CHARTERS TOWERS REGION, QUEENSLAND

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INTRODUCTION

Charters Towers is a historical gold mining town located 136 km southwest of Townsville in northern Queensland (Figure 1). The following report is based on regolith–landscape studies conducted to the west of Charters Towers (Aspandiar, 2000) and draws on soil–geomorphic work done further west in the Torrens Creek region (Coventry, 1978; Coventry and Willams, 1984).

PHYSICAL SETTING

Geology

The study area lies within the Charters Towers Region dominated by the Lolworth–Ravenswood Province (Hutton *et al*., 1997). The Ravenswood sub-province is composed of the Palaeozoic Ravenswood Batholith, which was intruded into basement over a period of 100 million years, and comprises rocks ranging in composition from gabbro to granite (Hutton *et al*., 1997). The basement of the region comprises Neoproterozoic metamorphic rocks, the Cambrian Kirk River Beds and Cambrian–Ordovician volcanic and sedimentary rocks of the Seventy Mile Range (Figure 1). The Cenozoic succession is represented by weathered, sandy gravel to sandy clay sediments of the Southern Cross Formation and less weathered, gravel to sand sediments of the Campaspe Formation (Grimes, 1979; Henderson and Nind, 1994). Tertiary basalt flows of the Nulla Volcanic Province crop out extensively to the north of the area (Figure 1).

Geomorphology

The region has a subdued relief, dominated by gently undulating plains that lack an integrated stream network. The upper reaches of the plains terminate in incised hills dominated by bedrock, or in breakaways that merge into erosional tracts of rapidly migrating streams. Mesas bounded by breakaways are present in the east of the study area and these have erosional areas between them. Plains with a few lava cones dominate the northwestern part of the area.

Climate and Vegetation

The climate of the area is semi-arid tropical; it is hot and wet in summer and dry and cool in winter with occasional frosts. The rainfall is strongly seasonal and has high index of variability with 80% of the annual precipitation falling in the period of November

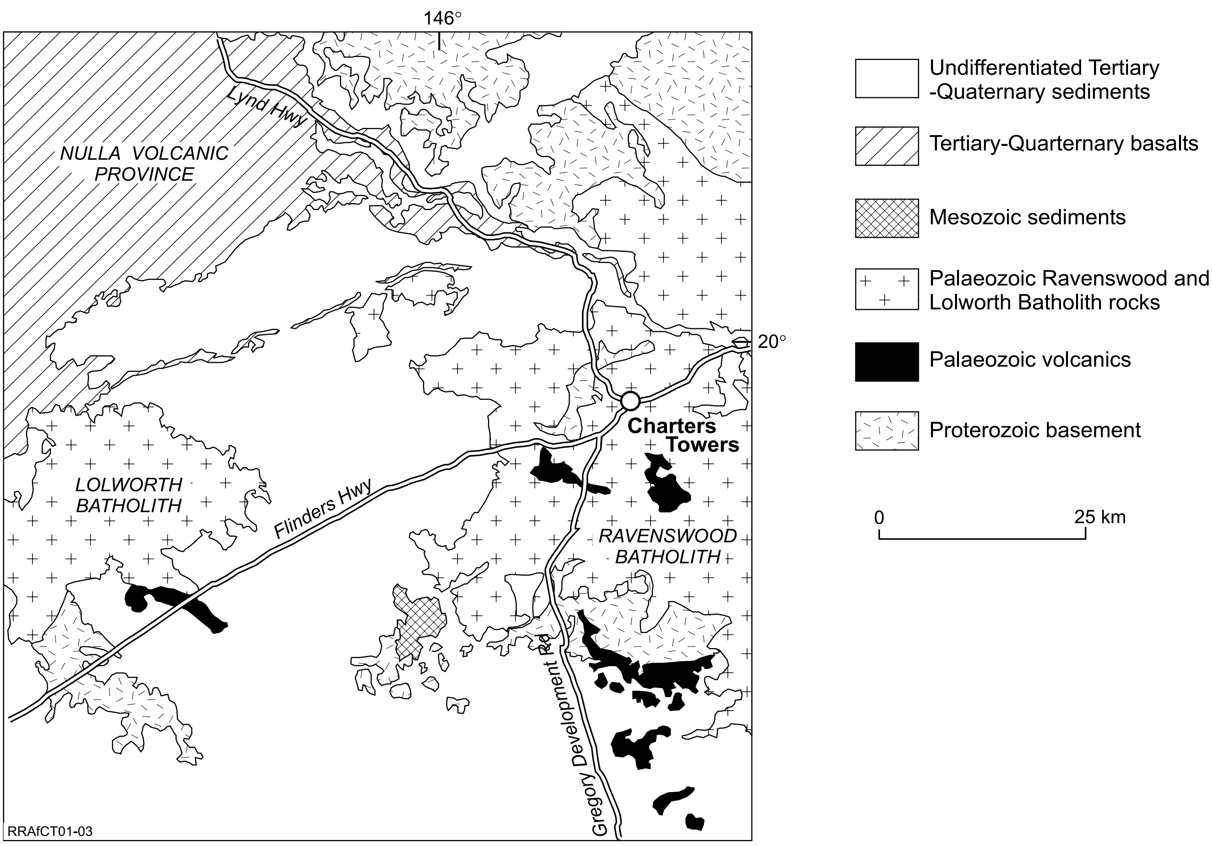

Figure 1. Simplified geology of the Charters Towers – Homestead region.

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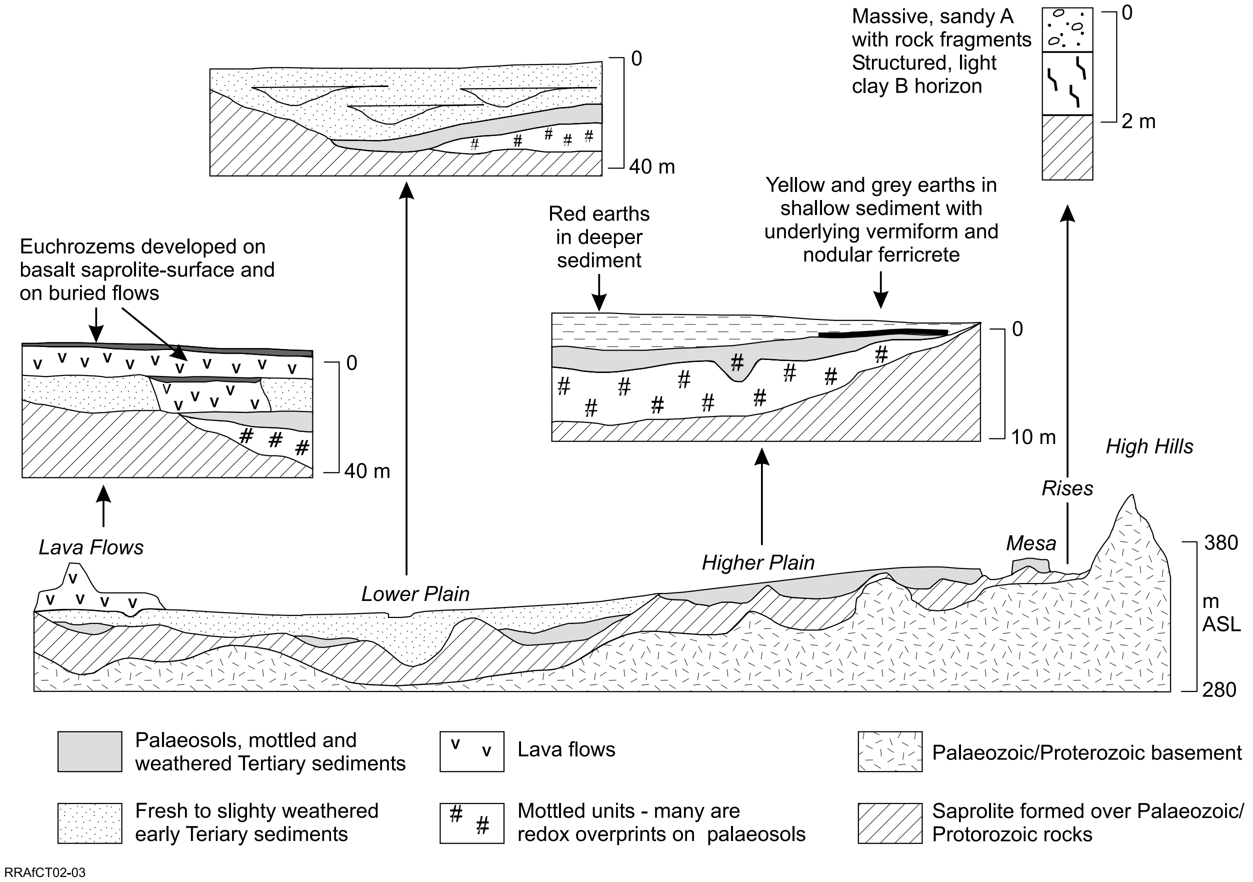

Figure 2. Schematic representation of regolith–landforms and the spatial relations between regolith units underlying individual landforms around Charters Towers.

to March. The vegetation is dominated by open woodlands of Eucalyptus and Acacia species and a discontinuous ground cover of spinifex (*Triodia pungens*), black spear grass (*Heteropogon contortus*), white spear grass (*Aristida leptopoda*) and golden beard grass (*Crysopogon fallax*).

REGOLITH–LANDFORM RELATIONSHIPS

Eight regolith–landform units were delineated within the study area, these being i) high hills, ii) low hills and rises, iii) high plains, iv) low plains, v) lava plains, vi) mesas, vii) alluvial plains, and viii) lacustrine plains and lakes (Figure 2). The high and low plains provided the best information about past weathering and geomorphological processes and are discussed in greatest detail below.

Underlying the soils of the high plains is a sequence of hydromorphic palaeosols formed within the Tertiary Southern Cross Formation. Similar to surface soils, the palaeosols are dominantly red earths with some yellow and grey earths. The palaeosols display several types of relationships: cumulate, composite, reformed and polygenetic, with polygenetic types being dominant. Very few palaeosols and their sediment hosts can be laterally traced for more than 500 m. Lateral changes in the morphological characteristics (e.g. colour, mottling) of individual palaeosols are common. Some palaeosols crop out on the present land surface as reformed soils. Subsurface mottling is common with many of the mottled units being redox overprints on buried soils. Most of the yellow earths are underlain by a hard, variably mottled vermiform ferricrete, which in some places merges downwards into a sub-horizontally mottled ferricrete or ironstone bands (Figure 2).

The breakaways of the high plains and mesas represent the limits of fluvial dissection, and are marked by outcrops of red massive to vermiform mottled ferricretes.

The low plains are underlain by yellow and grey earths, which have a mottled vermiform and nodular ferricrete substrate. The soils and ferricrete overlie either variably weathered sediment of the Campaspe Formation, red palaeosols of the Southern Cross Formation, or granitic basement (Figure 2).

The lava plains are underlain by fresh basalt which includes horizontal zones of clay-rich palaeosols. Weathered gravelly to sandy sediments are present between individual flows. The basalts unconformably overlie red and yellow palaeosols, basement saprolite, and grey, slightly weathered sediments of the Campaspe Formation (Figure 2).

The lacustrine plains, restricted to a couple of lakes, are underlain by clay-rich sediments, which in turn overlie fresh sandy sediment or red palaeosols.

All of the low relief landforms indicate a variable subsurface regolith and sediment cover, with red and yellow palaeosols and their mottled substrates being the dominant regolith units. Marked changes in the intensity and depth of weathering beneath present soils and palaeosols are common, with the weathering depth of granitic basement changing from 2 to 50 m within short horizontal distances (<200 m).

REGOLITH CHARACTERISTICS

Mineralogically, the red earths are composed of hematite, goethite, kaolinite and quartz, with trace amounts of maghemite. The yellow and grey earths are strongly partitioned in their constituents resulting in the formation of dark brown nodules set in a faintly mottled matrix. The nodules are composed of goethite, kaolinite and quartz, whereas the matrix is rich in kaolinite and quartz. No difference in Al-substitution in goethite was found between nodule samples indicating that the Al concentrations within the soils were similar. The mottled vermiform ferricrete is dominated by goethite, minor hematite and kaolinite. Microscopic analysis indicates strong mottling and at least two generations of redox events.

Most of the regolith units developed in sediments of the Southern Cross Formation or younger Campaspe Formation. The Southern Cross Formation sediments where unaffected by pedogenesis are crudely bedded, gravel- to mud-sized, and compositionally mature, with Al–Fe–Si minerals being dominant. The younger Campaspe Formation sediments are gravel- to sand-sized, with wide channels marked by large trough cross-beds, and compositionally less mature, with quartz–feldspar and some ferruginous particles making up the sediment. The compositional differences between the two formations indicate a change in source rock for the younger sediments.

Formation of the red, grey and yellow earths, which underlie much of the present landscape and occur as palaeosols beneath the high and low plains, has been strongly hydrologically controlled (Coventry and Williams, 1984). The red earths formed in comparatively free draining profiles, which correspond to an originally thicker unconsolidated sediment body. Free drainage promotes rapid oxidation of Fe^{2+} released from iron particles, which facilitates hematite formation over goethite (Schwertmann and Taylor, 1989) and thereby gives the soils their red colour. The yellow and grey earths formed in a thinner sediment body where drainage was comparatively impeded and high soil water tables prevailed for longer periods. This favoured reduction and the subsequent slow oxidation of Fe^{2+}, a mechanism suited to goethite formation. The strong sub-horizontal and vertical mottling in grey and red or grey–yellow–brown reflects the hydrological evolution of the thinner sediment cover. The previous surface cover (soil, ferricrete, basement saprolite or saprock) formed a hydrological barrier on deposition of new sediment cover. Pedogenesis within the newly deposited sediment resulted in the development of the soil and palaeosol characteristics currently observed.

LANDSCAPE AND REGOLITH EVOLUTION

The oldest expressions of landscape and regolith in the area are found in the high plain with its hydromorphic soils and palaeosols, ferricretes and mottled and weathered sediments. The Southern Cross Formation was probably deposited in a low gradient mud-dominated fluvial environment, possibly in meandering streams or meandering alluvial fans as currently found in the Gulf of Carpentaria (Grimes and Doutch, 1978). Pedogenesis of the fluvial sediments in areas away from active deposition resulted in formation of the red and yellow earths.

The stacking of palaeosols and development of their vertical and lateral relationships (composite, polygenetic, reformed) occurred in response to river aggradation and degradation and associated development of terraces (Wright, 1992). The aggradation, degradation and spatial differences in sedimentation of a fluvial system is part of the evolution of a fluvial basin and also accounts for the evolution and observed spatial relations between regolith materials, and the variable degree and depth of weathering of basement under the older Tertiary sediments. Furthermore, the operation of aggradation–degradation phases during the build up of the Southern Cross Formation accounts for the compositional maturity of the sediments, as the sediments would have experienced repeated weathering cycles at storage locations along the length of the fluvial system.

The extent to which aeolian processes contributed to in-channel sedimentation and regolith material formation, especially if arid to semi-arid climates prevailed, is difficult to evaluate. However, as outlined by Paton *et al*. (1995), this may have been important for regions to the west of Charters Towers. The age constraints of the older sediments and palaeosols are difficult to define, but Henderson (1996) placed the age at Paleocene via correlation with morphologically similar units marked by basalt flows.

The sedimentological character of the Campaspe Formation indicates a shift of source region and a change in depositional style during the late Pleistocene to Quaternary. Deposition of the Campaspe Formation began shortly after the commencement of volcanic activity in the Nulla Volcanic Province, which suggests that uplift associated with volcanic activity (Stephenson and Coventry, 1986) could have initiated the Campaspe depositional phase. Sedimentation, in an alluvial fan setting or as braid plains (Henderson and Nind, 1994), initially occurred in valleys incised into the older landscape underlain by palaeosols. Then, with the continued build up of sediment, deposition occurred over adjoining erosional parts of the landscape, thereby burying and overprinting palaeosols at varying elevations. Unlike the Southern Cross Formation, sedimentation of the Campaspe phase was rapid and fluvial style differed, which is the reason for the scarcity of palaeosols within the formation.

The comparatively low degree of weathering of the Campaspe Formation does not imply that weathering became dormant; merely that external factors (tectonically or climatically induced rapid sedimentation) precluded weathering from certain parts of the landscape. Even during the period of Campaspe deposition, the

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basalt flows show soil development (buried flows), indicating the continuation of weathering in landscape positions unaffected by fluvial deposition. It is difficult to establish the effect of continued weathering on the older soils unaffected by sedimentation, which were already depleted in bases and rich in kaolinite and iron oxides.

Subsequent river capture or river migration due to volcanic activity or uplift during the Quaternary exposed the Campaspe Formation sediments to weathering, resulting in the formation of yellow and grey earths with vermiform or slabby ferricretes as substrates, which locally merged with the older soils of the higher landscape. The evolution of these regolith units occurred in response to hydrological barriers controlled by sediment depth and substrate permeability. Subsequent rejuvenation of the drainage in the abandoned depositional fluvial landscape dissected the upper plain, (and to a degree the lower plain), and depending on the presence of red or yellow earths at the limits of fluvial dissection, caused red massive, vermiform and nodular ferricretes to crop out as breakaways. The ferricretes represent relief inversion in that they formed in fluvial sediments which now occupy elevated landscape positions, but they were not formed by the precipitation of iron along the margins of fluvial valley fills as proposed elsewhere (e.g. Pain and Ollier, 1995). Rather, the ferricretes formed first by vertical differentiation of Fe, Al and Si during pedogenesis, and the subsequent natural hardening of the soils at the edges following incision, and/or due to precipitation of Al–Si cements at the edges promoted by a change in direction of perched water tables towards the edges because of incision.

Similar origins for low relief plains of varying ages and elevations bearing red and yellow earths have been proposed for the Flinders Ranges to the west of Charters Towers by Coventry (1978) and Coventry *et al*. (1985). The distribution of regolith units developed in sediments, and the sediment character and relationships around Charters Towers, suggest that spatial differences in fluvial (and possible aeolian) sedimentation and erosion through the Tertiary were responsible for the nature of the observed regolith types, regolith architecture and regolith–sediment relationships.

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