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Landscapes and soils of the Lake Grace district

D N. Sawkins

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ACKNOWLEDGMENTS

I would like to thank the following for their invaluable assistance: Dr Bill Verboom for his ideas, encouragement and critique in the development of this bulletin; Phil Goulding for the map images, and Peter White of the Western Australian Department of Environment and Conservation for assistance with editing and the indicator vegetation guide.

Developed and compiled by Doug Sawkins, Department of Agriculture and Food, Western Australia, Narrogin office, April 2011.
INTRODUCTION

The agricultural areas of Western Australia are diverse, with a wide range of landscapes, soils and associated native vegetation.

This bulletin was designed as an induction course for employees of the Department of Agriculture and Food recently posted to the department’s district offices, but the information is also useful for other professionals and landholders who work in these areas. The publication aims to provide readers with the principles underlying the formation of local landscapes and soils, and the ability to identify landscapes and their associated soils. The emphasis is on field application.

The bulletin also provides a basis for developing a more detailed knowledge of:

- local soils and land capability
- salinity and hydrology
- local farming systems
- landcare and nature conservation.

Bulletins in this series cover the following areas (also see Figure 1).

<table>
<thead>
<tr>
<th>District</th>
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<tbody>
<tr>
<td>Albany</td>
<td>Denmark, Plantagenet, Albany, Cranbrook</td>
</tr>
<tr>
<td>Katanning</td>
<td>Wagin, Tambellup, Broomehill, Gnowangerup, Kojonup, Katanning, Woodanilling, Dumbleyung, West Arthur, Kent (west)</td>
</tr>
<tr>
<td>Lake Grace</td>
<td>Kulin, Lake Grace, Kondinin, Kent (east)</td>
</tr>
<tr>
<td>Merredin</td>
<td>Mount Marshall, Yilgarn, Bruce Rock, Mukinbudin, Westonia, Koorda, Trayning, Narembeen, Merredin</td>
</tr>
<tr>
<td>Moora</td>
<td>Gingin, Chittering, Dalwallinu, Dandaragan, Victoria Plains, Moora</td>
</tr>
<tr>
<td>Narrogin</td>
<td>Brookton, Pingelly, Cuballing, Williams, Narrogin, Wandering, Corrigin, Wickepin</td>
</tr>
<tr>
<td>Esperance</td>
<td>Esperance</td>
</tr>
<tr>
<td>Jerramungup</td>
<td>Ravensthorpe, Jerramungup</td>
</tr>
<tr>
<td>Geraldton</td>
<td>Greenough, Mullewa, Northampton, Irwin, Geraldton, Mingenew, Chapman Valley</td>
</tr>
<tr>
<td>Three Springs</td>
<td>Coorow, Carnamah, Three Springs, Morawa, Perenjori</td>
</tr>
<tr>
<td>Northam</td>
<td>York, Tammin, Quairading, Northam, Goomalling, Wyalkatchem, Beverley, Toodyay, Cunderdin, Dowerin</td>
</tr>
</tbody>
</table>
Each bulletin has been designed as a self-teaching module that contains the following components:

- section describing soil and landscape formation in the district
- decision aids for use in the field
  - indicator vegetation guide that is useful for a quick understanding of soil type variations as signified by remnant native vegetation
  - other decision aids to help you identify landscape types, land units and common soil types in the district
- half-day documented field trip with specific stops to provide field examples of the information covered in the bulletin, to give practice in using the decision aids
- case studies. Two examples of areas in the district displayed with a map and photographs of numbered points within the area to illustrate the soils and landscape. These real-life examples show the diversity of landscapes that make up the soil landscape systems and explain the variations that occur. Distances are shown so that you can visit each area using the document as a guide
- references
- glossary.

Figure 1 shows district boundaries and the proportion of the area that is available for agriculture (areas outside the reserves shown in green).
Landscape development in the Lake Grace district

This section introduces factors influencing soil and landscape development in the Lake Grace district.

This 9245 sq km district, also known as the Lakes district, is a part of the mallee zone that forms an arc from about Narembeen–Hyden in the north to the Jerramungup district in the south and the Esperance mallee in the east. Extensive salt lake chains in the Lake Grace district grade north-west to join the Avon Catchment and eventually the Swan River. They have very low gradient and the whole system only flows after exceptionally high rainfall.

Figure 2 shows the low divides that bound the district on all sides. The landscape is subdued in the south with mainly grey duplex soils. To the north the landscape becomes more undulating, with more lateritic sands and gravels on uplands, and rock outcrops on slopes.

![Figure 2: Major drainage areas in the Lake Grace district](image)
The ternary radiometrics image of the district in Figure 3 clearly shows the change in soil types from north to south. In the north, there is much greater variation in colours, with green-and red-dotted uplands that indicate laterite and rock outcrops in an undulating and partially dissected landscape. In contrast, black-dark blue (grey sand) and blue (shallow topsoil over pale clay) dominate the more subdued landscape to the south.

Radiometric imagery is an additional useful tool for mapping changes in soil type. More detailed examples of its use are contained in the case studies.

Figure 4 shows processes involved in landscape and soil formation, and factors that drive these processes.
Processes and factors influencing landscape and soil development

A discussion of the processes and factors influencing landscape and soil development follows.

Geology and tectonic movement

There are marked differences in underlying rocks, which weather and erode in distinctive ways. Differential weathering of rock types, faulting and geological uplift have had large effects on landscape relief and soil type.

Figure 4 Processes and factors influencing landscape and soil development

Figure 5 Geology of the Lake Grace district
The Lake Grace district lies on the Yilgarn Craton, an ancient and relatively stable area of granites and gneiss—a metamorphic-banded granite-like rock (Western Australian Department of Mines 1990).

Figure 5 shows that many features on the Craton, such as faults, dykes, major rock formations and waterways, trend north-west/south-east, east-west or north-east/south-west. The north-west alignment of the major rock bands reflects the Craton’s formation over many hundreds of millions of years, as ‘rafts’ of land on tectonic plates collided to form bands of gneiss. Over time, the bands of gneiss were intruded by granites.

Gneisses are metamorphosed igneous rocks that vary in their mineral content, ranging from light-coloured quartz-rich rocks to dark-coloured mafic rocks that are rich in magnesium and iron. Metamorphic rocks have been modified by heat, pressure and chemical processes while buried deep below the Earth’s surface.

Bands of greenstone were formed when intra-plate rifts were alternately filled by sediments and volcanic rocks, and then also became extensively metamorphosed by ongoing plate collision. Stresses associated with these events caused cracking and intrusion of dolerite as dykes throughout the Craton. These dykes can be locally significant as soil material (for example, the Binneringie dyke that traverses Kulin–Karlgarin–Hyden), and are frequently associated with mafic lateritic ridges. Although mainly igneous rocks underlie the district, major valleys have been infilled by sediments that form the extensive salt lake system.

Soils formed directly from igneous rocks are often found in relatively small patches in dissected landscapes intermixed with other soils. They tend to be more common where there is more slope and more effective surface drainage, particularly in mafic areas.

Figure 6 shows a range of soils formed directly from felsic (acidic) rocks in the district.

Figure 6  **Felsic (quartz-rich) rocks and associated soils**
Figure 7 shows a range of soils formed directly from mafic (basic) rocks. Examples include mafic gneiss, greenstone, dolerite and gabbro (a coarse-textured variant of dolerite). These rocks contain large proportions of ‘dark' minerals and high levels of calcium and iron. They weather to red-brown-to-brown clay loam, and to clay soils with alkaline and often calcareous subsoils. Soils formed on mafic rock are more common in the Kulin–Kondinin–Kарlgarin areas.

When Australia separated from India and Antarctica following the break-up of the Gondwana supercontinent, resultant stresses had a significant effect on landscape formation in Western Australia. Extensive faulting and uplifts on the south and west of the Yilgarn Craton caused marked changes to slope and drainage patterns.

About 70 million years ago, major rivers flowed south from north of Merredin to a gulf that formed as Australia began to separate from Antarctica (see Figures 8 and 9). These rivers were erosive, creating deep valleys that are now largely infilled.

About 43 million years ago, earth movements resulted in uplift parallel to the south coast. To the north of Jerramungup that uplift is called the Jarrahwood Axis. At the same time the Yilgarn Craton tilted down towards the north to a fault (called the Chin-Smith lineament) that runs west/south-west near Merredin. This caused the rivers to reverse their flow to the lineament that then diverted them west to join the Avon river system.

An associated uplift north of Hyden blocked the river that flowed from Lake King so that it created a west-flowing path exposing igneous rock and associated soils on the slopes of the trunk valley.
Another general upward tilt to the north of the Yilgarn Craton reduced the grade of north-flowing rivers which, with a general drying climate, resulted in the presently subdued landscape with salt lakes and associated aeolian soils.

Australia as part of the Gondwana supercontinent from CR Scotese (2007)

Inferred paleorivers in the Eocene period from Beard (1999)

Figure 8 Inferred major river systems in the late Cretaceous from Beard, JS (1998)

Native vegetation
In Western Australia there is a close relationship between soil types and native vegetation, with vegetation and associated soils often forming complex mosaics in the landscape. In most areas, the soil varies over short distances, and intergrade soils such as sand over gravel over clay are common, as are duplex sandy gravel soils.

Figure 10 shows an example of an intergrade soil from the mallee zone but similar changes are associated with a range of soils and vegetation communities that occur in Western Australia.
There is considerable evidence (Verboom & Pate, 2003) that plants can engineer soil conditions to deny water and nutrients to competitors. Plants and associated microorganisms create horizons in many of our soils, particularly through root secretions.

A general introduction to the role of biology in soil formation can be found in Bulletin 4823 (Sawkins et al. 2011). Common examples in the district are:

- laterite formation by members of the Proteaceae family and *Allocasuarina* genus (particularly tammas) that control access to soil phosphorus in well-drained acidic situations
- mallee duplex soils with silica ‘seals’ and/or dense clay on or above the subsoil that generally restrict understorey access to stored water. The mallees themselves use their roots to store and access water using a process called hydraulic redistribution. Surface water may also be transmitted directly to these storage zones via macro pores that arise when roots shrink during heavy rain
- formation of lime deposits in subsoils of alkaline soils assisting in soil water storage and perhaps controlling access to soil phosphorus.

Laterites are soils in which iron and aluminium have accumulated in the profile, usually as gravels. Reticulite is a hardened layer in a laterite profile, usually with residual root channels.
Most laterite formation involves plants and bacteria, which accounts for observations that different laterites occur under different populations of plants, and that laterite is still forming where there is sufficient rainfall. Figure 11 shows a simplified version of sandy gravel formation.

The following factors are required for laterite development:

- plants with proteoid roots (dense clusters of rootlets of limited growth) and associated bacteria. Plants secrete organic molecules of low molecular weight carboxylates (LMCs), which form a compound with phosphorus (and iron and other minerals such as aluminium and silica) that is soluble in water and can be absorbed by plant roots. Most of the plants with proteoid roots are Proteaceae (most noticeably dryandras, banksias and hakeas), and Casuarinaceae (tammas and sheoaks). Bacteria use excess LMCs as food and so precipitate the minerals. Gradually iron becomes depleted near the soil surface and accumulates further down as ferricretes (gravels and reticulite). Minerals are also mined using chelation (binding to LMCs), and uplifted and concentrated in the upper regolith by plant hydraulic lift. This is a primary reason why very sandy materials can have stony ferricretes over sandy lower layers, and why lateritic pallid zones occur

- low phosphate soils. Proteaceae and Casuarinaceae have a competitive edge over other vegetation in these soils. In more fertile soils other species are often more competitive

- leaching (acidic) soil conditions. Many proteaceous plants and associated bacteria function best in acid-to-neutral soil conditions. Laterites will not form on poorly drained or alkaline soils (the LMCs involved are deactivated by calcium). This explains why most laterites are found on well-drained ridges and slopes, or in valleys that have good internal drainage

- enough rainfall to move the dissolved minerals down the soil. Rainfall is required to move the chelated iron down the soil profile. If not, the iron would remain near the surface and the deeper laterite layers would not form. Typical laterite profiles are more common in higher rainfall areas, such as the Darling Range.

Figure 12 shows typical laterite-forming vegetation.
A ‘typical’ granitic laterite profile has five layers: a sandy surface overlying small round gravel; blocky ironstone; mottled clay and then a pallid zone, sometimes referred to as ‘pipe clay’. Saprock is a zone of partially weathered bedrock below the pallid zone that is quite permeable, allowing for groundwater movement. In fact there is a range of range of lateritic soils that support different plant communities, with each community in competition with each other and responding to variations in climate and landscape.

The profiles of lateric soils in the district vary according to:

- rock type. Laterites formed from mafic rocks have darker, heavier, more iron-rich ferricrete with more clay in the soil matrix (Figure 13). As mafic laterites are more resistant to erosion, mafic soil areas tend to be found on ridges and on undulating and dissected uplands. For more information, see Bulletin 4807 that describes the adjoining Narrogin district.
- climate. In well-drained, higher rainfall areas, laterites tend to be more fully developed. Pale sandy gravels are more common in felsic rock areas in the west of the district. In the drier north/north-eastern edge there is a transition to the wodjil sandplain of the eastern wheatbelt, characterised by yellow sandy earths with tamma gravel ridges. The sandy earths have good plant water-holding capacity but tend to be less acidic than wodjil soils further north. Gravels (particularly mafic laterites) also tend to be underlain by silcrete layers. For more information, see Bulletin 4788 that describes the adjoining Merredin district.

- drainage. To the south of the district, the landscape becomes generally flatter, poorly drained, and consequently less suitable for laterite-forming plants. Mallee-mixed-heath communities overlie duplex gravel soils in complex mosaics (often on the most well-drained points), with mallee-melaleuca or other eucalypts on duplex soils. These may have 30–80 cm of sandy-to-loamy gravel over mottled clay, and are the most common lateritic soils in the district.

Figure 14  Generalised diagram of laterite types in the Lake Grace district
Silver mallet (*E. argyphea*) and blue mallet (*E. gardneri*) form dense woodland clumps on shallow or loamy gravel ridges and slopes throughout the district. This would appear to contradict the Proteaceae-Casuarinaceae rule for laterites until you note that the shrub understorey is almost completely tammas and Proteaceae.

![Figure 15 Lateritic soils: yellow sandplain at Holt Rock (left); sandy gravel at Newdegate (centre); duplex gravel at south Pingrup (right)](image)

Hard-setting or duplex soils supporting eucalypts tend to dominate in areas less favourable to laterite development. These include fertile soils, alkaline soils, and situations with restricted water movement through the soil, such as winter waterlogged, heavy textured and poorly structured soils. Other plant LMC secretions and utilisation by soil bacteria and fungi appear to be responsible for phosphorus cycling in these soils, as well as the formation of kaolinitic clay layers, free lime, and lime/silcrete nodules.

Mallee-melaleuca scrub is generally associated with shallow duplex soils. Mallees with associated fungi have created specific layers to deny access to soil water from potential competitors. Verboom and Pate (2006) describe mechanisms by which these species create a sandy surface horizon separated from the subsoil by a relatively impermeable ‘seal’ composed of silica and sodic clay, and have roots that pump water from one layer to another as shown in Figure 16.
Mallee scrub is spread throughout the district and may appear to be uniform to the casual viewer. However, more careful observation reveals great variability in the shrub understorey indicating differing soil types.

**Climate**

Climate changes cause corresponding changes in landscape and native vegetation. Figure 17 shows that over the past 6 million years our climate has fluctuated greatly.

**Rainfall regimes in arid and semi-arid regions from the Miocene to recent**

- **Higher rainfall phases**
  - High sea levels
  - More vegetation
  - Less erosion, more stable landscapes
  - Deep weathering
  - Laterite formation on well-drained areas

- **Arid phases**
  - Low sea levels
  - Less vegetation
  - Unstable landscapes, droughts, flash floods, saline lakes
  - Sandplains from laterites, oceans, waterways
  - Silcretes, red-brown hardpans more common

**Figure 17 Climate changes and landscape consequences**

In wetter ancient times, the landscape tended to be more stable; soils formed faster and were more protected by dense vegetation. Plants favouring laterite development flourished on stable well-drained areas, probably with plants favouring duplex soils on lower slopes.
During arid phases, the soil was less vegetated and subject to erosion by flash floods and wind. Sandplain development was favoured at the expense of gravels, particularly in the eastern/north-eastern agricultural areas.

Aridity may also have been associated with two more factors: (1) very strong winds and (2) lower sea levels due to water being tied up as ice in the world’s polar regions. Lower sea levels increased the slope to the sea, which favoured water erosion, and also exposed seabeds to wind erosion. Sand blown from exposed areas by strong wind formed our coastal dunes. Similarly, wind action moved materials out of dry rivers and inland lakes to form lakeside sand and loamy soils. Some lateritic sandplain and duplex soils formed on this material when the climate became wetter again.

In low rainfall areas, salts and clays accumulated in the valleys where there was insufficient rainfall to flush salts out of the system in rivers or groundwater.

**Soil movement**

Soil particles are sorted and transported by three physical processes:

1. **Colluvial processes** are most widespread, with soil movement down slopes and on to valleys in both arid and wet climates. The soil moves downslope by raindrop action, by biological activity such as animal and insect burrowing, by flash floods or just by gravity acting on loose soil. Trunk valley soils are most likely based on colluvial deposits that overlie old alluvial sediments. Colluvial pale sands (‘spillway sands’), like the example in Figure 18, commonly occur in upland hollows and foot slopes.

2. **Alluvial processes** (movement by water) were extensive in the major valleys more than 15 million years ago when the climate was wetter. Colluvial sediments originating from redistributed materials sweeping down from uplands have buried these deposits. Such deposits in the valleys of the Lake Grace district are indicated by reddish colours in the radiometrics map (Figure 3).

3. **Aeolian processes** (movement by wind) were active in arid climatic times, with sand and loam being blown from ancient dry lakes, salt pans and river beds (Figure 19).

Grey and pale yellow sands are mainly found near salt lakes in the west and south of the district. Native vegetation tends to be similar on colluvial and aeolian pale sands, as these soils have similarly poor water-holding capacity. Colluvial pale sands tend to be localised and more frequent in lower slopes and hollows below sandy gravel or granite rises. Aeolian pale sands are usually south and east of valleys and are found in all landscape positions.
Blackbutt-morrel calcareous loams are common on the northern, southern and western side of salt lake chains. Adjacent to the lakes, soils are highly alkaline dunes that have a high salt content. Further inland, a thinner aeolian overlay has resulted in alkaline shallow loamy duplex soils.

Figure 19 **Aeolian soils: calcareous loam dune (top); yellow sand dune (above)**

The field tools are presented in the following pages in preparation for the field trip described on page 55.
Field tools

The following decision aids have been developed to help you identify and integrate clues that are available to you in the field for interpreting the landscape and its soils.

In time, you will automatically recognise the association between clues that reinforce each other, and you will be able to recognise landscape changes as you travel.

Many surface features can help. Remnant vegetation, fragments on the surface, the shape of the landscape, topsoil colour, or artificial features such as banks, dams, roaded catchments and gravel pits, all provide clues for interpreting the landscape and its soils.

Note: Beware of reliance on road surface soil or road verge soil. Gravel has often been carted from elsewhere and spread along the road verge during road construction. Also sand may accumulate along fence lines and road reserves due to wind and water erosion.

Four field tools are supplied:
- landscape investigation sheet (for you to photocopy)
- guide for recognising indicator remnant vegetation in the district
- soil texturing card for use in the field to manually texture soils
- guide to common soils in the Lake Grace district.
Lake Grace district soil/landscape investigation sheet

This is a summary sheet for you to identify and integrate clues in the field for interpreting the landscape and its soils.

Remnant vegetation is a handy guide to soils. However, note that there are exceptions and that you can be misled by:

- introduced vegetation, particularly on roadsides and fence lines
- remnant species that have taken over as the dominant species when the original vegetation was cleared or has degraded over time. Rock sheoak (*Allocasuarina huegeliana*), roadside tea tree (*Leptospermum erubescens*) and jam (*Acacia acuminata*) are common volunteer species
- grazing that leaves only hardy species.

You can also gain clues from weeds such as perennial veldt grass that invades roadside sands; tagasaste or pine plantations on poor sands; and barley grass on saline soils.

The decision aids also provide information to help you recognise surface clues such as landscape dissection. Landscape dissection and position in the landscape indicate likely soil-forming materials and features such as susceptibility to salinity or waterlogging.

Surface clues that can help you include:

- rock outcrops: weathered or relatively unweathered crystalline rocks (e.g. granites, gneisses, mafic rocks), banded ironstone or quartz ridges, or other rock types and exposed parts of the lateritic profile such as mottled or pallid zones or silcretes
- fragments on the surface
  - crystalline rock fragments associated with younger soils
  - gravels, pallid zone, silcrete or red-brown hardpan rocks
  - lime nodules on calcareous and alkaline soils
- farm dams (dam colour and rocks excavated), roaded catchments, banks and drains sandy ant mounds coming through gravel roads (can indicate deep sand or a deep sandy duplex)
- soaks and clusters of windmills can indicate water accumulation from upslope light sandy slopes at a change of slope or at low points in the landscape, or where less permeable clay or rock is coming closer to the surface
- gravel and sand pits.
Lake Grace district soil/landscape investigation worksheet

<table>
<thead>
<tr>
<th>Indicator vegetation</th>
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<tbody>
<tr>
<td># see indicator vegetation guide, page 20</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Where are you in the landscape?</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Look around and see where you are relative to other features. Are you on a ridge, a spur (a divide in a slope), or near a breakaway (a water-shedding area that often has shallower and/or more gravelly soils)? Are you in an area where soils may accumulate, such as a saddle (a basin on a ridge between high points), smooth hollows, breaks of slope or valleys? Is there evidence of aeolian (wind-driven) activity?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fragments on the surface</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite or gneiss, quartz, mafic (dark) rock, silcrete, saprock, sedimentary rock, laterite gravel or reticulite, mottled or pallid zone rocks, lime nodules</td>
<td></td>
</tr>
</tbody>
</table>

| Other clues (e.g. dams, sand or gravel pits road cuttings, rock outcrops, erosion, salinity or waterlogging) | |

<table>
<thead>
<tr>
<th>Your conclusion on the landscape and soil(s)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Dig a hole, texture the soil (page 32) identify the soil from the common soils list (page 33)</td>
<td></td>
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</table>
Indicator vegetation of the Lake Grace district

Eucalypts have three forms:

1. **Tree**: single trunk, with branches that usually start more than one metre above the ground and occupy about half of the tree’s height. If the main trunk is damaged, many branches can resprout from the base or stems (epicormic growth). Examples include salmon and York gums, wandoo, marri and jarrah.

2. **Mallet**: single trunk, with relatively steep-angled branches and a terminal crown. Mallets are sensitive to fire and do not recover if the main trunk is lost. Examples include mallets, yates, gimlet and moort. Mallets often occur as pure or massed stands.

3. **Mallee**: multi-stemmed plants, usually less than 10 m high. Several stems come from a lignotuber that can replace them when one or more are lost. Malleses that have not had to regenerate may have a single stem, but also have the basal ‘mallee root’.

The following species could be confused:

- **Salmon gum** (*E. salmonophloia*, below left) is a tree that occurs on mafic red-brown upland soils and calcareous valley soils.
- **Merrit** (*E. flocktoniae*, below centre) is a mallet that may be found with salmon gums, but also occurs on alkaline non-calcereous rocky soils.
- **Silver mallet** (*E. argyrea, E. ornate*, below right) grows on stony, often mafic, gravel uplands.