Biogeochemical expression of uranium mineralisation by Eremophila shrubs in the northern Flinders Ranges - western Lake Frome Plains, South Australia

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Abstract

The widespread shrub species *Eremophila freelingii,* of inland Australia, has successfully expressed elevated U contents in both leaf and twig samples at workings of known mineralisation in the Mt. Painter region, South Australia. Leaf material produced reasonable contrast in U concentrations and good success rate at expressing buried mineralisation with approximately 75% of all samples returning a U concentration greater than or equal to analytical detection limit (DL). A comparison of leaf with twig material from *E. freelingii* makes this study unique. Elements generally occur in higher concentration in twig tissues than leaves, although twigs have a greater tendency to host detrital (dust) inputs. The highest U concentration came from the high-grade historic Hodgkinson U-prospect (0.25% U_3O_8). Overall leaves contained 0.05 – 0.24 ppm U and twigs contained 0.08 – 0.41 ppm U (1.04-5.86 times higher). Twigs also hosted Re up to 266 times the DL when leaves produced values below the DL. Re elevations in leaf tissue is characteristic of the intrusive granites; Pinnacles and Needles. Beryllium is also unique to Hodgkinson and the Pinnacles and Needles sites. A few traditional U pathfinder elements have an association with U in plant tissues including; Y, Ce, La on a regional scale, and more exclusively at Four Mile West. Other elements; Li and Be displayed associations with U in twigs limited to the Hodgkinson prospect. Mineralisation in the Four Mile West sequence occurs in the Eyre Formation (Four Mile U-prospect) and in the Namba Formation (Beverley U deposit). *E. freelingii* displays elevations in U situated over these units at concentrations above the regional biogeochemical average. Other popular commodities, Au and Ag, were present in low concentrations and returned values ≥ DL in 25.3% and 57.8% of all samples respectively. The Four Mile West sequence hosts the highest Au concentrations, while the hematite breccias host the elevated Ag results. Elevated Zn concentrations are also characteristic of the hematite breccias. Copper showed high variation (3.12 – 32.02 ppm) in all samples but these results do not appear to be closely associated with geological setting. The wide range of element accumulation *E. freelingii* is able to display would stimulate further research with this species in biogeochemical exploration.

KEY WORDS: Uranium, biogeochemistry, mineral exploration, Eremophila, emu-bush, Flinders Ranges

Introduction

Previous biogeochemical studies

The biogeochemical association between plants and uranium has been well established in a range of applications. Previous studies have focused on U uptake in plants included in the human diet (Pulhani, 2005) and also in association with mine waste stabilisation (Overall, 2004; Thiry, 2005). Plants as a mineral exploration tool have been recognised in groundwater springs hosted within mineralised stratigraphy in the USA (Shacklette, 1982), the arid to semi-arid regions of Australia (Hill, 2004; Neimanis *et al.,* 2007; Neimanis & Hill, 2006; Hulme & Hill, 2005; Gallasch, 2007; Lowrey 2007) and sandstone-hosted U mineralisation in Canada (Boyle, 1982; Dunn 2007).

Perennial pine plantations in Germany have been used to stabilise soils derived from mine waste rock. A study that monitored the availability of U in the soil and the distribution in plant material found needles and twigs to be the highest U accumulators resulting in approximately 97% of the annual uptake to return to the soil through litter fall (Thiry, 2005). Similar remediation attempts have been made in the Northern Territory, Australia, at the Ranger Uranium Mine, where Chinese water chestnuts (*Eleocharis dulcis*) were used in an artificial wetland. Uranium was successfully removed from the mine's run-off water and accumulated in plant tissue (Overall, 2004).

The use of plants in mineral exploration has become increasingly popular in the last 30 years with the works of Dunn in Canada and Hill *et al.* in the arid Australian environments but is still poorly understood. Biogeochemical studies involve the strategic collection of plant material that, with careful preparation and laboratory analysis, can produce informative results. The selection and identification of suitable plant species is not only crucial in the success of biogeochemical exploration but contributes to the catalogue of suitable plants for future exploration programs.

Previous biogeochemical exploration

The northern Flinders Ranges - western Lake Frome Plains is a world-class U province, hosting the Beverley Uranium Mine, the Four Mile U-prospect and historical workings in the Mt. Painter – Mt. Gee area. There are increasing environmental and cultural sensitivities related to mineral exploration in these areas, requiring an effective and efficient, but also a minimal environmental impact approach. Recently, biogeochemical exploration techniques have been shown to meet these criteria in many parts of Australia but also in this region (Neimanis & Hill, 2006; Neimanis *et al.*, 2007; Gallasch, 2007; Jennings, 2007; Hill & Hore, 2009).

Eremophila shrubs, commonly called emu-bushes, are widespread across the region. The main species in the region include: *E. freelingii, E. duttonii*, and *E. longifolia*. Previous studies have provided limited results that show that these have some potential to biogeochemically express U mineralisation (Neimanis & Hill, 2006; Gallasch, 2007). These studies have been limited, not only by the number of samples collected, but also for testing and comparing a range of *Eremophila* species, and different plant organs. *Eremophilas* are not only widespread in the region but have colonised sites with known U mineralisation at Beverley, Four Mile and many of the historical workings in the ranges, such as the Armchair, and Streitberg prospects.

The previous work in the Mount Painter region has provided preliminary results using *E. freelingii* as a biogeochemical indicator for U mineralisation. Gallasch (2007) conducted opportunistic sampling of the *E. freelingii* leaves around the Four Mile Creek headwater catchment that successfully expressed U elevations in leaf tissue. Biogeochemical studies by Neimanis & Hill (2006) at the Armchair, Gunsight and Streitberg Ridge prospects used *E. freelingii* (among other species) to successfully express U mineralisation. In this study the use of *E. freelingii* has been expanded to cover numerous historic workings throughout the region, dating back to 1910, as well as a comparison between different plant tissues. Studies by Neimanis *et al.* (2007) also report U concentrations in river red gum material at 6.56 ppm in the Four Mile Creek tributaries.

The biogeochemical exploration method assumes U is mobile and biologically available. Uranium bound in refractory minerals is not displayed in plant tissue due to the high mineral stability. It also assumes the plant species does not have a barrier against the uptake of the element of interest, in this case U, and can accumulate the element within tissues proportional to concentrations in the substrate and accumulate to concentrations above the analytical detection limits (DL).

The U mineralisation in the Mt. Painter area follows three styles; vein, breccia and sandstone hosted. The vein deposit style, associated with fault zones, is characteristic of the Hodgkinson prospect. Sandstone hosted mineralisation includes Nob's Well, Four Mile West, and also Beverley. The breccia style deposit is characteristic of the Radium Ridge mineralisation, which has been a focus of recent biogeochemical studies (Neimanis & Hill, 2006).

Targets for this study include Nob's Well, the Hodgkinson prospect and Four Mile West mineralisation. Opportunistic samples were taken from other geological units and fault related breccias in close proximity to known mineralisation.

The aims of the study are; 1. Determine the effectiveness of *E. freelingii* as a biogeochemical exploration tool on both regional and mineralisation scale; and 2. Determine the most effective *E. freelingii* plant tissue in expressing mineralisation.

Setting

Location

The study area is in the northern Flinders Ranges, South Australia, approximately 500 km north of Adelaide **(**Figure 1**).** Target sample sites are in the Mount Painter Inlier area and immediate surrounds at historic exploration sites. The study area also covers a portion of the Paralana High Plains near the current Four Mile West U- prospect. The Beverly Uranium Mine is approximately 12 km east from the range-front, on the western Lake Frome plains. It is an *in-situ*-leach (ISL) mine, currently operated by Heathgate Resources.

Regional geology

The bedrock geology of the Mount Painter region spans the Lower Proterozoic to the Ordovician. The crystalline basement rocks are exposed in two blocks: 1. the largely metasedimentary Mount Painter Inlier; and, 2. the largely granitic Mt. Babbage Inlier. The two blocks are intruded by alkali granites, and the system was strongly folded prior to the deposition of the unconformably overlain Adelaidean sediments. Sedimentation was interrupted by multiple stages of mild tectonism through the Proterozoic with the suggested intrusion of the soda-rich granites (*The Pinnacles* and *Needles*) around this time (Coats & Blissett, 1971). The Four Mile Creek and Paralana Creek catchments originate in the Lower Proterozoic Freeling Heights Quartzite (FHQ) and the drainage system crosses several younger granite intrusions, Terrapinna and Mudnawatana granites, on the path to the plains. The region has experienced extensive faulting with the Jubilee and Hamilton fault systems splaying off the Yerelina syncline and combining with the larger Paralana Fault system. Fault, shear and breccia zones have been the source of much of the mineralisation in the region (Coats & Blissett, 1971).

Climate

Arkaroola is the closest weather station to the study area, situated ~10 km west into the ranges from the Lake Frome plains. The annual average climate (since 1938) has ~250 mm precipitation, with average maximum and minimum daily temperatures of 25.6 °C and 11.5 °C. Sample collection was conducted on May 9, 2009 after a rainfall of 11.2 mm, on April 24, 2009

(Weatherzone 2009; BOM 2009). The Four Mile Creek section is ~24 km NE on the eastern plains, Nob Well is ~45 km NW on the western plains of the ranges. In the past 10 years (1999-2008) the annual precipitation at Arkaroola has been recorded in the range 103 – 225.2 mm, with an average of 167.8 mm (Table 1). In 2008, the annual precipitation was 182.7 mm (BOM, 2009).

Vegetation

Vegetation in the ranges consists of spinifex (*Triodia irritants*), medium-sparse gum-barked coolabah (*Eucalyptus intertexta*), thickets of curly mallee (*Eucalyptus gillii*), and white cypress pine (*Callitris glaucophylla*) which are generally sparse throughout the ranges, but dominate some catchments. Mulga (*Acacia aneura*) and black oak (*Casuarina pauper*) are widespread and locally abundant on hill slopes and the yacca (*Xanthorrhoea quadrangulata*) is widespread on exposed hills and ridge tops. Smaller vegetation including emu-bush (*Eremophila freelingii*) commonly flanks the channels and slopes in the ranges and often grows directly within rock exposures. *E. freelingii* also covers the erosional rises of the Paralana high plains, with thickets of harlequin fuchsia bush (*Eremophila duttonii*) scattered across the erosional rises and plains. River red gums (*Eucalyptus camaldulensis*) dominate, and are limited to, the large alluvial channels in the ranges and continue up to 15 km onto the floodplain. Dense populations of inland tea-tree (*Melaleuca glomerata*) grow within the smaller drainage networks in the ranges.

History of mineral exploration

Prospecting in the Mt. Painter, Yudanamutana, Mt. Gee area dates back to the 1870s when Cu and Au were of primary interest. Uranium was first identified in the Mt. Painter region in 1910. In the years following this discovery, mining in the area opened up a number of ore bodies including the Mount Painter No. 6 workings. Operations ceased as they were unable to prove a sufficient tonnage of high-grade torbernite ore. Exploration methods at the time relied heavily upon scintillometers to identify radioactive sites.

Exploration efforts in the 1970's were focused on the high-grade Hodgkinson U-prospect and the exploration of the Nob's Well mineralisation at Yerelina Creek. It was also around this time that the sandstone-hosted Beverly U deposit was discovered in 1969 by the Oilmin-Transoil-Petromin group. The deposit was left unexploited until 1999 when Heathgate Resources began *in-situ*-leaching (ISL) operations. The nearby and recently discovered Four Mile uranium deposit is the largest Australian uranium discovery in 25 years (Alliance Resources Ltd., 2009b), and is a similar sandstone-hosted secondary deposit.

Geology of mineralisation

Four Mile West, Paralana high-plains

Secondary U mineralisation occurs as sandstone-hosted deposits on the Paralana high plains at Beverly and Four Mile (FM). The sedimentary sequence of Tertiary-age sediments (Heathgate Resources Ltd., 2009), hosting the mineralisation is exposed in a river cutting at the base of the ranges. The exposure occurs in a tributary of the Four Mile Creek headwaters, and throughout will be referred to as the Four Mile West (FMW) site. At this site there is a continuous exposure of the Mesozoic basement, Algebuckina Fm, Eyre Fm, and the Namba Fm, until the sequence dips south-easterly (40/130) below the cover of the plains. The FMW mineralisation is hosted in the Eyre Fm of the Four Mile embayment, which is constrained to the west by the Wooltana-Poontana fault zone that offsets the stratigraphy. The Beverly mineralisation is hosted in the overlying Namba Formation east of the fault zone. The FMW location is ideal for biogeochemical studies due to the constraint of the underlying bedrock and sediments exposed in the creek cutting.

The emplacement of U as a secondary mineralisation is REDOX controlled. Uranium is mobilised in oxidised conditions where it can migrate with ground waters. In the Mount Painter region, the fluids have moved along stratigraphy and precipitated out in a reducing trap. There are 2 types of traps: 1. fault bound regions off-setting the strata, exemplified by Four Mile mineralisation, and 2. paleodrainage networks, such as the mineralisation at Nob's Well and Beverley (Eromanga Uranium, 2007; Dobrzinski, 1997), where oxidised fluids meet zones of reduction and precipitation.

Nob's Well, Yerelina Creek

The Nob's Well site was a carnotite occurrence within a paleodrainage system uncovered in costeans in the 1970s. Situated 45 km NW of Arkaroola on the western plains, the workings sit on the northern bank of the active Yerelina Creek system. Limited vegetation exists at the site with a few *E. freelingii* shrubs marking the perimeter of the workings and nearby river red gums occupying the channel. Limited documentation on the activity at Nob Well results in the initial grade of the secondary U deposit being unknown. However, current exploration efforts are being directed to the nearby Marree paleodrainage system with the knowledge of the proven carnotite mineralisation only 50 km SE at Nob's Well (Eromanga Uranium, 2007). Interpretations suggest the paleodrainage system to the north is constrained by a NW-SE trending fault which off-sets the basement.

Hodgkinson Prospect, Yudnamutana Gorge

The Hodgkinson prospect differs from the 2 previously mentioned mineralisations which are located on the plains. Situated in Yudnamutana Gorge, the mineralisation is hosted by brecciated, foliated granites and granitic gneisses. The host rocks have also undergone intense kaolinisation, sericitisation and silicification. The mineralisation at Hodgkinson differs from others in the area due to the higher grade with historic estimates of 226 800 t at 0.25% U_3O_8 (Fairclough, 2006). The mineralisation is constrained to a smaller area with lower chlorite and hematite contents (Youles, 1975; Smith, 1992). The prospect is in Yudnamutana Gorge and is fault controlled by the nearby Lady Buxton and Paralana fault systems. The deposit, which contains torbernite, uraninite and thorite minerals, has been exposed in a cutting and the adjacent valley is covered by sediment.

Methods

Objectives

The *Eremophila* genus is widespread across arid regions in Australia. Their widespread distribution makes these an ideal candidate for biogeochemical analysis and mineral exploration applications. Initially, three species were selected for analysis; *E. freelingii, E. duttonii* and *E. longifolia.* Field observations found only *E .freelingii* to be regionally widespread and locally abundant. *E. duttonii* colonises colluvial rises at the range-front in clumped populations, coexisting with *E. freelingii*. The *E. freelingii* is a rounded perennial shrub having a parachute shape canopy after the lower leaves have dropped off the twigs. The leaves are green-grey or light green (depending on the health and the location), covered in fine hairs, and are sticky (Kutsche & Lay, 2003). Flowers and fruit were not an option for sampling due to their poor availability at the time of year that sampling was conducted. *E. longifolia* shrubs occur irregularly in the ranges with no pattern of distribution recorded. *E. freelingii* distribution was extensive across the region and present at each of the documented mineralised sites, however, was absent in the vicinity of the British Empire mine, a Cu-U Kasolite mineralisation (Plimer, 2002), where cypress pines are the dominant vegetation.

Previous studies using Scots pine (*Pinus sylvestris L.*) (Thiry, 2005) and wheat in India (Pulhani, 2005) have shown variations in element accumulation between different plant tissues. With only *E. freelingii* considered for sampling, a plant tissue comparison was performed with this species.

At each site *E. freelingii* leaves were collected. At the Hodgkinson prospect both the leaf clusters and the terminal ~10 cm of twig were collected for a plant organ comparison.

Procedure

Following the guidelines and sampling considerations as outlined by Dunn (2007) and the works of Neimanis & Hill (2006) and Gallasch (2007) in Australia, the following controls attributable to U variation have been noted. Samples were collected from similar sized and aged individuals with a consistent sampling procedure around the shrub canopy. *E. freelingii* grows to about 1 metre high, conveniently providing a homogenous, representative sample. Seasonal variability was insignificant within the sample set with only 1 collection period during the month of May. Samples were collected from living individuals and, where possible, those of good health. The health of the plants, however, varied within and between sites. The *E. freelingii* overlying the Four Mile West deposit were densely distributed, but individuals had thin, wilted leaves which were less abundant than plants at other sites.

Multiple *E. freelingii* samples were collected at historic workings. At the Four Mile West exposure multiple samples were collected above each formation and along transect at approximately 50 metre spacing out onto the plains. Samples on the plains were collected adjacent to the creek system to target the older deeper sediments rather than the young stream sediments.

Clean, jewellery-free, hands were used to collect the leaf clusters from around the plant's canopy and placed in a labelled brown paper bag. At the Hodgkinson prospect approximately 10 cm of twig supporting the leaf cluster was also collected with the leaf cluster for later separation and organ comparison.

Preparation

Preparation of the samples requires care to prevent contamination. Samples were dried, in the original collection bag, for at least 40 hours at approximately 55°C. After this time all samples were dry and brittle but showed variation in colour. The variation in colour was attributable to the oil content in the plant material, which presented problems during the milling process. Leaves were separated from twig material that supported the leaf cluster and placed in the mill. The darker leaf samples, following drying, were more difficult to manage during the milling process and subsequent transfer to envelopes. Some samples appeared darker due to residual oils. The lightest samples proved less difficult to mill and transfer with little to no aggregation of the milled sample. Oil present in the darker samples resulted in smearing the mill, longer milling time, and difficulty in removing the milled sample, which was overcome using a plastic knife. The mill was then cleaned thoroughly using ethanol following the removal of the sample.

An unmilled sample (MPER054) was dried for 48 hours at ~55°C before a portion was removed, placed in a yellow envelope and dried for a further 48 hours at ~110°C. The unmilled plant sample still produced oil after drying at the higher temperature. Oil marks left on the yellow craft envelope indicate that even after extensive drying and removal of water plant tissue retains oil (Figure 2).

Preparation of the twig samples involved the same drying process as the leaves. The removal of all leaves from the tip including the bud at the centre of the cluster (newest growth) was performed following drying. There was significantly less oil in the twig material than in the leaves which made milling and transferring of the sample a much easier process.

Chemical analysis

The dried, milled samples were sent to Acme Analytical Laboratories, Canada for aqua regia digest and ICP-mass spectroscopy (ICP-MS) analysis of a 53 element suite with the following lower analytical detection limits (DL):

Al (0.01 %), As (0.1 ppm), Au (0.2 ppb), B (1 ppm), Ba (0.1 ppm), Be (0.1 ppm), Bi (0.02 ppm), Ca (0.01 %), Cd (0.01 ppm), Ce (0.01 ppm), Co (0.01 ppm), Cr (0.1 ppm), Cs (0.005 ppm), Cu (0.01 ppm), Fe (0.001 %), Ga (0.1 ppm), Ge (0.01 ppm), Hf (0.001 ppm), Hg (1 ppb), In (0.02 ppm), K (0.01 %), La (0.01 ppm), Li (0.01 ppm), Mg (0.001 %) Mn (1 ppm), Mo (0.01 ppm), Na (0.001%), Nb (0.01 ppm), P (0.001 %), Pb (0.01 ppm), Pd (2 ppb), Pt (1 ppb). Rb (0.1 ppm), Re (1 ppb), S (0.01 %), Sb (0.02 ppm), Sc (0.1 ppm), Se (0.1 ppm), Sn (0.02 ppm), Sr (0.5 ppm),Ta (0.001 ppm), Te (0.02 ppm), Th (0.01 ppm),Ti (1 ppm), Tl (0.02 ppm), **U (0.01 ppm),** V (2 ppm), W (0.1 ppm), Y (0.001 ppm), Zn (0.1 ppm), Zr (0.01 ppm).

Quality Assurance / Quality Control

As a general guide, the achievable levels of precision currently available for ICP-MS of 1 g of dry vegetation are as follows (Dunn, 2007);

- < 2 times DL +/- 100%,
- 2-5 time DL +/- 50%,

- 5-10 times DL +/- 25%,
- > 10 times DL from about +/- 10-15%

To support the careful preparation, quality control measures were applied to validate the quality of the assays received from the laboratory by duplicating 1 in 10 samples. The error involved in replicating results varied between elements. From 9 duplicates, the average variation in U content between original and duplicate was 0.28%.

Uranium content in leaves can be determined with reasonable precision with a range from below DL to 24 times the DL (0.01 ppm). The precision achievable by ICP-MS analysis of twigs is much greater, with concentrations ranging from 8 to 50 times the DL.

Observations and Results

The analytical results of the 83 *E. freelingii* samples are presented in Appendix 1. Concentrations below the DL (e.g. <X) are assigned values of half the DL to prevent complications in analysis of the data set. Assays presented in the appendix contain unmodified values. Due to the distribution and the variation in the mineralisation of the sample sites, analysing the data on a site by site basis, as well as at the regional scale, help to identify relationships that may otherwise be missed.

From the full 53 element analytical suite, a sub-set of elements have been selected for further presentation and interpretation (Table 2). The select elements are those with known U associations; traditional pathfinders for U deposits (all types), elements in U host minerals, commodity elements, and contamination identifiers.

Traditional U Pathfinders

The traditional pathfinder elements, or indicator elements, have been identified by their geochemical association with U in ore bodies and the surrounding alteration halo. Not all of these elements can be applied to biogeochemical methods due to limitations in bioavailability in the substrate. Studies in the Colorado Plateau region have recognised Se as a pathfinder for biogeochemical exploration methods (Dunn, 2007). There is no consistency in the U-Se association displayed in *E. freelingii* tissue. Pathfinder elements are typically dependent on the type of mineralisation. Sandstone type deposits generally have Se, V and Mo associations and vein type deposits can have Cu, Bi, As, Co, Mo and Ni associations (Levinson, 1974). Typically U and Th can also be accompanied by Cu, Ag, Ba, Ra, Zn, Pb, Y, rare earth elements (REEs), Ti, Zr, P, As, V, Nb, Se, Mo, F, Co, Ni (Boyle, 1978), Be and Cd (Shacklette, 1982).

In the Mt. Painter region the biogeochemical association between U and other elements appear to vary between sites. Samples from the Hodgkinson prospect showed coinciding elevations in U and traditional U-pathfinder elements; Mo, Se and Cu, however, these are not consistent regionally. Regionally, elements that closely follow variation in U include: Y, La and Ce (Figure 31). The relationship between these elements and U are consistent throughout the Four Mile West sequence and at the FHQ, Yudnamutana workings, Mudnawatana granite, Hot Springs breccia, Nob's Well and the Pinnacles and Needles sites.

A different pattern of element-U relationships exist at the Hodgkinson prospect. Leaf samples taken from the reworked sediments in the adjacent valley display a higher U content than those growing on the outcrop. Element associations in the twig data are not totally equivalent to those with the leaf data, however, the higher U levels appear to have a good correlation with Be and Li in both the leaf and twig samples (Figure 32 & Figure 33). Samples from the Hodgkinson prospect also displayed high Re concentrations that are well above background. Elevations in Re, however, are not unique to U mineralisation with Pinnacles/Needles displaying high Re (Figure 10) and negligible U.

Biogeochemical U pathfinders appear to vary between plant species. Elements with a strong correlation with U in *E. freelingii* (Y, La, Ce, Li & Be) have poor correlation in river red gums (Johnson, 2009). Conversely, Se and Re have a strong U correlation in river red gums but not in *E. freelingii* (Johnson, 2009).

The highest As content occurs in samples from Hematite Valley (Figure 3) and present in lower concentrations at FMW and Nob's Well. While there is no clear U-As relationship at each of these sites, As shows good variation. Arsenic is below the DL in leaf and twig samples from the Hodgkinson prospect which suggests common REDOX controls at the FMW, Nob's Well and Hematite Valley sites.

The two combined sets of biogeochemical pathfinders for FMW and the Hodgkinson prospect; Y, Ce, La, Li and Be, are presented as regional distribution maps (Figures 5, 6, 7, 8 & 9) for comparison. The whole set of pathfinders is presented at FMW (Figures 13,14,15,16 & 17) and Hodgkinson prospect/Yudnamutana Gorge area (Figures 21, 22, 23, 24, 25 & 26) to illustrate the variation between mineralisations.

Mineralisation

Four Mile West

Plants growing on the Namba Formation in the Four Mile West sequence produced the regional maximum for multiple elements: Ce, Nb, Th and Zr (Table 2). Locally high concentrations (within the sequence) are also in plants growing in the Namba Formation for U (0.11 ppm) and La. The U distribution at FMW is presented in Figure 13. The high concentrations of these elements from plants growing on the Namba Formation had elevated Al content (0.1%) but similar Al elevations from other Four Mile samples did not share the same high concentrations (see *Contamination*). Moderately high variation exists in Mo (0.13 – 2.04 ppm) directly above the sequence but <0.46 ppm Mo where the sequence dips below cover sediments.

Sample MPER017 (Eyre Formation) coincidently shares the same location as '4MC 020 (E)' *E. freelingii* sample collected by Gallasch (2007) who found U concentrations of 0.01 ppm in plant tissue and 5.5 ppm in regolith carbonates. The two samples display a similar biogeochemical signature.

Hodgkinson prospect

Samples taken from the Hodgkinson prospect were either from the rock cutting or the reworked sediments in the adjacent valley. Samples produced a regional maximum for 5 elements: U (0.24 ppm), Cd (3.2 ppm), P (0.316%), S (0.67%) and Se (1.9 ppm). Again the results have a moderate variation in Mo in both leaves (0.18 – 1.31 ppm) and twigs (0.27 – 1.85 ppm). Hodgkinson is the only location, other than Pinnacles/Needles, to have Be values above DL. Uranium distribution in the Hodgkinson prospect area is presented in Figure 21.

Nob's Well

Samples from Nob's Well had low U concentrations (0.01 and 0.02 ppm). Vanadium, a required component of carnotite, was also low at 2 ppm (DL). Lithium and Sb have slightly elevated concentrations although the levels are not unique to the site. Samples from Nob's Well contain As which appears to have some method in distribution in the region.

Miscellaneous sites & workings

Away from the mineralised sites, U concentrations were low, however, each site generally had a characteristic biogeochemical signature. Biogeochemical assays from near the Quasar M2 drill hole have <0.01 ppm U. The drill hole, which was targeting a geophysical anomaly, displays 8.55

ppm U in the top 4 metres of drill chips (Quasar Resources, 2006). The rock chip geochemical data, however, does not distinguish between bio-available and the insoluble fraction of U. Apart from a slight Ag elevation (4 – 9 ppb), there were no elements with significant elevations at the M2 site.

Both the Pinnacles and Needles are classified as soda-leucogranites in diapirs (Coats & Blissett, 1971) and at 9.5 km apart; these sites have almost identical biogeochemical signatures. The most noticeable feature is an elevation in Re with concentrations ranging from 28 to 42 ppm. Uranium concentrations are low ranging from below DL to 0.02 ppm. Copper values are also among the lowest in the region.

Opportunistic samples from FHQ and Mudnawatana granite have low U contents ranging from 0.01 to 0.03 ppm. The sample from FHQ has a Au content of 0.8 ppb, exceeded only by the FMW sequence (1.9 ppb). Undocumented workings in a hillside cutting at Yudnamutana Gorge appeared to be of limited extent and the biogeochemical data could explain why; U is low (0.02 – 0.06 ppm) and Ni concentrations were also among the lowest in the region (0.5 – 0.6 ppm).

Hematite Valley breccias

The breccia hosting 4 *E. freelingii* samples, classified as undifferentiated breccias (Coats, 1969; Coats & Blissett, 1971), is likely fault controlled. The breccia north of Yudnamutana Gorge appears aligned with the SE trending section of the Lady Buxton Fault south of the gorge. The extension of the Lady Buxton Fault to the Jubilee Fault to the north intersects the Paralana Hot Springs Fault at approximately 90 degrees. The Hematite Valley breccia is characterised by high Zn values (94.1 – 155 ppm).

Paralana Hot Springs breccia (Paralana Fault)

An undifferentiated fault related breccia (Coats & Blissett, 1971) occurs in close proximity to the contact between the Terrapinna Granite and the Mount Neil Granite porphyry. Adjacent to the Paralana Hot Springs outlet is a breccia exposure similar in appearance to the Hematite Valley breccias. The Hot Springs breccia has the highest regional Li content in leaves at 2.36 ppm (Figure 8) which differentiates this breccia from Hematite Valley. The Hot Springs breccia also has a significantly lower Zn expression (34.3 ppm).

Popular commodities

The *E. freelingii* has been used primarily with a U focus but the multi-element results also apply to some of the other popular commodities, such as Au, Cu and Ag, which have attracted exploration in the Mt. Painter region, especially along the Paralana Fault.

Gold occurrence is rare (Coats & Blissett, 1971) and is displayed by the generally low concentration in *E. Freelingii* (Figure 11). Only 25.3% of samples expressed Au values above the DL (0.2 ppb). The highest values occurred in the Four Mile West section producing concentrations up to 1.9 ppb. Traditional Au pathfinders; As, Hg, Bi, Sb and Cd (Dunn, 2007), do not display a significant relationship with Au.

Copper mineralisation is locally abundant throughout the Mt. Painter region occurring as secondary minerals in zones of oxidation and as sulphides (Coats & Blissett, 1971). Generally, Cu variation in the region was high. The highest Cu concentration, 32.02 ppm, was expressed near the base of the Four Mile West sequence (Mesozoic). Copper was expressed at Hodgkinson with a maximum 28.96 ppm, among the highest in the region (Table 2).

Traces of Ag occur in Cu ore and in association with galena in the Mount Painter region but generally in minute quantities (Coats & Blissett, 1971). *E. freelingii* expressed concentrations of Ag with excellent precision above the DL in 57.8% of samples. The highest concentrations (34 – 131 ppb) occurred in the hematite breccias of Hematite Valley (Figure 12).

Host-mineral elements

Elements that are required components of the U minerals documented in the region include Ca, Ce, Ti, Fe, P, V and K, the statistics of which are included in Table 5 and Table 6. Some of these host-mineral elements are essential nutrients in plants. Generally, macronutrients (% mass dry tissue) include K (1.0 – 1.9%), Ca (0.5 – 1%) and P (0.2 %). In addition, Fe (0.01 %) is present as a micronutrient (Campbell & Reece, 2005; Dunn, 2007). Due to the indefinite presence of these elements in plants, it would be unwise to draw any conclusion on the relationship with U using biogeochemical studies.

With the exclusion of the essential nutrients, Ti, Ce and V remain. Titanium and Ce are both components of the U mineral brannerite. Titanium has broad variation with 100 % of the samples above DL up to a concentration of 21 ppm. Cerium also has broad variation with 100 % of samples reporting above DL and with some interesting elevations at the FMW and Hodgkinson prospect. In the brannerite mineral, Ti and Ce occur in a 2:1 ratio. Regionally Ti is on average 15 times higher than Ce although brannerite has not been documented at any of the sample sites.

Vanadium, a component of carnotite, was scarce in the region. Only 24% of samples returned values equal to the detection limit (2 ppm) or higher. Concentrations of V reached 3 ppm in only 2 samples, neither were at Nob's Well, where carnotite has been previously identified. Vanadium has a relatively high average crustal abundance of approximately 190 ppm (Table 2). Gallasch (2007) states the presence of V around the Four Mile creek headwaters in regolith carbonates at 5 – 95 ppm and bedrock geochemistry <5 – 330 ppm. While the geochemistry shows a high concentration of V in regolith carbonates and bedrock, *E. freelingii* does not bioaccumulate V in tissues to greater than 3 ppm. To use V as a pathfinder, samples would require ashing and back calculation to determine concentrations in dry tissue. The precision for V data close to the detection limit is poor due to interference in on the ICP-MS by a major isotope of Cl, resulting in a higher detection limit for V (2 ppm) (Dunn, 2007). While V is an essential trace element in some plants, it is unusual for V to accumulate in plant tissue to >2 ppm hence determining any relationship with U would require using a different analytical method.

Plant organ variation

The *E. freelingii* shrub has a leaf cluster at each twig extremity. New growth shoots from the tip with older leaves dropping off at the base of the cluster. The history of foliage loss appears as 'bumps' along the twig (Figure 30). The twig is the oldest tissue sampled. The comparison of plant organs from Hodgkinson prospect showed significant variation of element concentration between leaves and twigs. The twig:leaf concentration ratio was calculated for the 7 twig and 7 leaf samples (

Table 3). Uranium ratios ranged from 1.04 to 5.86 with an average of 2.74. Other elements with an average ratio greater than 2 include; Ag, Ge, Hg, Li, Na and Re, and are included in Table 3. The common detrital contaminants; Al, Ti, and Zr (Dunn, 2007) in twigs and leaves can be seen side by side in Figure 34 (also see *Contamination*).

U^2/Th ratio

This ratio is a frontier for biogeochemical exploration, typically showing an enhanced value for secondary U accumulations. An increased contrast between the two elements is influenced by the difference in mobility of the 2 elements. Since Th is more resistant to mobilisation from weathering, U readily migrates. A high ratio is suggestive of a secondary U deposit because they form in chemically reducing traps. Squaring the U value enhances the magnitude of the number and potentially increases the background to elevated response contrast. The highest regional U^2/Th ratio occurred at the Hodgkinson prospect in twig (3.125) and leaf (0.72) samples. The highest U^2/Th value in leaves (0.018) from Four Mile West corresponds to the roll front zone of the mid-Eyre Formation

Discussion

U distribution

From 76 leaf samples, 55 samples (~72%) reported U above 0.01 ppm (DL). Only 4 samples had U less than 0.01 ppm and 17 samples were equal to the DL. The highest U content in leaves (0.24 ppm) was from the Hodgkinson prospect. Uranium elevations also occurred in samples from the Four Mile West and Hematite Valley breccia sites. The 7 twig samples taken from the Hodgkinson prospect have detectable U in all samples (100%) and in high concentrations.

Contamination

Contamination is possible in the arid environments with windblown detritus. The following elements are in high concentrations in the regolith and generally are not accumulated in plant tissue: Al, Ti and Zr. The estimated average abundance worldwide of all tissues from all plants is as follows; Al: 80 ppm [0.008%], Ti: 5 ppm and Zr: 0.1 ppm (Dunn, 2007). Data from this study displays higher concentrations than the average abundance;

Aluminium (Al): has a range 0.03 – 0.13 % with mean 0.61 %.

Titanium (Ti): has range 7 – 21 ppm with mean 12.56 ppm

Zirconium (Zr): has range 0.2 – 1.14 ppm with mean 0.46 ppm

While this could immediately be interpreted as detrital contamination, it is only compared to an average abundance and does not account for possible exceptions of individual species. Multiple samples have corresponding Al and Zr elevations with trace elements at FMW. The highest Al content is from the 3 samples at the end of transect, closest to a frequently used access track. Corresponding elevated concentrations for Fe and Ti suggest some dust contamination. Consequently, Ce, Nb, Hf, Ga and La also have elevated concentrations in these samples.

The samples from the Namba Formation produce a local U and a regional Th high (MPER026), which also corresponds with the previously mentioned elements. The sample was collected 1000 metres from the track, and while traffic is an unlikely cause, the pattern of elevated elements could suggest contamination. Not all samples elevated in Al and Zr display trace element elevation.

Rinsing of samples is a possible measure that could introduce error. The sticky nature of the leaves may adsorb dust particles such that the removal of dust could result in the removal of the sticky/waxy coating on the leaf surface and possibly elements accumulated and excreted in the coating. The data collected appear to be 'fit for purpose'. While dust contamination may have produced elevations in some elements, U elevations occurred at mineralised sites as expected and U concentrations were low in non-mineralised zones also as expected.

Expression of buried substrates (bedrock and sediments)

Samples from above the Four Mile West sequence showed variation over the buried sequence with minimal bedrock exposure on the rise hosting the shrubs. Samples from the Hodgkinson prospect are from directly on exposed mineralisation or substrate derived from the cutting. Shrubs growing in sediments at the Hodgkinson prospect contained higher U, a likely result of higher mobility of U and water through the sediments. Regionally, the majority of shrubs were growing in shallow cover over bedrock where the depth of sediments ranges from a few centimetres at the Hodgkinson prospect to several metres at FMW.

Expression of mineralisation

Samples were collected from three mineralised zones. The highest U concentration in *E. freelingii* leaves corresponded with the highest grade mineralisation at the Hodgkinson prospect. Multiple elevations in U were expressed in shrubs over the FMW sequence, which approximately corresponded to the Namba Formation and the roll-front zone that host the Beverly and Four Mile mineralisation respectively.

Samples from the Nob's Well site had a low U content indicative of poor bioavailability of U in the substrate. The efficient removal of the mineralisation in previous excavations or the remaining U and V being secured in the stable carnotite mineral would control the bio-availability. Due to the disturbed nature of this deposit, the samples collected were on what seemed undisturbed ground around the perimeter of the workings.

Without the previous regolith carbonate studies from Gallasch (2007), it would have been unclear as to the relative abundance of elements in the substrate and the ability of the plant to accumulate certain elements, as for example shown for V. Due to the scale of the *E. freelingii* sampling, the regolith carbonate data are unlikely to be valid for sites other than FMW and may not account for the different soil chemistries and complex soil processes occurring at different sites.

Eremophila biogeochemistry

The depth and extent of the *E. freelingii* root system has not been documented but was noted to extend greater than 1 metre into the regolith surrounding the M2 drill pad. The lateral extent of the roots is also unquantified, however, it is possible *E. freelingii* have deeper sourcing roots due to the nature of the densely spaced population at FMW.

The weathering of bedrock and mineralisation results in the mobilisation of some elements into the overlying regolith (Figure 30). The root system representatively accumulates biologically available elements within plant tissues. Elements in refractory minerals are biologically unavailable and must be quantified with soil sampling techniques to determine a plant-substrate relationship. Elements known to be present in substrate (FMW) are not always bioaccumulated as demonstrated by V in regolith carbonate samples. The distribution of shrubs appears to be unrelated to the substrate.

An important discovery shows the concentration of U, and the majority of elements, to be higher in twigs than the leaves. This is likely due to twigs being older growth, but may also represent greater detrital material hosted within the fissured and rough bark. Similar Al and Ti values are seen in twigs and leaves with Zr higher in all 7 twig samples (Figure 34). The *E. freelingii* is a perennial shrub, where leaves represent approximately 2 years of growth. Twigs represent many seasons of growth and the rainfall associated with those seasons can influence the mobility of elements. The rainfall data from the past 10 years (Table 1) show fluctuations in rainfall which would produce variations in the mobility of elements. The monthly rainfall for 2009 (Table 4) is below average for each month. The Jan-May 2009 period has been drier than the 1938-2008 average (Weatherzone, 2009). It may be possible the uptake of elements is dependent on the rainfall which could result in the leaves collected in May 2009 having lower element concentrations than previous years.

Implications for mineral exploration

The use of biogeochemical methods in exploration would ideally supplement traditional exploration programs rather than replace them. With some prior planning, plants are able to identify mineralisation or at least express elevations of elements within the regolith. Orientation studies must be performed to assess a species' ability to accumulate the elements of interest. This study has shown the importance of sampling different plant organs. Finally, the continuity of the species presence across the region must be considered. This study showed *E. freelingii* was able to express U mineralisation and the concentrations were always higher in the twigs than in the leaves (Figure 35). Some elements (e.g. Be, Re) were barely expressed in leaves but were amplified in twig samples. While *E. freelingii* grew on most mineralised sites, there are some locations where they were absent. It may be beneficial to sample 2 coexisting species to cover areas when one species may be absent. The use of *E. freelingii* can be integrated with traditional soil sampling as well as other species that may coexist such as river red gums (Johnson, 2009), which are limited to alluvial channels and can potentially express much deeper mineralisation and a different suite of elements.

The twigs proved to be the highest accumulator of U. Conveniently, the twig is a more compact sample than the leaf clusters and is also much easier to prepare prior to chemical analysis. Only a small sample size is required (~ 2 handfuls of leaf clusters) such that after drying and milling approximately 5 gram samples can be sent to the labs. Contamination is an issue in the arid environments so care in interpreting results must be taken especially samples in close proximity to mining or exploration operations which may generate dust. Due to the sticky nature of the leaves, sampling twigs may be beneficial in showing higher element accumulation providing dust contamination is not significantly higher.

The program can be organised such that samples are collected along a transect or in a grid arrangement. The spacing between samples depends on the scale of the study; either at regional or outcrop scale, but also on the lateral extent and representation of the *E. freelingii* root system. On a local scale *E. freelingii* can grow in close proximity (FMW), so cluster sampling may help to remove errors associated with individuals.

Plants are an ideal light-weight sampling medium in locations where vehicle access may be limited and where a soil sample may not be representative or insufficient. The vegetation can be incorporated with other biogeochemical techniques; ant (Jennings, 2007) and macropod scat (McMahon, 2007) sampling, in combination with geochemical methods; surface soil samples using bioturbation of profiles by ants (Jennings, 2007) to provide a deeper and more representative soil sample.

Further Research

There is scope for further studies to improve the understanding of this new exploration technique. The identification of twigs to bioaccumulate elements to higher concentrations than leaves provides useful preliminary results to stimulate further research. The next step would be to conduct a regional twig sampling program to confirm the element relationships displayed in twigs at the Hodgkinson prospect. This would indicate whether the relationship with Li and Be against U is significant to use as a pathfinder relationship, rather than an element relationship with twig material.

A study could be conducted to test the suggestion; *the twig is representative of years of bioaccumulation independent of recent rainfall conditions.* This could be tested indirectly by collecting leaf material at different times of year to determine the sensitivity of the species as a biogeochemical indicator. Significant variation in leaves may favour the sampling of twig material.

To improve the knowledge and limits of *E. freelingii,* sampling alongside mineralisation at known depth could provide an understanding of the extent, depth and representation of the root system. This could be performed at the Beverly U deposit possibly expressing the deeply buried U in the Namba Formation or above the FMW mineralised zone which is at 150-200 m depth (Heathgate Resources, 2009). At present, the morphology of the root system is unknown in terms of maximum depth of expression and also the lateral representation which would assist in determining the sampling spacing.

Improvement to this study could include soil sampling, as a control, between mineralised sites and different styles of mineralisation. Sampling *E. freelingii* in a grid at Four Mile West to determine what variation occurs, if any, along the strike of the bedding and across the drainage tributaries in the head waters.

The use of As as a pathfinder for U has been limited to geochemical studies. The distribution of As coincides with the sandstone hosted secondary U mineralisation. Further attention should be given to biogeochemical association of U and As as the distribution of As appears to be REDOX controlled in a similar fashion to that of Fe-Oxides and U. The samples from Nob's Well are taken uphill of the previous excavations and are likely oxidised conditions barren of U. Arsenic is possibly stable with the Fe-O at Nob's Well and FMW sandstone sites, and share similar REDOX conditions of the fluids forming the Hematite Valley breccias. Further studies would be required in proving the effectiveness of As as an indicator for secondary mineralisation.

There is potential for the use of *E. freelingii* as an exploration tool for other commodities such as Cu. The species' gives a good Re expression in leaves and excellent expression in twigs if available in the substrate. Rhenium is commonly found with Mo ores due to the similar ionic size (Lebedev, 1960) and Mo is commonly associated with porphyry copper deposits. While Cu mineralisation was outside the scope of this investigation, attention to Re and Mo in further twig sampling programs could produce interesting findings.

Conclusion

The main findings of this study are;

Eremophila freelingii is the most practical species from the Eremophila genus (*E. duttonii & E. longifolia*) for biogeochemical exploration due to the continuity of coverage in the northern Flinders Ranges.

Specifically, *Eremophila freelingii* has been able to;

1. Express U mineralisation at shallow depths (limitation of study)
2. Display high contrast U bioaccumulation in leaf and especially twig material
3. Identify mineralised formations within a buried sequence at Four Mile West
4. Display a unique biogeochemical signature for different geology and the associated overlying substrates

The study has proven *E. freelingii* to be an effective indicator of U mineralisation on a regional scale. This study has also shown the importance of conducting pilot studies on the continuity of the species at both regional and local scales and also determining the most effective plant tissue for collection and analysis. Some association exists between U and the elements; Y, Ce, La, Li and Be which can be considered in further biogeochemical prospecting for U. Arsenic also appears to highlight the REDOX controlled U mineralisation.

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TABLES

Table 1- Ten years of annual rainfall data, Arkaroola

YEAR	ANNUAL PRECIPITATION (MM)
2008	182.7
2007	107.7
2006	199.2
2005	146.2
2004	188.0
2003	200.6
2002	103.0
2001	171.1
2000	225.2
1999	154.8

Adapted from Weatherzone 2009

Table 2 - Selected elements; based on traditional geochemical pathfinder elements, mineral host elements and apparent biogeochemical associations with uranium.

Element	Average crustal abundance	Max. Biological abundance (Leaves unless stated)	Geological associations
Ag	70 ppb	131 ppb	Hematite Valley breccia
As	2.1 ppm	0.6 ppm	4MW; Eyre Formation Hematite Valley breccia
Au	3.1 ppb	1.9 ppb	4MW; Basement
Be	1.9 ppm	0.4 ppm	Hodgkinson (valley sediments); twig + leaf
Cd	0.15 ppm	3.2 ppm	Hodgkinson (valley sediments)
Ce	60 ppm	4.62 ppm	4MW; Namba Formation
Co	30 ppm	0.56 ppm	Hodgkinson (cutting)
Cu	68 ppm	32.02 ppm	4MW; Basement
La	34 ppm	4.04 ppm	Hodgkinson (cutting)
Li	17 ppm	Twig; 3.27 ppm Leaf; 2.36	Twig; Hodgkinson (valley sediments) Leaf; Paralana Hot Springs breccia
Mn	1100 ppm	Twig; 117 ppm Leaf; 80 ppm	Twig; Hodgkinson (rehab) Leaf; Hodgkinson (rehab)
Mo	1.1 ppm	2.04 ppm	4MW; Lower Eyre Formation
Nb	17 ppm	0.1 ppm	4MW; Namba Formation
Ni	90 ppm	2.9 ppm	Mudnawatana granite
Pb	10 ppm	2.15 ppm	Hematite breccia
Re	2.6 ppb	Twig; 133 ppb Leaf; 42 ppb	Twig; Hodgkinson (valley sediments) Leaf; *The Needles,* Soda leucogranite
Se	0.05 ppm	1.9 ppm	Hodgkinson (rehab)
Th	6 ppm	1.65 ppm	4MW; Namba Formation
Ti	6600 ppm	21 ppm	Hodgkinson (valley sediments) + Nob Well
U	**1.8 ppm**	**Twig; 0.5 ppm** **Leaf; 0.24 ppm**	**Twig; Hodgkinson (valley sediments)** **Leaf; Hodgkinson (valley sediments)**
V	190 ppm	3 ppm	4MW; Unknown + *The Pinnacles,* Soda leucogranite
Y	29 ppm	3.547 ppm	Hodgkinson (cutting)
Zn	79 ppm	155 ppm	Hematite breccia
Zr	130 ppm	1.14 ppm	4MW; Namba Formation

Table 3 – Distribution of all 53 elements in twig and leaf material at the Hodgkinson Prospect. Ratios calculated by element concentration in twigs divided by the element concentration in leaf cluster from the same shrub sample.

Element	Smallest ratio	Largest ratio	Site Average (of 7 ratios)
Ag	1.00	3.00	2.24
Al	0.83	1.29	1.07
As	1.00*	1.00*	1.00*
Au	1.00	3.00	1.29
B	0.93	1.29	1.11
Ba	0.55	1.15	0.83
Be	0.50	2.00	1.29
Bi	1.00*	1.00*	1.00*
Ca	0.60	1.17	0.80
Cd	0.38	0.76	0.54
Ce	0.86	1.38	1.00
Co	0.79	1.27	0.96
Cr	0.72	0.93	0.84
Cs	0.92	1.28	1.11
Cu	0.35	1.78	0.76
Fe	0.85	1.32	1.05
Ga	0.50	2.00	1.07
Ge	0.40	8.00	2.24
Hf	1.15	2.83	1.85
Hg	1.80	3.00	2.34
In	1.00*	1.00*	1.00*
K	1.03	1.62	1.36
La	0.89	1.26	1.00
Li	1.39	5.27	2.82
Mg	0.84	1.62	1.25
Mn	0.86	1.65	1.09
Mo	0.74	2.18	1.28
Na	0.60	9.90	3.59
Nb	0.67	1.50	0.98
Ni	0.67	1.58	1.02
P	0.55	1.13	0.76
Pb	0.40	1.45	0.96
Pd	1.00	3.00	1.29
Pt	1.00*	1.00*	1.00*
Rb	0.88	1.42	1.21
Re	12.00	266.00	99.71
S	0.42	1.10	0.65
Sb	0.33	1.50	0.82
Sc	0.67	1.00	0.95
Se	0.79	2.00	1.39
Sn	0.40	1.60	1.04
Sr	0.52	0.93	0.67
Ta	1.00*	1.00*	1.00*
Te	1.00*	1.00*	1.00*
Th	0.82	2.13	1.46
Ti	0.76	1.17	0.93
Tl	1.00*	1.00*	1.00*
U	**1.04**	**5.86**	**2.74**
V	0.50	2.00	1.64
W	1.00*	1.00*	1.00*
Y	0.61	1.74	1.02
Zn	0.76	1.46	1.17
Zr	1.06	1.74	1.35

* Concentration below detection limit in both branch and leaf sample

Table 4 - Monthly rainfall data for 2009, Arkaroola

MONTH	MONTHLY AVERAGE PRECIPITATION 1938-2008 (MM)	PRECIPITATION IN 2009 (MM)
January	33.5	28.0
February	35.0	0.0
March	29.1	12.9
April	14.4	11.4
May (sample collection)	17.6	10.3
Total (Jan-May)	**129.6**	**62.6**

Adapted from Weatherzone 2009

Table 5 - Leaf data; summary statistics

Element (unit)	Count	Count ≥DL	% ≥DL	Minimum	Maximum	Mean	Median	Variance	Standard Deviation	Kurtosis	Skewness
Ag (ppb)	76	41	53.9	<2	131	6.16	2.00	257.47	16.05	50.14	6.63
Al (%)	76	76	100	0.03	0.13	0.06	0.06	0.00	0.02	1.07	0.82
As (ppm)	76	39	51.3	<0.1	0.6	0.16	0.10	0.02	0.15	1.35	1.45
Au (ppb)	76	20	26.3	<0.2	1.9	0.21	0.10	0.08	0.28	18.54	3.91
B (ppm)	76	76	100	10	23	14.33	14.00	5.40	2.32	1.65	0.81
Be (ppm)	76	7	9.2	<0.1	0.4	0.06	0.05	0.00	0.05	30.02	5.15
Ca (%)	76	76	100	0.79	3.07	1.66	1.65	0.21	0.46	0.68	0.66
Cd (ppm)	76	65	85.5	<0.01	3.2	0.14	0.02	0.19	0.43	35.84	5.58
Ce (ppm)	76	76	100	0.28	4.62	0.94	0.83	0.40	0.63	19.55	3.97
Co (ppm)	76	76	100	0.1	0.56	0.26	0.26	0.01	0.09	0.99	0.87
Cu (ppm)	76	76	100	3.12	32.02	15.87	14.45	46.77	6.84	-0.76	0.25
Fe (%)	76	76	100	0.024	0.125	0.06	0.06	0.00	0.02	0.89	0.81
K (%)	76	76	100	0.81	2.94	1.76	1.67	0.20	0.44	0.36	0.48
La (ppm)	76	76	100	0.16	4.04	0.54	0.44	0.26	0.51	32.73	5.25
Li (ppm)	76	76	100	0.24	2.36	0.59	0.51	0.10	0.32	13.44	3.00
Mn (ppm)	76	76	100	10	80	41.08	42.00	255.57	15.99	-0.62	0.10
Mo (ppm)	76	76	100	0.1	2.04	0.46	0.37	0.12	0.35	5.75	2.13
Nb (ppm)	76	75	98.7	<0.01	0.1	0.03	0.02	0.00	0.01	12.00	2.68
Ni (ppm)	76	76	100	0.4	2.9	1.04	1.00	0.15	0.39	6.18	1.67
P (%)	76	76	100	0.065	0.316	0.13	0.12	0.00	0.04	4.24	1.68
Pb (ppm)	76	76	100	0.14	2.15	0.39	0.33	0.06	0.25	31.32	4.82
Re (ppb)	76	55	72.4	<1	42	3.56	1.00	65.55	8.10	15.46	4.02
Se (ppm)	76	76	100	0.2	1.9	0.47	0.40	0.05	0.23	19.77	3.46
Th (ppm)	76	76	100	0.05	1.65	0.15	0.12	0.03	0.18	61.09	7.46
Ti (ppm)	76	76	100	7	21	12.46	12.00	7.56	2.75	1.69	1.00
U (ppm)	**76**	**72**	**94.7**	**<0.01**	**0.24**	**0.03**	**0.02**	**0.00**	**0.04**	**10.34**	**3.11**
V (ppm)	76	15	19.7	<2	3	1.22	1.00	0.23	0.48	3.69	2.07
Y (ppm)	76	76	100	0.097	3.547	0.35	0.25	0.17	0.42	47.63	6.41
Zn (ppm)	76	76	100	6.8	155	24.04	15.75	730.28	27.02	13.79	3.58
Zr (ppm)	76	76	100	0.2	1.14	0.46	0.42	0.03	0.18	3.14	1.47

Table 6 - Twig data; summary statistics

Element (unit)	Count	% ≥DL	Minimum	Maximum	Mean	Median	Variance	Standard Deviation	Kurtosis	Skewness
Ag_ppb	7	100	2	15.00	6.14	5	18.14	4.26	3.89	1.78
Al_%	7	100	0.05	0.09	0.07	0.07	0.00	0.02	-1.50	0.32
As_ppm	7	0	<0.1	<0.1	<0.1	<0.1	0.00	0.00	-	-
Au_ppb	7	14.3	<0.2	0.30	0.13	0.1	0.01	0.08	7.00	2.65
B_ppm	7	100	13	18.00	16.14	16	4.14	2.04	-1.20	-0.60
Be_ppm	7	71.4	<0.1	0.40	0.17	0.1	0.02	0.16	-0.90	1.14
Ca_%	7	100	0.87	2.25	1.42	1.2	0.32	0.57	-1.97	0.44
Cd_ppm	7	100	0.14	2.13	0.66	0.38	0.48	0.69	4.44	2.03
Ce_ppm	7	100	0.69	3.27	1.42	1.13	0.76	0.87	4.49	2.00
Co_ppm	7	100	0.2	0.44	0.33	0.35	0.01	0.08	-0.31	-0.34
Cu_ppm	7	100	8.79	16.51	11.00	10.16	7.37	2.72	2.95	1.72
Fe_%	7	100	0.045	0.09	0.06	0.058	0.00	0.02	0.60	1.01
K_%	7	100	1.27	2.85	2.30	2.58	0.32	0.57	0.31	-1.04
La_ppm	7	100	0.44	3.59	1.12	0.77	1.21	1.10	6.54	2.53
Li_ppm	7	100	0.5	3.27	1.33	0.95	1.01	1.01	1.55	1.46
Mn_ppm	7	100	48	117.00	72.43	64	622.29	24.95	0.33	1.17
Mo_ppm	7	100	0.27	1.85	0.74	0.61	0.27	0.52	4.89	2.08
Nb_ppm	7	100	0.02	0.03	0.02	0.02	0.00	0.01	-2.80	0.37
Ni_ppm	7	100	1	2.30	1.43	1.3	0.24	0.49	0.29	1.18
P_%	7	100	0.102	0.19	0.14	0.145	0.00	0.04	-2.30	-0.01
Pb_ppm	7	100	0.24	0.58	0.37	0.36	0.02	0.13	-0.70	0.80
Re_ppb	7	100	6	133.00	49.86	23	2738.81	52.33	-0.81	1.06
Se_ppm	7	100	0.3	1.50	0.73	0.6	0.18	0.42	0.82	0.98
Th_ppm	7	100	0.08	0.17	0.12	0.11	0.00	0.04	-1.83	0.39
Ti_ppm	7	100	12	16.00	13.71	14	2.24	1.50	-0.97	0.26
U_ppm	**7**	**100**	**0.08**	**0.50**	**0.29**	**0.27**	**0.02**	**0.14**	**-0.52**	**0.09**
V_ppm	7	71.4	<2	2.00	1.71	2	0.24	0.49	-0.84	-1.23
Y_ppm	7	100	0.312	2.18	1.01	0.782	0.38	0.62	1.57	1.16
Zn_ppm	7	100	21.2	63.20	40.20	38.4	186.74	13.67	0.27	0.45
Zr_ppm	7	100	0.36	0.66	0.45	0.4	0.01	0.11	1.79	1.47

FIGURES

Figure 1


SOUTH AUSTRALIA
Arkaroola
Lake Frome
N
0
200
Kilometres
Adelaide

Figure 2

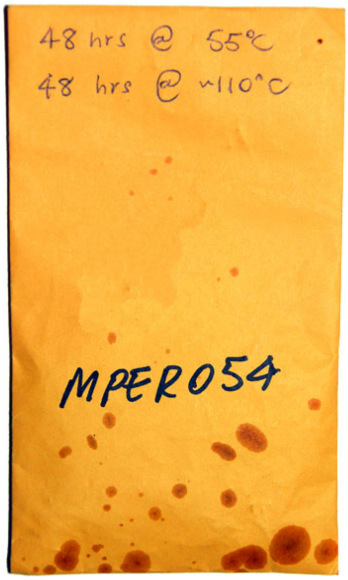


Figure 3

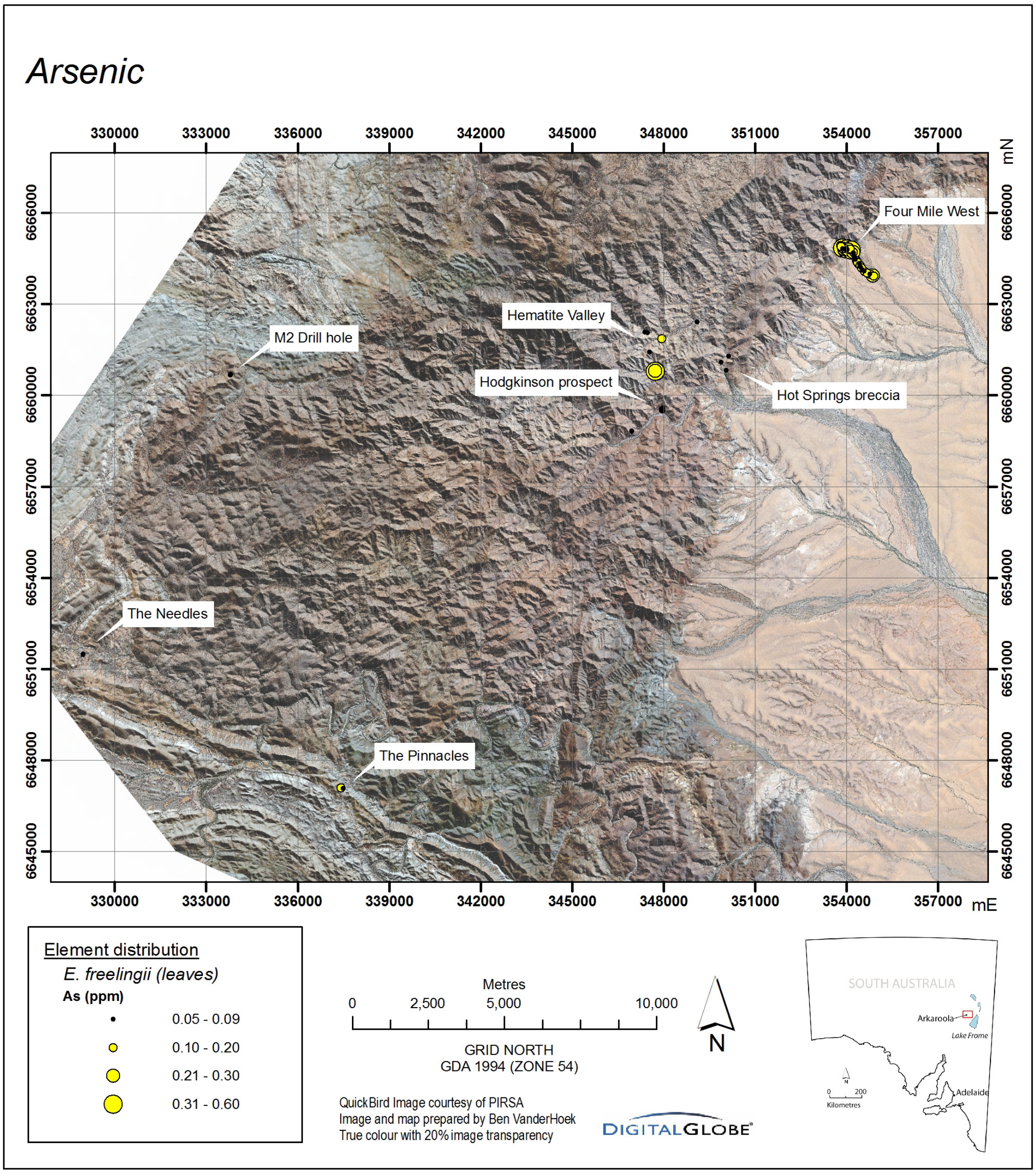

Arsenic
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
As (ppm)
0.05 - 0.09
0.10 - 0.20
0.21 - 0.30
0.31 - 0.60
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 4

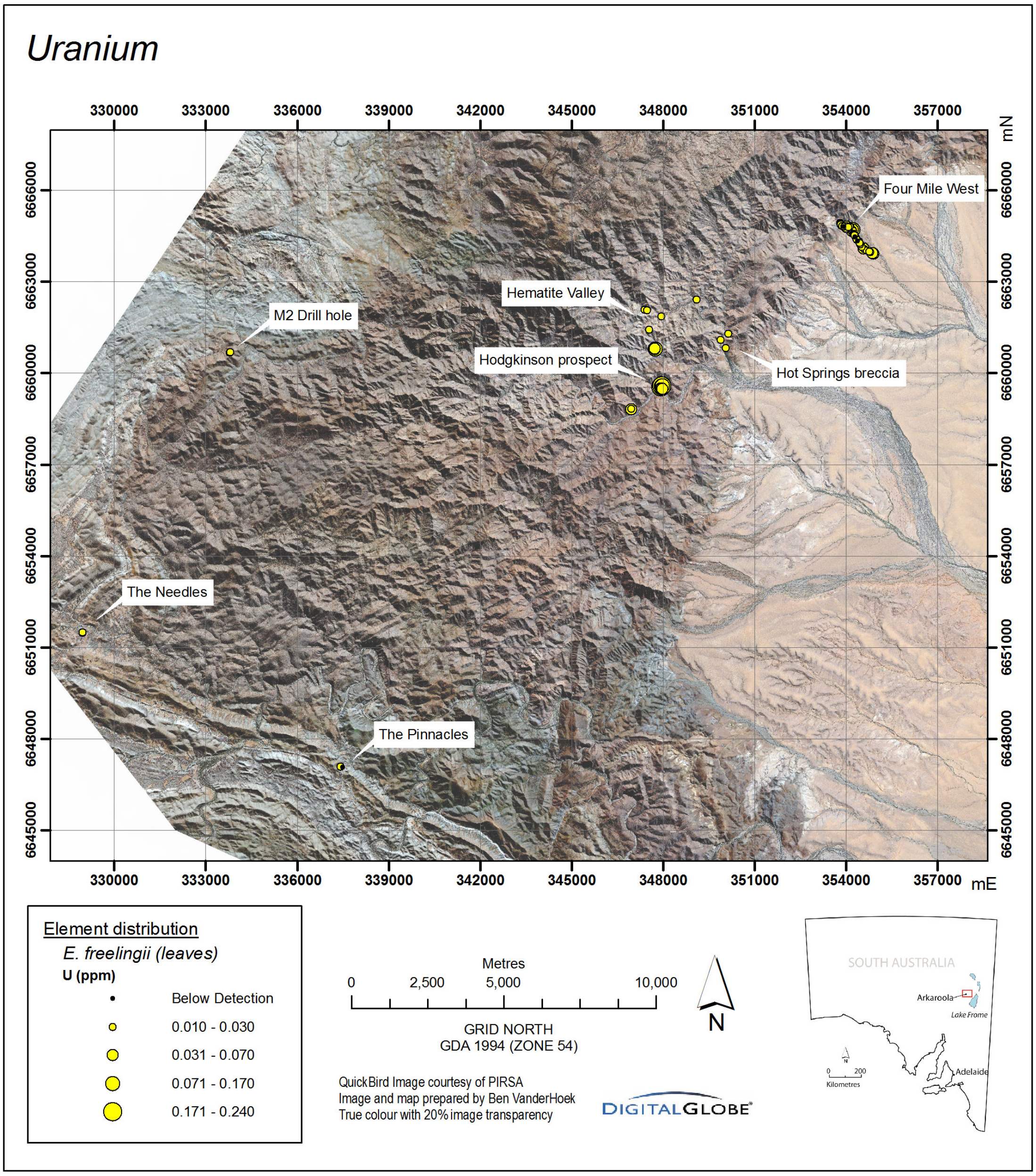

Uranium
330000 333000 336000 339000 342000 345000 348000 351000 354000 357000
mE
mN
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
U (ppm)
Below Detection
0.010 - 0.030
0.031 - 0.070
0.071 - 0.170
0.171 - 0.240
Metres
0 2,500 5,000 10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 5

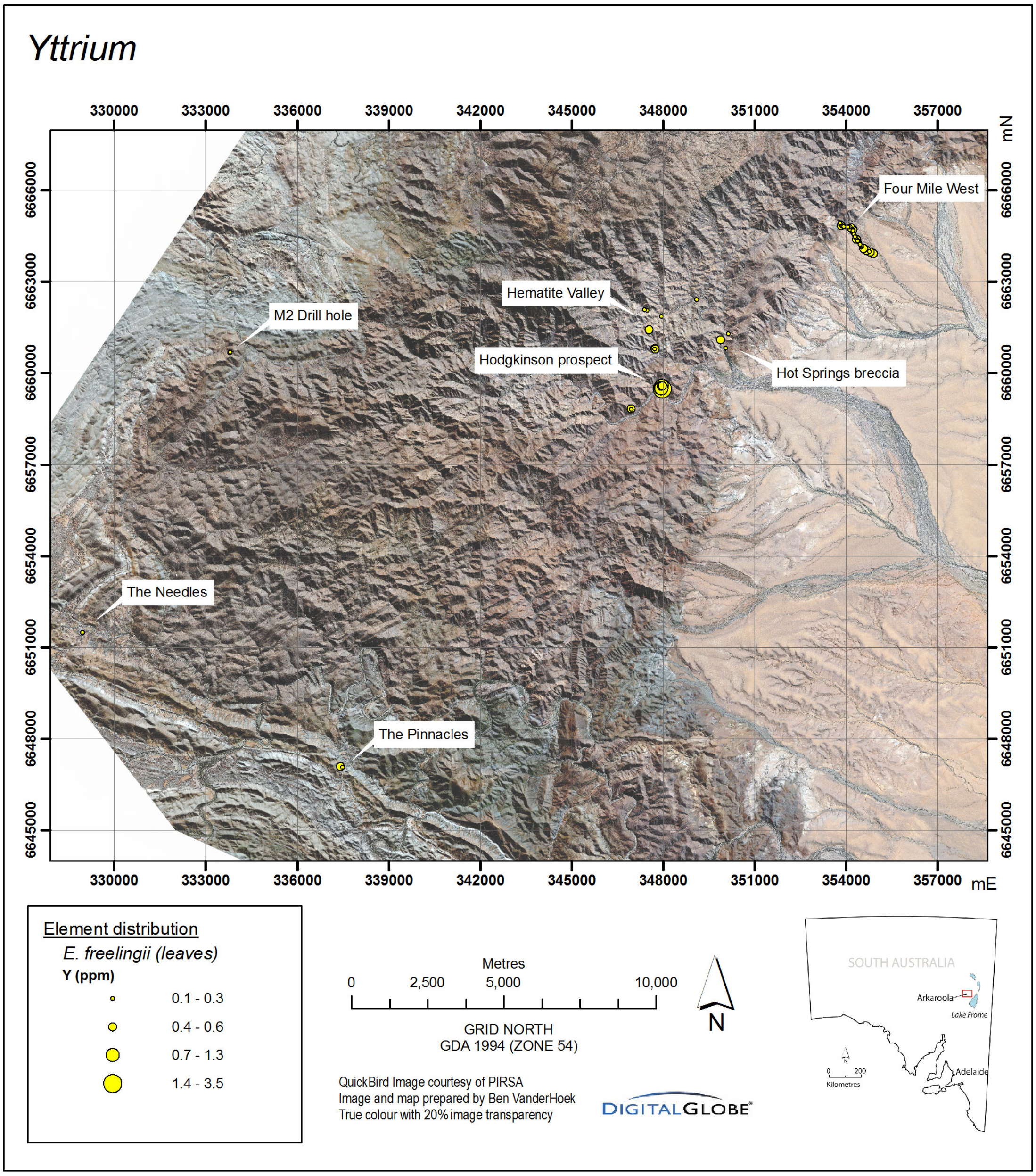

Yttrium
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
330000 333000 336000 339000 342000 345000 348000 351000 354000 357000 mE
6666000 6663000 6660000 6657000 6654000 6651000 6648000 6645000 mN
Element distribution
E. freelingii (leaves)
Y (ppm)
0.1 - 0.3
0.4 - 0.6
0.7 - 1.3
1.4 - 3.5
Metres
0 2,500 5,000 10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 6

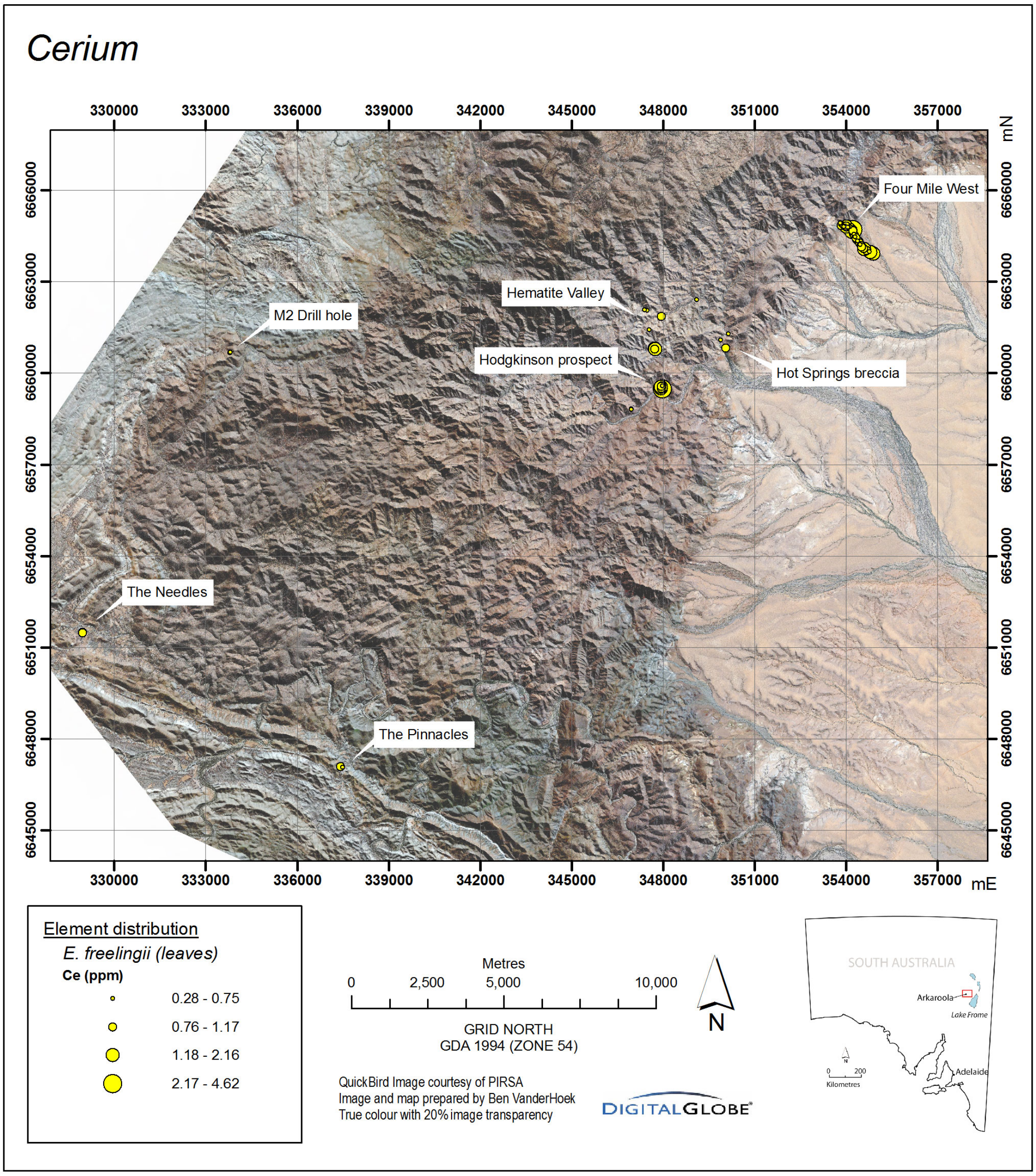

Cerium
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mN
mE
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Ce (ppm)
0.28 - 0.75
0.76 - 1.17
1.18 - 2.16
2.17 - 4.62
Metres
0
2,500
5,000
10,000
N
GRID NORTH
GDA 1994 (ZONE 54)
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 7

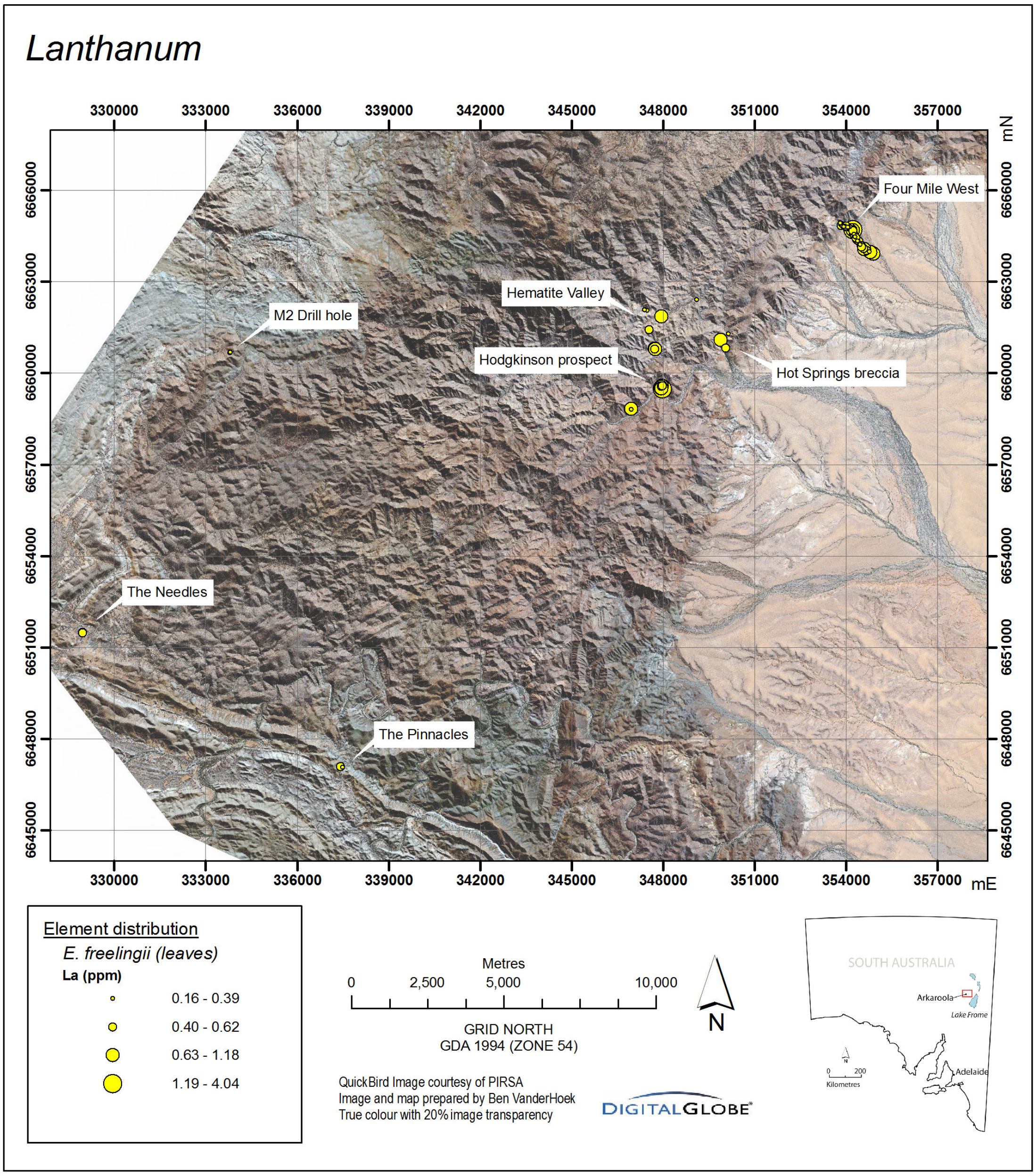

Lanthanum
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
6645000
6648000
6651000
6654000
6657000
6660000
6663000
6666000
mN
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
La (ppm)
0.16 - 0.39
0.40 - 0.62
0.63 - 1.18
1.19 - 4.04
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 8

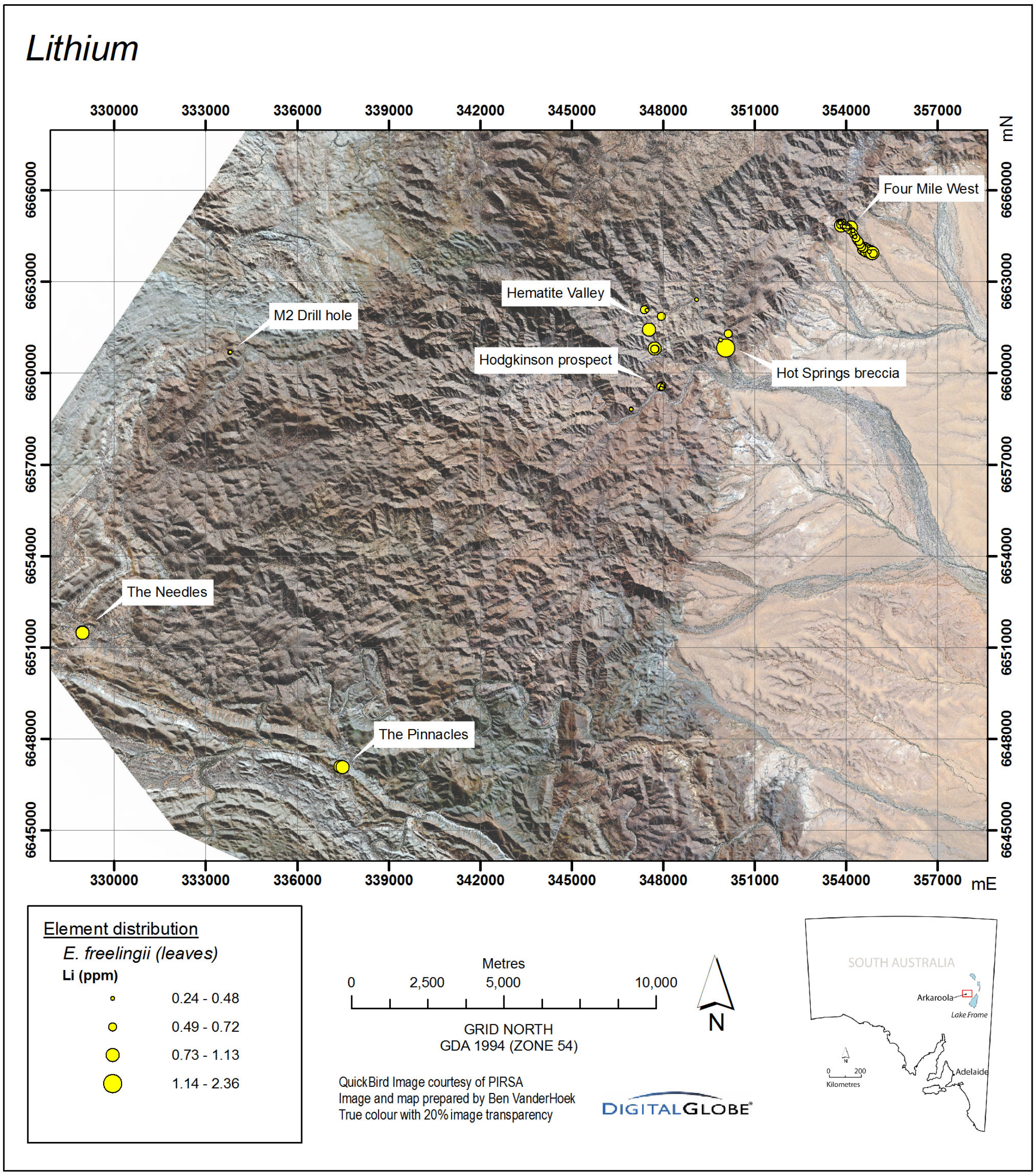

Lithium
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Li (ppm)
0.24 - 0.48
0.49 - 0.72
0.73 - 1.13
1.14 - 2.36
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 9

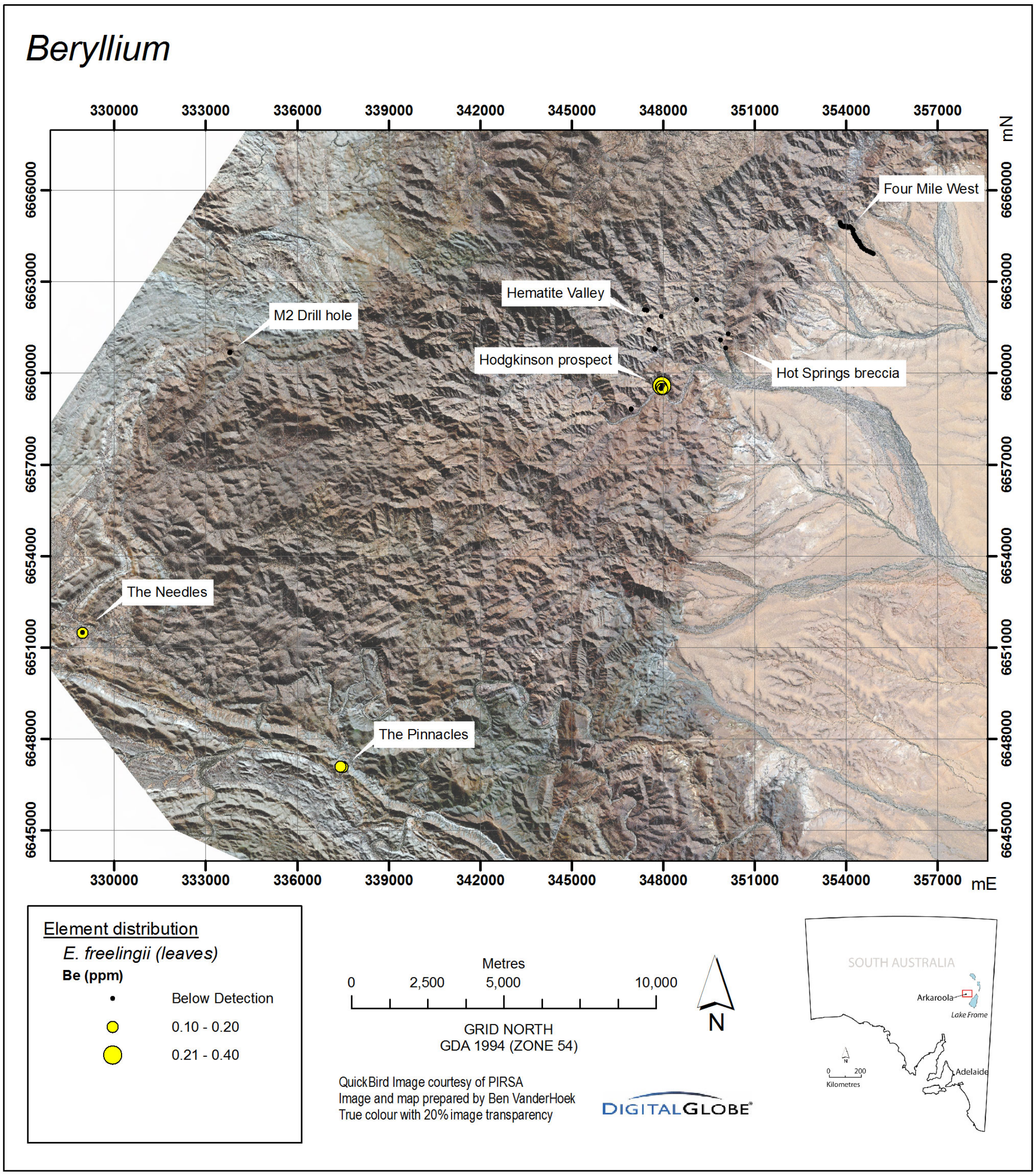

Beryllium
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Be (ppm)
Below Detection
0.10 - 0.20
0.21 - 0.40
Metres
0
2,500
5,000
10,000
N
GRID NORTH
GDA 1994 (ZONE 54)
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 10

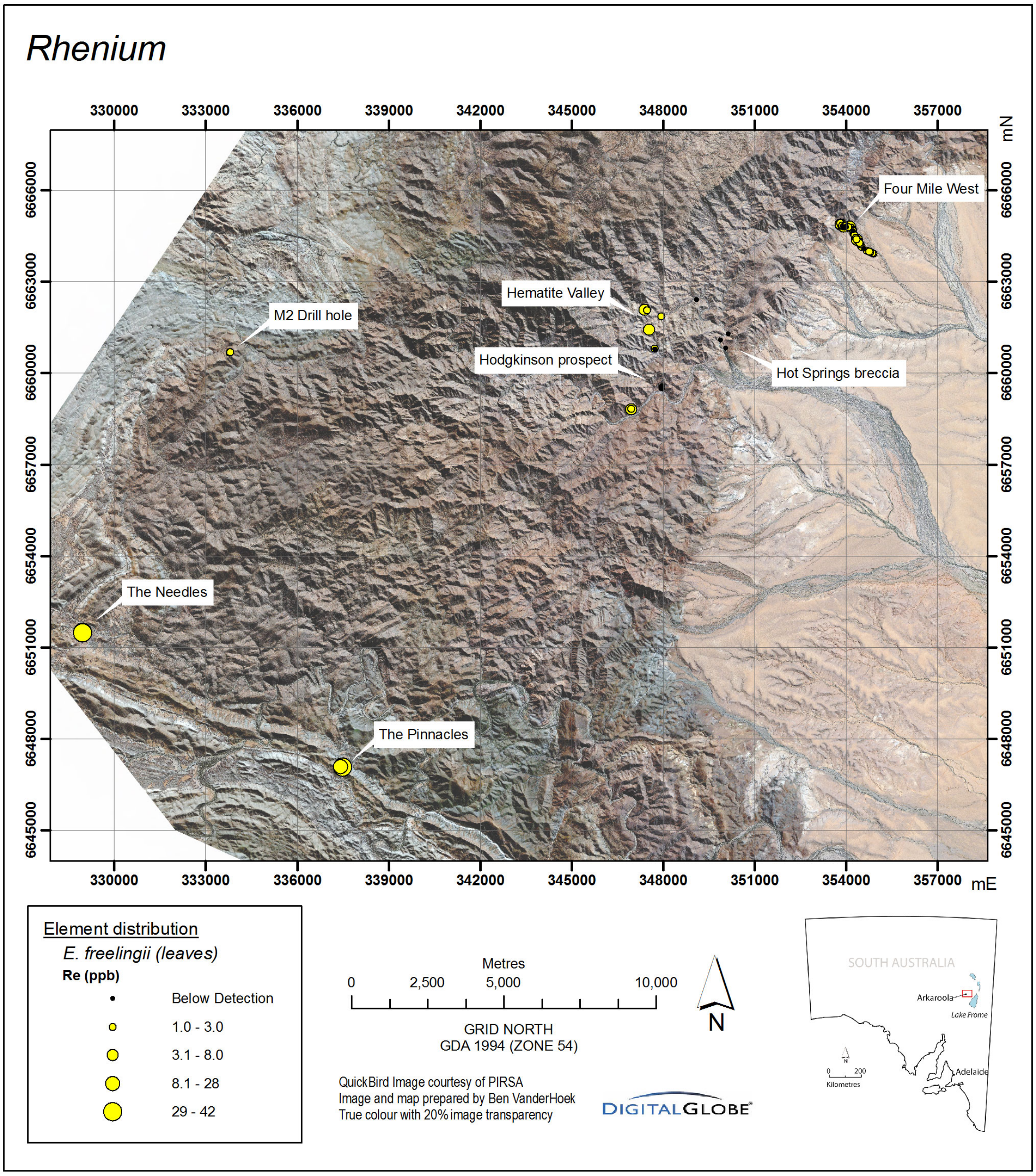

Rhenium
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Re (ppb)
Below Detection
1.0 - 3.0
3.1 - 8.0
8.1 - 28
29 - 42
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 11

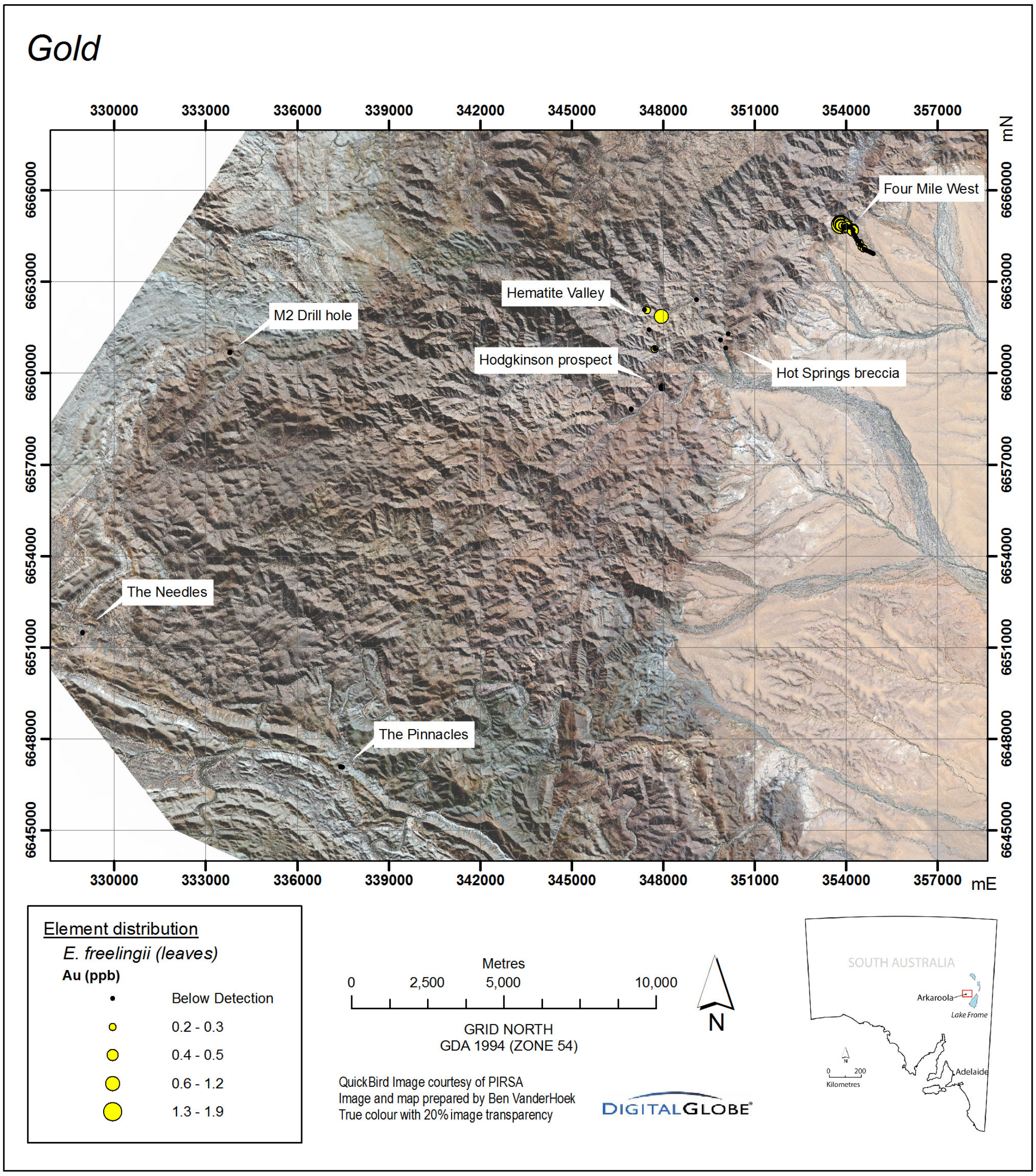

Gold
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6666000
6663000
6660000
6657000
6654000
6651000
6648000
6645000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Au (ppb)
Below Detection
0.2 - 0.3
0.4 - 0.5
0.6 - 1.2
1.3 - 1.9
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide
Kilometres

Figure 12

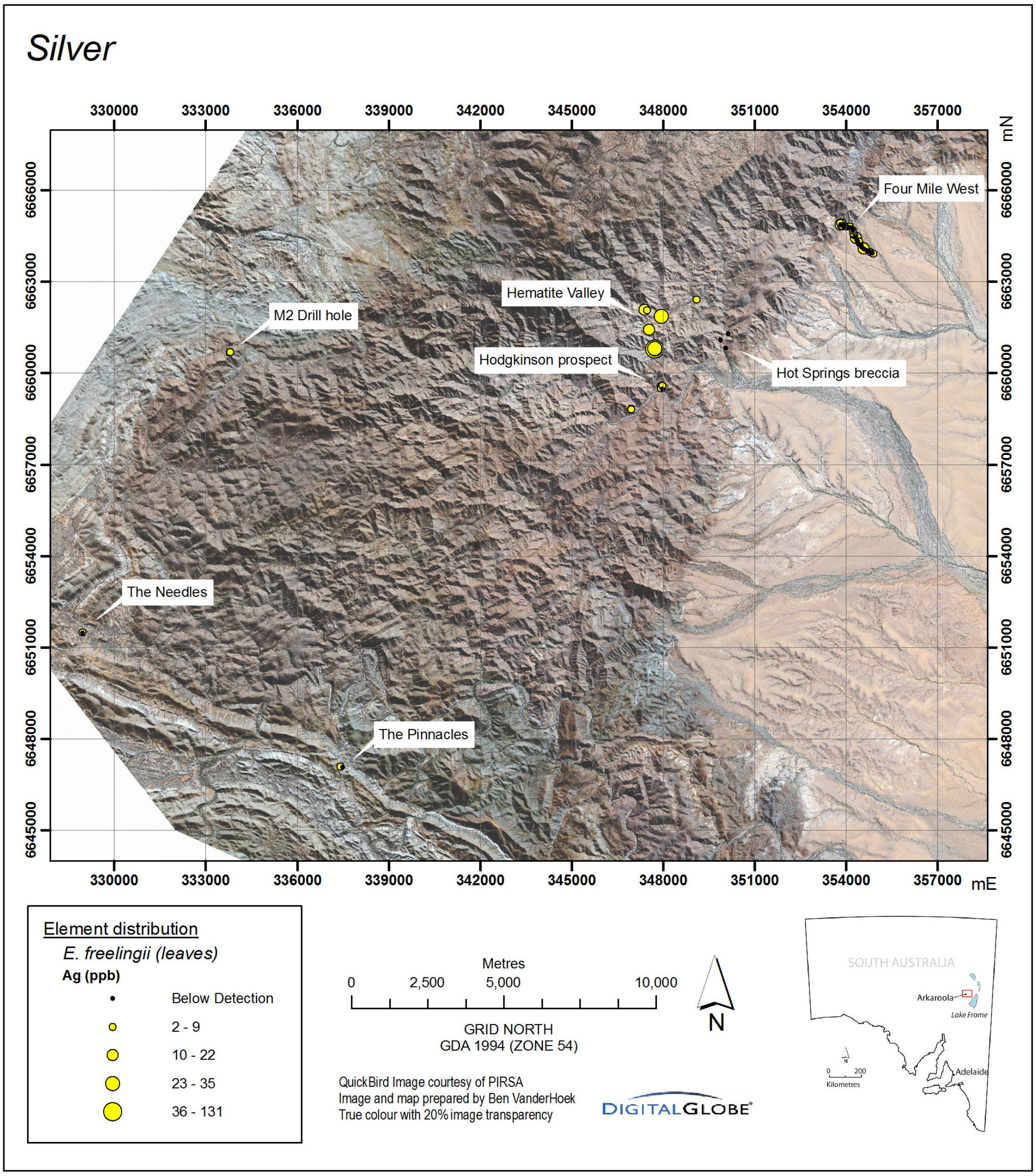

Silver
330000
333000
336000
339000
342000
345000
348000
351000
354000
357000
mE
mN
6645000
6648000
6651000
6654000
6657000
6660000
6663000
6666000
Four Mile West
Hematite Valley
M2 Drill hole
Hodgkinson prospect
Hot Springs breccia
The Needles
The Pinnacles
Element distribution
E. freelingii (leaves)
Ag (ppb)
Below Detection
2 - 9
10 - 22
23 - 35
36 - 131
Metres
0
2,500
5,000
10,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 13

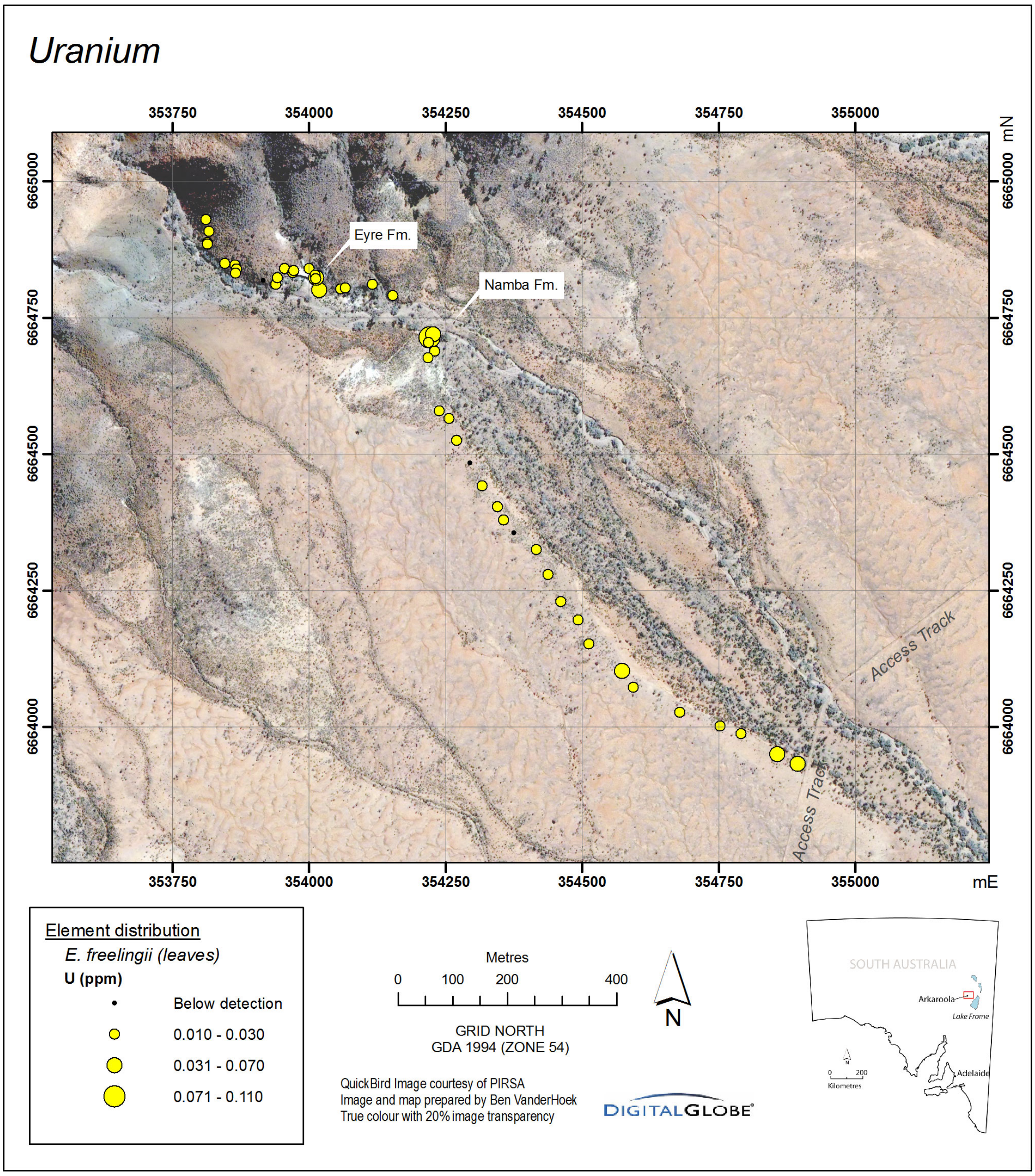

Uranium
353750
354000
354250
354500
354750
355000
mE
mN
6665000
6664750
6664500
6664250
6664000
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
U (ppm)
Below detection
0.010 - 0.030
0.031 - 0.070
0.071 - 0.110
Metres
0 100 200 400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 14

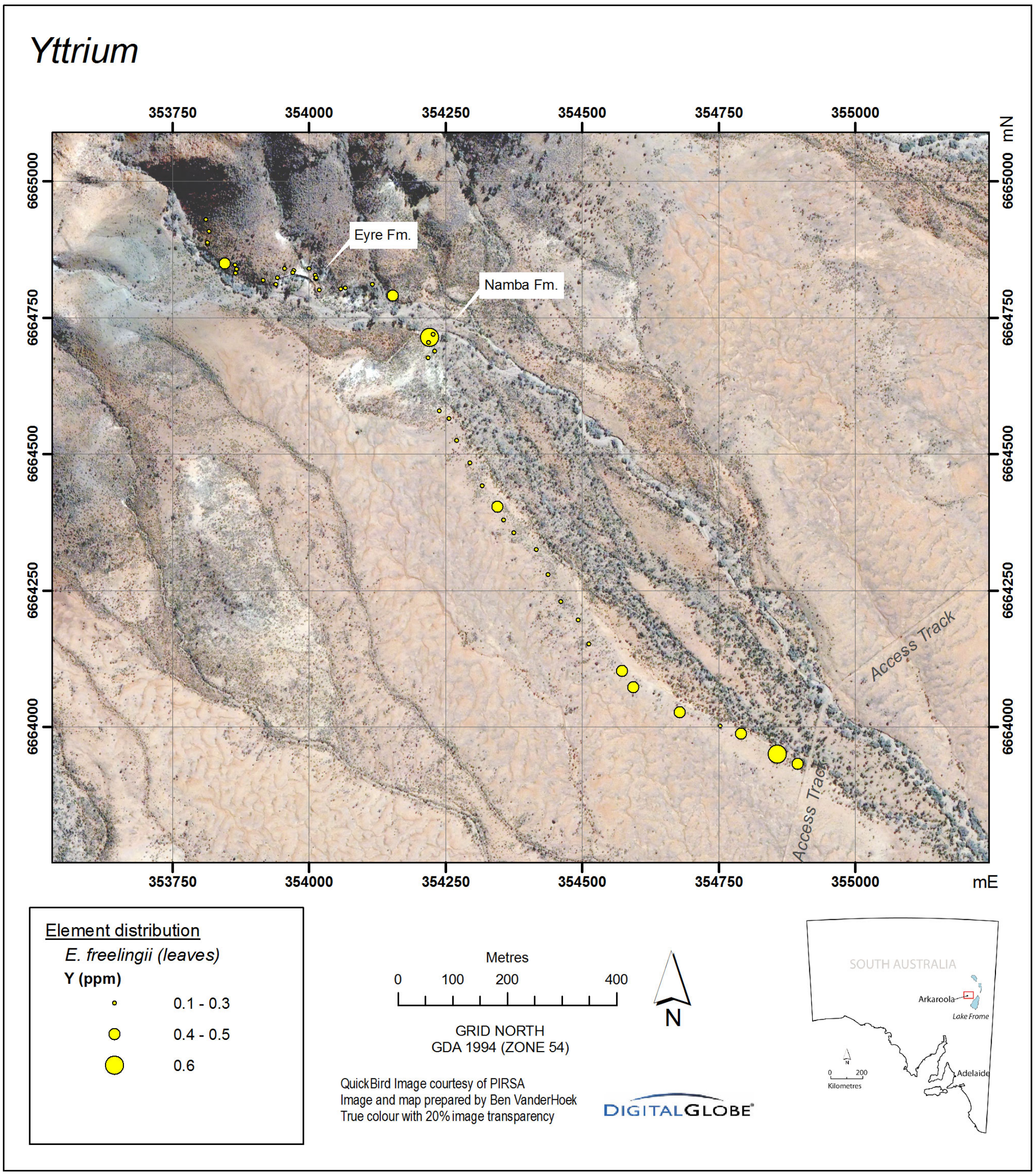

Yttrium
353750
354000
354250
354500
354750
355000
mN
mE
6665000
6664750
6664500
6664250
6664000
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Y (ppm)
0.1 - 0.3
0.4 - 0.5
0.6
Metres
0
100
200
400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 15

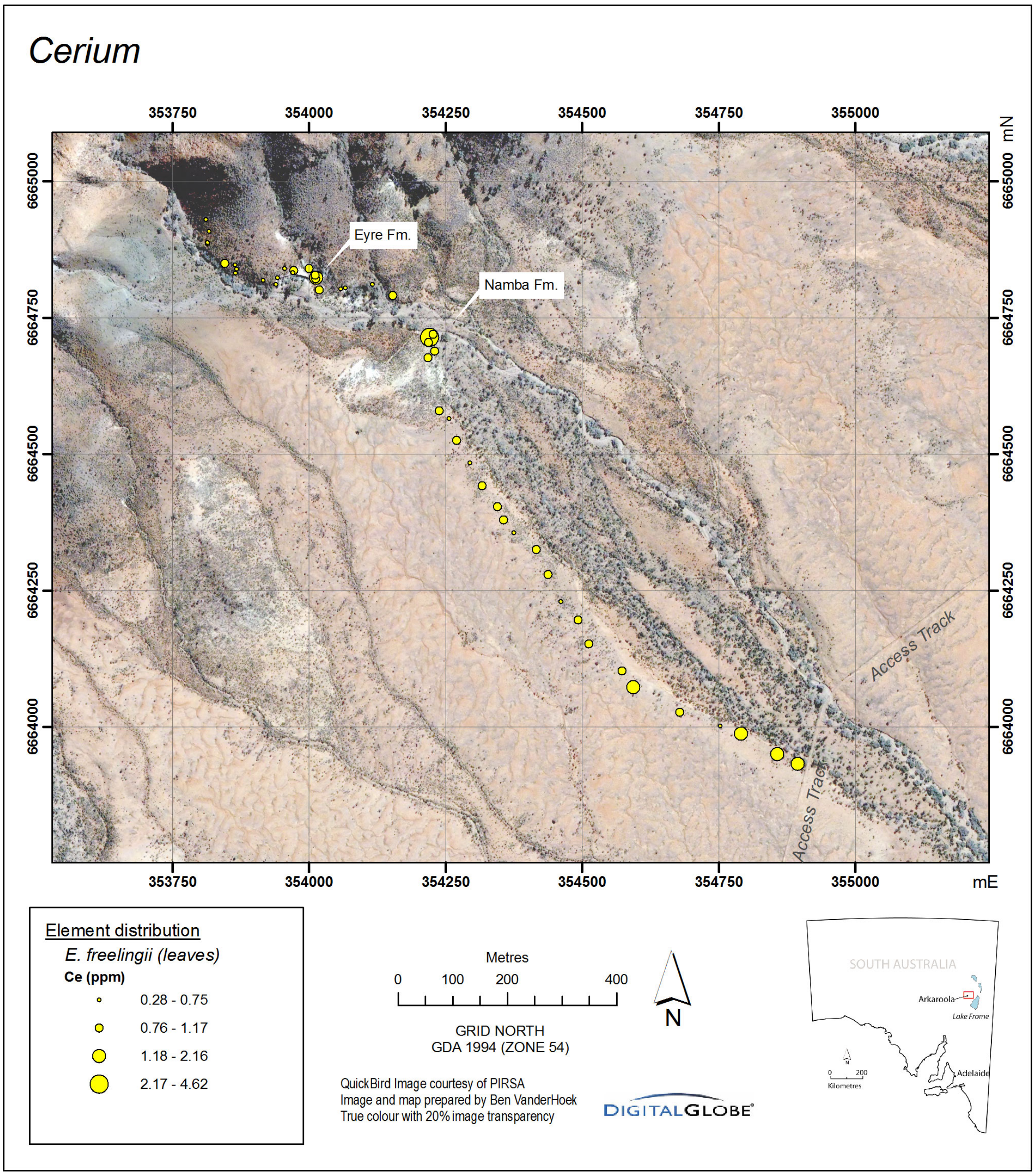

Cerium
353750
354000
354250
354500
354750
355000
6665000
6664750
6664500
6664250
6664000
mN
mE
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Ce (ppm)
0.28 - 0.75
0.76 - 1.17
1.18 - 2.16
2.17 - 4.62
Metres
0
100
200
400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 16

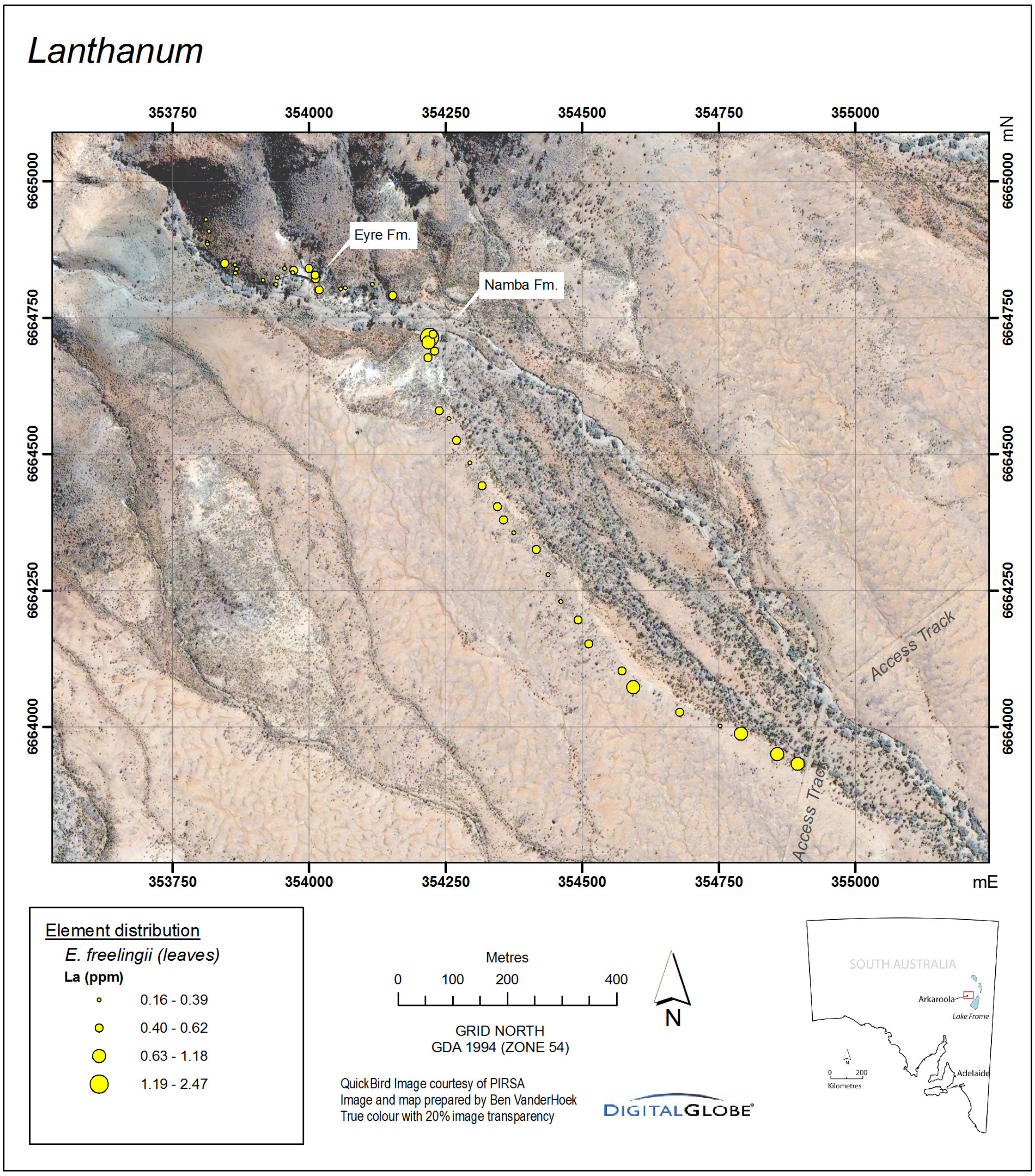

Lanthanum
353750
354000
354250
354500
354750
355000
6665000
6664750
6664500
6664250
6664000
mN
mE
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
La (ppm)
0.16 - 0.39
0.40 - 0.62
0.63 - 1.18
1.19 - 2.47
Metres
0
100
200
400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 17

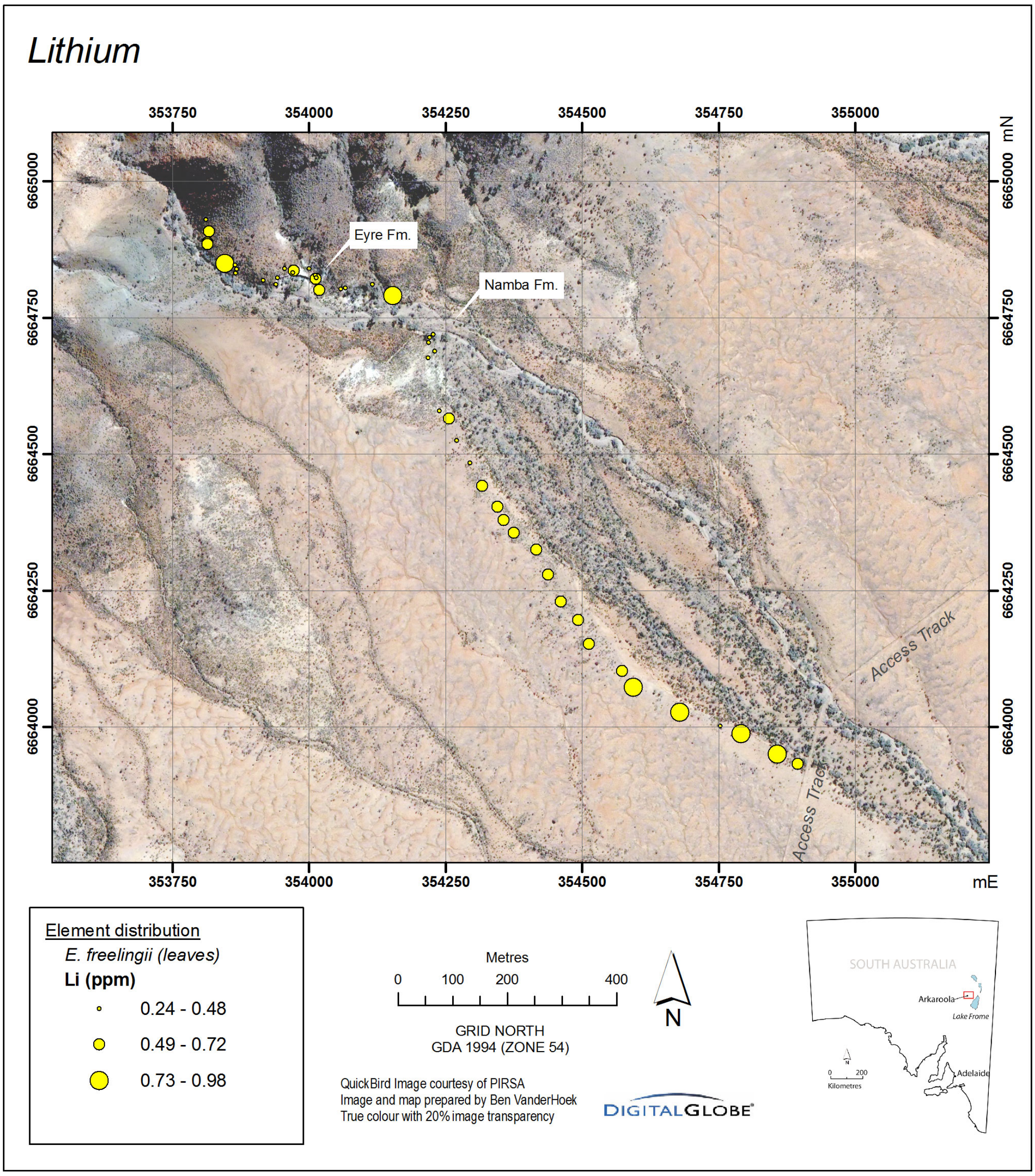

Lithium
353750
354000
354250
354500
354750
355000
mN
6665000
6664750
6664500
6664250
6664000
mE
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Li (ppm)
0.24 - 0.48
0.49 - 0.72
0.73 - 0.98
Metres
0 100 200 400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 18

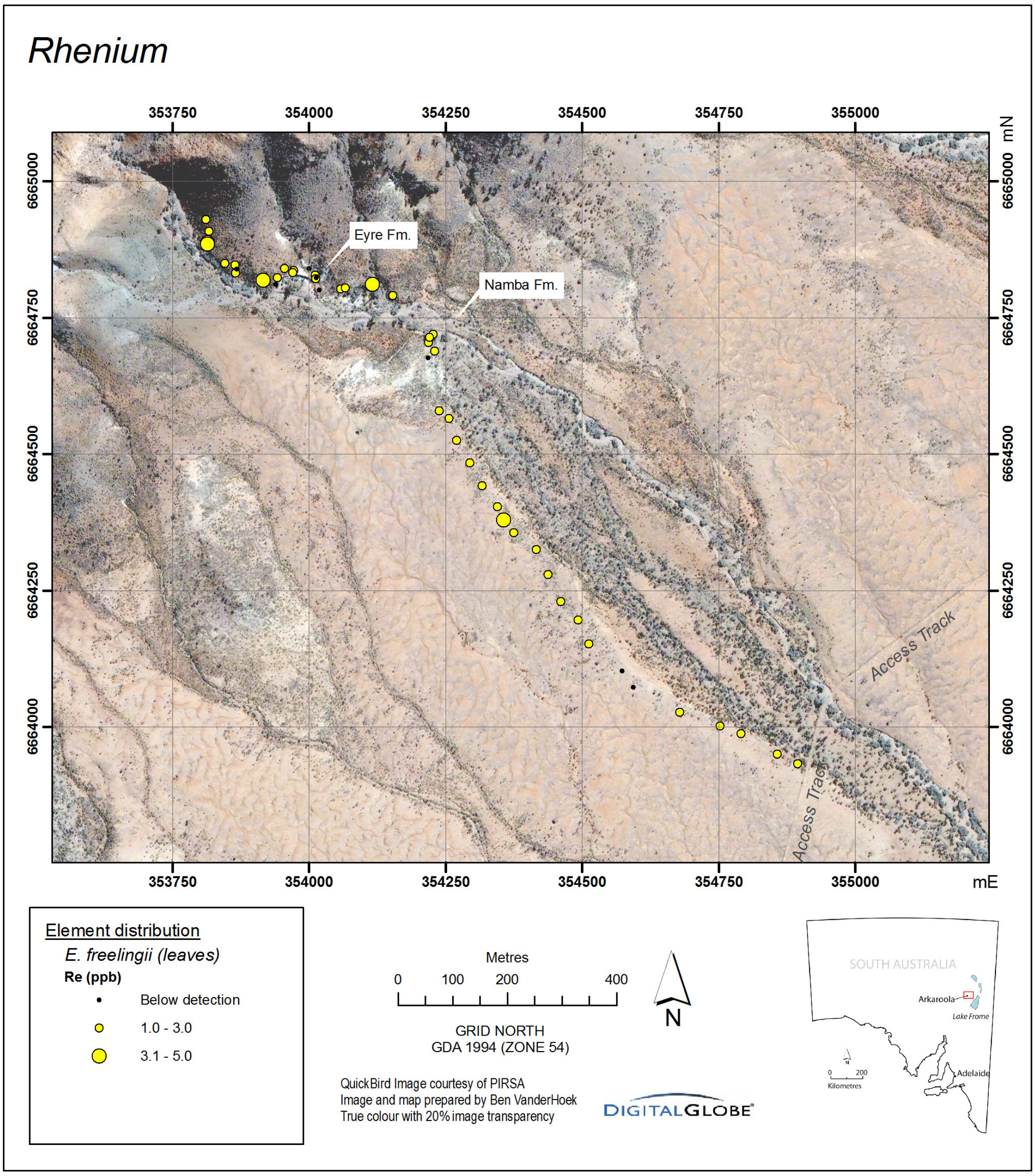

Rhenium
353750
354000
354250
354500
354750
355000
mE
mN
6665000
6664750
6664500
6664250
6664000
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Re (ppb)
Below detection
1.0 - 3.0
3.1 - 5.0
Metres
0 100 200 400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide
Kilometres

Figure 19

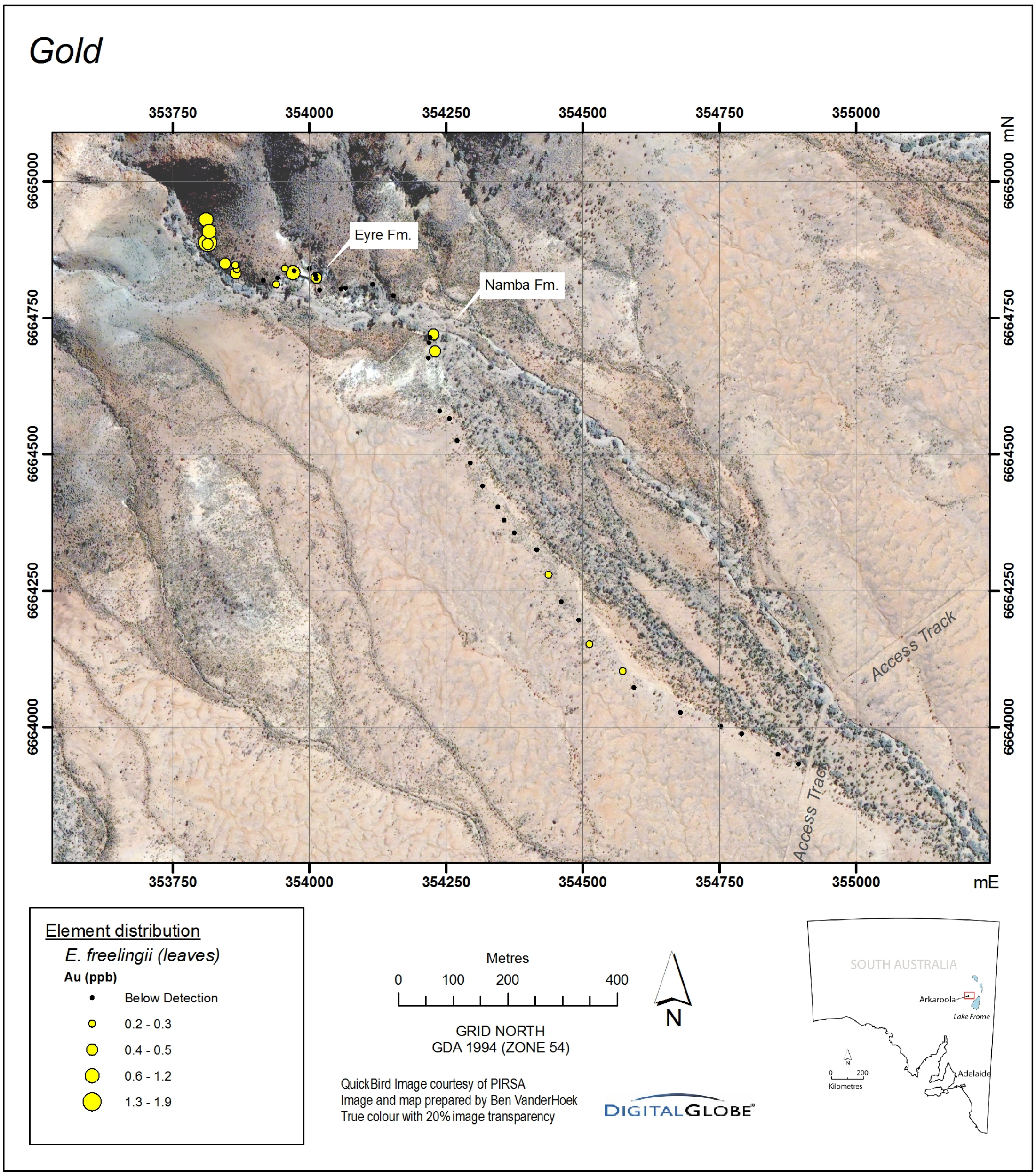

Gold
353750
354000
354250
354500
354750
355000
mE
6665000
6664750
6664500
6664250
6664000
mN
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Au (ppb)
Below Detection
0.2 - 0.3
0.4 - 0.5
0.6 - 1.2
1.3 - 1.9
Metres
0
100
200
400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 20

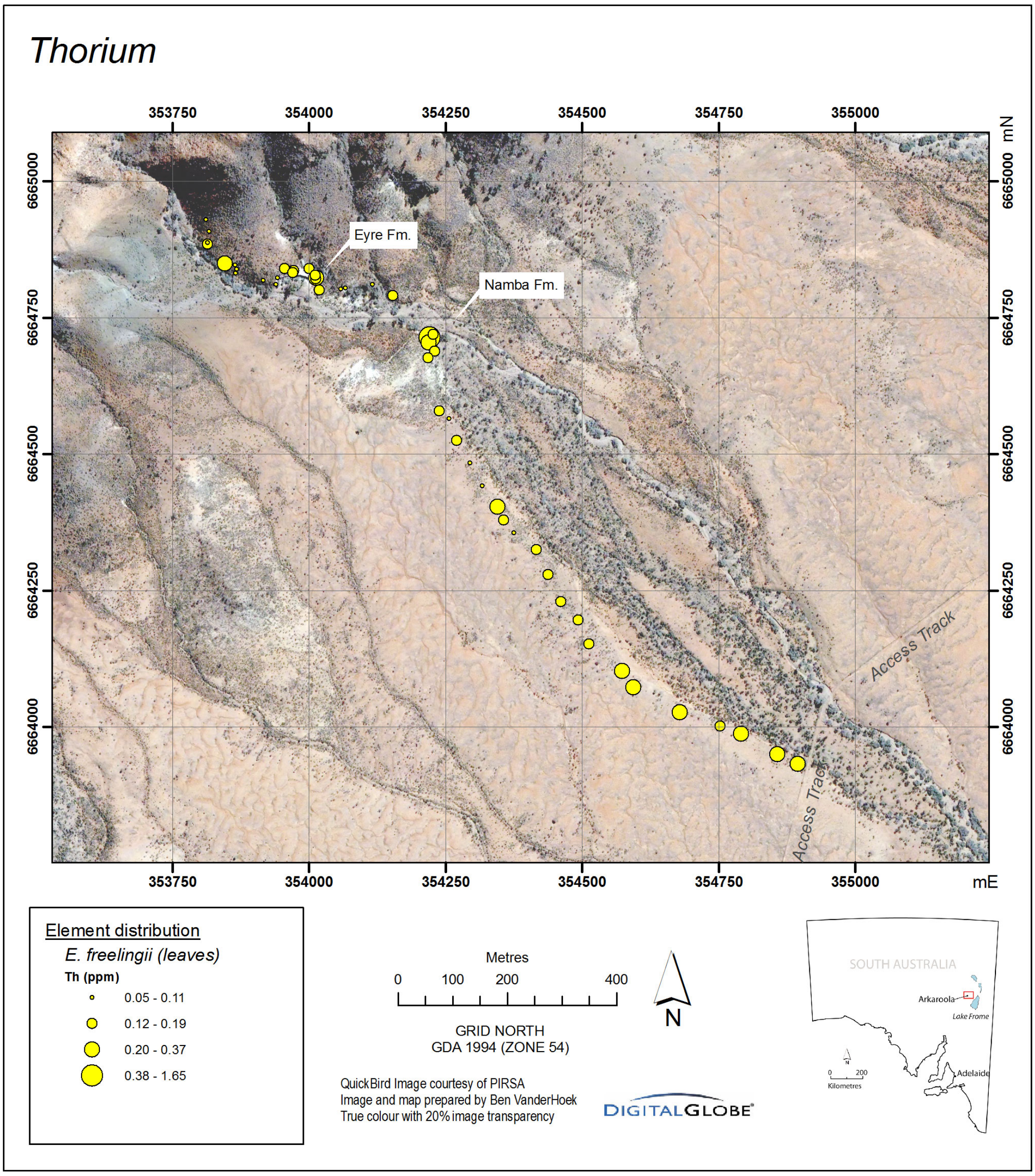

Thorium
353750
354000
354250
354500
354750
355000
mE
6665000
6664750
6664500
6664250
6664000
mN
Eyre Fm.
Namba Fm.
Access Track
Access Track
Element distribution
E. freelingii (leaves)
Th (ppm)
0.05 - 0.11
0.12 - 0.19
0.20 - 0.37
0.38 - 1.65
Metres
0
100
200
400
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 21

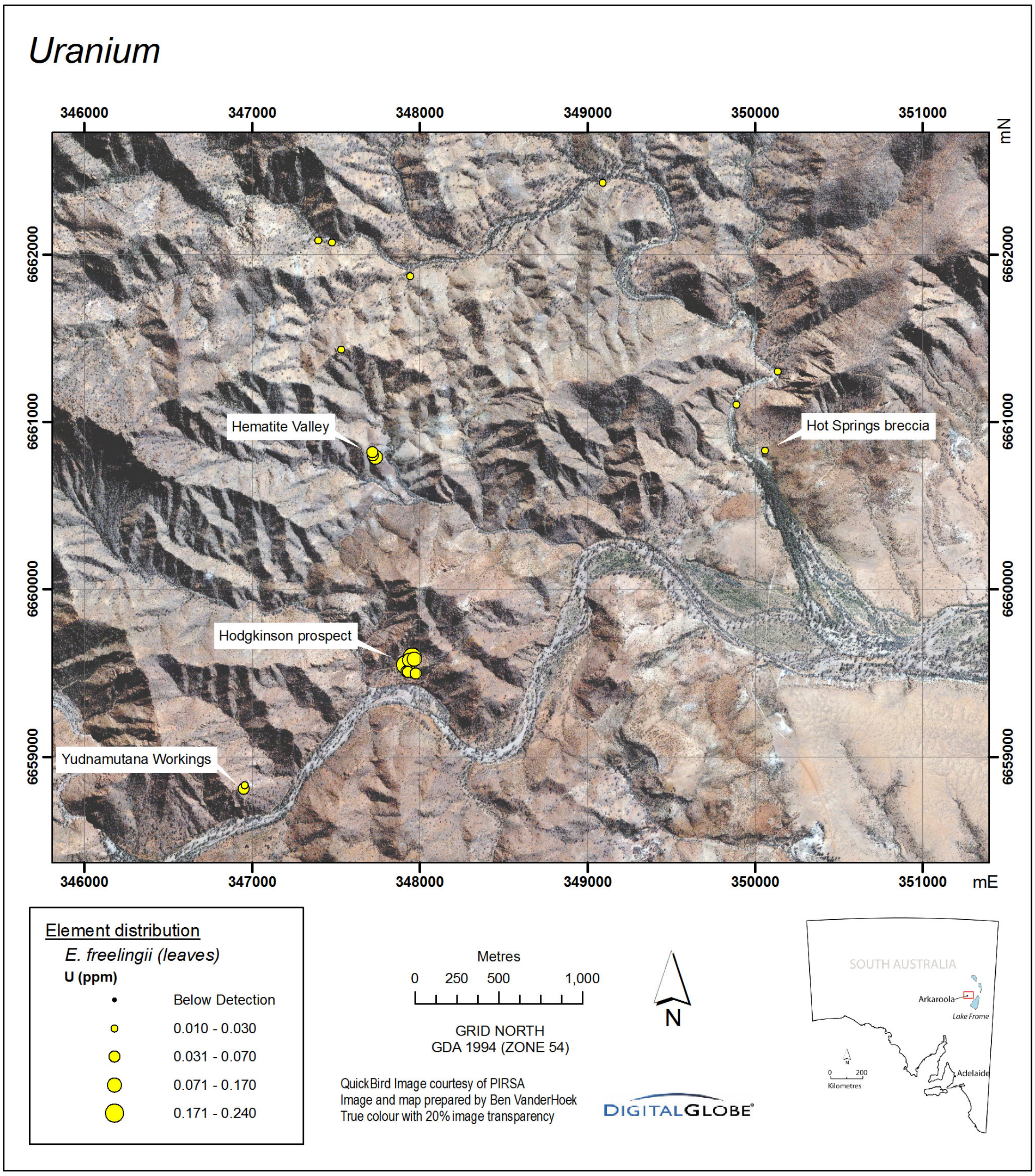

Uranium
346000
347000
348000
349000
350000
351000
mN
mE
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
U (ppm)
Below Detection
0.010 - 0.030
0.031 - 0.070
0.071 - 0.170
0.171 - 0.240
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 22

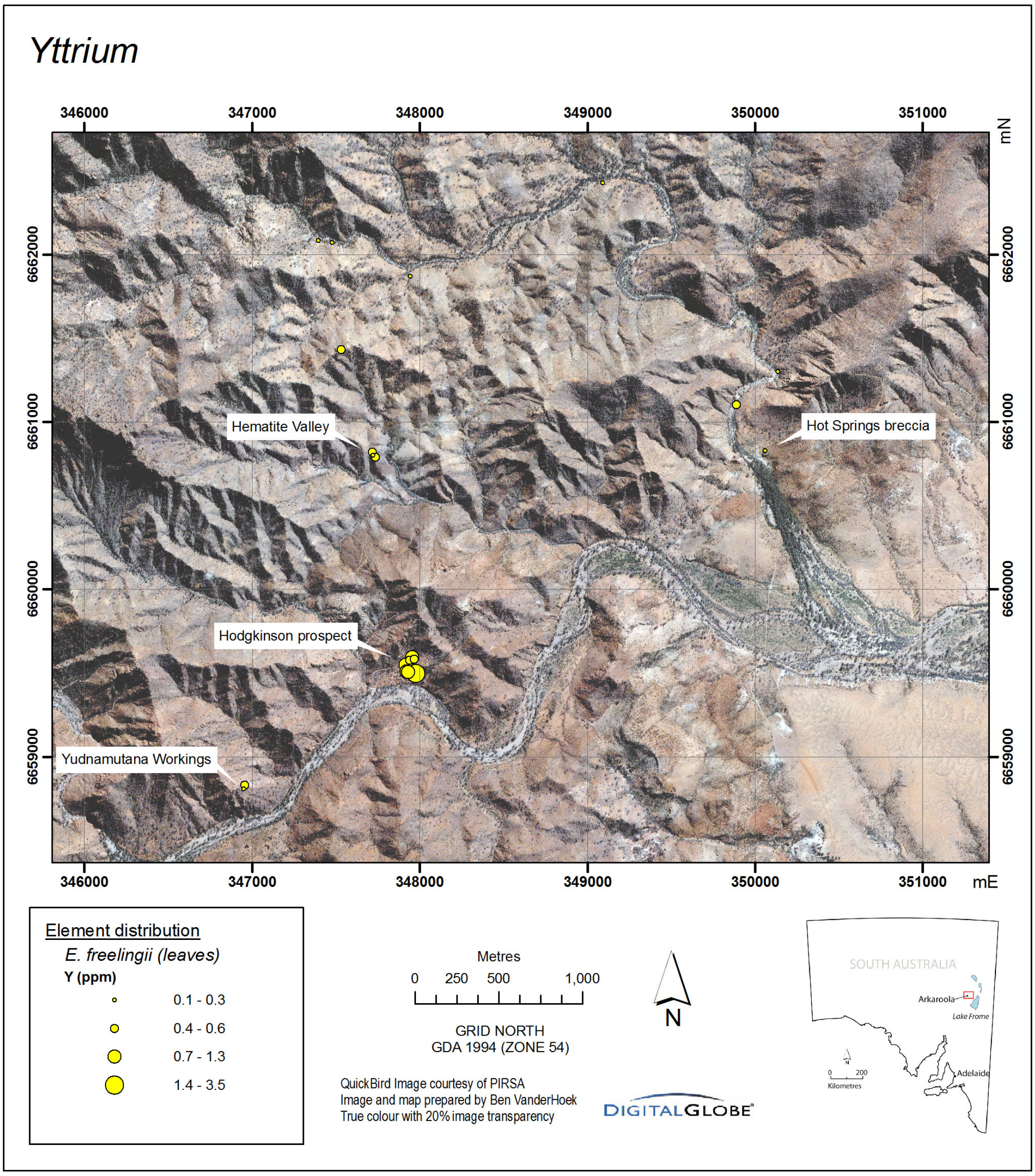

Yttrium
346000
347000
348000
349000
350000
351000
mN
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
mE
Element distribution
E. freelingii (leaves)
Y (ppm)
0.1 - 0.3
0.4 - 0.6
0.7 - 1.3
1.4 - 3.5
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 23

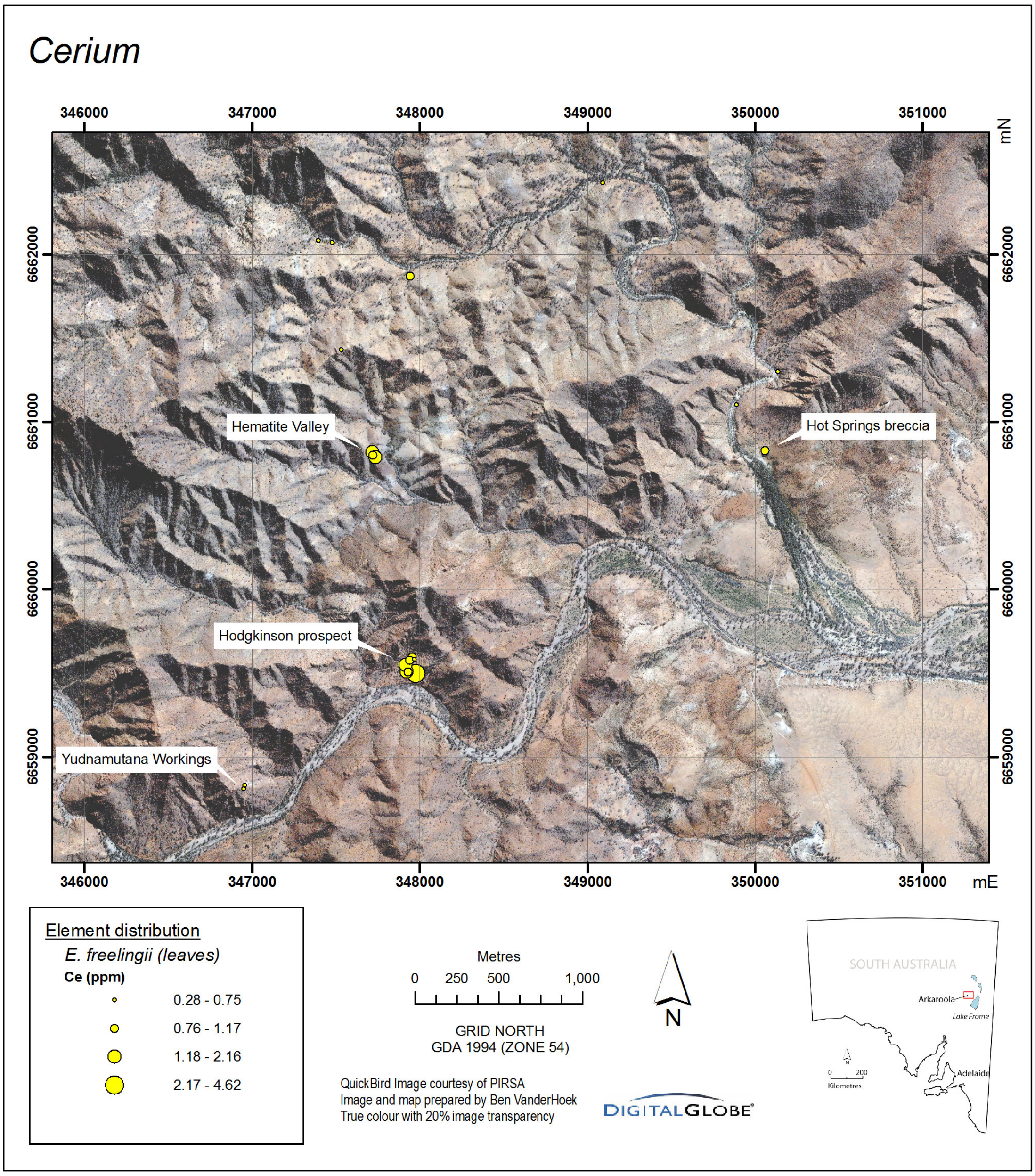

Cerium
346000
347000
348000
349000
350000
351000
mN
mE
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
Ce (ppm)
0.28 - 0.75
0.76 - 1.17
1.18 - 2.16
2.17 - 4.62
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
N
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 24

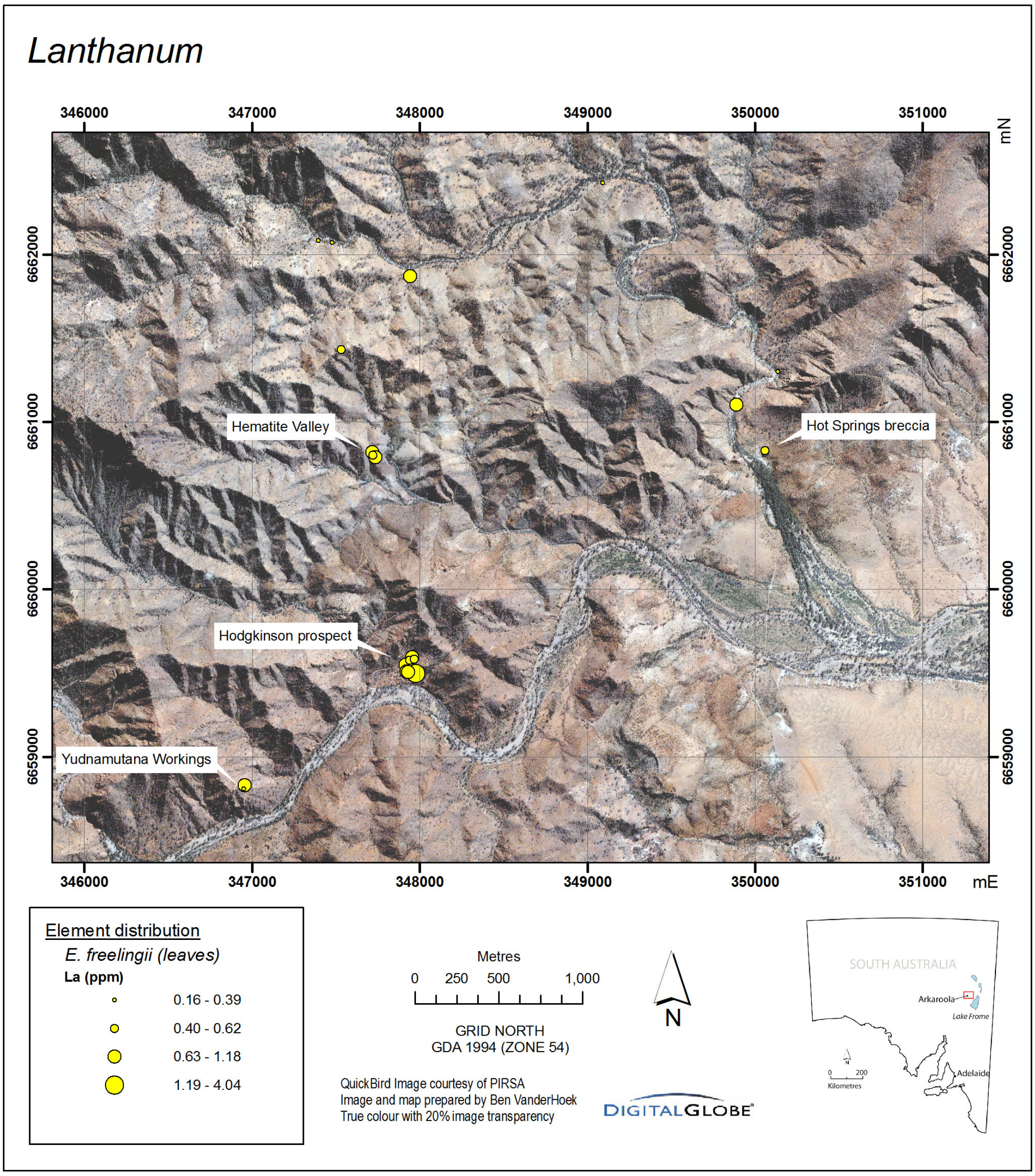

Lanthanum
346000
347000
348000
349000
350000
351000
mN
mE
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
La (ppm)
0.16 - 0.39
0.40 - 0.62
0.63 - 1.18
1.19 - 4.04
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 25

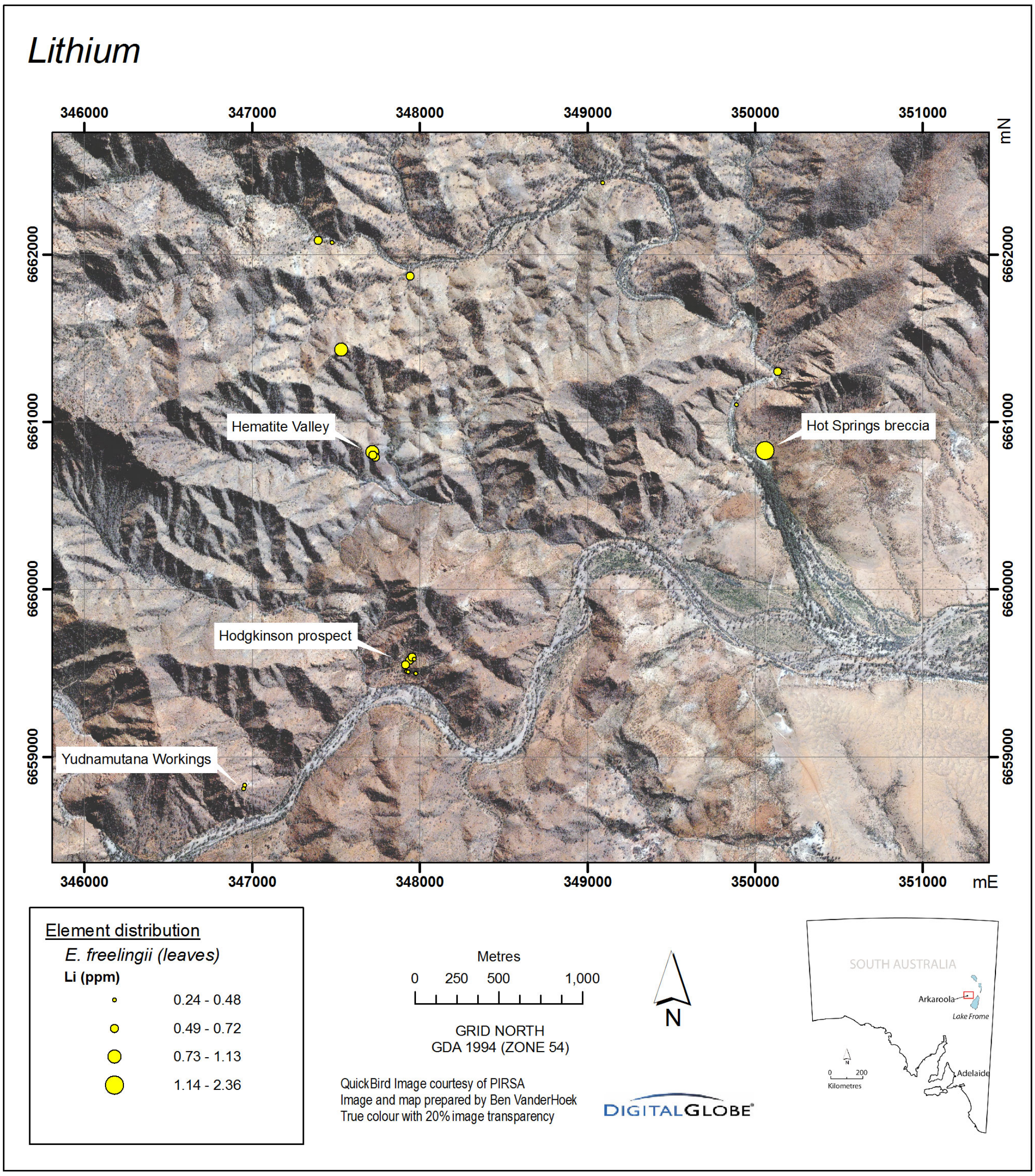

Lithium
346000
347000
348000
349000
350000
351000
mN
mE
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
Li (ppm)
0.24 - 0.48
0.49 - 0.72
0.73 - 1.13
1.14 - 2.36
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
N
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 26

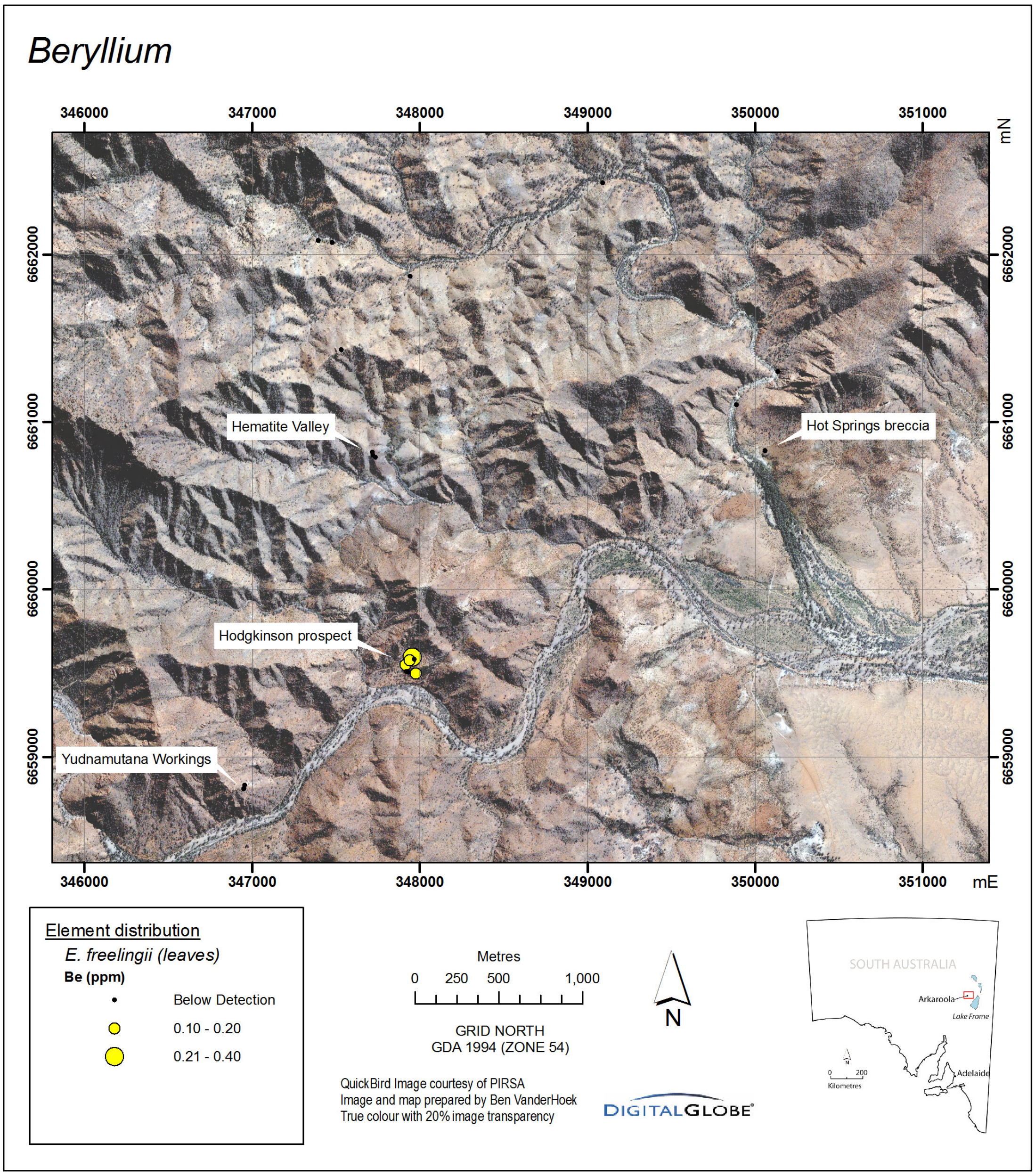

Beryllium
346000
347000
348000
349000
350000
351000
mE
mN
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
Be (ppm)
Below Detection
0.10 - 0.20
0.21 - 0.40
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 27

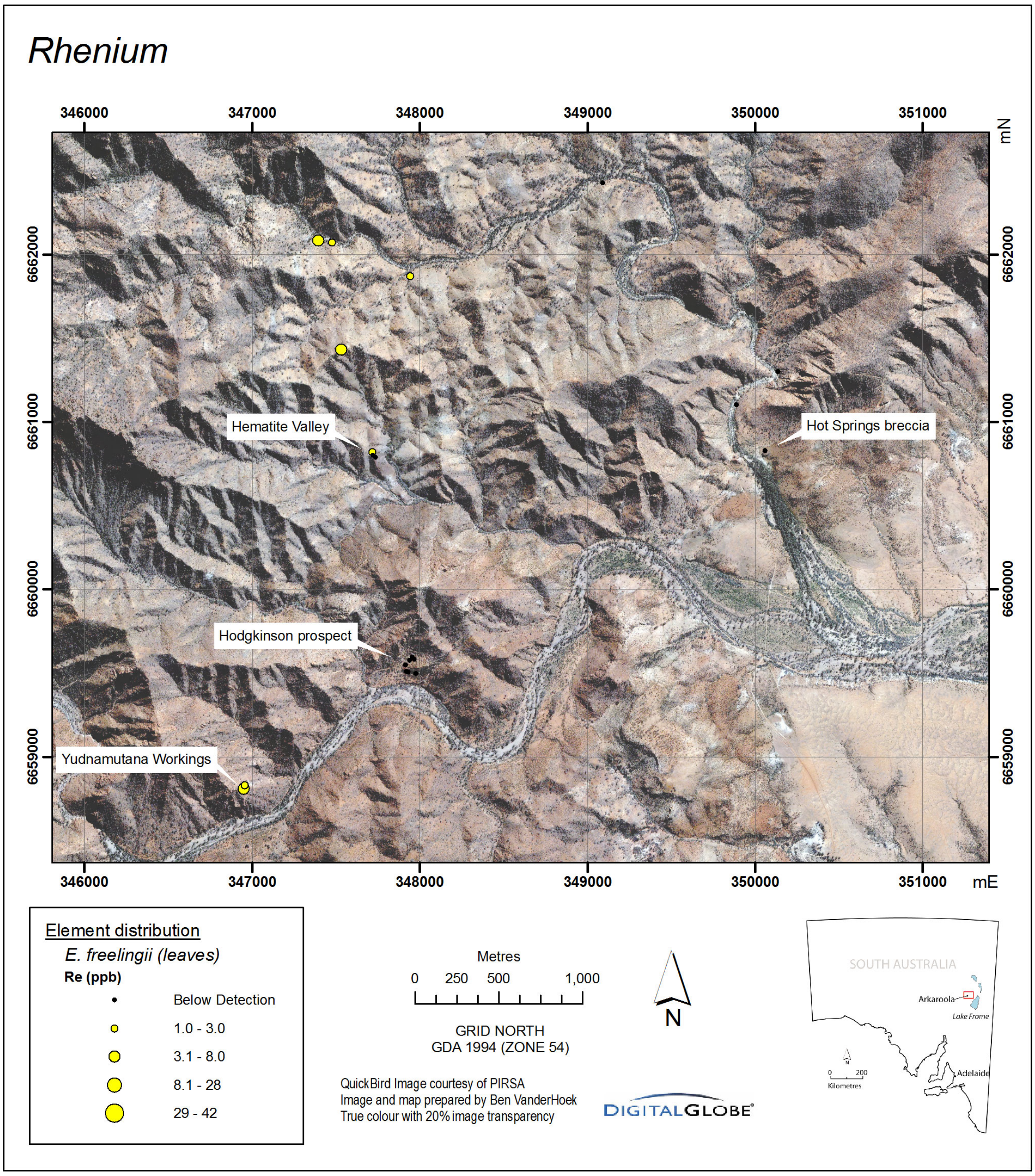

Rhenium
346000
347000
348000
349000
350000
351000
mN
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
mE
Element distribution
E. freelingii (leaves)
Re (ppb)
Below Detection
1.0 - 3.0
3.1 - 8.0
8.1 - 28
29 - 42
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
N
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 28

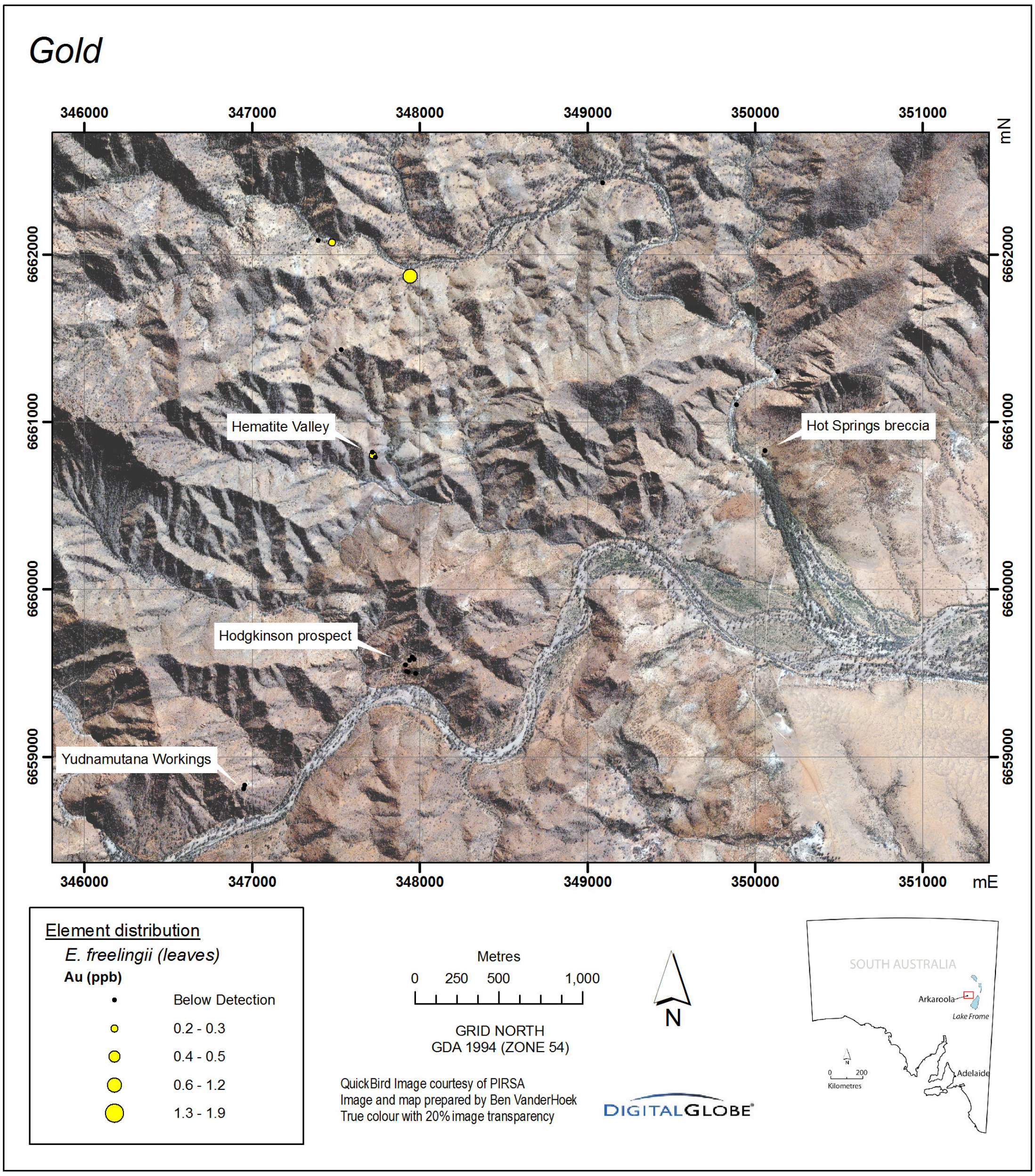

Gold
346000
347000
348000
349000
350000
351000
mE
mN
6662000
6661000
6660000
6659000
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
Au (ppb)
Below Detection
0.2 - 0.3
0.4 - 0.5
0.6 - 1.2
1.3 - 1.9
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 29

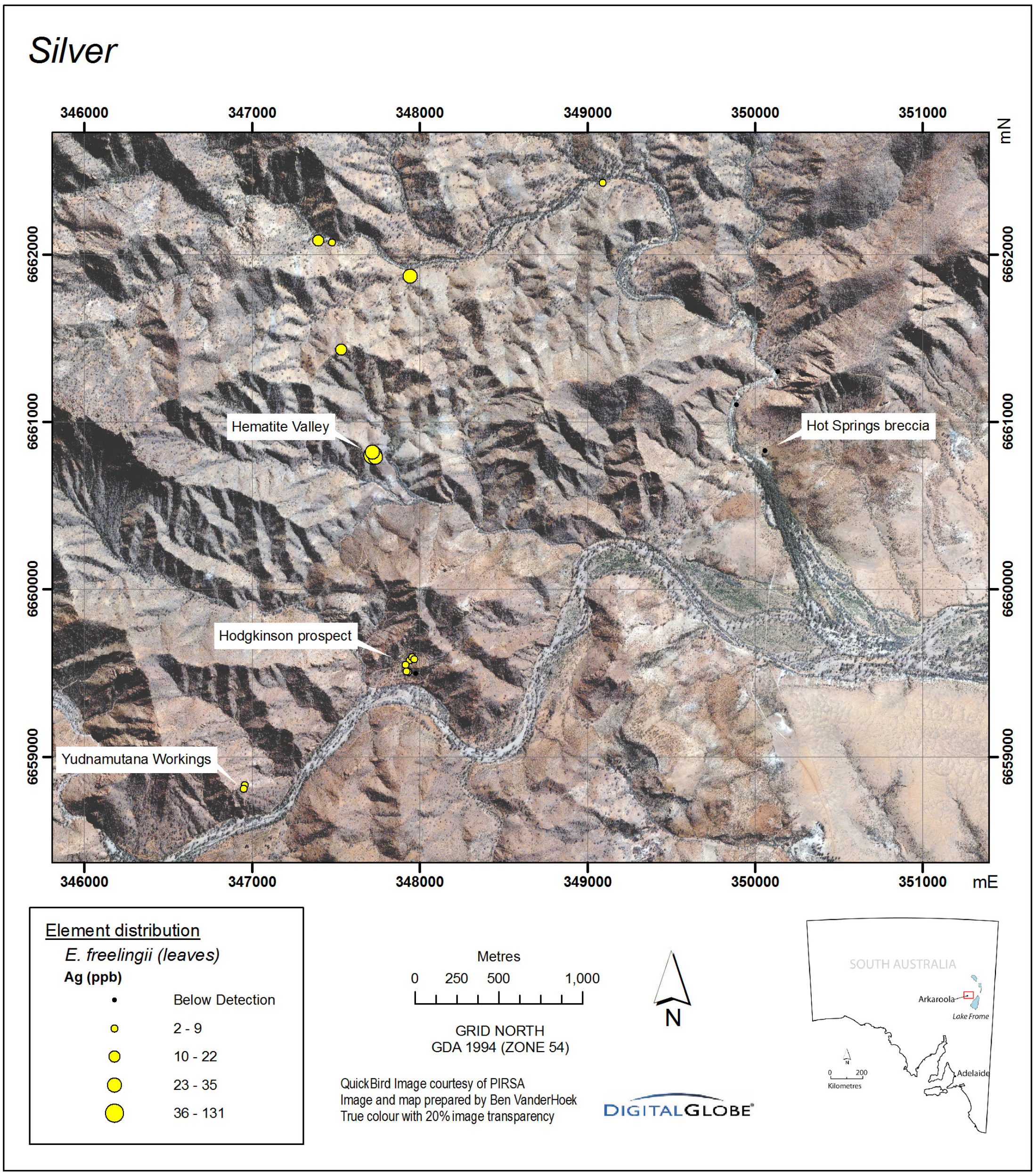

Silver
346000
347000
348000
349000
350000
351000
mN
6662000
6661000
6660000
6659000
mE
Hematite Valley
Hot Springs breccia
Hodgkinson prospect
Yudnamutana Workings
Element distribution
E. freelingii (leaves)
Ag (ppb)
Below Detection
2 - 9
10 - 22
23 - 35
36 - 131
Metres
0 250 500 1,000
GRID NORTH
GDA 1994 (ZONE 54)
N
QuickBird Image courtesy of PIRSA
Image and map prepared by Ben VanderHoek
True colour with 20% image transparency
DIGITALGLOBE
SOUTH AUSTRALIA
Arkaroola
Lake Frome
Adelaide

Figure 30

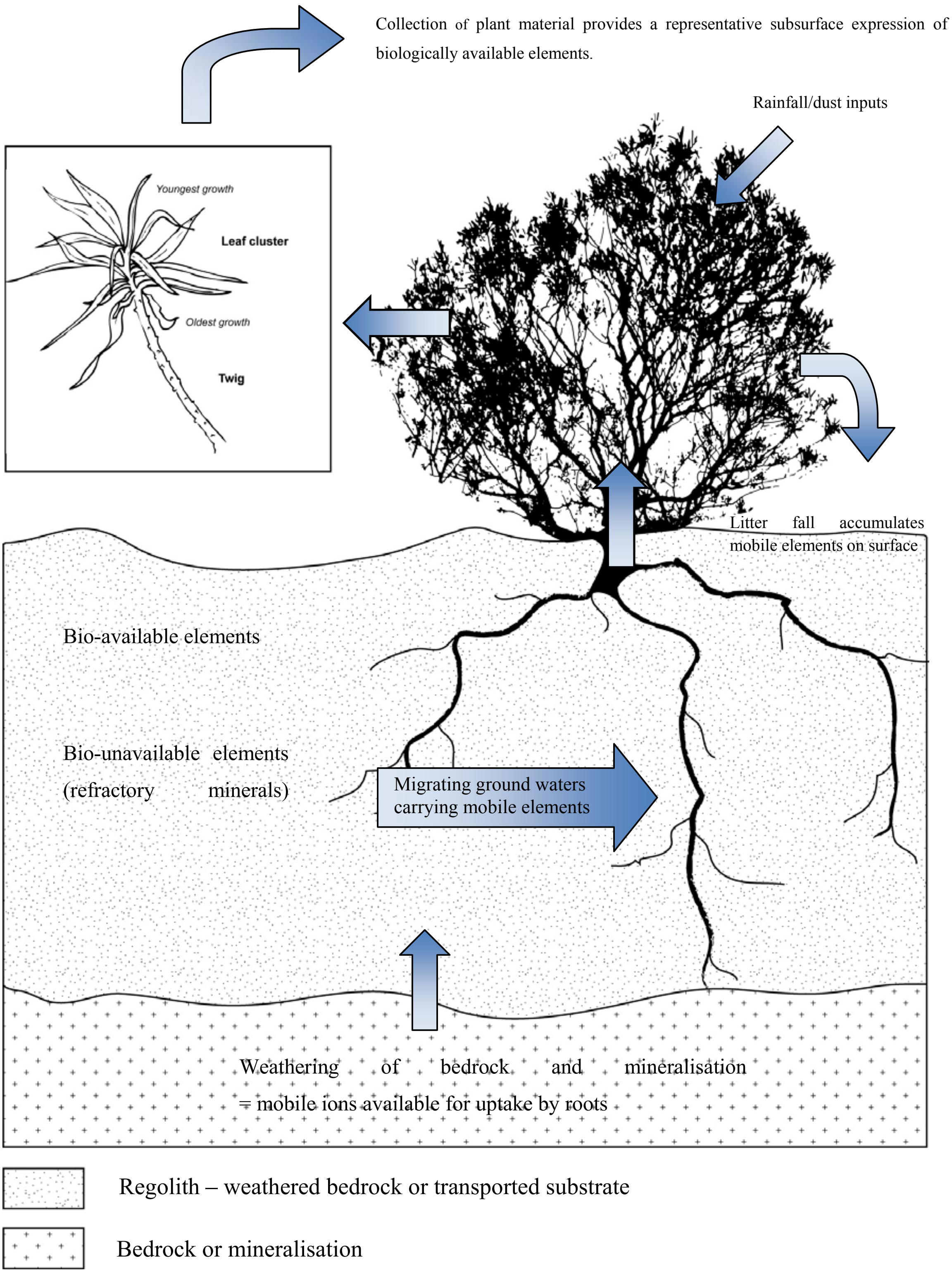

Collection of plant material provides a representative subsurface expression of biologically available elements.
Rainfall/dust inputs
Youngest growth
Leaf cluster
Oldest growth
Twig
Litter fall accumulates mobile elements on surface
Bio-available elements
Bio-unavailable elements (refractory minerals)
Migrating ground waters carrying mobile elements
Weathering of bedrock and mineralisation = mobile ions available for uptake by roots
Regolith – weathered bedrock or transported substrate
Bedrock or mineralisation

Figure 31

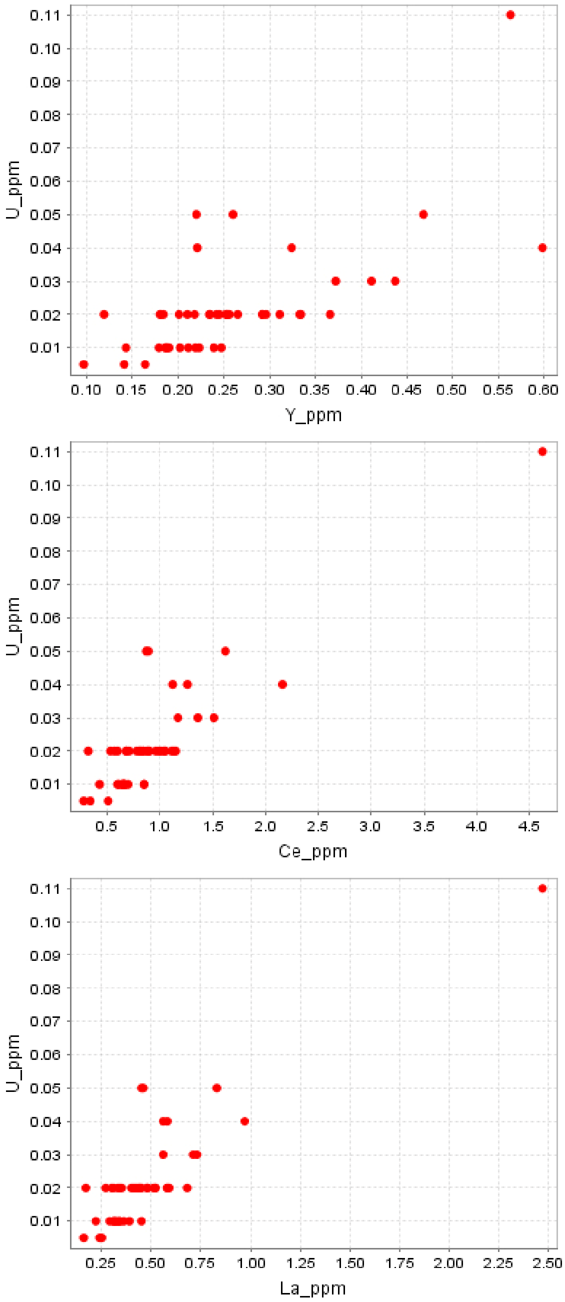

U_ppm
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60
Y_ppm
U_ppm
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
Ce_ppm
U_ppm
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
La_ppm

Figure 32

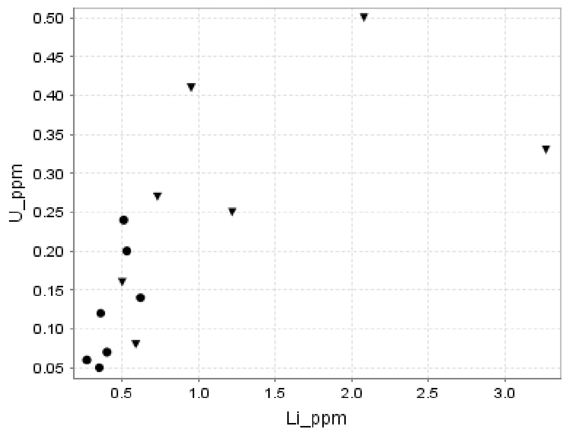


Figure 33

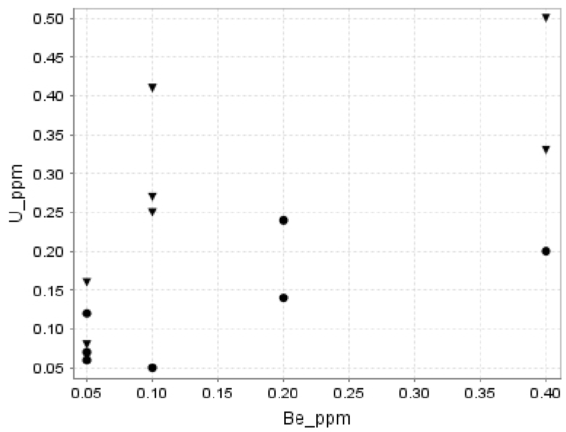


Figure 34

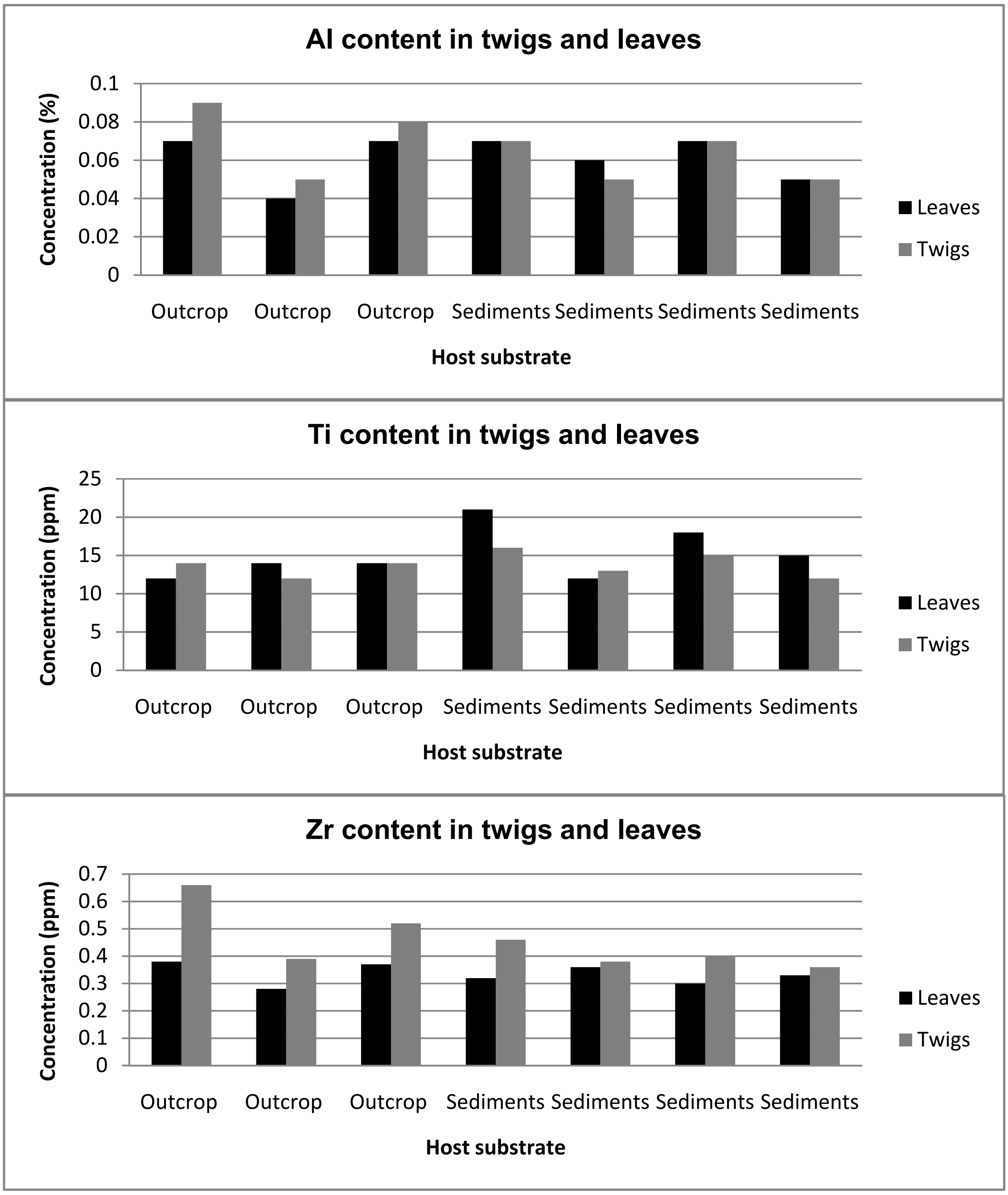
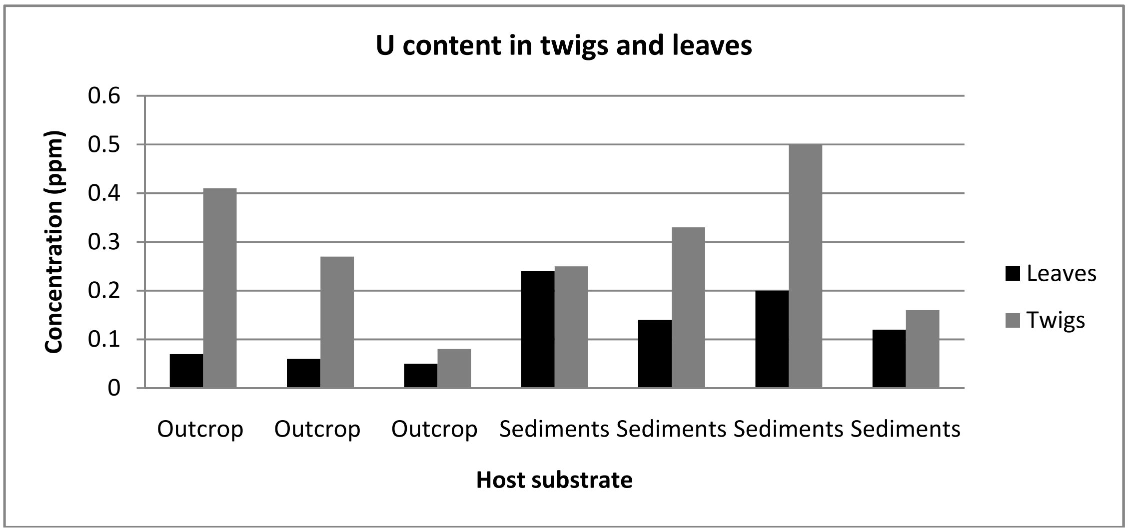

Al content in twigs and leaves
Concentration (%)
0.1
0.08
0.06
0.04
0.02
0
Outcrop Outcrop Outcrop Sediments Sediments Sediments Sediments
Host substrate
Leaves
Twigs
Ti content in twigs and leaves
Concentration (ppm)
25
20
15
10
5
0
Outcrop Outcrop Outcrop Sediments Sediments Sediments Sediments
Host substrate
Leaves
Twigs
Zr content in twigs and leaves
Concentration (ppm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Outcrop Outcrop Outcrop Sediments Sediments Sediments Sediments
Host substrate
Leaves
Twigs

Figure 35


U content in twigs and leaves
Concentration (ppm)
0.6
0.5
0.4
0.3
0.2
0.1
0
Outcrop
Outcrop
Outcrop
Sediments
Sediments
Sediments
Sediments
Host substrate
Leaves
Twigs

APPENDIX

Appendix 1

Sample	Site	Eastings (GDA94)	Northings (GDA94)	Ag (ppb)	Al (%)	As (ppm)	Au (ppb)	B (ppm)	Ba (ppm)	Be (ppm)	Bi (ppm)	Ca (%)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Fe (%)	Ga (ppm)	Ge (ppm)	Hf (ppm)	Hg (ppb)	In (ppm)	K (%)	La (ppm)	Li (ppm)	Mg (%)	Mn (ppm)	Mo (ppm)	Na (%)	Nb (ppm)
MPER001	Four Mile West: Basement	353811	6664930	2	0.03	0.1	1.2	18	42.5	<0.1	<0.02	2.1	0.03	0.32	0.11	2.3	0.052	32.02	0.028	0.1	<0.01	0.008	8	<0.02	1.92	0.17	0.35	0.445	42	0.13	0.216	0.01
MPER002	Four Mile West: Mesozoic	353817	6664909	8	0.06	0.1	0.8	16	14.5	<0.1	<0.02	2.08	0.03	0.68	0.29	2.6	0.106	21.66	0.057	0.2	0.02	0.017	12	<0.02	2.09	0.35	0.61	0.569	61	0.37	0.418	0.02
MPER003	Four Mile West: Basement	353814	6664888	18	0.05	0.2	1.9	13	7.3	<0.1	<0.02	1.87	0.03	0.61	0.19	2.6	0.131	24.73	0.052	0.1	0.01	0.013	8	<0.02	1.05	0.31	0.6	0.38	55	0.32	0.628	0.02
MPER004	Four Mile West: Basement	353814	6664885	<2	0.05	0.2	0.4	11	37.8	<0.1	<0.02	2.62	0.02	0.67	0.27	2.5	0.08	20.11	0.049	0.2	<0.01	0.012	9	<0.02	0.95	0.31	0.52	0.342	45	0.56	0.275	0.03
MPER005	Four Mile West: Mesozoic	353846	6664850	5	0.09	0.2	0.4	12	7.7	<0.1	<0.02	1.84	0.03	1.17	0.31	3.2	0.117	24.39	0.092	0.3	<0.01	0.032	12	<0.02	1.05	0.56	0.84	0.266	59	0.48	0.709	0.04
MPER006	Four Mile West: Lower Eyre Fm.	353865	6664832	4	0.05	<0.1	0.5	15	28	<0.1	<0.02	2.45	0.02	0.66	0.19	2.6	0.085	13.86	0.051	0.1	<0.01	0.015	7	<0.02	1.55	0.34	0.39	0.378	36	0.49	0.09	0.02
MPER007	Four Mile West: Mesozoic	353864	6664847	<2	0.05	0.4	0.2	16	12.5	<0.1	<0.02	1.81	0.01	0.6	0.2	2.5	0.141	25.03	0.053	0.1	<0.01	0.016	6	<0.02	2.26	0.31	0.38	0.258	35	0.68	0.369	0.02
MPER008	Four Mile West: Mesozoic	353867	6664840	2	0.04	0.2	0.3	13	44.3	<0.1	<0.02	2.08	0.04	0.53	0.14	2.4	0.088	27.39	0.041	0.1	<0.01	0.011	6	<0.02	1.89	0.27	0.32	0.159	35	0.43	0.126	0.02
MPER009	Four Mile West: Lower Eyre Fm.	353942	6664824	<2	0.05	0.3	<0.2	16	43.7	<0.1	<0.02	2.89	<0.01	0.65	0.15	2.9	0.059	25.46	0.049	0.2	<0.01	0.018	15	<0.02	2.07	0.29	0.46	0.18	11	0.99	0.06	0.02
MPER010	Four Mile West: Mesozoic	353916	6664819	<2	0.04	0.3	<0.2	16	84	<0.1	<0.02	3.07	0.01	0.51	0.17	2.3	0.085	25.16	0.042	0.1	<0.01	0.017	8	<0.02	1.36	0.25	0.41	0.258	18	0.53	0.163	0.02
MPER011	Four Mile West: Lower Eyre Fm.	353955	6664841	<2	0.05	0.2	0.2	16	17.8	<0.1	<0.02	1.56	0.01	0.71	0.23	2.7	0.069	17.63	0.055	0.2	<0.01	0.021	8	<0.02	1.88	0.33	0.45	0.278	34	0.49	0.211	0.03
MPER012	Four Mile West: Lower Eyre Fm.	353970	6664833	7	0.05	0.5	0.8	14	35.4	<0.1	<0.02	1.82	<0.01	0.68	0.2	2.8	0.045	11.98	0.05	0.2	<0.01	0.011	11	<0.02	2.8	0.34	0.29	0.242	18	2.04	0.085	0.02
MPER013	Four Mile West: Lower Eyre Fm.	353939	6664812	<2	0.05	<0.1	0.3	20	35.6	<0.1	<0.02	2.71	<0.01	0.57	0.15	2.5	0.057	20.01	0.047	0.1	<0.01	0.013	8	<0.02	2.48	0.3	0.27	0.196	10	0.21	0.187	0.02
MPER014	Four Mile West: Roll front zone	354013	6664824	5	0.06	0.3	0.5	15	11.5	<0.1	<0.02	1.65	<0.01	1.26	0.23	3.3	0.061	19.55	0.061	0.2	<0.01	0.018	9	<0.02	1.69	0.58	0.29	0.277	24	0.99	0.232	0.03
MPER015	Four Mile West: Roll front zone	354000	6664841	<2	0.06	0.5	<0.2	13	32.3	<0.1	<0.02	1.85	<0.01	0.88	0.24	3	0.094	23.19	0.063	0.2	<0.01	0.02	8	<0.02	2.08	0.45	0.47	0.387	40	0.55	0.211	0.03
MPER016	Four Mile West: Lower Eyre Fm.	353972	6664837	<2	0.08	0.6	<0.2	13	10.8	<0.1	<0.02	1.77	0.01	1.01	0.29	3	0.076	14.23	0.081	0.2	<0.01	0.024	11	<0.02	2.05	0.48	0.51	0.251	38	1.14	0.138	0.03
MPER017	Four Mile West: Roll front zone	354011	6664828	<2	0.07	<0.1	<0.2	11	15.6	<0.1	0.02	2.02	0.02	0.84	0.24	2.9	0.061	24.83	0.067	0.2	<0.01	0.02	10	<0.02	1.8	0.42	0.44	0.392	46	0.95	0.121	0.03
MPER018	Four Mile West: Roll front zone	354012	6664822	<2	0.07	0.4	<0.2	13	16.3	<0.1	<0.02	1.37	0.02	0.96	0.29	2.9	0.059	11.8	0.065	0.2	<0.01	0.019	16	<0.02	2.69	0.48	0.59	0.248	50	0.41	0.136	0.03
MPER019	Four Mile West: Roll front zone	354019	6664801	<2	0.07	<0.1	<0.2	17	8.2	<0.1	<0.02	1.1	0.02	0.89	0.26	2.7	0.064	20.55	0.074	0.2	<0.01	0.016	12	<0.02	2.43	0.45	0.49	0.166	30	0.46	0.179	0.03
MPER020	Four Mile West: Upper Eyre Fm.	354116	6664812	4	0.06	0.1	<0.2	14	11.9	<0.1	<0.02	2	0.02	0.66	0.25	2.5	0.054	11.53	0.051	0.2	<0.01	0.019	9	<0.02	2.49	0.33	0.38	0.304	29	0.37	0.066	0.02
MPER021	Four Mile West: Upper Eyre Fm.	354058	6664803	<2	0.03	0.3	<0.2	16	18.6	<0.1	<0.02	1.55	<0.01	0.43	0.11	1.9	0.047	4.66	0.034	<0.1	<0.01	0.01	8	<0.02	2.09	0.22	0.29	0.283	20	0.68	0.311	0.01
MPER022	Four Mile West: Upper Eyre Fm.	354153	6664791	<2	0.08	0.4	<0.2	12	22.3	<0.1	<0.02	1.23	<0.01	1.05	0.44	3.7	0.078	15.35	0.079	0.2	<0.01	0.02	10	<0.02	1.59	0.52	0.83	0.297	28	0.29	0.479	0.03
MPER023	Four Mile West: Silcrete	354227	6664720	<2	0.06	0.2	0.5	23	7.9	<0.1	<0.02	1.06	<0.01	0.87	0.17	2.5	0.065	13.86	0.06	0.2	<0.01	0.016	8	<0.02	2.94	0.46	0.46	0.202	14	0.43	0.198	0.03
MPER024	Four Mile West: Upper Eyre Fm.	354066	6664805	<2	0.05	0.2	<0.2	12	72.7	<0.1	<0.02	1.31	0.01	0.64	0.16	2.3	0.08	6.52	0.047	0.1	<0.01	0.013	6	<0.02	2.04	0.32	0.32	0.231	12	0.25	0.173	0.01
MPER025	Four Mile West: Namba Fm.	354219	6664705	<2	0.08	<0.1	<0.2	14	19.2	<0.1	<0.02	2.1	0.02	1.11	0.26	3.2	0.127	11.58	0.081	0.2	<0.01	0.029	10	<0.02	1.79	0.68	0.48	0.344	29	0.54	0.229	0.03
MPER026	Four Mile West: Namba Fm.	354220	6664714	<2	0.1	0.3	<0.2	12	17.2	<0.1	<0.02	2.04	0.01	4.62	0.32	3.9	0.134	5.54	0.106	0.3	<0.01	0.035	13	<0.02	1.16	2.47	0.48	0.253	26	0.71	0.289	0.1
MPER027	Four Mile West: Namba Fm.	354230	6664689	3	0.06	<0.1	0.4	13	40.4	<0.1	<0.02	1.68	0.01	0.78	0.18	2.7	0.052	10.15	0.056	0.1	<0.01	0.019	9	<0.02	2.34	0.4	0.34	0.197	29	0.93	0.025	0.02
MPER028	Four Mile West: Namba Fm.	354218	6664677	<2	0.07	<0.1	<0.2	15	20.7	<0.1	<0.02	2.02	<0.01	1.04	0.27	2.6	0.126	9.82	0.076	0.2	<0.01	0.026	11	<0.02	1.36	0.59	0.46	0.182	20	1.05	0.327	0.03
MPER029	Four Mile West: Unknown	354238	6664580	6	0.05	<0.1	<0.2	15	11.4	<0.1	<0.02	1.62	0.05	0.89	0.21	2.7	0.078	14.17	0.057	0.2	0.01	0.016	9	<0.02	1.65	0.52	0.4	0.251	53	0.2	0.201	0.02
MPER030	Four Mile West: Unknown	354256	6664566	9	0.05	<0.1	<0.2	14	11.6	<0.1	<0.02	1.5	0.03	0.6	0.21	2.2	0.086	16.93	0.047	0.1	<0.01	0.012	11	<0.02	1.82	0.32	0.56	0.274	49	0.16	0.5	0.02
MPER031	Four Mile West: Unknown	354294	6664484	<2	0.03	<0.1	<0.2	11	54.5	<0.1	<0.02	2.21	0.03	0.28	0.14	2	0.048	20.94	0.024	<0.1	<0.01	0.009	9	<0.02	0.81	0.16	0.24	0.216	45	0.23	0.621	0.01
MPER032	Four Mile West: Unknown	354356	6664380	<2	0.08	0.1	<0.2	11	19.9	<0.1	<0.02	1.36	0.03	0.99	0.28	2.5	0.07	16.18	0.076	0.2	<0.01	0.027	16	<0.02	1.39	0.51	0.69	0.177	42	0.14	0.53	0.02
MPER033	Four Mile West: Unknown	354270	6664526	9	0.06	<0.1	<0.2	14	4.9	<0.1	<0.02	1.71	0.04	0.85	0.21	2.5	0.097	17.8	0.061	0.2	0.01	0.014	10	<0.02	1.58	0.45	0.47	0.324	58	0.18	0.446	0.03
MPER034	Four Mile West: Unknown	354317	6664442	12	0.05	0.2	<0.2	10	15	<0.1	<0.02	1.71	0.04	0.81	0.21	2.3	0.085	12.16	0.051	0.2	0.01	0.011	8	<0.02	1.18	0.43	0.49	0.296	57	0.23	0.422	0.02
MPER035	Four Mile West: Unknown	354857	6663951	<2	0.13	0.3	<0.2	12	30.9	<0.1	<0.02	1.77	0.01	2.16	0.43	3	0.122	12.73	0.125	0.4	0.04	0.04	14	<0.02	1.54	0.97	0.77	0.201	39	0.45	0.138	0.06
MPER036	Four Mile West: Unknown	354791	6663988	3	0.1	0.2	<0.2	12	12.7	<0.1	<0.02	1.42	0.03	1.51	0.38	3	0.094	14.5	0.107	0.3	<0.01	0.035	12	<0.02	1.55	0.73	0.82	0.225	39	0.23	0.365	0.05
MPER038	Four Mile West: Unknown	354894	6663933	2	0.09	0.1	<0.2	11	35.3	<0.1	<0.02	2.09	0.02	1.62	0.38	2.9	0.099	20	0.092	0.3	0.01	0.029	10	<0.02	1.53	0.83	0.69	0.241	62	0.27	0.061	0.06
MPER039	Four Mile West: Unknown	354375	6664356	<2	0.03	0.2	<0.2	15	26.2	<0.1	<0.02	2.28	0.02	0.34	0.18	1.9	0.056	17.94	0.029	<0.1	<0.01	0.01	10	<0.02	1.62	0.24	0.54	0.227	42	0.44	0.167	0.01
MPER040	Four Mile West: Unknown	354461	6664230	<2	0.05	<0.1	<0.2	15	20.2	<0.1	<0.02	1.64	0.04	0.7	0.18	2.3	0.07	20.95	0.052	0.1	0.02	0.012	9	<0.02	1.65	0.36	0.53	0.179	51	0.46	0.273	0.02
MPER041	Four Mile West: Unknown	354416	6664326	2	0.07	<0.1	<0.2	14	12.9	<0.1	<0.02	1.41	0.02	0.9	0.29	2.6	0.08	9.35	0.069	0.2	<0.01	0.02	12	<0.02	0.95	0.44	0.52	0.217	49	0.27	0.54	0.02
MPER042	Four Mile West: Unknown	354437	6664280	4	0.07	0.1	0.2	17	29.8	<0.1	<0.02	1.76	0.01	0.85	0.23	2.4	0.064	9.55	0.062	0.2	<0.01	0.028	12	<0.02	1.1	0.39	0.68	0.171	44	0.32	0.278	0.02
MPER043	Four Mile West: Unknown	354492	6664197	<2	0.07	0.1	<0.2	14	17.7	<0.1	<0.02	1.58	0.03	0.84	0.23	2.4	0.067	15.14	0.061	0.2	<0.01	0.021	11	<0.02	1.7	0.44	0.65	0.225	36	0.37	0.265	0.02
MPER044	Four Mile West: Unknown	354678	6664027	<2	0.08	0.1	<0.2	14	49.1	<0.1	<0.02	1.73	0.01	1.13	0.29	2.8	0.092	18.18	0.079	0.2	0.01	0.024	16	<0.02	1.68	0.58	0.89	0.197	43	0.3	0.125	0.03
MPER045	Four Mile West: Unknown	354512	6664153	<2	0.06	<0.1	0.3	14	16.3	<0.1	<0.02	1.8	0.03	0.81	0.26	2.9	0.063	26.84	0.059	0.2	<0.01	0.018	13	<0.02	1.58	0.41	0.6	0.19	42	0.31	0.276	0.02
MPER046	Four Mile West: Unknown	354573	6664103	13	0.06	<0.1	0.2	11	6.3	<0.1	<0.02	1.21	0.03	1.12	0.26	2.7	0.067	24.81	0.065	0.2	<0.01	0.018	9	<0.02	1.57	0.56	0.63	0.206	61	0.17	0.479	0.04
MPER047	Four Mile West: Unknown	354752	6664002	<2	0.05	<0.1	<0.2	14	20.6	<0.1	<0.02	1.93	0.02	0.65	0.17	2.3	0.064	19.58	0.043	0.1	0.01	0.012	12	<0.02	1.62	0.34	0.39	0.295	27	0.39	0.146	0.02
MPER048	Four Mile West: Unknown	354593	6664073	<2	0.09	0.2	<0.2	11	24.3	<0.1	<0.02	1.33	0.01	1.36	0.33	2.8	0.08	9.41	0.085	0.2	0.02	0.031	14	<0.02	1.42	0.71	0.98	0.24	36	0.14	0.275	0.04
MPER049	Four Mile West: Unknown	354345	6664404	<2	0.09	0.2	<0.2	14	30.2	<0.1	<0.02	1.51	0.02	1.15	0.33	3	0.112	16.12	0.089	0.3	<0.01	0.025	11	<0.02	1.73	0.58	0.68	0.171	27	0.26	0.294	0.04
MPER037	Freeling Heights Quartzite	347394	6662083	12	0.03	<0.1	<0.2	17	68.9	<0.1	<0.02	0.96	0.12	0.4	0.1	2.3	0.034	13.98	0.033	0.1	<0.01	0.013	8	<0.02	2.3	0.22	0.5	0.334	32	1.59	0.21	<0.01
MPER050	Freeling Heights Quartzite	347477	6662072	3	0.05	<0.1	0.3	18	64.8	<0.1	<0.02	1.37	0.04	0.58	0.16	3.2	0.045	8.82	0.048	0.1	0.01	0.013	10	<0.02	2.25	0.32	0.41	0.41	18	0.28	0.027	0.02
MPER051	Freeling Heights Quartzite	347941	6661870	26	0.03	0.1	0.8	12	39.9	<0.1	<0.02	1.38	0.02	0.79	0.3	2.2	0.039	8.44	0.03	<0.1	0.01	0.009	9	<0.02	1.62	0.65	0.55	0.272	53	0.34	0.155	0.02
MPER052	Freeling Heights Quartzite	349090	6662429	3	0.04	<0.1	<0.2	14	22.7	<0.1	0.02	1.66	0.03	0.54	0.17	2.6	0.049	4.63	0.038	0.1	0.02	0.012	11	<0.02	1.71	0.35	0.41	0.371	41	0.39	0.017	0.02
MPER053	Mudnawatana Granite	350135	6661303	<2	0.04	<0.1	<0.2	15	16.7	<0.1	<0.02	1.43	0.05	0.57	0.15	2.5	0.044	6.91	0.04	0.1	0.02	0.012	10	<0.02	1.56	0.36	0.72	0.433	45	0.26	0.125	0.02
MPER054	Mudnawatana Granite	349888	6661103	<2	0.05	<0.1	<0.2	13	18.5	<0.1	<0.02	1.64	0.02	0.7	0.22	2.6	0.053	12.21	0.054	0.2	0.05	0.014	11	<0.02	2.23	0.98	0.34	0.297	22	0.28	0.044	0.03
MPER055	Hot Springs Breccia	350058	6660829	<2	0.05	<0.1	<0.2	17	19.2	<0.1	<0.02	1.19	0.07	0.78	0.36	2.6	0.202	9.91	0.052	0.1	0.03	0.015	10	<0.02	2.13	0.41	2.36	0.164	71	0.34	0.066	0.03
MPER056	M2 Drillhole	333781	6660680	9	0.05	<0.1	<0.2	19	18.2	<0.1	<0.02	1.33	0.02	0.6	0.35	2.7	0.064	21.23	0.049	0.1	0.03	0.016	14	<0.02	1.66	0.32	0.48	0.254	25	0.16	0.146	0.02
MPER057	M2 Drillhole	333794	6660691	4	0.05	<0.1	<0.2	16	10.8	<0.1	<0.02	1.04	<0.01	0.6	0.21	2.9	0.048	14.4	0.05	0.1	0.03	0.021	15	<0.02	1.76	0.29	0.47	0.269	31	0.15	0.248	0.02
MPER062	Nob's Well	308008	6677641	3	0.08	0.4	<0.2	16	7.8	<0.1	<0.02	1.68	0.01	1.1	0.41	3.8	0.098	13.68	0.088	0.3	0.03	0.021	11	<0.02	1.47	0.56	1.62	0.215	45	0.15	0.19	0.04
MPER063	Nob's Well	308070	6677711	3	0.06	0.2	<0.2	14	11.9	<0.1	<0.02	1.38	0.02	0.82	0.44	3	0.067	11.32	0.064	0.2	0.03	0.018	12	<0.02	1.4	0.39	1.06	0.256	61	0.2	0.326	0.02
MPER064	The Pinnacles	337489	6647075	<2	0.04	<0.1	<0.2	17	4.2	0.1	<0.02	0.93	0.03	0.48	0.13	2.4	0.106	3.12	0.036	0.1	0.01	0.007	11	<0.02	1.92	0.25	0.83	0.608	43	0.21	0.139	0.03
MPER065	The Pinnacles	337410	6647094	4	0.09	0.1	<0.2	15	5.4	0.1	<0.02	0.79	0.02	1.09	0.32	3.3	0.081	8.24	0.079	0.3	0.02	0.012	12	<0.02	2.85	0.54	1.13	0.377	28	0.29	0.154	0.05
MPER066	The Needles	328958	6651487	2	0.07	<0.1	<0.2	13	10.2	<0.1	<0.02	0.92	<0.01	0.86	0.26	2.7	0.07	6.6	0.072	0.2	0.02	0.02	19	<0.02	2.05	0.43	1.01	0.228	38	0.3	0.093	0.03
MPER067	The Needles	328950	6651476	<2	0.07	<0.1	<0.2	13	12.9	0.2	<0.02	1.14	0.04	0.83	0.23	3	0.066	4.32	0.069	0.2	0.03	0.021	17	<0.02	1.77	0.4	0.92	0.295	51	0.17	0.125	0.03
MPER068	Hodgkinson Outcrop	347920	6659509	2	0.07	<0.1	<0.2	14	11.9	<0.1	<0.02	1.45	0.86	1.28	0.3	3.7	0.064	10.25	0.068	0.2	0.04	0.012	8	<0.02	1.64	0.68	0.4	0.233	67	0.28	0.011	0.03
MPER069	Hodgkinson Outcrop	347931	6659507	3	0.04	<0.1	<0.2	14	8.3	<0.1	<0.02	1.18	0.3	1.07	0.33	2.9	0.043	23.26	0.041	0.1	0.01	0.006	6	<0.02	2.2	0.68	0.27	0.208	58	0.18	0.01	0.03
MPER070	Hodgkinson Outcrop	347975	6659497	<2	0.07	<0.1	<0.2	15	16.8	0.1	<0.02	2.11	0.32	3.8	0.56	3.6	0.062	26.41	0.068	0.2	0.04	0.013	9	<0.02	1.54	4.04	0.35	0.33	64	0.81	0.02	0.02
MPER071	Hodgkinson Sediments	347915	6659549	3	0.07	<0.1	<0.2	16	11.9	0.2	<0.02	2.24	3.2	1.27	0.42	3.5	0.07	28.96	0.071	0.2	0.05	0.011	7	<0.02	1.6	0.79	0.51	0.516	62	0.69	0.114	0.03
MPER072	Hodgkinson Sediments	347938	6659578	5	0.06	<0.1	<0.2	13	18.3	0.2	<0.02	1.52	0.94	0.93	0.32	3.2	0.057	9.28	0.052	0.2	0.04	0.01	10	<0.02	1.85	0.62	0.62	0.211	80	0.58	0.196	0.02
MPER073	Hodgkinson Sediments	347955	6659595	3	0.07	<0.1	<0.2	15	9.4	0.4	<0.02	1.92	0.83	1.16	0.28	3.9	0.064	14.13	0.068	0.2	<0.01	0.007	11	<0.02	1.23	0.91	0.53	0.368	71	1.31	0.03	0.03
MPER074	Hodgkinson Sediments	347966	6659584	2	0.05	<0.1	<0.2	15	21.1	<0.1	<0.02	1.72	1.5	0.75	0.24	3.2	0.053	13.25	0.051	0.2	0.02	0.008	6	<0.02	1.67	0.49	0.36	0.351	55	0.48	0.094	0.02
MPER101	Yudnamatana Gorge Workings	346954	6658832	3	0.06	<0.1	<0.2	18	12.5	<0.1	<0.02	0.97	0.08	0.72	0.28	2.6	0.049	10.37	0.049	0.1	0.02	0.02	18	<0.02	2.01	1.18	0.42	0.244	24	0.1	0.106	0.02
MPER102	Yudnamatana Gorge Workings	346949	6658811	3	0.04	<0.1	<0.2	16	10.1	<0.1	<0.02	1.57	0.18	0.53	0.27	2.4	0.039	11.23	0.043	0.1	0.03	0.01	12	<0.02	1.49	0.3	0.33	0.334	48	0.38	0.051	0.02
MPER103	Hodgkinson [O] Twig (Leaf; MPER068)	347920	6659509	6	0.09	<0.1	<0.2	18	8.6	0.1	<0.02	0.97	0.38	1.49	0.38	3.2	0.08	8.91	0.09	0.2	0.03	0.021	19	<0.02	2.66	0.77	0.95	0.339	64	0.61	0.066	0.03
MPER104	Hodgkinson [O] Twig (Leaf; MPER069)	347931	6659507	7	0.05	<0.1	<0.2	13	5.9	0.1	<0.02	0.87	0.14	1.48	0.37	2.7	0.055	12.42	0.053	0.2	0.03	0.017	17	<0.02	2.85	0.86	0.73	0.337	58	0.27	0.099	0.02
MPER105	Hodgkinson [O] Twig (Leaf; MPER070)	347975	6659497	3	0.08	<0.1	<0.2	14	19.3	<0.1	<0.02	1.89	0.16	3.27	0.44	3.1	0.077	9.73	0.074	0.2	0.04	0.015	21	<0.02	1.98	3.59	0.59	0.329	55	0.81	0.056	0.03
MPER106	Hodgkinson [S] Twig (Leaf; MPER071)	347915	6659549	5	0.07	<0.1	0.3	16	11.1	0.1	<0.02	1.88	2.13	1.13	0.35	2.9	0.07	10.16	0.064	0.2	0.02	0.016	15	<0.02	2.01	0.72	1.22	0.433	69	0.51	0.105	0.02
MPER107	Hodgkinson [S] Twig (Leaf; MPER072)	347938	6659578	15	0.05	<0.1	<0.2	16	10.1	0.4	<0.02	0.91	0.36	0.81	0.28	2.6	0.058	16.51	0.052	0.2	0.04	0.013	18	<0.02	2.73	0.56	3.27	0.294	96	0.65	0.14	0.02
MPER108	Hodgkinson [S] Twig (Leaf; MPER073)	347955	6659595	5	0.07	<0.1	<0.2	18	9.4	0.4	<0.02	2.25	0.63	1.05	0.28	2.8	0.059	10.47	0.058	0.2	0.04	0.018	21	<0.02	1.27	0.89	2.08	0.54	117	1.85	0.125	0.03
MPER109	Hodgkinson [S] Twig (Leaf; MPER074)	347966	6659584	2	0.05	<0.1	<0.2	18	15.2	<0.1	<0.02	1.2	0.81	0.69	0.2	2.8	0.055	8.79	0.045	0.1	0.03	0.015	18	<0.02	2.58	0.44	0.5	0.347	48	0.48	0.056	0.02
MPER061	Hematite Valley Breccia	347530	6661432	22	0.04	<0.1	<0.2	14	31.9	<0.1	<0.02	1.68	0.15	0.74	0.18	2.7	0.039	20.02	0.039	0.1	0.02	0.012	13	<0.02	1.57	0.4	0.99	0.415	44	0.36	0.013	0.02
MPER110	Hematite Valley Breccia	347735	6660790	35	0.05	0.6	<0.2	14	9.2	<0.1	<0.02	1.27	0.42	1.4	0.27	2.7	0.221	21.69	0.049	0.1	<0.01	0.015	11	<0.02	1.58	0.68	0.69	0.386	62	0.59	0.093	0.03
MPER111	Hematite Valley Breccia	347719	6660801	131	0.05	0.5	0.3	11	5.7	<0.1	<0.02	1.16	0.13	0.92	0.33	2.5	0.503	28.29	0.049	0.2	0.03	0.014	15	<0.02	1.72	0.46	0.56	0.399	62	1.02	0.095	0.03
MPER112	Hematite Valley Breccia	347715	6660821	34	0.1	0.3	<0.2	13	19.8	<0.1	<0.02	1.12	0.11	1.52	0.53	3.5	0.23	15.07	0.092	0.3	<0.01	0.027	14	<0.02	1.42	0.72	0.8	0.284	25	0.43	0.159	0.03

Appendix 1 cont.

Sample	Site	Eastings (GDA94)	Northings (GDA94)	Ni (ppm)	P (%)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Rb (ppm)	Re (ppb)	S (%)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Te (ppm)	Th (ppm)	Ti (ppm)	Tl (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
MPER001	Four Mile West: Basement	353811	6664930	0.7	0.17	0.16	<2	<1	26	2	0.28	0.03	0.3	0.5	0.04	217.6	<0.001	<0.02	0.05	10	<0.02	0.02	<2	<0.1	0.119	21.7	0.2
MPER002	Four Mile West: Mesozoic	353817	6664909	1.3	0.128	0.34	<2	<1	26	3	0.29	0.04	0.2	0.4	0.07	213.4	<0.001	<0.02	0.1	11	<0.02	0.02	<2	<0.1	0.245	14.6	0.45
MPER003	Four Mile West: Basement	353814	6664888	1.3	0.091	0.27	<2	<1	17.5	5	0.25	0.03	0.2	0.3	0.04	146.6	<0.001	<0.02	0.1	10	<0.02	0.01	<2	<0.1	0.19	11	0.43
MPER004	Four Mile West: Basement	353814	6664885	0.8	0.086	0.29	<2	<1	7.8	4	0.28	0.05	0.2	0.4	0.08	128	<0.001	<0.02	0.12	9	<0.02	0.01	<2	<0.1	0.219	8.7	0.42
MPER005	Four Mile West: Mesozoic	353846	6664850	1.3	0.078	0.49	<2	<1	12.6	3	0.28	0.05	0.4	0.6	0.06	97.4	<0.001	<0.02	0.21	13	<0.02	0.03	<2	<0.1	0.372	15.5	0.73
MPER006	Four Mile West: Lower Eyre Fm.	353865	6664832	0.8	0.153	0.33	<2	<1	23.5	3	0.27	0.05	0.3	0.7	0.04	172.4	<0.001	<0.02	0.11	12	<0.02	0.01	<2	<0.1	0.211	11.5	0.38
MPER007	Four Mile West: Mesozoic	353864	6664847	0.9	0.141	0.25	<2	<1	33.7	2	0.23	0.04	0.3	0.5	0.05	111.8	<0.001	<0.02	0.11	12	<0.02	0.02	<2	<0.1	0.201	16	0.39
MPER008	Four Mile West: Mesozoic	353867	6664840	1.3	0.092	0.23	<2	<1	20.1	<1	0.23	0.04	0.3	0.5	0.06	125.2	<0.001	<0.02	0.1	9	<0.02	0.02	<2	<0.1	0.18	14.7	0.33
MPER009	Four Mile West: Lower Eyre Fm.	353942	6664824	0.8	0.114	0.29	<2	<1	5.1	1	0.27	0.04	0.3	0.2	0.07	163.7	<0.001	<0.02	0.11	10	<0.02	0.01	<2	<0.1	0.188	12.3	0.41
MPER010	Four Mile West: Mesozoic	353916	6664819	0.6	0.088	0.25	<2	<1	15.6	4	0.24	0.05	0.2	0.5	0.05	164.9	<0.001	<0.02	0.09	9	<0.02	<0.01	<2	<0.1	0.164	6.8	0.34
MPER011	Four Mile West: Lower Eyre Fm.	353955	6664841	1.1	0.095	0.38	<2	<1	21.9	2	0.21	0.03	0.4	0.4	0.06	119.5	<0.001	<0.02	0.12	10	<0.02	0.02	<2	<0.1	0.21	11.3	0.43
MPER012	Four Mile West: Lower Eyre Fm.	353970	6664833	0.6	0.152	0.32	<2	<1	4	1	0.27	0.05	0.3	0.4	0.04	237.6	<0.001	<0.02	0.12	12	<0.02	0.02	<2	<0.1	0.184	7.6	0.4
MPER013	Four Mile West: Lower Eyre Fm.	353939	6664812	0.6	0.092	0.27	<2	<1	22.5	<1	0.27	0.04	0.3	0.6	0.06	153.8	<0.001	<0.02	0.09	9	<0.02	0.02	<2	<0.1	0.181	12	0.39
MPER014	Four Mile West: Roll front zone	354013	6664824	0.8	0.138	0.31	<2	<1	6.8	<1	0.28	0.07	0.5	0.7	0.06	106.3	<0.001	<0.02	0.26	12	<0.02	0.04	<2	<0.1	0.221	8.3	0.47
MPER015	Four Mile West: Roll front zone	354000	6664841	0.9	0.181	0.34	<2	<1	12.7	<1	0.24	0.04	0.3	0.7	0.07	121.5	<0.001	<0.02	0.17	14	<0.02	0.02	<2	<0.1	0.254	9.6	0.46
MPER016	Four Mile West: Lower Eyre Fm.	353972	6664837	1	0.109	0.42	<2	<1	4.3	2	0.2	0.05	0.4	0.3	0.05	123	<0.001	<0.02	0.18	14	<0.02	0.02	<2	<0.1	0.292	9.1	0.65
MPER017	Four Mile West: Roll front zone	354011	6664828	1.1	0.137	0.32	<2	<1	5.9	2	0.29	0.03	0.2	0.6	0.04	129.1	<0.001	<0.02	0.14	14	<0.02	0.02	<2	<0.1	0.256	13	0.52
MPER018	Four Mile West: Roll front zone	354012	6664822	1	0.133	0.36	<2	<1	4.7	2	0.17	0.04	0.4	0.3	0.07	98.6	<0.001	<0.02	0.16	13	<0.02	0.02	<2	<0.1	0.252	10.7	0.57
MPER019	Four Mile West: Roll front zone	354019	6664801	0.9	0.133	0.38	<2	1	4.7	<1	0.18	0.02	0.4	0.4	0.07	63.9	0.001	<0.02	0.14	14	<0.02	0.05	<2	<0.1	0.26	19.2	0.62
MPER020	Four Mile West: Upper Eyre Fm.	354116	6664812	0.9	0.109	0.27	<2	<1	7.9	5	0.25	0.03	0.3	0.6	0.05	169.9	<0.001	<0.02	0.1	11	<0.02	0.01	<2	<0.1	0.202	22.6	0.45
MPER021	Four Mile West: Upper Eyre Fm.	354058	6664803	0.4	0.123	0.21	<2	<1	4.7	1	0.2	0.03	0.3	0.2	0.03	139.1	<0.001	<0.02	0.06	9	<0.02	0.01	<2	<0.1	0.143	11.5	0.28
MPER022	Four Mile West: Upper Eyre Fm.	354153	6664791	1.3	0.08	0.46	<2	<1	9	3	0.16	0.04	0.3	0.3	0.04	103.1	<0.001	<0.02	0.14	13	<0.02	0.02	<2	<0.1	0.334	8.8	0.59
MPER023	Four Mile West: Silcrete	354227	6664720	0.6	0.151	0.27	<2	<1	11.3	2	0.2	0.04	0.3	0.3	0.05	53.9	<0.001	<0.02	0.19	14	<0.02	0.05	<2	<0.1	0.22	23.5	0.48
MPER024	Four Mile West: Upper Eyre Fm.	354066	6664805	0.8	0.065	0.22	<2	<1	10.9	1	0.17	0.03	0.3	0.5	0.03	106.9	<0.001	<0.02	0.1	9	<0.02	0.01	<2	<0.1	0.179	9.3	0.4
MPER025	Four Mile West: Namba Fm.	354219	6664705	1.1	0.082	0.37	<2	<1	25	3	0.19	0.03	0.3	0.2	0.05	141.6	<0.001	<0.02	0.22	13	0.02	0.02	<2	<0.1	0.311	17.9	0.63
MPER026	Four Mile West: Namba Fm.	354220	6664714	1.1	0.084	0.65	<2	<1	10.2	2	0.24	0.04	0.4	0.5	0.08	125.5	<0.001	<0.02	1.65	17	<0.02	0.11	<2	<0.1	0.563	11.2	1.14
MPER027	Four Mile West: Namba Fm.	354230	6664689	0.6	0.141	0.26	<2	<1	10.8	2	0.2	0.03	0.5	0.4	0.04	98.2	<0.001	<0.02	0.16	13	<0.02	0.02	<2	<0.1	0.218	16.2	0.46
MPER028	Four Mile West: Namba Fm.	354218	6664677	0.6	0.13	0.41	<2	<1	29.2	<1	0.2	0.02	0.3	0.6	0.06	102.2	<0.001	<0.02	0.16	14	<0.02	0.02	<2	<0.1	0.296	8	0.59
MPER029	Four Mile West: Unknown	354238	6664580	1.1	0.103	0.29	<2	<1	20.3	1	0.21	0.03	0.3	0.4	0.05	143.7	<0.001	<0.02	0.16	11	<0.02	0.02	<2	<0.1	0.235	25	0.46
MPER030	Four Mile West: Unknown	354256	6664566	1	0.094	0.25	<2	<1	23.5	1	0.18	0.02	0.3	0.4	0.03	147.9	<0.001	<0.02	0.1	11	<0.02	0.01	<2	<0.1	0.186	17.8	0.41
MPER031	Four Mile West: Unknown	354294	6664484	1.1	0.096	0.14	<2	<1	9.9	2	0.22	0.03	0.2	0.7	0.03	171.5	<0.001	<0.02	0.05	7	<0.02	<0.01	<2	<0.1	0.097	17.9	0.2
MPER032	Four Mile West: Unknown	354356	6664380	1.2	0.077	0.37	<2	<1	8	5	0.21	<0.02	0.3	0.5	0.05	72.2	<0.001	<0.02	0.16	12	<0.02	0.02	<2	<0.1	0.292	15.9	0.62
MPER033	Four Mile West: Unknown	354270	6664526	0.8	0.093	0.31	<2	<1	15.1	1	0.22	0.02	0.4	0.3	0.05	136.6	<0.001	<0.02	0.13	11	<0.02	0.01	<2	<0.1	0.239	10.1	0.45
MPER034	Four Mile West: Unknown	354317	6664442	1.5	0.083	0.26	<2	<1	18.1	1	0.18	<0.02	0.2	0.4	0.05	183	0.002	<0.02	0.08	9	<0.02	0.02	<2	<0.1	0.253	14.9	0.51
MPER035	Four Mile West: Unknown	354857	6663951	1.6	0.1	0.59	<2	<1	11.5	1	0.19	<0.02	0.4	0.7	0.06	81.7	0.001	<0.02	0.23	15	<0.02	0.04	3	<0.1	0.598	9.5	1.05
MPER036	Four Mile West: Unknown	354791	6663988	1.1	0.124	0.54	<2	<1	9.5	1	0.2	0.03	0.4	0.3	0.05	123.3	<0.001	<0.02	0.25	17	<0.02	0.03	<2	<0.1	0.437	30.4	0.86
MPER038	Four Mile West: Unknown	354894	6663933	1	0.085	0.44	<2	<1	14.2	2	0.19	0.03	0.4	0.6	0.06	91.4	<0.001	<0.02	0.37	14	<0.02	0.05	<2	<0.1	0.468	8.5	0.75
MPER039	Four Mile West: Unknown	354375	6664356	1.5	0.109	0.16	<2	<1	18.7	1	0.28	0.02	0.2	0.3	0.04	110.3	<0.001	<0.02	0.05	8	<0.02	<0.01	<2	<0.1	0.141	15.6	0.24
MPER040	Four Mile West: Unknown	354461	6664230	1	0.094	0.26	<2	<1	22.5	1	0.2	0.03	0.3	0.3	0.06	104.4	<0.001	<0.02	0.14	11	<0.02	0.01	<2	<0.1	0.223	18.1	0.41
MPER041	Four Mile West: Unknown	354416	6664326	0.9	0.096	0.41	<2	<1	11.3	1	0.18	0.03	0.4	0.4	0.06	89	<0.001	<0.02	0.15	12	<0.02	0.02	<2	<0.1	0.265	12.9	0.54
MPER042	Four Mile West: Unknown	354437	6664280	1.1	0.097	0.38	<2	<1	7.7	1	0.19	0.02	0.3	0.5	0.05	111.9	<0.001	<0.02	0.15	12	<0.02	0.01	<2	<0.1	0.247	10.5	0.5
MPER043	Four Mile West: Unknown	354492	6664197	1	0.084	0.32	<2	<1	12.4	2	0.2	0.02	0.3	0.4	0.06	74.9	<0.001	<0.02	0.14	11	<0.02	0.02	<2	<0.1	0.234	15	0.5
MPER044	Four Mile West: Unknown	354678	6664027	1.4	0.098	0.43	<2	<1	13.8	1	0.19	0.03	0.4	0.4	0.07	85.8	<0.001	<0.02	0.2	13	<0.02	0.02	<2	<0.1	0.333	14.3	0.65
MPER045	Four Mile West: Unknown	354512	6664153	1.9	0.102	0.34	<2	<1	12.6	2	0.23	0.04	0.3	0.3	0.05	80.9	<0.001	<0.02	0.13	11	<0.02	0.02	<2	<0.1	0.242	26.5	0.47
MPER046	Four Mile West: Unknown	354573	6664103	1.4	0.108	0.33	<2	<1	13.2	<1	0.25	0.02	0.2	0.4	0.05	88.1	<0.001	<0.02	0.24	12	<0.02	0.04	<2	<0.1	0.324	19.8	0.52
MPER047	Four Mile West: Unknown	354752	6664002	1	0.1	0.21	<2	<1	12.1	1	0.19	<0.02	0.2	0.4	0.04	89.5	<0.001	<0.02	0.12	10	<0.02	0.01	<2	<0.1	0.187	12	0.36
MPER048	Four Mile West: Unknown	354593	6664073	0.8	0.085	0.5	<2	<1	7.3	<1	0.17	0.02	0.3	0.4	0.05	89.6	<0.001	<0.02	0.23	13	<0.02	0.03	<2	<0.1	0.411	16.2	0.69
MPER049	Four Mile West: Unknown	354345	6664404	1.1	0.082	0.46	<2	<1	18.9	1	0.17	0.03	0.4	0.5	0.06	87.1	<0.001	<0.02	0.24	14	<0.02	0.02	<2	<0.1	0.366	10.3	0.8
MPER037	Freeling Heights Quartzite	347394	6662083	0.7	0.183	0.17	<2	<1	11.4	5	0.19	0.02	0.3	0.8	0.03	86.1	<0.001	<0.02	0.06	12	<0.02	0.03	<2	<0.1	0.15	50.6	0.26
MPER050	Freeling Heights Quartzite	347477	6662072	1.1	0.147	0.2	<2	<1	4.4	1	0.21	<0.02	0.3	0.4	0.04	120.7	<0.001	<0.02	0.09	12	<0.02	0.03	<2	<0.1	0.178	33.6	0.34
MPER051	Freeling Heights Quartzite	347941	6661870	0.6	0.113	0.17	<2	<1	8.8	1	0.2	<0.02	0.2	0.4	0.05	124.5	<0.001	<0.02	0.07	9	<0.02	0.02	<2	<0.1	0.311	25.2	0.25
MPER052	Freeling Heights Quartzite	349090	6662429	0.9	0.113	0.58	<2	<1	7.7	<1	0.25	<0.02	0.3	0.5	0.03	111.1	<0.001	<0.02	0.08	11	<0.02	0.01	2	<0.1	0.22	14.1	0.29
MPER053	Mudnawatana Granite	350135	6661303	0.8	0.121	0.25	<2	<1	7.4	<1	0.24	<0.02	0.3	0.3	0.04	108.2	<0.001	<0.02	0.09	11	<0.02	0.02	2	<0.1	0.279	17.6	0.28
MPER054	Mudnawatana Granite	349888	6661103	2.9	0.14	0.51	<2	<1	11.8	<1	0.23	0.03	0.3	0.3	0.04	113.4	<0.001	<0.02	0.12	13	<0.02	0.02	2	<0.1	0.364	27.8	0.41
MPER055	Hot Springs Breccia	350058	6660829	1.2	0.15	0.3	<2	<1	28.1	<1	0.2	0.04	0.3	0.2	0.04	71.8	<0.001	<0.02	0.11	13	0.02	0.02	2	<0.1	0.263	34.3	0.39
MPER056	M2 Drillhole	333781	6660680	0.5	0.152	0.33	<2	<1	6.7	2	0.23	0.02	0.3	0.4	0.04	88.9	<0.001	<0.02	0.09	13	<0.02	0.01	2	<0.1	0.196	21.1	0.39
MPER057	M2 Drillhole	333794	6660691	0.7	0.104	0.31	<2	<1	3	2	0.21	<0.02	0.3	0.5	0.02	100.1	<0.001	<0.02	0.09	12	<0.02	0.01	2	<0.1	0.181	18.7	0.39
MPER062	Nob's Well	308008	6677641	1.3	0.181	0.39	<2	<1	3.4	4	0.23	0.04	0.4	0.5	0.05	92.7	<0.001	<0.02	0.14	21	<0.02	0.02	2	<0.1	0.283	10.4	0.61
MPER063	Nob's Well	308070	6677711	0.9	0.138	0.29	<2	<1	3	2	0.24	0.03	0.3	0.5	0.03	52.9	<0.001	<0.02	0.13	15	<0.02	0.01	2	<0.1	0.203	11.3	0.44
MPER064	The Pinnacles	337489	6647075	0.6	0.191	0.2	<2	<1	15	39	0.22	<0.02	0.3	0.6	<0.02	31.4	<0.001	<0.02	0.07	14	<0.02	<0.01	<2	<0.1	0.234	14.2	0.25
MPER065	The Pinnacles	337410	6647094	1	0.243	0.46	<2	<1	16	28	0.25	0.03	0.3	0.4	0.03	40.1	0.001	<0.02	0.05	20	<0.02	0.02	3	<0.1	0.404	17.3	0.42
MPER066	The Needles	328958	6651487	0.7	0.144	0.5	<2	1	10	42	0.19	0.03	0.3	0.5	0.03	50.4	<0.001	<0.02	0.14	15	<0.02	0.01	2	<0.1	0.233	8.1	0.53
MPER067	The Needles	328950	6651476	0.8	0.145	0.43	<2	<1	7	38	0.24	0.04	0.3	0.3	0.03	74	<0.001	<0.02	0.11	14	<0.02	0.02	2	<0.1	0.239	12.1	0.54
MPER068	Hodgkinson Outcrop	347920	6659509	1.2	0.107	0.39	<2	<1	6	<1	0.2	0.02	0.4	0.2	0.04	91.5	<0.001	<0.02	0.09	12	<0.02	0.07	<2	<0.1	0.849	28.4	0.38
MPER069	Hodgkinson Outcrop	347931	6659507	1.3	0.197	0.22	<2	<1	14.7	<1	0.27	<0.02	0.3	0.2	0.03	75.5	<0.001	<0.02	0.08	14	<0.02	0.06	<2	<0.1	0.716	33.5	0.28
MPER070	Hodgkinson Outcrop	347975	6659497	1.2	0.183	0.4	<2	<1	7.3	<1	0.39	0.04	0.3	0.9	0.05	155.4	<0.001	<0.02	0.08	14	<0.02	0.05	<2	<0.1	3.547	27.8	0.37
MPER071	Hodgkinson Sediments	347915	6659549	1.8	0.316	0.46	<2	<1	6.2	<1	0.67	0.03	0.3	1.9	0.04	134.1	<0.001	<0.02	0.08	21	<0.02	0.24	2	<0.1	1.275	53.8	0.32
MPER072	Hodgkinson Sediments	347938	6659578	1.2	0.157	0.68	<2	<1	6.9	<1	0.3	0.03	0.2	0.3	0.05	120.5	<0.001	<0.02	0.11	12	<0.02	0.14	<2	<0.1	0.462	32.4	0.36
MPER073	Hodgkinson Sediments	347955	6659595	1.5	0.246	0.41	<2	<1	4.1	<1	0.53	0.02	0.3	0.4	0.04	128.6	<0.001	<0.02	0.07	18	<0.02	0.2	<2	<0.1	0.967	34.4	0.3
MPER074	Hodgkinson Sediments	347966	6659584	1.7	0.202	0.32	<2	<1	8	<1	0.49	0.04	0.3	0.6	0.04	144.6	<0.001	<0.02	0.09	15	<0.02	0.12	<2	<0.1	0.404	27.8	0.33
MPER101	Yudnamatana Gorge Workings	346954	6658832	0.5	0.122	0.29	<2	<1	5.7	2	0.2	0.02	0.3	0.4	0.05	65.7	<0.001	<0.02	0.1	11	<0.02	0.02	<2	<0.1	0.446	36	0.4
MPER102	Yudnamatana Gorge Workings	346949	6658811	0.6	0.111	0.37	<2	<1	3.8	8	0.22	<0.02	0.3	0.8	<0.02	91.9	<0.001	<0.02	0.08	10	<0.02	0.06	<2	<0.1	0.303	45.5	0.31
MPER103	Hodgkinson [O] Twig (Leaf; MPER068)	347920	6659509	1.9	0.102	0.5	<2	<1	8.5	6	0.22	0.02	0.4	0.3	0.05	53.7	<0.001	<0.02	0.17	14	<0.02	0.41	2	<0.1	1.229	32.8	0.66
MPER104	Hodgkinson [O] Twig (Leaf; MPER069)	347931	6659507	1.3	0.112	0.26	<2	<1	18.7	8	0.21	<0.02	0.3	0.3	0.03	41.3	<0.001	<0.02	0.14	12	<0.02	0.27	2	<0.1	1.246	46.9	0.39
MPER105	Hodgkinson [O] Twig (Leaf; MPER070)	347975	6659497	1	0.116	0.58	<2	<1	8.4	23	0.24	0.03	0.3	1	0.08	120.3	<0.001	<0.02	0.17	14	<0.02	0.08	2	<0.1	2.179	21.2	0.52
MPER106	Hodgkinson [S] Twig (Leaf; MPER071)	347915	6659549	1.2	0.175	0.37	<2	<1	7	43	0.28	0.02	0.3	1.5	0.03	100.4	<0.001	<0.02	0.1	16	<0.02	0.25	<2	<0.1	0.782	63.2	0.46
MPER107	Hodgkinson [S] Twig (Leaf; MPER072)	347938	6659578	1	0.177	0.27	<2	<1	8.6	21	0.22	<0.02	0.2	0.6	0.02	62.4	<0.001	<0.02	0.09	13	<0.02	0.33	2	<0.1	0.547	47.4	0.38
MPER108	Hodgkinson [S] Twig (Leaf; MPER073)	347955	6659595	1.3	0.187	0.36	3	<1	3.6	133	0.23	0.03	0.2	0.6	0.05	119	<0.001	<0.02	0.08	15	<0.02	0.5	2	<0.1	0.748	38.4	0.4
MPER109	Hodgkinson [S] Twig (Leaf; MPER074)	347966	6659584	2.3	0.145	0.24	<2	<1	11.2	115	0.23	0.02	0.3	0.8	0.04	81.8	<0.001	<0.02	0.11	12	<0.02	0.16	<2	<0.1	0.312	31.5	0.36
MPER061	Hematite Valley Breccia	347530	6661432	1.3	0.12	2.15	<2	<1	2.9	4	0.23	0.03	0.3	0.8	<0.02	139	<0.001	<0.02	0.16	10	<0.02	0.03	2	<0.1	0.335	155	0.26
MPER110	Hematite Valley Breccia	347735	6660790	0.8	0.131	0.97	<2	<1	21.6	<1	0.21	<0.02	0.3	0.4	0.03	55.9	<0.001	<0.02	0.13	12	<0.02	0.17	<2	<0.1	0.378	150.3	0.35
MPER111	Hematite Valley Breccia	347719	6660801	1.1	0.135	0.65	<2	<1	43.9	<1	0.25	0.03	0.3	0.4	0.04	52.3	<0.001	<0.02	0.1	12	<0.02	0.07	<2	<0.1	0.268	107.9	0.38
MPER112	Hematite Valley Breccia	347715	6660821	1.3	0.15	0.85	<2	<1	12.9	1	0.22	0.03	0.4	0.4	0.07	68.4	<0.001	<0.02	0.16	17	<0.02	0.04	2	<0.1	0.427	94.1	0.72

Appendix 2 - Spearman (pair) correlation matrix from ioGAS. Correlation coefficients regionally and for each site. Highlighted values are elements with a correlation coefficient of <0.6 with U for at least one site. Number of samples presented in [ ]

Spearman	Regional [83]	Four Mile [48]	Hodgkinson (leaves) [7]	Hodgkinson (branches) [7]	Hematite Breccias [4]	Pinnacles/ Needles [4]	FHQ [4]	FHQ,Yud,Nob, Mud,Ter [11]
U	1	1		1	1	1	1	1
Y	**0.75**	**0.68**	0	-0.2	0	**0.74**	-0.7	0
La	**0.69**	**0.73**	-0.1	0.071	0.4	**0.63**	-0.7	-0.5
Ce	**0.63**	**0.74**	-0.3	-0.1	0.4	**0.63**	-0.2	-0.5
Zn	0.58	0.12	0.7	0.36	-0.2	0.21	0.95	0.74
Cd	0.54	-0.1	**0.71**	0.036	0.4	0.21	0.74	0.6
Cr	0.52	0.65	0.2	-0.2	-0.3	0.95	0.21	-0.3
Co	0.49	0.56	-0.3	-0.2	0.2	0.63	-0.7	-0.4
Ti	0.48	0.7	0.56	0.24	0.32	0.39	0.78	-0.3
Mn	0.42	0.013	0.25	0.79	0.74	-0.1	-0.7	-0.3
Pb	0.41	0.62	0.64	0	-0.4	0.32	-0.5	-0.4
Be	0.41	0	**0.67**	**0.85**	0	0.5	0	0
Ni	0.4	0.15	0.63	0.2	-0.9	0.95	0.21	-0.2
Ga	0.39	0.67	0.41	0.41	-0.1	0.83	0.27	-0.3
Nb	0.36	0.7	0.29	0.29	0.77	0.54	-0.5	-0.2
Fe	0.35	0.7	0.44	0.11	0.32	0.63	0.21	-0.3
Al	0.34	0.65	0.26	0.11	0.32	0.83	0.056	-0.3
Ge	0.33	0.042	0.15	0.19	-0.2	0.83	-0.8	-0.3
Mo	0.32	0.0048	0.39	0.32	0.8	-0.2	-0.1	0.31
P	0.32	0.072	0.61	0.25	0.2	0.21	0.89	0.14
Ag	0.28	0.022	0.62	0.58	0.8	0.39	0.056	0.18
Li	0.22	0.31	**0.79**	**0.71**	-0.8	0.63	0.056	-0.4
Pd	0.2	0	0	0.61	0	0	0	0
Mg	0.19	-0.2	0.64	0.29	-0.4	-0.3	0.21	0.26
Th	0.18	0.72*	-0.1	-0.5	-0.7	-0.2	-0.1	-0.4
Se	0.15	0.14	0.34	-0.7	-0.8	-0.9	0.056	0.23
S	0.14	-0.1	0.68	-0.5	-0.4	0.74	-0.6	-0.6
V	0.12	0.21	0.61	0.47	-0.9	0.83	-0.8	-0.7
Zr	0.11	0.7	-0.3	0.11	0.2	0.63	0.21	-0.3
K	0.1	0.081	-0.2	0.071	0.6	0.11	0.74	0.39
Sn	0.07	0.42	0	-0.1	0.2	0.82	0.056	-0.1
Hf	0.059	0.55	-0.2	0.59	0.4	0.63	0.78	-0.3
B	0.039	-0.2	0.36	0.45	-0.1	-0.5	0.74	0.51
Cu	0	-0.1	0	0.39	0.6	0.63	0.95	0.29
As	-0.1	0.13	0	0	**1**	0.54	-0.3	-0.4
Sb	-0.1	0.046	0	-0.1	-0.8	0.83	0.54	-0.3
Re	-0.1	-0.2	0	-0.1	-0.9	-0.7	0.83	0.51
Sr	-0.3	-0.5	0.036	-0.3	-0.8	0.63	-0.2	0.14
Ba	-0.3	-0.3	0	-0.7	-0.8	0.63	0.95	0.18
Na	-0.3	0.01	**0.71**	0.67	0.2	0.21	0.63	-0.1

*Unique U-Th relationship for sample MPER026. Sites with 4 samples have poor statistical significance.