LAWLERS DISTRICT, WESTERN AUSTRALIA

R.R. Anand
CRC LEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, WA 6102
Ravi.Anand@csiro.au

INTRODUCTION

The Lawlers district lies some 300 km north of Kalgoorlie centred at 28° 02'25"S and 120° 33'10"E, and spans the boundary between the SIR SAMUEL (SG51-13) and LEONORA (SH51-01) 1: 250 000 map sheets. The following summary is based on several regolith studies in the district, including regolith–landform mapping, regolith characterisation and geochemical studies (Anand *et al.*, 1991; Twomey, 1992; Ward, 1993).

PHYSICAL SETTING

Geology

The Lawlers district lies within the Agnew Supracrustal belt of the Archaean Yilgarn Craton (Figure 1). The Lawlers greenstone sequence, that forms part of the Agnew Supracrustal belt, is up to 3 km thick and consists of interlayered high-Mg basalt, ultramafic rocks, gabbro and differentiated gabbro-pyroxenite-peridotite sills and thin fine-grained sedimentary and silicic volcanogenic layers (Platt *et al*., 1978).

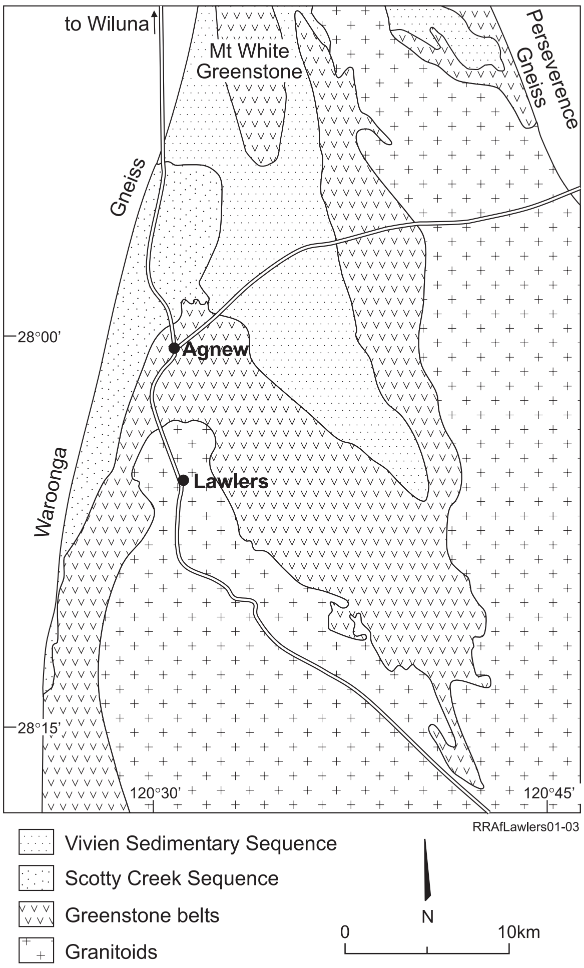

Figure 1. Regional geology of the Lawlers region. (after Platt *et al*., 1978)

Geomorphology

The Lawlers district is a gently undulating terrain with scattered hill belts providing some local relief. The district straddles a divide between the Lake Raeside drainage to the south and that of Lake Miranda and Lake Darlot to the north. For much of its length, the northwest oriented divide comprises the crests of prominent breakaways (Figure 2). Extensive erosional tracts extending south from these breakaways are first dominated by hill belts that give way, southwards, to gently sloping pediments, thinly mantled by debris from the intermediate hinterland. To the north of the divide, the topography is dominated by long, very gentle, smooth slopes. Many of these slopes have their origin on the broadly convex ferruginous duricrust-mantled-crests, immediately above the breakaway and gradually merge down to broad alluvial floors.

Climate and vegetation

The climate is semi-arid with hot summers and mild winters. The mean annual rainfall of 205 mm falls mainly in the summer months during erratic local thunderstorms. The mean daily maximum temperature is 36°C in January and 18°C in July. Sparse, low acacia woodlands with dominant mulga (*Acacia aneura*) characterise the area. The shrub layer is dominated by poverty bush, turpentine (various *Eremophila* spp) and rattle bush (various *Cassia* spp).

REGOLITH–LANDFORM RELATIONSHIPS

A map of regolith–landform relationships at 1:50 000 scale was produced by the interpretation of aerial photographs and Landsat TM imagery substantiated by ground traverses (Figure 3). Several regolith–landform mapping units were identified. The regolith materials that comprise these units were either zones of a deep profile developed by *in situ* weathering of bedrock or consist of unconsolidated, transported debris, parts of which are secondarily cemented. Regolith–landform units have been classified into three major groups. These are (i) ferruginous duricrust and gravel dominated terrain, (ii) saprolite and bedrock-dominated terrain and (iii) sediment-dominated terrain. Simplified regolith–landform relationships for the Lawlers area are shown in Figure 4.

Dark brown to black ferruginous duricrusts and gravels comprise 15% of the mapped area and occupy buttes, crests and backslopes. They occur in both mafic and felsic terrain, but are more common on mafic rocks. Ferruginous duricrusts are either developed from the weathering of underlying rocks (lateritic residuum) or by ferruginisation of sediments (ferricrete). These surfaces are typically mantled by a veneer of gravel lags consisting of pisoliths and nodules and fragments of ferruginous saprolite.

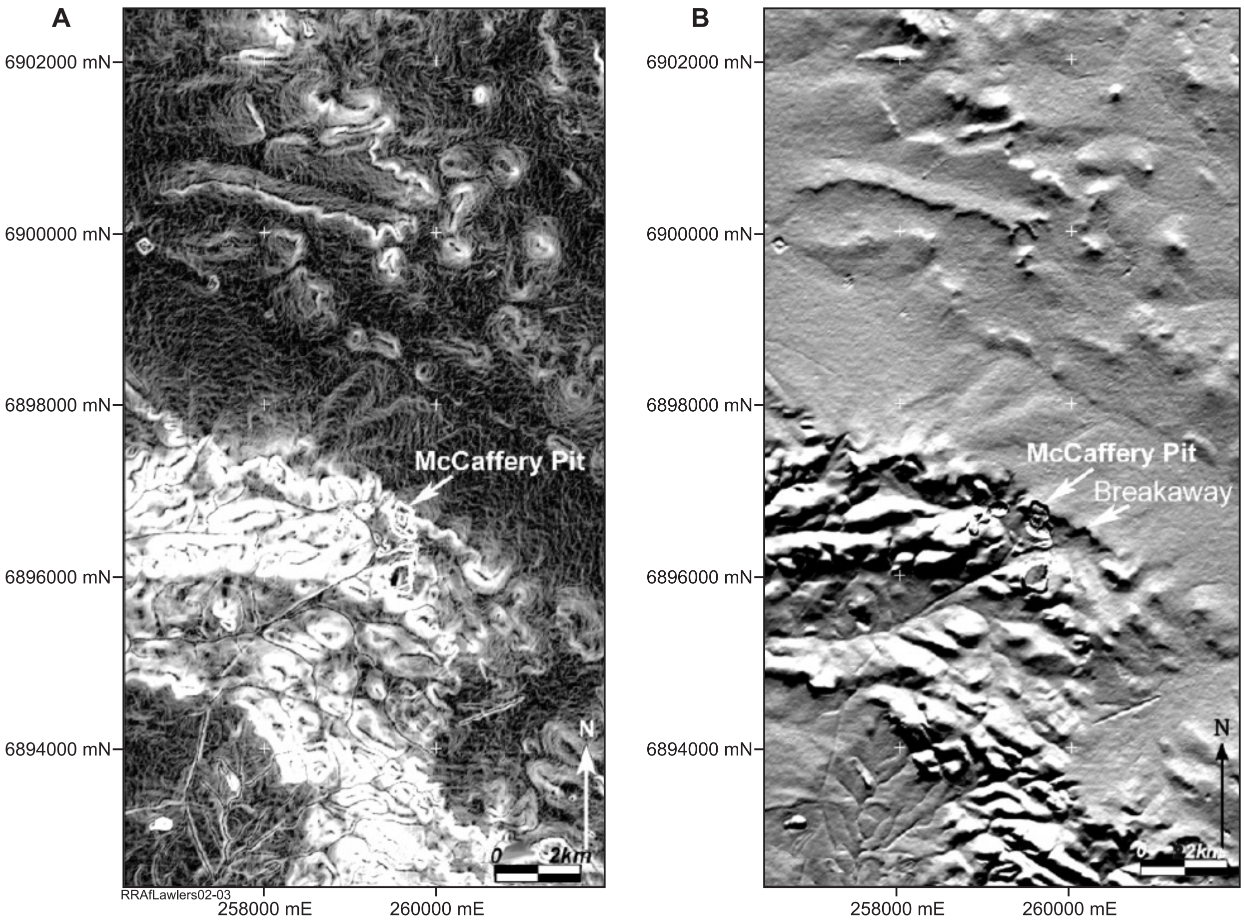

Figure 2. Geomorphic features of the Lawlers district. (a) Intensity of slope about the Lawlers district with slope ranging from 0 to 20. (b) Shaded elevation model about the Lawlers district. (from Tapley, 1998)

The regolith of saprolite and bedrock dominated terrain is characterised by a subcropping ferruginous saprolite, saprolite, saprock and in places by fresh rock outcrop. These materials typically occur on pediments and low and high hills. The pediments are commonly traversed by shallow, open drainages and are commonly mantled with a scree of ferruginous gravels and ferruginous saprolite. A metre or more of sediments may bury the saprolite down slope. On low hills, calcareous soils are common. Iron segregations related to sulphide-rich rocks forming low hills and gently undulating tracts up to several kilometres in length are common. As well occurring in place along the strike of sulphide-rich rocks, they also occur loosely as lag at the surface having been eroded from their original position.

Sediment dominated areas form widespread regolith–landform units whose surfaces are strewn with a polymictic lag. These units account for about 40% of the mapped area and are up to 40 m thick (Figures 3 and 5). Concealed within this colluvial–alluvial cover are earlier depositional regimes comprising Eocene megamottled clay-rich materials confined to inset-valleys[1] and Permian glaciofluvial sediments. Lateritic residuum and ferricrete-capped profiles also occur beneath these sediments, particularly the alluvial plains. Transported maghemite-rich ferruginous gravels occur as sporadic lenses within these sediments. Multi-coloured saprolite developed from mafic and ultramafic rocks typically underlies the ferruginous duricrust and extends to a depth of around 40 m.

REGOLITH CHARACTERISATION

The weathering of felsic rocks results in a relatively homogeneous, pale kaolinitic saprolite profile which is overlain by plasmic and mottled clay zones. In contrast, over mafic and particularly ultramafic rocks the mottled clay zone is absent; instead, the saprolite becomes increasingly ferruginous and brecciated, before merging into ferruginous gravel or duricrust. Towards the top, ferruginous saprolite has undergone solution weathering, resulting in development of a marked porosity in the form of coarse, generally vermiform voids. Amalgamation of these coarse voids leads to the ultimate collapse of ferruginous saprolite. Typically hematite-goethite-rich homogeneous nodules and pisoliths (lateritic residuum) overlying the collapsed ferruginous saprolite comprise both lithic and non-lithic nodules, the fabric and chemical composition of which reflect mafic and ultramafic

[1] The term "inset-valley" is used as an alternative to the word "palaeochannel" or "deep lead" to emphasise their subordinance and entrenched position within a pre-existing network of much broader "primary valleys" (P. de Broekert, written communication, 2002).

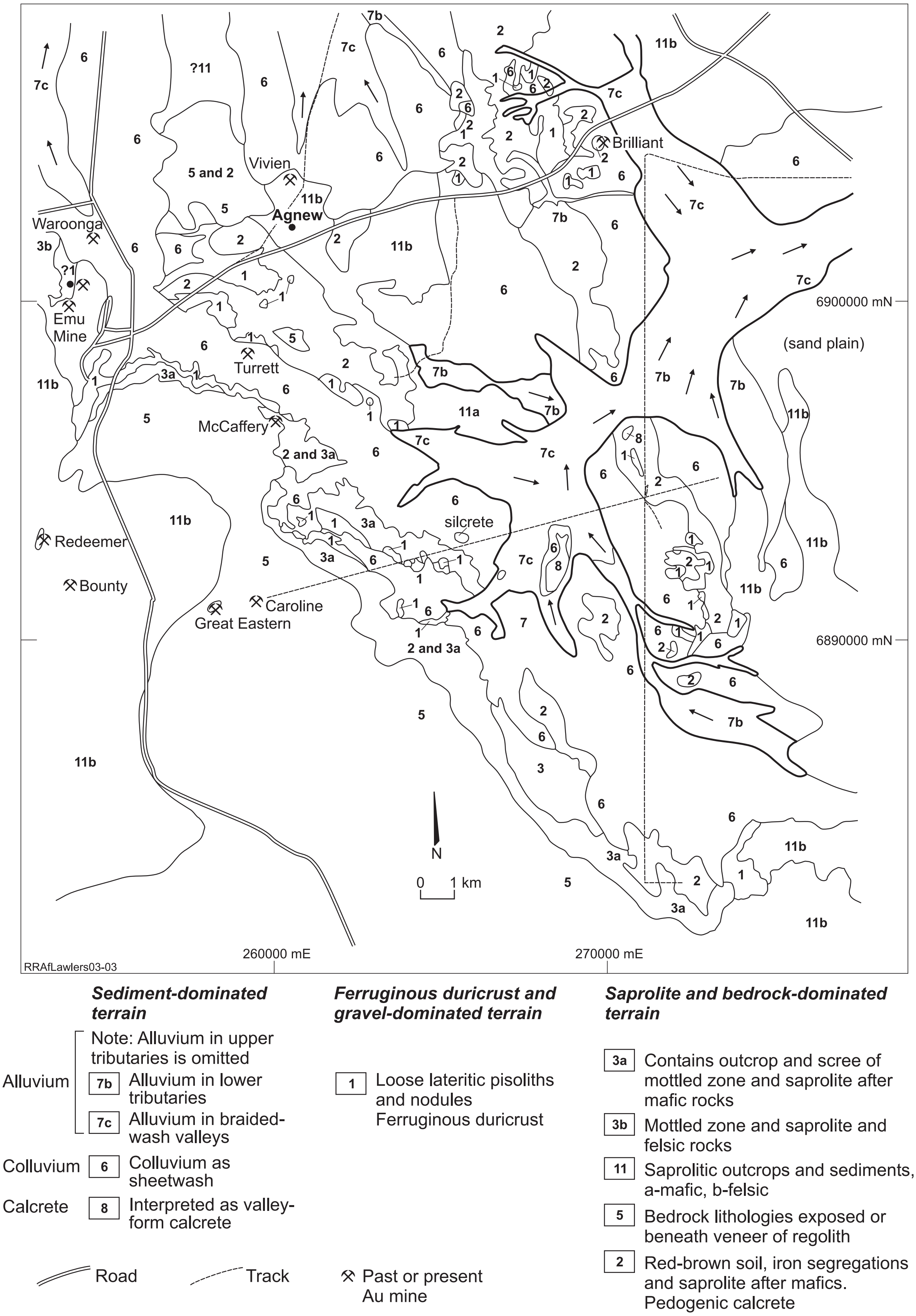

Figure 3. Map showing the surface distribution of regolith–landform units for the Lawlers district. (After Anand *et al*., 1991)

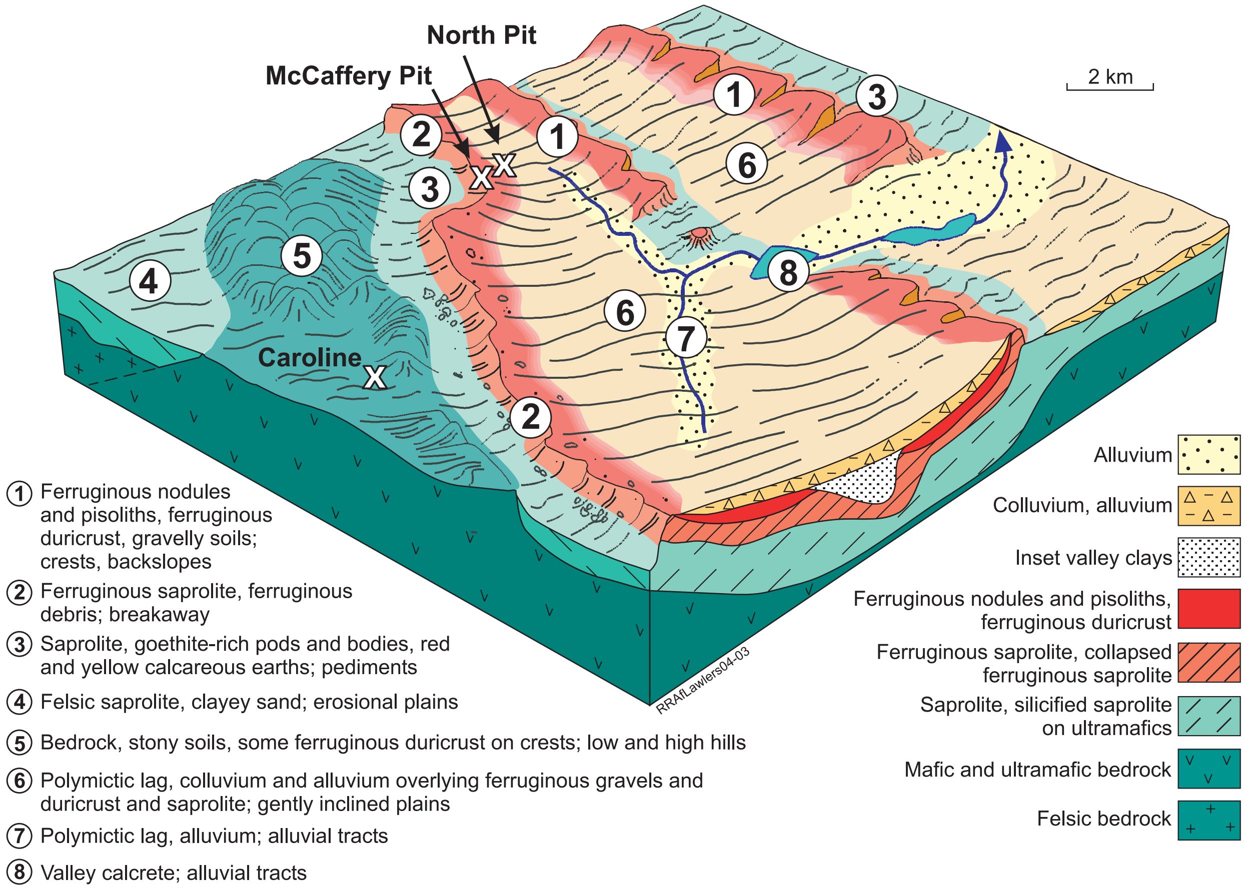

Figure 4. Simplified regolith–landform relationships for the Lawlers area.

lithologies. Lateritic residuum (nodular duricrust and loose nodules) is lower in Fe_2O_3 (32–53%) and higher in Al_2O_3 (25–55%) and SiO_2 (22–35%) relative to the ferricrete.

Ferricretes have a variety of ferruginous clasts derived from erosion of ferruginous duricrust and ferruginous saprolite. They typically comprise dark brown to black, hematite-maghemite-rich nodular or pisolitic clasts supported in a dark brown, goethite-rich matrix. Maghemite is a significant constituent in pisoliths. Some pisoliths are ferruginised wood fragments. Ferricretes are characterised by Fe_2O_3 (69–82%) and very low concentrations of Al_2O_3 (4–7%) and SiO_2 (4–7%). Typically, they show high concentrations of TiO_2 (1–8%).

Goethite in ferricrete shows the least Al substitution (0–11 mole %). In contrast, Al substitution in goethite from lateritic residuum ranges from 6 to 28 mole % with an average value of 18 mole %. The differences in Al substitution suggest different environments and/or mechanisms of formation. Massive, silicified saprolite is characteristic of Al-poor ultramafic rocks.

Some iron segregations are gossans which exhibit boxwork fabrics, while others are formed by the ferruginisation of the wall rocks and redeposition of Fe in the saprolite, forming stringers, pods and tubular bodies. The chemical composition of iron segregations is different from that of lateritic residuum and ferricrete. Iron segregations are charactertised by greater concentrations of Fe_2O_3 (>75%), Mn (2820–4328 ppm), Zn (320–695 ppm) and Co (84–137 ppm).

There are three principal sedimentary units:

1. Quaternary sediments are typically colluvial talus and detritus shed from upslope during rare flooding and sheetwash events and alluvial channel deposits. In general, colluvial and alluvial deposits fine toward the top so that this unit may be subdivided into an upper, sandy clay component, and a lower gravelly component. Authigenic silicification (hardpanisation) is most strongly developed in the upper, sandy clay component of the profile, reaching a thickness of some 15 m, but most commonly 6–7m. Red-brown hardpans are formed by partial replacement and cementation of the matrix and clasts by opal A with lesser goethite and hematite, accompanied by clay illuviation. Colluvial units show the effects of post-depositional weathering in the form of goethitic mottles and secondary goethite associated with void-infill material.

2. Inset-valley fills are poorly crystalline kaolinite-smectite clays that are extensively megamottled. Minor quartz sands, up to 1mm in diameter occur in the clays and are rounded and water worn. In places, the grey clays contain spherical, 1–10 mm yellow-brown goethite-rich pisoliths. Some have a thin (<1mm) goethite cutan but most have multiple cutans and

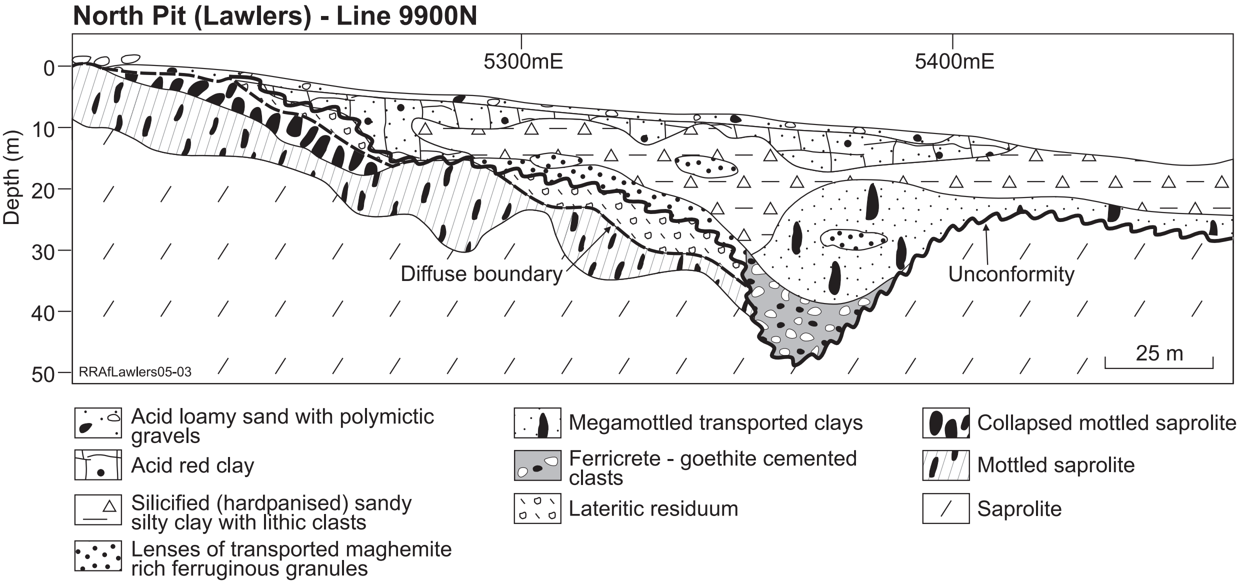

Figure 5. Regolith distribution in depositional areas at North Pit, Lawlers.

a variety of cores including hematite–maghemite fragments, ferruginous lithic fragments, clay, organic debris, quartz or a mixture of these.

DATING

Palaeomagnetic results from the Turret and North Pits assign a Late Cretaceous and Palaeozoic age respectively for the saprolite (B. Pillans, CRCLEME/ANU, written communication, January, 2000).

REGOLITH EVOLUTION

Regolith records a complex history including weathering, truncation and burial. Glaciation during the Late Carboniferous and Early Permian (BMR Palaeogeographic Group, 1990) is evidenced by the prominance of glaciogene sediments in the Genesis pit at Lawlers. It is envisaged that glaciation would have stripped most traces of any pre-existing regolith. Pre-glacial remnants may however have been preserved e.g. saprolite in the North Pit. The regolith in the Lawlers district can be explained by progression from a moist, humid to possibly temperate climate with high water tables to the presently arid and semi-arid conditions. The humid climate during the Cretaceous to Mid Miocene gave rise to extensive, deep weathering. It is thought that Mesozoic landscape on greenstones comprised broad, shallow valleys that were surrounded by an elevated granitic and greenstone hinterland. Broadly contemporaneous weathering of topographically higher parts and palaeovalley formed saprolite, lateritic residuum and ferricrete; the valleys were prone to ferruginisation. This has resulted in ferruginous upper horizons forming in residuum and in sediments. Lateritic residuum has developed from bedrock by essentially residual processes. In contrast, ferricretes develop by impregnation and cementation by Fe oxides of clasts, clays and sands. In places ferricretes now occupy topographically higher areas because of relief inversion.

During the Early Eocene, drainage incision along broad valleys in the weathered landsurface developed a younger generation of inset-valleys. Formation of the inset-valleys involved stripping of the regolith both beneath and beyond the inset-valley margins. Incision of the inset-valleys was most likely caused by stream rejuvenation following epeirogenic uplift (Cope, 1975). A change in conditions occurred which caused the stream beds to aggrade. Deposition of the clay facies in these inset-valleys probably took place under lucustrine to swampy settings. The landscape following deposition of these sediments probably comprised slightly elevated (but dissected) area of Mesozoic terrain, surrounded by lower sediment-covered terrain. Post-depositional weathering has affected both the inset-valley fills and the underlying bedrock.

In the late Tertiary and Quaternary, weathering under semi-arid to arid conditions was dominated by evaporation and reduced groundwater migration, accumulating weathering products in the regolith that would otherwise be leached. Erosional modification has been considerable, reflecting widespread and frequent landscape instability but, in the absence of effective drainage systems, the resulting superficial deposits have been retained in the landscape. Colluvial, alluvial and aeolian sediments are extensively overprinted by current pedogenic and diagenetic processes. Extensive hardpanisation of the sediments and *in situ* regolith indicates widespread mobilisation of silica and deposition in the upper regolith. Calcification is the youngest event and postdates silicification.

REFERENCES

Anand, R.R., Churchward, H.M., Smith, R.E. and Grunsky, E.C., 1991. Regolith-landform development and consequences on the characteristics of regolith units, Lawlers District, Western Australia. CSIRO Division of Exploration

Geoscience, Perth. Restricted Report 166R, 167pp.

Bureau of Mineral Resources Palaeogeographic Group, 1990. Australia: Evolution of a continent. Bureau of Mineral Resources (Geoscience Australia), Canberra.

Cope, R.N., 1975. Tertiary epeirogeny in the southern part of Western Australia: Western Australian Geological Survey Annual Report for 1974, 40-46.

Platt, J.P., Allchurch, P.D. and Rutland, R.W.R., 1978. Archean tectonics in the Agnew supracrustal belt, Western Australia. Precambrian Research, 7: 3-30.

Tapley, I.J., 1998. Landform, regolith and geological mapping in Australia using polarimetric and interferometric radar datasets. CSIRO Exploration and Mining. Restricted Report 529R.

Twomey, R.F., 1992. Regolith-landform relationships in the Agnew area and multi-element dispersion into the weathering profiles of the Genesis and Waroonga gold deposits, Lawlers. BSc Honours Thesis, University of Western Australia, Perth. 98 pp. (Unpublished).

Ward, R.S., 1993. Regolith-landforms and geochemical dispersion in transported regolith in the Genesis gold deposit, Agnew region, Western Australia. BSc Honours Thesis, Curtin University of Technology, Perth. 81 pp. (Unpublished).