TIBOOBURRA, NEW SOUTH WALES

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INTRODUCTION

Tibooburra is centred on a bedrock inlier surrounded by sediments of the Eromanga and Lake Eyre Basins. As such it has the potential to provide valuable insights into the regolith and landscape evolution of this part of southeastern central Australia, particularly relating to the relationships between the evolution of bedrock-dominated uplands and the flanking and overlying basin cover. The region hosts significant gold deposits, most of which are associated with Mesozoic and Cenozoic sediments deposited as part of the region's landscape development. Although the extensive regolith cover has been traditionally seen as an impediment to mineral exploration, there are few regions where mineralisation and its exploration are so intimately linked with regolith and landscape evolution.

PHYSICAL SETTING

Location

Tibooburra is located in far northwestern New South Wales, approximately 350 km north of Broken Hill. The area considered here includes the Tibooburra Inlier and the immediately adjacent basin cover (Figure 1).

Geology

The Tibooburra Inlier is the northernmost of several small basement inliers in the northwest of New South Wales. The oldest rocks exposed in the inlier are metasediments consisting of pelitic and arenaceous phyllites, schists, and sandstones, with minor volcanic rocks, regionally metamorphosed to greenschist facies (Stevens and Etheridge, 1989; Thalhammer *et al.*, 1998). These rocks have been recently referred to as the Easter Monday Beds (Thalhammer *et al.*, 1998) and are interpreted as being of Cambrian to Early Ordovician age (Webby, 1984; Thalhammer *et al.*, 1998; Scheibner and Basden, 1998). The metasediments were intruded and contact metamorphosed by the Late Silurian to Early Devonian Tibooburra Granodiorite and associated tonalite bodies (Morton, 1982; Stevens and Etheridge, 1989). None of the bedrock of the Tibooburra Inlier has been found to host extensive Au mineralisation.

Mesozoic sediments of the Eromanga Basin flank and overlie parts of the Tibooburra Inlier. These sediments broadly range from Jurassic to Cretaceous, and include lowermost fluvial and lacustrine sediments (e.g. Westbourne Formation and Hooray Sandstone, and Algebuckina Sandstone equivalents), followed by a marine transgressive sequence from the Late Neocomian to Albian (Cadna-Owie Formation and its local equivalent the Gum Vale Formation (or 'Gum Vale Beds') followed by the Rolling Downs Group). Non-marine conditions returned in the Late Albian to Cenomanian with deposition of the predominantly alluvial Winton Formation. Considerable conflict exists in many of the previous stratigraphic interpretations of these sediments in the Tibooburra region, with stratigraphic syntheses appearing in Hawke and Bourke (1984), Kreig and Rogers (1995), and Scheibner and Basden (1998).

Overlying the Eromanga Basin sediments are Cenozoic sediments from the Lake Eyre Basin (Callen *et al.*, 1995; Alley, 1998). The depositional record in this basin extends from dominantly alluvial sediments from the late Palaeocene to mid-Eocene (Eyre Formation), through late Oligocene to Pliocene lacustrine and low-energy alluvial deposition (Namba Formation), followed by an assortment of alluvial, aeolian, lacustrine and minor colluvial deposition through to the present. Weathering and regolith induration are accommodated in most previous stratigraphic frameworks for the basin, most notable being an interpreted widespread, Oligocene–Miocene, silicification of regolith on a low relief landsurface (Cordillo Silcrete of Wopfner, 1974; 1978, and Alley, 1998).

Geomorphology

The Tibooburra Inlier forms an undulating range of hills and rises on the eastern margins of the Grey Range. Surrounding the inlier are extensive plains which include the dunefields and alluvial outwash areas of the Strzelecki Desert. The highest relief occurs to the west of Tibooburra where hills reach up to 260 m above sea level, with the adjacent plains generally between 100 to 180 m above sea level.

The upland area of the Tibooburra Inlier forms a local drainage divide between Twelve Mile and Thomsons creeks. Twelve Mile Creek and its tributaries drain the western and northern margins of the inlier, before flowing through Mt Wood Gorge and into Caryapundy Swamp (part of the Bulloo Overflow) to the east. Thomsons Creek also flows into Caryapundy Swamp, however, this creek and its tributaries drain the southern and eastern margins of the inlier (Figure 1).

Climate

The Tibooburra region presently experiences an arid climate, with an average annual rainfall of about 230 mm, falling with a slight summer-dominated pattern. Daily maximum temperatures in summer are typically over 30°C and daily minimum temperatures in winter are typically about 5°C.

Vegetation

The dominant vegetation communities in the area include:

- mulga (*Acacia anuera*) woodlands and shrublands, with occasional emu bush (*Eremophila spp.*) and chenopod shrubs, mostly restricted to rises and hills with slightly weathered bedrock and lithosols. Sandsheets flanking the inlier also support extensive mulga woodlands and shrublands also with sandhill wattle (*Acacia ligulata*), needlewood (*Hakea leucoptera*), whitewood (*Atalaya hemiglauca*) and beefwood (*Grevillea striata*);

- open bloodwood (*Eucalyptus terminalis*) woodland with chenopod shrubs (*Atriplex spp.* and *Maireana spp.*), and drainage depressions colonised by prickly wattle (*Acacia victoriae*), mostly on undulating hills and rises composed of granite;
- chenopod shrublands dominated by saltbush (mostly *Atriplex vesicaria*) and bluebush (mostly *Maireana pyramidata*) with occasional prickly wattle trees (*Acacia victoriae*), widespread across the region but particularly on rises adjacent to the inlier composed of Mesozoic and Cenozoic sediments, and hills and rises composed of weathered metamorphic bedrock;
- eucalypt woodlands dominated by river red gum (*Eucalyptus camaldulensis*), coolibah (*Eucalyptus microtheca*) and occasional thickets of gidgee (*Acacia cambagei*) along major ephemeral drainage systems; and,
- grasslands dominated by mitchell grass (*Astrebla spp.*), with some neverfail (*Eragrostis setifolia*) on the extensive gibber covered plains flanking the inlier .

REGOLITH–LANDFORM RELATIONSHIPS

The regolith–landforms of the Tibooburra Inlier have been mapped at 1:25,000 scale (Chamberlain and Hill, 2002), with more detailed mapping of the Dee Dee Creek catchment headwaters immediately east of Tibooburra also being undertaken at 1:10,000 scale (L. Hill, in prep.). Further detailed mapping of adjacent inliers on the MILPARINKA 1:250,000 sheet and the development of regional regolith and landscape evolution models are proposed for future work.

Weathered bedrock

Variably weathered bedrock is most extensively exposed on the rises and hills throughout the inlier, and in sections where it underlies a variety of sedimentary cover types. At Quarry Hill (Figure 1) and at a low hill approximately one kilometre north of Tibooburra, saprolite derived from moderately weathered granodiorite is exposed at the base of many of the sedimentary sections. At Nuggety Hill and along the northern margins of the inlier, gully sections reveal moderately to highly weathered metasediments beneath the sedimentary sequences. The slightly weathered granodiorite mostly forms erosional rises covered by rounded tors (koppies), many of which display spheroidal weathering. The metasediments typically form rounded hills and rises with angular slabs of slightly weathered rock. The more arenaceous metasediment lithologies (e.g. quartzites) tend to form the most prominent landscape expressions as strike ridges and hill crests.

Transported regolith

Assorted alluvial, colluvial, and aeolian sediments are widespread across the region, particularly flanking the hills and rises of the Tibooburra Inlier. These sediments are most extensive in low-lying landscape settings, although some may occur on the upper parts of rises and hills.

Ancient transported regolith of a variety of origins is widespread around the margins of the inlier, and at several sites overlying weathered bedrock over the central part of the inlier (e.g. Quarry Hill and a low hill approximately one kilometre north of Tibooburra). This mostly forms low hills, rises and erosional plains, some of which are locally covered by aeolian sandsheets, alluvial plains, and sheetflow fans. Low-lying exposures flank the inlier and extend between the low, slightly weathered bedrock hills and rises on the inlier (e.g. surrounding the township of Tibooburra and near the Easter Monday diggings). Well-cemented sandy beds and lag-armoured surfaces may form 'flat-iron' slope facets, particularly along the northernmost margins of the inlier, some of these may correspond with dip-slopes however in most cases they are lag-armoured erosive slopes.

Alluvial sediments are mostly associated with the contemporary drainage network, and as minor eroded exposures in elevated landscape positions. Contemporary alluvial deposition occurs within alluvial channels and the flanking depositional plains, drainage depressions, and outwash fans and swampy depressions downstream of the intersection points of channels. Many of the alluvial channels conform to meanders incised into depositional plains (arroyos) with areas downstream of channel-floodplain intersection points characterised by alluvial plain deposition.

Colluvial sediments are widespread across the area, particularly flanking hills and rises, and extending across the adjacent lowlands. The most widespread colluvial deposits are associated with sheetflow and may form a thin cover on erosional hills and rises or extensive sheetflow fans. Many areas characterised by sheetflow have a distinctive 'contour-band' surface pattern defined by the surficial organisation of pebbly surface lags with sparse vegetation cover and more densely vegetated areas composed of fine red-brown sands. Minor colluvial deposits derived from slope creep and rockfall are limited to steep slopes typically flanking bedrock exposures or indurated regolith.

Aeolian sediments are very extensive across the area. They variably mantle most of the landscape ranging from forming a minor component of the regolith on rise and hill crests to forming extensive sand plains and linear dunefields in lower lying settings, particularly flanking the inlier.

Indurated regolith occupies a wide range of landscape settings. Regolith carbonate accumulations are limited in their distribution, mostly occurring as hardpan coatings along hydromorphic barriers such as the interface between slightly weathered bedrock and transported regolith. Disseminated powder regolith carbonate accumulations are associated with many of the ancient transported regolith materials, particularly in Mesozoic sediments with calcareous cements, and in the overlying aeolian sediments.

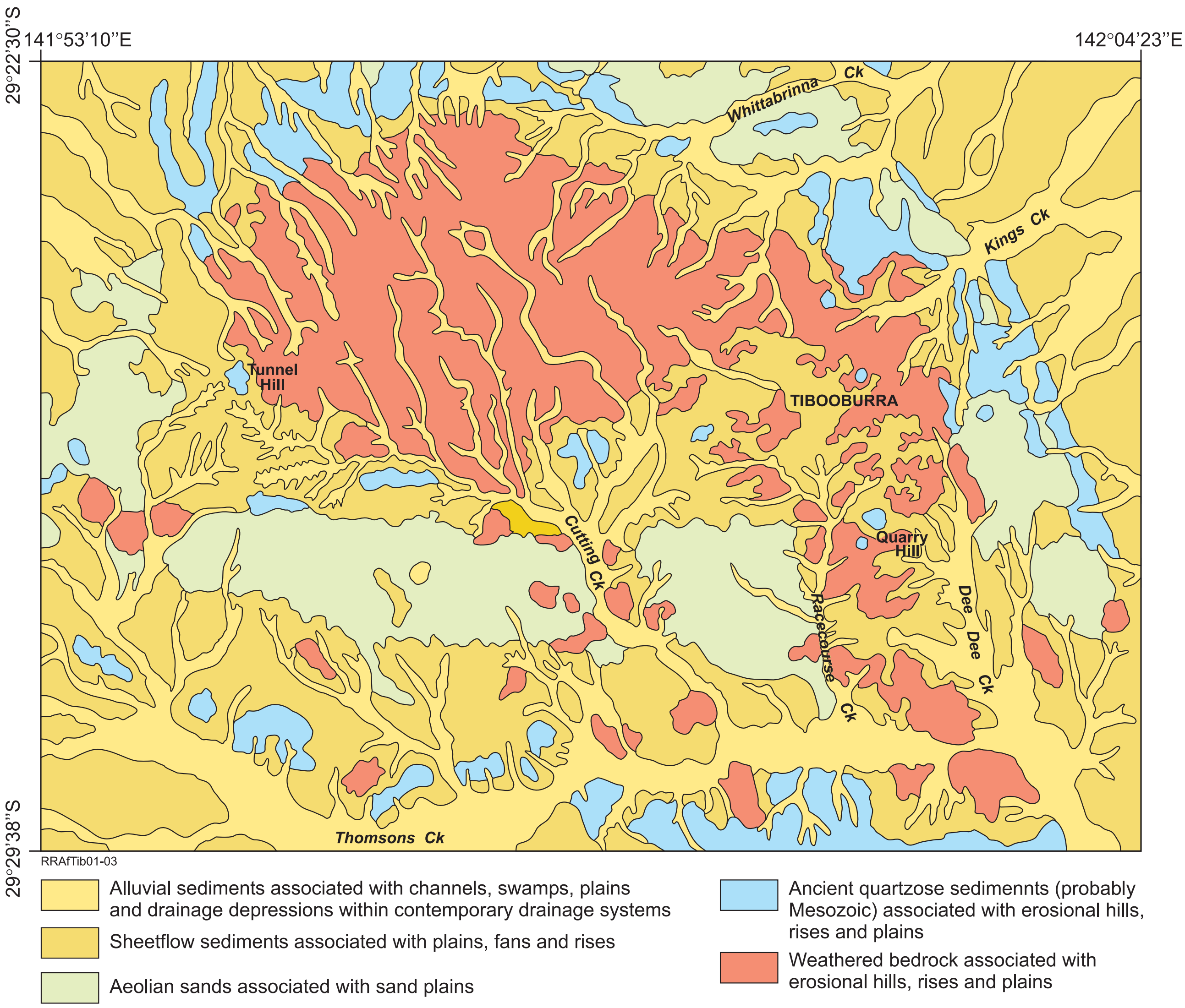

Figure 1. Simplified regolith–landforms of the Tibooburra Inlier area. (After Chamberlain and Hill, 2002).

Ferruginisation is associated with some weathered bedrock exposures, particularly within the weathered metasediments in the west of the inlier (e.g. near Nuggety Hill). Ferruginised sediments are very common in the ancient transported regolith and typically form low rises or prominent breaks in slope on hills. Ferruginous gossanous material also occurs along some beds within the hills composed of weathered metasediments, west of Tibooburra. Silicified regolith is most prominent on rises and low hills composed of ancient transported regolith. It is a common detrital component of surface lags on sheetflow fans and deposits flanking the inlier where it forms gibber.

REGOLITH CHARACTERISATION

Weathered bedrock

Most bedrock in the inlier is slightly weathered, generally characterised by minor red-brown ferruginous surface staining and open joint and fracture sets, particularly along cleavage planes in metasediments. Moderately weathered bedrock is mostly composed of friable, kaolinitic saprolite, with moderately weathered granodiorite including rounded corestones of slightly weathered bedrock within a friable, quartzose-micaceous-kaolinitic saprolite. In some areas, such as near Nuggety Hill, west of Tibooburra, some of the moderately weathered metasediments are ferruginised.

Transported regolith

Ancient transported regolith is composed of pale grey fine-grained sandstone and siltstone with grey to orange-brown, medium to coarse-grained sandstone and gravel (including quartzose pebbles and boulders and rare felsic volcanic pebbles) inter-beds. The main minerals are quartz (both as detrital clasts and cement), micas, feldspars, heavy minerals and minor calcite cement. Plane laminations, cross-laminations and bedding, and bioturbation are common.

Alluvial sediments associated with contemporary drainage systems contain a mixture of red-brown and white quartzose sand, kaolinitic clays and lithic fragments. Some alluvium derived from erosion of areas with ancient sediment accumulations consist of quartzose gravels and sand. Alluvium derived from the erosion of aeolian sand sheets consists of fine quartzose sand. Alluvial sediments associated with contemporary drainage systems but no longer carrying streamflow are lithologically similar to the active alluvium.

Aeolian sediments are widespread in the region and mostly consist of rounded, red-brown quartzose, fine sands. Localised source-bordering aeolian deposits flanking ephemeral stream channels mostly consist of pale red-brown, quartzose sands with minor micaceous and lithic clasts.

Colluvial sediments mainly consist of locally-derived lithic, quartzose and indurated regolith pebbles, with red-brown quartzose sands.

Indurated Regolith

Silicified regolith in the area of the inlier mostly consists of massively indurated sediment that still preserves many of the primary sedimentary structures. The cement consists of micro-crystalline quartz with very minor micro-crystalline anatase. Some silicified sediments display complex 'glerpy' and slabby morphologies. More complex varieties of silicified sediment occur in the wider region (e.g. Watts, 1978; Wopfner, 1978; Walther, 1993; Tait and Webb, 1998).

Ferruginised regolith mostly consists of goethite and hematite, plus minerals (such as quartz) derived from the regolith material hosting induration. The main morphological facies include ferruginised sediments and ferruginised saprolite. The ferruginised sediment typically conforms to slabby to massive morphologies within sediments, with liesegang ring patterns mostly expressed in the ferruginised saprolite.

Regolith carbonate accumulations are mostly calcite-dominated hardpans mainly coating weathered bedrock surfaces, with minor powdery carbonates, mostly associated with weathered Mesozoic sediments containing calcareous cements.

DATING

Dating of regolith materials in the region has been extremely limited, and has been mainly restricted to examinations of microfossil and macrofossil remains, and lithostratigraphic correlations. The main palaeontological evidence directly from the area of the inlier is restricted to plant fossils from Quarry Hill that Kenny (1934) reported as being from the Jurassic, but Morton (1982) later considered to be from the Palaeogene. Morton also reports the presence of plant remains from sediments immediately flanking the inlier (e.g. on the northern margins of the inlier), most of which were tenuously considered to be from the Palaeogene. Other palaeontological results from the wider region have been mainly used to determine the presence of Cenozoic and Mesozoic sedimentary units (Hanlon, 1966; Morgan, 1978; Morton, 1982), however, their direct relationship with sediments on or immediately flanking the Tibooburra Inlier is not entirely clear. Fanning (1999) used radiocarbon dating in a study of recent sedimentation and erosion immediately to the west of this study area near Mt Wood.

Lithostratigraphic correlations have been extremely tenuous and controversial from the area of the inlier. These have largely focused on the correlation and distinction between the Palaeogene Eyre Formation and the Late Neocomian to Albian Cadna-Owie Formation (or Gum Vale Formation). The main problems with lithostratigraphic correlations have been the limited continuation of the exposure of sedimentary sequences, and the modification of primary sediment lithologies due to weathering, induration and differential erosion. In many cases previous workers have been faced with making stratigraphic correlations and assignment based on the presence of surface lags consisting of quartzose gravels, which is a common attribute to a wide range of sedimentary units and their weathering products. Many of the regolith and landscape features composed of weathered bedrock have the potential to pre-date the ancient sedimentary basin cover and therefore could be exhumed pre-Jurassic landscape remnants. Morphostratigraphic correlations relating to induration (e.g. silcrete and 'laterite') and palaeosurfaces (e.g. Wopfner and Twidale, 1967; Wopfner, 1974; 1978; Firman, 1994) have even greater shortcomings in this area.

REGOLITH EVOLUTION

Some of the important features of the history of regolith and landscape evolution of the Tibooburra Inlier include:

1. the poorly understood Mesozoic–Cenozoic sedimentary history and depositional environments. In particular there are major uncertainties regarding the age and depositional environment of sediments at the Quarry Hill and Nuggety Hill outliers, and flanking the Tibooburra Inlier. Previous studies such as Kenny (1934) suggest that some of these may be part of the Mesozoic sequence, however, more recent studies by Morton (1982) and Stevens (1988) consider some to be from the Palaeogene Eyre Formation. Furthermore, Morton (1982) and Stevens (1988) disagree on the stratigraphic context of similar sediments flanking the inlier, varying between correlations with the Eyre Formation and the Cadna-Owie Formation (Gum Vale Formation). The stratigraphic significance of many of these sediments was further investigated by Chamberlain (2001), where results suggest that previous widespread correlations and extrapolations of the Eyre Formation in the immediate vicinity of the Tibooburra Inlier are tenuous;
2. weathering and regolith induration appear to have taken place within a complex evolutionary history throughout the course of landscape development. Many of the indurations are closely related to variations in hydromorphic settings within the regolith host, suggesting that they are intimately related to groundwater processes and evolution, perhaps during the history of sedimentation and burial;
3. the main input of gold to the region is largely hosted by ancient sediments such as those immediately flanking the inlier and at sites such as Nuggety Hill. The origins of these sediments have been poorly constrained in previous studies. At the time of deposition (probably Mesozoic) these sediments were more extensive across the area of the inlier, with the valleys between bedrock rises acting as 'traps' for

gold deposition and secondary enrichment. Palaeocurrent indicators in these sediments are highly variable, but are mostly consistent with a southern source area. The primary gold source for these sediments is therefore likely to be in an area presently covered by regolith and basin sediments. These ancient sediments have since been reworked throughout the landscape history into alluvial and colluvial deposits that in many cases have further concentrated the gold (e.g. the Granites diggings);

4. Previous studies such as Morton (1982), Stevens (1988), and Stevens and Etheridge (1989) have interpreted the Tibooburra Inlier to be the centre of a major domal uplift. The main evidence used to support this has been the identification of dip slopes away from the inlier in the ancient sediments surrounding the inlier. The nature of any structural deformation of these sediments however is not clear. Many of the interpreted dip slopes in these sediments could instead be erosional slopes. In the wider region Cenozoic tectonics have been a major component of the regolith and landscape evolution. Tectonic activity along regional structures such as the Wahratta Fault to the southwest could have important implications for regional palaeogeographic reconstructions, such as relating to the provenance of the ancient gold-bearing sediments.

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