ELURA MINE AREA, NEW SOUTH WALES

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INTRODUCTION

The Elura lead–zinc mine is located about 40 km northwest of Cobar at latitude 31°10'S and longitude 145°39'E in the COBAR (SH55-14) 1:250 000 map sheet, western NSW (Figure 1). Studies of regolith and landforms in the area around the mine undertaken by Gibson (1998a,b; 1999; 2000), Reilly (1998), Gibson and Pain (1999), Reilly *et al*. (2000), and McQueen *et al*. (2001) are used as a basis for this case study.

PHYSICAL SETTING

Geology

The area is mostly underlain by tightly folded sedimentary rocks of the Early Devonian Cobar Basin, primarily deep-water turbidites of the Amphitheatre Group, with interbedded shallow water sandstone and mudstone of the Winduck Group in the west. A locally preserved thin cover of flat-lying sandstone and conglomerate unconformably overlies the older rocks (Figure 2). Glen (1994) considered these sediments to be Cenozoic, but evidence presented by Gibson (2000) suggests they may be Mesozoic, and represent the basal beds of a now dominantly eroded Eromanga Basin sequence. Most outcrops of the cover sediments have been silicified, but company drilling indicates that they are largely poorly cemented. Low-grade metasedimentary rocks of the Ordovician Girilambone Group are faulted against the Devonian rocks in the east of the area.

Geomorphology

The area straddles low-relief divides between catchments of several major creeks draining into the Darling River, about 70 km distant (Figure 1). Local relief is mostly less than a few tens of metres over several kilometres, especially near the divides, but increases slightly to the north and west as a result of increased incision in catchments with steeper gradients. Erosional plains and low rounded rises predominate; generally these have slopes less of than 1° and are separated by colluvial and alluvial plains. Scattered steep-sided rises of iron-indurated saprolite and small mesas with remnants of ?Mesozoic cover sediments are also locally present (Figure 2). Varying base levels in adjoining catchments result in some drainage divides being distinctly asymmetric, suggesting that the divides may be migrating due to more rapid erosion in the catchment with the lower base level. There is little geomorphic activity within the area, despite its high position in the regional landscape.

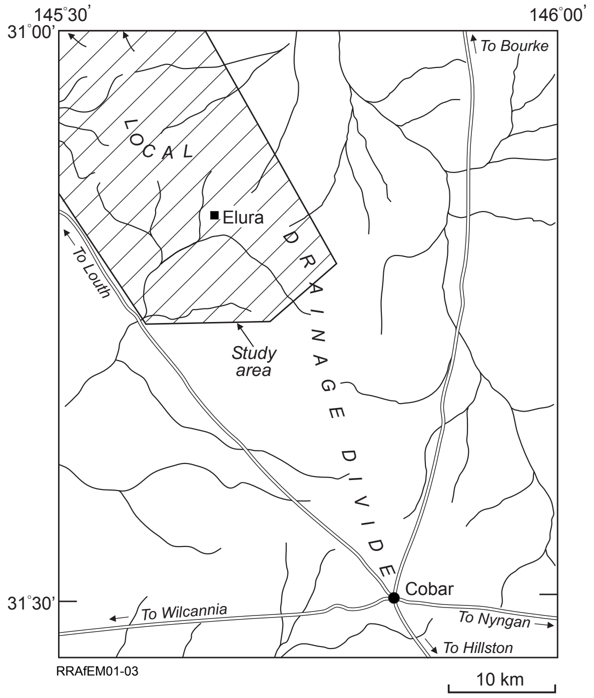

Figure 1. Location of Elura study area.

Climate and vegetation

The climate is semi-arid with a mean annual rainfall of 352 mm. Summers are hot with an average maximum temperature of 35°C, and winters are cool with an average minimum of 4°C (Cunningham *et al*., 1992). Vegetation consists of scattered mulga (*Acacia aneura*), several species of Eucalyptus, belah (*Casuarina cristata*) and white cypress pine (*Callitris columellaris*). The understorey vegetation is dominantly composed of woody shrubs including several species of the genera *Eremophila*, *Dondonea* and *Cassia*, and various grasses (Walker, 1991). The area is used for low-intensity grazing on partly cleared pastoral leases.

REGOLITH–LANDFORM RELATIONSHIPS

Drilling and exposures in the Elura mine indicate that the Devonian basement rocks have been weathered to depths of up to 130 m. Bleached saprolite predominates, but mottled saprolite is locally exposed in gullies and borrow pits at Elura. Beds and fractures within the saprolite have locally been indurated by iron oxides mobilised during weathering. These ferruginous saprolites outcrop on scattered steeper rises and low hills (Figure 2), and are also exposed in the Elura mine (Taylor *et al*., 1984). The uppermost several metres of saprolite beneath some outcrops of silicified ?Mesozoic sediment are partially cemented to form moderately resistant rock, which displays cavernous weathering.

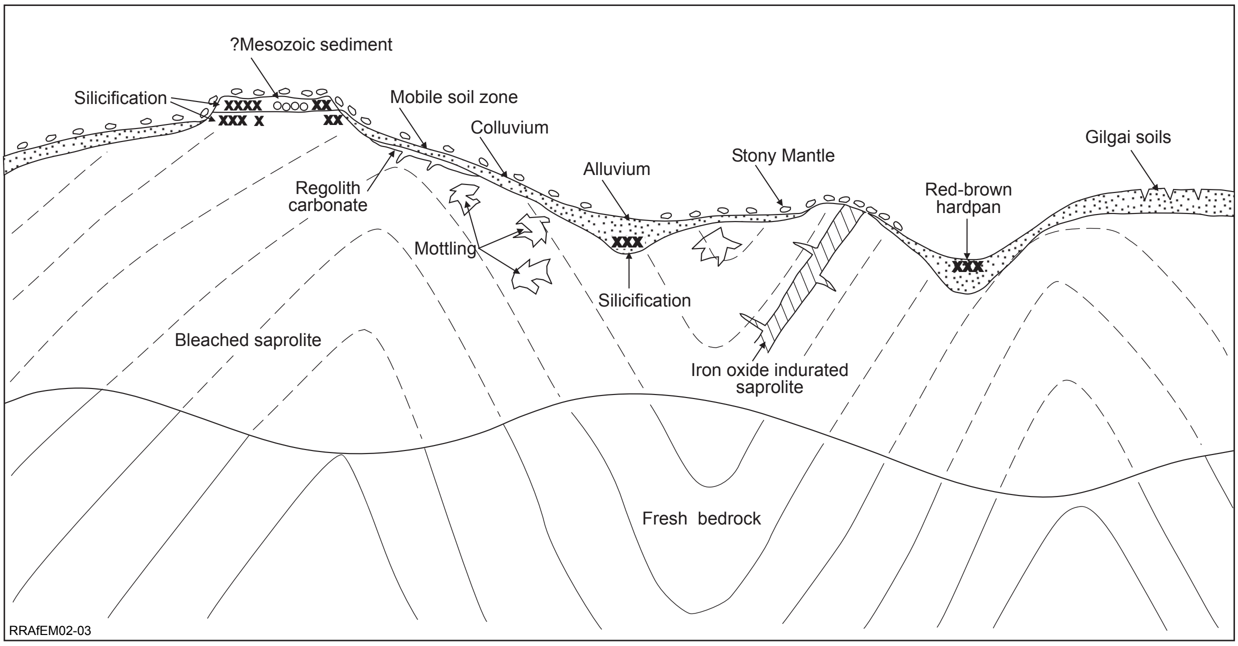

Figure 2. Schematic of regolith–landform relationships in the Elura area.

This material has crude vertical columnar and nodular cementation structures, as well as indistinct dipping bedding.

The *in situ* regolith materials are overlain by regolith carbonate, sediment, and soil. Regolith carbonate is present as a veneer over saprolite, as veins within fractures, and as powdery to solid masses within sediment and soils. Post-Devonian sediments consist of topographically inverted remnants of ?Mesozoic gravel which have been partly silicified, and alluvium and colluvium in modern valleys (Figure 2). Clasts of milky quartz and other rock types, mostly well rounded and many with highly polished surfaces, are prominent in the topographically inverted gravels. The polish may be a result of prolonged transport, or precipitation of silica at the clast surface. Detrital clasts within the ?Mesozoic sediment are up to 1 m in diameter, indicating possible glacial or seasonal ice conditions during deposition (Gibson, 2000).

Alluvium along modern watercourses is mostly less than 2 m thick, but sections up to 5 m are exposed in borrow pits at Elura. Most of the alluvium is red to brown, and is composed of reworked soil material, clasts of ferruginised and bleached saprolite, detrital magnetic pisoliths, and clasts reworked from the ?Mesozoic sediment. However, some deeper exposures are light coloured and sandy, with no magnetic pisoliths. Locally, the upper part of the alluvium is cemented to form a red–brown hardpan. Silicified deeper sandy alluvium is exposed in pits at Elura and has been excavated in some farm dams. The maghemite-bearing alluvium shows up clearly on regional magnetic images as areas with high frequency anomalies (Gidley, 1981). Red to brown loamy sediments on low angle depositional slopes adjacent to watercourses are assumed to be colluvial, deposited by sheetwash.

Three main types of soil are present in the erosional areas. Predominant amongst these is a 30–60 cm thick red to brown loamy soil mostly formed from the underlying saprolite, but also with a possible aeolian input (e.g. Chartres, 1983). The contact with the underlying predominantly bleached saprolite is sharp. This soil forms a mobile surface layer that is affected by bioturbation, sheetwash, creep and clay shrink-swell. It is a desert loam that is poorly differentiated into soil horizons. A few gravel clasts are generally present. The red–brown desert loam passes laterally into thicker loamy soils formed in valley-floor alluvial and colluvial sediments (Figure 2).

Thin stony skeletal soils are present over areas of ?Mesozoic sediment, with ubiquitous clasts exhumed from the sediment, and silcrete and ferruginous fragments. Steeper slopes over ferruginised Devonian saprolite also have stony skeletal soils with many ferruginous saprolite fragments (Figure 2).

The third soil type is grey to red to brown clay with numerous gilgai (Figure 2). This soil is present in high parts of the landscape with low local relief, including an area that forms the junction between the divides between the three main drainage systems of the area. It has mostly been colonised by casuarina (rather than the acacia/eucalypt scrub that dominates most of the area). The origin of this soil type is not well understood. Company drilling shows that it is less than 2 m thick.

A multi-component surface stony mantle is widespread throughout the area. Small, magnetic ferruginous pisoliths predominate in many areas. These pisoliths contain maghemite, which probably formed in the surficial environment as a result of the heating of iron oxides in the presence of organic matter during bushfires (e.g. Schwertmann *et al*., 1995), or possibly biological activity. The pisoliths probably originated by the fragmentation of ferruginous mottles in Devonian saprolite at the base of the mobile soil layer, and from fragmentation and erosion of outcrops of massive ferruginised saprolite.

The stony mantle on rises of ferruginised saprolite includes ferruginous fragments of varying size. Magnetic susceptibility of the fragments increases with decreasing size, indicating that the maghemite may form a surface layer to the clasts. Other bedrock-derived mantle components include fragments of bleached saprolite, silica-cemented saprolite originating from beneath silicified cover sediments, and non-magnetic partly to highly ferruginised saprolite. Mantle components originating from the ?Mesozoic cover includes fragments of silicified sediment (some ferruginous), rounded granules and pebbles reworked from the sediment, and magnetic ferruginous fragments. These types of fragments are present in many areas where soil directly overlies Devonian saprolite, indicating an original capping of now completely eroded ?Mesozoic cover or lateral transport of these materials from nearby outliers. The mantle is considered to be colluvial, the clasts having been generated upslope from their current location, and transported mainly by sheetwash.

EVOLUTION OF REGOLITH AND LANDSCAPE

Gibson (2000) inferred that the patchily preserved and topographically inverted cover sediment is probably Mesozoic (basal part of the Eromanga Basin sequence) on the basis of the large size (≤1 m) of clasts in the sediment. Similar outliers of sediment with boulder-sized clasts located about 60 km west of Cobar have been dated as Early Cretaceous using foraminifera (Ludbrook, in Rayner, 1969). As most of the Elura area is of low relief, Gibson concluded that erosion in the area has not proceeded more than a few tens of metres past the pre-depositional Mesozoic land surface. Recent palaeomagnetic dating (McQueen *et al*., 2001) of mottled saprolite exposed in a borrow pit at Elura indicates two periods of iron mobilization. These are latest Cretaceous to early Palaeocene (60 ± 10 Ma), and Middle Miocene (ca. 15 Ma). The preservation of old weathering features indicates very slow landscape evolution.

Regional apatite fission track data (O'Sullivan *et al*., 1998; 2000) suggests that late Mesozoic deposition was widespread in western NSW, but that this sediment was largely eroded prior to onset of sedimentation in the Murray Basin in the Palaeocene. Thus it is probable that the Elura area was covered with late Mesozoic sediment, which was then mostly eroded by the beginning of the Tertiary. At least the upper part of the weathering profile now preserved in basement rocks at Elura developed at about this time, possibly initially beneath a veneer of Mesozoic sediment. Since then there has been insufficient erosion to completely remove the material that was weathered by this time. However, iron within the profile has been remobilised at least once, in the mid Miocene, and the weathering front may have been deepened. During this period of high landscape stability, alluvial sediments were deposited in lower parts of the landscape, and a ubiquitous colluvial mantle developed. The age of the alluvial and colluvial deposits is, however, unknown.

The timing of silcrete formation within the ?Mesozoic sediments and cementing of underlying basement saprolite remains unclear. This may have occurred at depth prior to or during erosion of the sediment in the late Mesozoic, or near the surface in the Tertiary prior to relief inversion. Silicification of alluvium in modern valley floors probably occurred at a later time. Older sediment in the modern valley floors does not contain maghemite, indicating that it was deposited prior to the drying of climate and the change from rainforest to sclerophyllous vegetation (more susceptible to bushfire) during the late Tertiary and Quaternary.

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