CAIRLOCUP AREA, WESTERN AUSTRALIA

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INTRODUCTION

The Cairlocup area is situated about 400 km southeast of Perth in the southern wheatbelt of Western Australia (centre point 33°43'30"S, 118°47'30"E), at the southern extremity of the Swan–Avon Drainage System, which flows into the Indian Ocean near Perth. It comprises 5 200 ha, with the southern boundary adjacent to the Jarrahwood axis (Cope, 1975), a line that separates regional northerly and southerly drainage (Figure 1). The area occurs on the NEWDEGATE (SH50-8) 1:250 000 map sheet.

The Cairlocup area is beset by various forms of land degradation and was studied primarily in order to relate the distribution of land degradation to landscape processes and hence also the distribution of soil parent materials (Harper, 1994; Harper and Gilkes, 1994a, b, c). This geomorphic framework has subsequently been used to provide an indication of the distribution of soil potassium (Wong and Harper, 1999) and soil carbon fluxes (Harper and Gilkes, 2001), an important consideration in managing global warming.

The study required the development of a soil–landscape model, which also has relevance for mineral exploration, particularly for techniques that are influenced by variations in properties of surficial materials. An overview of this soil landscape model is presented here.

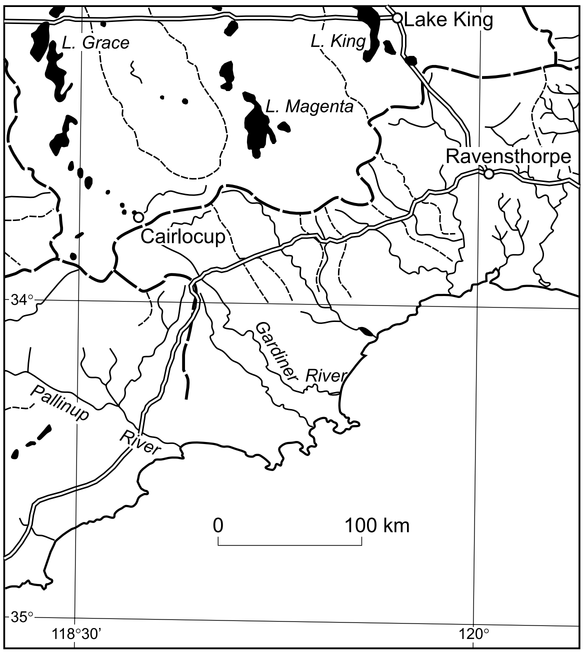

Figure 1. Location of the Cairlocup area.

PHYSICAL SETTING

Geology

The geology of the NEWDEGATE sheet area has been mapped by Thom *et al.* (1984). The Cairlocup study area is underlain by Precambrian granitic rocks, ranging from post-tectonic porphyritic granite and adamellite in the west, to strongly foliated gneiss of adamellitic, granitic or granodioritic composition in the east (Thom *et al.,* 1984). The basement rocks are totally obscured by deep weathering. Quaternary deposits of at least 30 m thickness occur beneath the valley floor.

Geomorphology

The study area comprises a gently undulating landscape. A broad valley floor contains both relict and active playas of which Lake Cairlocup (200 ha) is the largest (Figure 2). The valley hosting Lake Cairlocup is bounded to the north and east by ridges which have a relief of 30–40 m and side-slopes of 1–3%. These ridges are composed of deeply weathered granite. The deep weathering mantle has been variably truncated, with soils formed on the mottled and pallid zones of the former lateritic profile. Unlike other deeply weathered areas of the Yilgarn Craton, marked erosional scarps (breakaways) and granite outcrops (inselbergs) do not occur.

Lunettes, which are clayey aeolian saltation deposits, occur either as single members or multiple arrays on the southeastern shore of both contemporary and relict playas (Figure 2). The valley floor is dominated by a seven member, 5 km long, multiple lunette array, the lunettes ranging in height from 1 to 14 m.

Sand dunes and sheets occur in the valley floor and surrounding hills within a distinct 10 km long and 2 km wide belt, downwind of the ephemeral Cairlocup Creek (Figure 2).

Climate and vegetation

The annual rainfall of 350 mm is mostly received in winter. Native vegetation comprises mallee woodland (*Eucalyptus* spp.) and farming involves annual rotations of cereal (*Triticum aestivum*, *Hordeum vulgarum*) or legume (*Lupinus angustifolius* L.) crops with improved annual pastures (*Trifolium subterraneum*, *Lolium rigidum*).

REGOLITH–LANDFORM RELATIONSHIPS

The study area was mapped at a scale of 1:12 500 using field observations and aerial photographic interpretation. Seven geomorphic units containing 15 soil series were identified (Figure 2). For simplicity, only the geomorphic units are described here.

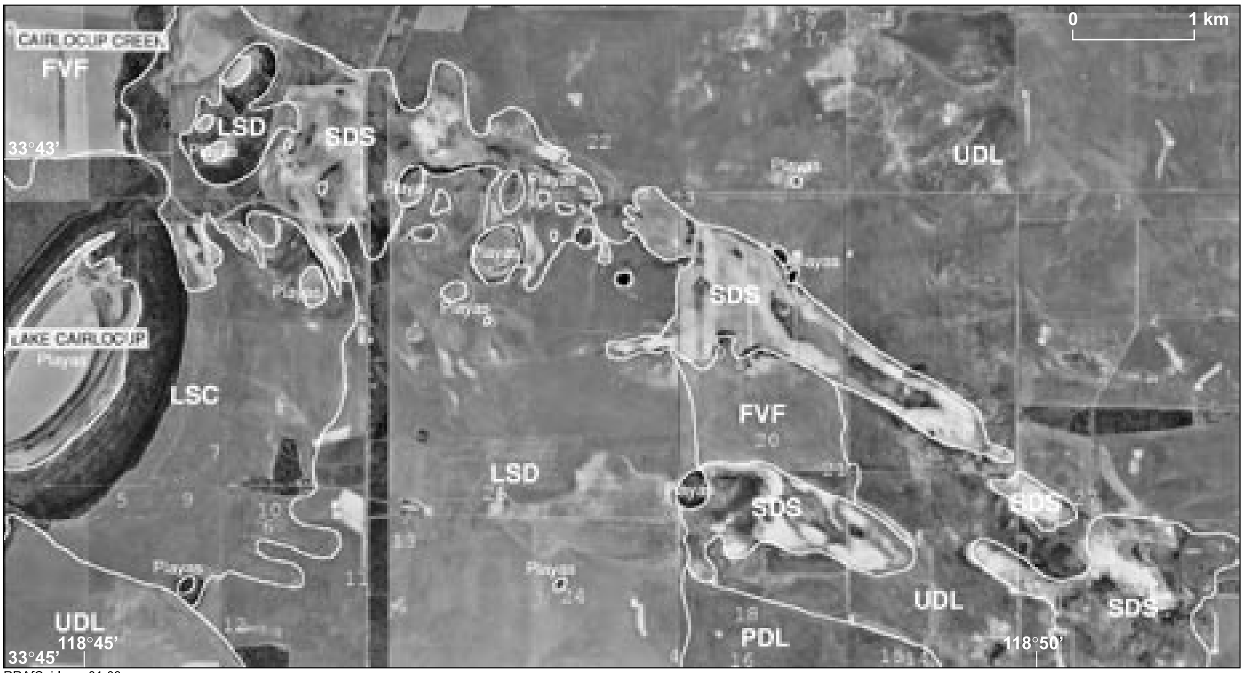

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Figure 2. Aerial photograph of Cairlocup area showing major geomorphic units.

The seven geomorphic units can be considered in terms of the following three major groups:

1. *Deeply weathered granitic ridges and slopes*. Two geomorphic units were defined in the deeply weathered granitic terrain, based on the degree of landscape dissection. Here the soil parent materials have been deeply weathered and subsequently dissected to various degrees, with the soil parent materials comprising the horizons of the previous lateritic profiles (Mulcahy, 1960). Unit UDL occurs where dissection appears to have been minimal and the soils have formed on ferricrete horizons, and associated slope deposits. Sandy surfaced, texture contrast soils occur within these areas (Plinthoxeralfs, Natrixeralfs (Soil Survey Staff, 1987); Dy 3.81, 3.84, 5.86, Gn 2.21 (Northcote, 1979)).

Unit PDL occurs where the pallid zone, a deeper horizon of the former lateritic profile, has been exposed. Sandy surfaced texture contrast soils also occur within these areas (Natrixeralfs; Dy 2.53, 2.83, 4.86), often containing calcrete nodules or concretions.

2. *Valley floor*. The valley floors are poorly drained and comprise sequences of Quaternary sediments (Thom *et al.,* 1984) dominated by Lake Cairlocup, a 200 ha hypersaline playa. This is bounded by a series of source bordering lunettes (clay or parna dunes) that extend 5 km to the southeast (Figure 2). These clay dunes were formed from materials eroded by wind from the playa bed during former dry periods (Bowler, 1973) and represent a chronosequence, with the youngest materials closest to the playa shore. Pedogenesis of the clayey sediments has produced an array of soils.

Areas of the valley floor with lunettes and associated swales have been separated into two geomorphic units — those composed of loamy soils (Xerochrepts; Dy 2.13, Gc 1.12, Gn 3.93), which occur immediately adjacent (0–2 km) to Lake Cairlocup (Unit LSC), and those with sandy texture contrast soil profiles (Natrixeralfs; Dy 2.83, 3.43, 3.83, 5.83), some distance (2-5 km) from Lake Cairlocup (Unit LSD). A third, small, geomorphic unit (Unit FVF) was defined for those areas of the valley floor without playas or lunettes. This contained texture contrast soils with carbonate nodules at depth (Natrixeralfs; Dy 2.23)

3. *Sandy aeolian deposits* Sand dunes and sheets of variable depth occur as a discontinuous, NW–SE oriented belt ~10 km long and 2 km wide, directly southeast of the ephemeral Cairlocup Creek (Unit SDS). These are most likely saltation deposits associated with a former source-bordering sand dune system. Deep (>1 m) quartzose sands (Typic Quartzipsamments; Uc 2.21, 2.23) overlie a range of substrates and landscape positions. This feature most likely represents former quartzose aeolian deposits, derived from an ephemeral drainage line.

Texture contrast soils thus predominate in both lateritised uplands and valley floor positions. The nature of the surface sand horizon varies systematically in depth and field texture across the landscape. Whereas crests often have shallow (~10 cm deep) clayey sand surface horizons, the surface horizons in lower slopes and upland depressions are deeper (~60 cm), sandy, and better sorted. Deep sandy soils occur on former sand dunes and sheets.

Nodular ferricretes are mainly associated with the lateritised terrain, however ferricretes also occur in some sand dunes and the swales of multiple lunette arrays. Calcrete mainly occurs in the valley floor, but also occurs in the lateritised uplands where it may cement ferricrete nodules. Calcrete occurs either as nodules or soft segregations, and is comprised either of calcite or dolomite, or some combination of the two. Silcrete occurs in isolated areas fringing the lateritised uplands. Kaolin clays occur in all soils, with illites also occurring in some valley floor soils, and in the upland soils southeast of Lake Cairlocup.

PATTERN OF LANDSCAPE DEVELOPMENT

The broad geomorphic history and pattern of soil development in the Cairlocup area can be summarised as follows:

1. An undulating landscape mostly on granitic rocks was intensely weathered, producing deeply weathered profiles with associated ferricrete.
2. The deeply weathered profiles were variably stripped, as a result of climate change and the rejuvenation of drainage lines. Remnants of old weathering profiles are omnipresent and include ferricretes on ridge crests and spurs, and deeply weathered materials (pallid zones and saprolites) under much of the landscape.
3. The valley floor was filled with an array of sediments, to a depth of at least 30 m. The nature of these materials, particularly their depth, requires further investigation.
4. Playas and associated lunettes formed along the valley floor in response to changes in local and regional hydrology. Multiple lunette arrays are evidence that lunettes have been formed over a long period of time, with lunette building likely to be a periodic event in response to previous climatic cycles. Similarly, the lunettes are evidence of previous periods of more extensive salinization (Harper and Gilkes, in press).
5. Dust was eroded from the playas coeval with lunette building. This dust was deposited as a veneer over the soils in a plume to the southeast of Lake Cairlocup. Consequently, in contrast to soils elsewhere in the landscape, these soils are more alkaline and contain carbonates and illitic clays.
6. Colluviation of sand resulted in the sandy horizons of soils in lower slope positions being deeper, less clayey, and better sorted than those further upslope. This occurred in both the lateritised uplands and on lunettes.
7. Sand was transported by wind from Cairlocup Creek and deposited on an array of landscape elements. This was most likely a periodic process with the sand supply in Cairlocup Creek being replenished by periodic flooding, and deflated by periodic strong winds. Similarly, localized aeolian movement of sand resulted in deeper sands on the southeastern slopes of some ridges.

Aspects of this interpretation of landscape development and the distribution of soil parent materials are broadly similar to those developed in previous studies (Mulcahy, 1960; Mulcahy and Hingston, 1961; Bettenay and Hingston, 1964; Churchward, 1970). Contemporary soils have mostly formed on a range of pre-weathered materials variably exposed by gross landscape stripping, and from aeolian deposits derived from playas (Bettenay, 1962). Some of the previous interpretations can, however, be modified as a result of this study.

A strong aeolian influence is evident across the landscape, with features such as playa shapes, the orientation of the multiple lunette arrays and parabolic blowouts in clayey lunettes suggesting that the geomorphologically most effective winds have been from the northwest. Wind is also a contemporary agent affecting the landscape, periodically causing severe soil erosion (Harper and Gilkes, in press).

PATTERN OF SOIL PROPERTIES AND LAND DEGRADATION IN RELATION TO GEOMORPHIC SURFACES

There are broad differences in the response of different parts of the landscape to land degradation. For example, the geomorphic surfaces UDL, LSD and SDS are susceptible to wind erosion, with 47% of the total area of SDS eroded (Figure 3a). Similarly, water repellency is most prevalent on the sandy surfaces SDS and UDL (Figure 3b).

Strong patterning is also apparent for other soil properties, with surface LSC having the greatest mechanical strength (Figure 3c), containing the most organic carbon (Figure 3d), being the most alkaline (Figure 3e), and having the greatest fertility (Figure 3f). Surface SDS, by contrast, has the weakest soils and poorest fertility, as measured by organic carbon and exchangeable potassium contents.

CONCLUSIONS

The pattern and properties of soils in the Cairlocup area can be explained by a conceptual soil–landscape model in which the results of wind and water dependent geomorphic processes are superimposed on a previously deeply weathered terrain. As several land degradation processes are related to soil properties, this soil–landscape model also provides an insight into the distribution of contemporary land degradation. Much of this is due to the strong geomorphic control of the clay content and mineralogy of the soil surface horizons, with systematic differences in clay content across the landscape.

The findings of this study are also relevant to mineral exploration, since geochemical models in the deeply weathered terrain of Australia often rely on correlations between sub-surface and surface contents of various elements. These models will, for example, be confounded by the movement of surface sands and deposition of aeolian dust, which has a composition dissimilar to the underlying deeply weathered material.

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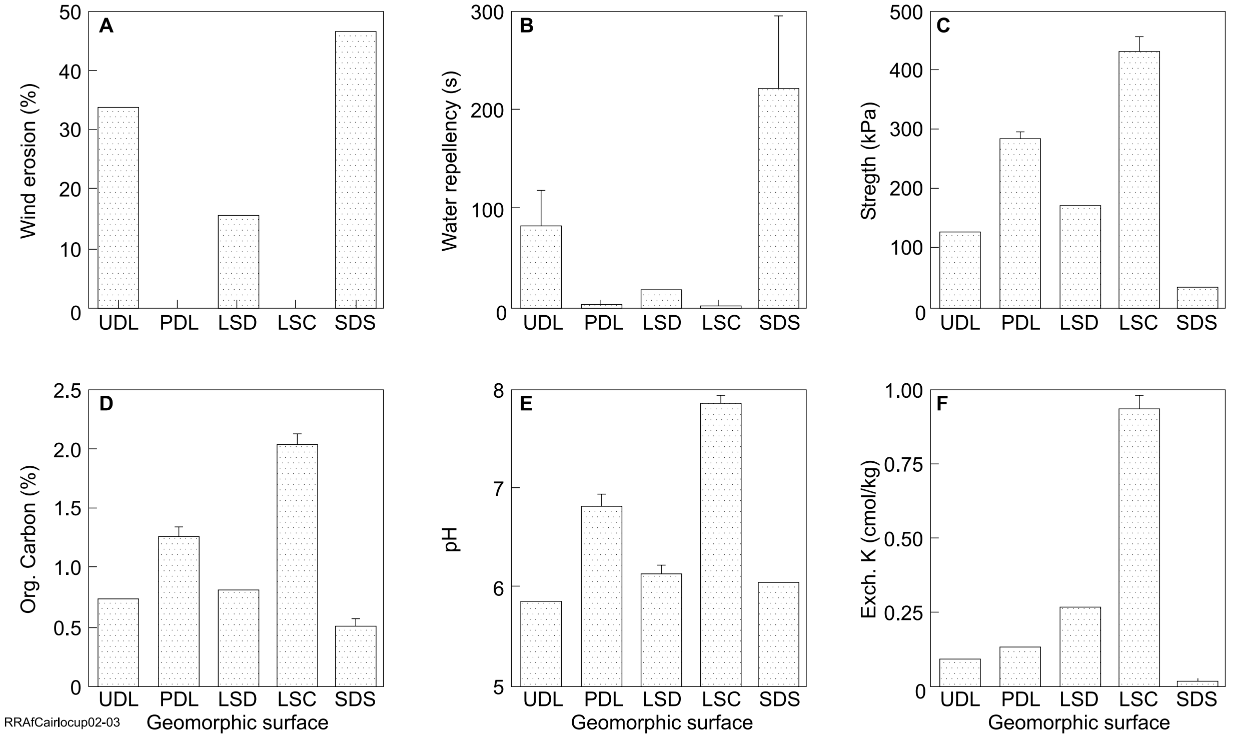

Figure 3. Variation in land degradation and various soil properties for the five major geomorphic units. (A) wind erosion measured as the proportion of the total area of each unit eroded; (B) mean water repellency assessed with the water drop penetration test; (C) soil strength measured with a penetrometer; (D) organic carbon content; (E) pH measured in a 1:5 soil–water mixture; and (F) exchangeable potassium content. Analysis based on 219 samples.

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