium, followed by *Eucalyptus miniata* and *Melaleuca viridiflora*. *Eucalyptus foelscheana* and *Corymbia polycarpa* were more locally abundant at Great Northern and McKinlay respectively. All of the species sampled appear to provide a suitable distinction between mineralised and 'background' sites, however, *Melaleuca viridiflora, Corymbia polycarpa* and *Eucalyptus foelscheana* were not sampled over known mineralisation (largely because these species are almost exclusively restricted to 'black-soil plains' rather than the erosional rises where mineralisation has been found to date).

A combination of *Heteropogon triticeus* and *Eucalyptus miniata* would be excellent alternative media to the extensive costean digging that has previously been conducted on erosional rises near known mineralisation at many of these sites. These plants appear to provide expressions of mineralisation consistent with previous costean results (Australasia Gold, confidential) and can be more efficiently sampled at less cost and environmental impact than costean digging. This sampling could then be more reliably extended onto the 'black-soil plains' using *Melaleuca viridiflora, Eucalyptus foelscheana,* and *Corymbia polycarpa* where available.

### Conclusions

The sampling at the study sites show that the region is suitable for biogeochemical sampling that could be used for regional exploration programs across the transported regolith of the black soil plains. All media were successful at expressing known mineralisation, and potential targets for further investigation were identified at Glencoe and Great Northern and to lesser extents at Johns Hill and McKinlay. Adequate constraint of the regolith-landform setting, the use of multi-element assay suites and consistent and robust sample collection and preparation techniques are critical ingredients for further application of these techniques.

## 7.3 Gawler Craton: Tunkillia Field Site – Background

### 7.3.1 Introduction

The Gawler Craton in South Australia covers much of the state's west and central regions. Large areas of this region are covered in thick regolith before reaching bedrock. This can be weathered materials which are *in-situ* or transported material.

The Tunkillia Prospect is 70 km south-southeast of Tarcoola (see Figure 7.55). There is moderate grazing in the area, but usually on flat areas due to poor access. The area over the Tunkillia Prospect is dominated by a vast aeolian dunefield to the south and sheetwash materials to the north. This area had been examined for biogeochemical exploration by Jack Lowrey (Lowrey 2007) who looked at species growing between the dunes. So the aim of this small study was to see whether sampling spinifex (*Triodia irritans*) on the dune crest would be able to detect mineralisation as it worked well in the Tanami Region.

The dunes were well vegetated and hence very old, which made the possibility of a mineralisation signature penetrating to the surface much greater. Aeolian dunes are common and are often an impediment to normal surficial exploration techniques.

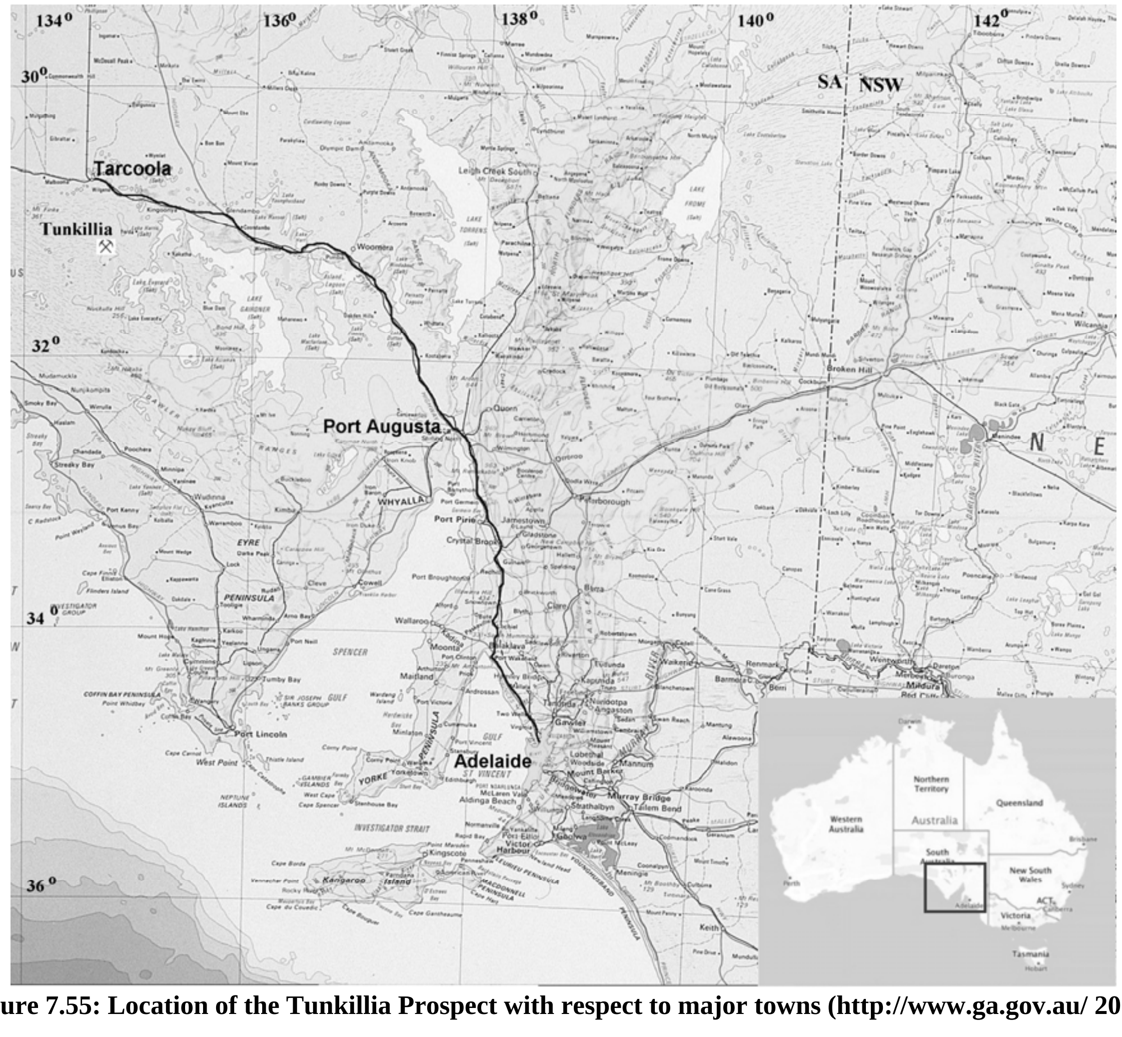

**Figure 7.55: Location of the Tunkillia Prospect with respect to major towns (http://www.ga.gov.au/ 2006).**

### 7.3.2 Previous work

Preliminary biogeochemical studies in the Gawler Craton have been limited. One site that has received attention is the Barns Gold Prospect in northern Eyre Peninsula (Lintern 2004). This study sampled several species across an aeolian dune with mineralisation hosted below. However, the site had several disadvantages; it was in the middle of agriculture (pesticides and fertilisers), it was highly cleared and there was little differentiation of species and organs within the study. The study by Lowrey (Lowrey & Hill 2006; Lowrey 2007) sampled 6 dominant species over the Tunkillia Prospect which was aimed at crossing the surface projection of mineralisation and the Au-in-calcrete anomaly that was used to discover the site. Several species within that study are promising biogeochemical exploration sampling media.

### 7.3.3 Regional setting

#### Landscape and geology

The Central Gawler Craton is comprised of Archean and Palaeoproterozoic granites and granite-gneiss, which is intruded by the Hiltaba Suite Granitoids (Mesoproterozoic in age) (Ferris & Wilson 2004). The Tunkillia Prospect lies on the western edge of the Yarlbrinda Shear Zone, a major regional structure that hosts several Cu-Au mineralisation occurrences (Ferris & Wilson 2004). Surrounding lithologies consist predominantly of foliated-mylonitised, medium to coarse-grained granitoids of the Palaeoproterozoic, Tunkillia Suite (1690-1670 Ma), mostly ranging in composition from adamellite to granodiorite with minor mafic and felsic dykes (Ferris & Wilson 2004).

The Tunkillia Prospect was discovered within an extensive Au-in-calcrete anomaly (Ferris & Wilson 2004). The anomaly is the largest >10 ppb Au anomaly found in calcrete geochemical results found anywhere in the world (Ferris & Wilson 2004; Lowrey & Hill 2006; Lowrey 2007). However, the mineralized zone is only relatively small, with 2 main ore bodies hosted within narrow, steeply dipping quartz veins which are parallel with the main shear directions of the region (Ferris & Wilson 2004; Martin & Wilson 2004). Gold is mostly hosted within sulphide minerals (pyrite, galena and minor chalcopyrite and sphalerite) (Ferris & Wilson 2004). The top *in-situ* regolith materials (saprolite) is depleted in Au which can hinder exploration (Figure 7.56).

NOTE:
This figure is included on page 195
of the print copy of the thesis held in
the University of Adelaide Library.

**Figure 7.56: Geological cross section across the Tunkillia mineralisation (Ferris & Wilson 2004)**

The dominant feature of the study area were the dunes, which were parallel and linear, comprised of well sorted, rounded quartz grains with orange-red, Fe-oxide coatings. The swales between the dunes were broad, low-relief sand plains, comprised of finer sand materials than the dune crests (Lowrey 2007). Other important features are the large, erosional plains over the northern part of the area, comprised of fine, red-brown sands, silts and clays (Lowrey 2007).

### Climate

The Central Gawler Craton is semi-arid, with a winter dominated rainfall regime (Bureau of Meteorology 2007). Rainfall is measured from Tarcoola, where the average is 174 mm. Maximum daily temperature averages approximately 35° C in summer and 18° C in winter. Minimum daily temperatures average approximately 18° C in summer and 5° C in winter (Bureau of Meteorology 2007).

## 7.3.4 Vegetation

The main vegetation of the Central Gawler Craton is within the Gairdner-Torrens Zone (Jessop & Toelken 1986) which is plants which can tolerate long periods of drought and ephemeral plants which grow after rainfall. Main vegetation communities consist of various *Acacia spp.*, *Triodia irritans*, *Casuarina pauper*, *Eucalyptus socialis,* and chenopods (mainly *Maireana sedifolia*). Minor species are *Bossiaea walkeri* growing on dune crests, and *Cratystylis conocephala* growing in the swales (Lowrey 2007).

### ***Triodia irritans* (porcupine grass)**

*Triodia irritans* has a much more restricted distribution than some of the other species as it only occurs in the winter rainfall dominated part of the spinifex range (Figure 7.57) (Burbidge 1953; Griffin 1990). It is one of Brown’s original 6 named species (Burbidge 1953). This species occurs over much of the Gawler Craton in South Australia, where it grows in mallee regions often associated with *Melaleuca uncinata* (Burbidge 1953; Hudspith *et al.* 2001). The general structure is much the same as the other *Triodia* species, but this species is a ‘buck spinifex’ or hard species as its leaves are often very rigid (Burbidge 1946a).

NOTE:
This figure is included on page 197
of the print copy of the thesis held in
the University of Adelaide Library.

**Figure 7.57: Distribution of *Triodia irritans* adapted from Sharp & Simon 2002.**

The general form is 0.3 – 1 m high, 0.3 – 4 m diameter (when in rings, Figure 7.58), densely tufted, circular or annular shaped tussocks (Burbidge 1953; Sharp & Simon 2002). This species grows on hills and ranges, and along sand dunes and sand plains on skeletal, shallow or rocky soils or in red sandy loams (Burbidge 1953; Hudspith *et al.* 2001; Sharp & Simon 2002).

**Figure 7.58: Ring form and roots exposed of *Triodia irritans* at the Tunkillia Prospect.**

## 7.4 Gawler Craton: Tunkillia Field Site –Results and Discussion

The *Triodia irritans* results show 6 distinct elemental patterns:

1. Elements that are elevated over the mineralisation (Al, As (ash), Au (ash), B, Cd, Ce, Cs, Hf, La, Li, Pb, Pd (ash), Pd, Pt (ash), Sb (ash), Th (ash), Th, Ti, U (ash), W (ash), Y, and Zr) (Figures 7.59 and 7.60);
2. Elements in low abundance over mineralisation (Cr);
3. Elements elevated to the east (Au, Ca, Ge, K, Mg, Mn, S, Sc, Sr, and Te); and,
4. Elements elevated to the west (Bi (ash), Cu, Hg, Mo, Rb, V (ash), and Zn).

There are also elements that irregularly distributed (Ba, Co, Fe, Na, Nb, Ni, P, Se (ash), and Se).

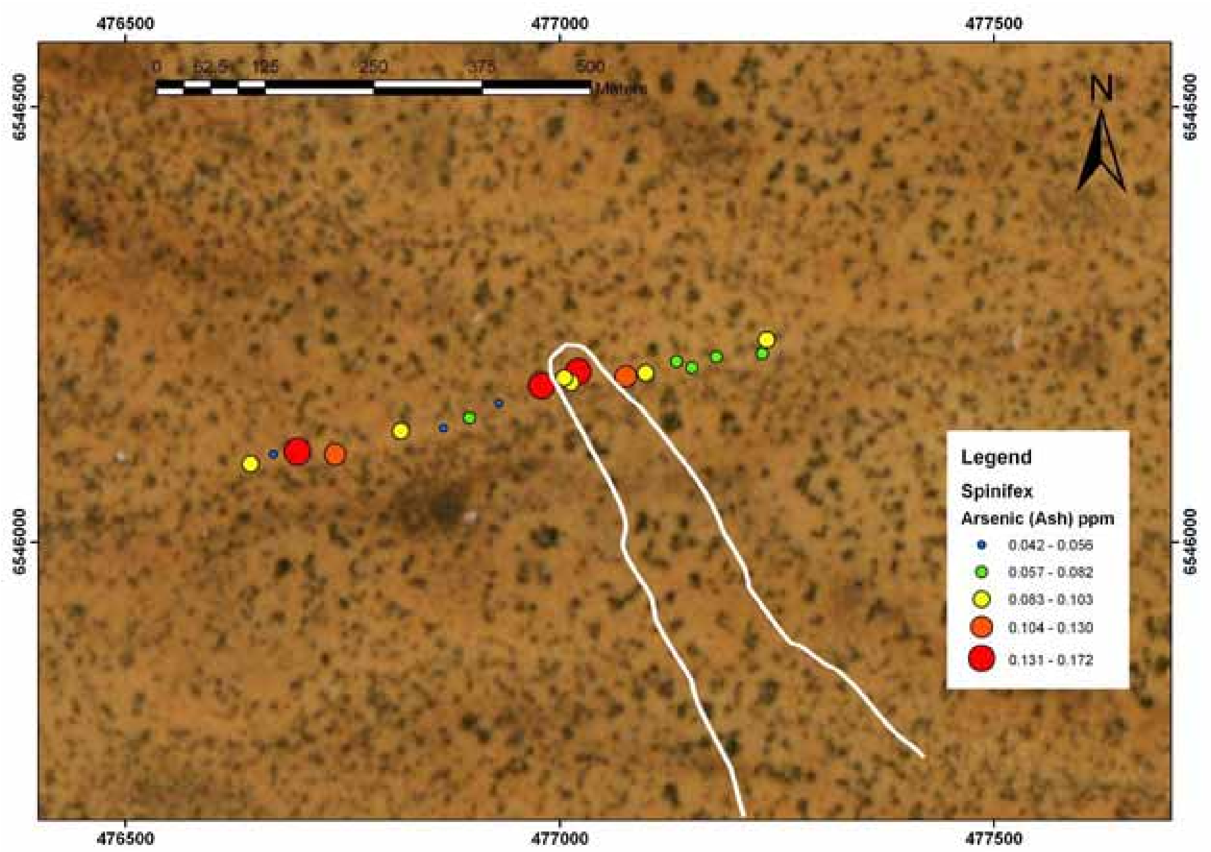

**Figure 7.59: Spatial distribution of ashed As assay results for *Triodia irritans* along the Tunkillia transect. The white line represents the boundary of the Au resource with the ore body within this boundary.**

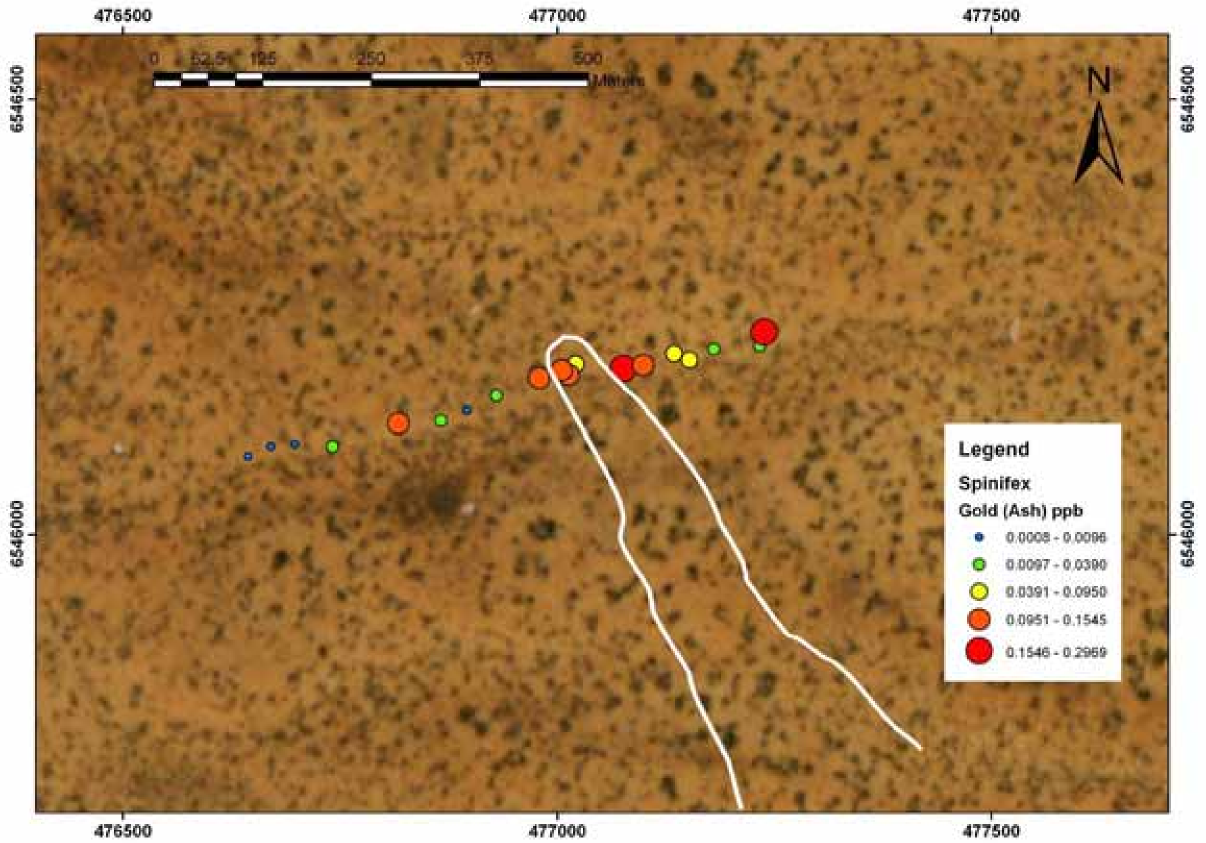

**Figure 7.60: Spatial distribution of ashed Au assay results for *Triodia irritans* along the Tunkillia transect. The white line represents the boundary of the Au resource with the ore body within this boundary.**

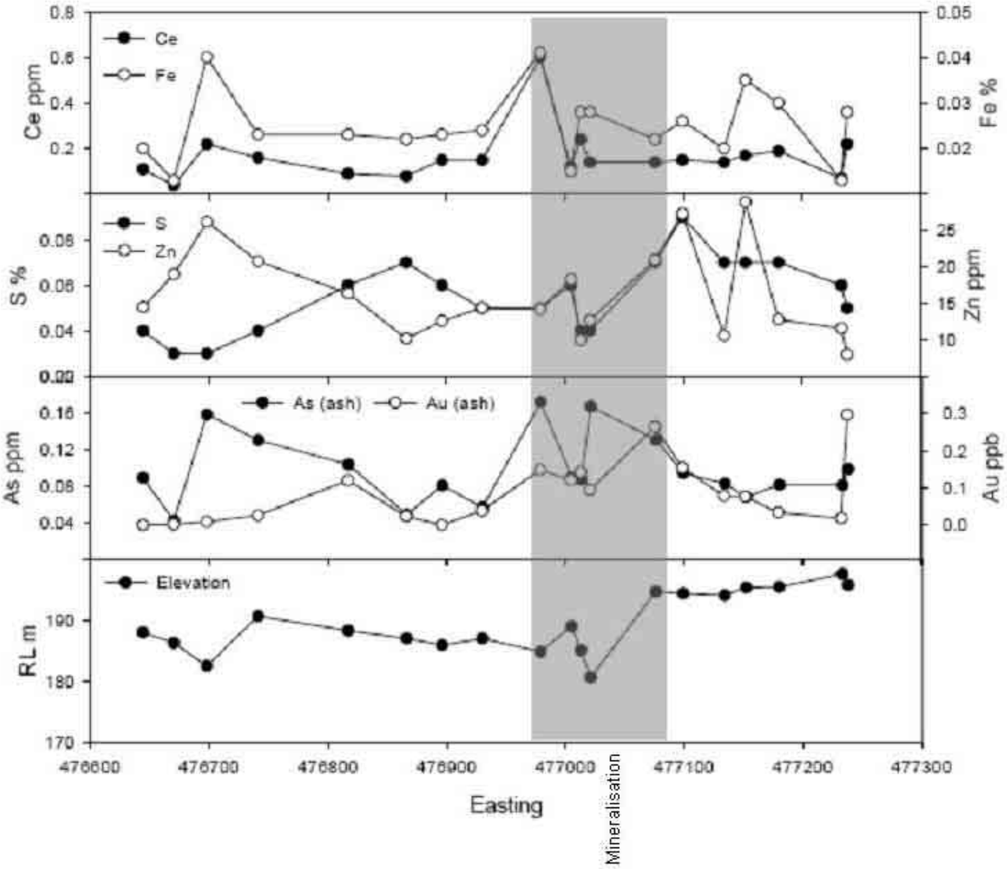

**Figure 7.61: *Triodia irritans* elemental cross section across the Tunkillia transect**

**Discussion**

In general the *Triodia irritans* results highlight the need for pre-concentrating the sample in order to gain a meaningful result. Over the mineralisation at Tunkillia, As and Au do not detect the ore body but the ashed As and Au results provide elevated values (Figures 7.59 - 7.61). This is matched with a multi-element suite; however there is little dispersion either side of the projected ore body. The only elements that show any form of dispersion are Zn and S which show a trend towards the east which is against the elevation of the dune. Some of the usual contaminant elements (Al, Fe, Hf, Zr) are associated with the mineralised zone, but some are not, such as Fe, this shows that there is some component of contamination in the samples; however, the maximum concentrations are still insignificant.

### 7.4.1 Elemental correlations

There were very few correlations found between the elements at the Tunkillia Prospect (shown visually in Figures 7.62 – 7.69). The usual correlations of the REE to each other are there. There is a mafic signature present, as shown by correlations between Co, Cr, Fe and Ni, this corresponds to the mafic dykes seen in the geological section (Figure 7.56). There was, however, no correlation with either Fe or Al with any of the pathfinder elements which indicates low contamination within the spinifex samples and the anomalies generated would be from the source and not drill spoil. There are correlations between the ash analyses and the normal analyses, but the only one that shows this effectively is Th (0.97).

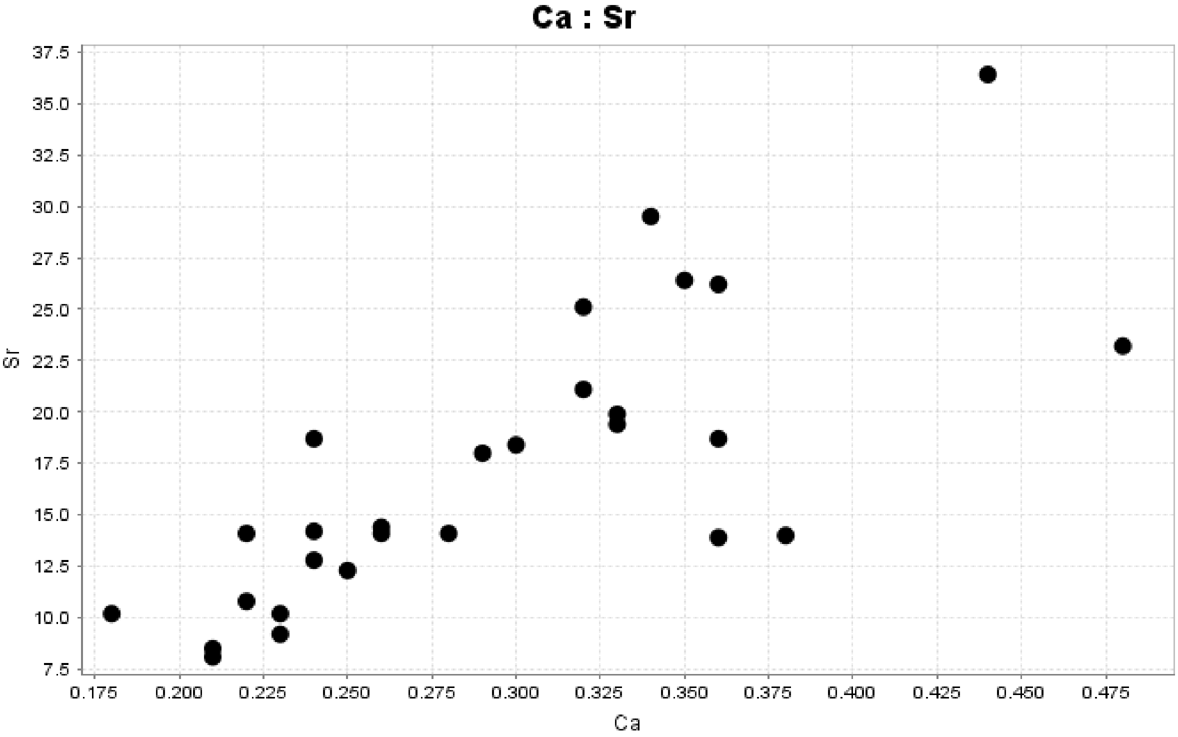

Figure 7.62: Ca and Sr visual correlation at the Tunkillia Prospect.

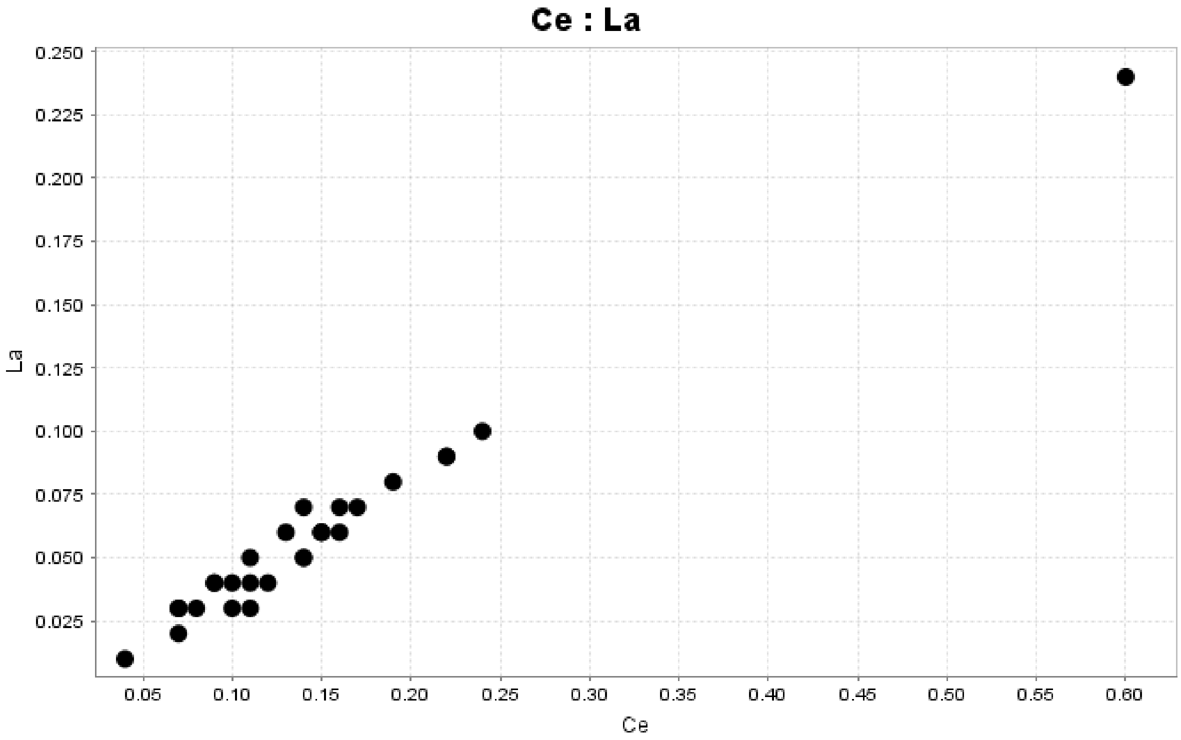

**Figure 7.63: Ce and La visual correlation at the Tunkillia Prospect.**

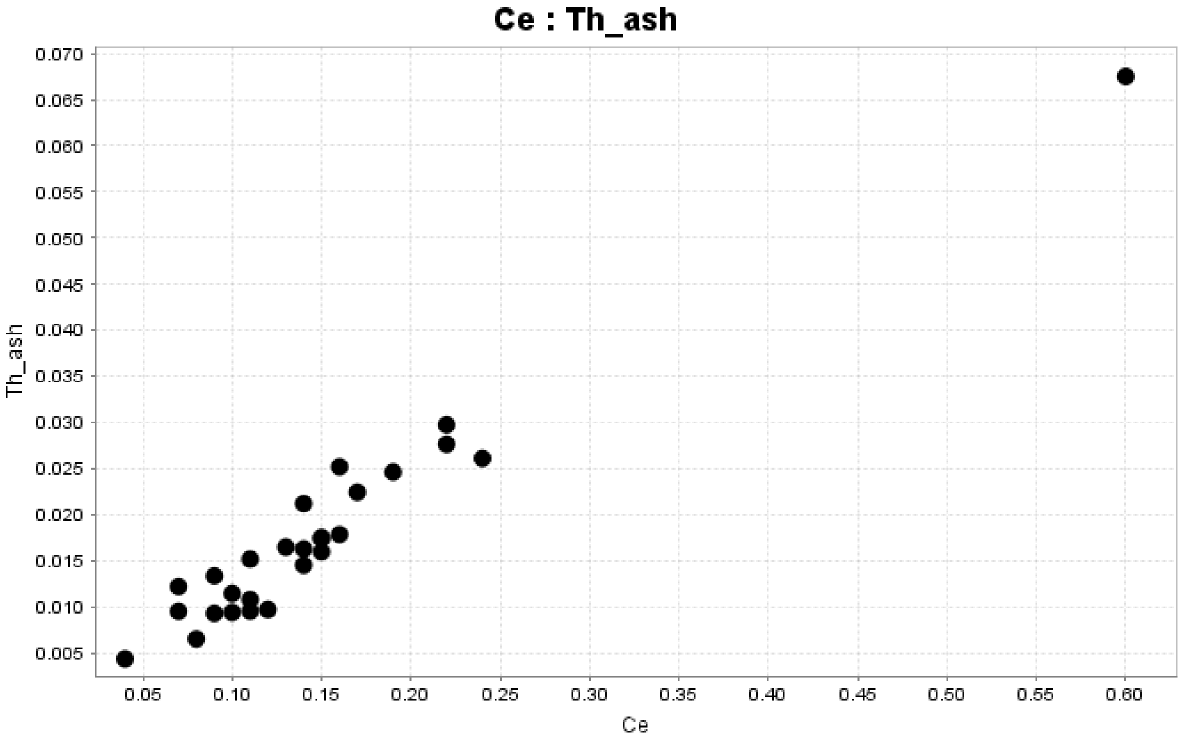

**Figure 7.64: Ce and Th (ashed) visual correlation at the Tunkillia Prospect.**

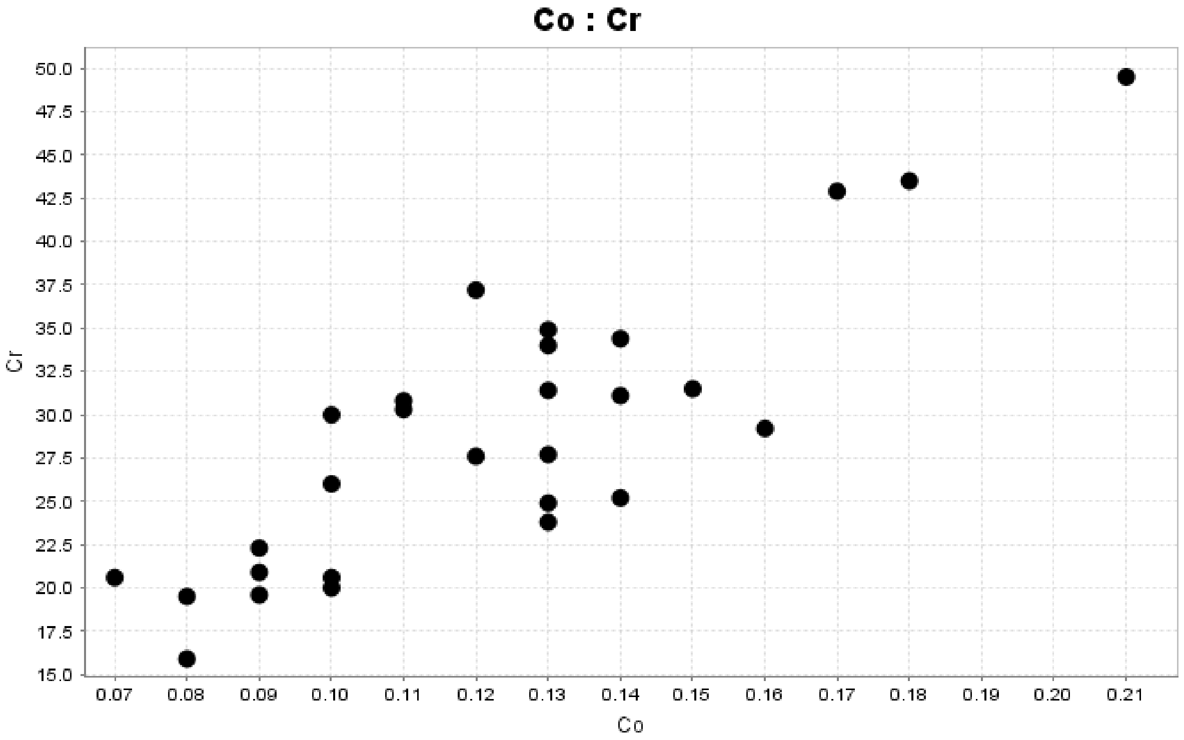

Figure 7.65: Co and Cr visual correlation at the Tunkillia Prospect.

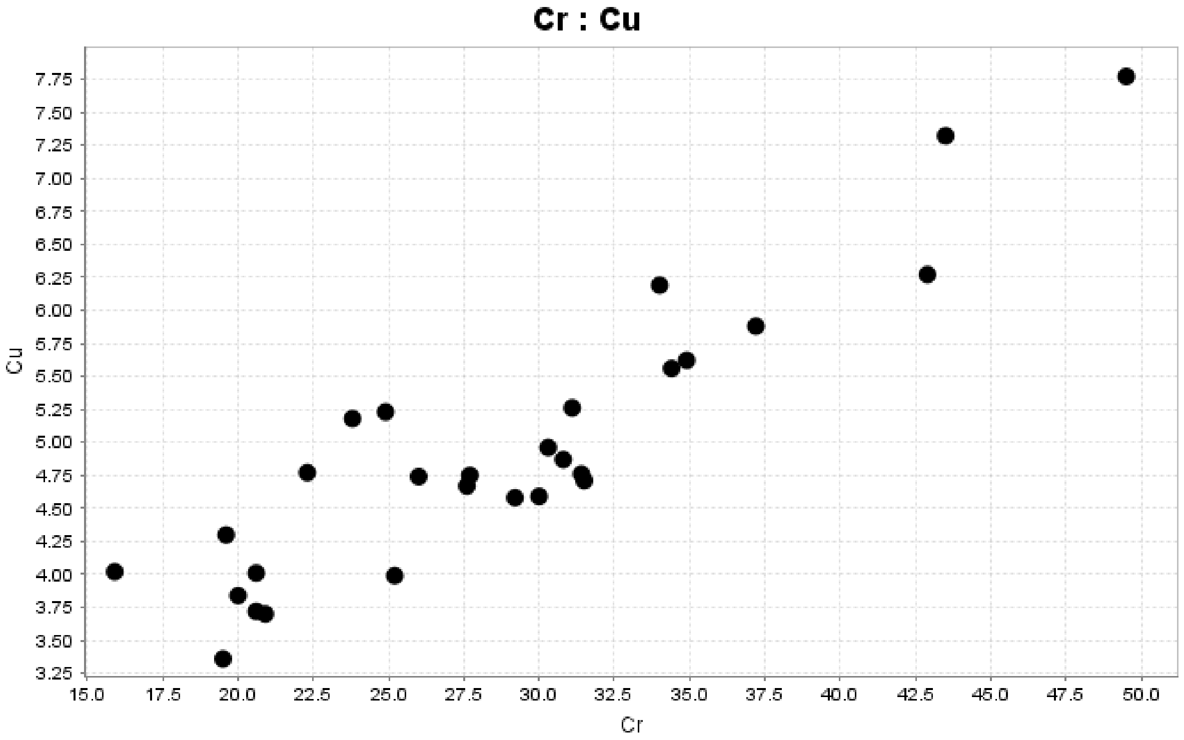

Figure 7.66: Cr and Cu visual correlation at the Tunkillia Prospect.

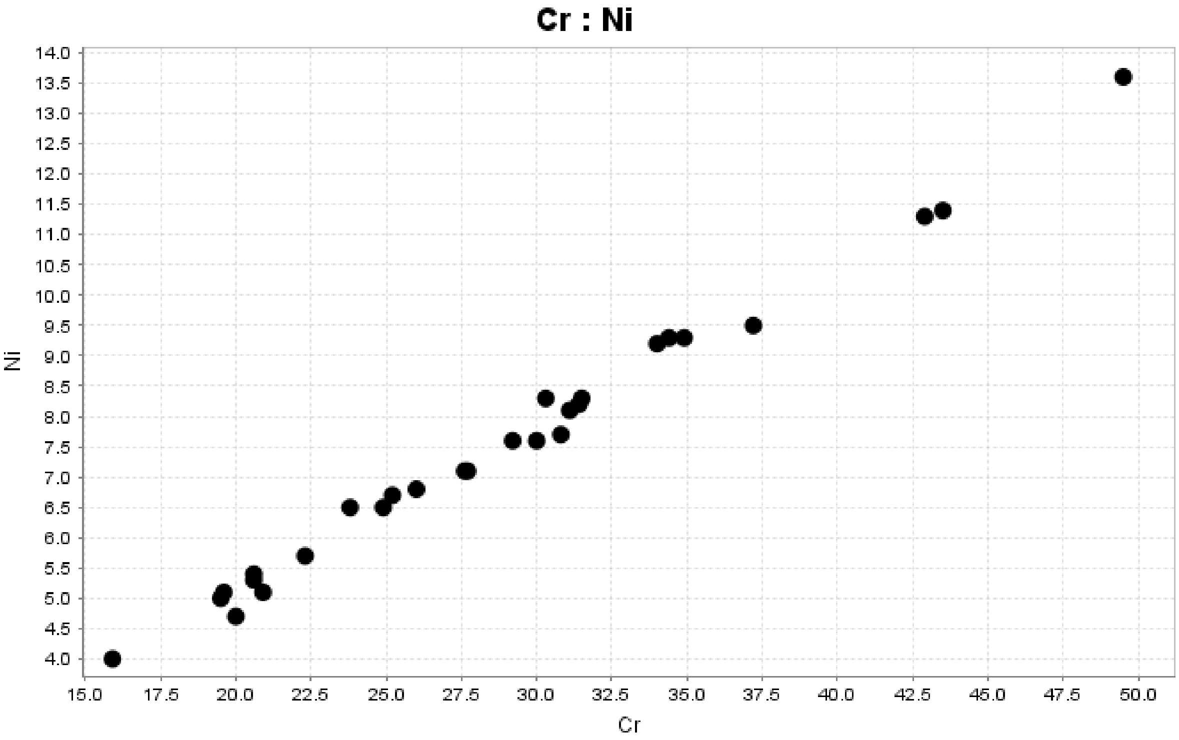

**Figure 7.67: Cr and Ni visual correlation at the Tunkillia Prospect.**

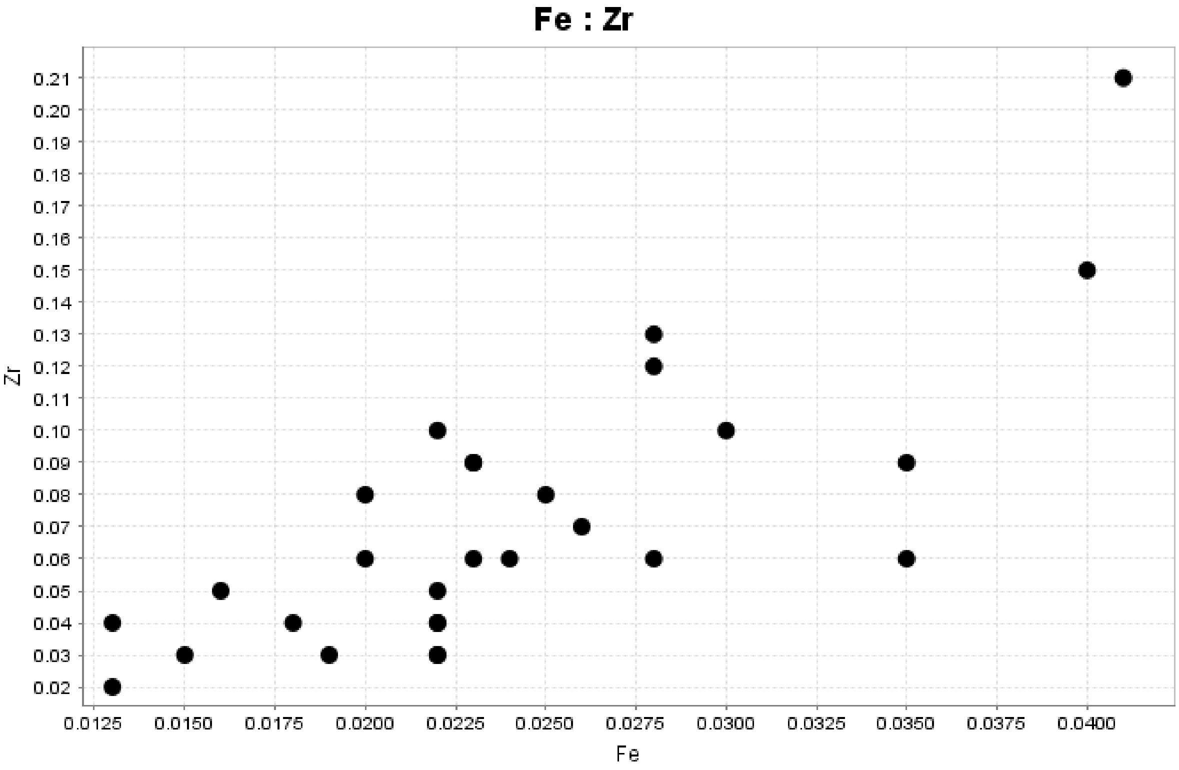

**Figure 7.68: Fe and Zr visual correlation at the Tunkillia Prospect.**

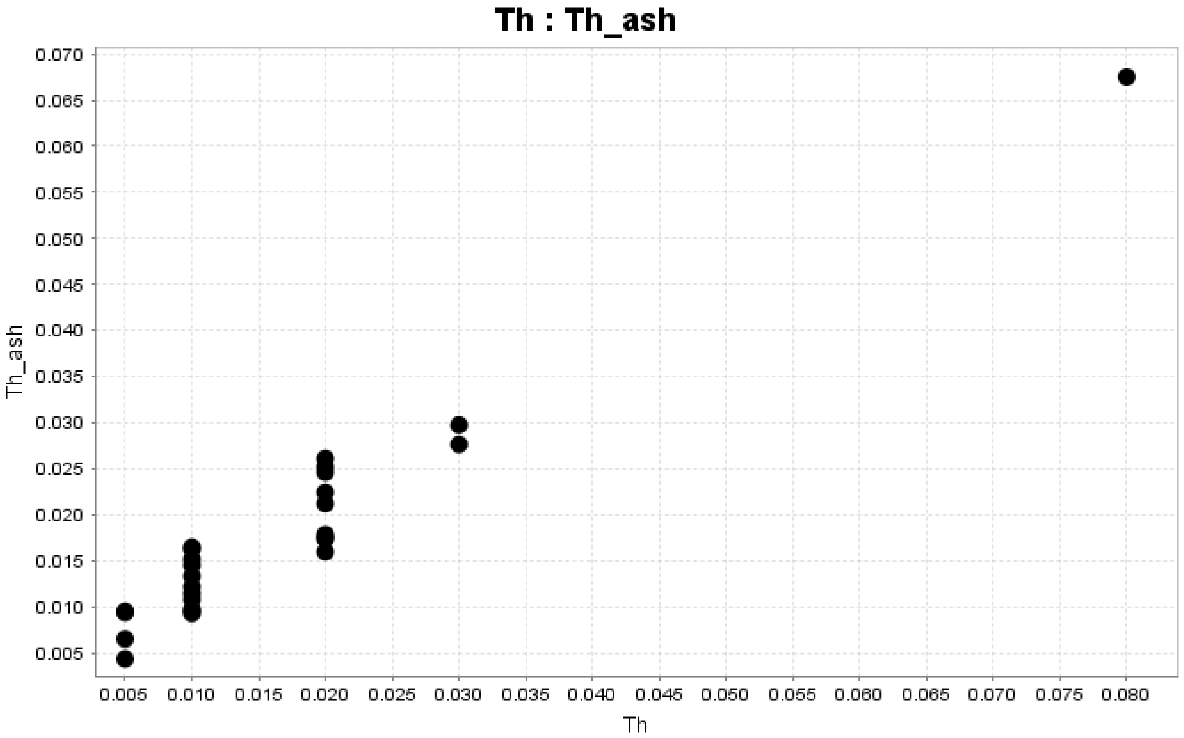

Figure 7.69: Th and Th (ashed) visual correlation at the Tunkillia Prospect.

### 7.4.2 Discussion

The conclusions that can be drawn from this site are that mineral exploration through transported cover (sand dunes) is possible with the right plant species. If it is known that the transported cover is thick and chemically very similar (as with quartz sand in a dune), then it is recommended to ash samples prior to analysis. This will pre-concentrate the elements in the ash enabling better detection through materials that would otherwise 'dilute' the signal. Also that more background knowledge must be known to determine whether elevated values relate to mineralisation. A multi-element suite can provide 'better' targets which have high concentrations in several elements rather than high values in Au alone.

## 8 Elemental Vectors and Processes

A significant aspect of this study involves relating the elemental concentrations of the plant materials to substrate sources and characterising the differences between different species and at different sites. The most important mechanisms involved in transporting an As, Au, S and Zn signature to plant leaves are often complex, involving oxidation and dissolution processes to release As and S from arsenopyrite into solution. The As is oxidised to arsenate and arsenite ($AsO_4^{3-}$ and $AsO_3^{-}$) or can be complexed via microbial interactions to monomethylarsonic acid (MMAA) or dimethylarsinic acid (DMAA), these compounds are transported from the ore body through the groundwater until they come into contact with the plant root zone (Abedin *et al.* 2002; Meharg & Hartley-Whitaker 2002). Metal ions can enter the plant root actively through specialised plasma membrane metal ion transporters (Salt *et al.* 1998; Meharg & Hartley-Whitaker 2002) . Arsenate is the most common form of As in groundwaters and can substitute for phosphate in the plant structure (Abedin *et al.* 2002; Meharg & Hartley-Whitaker 2002; Wang *et al.* 2002) which can be critical in Australian environments where phosphate is limiting and each plant would actively uptake arsenate to fill this position. The S from sulphides are oxidised generally to sulphate ($SO_4^{2-}$) which is readily mobile and moves through the profile in the groundwater. There is a specific sulphate transporter in the root membrane which allows the transport of sulphate from the soil solution to the root structure (Smith *et al.* 2000). The Zn is sourced from sphalerite which is released into solution with the dissolution of the sulphides. Zn also has its own ion transporter and is actively transported as it is an essential trace element. Once in the root structure the ions are either transported, transformed or stored. The transport is generally driven by transpiration causing high osmotic pressures which enable water and ion transport between the root zone and the leaf zone where the water is lost to the atmosphere (Salt *et al.* 1998). Gold is not a trace nutrient and is passively uptaken as shown by the 'nuggety' nature of the results. This means that Au would need to be uptaken instead of an essential element, possibly Cu or Zn which are similar size and charge, however, this mechanism is still not fully understood.

## 8.1 Elemental Variations

### 8.1.1 Between Species

There is considerable variation of elemental uptake between the different species and genera at each field site. Many of these differences have been outlined in the discussions for Chapters 5-7. Most of the differences are assumed to be largely dependant on the root structures and therefore substrate access for elemental uptake by the plants. If the different species derive nutrients from different soil-water-rock horizons then they are going to have different chemical characteristics. However, different families of plants show different uptake potentials even if they are interacting with similar substrates. For example, *Triodia pungens* and *Melaleuca lasiandra* have different rooting structures, but interact with similar depths. As shown by the chemical patterns expressed at the Titania Prospect, where As results showed a similar sized and positioned halo and the Zn and S dispersions were of similar size and direction.

Some of the elemental uptake patterns therefore are very similar, but some are very different, as shown with the Cr results. The perennial grasses (*Triodia spp.* and *Heteropogon triticeus*) all seem to be Cr accumulators, or they do not possess the barrier mechanism for Cr that the other plants may have. Plants of different species that have similar rooting structures tend to have similar chemical characteristics. For example, the 'bloodwood' type *Eucalyptus/Corymbia spp.* in both the Tanami and Pine Creek regions are all Co accumulators relative to adjacent plants, even though these different species are growing in different environments and soil types.

### 8.1.2 Between Field Sites

There were major elemental differences between the field sites within this study. Mostly between the different regions, however, since there was not an overlap of species between the regions it is difficult to make accurate predictions of differences due to species differences as described above. Each of the field sites covered in this study are Au mineralisation sites, however, there are differences between the settings for each prospect, and between the regions.

Some of the major differences within each region are outlined in Figures 8.1 – 8.8 for the Tanami sites and Figures 8.9 – 8.14. These graphs show the plant chemistry for each site combined into one data set to enable broad comparisons between sites.

In the Tanami there are insignificant differences between the Au, As, Cr, and P results, highlighting the similar uptake mechanisms within each of the plants for passive uptake of ore related elements. The P results highlight that each of the sites are P limited and hence only the maximum can be taken up, and the Cr highlights that the *Triodia pungens* at each site is behaving the same. The major differences within the Tanami results can be seen with the Ca, Ce, Fe and S concentrations. The Ca and S results highlight that *Acacia bivenosa* at the Titania Prospect is utilising gypsum within the surface soil profiles. The Fe concentrations show that since the Titania Prospect was burnt 6 months before sampling, there was significantly more contamination potential than the other sites as there had not been enough regrowth to hold the surface soils in place. The Ce concentrations show the *Acacia coriacea* being able to dissolve primary monazites from the Hyperion Prospect.

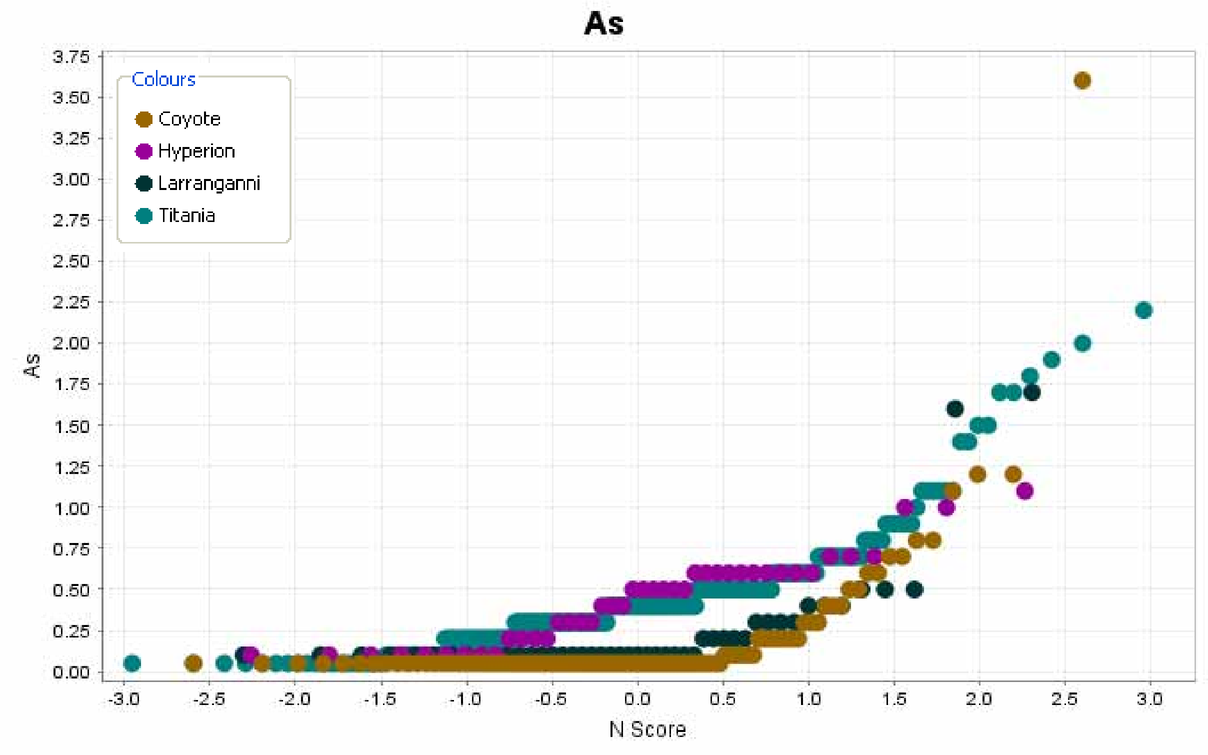

**Figure 8.1: As results split by site at the Tanami Prospects.**

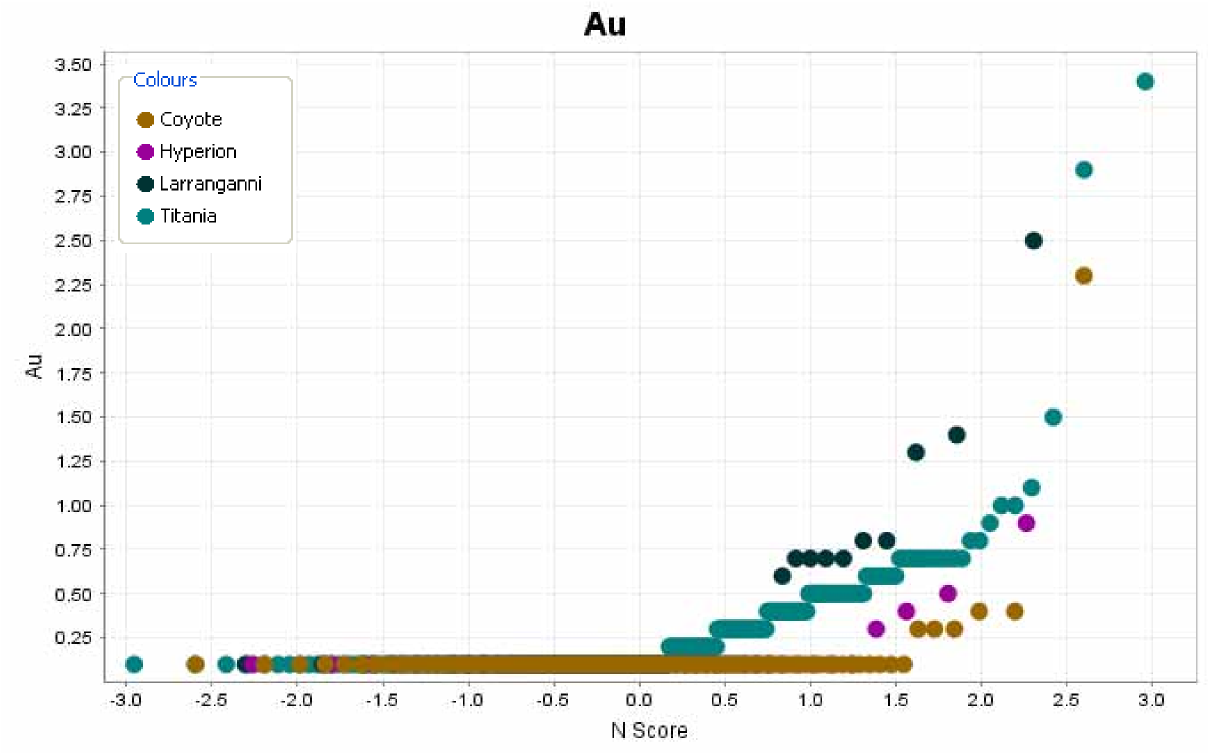

Figure 8.2: Au results split by site at the Tanami Prospects.

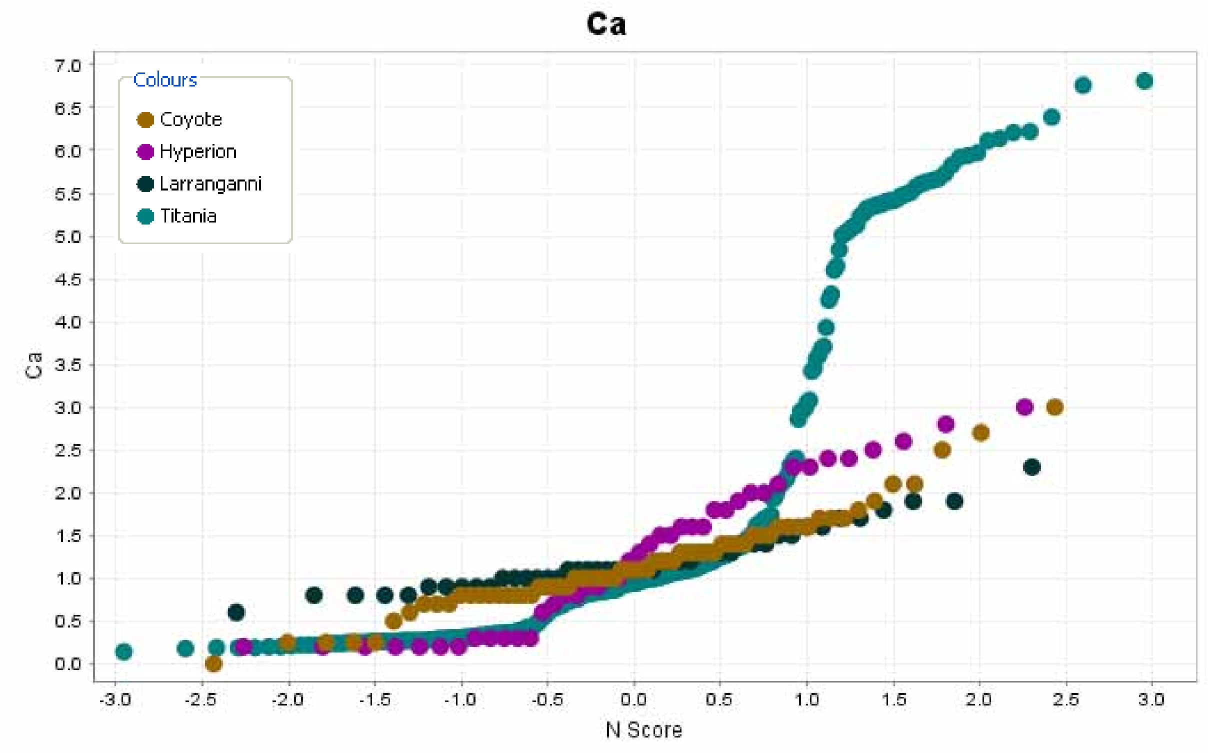

Figure 8.3: Ca results split by site at the Tanami Prospects.

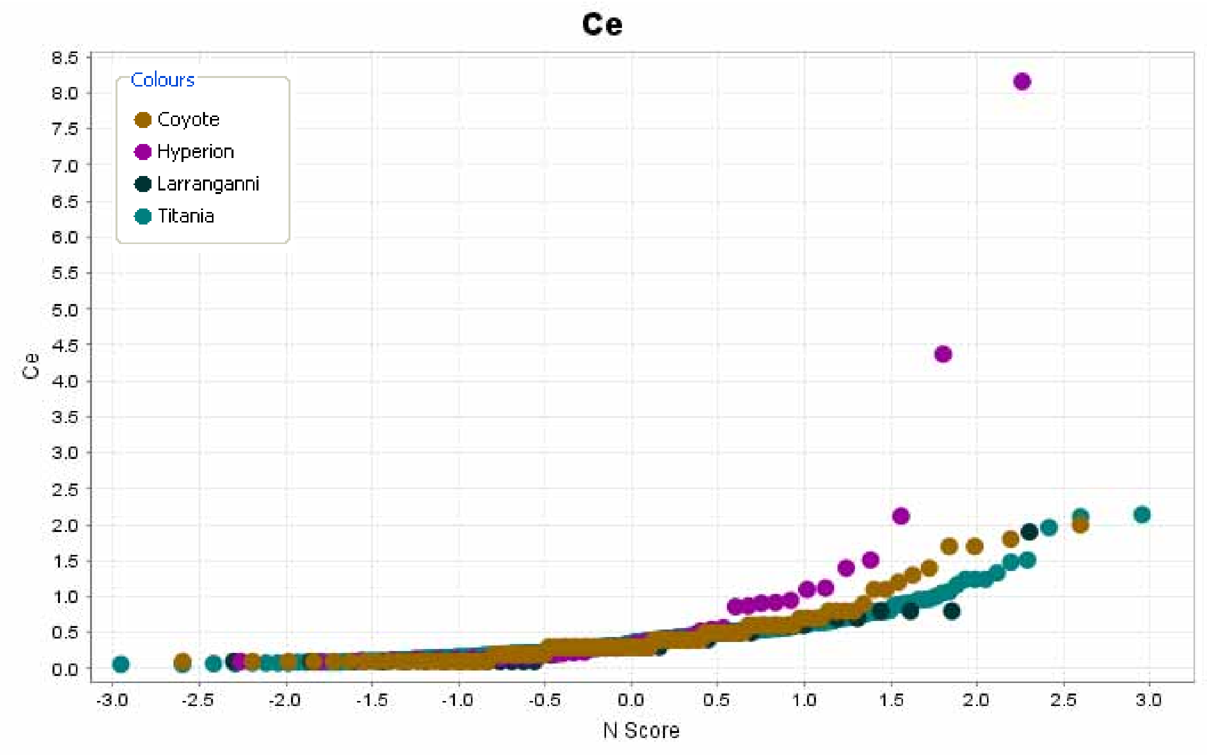

Figure 8.4: Ce results split by site at the Tanami Prospects.

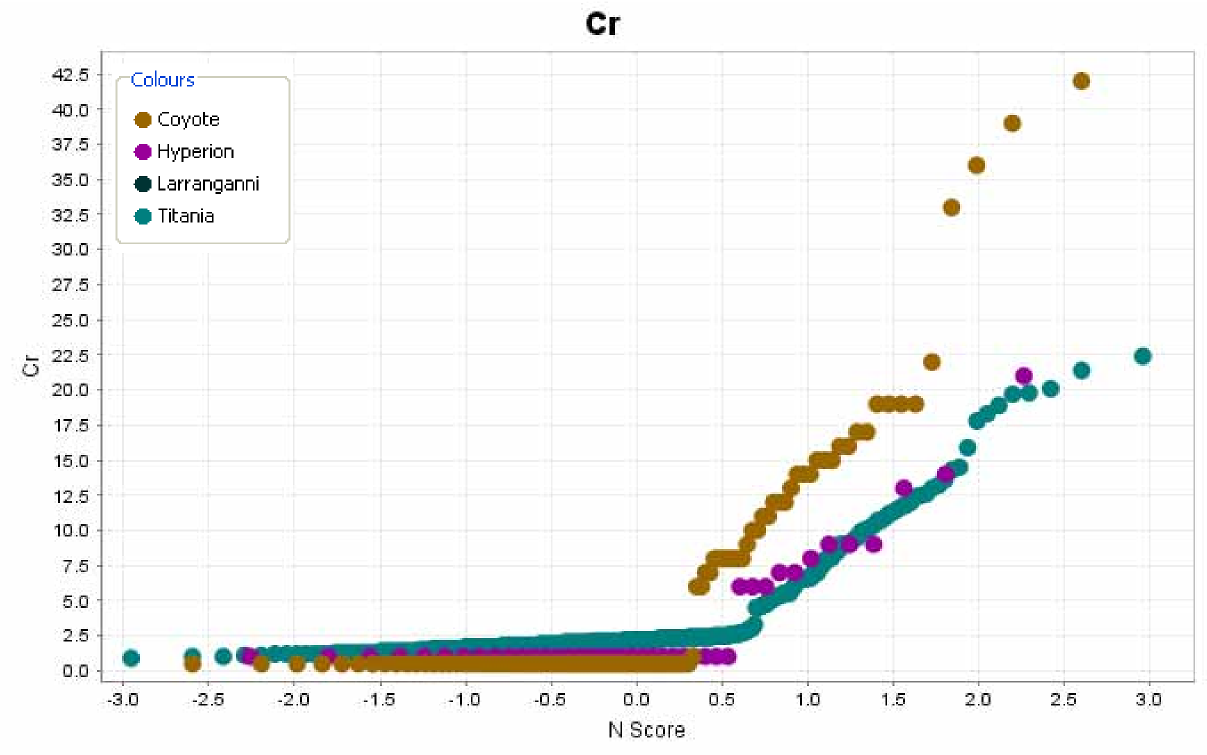

Figure 8.5: Cr results split by site at the Tanami Prospects.

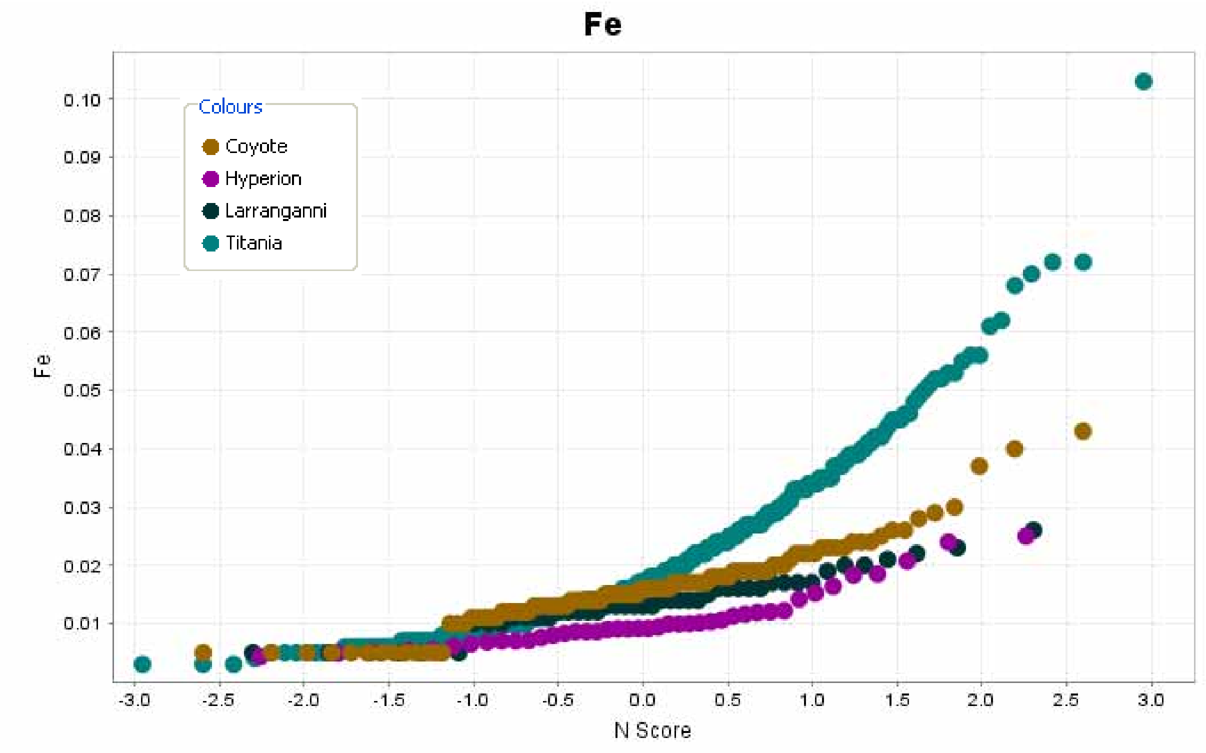

Figure 8.6: Fe results split by site at the Tanami Prospects.

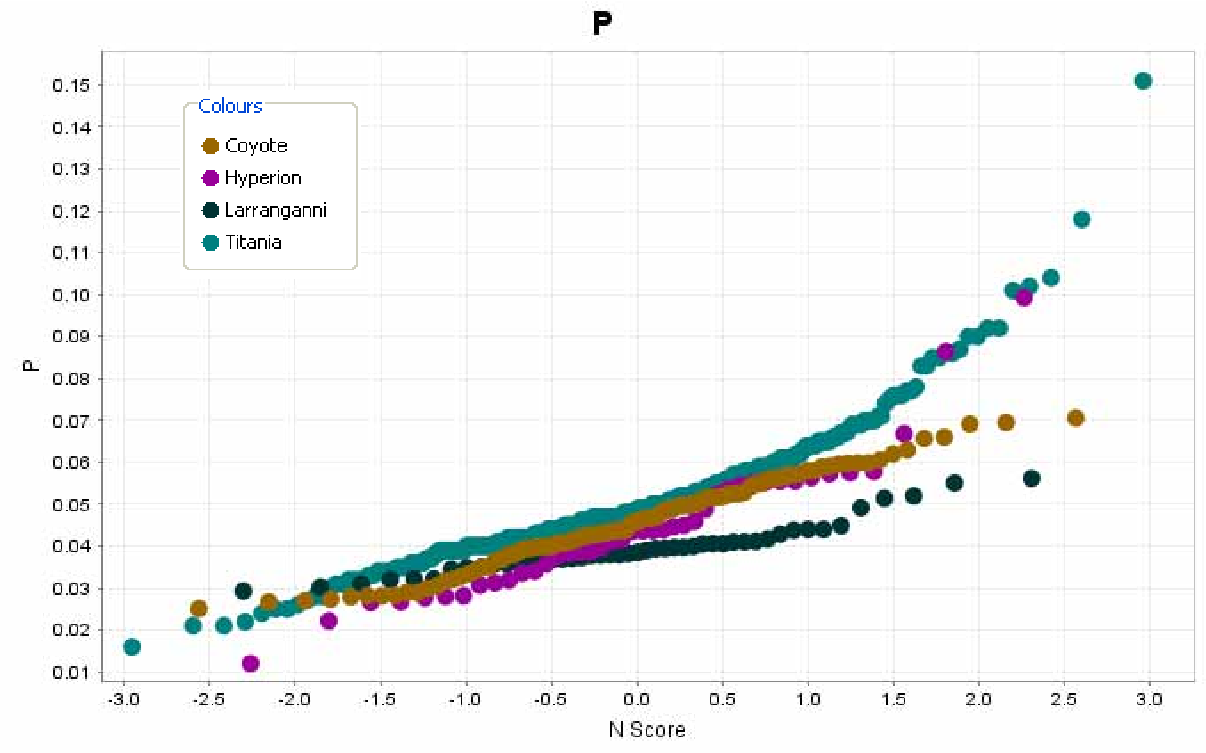

Figure 8.7: P results split by site at the Tanami Prospects.

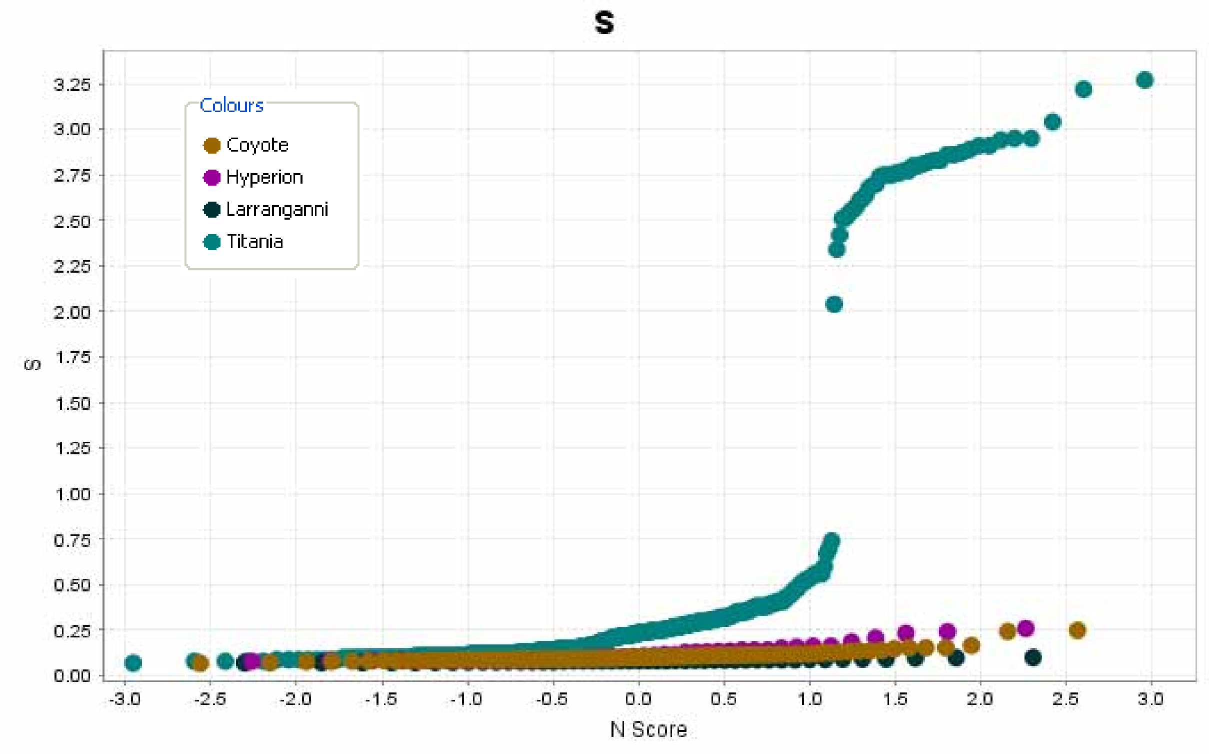

**Figure 8.8: S results split by site at the Tanami Prospects.**

In the Pine Creek field sites there was no significant difference in the Cu results, indicating a Cu limited regime as the plants are only able to take up what is present and there is not enough to highlight differences between the species. The elements with significant differences are Au, Cd, Ce, Fe and P. The Au, Ce and Fe results all show the Johns Hill Prospect to have the highest concentrations, then Great Northern. This can be explained by the other sites having decreasing amounts of transported cover, as expressed in the *Heteropogon triticeus* results. Johns Hill has soils affected the most by transport processes as it includes a large fan near a creek. Great Northern is near a creek and crosses two fan lobes either side of a small ridge that hosts the mineralisation. The creek cutting through the McKinlay Prospect has much greater discharge and is highly erosional, hence there is not as much transported material, and the Glencoe Prospect is near a shallow swampy area, but since samples were not collected across this swamp there is minimal expression of it in the plant analyses.

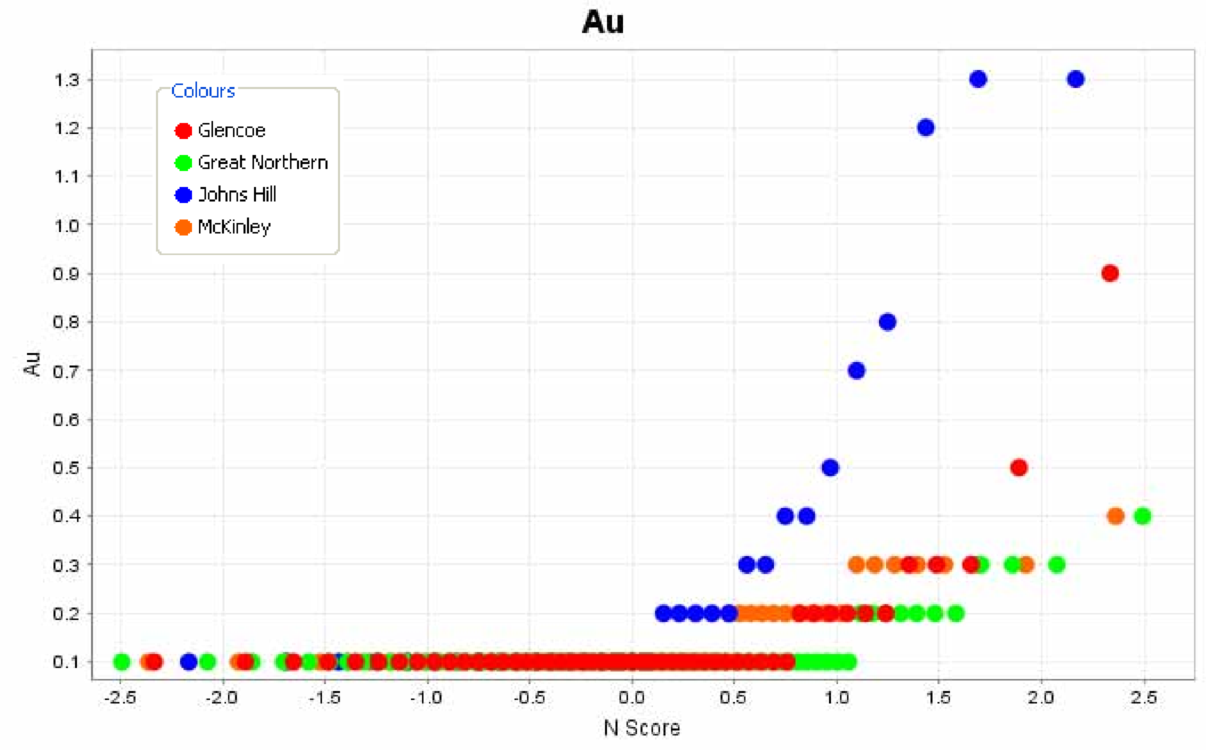

Figure 8.9: Au results split by site at the Pine Creek Prospects.

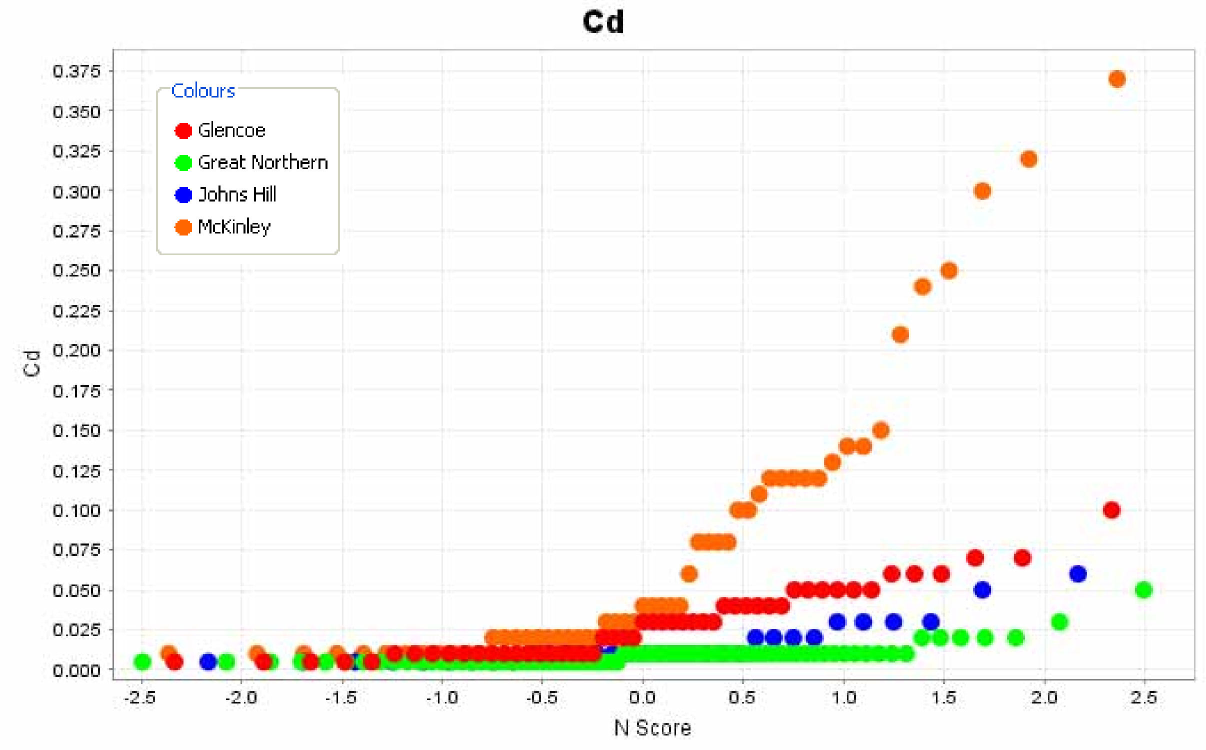

Figure 8.10: Cd results split by site at the Pine Creek Prospects.

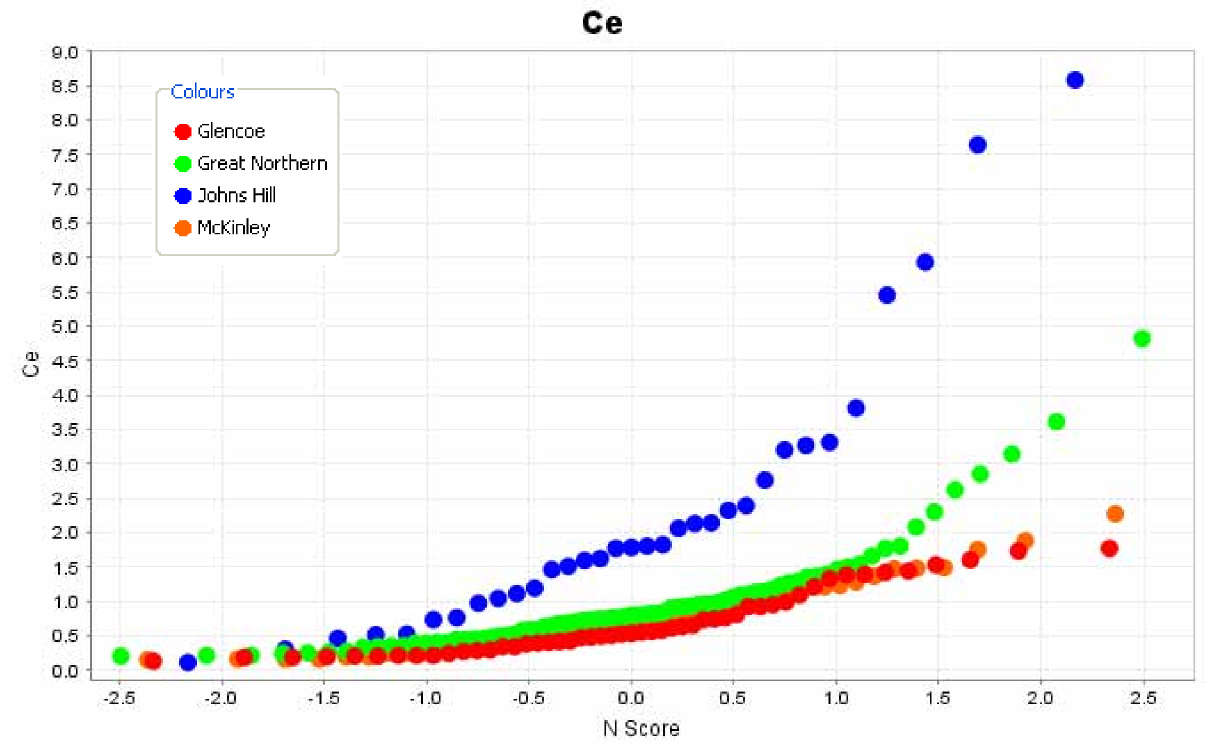

Figure 8.11: Ce results split by site at the Pine Creek Prospects.

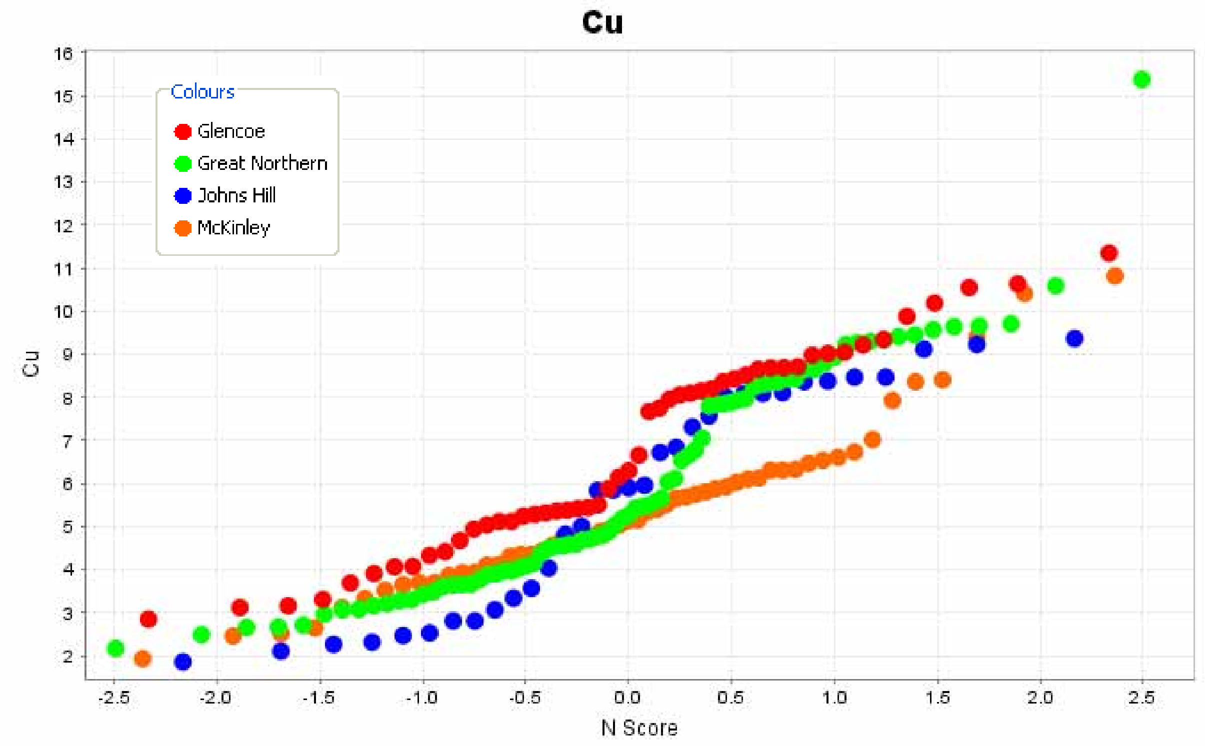

Figure 8.12: Cu results split by site at the Pine Creek Prospects.

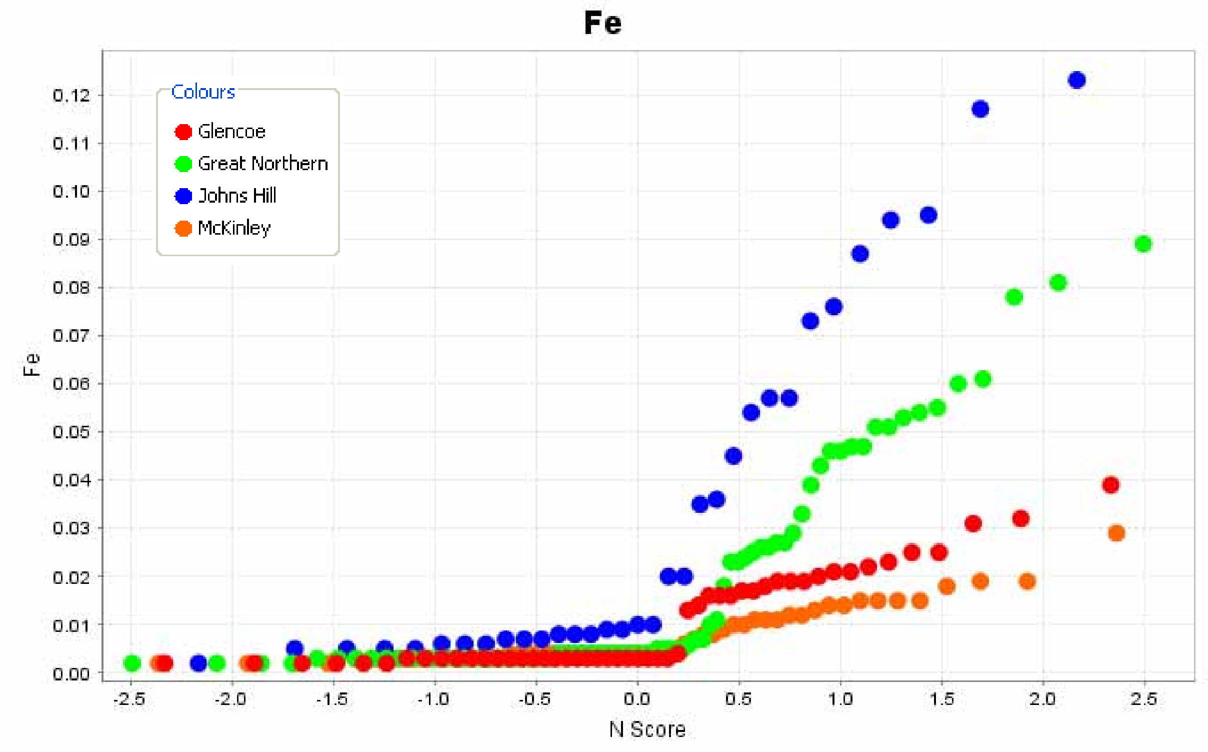

Figure 8.13: Fe results split by site at the Pine Creek Prospects.

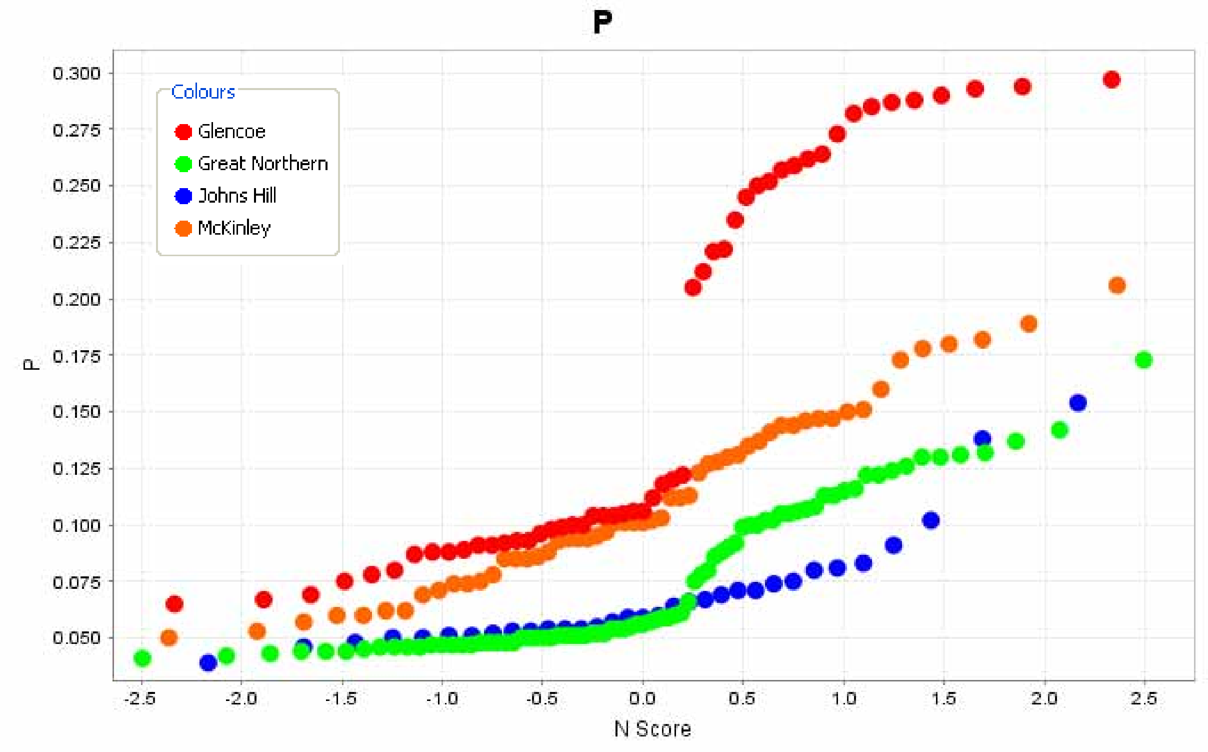

Figure 8.14: P results split by site at the Pine Creek Prospects.

## 8.2 Elemental Links

Elemental links are directed towards finding the source of the elemental components of the plant matter. If basic botanical or geological knowledge is known about a site then interpretations can be made on the elemental signals. The most obvious links that can be drawn are between: the plants and rooting depth within the profile; mineralogy of the substrate; and, contamination from either airborne particles or drill spoil.

### 8.2.1 Depth

Finding links between plant chemistry and substrate depth can be very difficult, there needs to be an amount of background knowledge about the plants to be able to draw reasonable conclusions. If rooting depths are known or suspected, then combining results from a shallow rooted species and a deep rooting species provides a potential 3D geochemical perspective.

The only site where this was possible was at the Titania Prospect where *Acacia bivenosa* is shallow rooted that expressed surficial chemical properties over the site, whereas, *Triodia pungens* is deep rooted and provided deeper substrate chemical properties. Combining the results from the 2 species highlights the differences between the surface and at least the underlying aquifer. The implications of this are that during a biogeochemical sampling program, if both a shallow and a deep rooting species were sampled this could aid in planning follow up drilling of a prospect by providing an indication of whether the mineralisation may be near the surface or at depth. This may further distinguish shallow dispersion haloes in the regolith from deeper mineralisation responses.

### 8.2.2 Mineralogy

Using the plant chemistry to recognise what primary minerals are elemental sources is difficult due to the preferential uptake of major nutrients. There were three recognisable links to mineralogy within the results. They were generally highlighted by higher positive correlation values. There are monazites (shown by REE), Fe-oxy hydroxide coatings on clays (shown by Fe, Al, Th, and some K), and gypsum +/- carbonates (shown by Ca, Sr and S). The REE correlations all showed that the main source were likely to be from the dissolution of monazites, correlations with other elements showed that at the Hyperion Prospect *Acacia coriacea* was likely to be sourcing elements from dissolving primary monazites (correlation with P). At the Pine Creek sites correlations with Al, Fe and other ‘contaminant’ elements showed that the REE in these settings were from detrital sources, that could indicate that monazites had these dusts and clays as coatings, or that monazites were part of the dust component.

The gypsum ($CaSO_4$ +/- carbonates) was only expressed in results from the Titania Prospect, and this was also the only site where gypsum crystals were at the soil surface as well as some subsurface carbonates. *Acacia bivenosa* was able to utilise the Ca and S from gypsum and carbonates and incorporate it into the plant structure at extremely high levels.

The Fe-oxide coatings on clay particles were at all sites, but were less prevalent at the Pine Creek sites, due to greater precipitation levels remobilising Fe-oxides. This correlation can be used to help identify the amount of detrital contamination in the samples, as greater Fe and Al contents relate to more clays and Fe-oxides, which often bind cations within the structure and can skew the vegetation results.

### 8.2.3 Contamination

Contamination is particularly important in determining if a signal is related to small contaminant particles adhering to the plant leaves. If those particles are clays and/or Fe-oxyhydroxides then they can bind important metals, like Au, within the mineral structure and distort the assay results. There will tend to be some proportion of contamination in samples. The aim is to minimise this contamination and account for it consistently.

One of the most important steps in contamination minimisation is the choice of plant species. Plants with sticky or hairy leaves should not be chosen as small particles will be trapped. Smaller plants, which are closer to the soil surface, will tend to have a greater amount of contaminant particles, as seen with the grasses sampled in this study. However, even though these samples had greater amounts of contamination than the other plants, the amounts were still very low, and are mostly insignificant.

### Air Blown Dust

Wind-borne dust (sand, clay or small mineral particles) is typical of arid environments where the substrate is mostly very sandy, with bare patches between vegetation. This can be enhanced by fire such as affected the Titania Prospect 6 months prior to sampling. As shown in Figure 8.1.1, the Fe concentration at the Titania Prospect is much greater than the other Tanami sites, which is due to fire allowing more sand mobilisation. If this is known then the elements associated with them can be accounted for, such as Fe, Th, Al, K, for iron oxide coatings or clay particles, Hf and Zr for micro-zircons which are generally not otherwise taken up by plants.

### Drill Spoil

Contamination from drill spoil is due to previous exploration leaving materials from mineralisation at the surface or else dust emissions during drilling. This material is then either washed or blown around, and can be incorporated into the soil by bioturbation processes. This leads to surficial signals being much wider and more pronounced than those at depth. Deep rooting species with no surface lateral roots are less influenced by this as they do not sample nutrients from the surface.

Drill spoil contamination will generally show ‘bullseye’ haloes within many elements over individual drill holes over the ore deposit, as well as some surface dispersion patterns derived from these points. So it is essential to have a detailed regolith-landform map of the area in order to recognise these artefacts.

## 9 Summary design of phyto-exploration methodology

The initial decisions of what sampling medium to use for exploration are based on what scale of sampling needs to be carried out. Whether there is a lot of unknown ground to cover (regional sampling program), or tracking down geophysical anomalies (prospect sampling program), or exploring over a mining lease (tenement sampling program). If sampling through very thick, unconsolidated, transported cover (sand dunes), it would be advisable to consider ashing vegetation samples to enhance the returned signal. This study was specifically aimed at plants within Australia, however, the same principles can be applied to arid and tropical regions around the world. The rooting systems of the plants are the most important factor to consider. A summary of all the species covered in this study can be seen in Table 2. This shows the ideal sampling program for these species as well as a guide to the ideal ranges of sample spacing. The upper ranges are an estimate based on maximum halo size for pathfinder elements seen in this study, hence taking one sample in this region would highlight elevated values compared to ‘background’ concentrations.

**Table 2: Summary of all species sampled and their ideal sampling uses.**

| **Species** | **Ideal Sampling Program** | **Ideal Sample Spacing** |
|---|---|---|
| *Acacia bivenosa* | None – surficial roots | n/a |
| *Acacia coriacea* | Regional | >500 m |
| *Acacia lysiphloia* | None – sticky leaves | n/a |
| *Corymbia opaca* | Regional – prospect | 25 – 2000+ m |
| *Corymbia polycarpa* | Regional – prospect | 25 – 2000+ m |
| *Eucalyptus brevifolia* | Regional – prospect | 25 – 2000+ m |
| *Eucalyptus foelscheana* | Regional – prospect | 25 – 2000+ m |
| *Eucalyptus miniata* | Regional – prospect | 25 – 2000+ m |
| *Eucalyptus pachyphylla* | Regional | >250 m |
| *Eucalyptus pruinosa* | Regional – prospect | 25 – 2000+ m |
| *Grevillea striata* | Prospect | 25 – 500 m |
| *Hakea macrocarpa* | Regional | >500 m |
| *Heteropogon triticeus* | Prospect | 25 – 250 m |
| *Melaleuca glomerata* | Regional – prospect | 25 – 2000+ m |
| *Melaleuca lasiandra* | Regional – prospect | 25 – 2000+ m |
| *Melaleuca viridiflora* | Regional – prospect | 25 – 2000+ m |
| *Triodia irritans* | Prospect | 25 – 250 m (amalgamate samples) |
| *Triodia pungens* | Prospect | 25 – 250 m (amalgamate samples) |

### 9.1 Regional Sampling Programs

Regional sampling occurs when a large area must be covered and samples are desired at 1-10 km sample spacings or even greater in certain circumstances. In this case the selection of a suitable species is dependant on the species having a very wide spread distribution so that a sample can be collected at every point. Also the sample must incorporate a signal derived from a wide area at the collection point. This can be carried out by having plants with very broad root systems that can grow in a variety of landscape settings. There are several alternatives to this strategy. One is to sample plants that are growing in stream sediments that sample material from upstream; and, another is sampling leaves from several plants within an area thereby amalgamating the signal of a broader area.

Within the Tanami and Pine Creek regions all tall trees with sinker roots and lateral root systems ( *Eucalyptus/Corymbia spp.*) would be appropriate for regional sampling. Species that have known associations with groundwater (apparent due to regrowth after fire independent of rain) are of great interest as they are a surrogate hydrogeochemical medium. If there is information known about the groundwater conditions then it is possible to use these species (*Melaleuca/Eucalyptus spp.*) to gain vectors towards mineralisation.

## 9.2 Prospect and Tenement Scale Sampling Programs

Prospect or tenement-scale sampling is carried out at much more detailed scale than regional sampling programs. This means that more species are available for sampling as it is more likely for a species to be locally abundant over a small area than regionally. Ideal sampling species are deep rooted, and able to grow in a variety of landscape settings (*Eucalyptus/Corymbia*, *Triodia*, *Melaleuca spp*.), which would enable the plants to express chemical signals from depth and not from the overlying transported regolith materials. The chosen species must be locally abundant so that a sample can be guaranteed on a 25-500 m spacing. The use of perennial grasses is also not to be underestimated as the thin fibrous root systems may be deep penetrating, as shown with *Triodia pungens* (Reid *et al.* 2008).

## 9.3 Exploration Methodology

The ideal use of biogeochemical sampling for regional mineral exploration would be the use of a widespread, deep and spreading rooting species. Once these results were analysed, any values higher than background (no absolute cut-off values have been determined as every species is different) should be followed by a more detailed tenement-scale sampling program surrounding the highest values from the regional study. This should then be followed by a detailed, mineralisation delineation study at prospect-scale. If all these samples highlight a geochemical footprint within a multi-element suite then drilling should better define the possible source. This exploration strategy would be quick, sustainable and relatively cheap compared to other methods of exploration. Biogeochemical sampling is however, not the only tool needed for further mineral exploration in Australia, but it will become a great addition to the tools used. This process would work best if integrated with other exploration methods such as geophysics and some soil sampling techniques.

## 10 Conclusions

The main objectives of this study were to determine:

- vegetation associations over known mineral deposits;
- the chemical characteristics of vegetation in relation to the geology and regolith materials;
- relationship between different plant species and different depths within the regolith profile and whether predictions could be made about regolith stratigraphy; and,
- developing vegetation sampling as an effective and efficient mineral exploration tool (phyto-exploration).

Initially vegetation samples were collected and analysed from 9 field sites across Australia, over or near known Au mineralisation. It was found that plants were effective at expressing buried mineralisation in a multi-element suite (pathfinders: Au, As, S, Zn, ±REE, ±Mo and ±Cu) through cover in these terrains provided care was taken with sampling and interpretation.

Previous studies have shown the importance of the plant roots for the absorption of chemical elements into plant matter (Kabata-Pendias & Pendias 1984; Brooks *et al.* 1995; Hulme & Hill 2003; Dunn 2007). The elements taken up and the magnitude of this uptake mechanism is determined by the depth and structure of the plant roots, and the substrate sources that the roots are able to extract bioavailable elements from (e.g. groundwaters, soils and different rock types). Species shown to be hyperaccumulators of elements are not ideal for mineral exploration as they tend to have little association between substrate chemistry and plant chemistry, unless they are able to provide a geobotanical link to mineralisation like some Ni hyperaccumulators do (Brooks, 1998; Prasad, 2005). If a species is identified as a hyperaccumulator then it would be best investigated for phytoremediation or phytomining purposes rather than exploration.

The first biogeochemical investigations in this study were conducted at the Coyote Prospect in Western Australia. This study included a single 3 km transect with 5 species sampled. Different plant organs were sampled at this site and leaves provided the best chemical contrast between mineralisation and background concentrations. This enabled sampling of leaves to be carried out at the other field sites. The site highlighted the influence of different root structures of the plants on their biogeochemical characteristics. *Triodia pungens* had multiple fibrous roots that extended to the greatest depth and had little lateral spread, therefore generating ‘point-source’ chemical signatures leading to a multi-elemental footprint of the ore body. *Eucalyptus brevifolia* had more dispersed and hydrogeochemically influenced biogeochemical characteristics. The other species showed potential for expressing mineralisation but had more restricted distributions and therefore were not as widely applicable as *Triodia pungens* and *Eucalytpus brevifolia*.

The results from Larranganni showed that plants growing directly into mineralised bedrock gave a direct mineralisation signature with very little lateral dispersion. Hyperion had shallow transported cover (7-8 m) and 5 species were sampled. The *Eucalyptus brevifolia* results showed that this species was able to represent mineralisation within a multi-elemental footprint with some lateral dispersion. *Acacia lysiphloia* has sticky phyllodes, and showed characteristics related to wind-blown detritus within the chemical signatures. *Acacia coriacea subsp. sericophylla* showed potential for mineral exploration applications but had greater promise with respect to understanding bedrock chemistry as this species had high REE concentrations corresponding to primary monazites.

The Titania Prospect in Northern Territory hosted the largest sampling program undertaken within this study. It comprised of the leaves of 9 species along 7 transects, 2 km in length, forming a grid. This site had the deepest transported cover (15-30 m) of the Tanami sites and was adjacent to a large palaeo-drainage system. *Triodia pungens, Melaleuca lasiandra* and *Melaleuca glomerata* all showed delineation of the main mineralisation bodies (Au, As, S and Zn) as well as dispersion along hydrogeological gradients. Hence, all 3 species have potential for being useful mineral exploration sampling media, however, the two *Melaleuca* species have limited distributions due to being restricted to soils with greater moisture contents than the other species. *Acacia coriacea subsp. sericophylla* and *Acacia bivenosa* both highlighted surficial chemical features, with *Acacia bivenosa* showing signatures from gypsum and carbonates that were precipitated at the ground surface over much of this site. The soil samples collected from this site over two sampling periods showed that the topsoil showed seasonality effects in the same way that vegetation samples do. This effect was linked to surface water movement (precipitation) and landform setting (source and sink effects). The collection of soil samples from the same trip as the vegetation sampling allowed correlations between the elements within the soils and each plant species, which was able to be used to provide information about some of the minerals that were the dominant source of the elements.

Johns Hill contained a large creek that cut through the transect draining from the mineralised hill. This affected the results from *Heteropogon triticeus,* which showed high concentrations of most elements around the creek. *Corymbia polycarpa* and *Melaleuca viridiflora* both highlighted areas of potential mineralisation ideally tested in follow-up drilling. Great Northern showed influences from sheetwash on either side of the mineralised hill. There were also signatures derived from either the road or creek, to the east of the transect. This was highlighted most within the *Heteropogon triticeus* results, but both *Eucalyptus foelscheana* and *Melaleuca viridiflora* were also influenced. All 3 species delineated a zone of potential mineralisation over the centre of the transect where the mineralisation is predicted to continue under cover. Glencoe showed major influences from a large drainage depression (swamp) to the south of the transect, which meant that secondary chemical peaks would need to be considered for expressions of mineralisation. Both *Heteropogon triticeus* and *Eucalyptus miniata* showed a secondary peak within a multi-element suite, around the centre of the transect in an area that had shallow cover and could be the extension of the main mineralisation. McKinlay was the most difficult site to interpret results from as there was a large creek through the centre of the transect that was close to the area of predicted mineralisation extension. All species sampled at this site, however, showed that there was an elevated zone within a multi-element suite to the west of the creek, but the main overbank dispersion was to the east, indicating that this area would be of interest for follow-up drilling.

The final field site examined within this study was the Tunkillia Au-in-calcrete anomaly. Over this site *Triodia irritans* was collected from the top of a sand dune across the mineralisation. The results from this site showed the problems associated with sampling a plant that must transport a mineralisation signature through 30+ m of chemically depleted sand that would dilute any mineralisation signature. In this case, ashing of the samples was used as a precaution against below-detection limit limitations. The results show that ashing samples before ICP-MS analysis pre-concentrates the signal and enhanced the mineralisation signature, which would have been of low magnitude without the ashed analyses.

Combining the outcomes from each of the field sites led to the exploration strategies outlined in Chapter 9. Regolith materials, botanical properties and landforms are essential background knowledge for determining the effectiveness of biogeochemical sampling. Plants with deep root systems with little lateral spread are ideal for prospect/tenement mineral exploration programs, and plants with wide lateral spreads and large chemical uptake potentials are ideal for regional mineral exploration programs. This exploration strategy would be quick, sustainable and relatively cheap compared to other methods of exploration. This is not to say that biogeochemical sampling would be the only tool needed for further mineral exploration in Australia. This process would work best if used in conjunction with other sampling methods like geophysics and some soil sampling techniques.