A FRAMEWORK FOR REGOLITH-LANDFORM MAPPING IN THE FLYING DOCTOR PROSPECT, BROKEN HILL, NSW.

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INTRODUCTION

This study provides a detailed regolith-landform map with accompanying regolith-landform unit descriptions for a study site, ca. 8 km east of Broken Hill, NSW. This can then be used as a basis for further geochemical, geobotanical and biochemical studies. The study site, which we have named the 'Flying Doctor Prospect', is highly suitable as a case study because: it is in a regolith-dominated terrain; it includes a variety of surface materials and vegetation that are widely represented in the region; and it is a continuation of the Broken Hill lode rocks.

The Broken Hill ore body was discovered in 1883. Since its discovery there has been continued exploration for additional ore-bodies at high cost and with limited success. To the NE of Broken Hill, exploration and mining activity was intense following the line of lode. There are many old workings here, mostly based on surface gossans, such as at the Round Hill, Silver Peak and Potosi mines (Andrews 1922, Morland & Leevers 1998). Pasminco Mining actively explored this area until 2002. As well as looking for large tonnage underground targets, they also searched for small, near-surface ore-bodies that could supplement the reserves at Broken Hill. Work at the Flying Doctor Prospect and the Round Hill Mine found more mineralisation but was not successful in proving up an economic ore-body, however it was successful at the nearby Potosi workings (Morland & Leevers 1998).

The Flying Doctor Prospect was mapped at 1:10,000 scale, and surface soil, bedrock and vegetation sampling was conducted in a NW-SE diagonally trending swath through the mapped area. The regolith mapping field sites, in conjunction with geochemical and biochemical analyses are intended for use in later research to make a more informative interpretation of the regolith, and mineralisation signatures. Further detail of this work can be found in Thomas *et al.* (in prep.) and Earl *et al.* (in prep.).

NORTHERN LEASES SETTING

The Flying Doctor Prospect is centred on a northern tributary of Willa Willyong Creek, opposite the old Royal Australian Flying Doctor Base, approximately 8 km east of Broken Hill. It is within an area of mineral exploration leases referred to as 'the Northern Leases', which extend from the Broken Hill North Mine to the Stephens Creek Reservoir, and includes the north-eastern continuation of Broken Hill lode rocks from the main Line of Lode. The area is within the Broken Hill Common and includes land held for public use surrounding the City of Broken Hill. The Flying Doctor Prospect is in the central-eastern part of the Barrier Ranges. The drainage pattern of the Flying Doctor Prospect shows a well-developed trellis pattern (i.e. a dominant drainage pattern with a secondary drainage at right angles to the first), reflecting a strong bedrock lithological and structural control. The central axis of the study area catchment trends approximately NW-SE. Tributaries of the main stream trend approximately NE-SW, which closely corresponds to the structural grain and trends of bedrock lithological boundaries in the area. The Flying Doctor Prospect consists of an undulating landscape with a combination of bedrock rises, low hills and alluvial plains.

Vegetation in the Flying Doctor Prospect is composed predominantly of chenopod shrublands and open woodlands with a shrubland understorey. Chenopod shrubland species include *Acacia, Maireana, Rhagodia, Atriplex, Bassia, Sida, Cassia, Ptilotus, Myoporum, Prostanthera and Solanum spp.* Open woodlands occur along drainage lines and on areas of higher relief, typically associated with bedrock outcrops and include *Eucalyptus camaldulensis*, *Acacia victoriae* and *Acacia aneura*. Cryptogam (lichen and moss) cover is widespread on exposed bedrock and in areas with low relief and fairly stable surface soil such as plains.

GEOLOGICAL SETTING

The bedrock of the Flying Doctor Prospect has been mapped at approximately 1:12,000 and compiled at 1:25,000 as a part of the Mt Gipps 1:25,000 Geological Sheet (Bradley 1984). The major rock types in the area include psammite, psammopelite, retrograde schists and quartzo-feldspathic gneisses. Most of the rocks in the area exhibit mineral assemblages typical of amphibolite or granulite facies metamorphism, overprinted to some degrees by retrograde metamorphic features (Bradley 1984). Mineralisation has been widely reported in the region and an overview of this can be found in Burton (1994). The study area is within the Flying Doctor Prospect of the Northern Leases. Broken Hill-type deposits in the Northern Leases are situated along a NE-trending linear zone that includes two main lodes: the Main Lode Horizon; and the Upper Lode Horizon (Burton 1994). Two examples of known mineralisation in the catchment study area are the Barrier Main Lode and the Flying Doctor mineralisation, both of which are part of the Upper Lode Horizon. The Flying Doctor mineralisation is not exposed but lies within 100 m of the surface with a strike length of 250 m (Burton 1994). It contains 300,000 t of mineralisation with average grades of 7% Pb, 2.4% Zn and 60 g/t Ag (Department of Mineral Resources 1981).

METHODOLOGY

Field mapping and sample collection was undertaken in July 2002. The strategy for fieldwork was based on opportunistically targeting the most appropriate sites for sample collection rather than adhering strictly to a grid. Where possible, sites were selected that had more than one of the targeted vegetation types and, if possible, bedrock outcrops. The distribution of sample sites in the swathe was no closer than 20 m and no further than 85m from the next site. Lithology, surface materials, landform and vegetation information was recorded at each sample location and each site was photographed. Over 320 samples were collected including: 37 bedrock samples; 80 surface (< 10 cm depth) soil samples (which were later sieved into 0-80 μm, 80-300 μm, and > 300 μm portions); 14 Regolith Carbonate Accumulation (RCA) samples; and 185 vegetation samples from four different species. Samples were also catalogued in Geoscience Australia's 'Sites' and 'Regolith' databases.

Bedrock was sampled to provide comparative data to the soil and vegetation. Bedrock samples were collected where present at the field sites. These have been analysed using XRF, ICP-MS and INAA; the results of these analyses will be presented in another publication.

Soils in the catchment, as in much of the region, are mainly lithosols (skeletal soils) and desert loams. Lithosols are typically associated with the higher elevation parts of the area. They are particularly prone to wind and sheetwash erosion. Desert loams are found on lower slopes and typically include a clay component that gives the subsoil a high water holding capacity. They are prone to wind, sheetwash and gully erosion.

Regolith carbonate accumulations (RCAs), also known as calcretes, are highly suitable as a geochemical sampling medium as they are easily identified in the area. The RCAs occur in a range of settings in the regolith, from the surface to the bedrock interface. In the Flying Doctor Prospect, RCAs occur in laminar, nodular and powdery forms (as described by Hill *et al.* 1998). Powdery RCAs occur in areas of low relief where softer, more clay-rich soils accumulate (such as in plains), while nodular RCAs occur more in sheetflow units. RCAs also occur in some creek beds along bedrock interfaces, where they have laminar morphology.

VEGETATION SAMPLING AND METHODOLOGY

The vegetation sampling technique used is that described by Hill (2002). Sampled species include: *Acacia victoriae* (prickly wattle); *Acacia aneura* (mulga); *Maireana pyramidata* (black bluebush); and *Sida petrophila* (rock sida). Vegetation sampling is not a common practise in exploration and regolith studies, and analysing for trace metals is not yet widely considered as a possible tracer for mineral deposits. Only a few of the vegetation species in the region have been previously analysed for trace metal contents, e.g.: *Maireana pyramidata* in Hill (1998), Jones (1999), Debenham (2000) and Senior (2000); *Acacia aneura* in Hill (in prep.); *Maireana sedifolia* in Jones (1999), Senior (2000) and Hill (in prep.); and *Eucalyptus camaldulensis,* in Dann (2001). It is hoped that the sampled species will reveal important new information regarding trace metals, not only in plant tissue, but also reflecting chemical pathways though the regolith.

The chosen plant species encompass a variety of preferred soil types and have varying root depths that could be used to provide a comparison of metal accumulation in the regolith. They range in height from 1-8 m and include trees, tall shrubs, shrubs and forbs or light shrubs. Root penetration can be seen in many stream gully sections to extend over 2m deep though the regolith cover to the underlying bedrock.

MAP PRODUCTION METHODOLOGY

The mapped area is a square of 2 by 2 km with the main drainage flowing NW–SE across the map area. Detailed site descriptions and field observations were used to create both a regolith-landform map (Figure 1) and a vegetation distribution map (Figure 2). The production of a regolith-landform map involves a series of steps combining aerial photo interpretation, fieldwork and post-field work map production. The unit classification used in this study is based on the regolith-landform unit (RLU) mapping scheme in Pain *et al.* (in prep.) and the mapping technique is described in Foster (in prep.). RLU descriptions mapped for this project are in Table 1. RLUs in the Flying Doctor Prospect have been mapped as part of regional projects at 1:500,000 (Gibson & Wilford 1996), 1:100,000 (Hill 2000), and 1:25,000 (Lewis *et al.* 2002) scales.

GEOBOTANICAL ASSOCIATIONS

A 1:10,000 vegetation distribution map was constructed to complement the regolith-landform map. Changes in vegetation communities may be related to changes in the regolith and bedrock substrates, thereby adding another dimension to the sampling program. The vegetation in the catchment was grouped into communities that represented notable geobotanical associations. *Maireana sedifolia* (pearl bluebush) displayed the most prominent example of a geobotanical association in the map area. *Maireana* sp. are known to have an association with RCAs (Cunningham *et al.* 1992, Hill 2000) and also showed a striking association with micaceous schist outcrops in the central north of the map area. *Maireana sp.* was found to occur in abundance (5-7 plants per 5 m^2) on the mica schist outcrops but not on adjacent units (< 1 plant per 5 m^2). *Maireana sp.* also follows bedrock outcrop trends into regolith-dominated areas, although they are in reduced numbers (1-5 plants per 5 m^2).

CONCLUSIONS

This study of the Flying Doctor Prospect, with the 1:10,000 scale regolith-landform map and accompanying map units, has demonstrated the scope of regolith-landform mapping techniques and their application to look at whole landscapes and environments in detail. This project shows that large scale regolith-landform mapping in a landscape of regional as well as international significance is possible, and demonstrates its ability to view a landscape and its components. The making of a detailed map and the collection of samples allows each component of the landscape to be identified and then related to other parts of the landscape. As with all types of maps, we have been able to catalogue the geographic distribution of data, in this case, accurate details on surface materials and lithology, vegetation community distribution and geobotanical associations, and the effects of landuse on the regolith and its environment. It is hoped that further analyses of samples collected for this project will illustrate the benefits of looking at all aspects of regolith to understand chemical pathways in landscapes. It is also hoped that subsequent geochemical, geobotanical and biogeochemical studies will be used in combination with the regolith map and accompanying map units to provide a multi-dimensional tool to interpret landscapes by understanding mineral transport in the regolith and identifying chemical signatures in the landscape.

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Table 1: Regolith Landform Units.

	TRANSPORTED REGOLITH
	ALLUVIAL SEDIMENTS
Aap_1	RBSS on a low relief land surface with numerous channels (<20 cm deep). Angular to sub-rounded fine quartz and lithic gravels. Chenopod shrublands dominated by *Acacia victoriae*, *Maireana pyramidata*, *Rhagodia spinescens* and *Atriplex vesicaria* with minor *Bassia spp*.
Aap_2	RBSS on a low relief land surface with numerous channels (<20 cm deep). Angular to sub-rounded predominantly quartz gravel lag. Chenopod shrubland dominated by *Acacia victoriae*, *Maireana pyramidata*, *Rhagodia spinescens* and *Atriplex vesicaria* with minor *Bassia spp*.
Aed_1	RBSS with fine quartz and lithic gravels, minor bedrock exposures and some sub-angular to sub-rounded lithic pebbles in elongate drainage depressions. CS dominated by *Maireana pyramidata* and *Sida petrophila*.
Apd_1	RBSS on low lying areas with very minor channels (<30 cm deep). Minor clay and sub-angular to sub-rounded quartz and lithic gravels, and pebbles. CS dominated by *Atriplex nummularia*.
Apd_2	RBSS on low lying areas between creeks with very minor channels (<30 cm deep). Minor clay and sub-angular to sub-rounded quartz and lithic gravels, and pebbles. CS dominated by *Maireana pyramidata*.
	CHANNEL DEPOSITS
$ACar_1$	BGSS in an incised, meandering channel (<1.5 m deep). Quartz and lithic gravels and pebbles with minor bedrock exposure. Open woodlands dominated by *Eucalyptus camaldulensis*.
$ACar_2$	BGSS on an incised, meandering channel (<1.5 m deep). Quartz and lithic gravels and pebbles with minor bedrock exposure. Open woodlands dominated by *Acacia victoriae*.
	COLLUVIAL SEDIMENT – SHEETFLOW DEPOSIT
$CHer_1$	RBSS on slight topographic relief. Surface lag of coarse lithic and quartzose sands and gravels conforming to a contour banding surface pattern. CS dominated by *Maireana pyramidata*.
$CHpd_1$	RBSS on a low relief land surface. Surface lag of quartzose and lithic gravels. CS dominated by *Maireana pyramidata*, *Bassia spp*. and *Maireana sedifolia*.
$CHpd_2$	RBSS on a low relief land surface. Surface lag of quartzose dominated gravels. CS dominated by *Maireana pyramidata*, *Bassia spp*. and *Maireana sedifolia*.
$CHpd_3$	RBSS on a low relief land surface. Surface lag of lithic dominated gravels. CS dominated by *Maireana pyramidata*, *Bassia spp*. and *Maireana sedifolia*.
	FILL
Fm_1	Paved and landscaped area including the immediate surrounds of mine sites. Surface lags are highly variable. Vegetation is typically cleared and/or includes abundant exotic species.
	IN-SITU REGOLITH
	SAPROLITH
$SSel_1$	Exposed bedrock with moderate topographic relief (30 m to 90 m) and surficial weathering. Angular to sub-rounded fine quartz and lithic gravels, angular to sub-angular quartz and lithic pebbles. CS dominated by *Maireana pyramidata*, *Acacia tetragonophylla*, *Acacia aneura* and *Maireana sedifolia*.
$SSer_1$	Bedrock exposure with surficial weathering, minor silt and fine sand. Angular to sub-rounded fine quartz and lithic gravels, angular to sub-angular quartz and lithic pebbles. CS dominated by *Maireana pyramidata*, *Acacia tetragonophylla*, *Acacia aneura* and *Maireana sedifolia*.

*RBSS= Red-brown quartzose silt and sand, BGSS= Brown-grey quartzose silt and sand

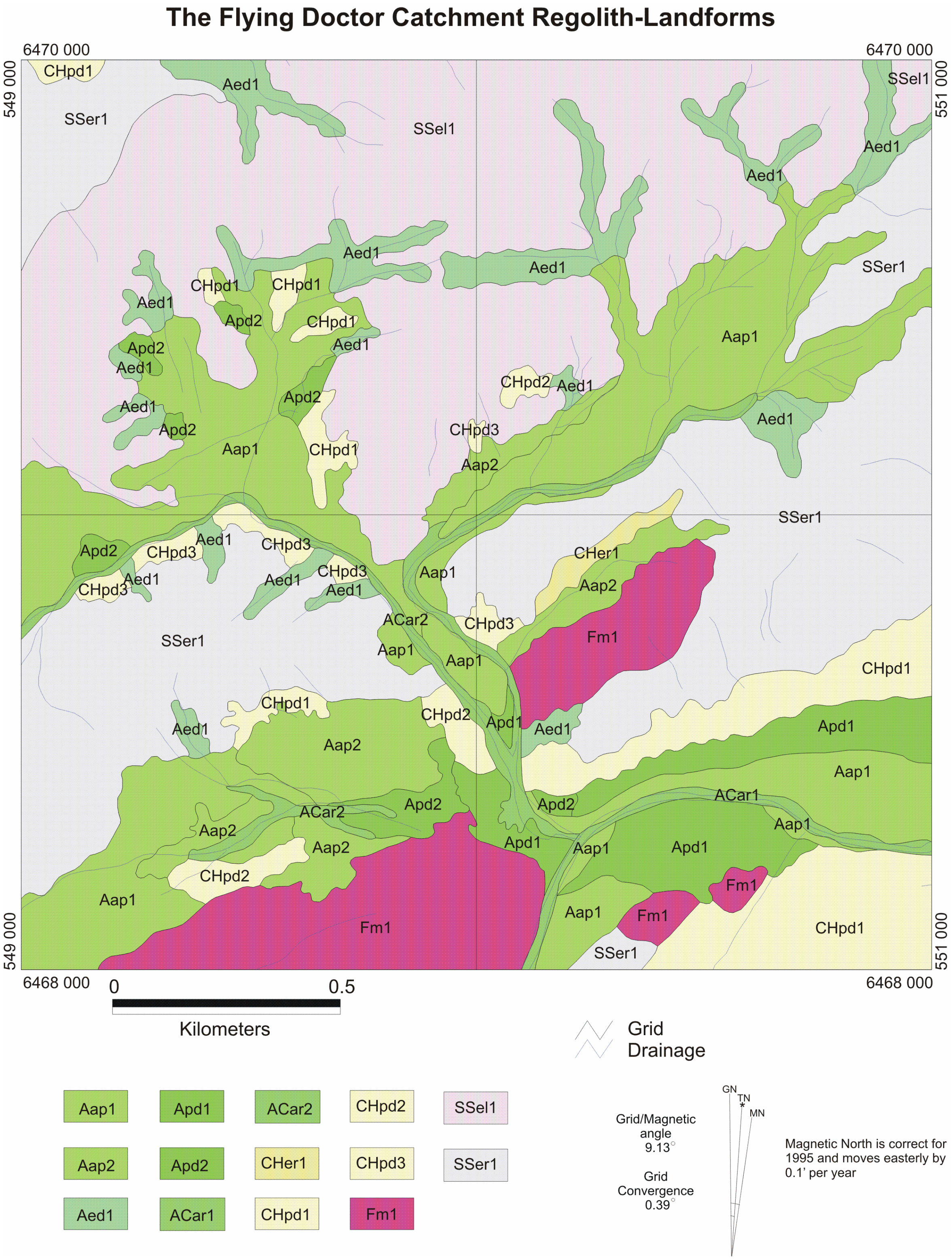

Figure 1: The Flying Doctor Prospect 1:10,000 Regolith Landform Map from Earl *et al*. (in prep). See Table 1 for descriptions of regolith-landform units.

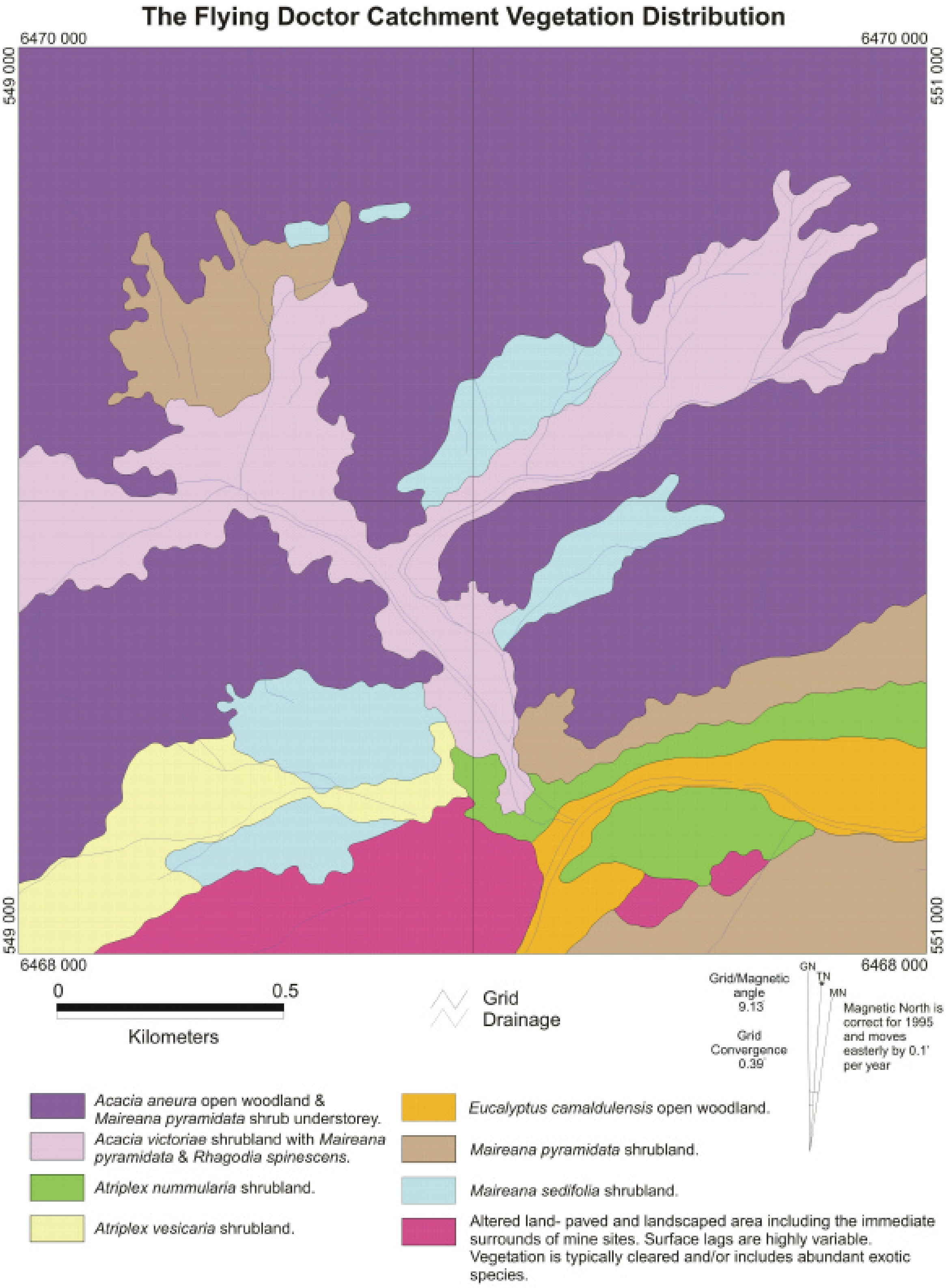

Figure 2: The Flying Doctor Prospect 1:10,000 Vegetation Distribution Map from Earl *et al*. (in prep).