RIVER RED GUM BIOGEOCHEMISTRY ASSOCIATIONS WITH SUBSTRATE: BEDROCK PENETRATORS OR STREAM SEDIMENT AMALGAMATORS?

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INTRODUCTION

River red gums (*Eucalyptus camaldulensis*) have recently been recognised as a valuable regional sampling media in biogeochemical surveys (Hulme & Hill 2003, Hulme & Hill 2004, Hill 2004) and have led to the discovery of mineralisation buried by transported regolith, where more traditional approaches have failed (Hulme & Hill 2005). The ability for plant biogeochemistry to reflect buried mineralisation may occur in two main ways (Hill 2004, 2005) (Figure 1):

1. Root and associated biogeochemical 'penetration' of transported regolith to the underlying bedrock; or,
2. Root 'amalgamation' of stream sediment (and possibly hydrogeochemistry of shallow aquifers) from within the transported regolith providing a chemical vector reflecting the underlying bedrock geochemistry.

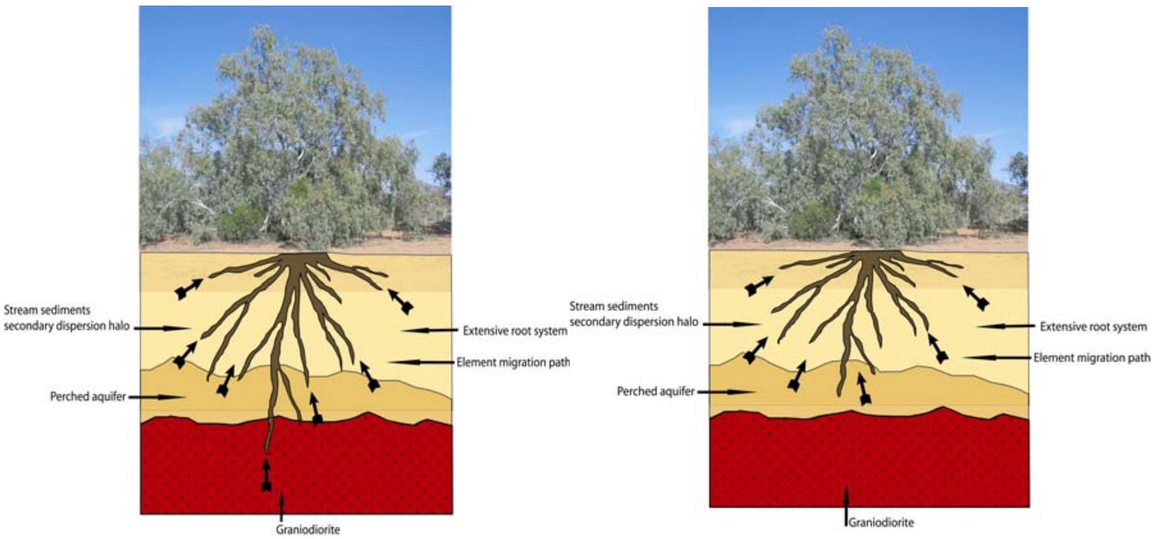

Figure 1a (left): Root and associated biogeochemical 'penetration' to the underlying bedrock. **Figure 1b (right):** root 'amalgamation' of stream sediments and possible hydrochemistry of perched aquifers, from within the transported regolith providing chemical vector reflecting underlying bedrock chemistry.

In the case of river red gums, either of these two mechanisms will make them valuable regional mineral exploration and environmental chemistry sampling media, however, further sample program design and the subsequent interpretation and application of results depends on developing an understanding of the significance of each mechanism. This manuscript examines the significance of these mechanisms by examining the biogeochemical associations with transported regolith substrates and the underlying bedrock.

River red gums are one of the most widely distributed tree species within Australia and in particular northwestern New South Wales. They mostly occur along riparian zones of large alluvial channel systems and associated alluvial swamps. In these regolith-landform settings, transported regolith thicknesses are variable, although typically at least several metres thick, and in many cases tens of metres thick. River red gum roots have been observed to extend over 100 metres laterally, and in many cases at least beyond their upper canopy height vertically (over tens of metres). The characteristics of bedrock across a region are generally least known from beneath areas with most significant transported cover thickness, which for many parts of semi-arid Australia, corresponds with the riparian zones that are typically colonised by river red gums. This scenario provides the potential for river red gums to provide valuable information on bedrock characteristics from areas significantly buried by transported regolith, both in the case of buried mineralisation or even buried bedrock lithological and chemical differences. Ideally the sampling of subaerial

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plant organs (such as leaves, twigs, fruit, flowers) is a much more efficient technique for chemical exploration under cover than expensive, destructive and time-consuming drilling and excavation.

BACKGROUND

River red gum trees examined for this study are from northwestern NSW on the margins of the Tibooburra Inlier (Stevens & Etheridge 1989) and the flanking Eromanga Basin, Lake Eyre Basin and Bulloo-Bancannia Basin sediments (Hill 2005). The leaves from mature river red gum trees were sampled along the channel of Racecourse Creek from its headwaters at Tibooburra Township, down stream to its junction with Thomson Creek (Figure 2). This channel sampling transect crosses bedrock substrate types including (Figure 3):

- Devonian Tibooburra Granodiorite and associated intrusives; and,
- Cambrian-Ordovician metasediments of the Easter Monday Beds (Thalhammer *et al.* 1998), including hornfels, phyllite and quartzite.

Mesozoic sediments associated with the Eromanga Basin extended across many of the low-lying parts of the catchment. These sediments include quartzose gravels and sands with minor silts, that are part of the late Jurassic to Early Cretaceous Cadna-owie Formation (locally described as the Gum Vale Formation; Morton 1982) and the overlying fine sands, silts and clays of the Rolling Downs Group (locally including units such as the Wittabrinna Shale; Morton 1982). The deposition of these sediments is interpreted as within fluvial to marginal marine environments, overlain by shallow marine deposits. Underlying these sediments is a regionally significant unconformity and locally exhumed palaeosurface (Hill 2000, 2005), associated with significant Au-dispersion and surficial concentration during the region's long-term landscape evolution (Hill *et al*, 2005, Hill 2005).

The geochemical distinctions between the major bedrock rock types, based on whole rock chemistry in this study as well as Stevens & Etheridge (1989), can be summarised as:

- Granodiorite: relatively high SiO_2, Sb and Sr; and,
- Metasediments: relatively high Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, MnO, Na_2O, P_2O_5, SO_3, TiO_2, Ag, As, Ba, Be, Bi, Cd, Ce, Cr, Cs, Cu, Dy, Er, Eu, F, Ga, Gd, Ge, Hf, Ho, La, Lu, Mo, Nb, Ni, Pb, Pr, Rb, Sc, Sm, Sn, Ta, Tb, Th, U, V, Y, Yb, Zn and Zr.

Regolith-landform maps of the area have been produced at 1:25,000 scale (Chamberlain & Hill 2002), with more detailed mapping 1:10,000 of the Dee Dee catchment headwaters (L.J. Hill 2004) and Racecourse catchment headwaters (Hulme, in prep., Figure 2). Weathered bedrock forms erosional hills, rises and plains in the area, as well as underlying the transported regolith. Widespread transported regolith occurs across the area and includes an assortment of alluvial, colluvial and aeolian sediments. These sediments are mostly in low-lying landscape settings, however, they may occur on the flanks of rises and hills.

The area presently experiences a semi-arid to arid climate, with an average annual rainfall of 227 mm, predominantly in the summer. Temperatures range from an average summer maximum of 35.4°C to an average winter minimum of 6.2°C (Bureau of Meteorology 2005). The northern parts of the area are within the Tibooburra town common, whereas the southern parts are within 'Mt Stuart' station. The area has previously been host to minor Au-mining and prospecting, particularly during the 1880s when mines were active as a part of the Albert goldfields. Most of the Au mined from the Tibooburra Inlier was hosted within transported regolith, either from Mesozoic sediments, or later sediments associated with erosion and redeposition of older sediments.

SAMPLING AND ANALYTICAL METHODS

In March 2004, 234 river red gums were sampled. This sampling program extended from the northernmost river red gum along Racecourse Creek and then southwards for 5.6 km towards Thomsons Creek. River red gum leaves were sampled based on a protocol initially developed by Hill (2002, 2004), with some modification by Hulme (in prep.) and included:

- All jewellery and any other metallic objects were removed from hands and lower arms, and hands were washed if sunscreen had been earlier applied;
- Powder-free latex gloves were worn on both hands during sampling, and gloves were changed between samples to minimise the risk of cross-contamination between different samples;
- Lower branches (typically 1-2 m above ground level) were sampled from around the tree canopy;
- Samples were placed in labelled, individual, unbleached brown paper bags;
- Samples were dried at 40°C for 48 hours;
- Samples were milled, in accordance with an approach initially used by Becquerel Laboratories (David Garnett *pers. comm.* 2003) utilising a Breville™ 'Coffee-n-Spice' grinder, CG-2.

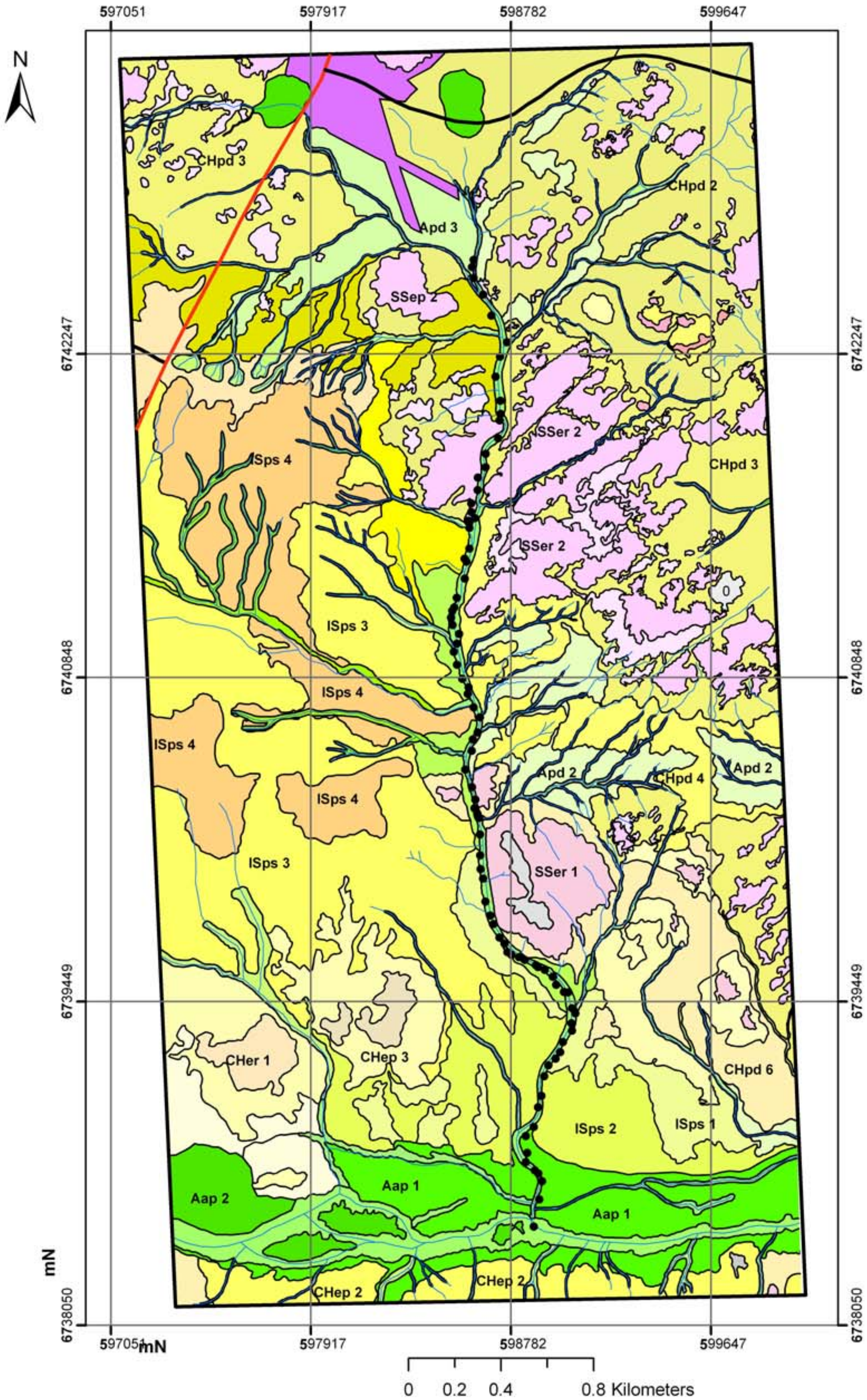

Figure 2: Regolith-landform map of the study area showing Racecourse Creek and the locations of sampled river red gums.

Samples were assayed through Becquerel Laboratories, Lucas Heights, NSW. This included Instrumental Neutron Activation Analysis (INAA), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Samples assayed by ICP-MS and ICP-OES were digested using a nitric and perchloric acid mix.

Bedrock samples of the granodiorite and metasediment were sampled and then assayed by ICP-MS and X-Ray Fluorescence (XRF) at the Geoscience Australia laboratories, Canberra.

RESULTS

The elements Ag, Sb, Cs, Hf, Ir, Se, Ta, In, Te, TI, Th, V, U, Zr, Be, Bi, Pb, Mo, Eu, La, Yb, and Ga were all below detection limits for the biogeochemical assays of the vegetation samples (leaves). The following elements were detected: Al, Ba, Br, Au, Fe, K, Ca, Cr, Co, Na, Zn, Cd, Cu, Mg, Mn, Ni, P, S, Sm, Nd, Zn and Sr. Whole rock analysis revealed that all major and trace elements were detected for both the granodiorite and metasediment. Elements such as As, Fe, K and Mg revealed concentrations values in the metasediment > 10 times that of the granodiorite, and were chosen as possible chemical indicators of the lithological boundary between the granodiorite and metasediment (Table. 1).

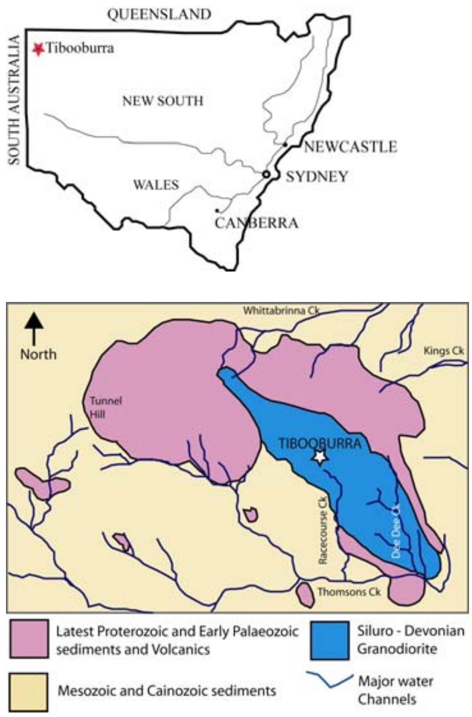

Figure 3: Simplified geology of the Tibooburra Inlier.

The leaf assay results for Fe, K, and Mg provide only a very subtle distinction between the underlying granodiorite and metasediment substrates. The metasediments generally have much higher Mg, K and Fe contents than the granodiorites, whereas the leaf chemistry from plants growing over these two rock types show insignificant, or at the most very slightly higher amounts of these elements overlying the metasediments (Figure 4). The Mg, K and Fe contents of the leaves are more equivalent to the relative concentrations of these elements in the stream sediments (which also contain chemical signatures from shallow groundwater systems both within the alluvium and at the sediment-bedrock interface). Rather surprisingly the As content of the leaves is much greater in trees growing over the granodiorite rather than in trees growing over the metasediments, and is the inverse of the relative chemical trends observed in the bedrock.

Table 1: Variations of selected metal concentration in oven dried tissue (leaves) of individual river red gums across two bedrock substrates.

Elements (ppm)	Granodiorite RRG Leaves (n=38)	Metasediment RRG Leaves (n=25)	Granodiorite WR	Metasediment WR	Stream sediment
As	0.11 ± 0.07 (* - .31)	0.049 ± 0.027 (* - 0.098)	7	77	3.12 ± 0.72
Fe	100 ± 20 (56 – 139)	119 ± 19 (88 – 147)	4364	56343	23700 ± 4265
K	8847 ± 1119 (6161 – 10900)	9158 ± 2192 (5520 – 13700)	1618	36325	15050 ± 2521
Mg	2496 ± 549 (1768 – 3925)	2731 ± 349 (1984 – 3554)	326	17029	4643 ± 1575

Metal concentration in whole rock (WR) chemistry of the granodiorite and metasediment. Initial value represents the mean value ± 1 sigma; values in brackets() are the range of values; and * signifies values below detection limit. To calculate means, below detection limit values were taken as half the detection limit value. Values with a mean but no range recorded represent only one sample in that set. n = the number of samples recovered.

DISCUSSION

These results potentially reflect some of the major chemical sources for the biogeochemical characteristics of the river red gums, and as such the general relationship between the plant chemical characteristics and substrate. At least for the elements As, Fe, K, and Mg, in general the leaf chemical characteristics are more consistent with these plants being chemical amalgamators of their regolith substrates, rather than chemical 'penetrators' of the underlying bedrock. The biogeochemistry results tend to broadly reflect the catchment's environmental chemistry, rather than strongly reflect local changes throughout the catchment, such as underlying bedrock lithological changes. This is shown by the general homogeneity, particularly of Fe, K and Mg contents in the leaves throughout the catchment. The chemical composition of the leaves appears to possibly more closely reflect the biological requirements of essential elements as well as the chemical composition of stream sediments (and probably also shallow groundwater aquifers within the sedimentary system and at the bedrock-sediment interface). The As contents of the leaves show a greater distinction between the two bedrock types, however, because this distinction is the inverse of the trend in the differences in the As contents of the two rocks, it is problematic to fully account for. One possibility is that that As is more strongly contained within the metasediment minerals and rock than in the granite. However, more likely is that if the As is associated with sulphides then it has been observed to have a very heterogeneous distribution throughout the rock units (mostly within narrow alteration zones and associated with quartz veins; Thalhammer 1991). This may be significant from a mineral exploration perspective, as it suggests that the headwaters of this catchment are heterogeneously more As-rich, which broadly coincides with the locations of known alluvial Au mineralisation in the catchment near Tibooburra (e.g., 'The Granite Diggings').

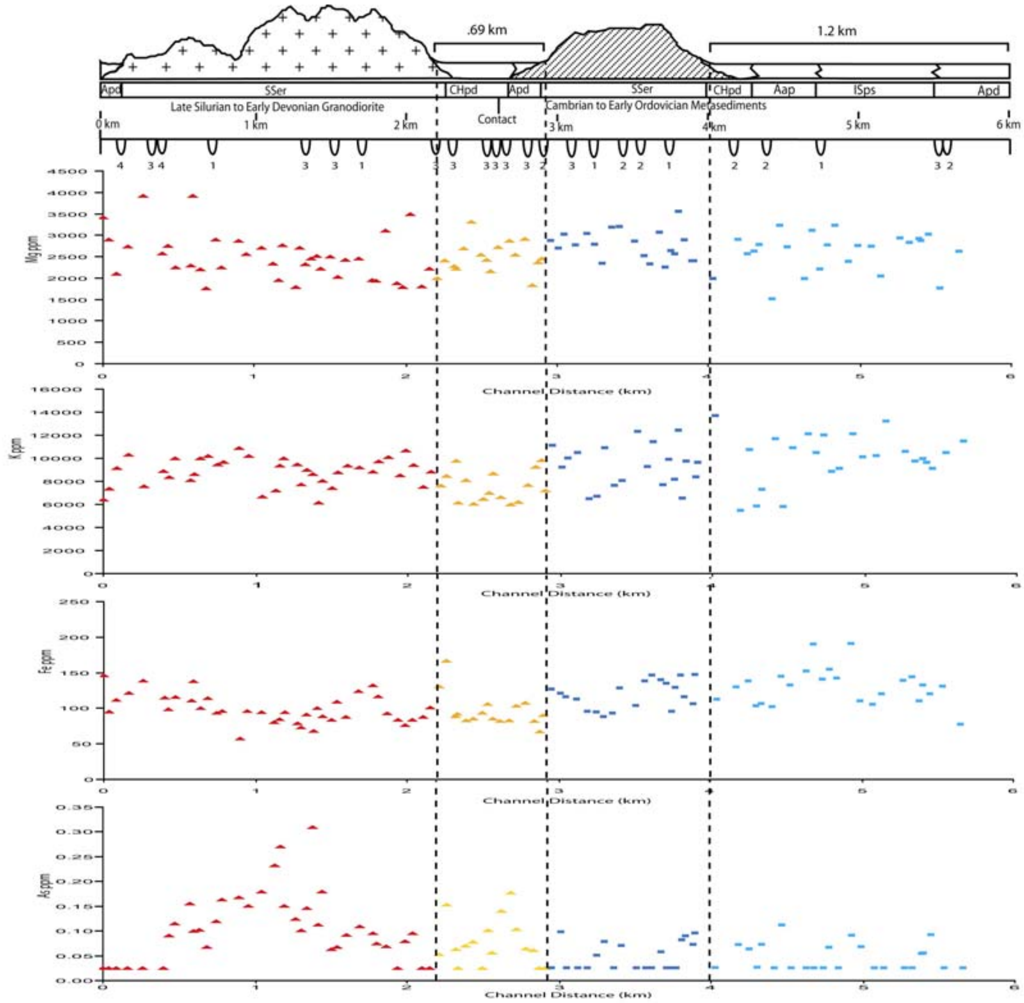

Figure 4: Mg, K, Fe and As abundance in oven dried tissue (leaves) of individual river red gums across two bed rock substrates.

The chemical amalgamation of stream sediment and shallow alluvial aquifers is consistent with the extensive lateral spread observed for river red gum root systems exposed in creek gullies and within stream sediments. In this way these trees are able to obtain water and nutrients from their spreading roots throughout the stream sediments for over 100 lateral metres. The suggestion that these trees are more chemically akin to being regolith chemistry amalgamators rather than penetrators is also consistent with associated studies of river red gums in the Pine Creek–Pinnacles area west of Broken Hill (Hulme & Hill 2005). In that study, chemical signatures of Broken Hill type mineralisation extend down Pine Creek from the Pinnacles Mine, as well as being expressed at the confluence of tributaries draining from the area of the Broken Hill Line of Lode. A major implication of this for mineral explorers and environmental chemists is that the amalgamator characteristics of river red gums are ideal for regional sampling programs. For some elements this may allow for representative sampling on the spacing of 100s of metres, up to the size of individual stream catchments.

CONCLUSIONS

This study presents results consistent with the conclusion that river red gums are chemical amalgators of their alluvial regolith setting. The biogeochemical characteristics of leaf samples were more closely related to the stream sediment (possibly also including shallow groundwater) chemical characteristics rather than changes in underlying bedrock lithology. This suggests that river red gums would make a suitable regional chemical sampling medium for mineral exploration programs and regional geochemistry baseline studies.

REFERENCES

BUREAU OF METEOROLOGY 2005. Averages for Tibooburra: Tiboobura Post office. http://www.bom.gov.au/climate/averages/tables/cw_046037.shtml.

CHAMBERLAIN T. & HILL S.M. 2002. *Tiboobura Inlier regolith-lanform map* (1:25 000). CRC LEME, Perth.

HILL L.J. 2002. Branching out into Biogeochemical surveys: A guide to vegetation sampling. *In*: ROACH I.C. ed. *Regolith and Landscapes in Eastern Australia.* CRC LEME, pp. 50-53.

HILL L.J. 2004. *Geochemical and biogeochemical dispersion and residence in landscapes of western New South Wales*. PhD Thesis, Department of Earth and Marine Sciences Australian National University, unpublished.

HILL S.M. 2000. *The regolith and landscape evolution of the Broken Hill Block, western NSW, Australia*. PhD Thesis, Department of Geology, Australian National University, unpublished.

HILL S.M. 2004. Biogeochemical sampling media for regional to prospect-scale mineral exploration in regolith-dominated terrains of the Curnamona Province and adjacent areas of western NSW and eastern SA. *In:* ROACH I.C. ed. *Regolith 2004.* CRC LEME, pp. 128-133.

HILL S.M., BROWN A, HULME K., PETTS A. & REID N. 2005. Using biogeochemistry and geobotany to explore through transported cover for mineral exploration. *2005 Mineral Exploration Seminar* **Abstracts**. CRC LEME, Perth, pp. 27-30.

HULME K.A. & HILL S.M. 2003. River red gums as a biogeochemical sampling medium in mineral exploration and environmental chemistry programs in the Curnamona Craton and adjacent regions of NSW and SA. *In:* ROACH I.C. ed. *Advances in Regolith.* CRC LEME, pp. 205-210.

HULME K.A., & HILL S.M. 2004. Seasonal element variations of Eucalyptus camaldulensis biogeochemistry and implications for mineral exploration: An example from Teilta, Curnamona Province, western NSW. In: ROACH I.C. ed. *Regolith 2004*. CRC LEME, pp. 151-156.

HULME K.A. & HILL S.M. 2005. Mineralisation discovery through transported cover using River Red Gums (*Eucalyptus camaldulensis). 2005 Mineral Exploration Seminar* **Abstracts**. CRC LEME, Perth, pp. 31-33.

HULME K.A. & HILL S.M. in prep. *Biogeochemistry: River red gums (Eucalyptus camaldulensis) and the development of a systematic sampling program reflecting different environmental and mineralisation settings in the Curnamona Province and adjacent region of SE central Australia*.

HULME K.A. in prep. *Tibooburra Inlier regolith-landform map (1:10 000).*

MORTON J.G.G. 1982. *The Mesozoic – Cainozoic stratigraphy and faunas of the Tibooburra – Milparinka area*. University of New South Wales Masters Thesis, unpublished.

STEVENS B.P.J. & ETHERIDGE L.T. 1989. Traverse geology of the Tibooburra Inliers. *New South Wales Geological Survey* **Report GS1989/390**.

THALHAMMER O.A.R. 1991. Indications of the source of gold in the Milparinka-Tibooburra vein-type gold deposits, NSW Australia: geochemical and isotopic evidences. *In:* PAGEL & LEROY eds. *Source, Transport and Deposition of Metals.*, Balerna, Rotterdam, pp. 363-366.

THALHAMMER O.A.R., STEVENS B.P., GIBSON J.H & GRUM W. 1998. Tibooburra Granodiorite, western New South Wales: emplacement history and geochemistry. *Australian Journal of Earth Sciences* **45**, 775-787.