REGOLITH-LANDFORMS OF THE PINNACLES 1:25,000 SHEET, WESTERN NSW: MAPPING AND GEOCHEMICAL CHARACTERISATION

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INTRODUCTION

The majority of the bedrock in the Pinnacles region is covered by transported colluvial, alluvial or aeolian material, and where bedrock is exposed it is weathered and may be difficult to identify. Future discoveries of mineralisation therefore are most likely to be in areas covered by regolith materials. As a result it is important to understand the regolith materials and processes when exploring in these regions for ore deposits.

There has been a lot of mineral exploration interest in the Pinnacles 1:25,000 scale map sheet area due to its close proximity to the world class Broken Hill Pb-Zn-Ag ore body, and the large number of known mineralised sites and ore bodies in the area. The most famous area of mineralisation in the area is the Pinnacles, a Broken Hill-type deposit, the largest volume of mineralisation in the district away from the main Broken Hill Line of Lode. Previous exploration has largely targeted exposed bedrock across the area and the regolith has been seen as something to 'penetrate' or 'punch through' in the search for bedrock-related sampling media. Regolith however can be used advantageously in exploration programs where dispersion haloes, and hence target size, may be larger than bedrock signatures. However, before regolith can be advantageously used in exploration programs it needs to be understood. Regolith-landform mapping and characterisation within a landscape evolution framework is one of the first steps in this.

STUDY AREA SETTING

The study area is located approximately 1,000 km west of Sydney, and 5 km southwest of Broken Hill in western New South Wales (Figure 1) and is equivalent to the Pinnacles 1:25,000 scale geological map (Brown 1978). The land around the Pinnacles is mostly used for rangeland grazing of sheep and cattle from Thackaringa, White Leads and Balaclava Stations. There are presently two active mining leases in the area: the Pinnacle Mine; and a garnet mine near Staurolite Ridge.

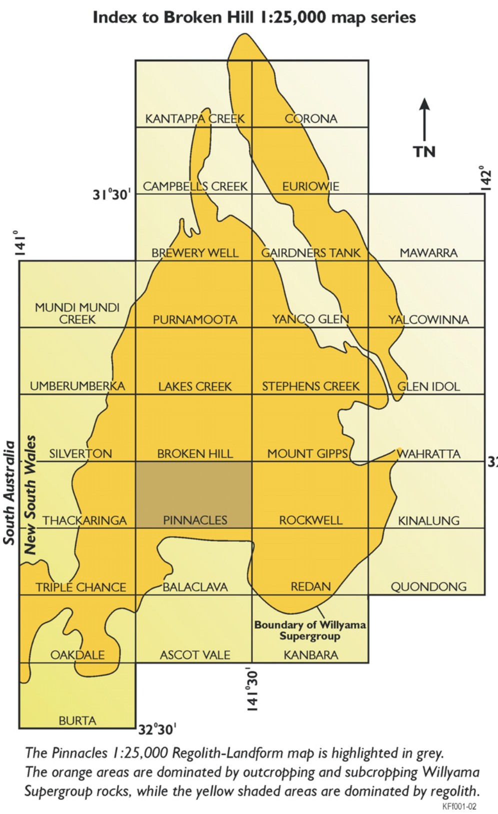

Figure 1: Location of the Pinnacles 1:25,000 scale map sheet, shown with the outcropping bedrock of the Broken Hill Block and Euriowie Block of the Willyama Supergroup.

The mapping area is located within the Broken Hill Domain, composed of Palaeoproterozoic Willyama Supergroup metamorphic rocks including schists, gneisses, amphibolites, mafic granulites and minor felsic, mafic and ultramafic intrusives. Most of the area is within the hinterland of the Murray Basin, except for the far northwest which is part of the hinterland of the Lake Eyre Basin.

Vegetation communities of the Pinnacles mapping area relate to a combination of the area's arid climate and changes in landscape setting, regolith substrate and land use (especially grazing). The most widespread vegetation community of the area is chenopod shrubland which is typically dominated by bladder salt bush (*Atriplex vesicaria*), pearl bluebush (*Maireana sedifolia*), black bluebush (*Maireana pyramidata*) and mostly occurs on undulating plains and rises. Open mulga (*Acacia aneura*) and belah (*Casuarina pauper*) occur on some rises and hills with bedrock exposure. River red gums (*Eucalyptus camaldulensis*) form linear corridors along major stream channels, such as Pine Creek and its major tributaries, with lesser channels typically supporting a dense to open shrubland dominated by prickly wattle (*Acacia victoriae*).

In: Roach I.C. ed. 2002. *Regolith and Landscapes in Eastern Australia*, pp. 113-118. CRC LEME.

REGOLITH-LANDFORMS

The regolith-landform mapping approach used here is based on the Geoscience Australia (GA) regolith-landform unit (RLU) scheme (Pain *et al.* 2000, Pain 1997). RLUs are consistent with the RLU framework specific for 1:25,000 units in the Broken Hill area produced by the CRC LEME Broken Hill project. Initially the western half of the Pinnacles map sheet was mapped as part of an honours project (Senior 2000) but was subsequently remapped to add the eastern half of the map sheet prior to map publication and release (Senior *et al.* 2002). Mapping was conducted using a combination of enlarged 1:50,000 colour aerial photographs plus raster data sets from the Broken Hill Exploration Initiative (BHEI) releases including radiometric, digital elevation and total magnetic data. Field mapping proceeded by the establishment and checking of polygon boundaries including the description of field site attributes such as: regolith materials; landforms; surface materials; and vegetation communities and dominant species. Regolith carbonate accumulations (RCAs) were collected for geochemical analysis from 48 sites throughout the map sheet. Sites typically coincided with places where these materials were well exposed in the field (such as within gullies, pits and rabbit burrows). An RCA map was also produced in conjunction with the regolith-landform map, mostly based on field observations (Figure 2).

The hills and rises of the Barrier Ranges are the most prominent topographic features of the Pinnacles sheet area, particularly towards the northwest. Towards the south the ranges grade into low, undulating rises and plains. The Barrier Ranges in the northwest of the area coincide with the major regional drainage divide between the headwaters of Umberumberka Creek, which drains into the Mundi Mundi Plain (Lake Eyre Basin), and the Pine Creek system, which drains into the Murray Basin. This drainage divide is asymmetric in cross-section, with the south-flowing drainage from this divide (Pine Creek system) displaying generally steeper gradients and more erosive channels than the north-flowing drainage (Umberumberka system).

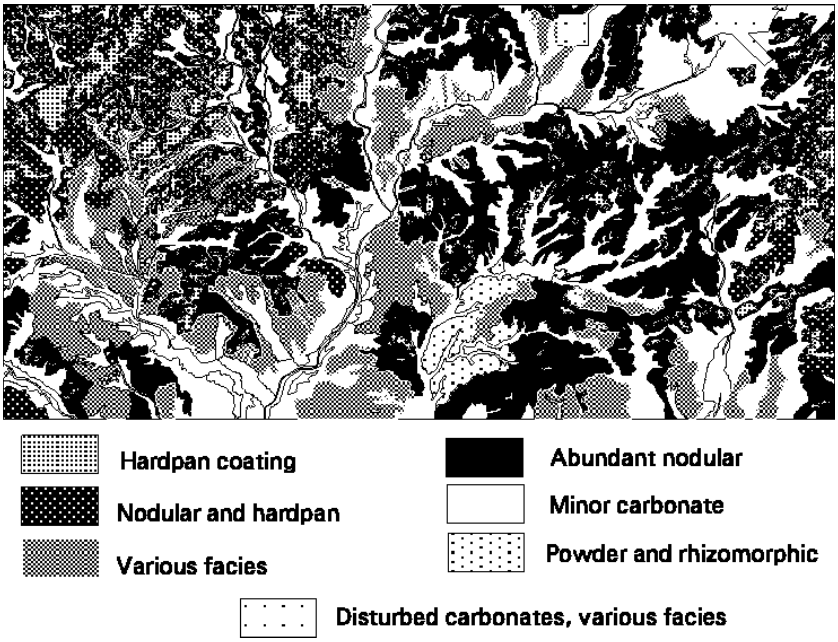

Figure 2: Pinnacles 1:25,000 scale RCA distribution map showing different RCA facies.

The Pinnacles mapping area is dominated by regolith (approximately 80% regolith, the remaining 20% consisting of poorly- to well-exposed weathered bedrock). The regolith of the Pinnacles region comprises *in situ*, transported and indurated materials. Seventeen RLUs are shown on the Pinnacles 1:25,000 scale map sheet (Figure 3).

Transported regolith

The transported regolith in the area can be sub-divided into alluvial, colluvial and aeolian units.

Alluvial sediments are associated with drainage systems, particularly within and on the margins of the major channels of Pine Creek, Thackaringa Creek and Feldspar Creek and their tributaries. The alluvial sediments are composed of mostly quartzose and lithic sands with lesser clay, silt, and gravels. The sediments may be expressed in alluvial channels (Aca_1 & Aca_2), alluvial and depositional plains (Aap_1 & Aap_2, Apd_1), and drainage depressions mostly incised into erosional rises and hills (Aed_1). All drainage on the Pinnacles map sheet is ephemeral, flowing only after significant rainfall events, typically giving rise to high discharge, low frequency sediment erosion, transport and deposition. Alluvial channels are mostly of braided and meandering forms (in many cases of composite morphology) and are further subdivided on the map into channels hosting river red gum woodlands and channels hosting prickly wattle shrublands. This distinction appears to relate to size and depth of the alluvial channel sediments as well as the presence of shallow groundwater aquifers. River red gums preferentially colonise the riparian zones of larger channels. These shallow aquifers occur in thicker sandy alluvial sediments. Alluvial plains form very slightly undulating, low relief land surfaces adjacent to major stream channels and typically host a wide array of alluvial landforms including depositional plains and minor channels. In contrast, the alluvial depositional plain units have a smoother surface morphology and mostly host depositional features, rather than minor erosive channels. There are two alluvial swamp depressions composed of silt, and clay materials (Aaw_1).

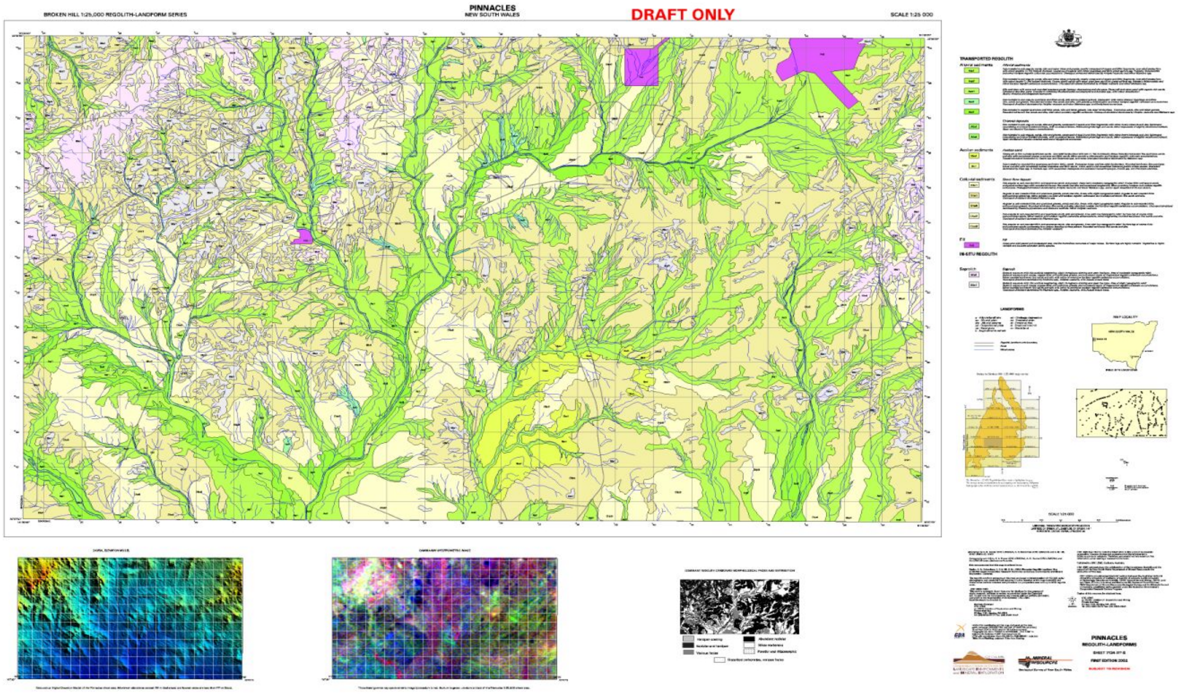

Figure 3: Pinnacles 1:25,000 scale regolith-landform map.

Colluvial RLUs are widespread in the map sheet, mostly flanking rises and hills shedding detritus into lower-lying parts of the landscape. The most widespread mechanism for colluvial transport and deposition is sheetflow, which in many units is reflected in the prominent surface contour banding arrangement of vegetation colonisation and surface lag clasts. Sheetflow units with well-developed RCAs do not have well-developed surficial contour band patterns, perhaps due to enhanced infiltration and reduced surface runoff in this regolith substrate. Minor RCAs (powdery, nodular and hardpan) are rarely associated with these landforms. Regolith materials are mostly composed of poorly-sorted, angular, quartzose and lithic gravels with red-brown fine sands and silts. The distinction between lithic and quartzose clast-rich units mainly reflects local bedrock and in turn the nature of sediment supply. Colluvial RLUs have three main landform expressions: low hills ($CHel_1$); rises ($CHer_1$& $CHer_5$); and depositional plains ($CHpd_1$& $CHpd_2$). The low hills and rises mostly flank bedrock exposures or overlie sub-cropping bedrock and serve as areas of sediment transit into lower-lying depositional plains that act as depositional sinks.

Two types of aeolian RLUs are identified on the Pinnacles map sheet: source bordering dunes ($Isps_1$), found mostly on the eastern and north-eastern side of many of the major alluvial channels; and small hummocky dune fields (Isu_1), which mostly occur on the edges of colluvial rises. Both types of dunes are composed of fine, red-brown, quartzose sand with minor lithic sands and clay. The dunes have a distinctive red colour suggesting that iron oxides are present, mostly as surface coatings on quartz grains.

***In situ* regolith**

Slightly weathered bedrock consists of a wide range of bedrock lithologies that have undergone some weathering alteration in surface and near-surface settings. These materials are readily identified as bedrock, although they typically have surficial iron-oxide staining and many of their joint sets and fractures are open.

Slightly weathered bedrock is associated with erosional landforms such as rises ($SSer_1$) and low hills ($SSel_1$). The low hills are located within the Barrier Ranges in the northwestern parts of the sheet area. Erosional rise landforms have slight topographic relief and are mostly associated with the lowlands flanking the Barrier Ranges. Towards the center of the map sheet, bedrock-dominated landscapes become less abundant with an increase in the extent of regolith. These RLUs typically host minor surficial deposits, including red-brown fine sand, interpreted to be of aeolian origin, and minor angular lithic and quartzose gravels, which are mostly locally-derived colluvium. Regolith carbonates are associated with many bedrock exposures, and in particular amphibolites. RCA morphologies include powder and hardpan morphological facies, mostly infilling fractures in the rock or as clasts of fragmented accumulations.

Bedrock lithology and structure are major controls on the landscape expression and regolith evolution in the area. For example, the quartz-magnetite rocks at the three peaks of the Pinnacles are much more resistant to weathering and erosion than surrounding bedrock lithologies and therefore are prominent landscape features of positive topographic relief. Conversely, the fractured and labile micaceous lithologies of the Pinnacles-Thackaringa Shear Zone correspond with an area of minimal bedrock exposure and low topographic relief.

Indurated regolith

RCAs are widespread in the Broken Hill region and form the most abundantly exposed indurated regolith in the Pinnacles map area. Regolith carbonate accumulationss in the Pinnacles sheet area show a strong landscape control in their distribution and development—they are most extensively developed on the sides of hills and rises but are also rarely observed capping rises. Pearl bluebush (*Maireana sedifolia*) and rabbit burrows have a strong association with RCAs near the landsurface. A range of RCA morphological facies occurs in the area (Hill *et al*, 1999, Hill 2000, Senior 2000) including nodular, laminated hardpan, massive hardpan and powdery morphologies. Three profiles were examined within a costean just north of the Pinnacles mine. This costean had been previously sampled and described in Hill *et al*. (1999) and Hill (2000), where it was shown that Au contents varied throughout the profile, being directly proportional to both the Ca content and the development of nodular RCAs with biogenic coatings. Further sampling and analysis of three profiles from this costean confirm the relatively high Au contents in RCAs here (up to 69 ppb).

Some recently obtained RCA analyses of samples from the far southeast of the sheet area showed relatively high Au contents of up to 770 ppb. This area has recently been further sampled to test and constrain these exciting results.

Regolith geochemistry

Geochemical dispersion and residence were examined within a regolith-dominated catchment near Staurolite Ridge and North Tank. The study site was chosen because: it is regolith-dominated; it hosts quartz-gahnite lodes associated with mineralisation; and regional soil sampling by Pasminco revealed high levels of many trace metals, yet a primary source for these has not been found. The types of regolith samples collected during this study were lower-level soils (darker, more clay-rich, superficially resembling a B-horizon), RCAs, saprolite-soil interface and black bluebush (*Maireana pyramidata*) leaves. A grid was laid out across the catchment at 50 m spacing and each of the four different media were collected. All sampling media were able to detect the buried quartz-gahnite lode, in particular geochemical maps for Pb, Zn and Cu showed zones of relatively high values decreasing away form the mineralisation source. These results are further shown in Senior (2000) and are in the process of being written up in detail. The results for Cu are given here as an example (Figure 4).

Copper results within the catchment all showed relatively high Cu values around the buried quartz gahnite lode. The soil results showed the broadest zone of relatively high Cu contents (across a zone approximately 400 m^2). This relatively large halo reflects the dispersion processes in the soil and in this case mostly due to colluvial sheetwash processes. Regolith carbonate accumulation and saprolite-soil interface sampling results both also show broad dispersion zones in sympathy with the valley form of the catchment. The encouraging results from black bluebush leaves showed high copper results up to 100 m away from source.

A program of stream sediment and river red gum sampling has also been undertaken within the Pine Creek system on the Pinnacles map sheet. Results from this study are expected to be released in the near future. Preliminary results from river red gum sampling along Stephens Creek suggests that they have some potential to be developed as a mineral exploration sampling media with affinities to results of well-sorted stream sediments, shallow aquifer systems and buried bedrock (Dann 2000).

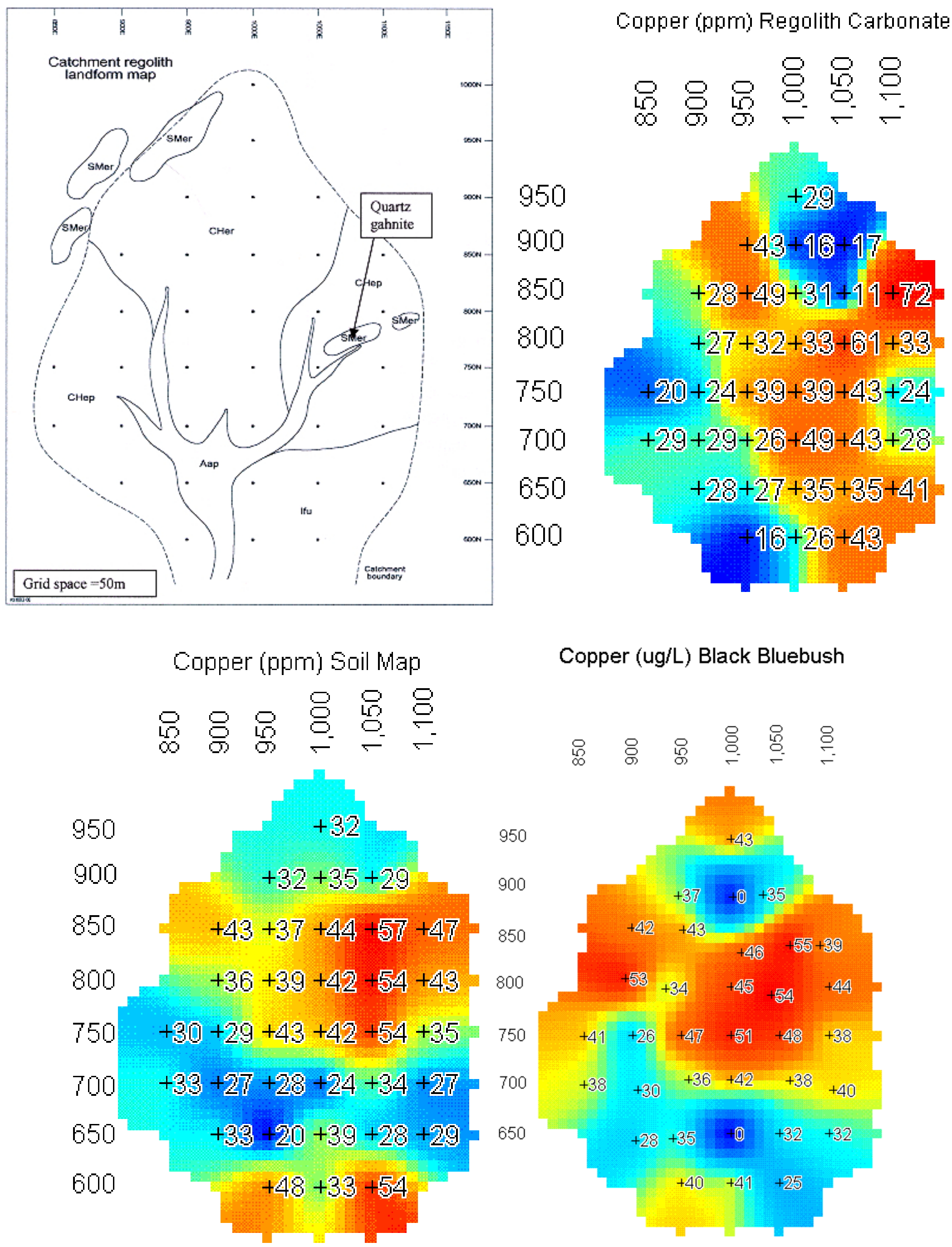

Figure 4: Regolith-landform map of the catchment with Cu dispersion results for RCAs, soil and vegetation.

CONCLUSIONS

Regolith-landform mapping and regolith characterisation in the Pinnacles area provides new insights into this landscape. These insights will enhance mineral exploration programs in this regolith-dominated terrain and may also have applications for land management and further landscape research. Geochemical and biogeochemical studies of the regolith in this area already show that regolith and biological materials have potential applications as a sampling media in mineral exploration programs. In particular, trace metal contents in RCAs, soils and black bluebush leaves were successfully used to detect buried mineralisation associated with a quartz-gahnite lode. Some relatively high Au assays in a regional RCA sampling program across the sheet area also warrant further investigation.

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