GIRILAMBONE REGOLITH AND LANDSCAPE EVOLUTION

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INTRODUCTION

The Girilambone Terrain lies between Cobar, Nyngan, Bourke and Nymagee in the western Lachlan Orogen of eastern Australia. This Terrain abuts the Palaeozoic Thomson Orogen to the north and is onlapped by the Mesozoic Surat Basin to the east and north. The Girilambone Terrain is underlain by Cambro-Ordovician Girilambone Group basement rocks with some in-faulted slices of probable Latest Silurian to Early Devonian rocks, perhaps equivalent to the Cobar Supergroup, and some Late Devonian outliers or down-faulted blocks. Granite intrusions, especially in the north, a number of Alaskan-type mafic-ultramafic complexes in the south-east and Miocene leucitites in the central and northern areas intrude and/or overlie this terrain. The Girilambone-Cobar-Nymagee region is one of the richest mineral provinces in New South Wales. Major deposits occur in the Cobar Basin, around Girilambone and at Canbelego and Nymagee, however, exploration has been hampered by the extensive regolith cover as well as poor knowledge of the underlying geology. Much of the area remains to be explored in detail using modern exploration methods.

A major study of this region has just been completed by CRC LEME and the New South Wales Department of Mineral Resources (now Department of Primary Industry). The objective of this study was to gain improved knowledge and understanding of the regolith of this poorly known and explored region. The work was conducted in three stages using an integrated, multi-disciplinary approach. The study covered the Byrock area in the north-west, the Sussex and Coolabah central areas, and the Hermidale area in the south-east (Figure 1, Chan *et al.* 2003a, 2003b, 2004, 2005). Since completion of this study there has been increased exploration activity in the Girilambone region.

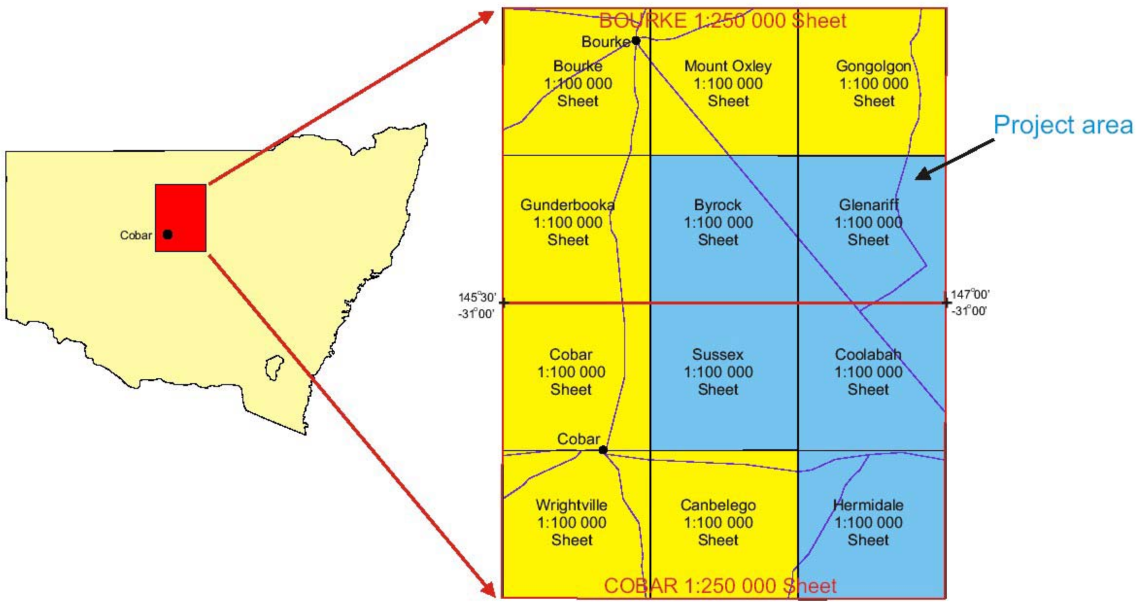

Figure 1: Location of the Girilambone study area.

METHOD

The use of shallow air core drilling along a series of road traverses was instrumental in gaining regolith profile information from petrographic, mineralogical and geochemical analyses of samples from 247 drill holes. This, combined with data from regolith-landform mapping and airborne magnetic imagery, provided insight into the 3D distribution of the regolith. A key development was the characterisation of PIMA data, which together with petrographic information and allowed for the discrimination of redeposited clays from *in situ* clays, thereby helping to distinguish the transported sequences. Geochemical characterisation in support of petrographic identification of weathered bedrock lithologies and identification of less weathered saprock chips assisted the bedrock mapping. The evolution of the regolith and landscape is partly constrained by palynological, palaeomagnetic and apatite fission track dating of various regolith and landscape features.

REGOLITH AND LANDFORMS

The Girilambone region is covered by colluvial and alluvial sediments with small, scattered areas of slightly weathered bedrock rises (9-30 m relief) and occasional low hills (30-90 m relief). Larger areas of highly weathered bedrock rises in the Byrock area are surrounded by widespread colluvial plains and extensive stagnant alluvial plains. Alluvial plains and fans occur along the major north-draining (Mulga and Tindarey Creeks) and east-draining (Whitbarrow and Pangee Creeks) watercourses. A few small volcanic plateaus of slightly to moderately weathered leucitite basalt occur in the Sussex and Byrock sheet areas. Inverted relief palaeosediments occur on rises in the vicinity of Coolabah village and these sediments also occur on erosional plains immediately to the west.

There are three major unconformity-bound depositional sequences which are, from older to younger: a fluvial sediment sequence; a proximal estuarine to marine and fluvio-lacustrine sediment sequence; and, a colluvial-alluvial sediment sequence, which includes a component of redeposited clays derived from the older sequence. Preserved sediments from the oldest sediment sequence are inverted in relief in the present landscape. The two younger sequences constitute the preserved sediments in two palaeovalley systems, one superimposed upon the other.

The older inverted sediment sequence in the vicinity of Coolabah village consists of flat lying beds of undeformed sandstone, quartz-lithic conglomerate and minor mudstone sediments. The older palaeovalley sequence consists of clay and minor quartz silt-sand-gravel sediments and is more widespread at depth and thicker in the Byrock area, although remnants are preserved in higher terrain in the Sussex-Coolabah and Hermidale areas. The younger palaeovalley sequence, which includes ferruginous pisoliths, lithic fragments (which may be ferruginised), quartz pebbles and granules, sand, and minor silt and clay is more widespread and buries palaeohighs in places. This sequence also has a grey to white clay component that is interpreted as redeposited clays eroded from the older palaeovalley sequence, and only occurs in the Sussex-Coolabah and Hermidale areas where the elevation is higher than in the Byrock area. The magnetic ferruginous pisoliths define a palaeodrainage network which commonly deviates from the mid to lower parts of present low gradient drainage systems. The younger palaeovalley sediments are up to at least 40 m thick in broad palaeovalleys up to 19 km wide, whereas the underlying older palaeovalley sediments are up to at least 60 m thick in steeper sided palaeovalleys up to at least 8 km wide.

The depth and degree of bedrock weathering is generally very variable, but tends to be greater beneath and adjacent to the older palaeovalley sediments where pallid zones often occur. Quartz veins, ferruginous induration and, to a lesser extent, silicification are widespread in the drill hole regolith profiles. Carbonate induration is dominant at and just below the base of the transported material. Aeolian dust, in the form of silt-size quartz grains, impregnates the upper regolith layers (both transported and *in situ*) across most of the area.

MODEL OF REGOLITH AND LANDSCAPE EVOLUTION

The association and nature of preserved regolith materials holds important clues as to the history of a landscape and the evolution of the regolith. The model of regolith and landscape evolution presented here for the Girilambone terrain (Figure 2) is an important predictive tool with respect to the nature of physical and chemical dispersion processes and the formation of geochemical anomalies.

Early Jurassic

Palaeomagnetic dating of oxidised saprolite at the New Cobar open cut mine to the west of the Girilambone study area indicates an episode of weathering-related oxidation and haematite fixation at approximately 180 Ma (McQueen *et al.* 2002). Preservation of this Early Jurassic weathering profile close to the present surface indicates either prolonged exposure of this elevated site or possibly later burial and exhumation. Interpretation of apatite fission track data from five samples in the study area (Donelick & O'Sullivan 2002) indicates that the Hermidale and Sussex areas have been close to the surface (less than 1 km of cover) since at least the Early Jurassic.

Late Jurassic

Inverted relief flat-lying fluvial sandstone, quartz-lithic conglomerate and minor mudstone sediments with north trending imbrication and cross-beds at Coolabah village are very similar to Late Jurassic sediments in the Parkes area on top of the northwest trending Canobolas Divide to the south of the Girilambone region. These latter sediments have been dated by palynology as Late Jurassic Surat Basin equivalent and also have northerly palaeocurrent directions (Gibson & Chan 1999a, b). Sediments of similar appearance occur widely scattered across the Girilambone and surrounding regions on both sides of all major drainage divides over the Cobar Uplands (Gibson 1999) and some of these deposits are possibly equivalent in age. This indicates a widespread north-flowing drainage system prior to the initiation of these divides, which may correlate with the maximum fluvial deposition in this region from 150 Ma to 148 Ma (Jurassic Time Slice 9, Palaeogeographic Atlas of Australia, Geoscience Australia).

Earliest Cretaceous

Erosion of the less weatherable quartz-lithic fluvial sediments and incision of the more weatherable saprolite, together with the export of sediments from the catchment, may be in response to a rapid decrease in global sea level in Earliest Cretaceous ("Australia through time" poster, Geoscience Australia). Erosion of the saprolite formed relatively steep-sided deep valleys (5° slope). The location of some deep narrow palaeovalleys may relate to preferential erosion of less resistant bedrocks such as claystone and metashale. Quartz veining, metamorphism and deformation in evidence have the reverse affect by protecting the bedrock from erosion and forming palaeohighs. However, some deep narrow palaeovalleys terminate abruptly in cross-section, which suggests their form may well reflect faulting at a later stage (see below).

Early Cretaceous

Many of the drill holes intersected grey-white clays, mostly in the lower parts of palaeovalleys, but also exposed at or near the surface in the Sussex and Coolabah areas. Isolated sand size quartz clasts in some clay units may be indicative of vegetation rafting or occasional debris flows in a near-shore environment. Palynological dating of drill hole samples by MacPhail (2004) reveals Early Cretaceous (Aptian) palynomorphs indicative of a freshwater pond or lake, pollens and spores with wider age ranges of Late Jurassic to Early Cretaceous and Early Cretaceous pollen and spores with marine dinocysts (M. MacPhail *pers. comm.* September 2004).

The main factors that indicate the microfloras in the above drill hole samples are coeval with the sampled units (i.e., the microfloras are not recycled and therefore the sediments are not younger in age):

- The retention of fragile features of gymnosperm pollen which are unlikely to survive long distance transport or prolonged weathering, e.g., sacci or air bladders (MacPhail 2004);
- The consistency of the age of the palynomorphs across the area at different elevations as well as higher and lower within this sequence profile; and,
- The lack of any Cenozoic palynomorphs.

Similar Aptian to basal Albian samples 70 km to the northwest of Byrock with abundant spores and pollen, together with relatively few dinoflagellates, indicate dominantly terrestrial deposition, possibly with some marine influence (Mount 1992). Martin suggests the upper reaches of an estuary, subjected to inundation from occasional high tides, as a likely environment. A similar proximal estuarine environment of deposition is highly plausible for parts of the Girilambone study area. Several periods of transgression and regression, or alternatively one major period with fluctuations, are indicated by the multiple fining-up and coarsening-up sequences capped by palaeosols. As there is evidence for terrestrial, including fresh water, and marine environments of deposition, it is likely that these Early Cretaceous sediments belong to the Minmi Member of the Bungil Formation of the Surat Basin (Raza *et al.* 1995), which incorporates both coastal plain and marine shelf depositional environments.

The palynomorphs indicate a seasonally wet to very wet and cold environment with source vegetation being an early Austral Conifer Forest (MacPhail 2004). Areas with isolated large rounded quartzite boulders to 1 m, such as those found 64 km west of Cobar in an almost flat-lying conglomerate bed dated as Early Cretaceous from foraminifera (Rayner 1969) could be isolated boulders indicative of rafting by ice.

Remnants of the grey-white clay sequence are found at elevations up to 230 m ASL, and younger redeposited clays are preserved up 285 m ASL Since these redeposited clays are widespread and overlie the older primary grey to white clays, it is likely that they were derived from eroded older clays at still higher elevations. Deposition was probably associated with the transgressive maximum in the Eromanga Basin from 119 Ma to 114 Ma (Cretaceous Time Slice 4, Palaeogeographic Atlas of Australia, Geoscience Australia).

The formation of pallid zones in saprolite preferentially beneath palaeovalleys with clay sediments may have been initiated by acid leaching in an estuarine environment, such as tidal flats, in the early stages of a fluctuating marine transgression. This acid leaching could have resulted from the formation of authigenic sulphides in a reduced environment that, upon oxidation, would have produced acid sulphate weathering in the underlying saprolite (Worrall & Clarke 2004)

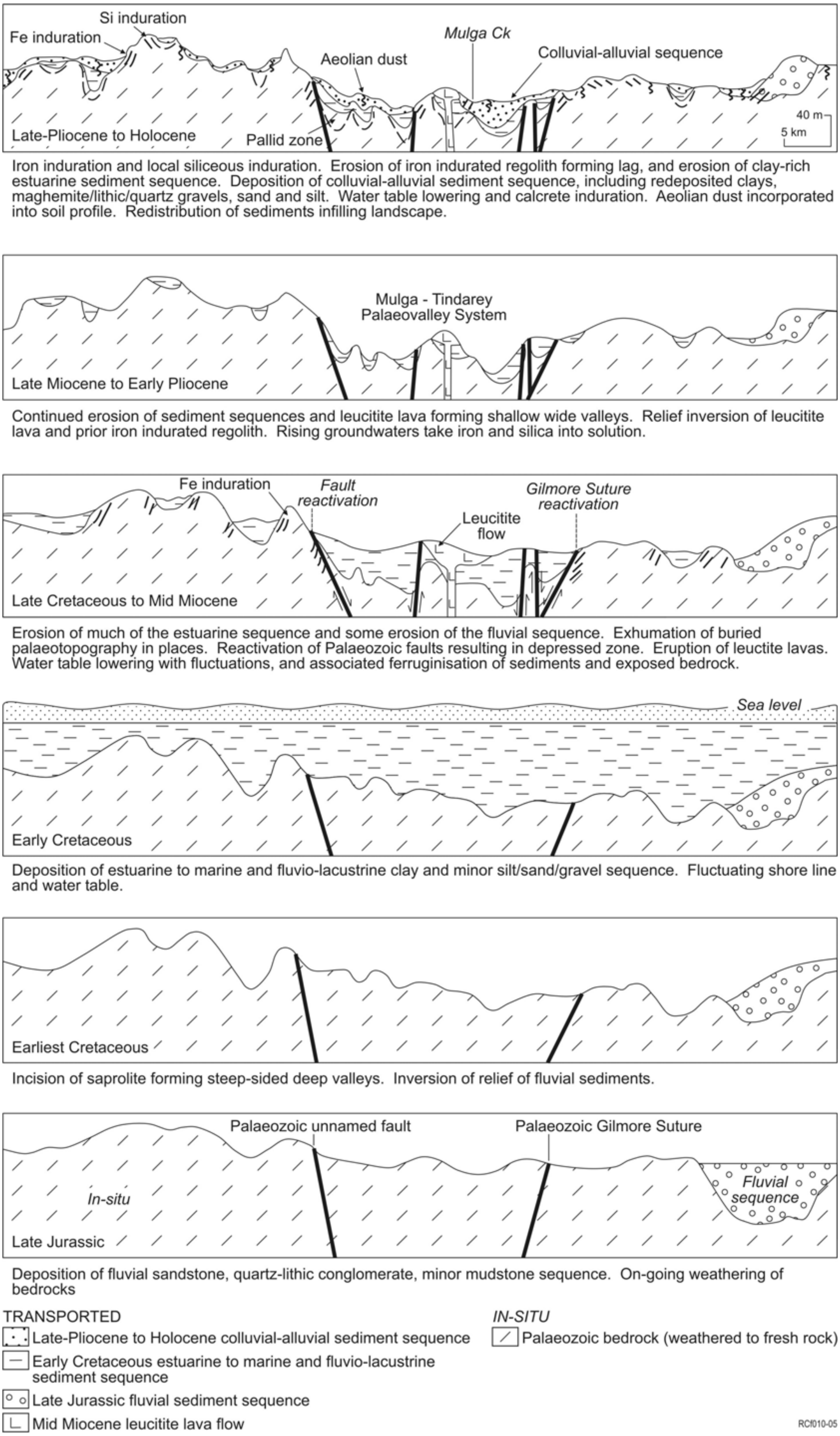

Figure 2: Model of regolith and landscape evolution for the Girilambone terrain.

Late Cretaceous to Early Miocene
Substantial erosion of the Early Cretaceous sediments is indicated by the variability in elevation of the top of the preserved sequence over short distances. Partial exhumation of buried palaeotopography with minor erosion of the harder underlying bedrock is evidenced by present numerous dry valleys. These cut ridge crests in the higher central areas that appear to be unrelated to bedrock lithology and structure, and which may represent an older drainage superimposed from a sediment cover onto an exhumed underlying bedrock palaeotopography. Early Cretaceous clay sediments in the bottom of deep palaeovalleys in a very low elevation zone to the west of Coolabah village coincide with two major concealed faults diverging to the north, one of which is the Palaeozoic Gilmore Suture (Glen *et al*. 1996). It is speculated that the depressed zone between the two faults was down-faulted sometime post Early Cretaceous as there are no Jurassic sediments beneath the Early Cretaceous sediments. Also, there are no locally derived colluvial sediments beneath the Early Cretaceous sequence, as might be anticipated if the steep sides of a faulted depression were eroded and reworked into the consequent valley.

Late Early Miocene to Mid Miocene
Leucitite lavas erupted in the Sussex and Byrock areas during the Miocene (17 Ma) burying the remnants of Early Cretaceous sediments, weathering profiles and bedrock. Mottled saprolith with a palaeomagnetic age of 12 Ma suggests hematite fixation in the profile after leucitite eruption, consistent with drying out of a well-developed profile significantly later than its initial formation. The continuing trend to a warmer and dryer, though seasonal, climate through the Miocene (MacPhail 2000) resulted in further lowering of the water table, with fluctuations due to seasonality.

Late Miocene to Early Pliocene
Continued erosion leads to further stripping of the Early Cretaceous sediments and weathered bedrock resulting in the formation of broad shallow valleys as well as inversion of relief of leucitite lavas and prior iron-indurated regolith. The climate continued to be warm but became wetter, and rising groundwaters took iron and silica from weathering into solution.

Late Pliocene to Holocene
Progressive change from a warm wet climate to a drier more arid climate resulted in a falling water table and decreasing stream capacity. Streams became choked with colluvial-alluvial sediments, including redeposited grey to white clays, and magnetic ferruginous pisoliths, which were deposited in broad valleys. Iron induration and extensive lag deposits developed on the lower valley slopes. Widespread accession of aeolian dust in the form of quartz silts (Tate *et al.* 2003), which were incorporated into soil profiles due to biotic transfer and pedogenesis. With increased aridity calcrete induration of saprolite and younger sediments became widespread. Neotectonic activity occurred in places and redistribution of sediments gradually infilled the landscape.

CONCLUSIONS
Interpretation of analyses of shallow air core drilling samples, together with regolith-landform mapping and aeromagnetic imagery, has defined the present 3D regolith architecture. A model of regolith and landscape evolution for the Girilambone region has thereby been reconstructed with support from dating. Widespread north flowing fluvial systems deposited quartz-lithic sediments in the Late Jurassic. Proximal estuarine-marine and fluvio-lacustrine sediments were deposited over much of the Girilambone study area during one or more transgressions during the Early Cretaceous, and most, if not all of the area would have been under water, in a cold and seasonally wet to very wet climate. Reactivation of Palaeozoic faults associated with the Gilmore Suture during the Late Cretaceous to Early Miocene may have formed a depressed zone (Mulga-Tindarey palaeovalley system), thereby preferentially preserving the Early Cretaceous clays. Leucitite lavas which erupted from late Early Miocene to Mid Miocene were inverted in relief due to erosion from Late Miocene to Early Pliocene; this erosion formed widespread broad shallow valleys which were infilled with colluvial and alluvial sediments from Late Pliocene to Holocene. Widespread incorporation of aeolian quartz silt into the upper regolith profile and calcrete induration occurred with increased aridity during this period.

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