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# Landscapes and soils of the Narrogin district

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Copies of this document are available in alternative formats upon request.

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## Acknowledgments

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# Introduction

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

This bulletin was designed as an induction course for Department of Agriculture and Food employees who have been recently posted to the department's district offices, but the information is fundamental for many who work in these districts.

This Bulletin provides readers with principles underlying the formation of local landscapes and soils, and information needed to identify landscapes and their associated soils. The emphasis is on field application.

It 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.

Table 1 **Areas covered in this series (see also Figure1)**

| District | Shires |
|---|---|
| Albany | Denmark, Plantagenet, Albany, Cranbrook |
| Katanning | Wagin, Tambellup, Broomehill, Gnowangerup, Kojonup, Katanning, Woodanilling, Dumbleyung, West Arthur, Kent |
| Lake Grace | Kulin, Lake Grace, Kondinin, Kent |
| Merredin | Mount Marshall, Yilgarn, Bruce Rock, Mukinbudin, Westonia, Koorda, Trayning, Narembeen, Merredin |
| Moora | Gingin, Chittering, Dalwallinu, Dandaragan, Victoria Plains, Moora |
| Narrogin | Brookton, Pingelly, Cuballing, Williams, Narrogin, Wandering, Corrigin, Wickepin. |
| Esperance | Esperance |
| Jerramungup | Ravensthorpe, Jerramungup |
| Geraldton | Greenough, Mullewa, Northampton, Irwin, Geraldton, Mingenew, Chapman Valley |
| Three Springs | Coorow, Carnamah, Three Springs, Morawa, Perenjori |
| Northam | York, Tammin, Quairading, Northam, Goomalling, Wyalkatchem, Beverley, Toodyay, Cunderdin, Dowerin |

Each bulletin has been designed as a self-learning module that contains the following components:

1. Two articles

   These describe the development and distribution of the soils, landscapes and soil landscape systems in the district.

2. Decision aids for use in the field

   - Indicator vegetation guide that is useful for quickly understanding soil type variations from remnant pre-European vegetation.
   - Other decision aids to help you identify landscape types, land units and common soil types in the district.

3. A half-day documented field tour to provide field examples of the information covered in the lectures, and specific stops to give practice in using the decision aids.

4. Case studies

   These are areas in the district that have been displayed as a map with photographs of numbered points to illustrate the soils and landscape. These real-life examples show the diversity of landscapes that make up the soil landscape systems in the district, and explain the variations that occur. Distances are shown so that you can visit each area with the document as a guide.

5. Appendixes with supporting information, a glossary and references.

   To get the best value from this course, I recommend that you refer to the 'Soil guide: a handbook for understanding and managing agricultural soils', WA Department of Agriculture Bulletin no. 4343.

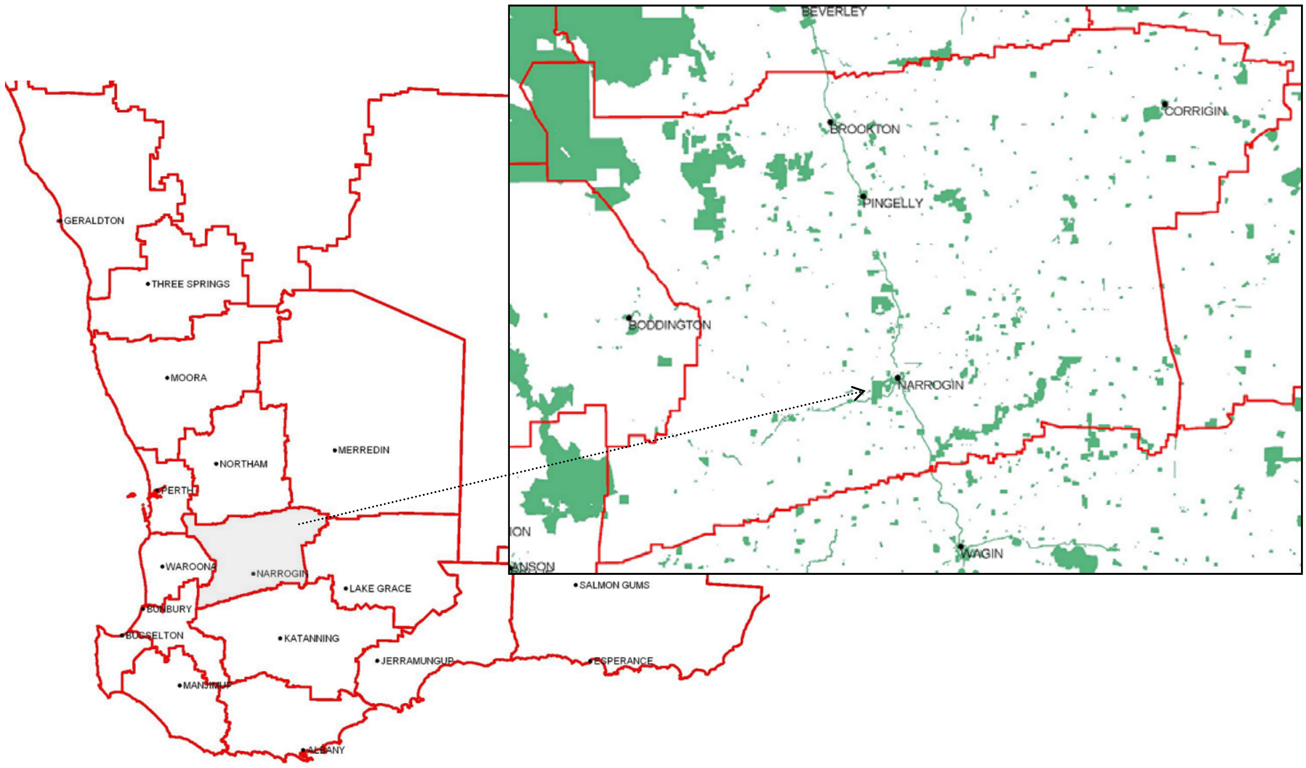



Figure 1 **Areas covered in this Bulletin series with reserves shown in green**

## Landscape development in the Narrogin district

In this section, you will be introduced to factors influencing soil and landscape development in the Narrogin district.

The landscape of the Narrogin district generally becomes more subdued from west to east.

Shaded areas in Figure 2 highlight three landscape categories in the district.

The western part is the **Darling Range Zone (DRZ),** a broad uplifted plain of the Darling Range and its eroded margins. This has distinct NW/SE patterns in ridges and valleys, and has been cut by a few large waterways from further east.
Yellow brown gravelly soils and sheet ironstone are common.

To the east is the **Ancient Drainage Zone (ADZ)**, where the landscape is more subdued with frequent yellow sandy gravel uplands and wide, flat drainage systems, with salt lakes. Runoff often does not reach the sea.

Between the two is the **Rejuvenated Drainage Zone (RDZ),** which has active river drainage systems that joins the Avon, Murray and Blackwood rivers. The landscape is more dissected, often with variable soils formed from dissected laterites and underlying igneous rock. In the south there are some broad saline valleys intruding from the ADZ.

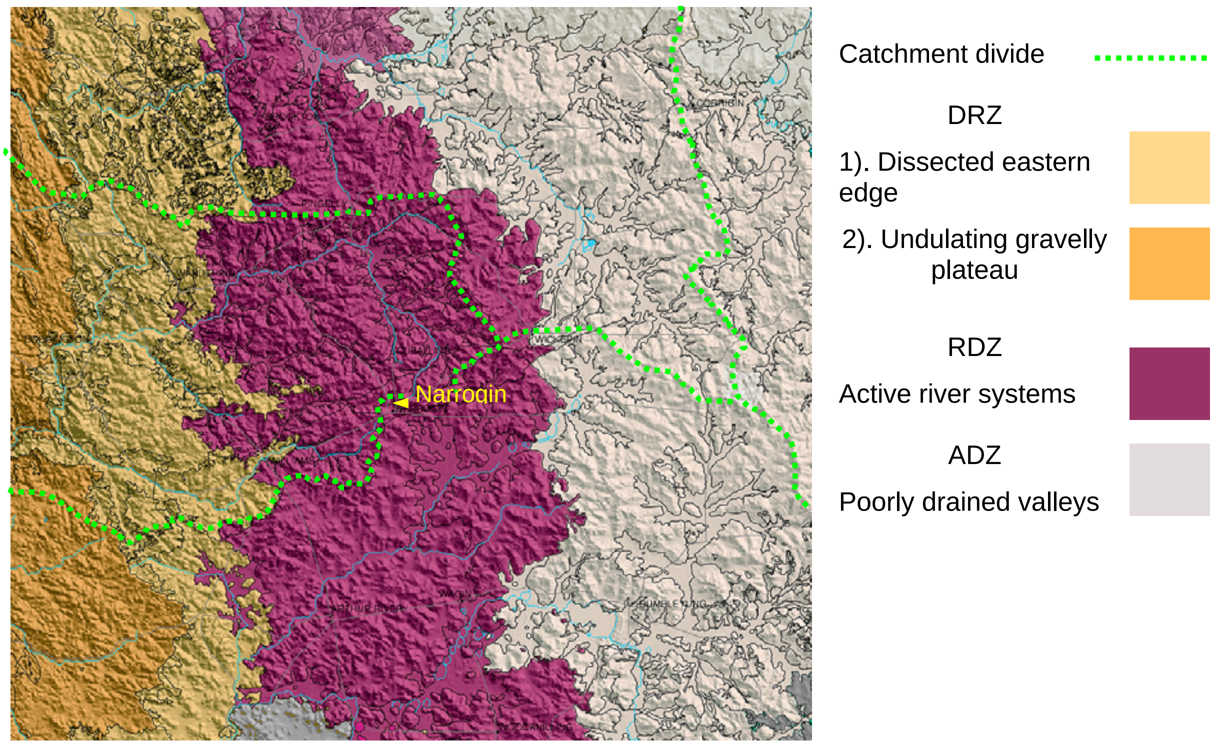



Figure 2 **Drainage zones in the Narrogin district**

A number of factors and processes have interacted to develop the landscapes and soils (see Figure 3).

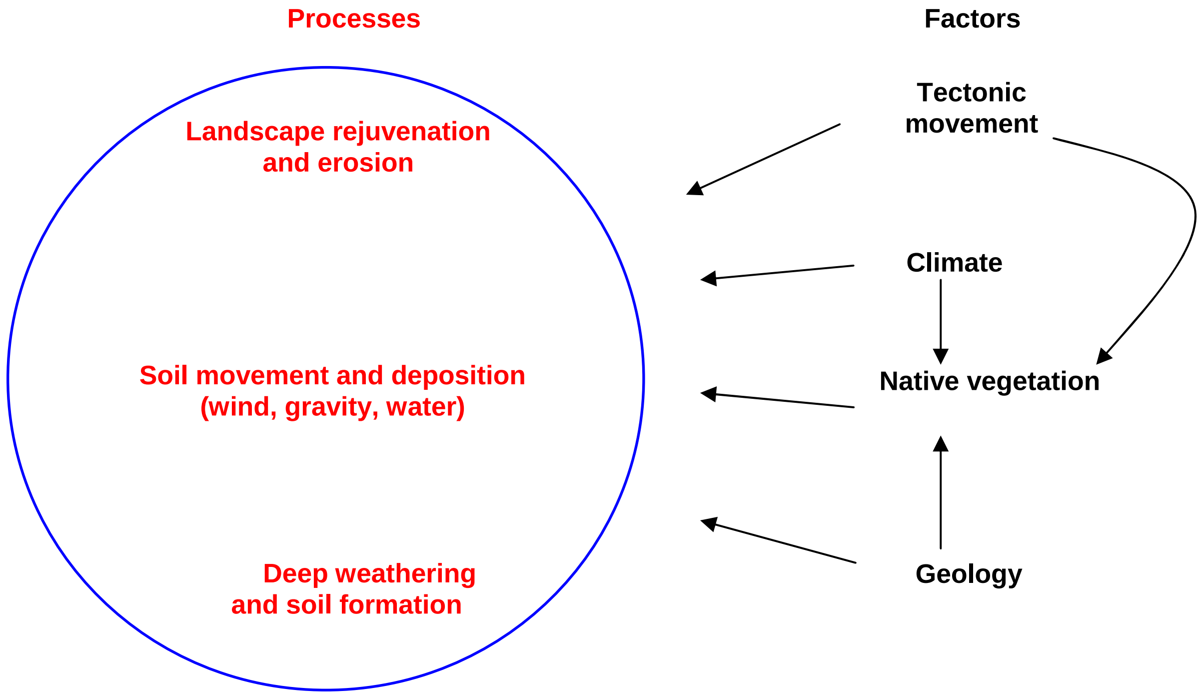



Figure 3 **Factors and processes influencing landscape and soil development**

## Geology and tectonic movement

There are marked differences in the 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.
The geology of southern Western Australia is dominated by the Yilgarn Craton, an ancient and relatively stable area of granites and gneiss (a metamorphic banded granite-like rock).

You will notice in Figure 4 that many features such as faults, dykes, major rock formations and waterways trend NW/SE, E/W or NE/SW. The north-west alignment of major rock bands of the Yilgarn Craton reflects its formation over many hundreds of million years as ‘rafts’ of land on tectonic plates collided to form bands of gneiss that were intruded by granites. Stresses associated with these events caused cracking and intrusion of the dolerite dykes that occur throughout the craton. These dykes can be a locally significant as soil material (e.g. the Binneringie dyke), and are frequently associated with mafic lateritic ridges.

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.

In the Narrogin district there are few sedimentary rocks as in the Perth basin. Igneous rocks include granite, dolerite, gabbro, quartz and metamorphic rocks such as gneiss, that are parent materials for wind and waterborne deposits, laterites and a range of soils. Outcrops are relatively common in dissected (rejuvenated) areas.

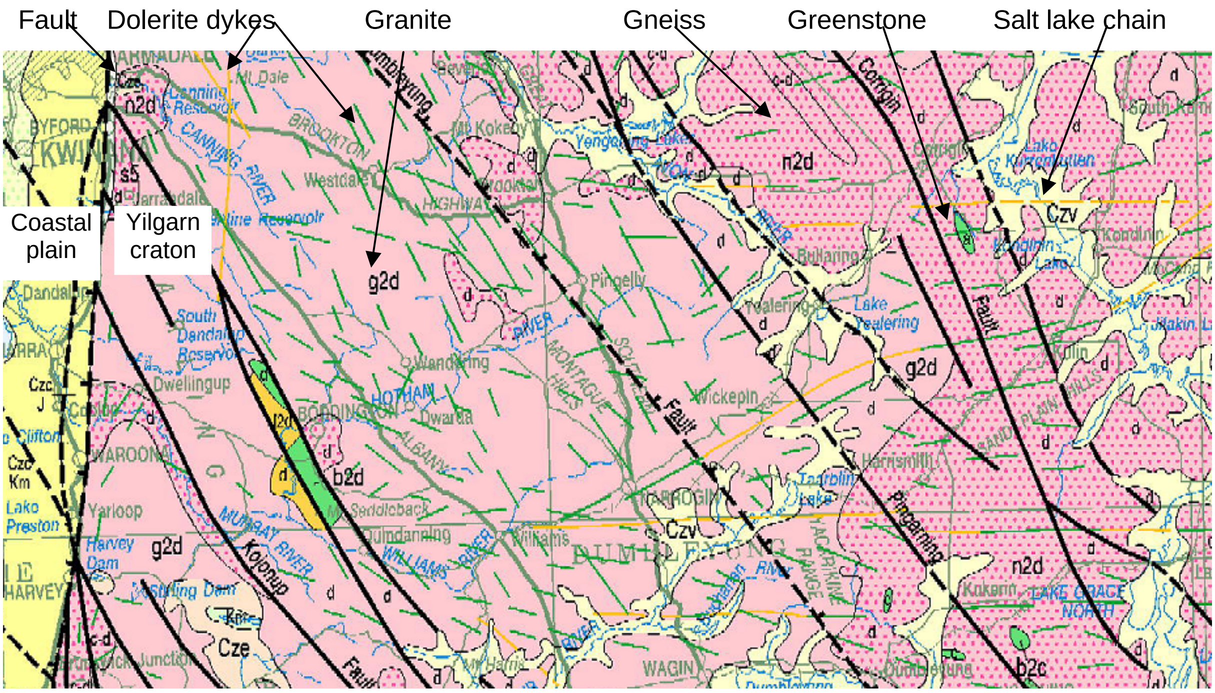



Figure 4 **Geology of the Narrogin district**

Figure 5 shows a range of soils formed directly from felsic (acidic) rocks in Western Australia. These are the most common basement rocks, have relatively high amounts of quartz, and weather to sandy surfaced soils.  They are mainly granites but include other igneous rocks such as felsic gneisses. Gneisses are metamorphosed igneous rocks that vary in their dark mineral content, ranging from light-coloured silica-rich rocks in Figure 5 to dark-coloured mafic rocks in Figure 6.

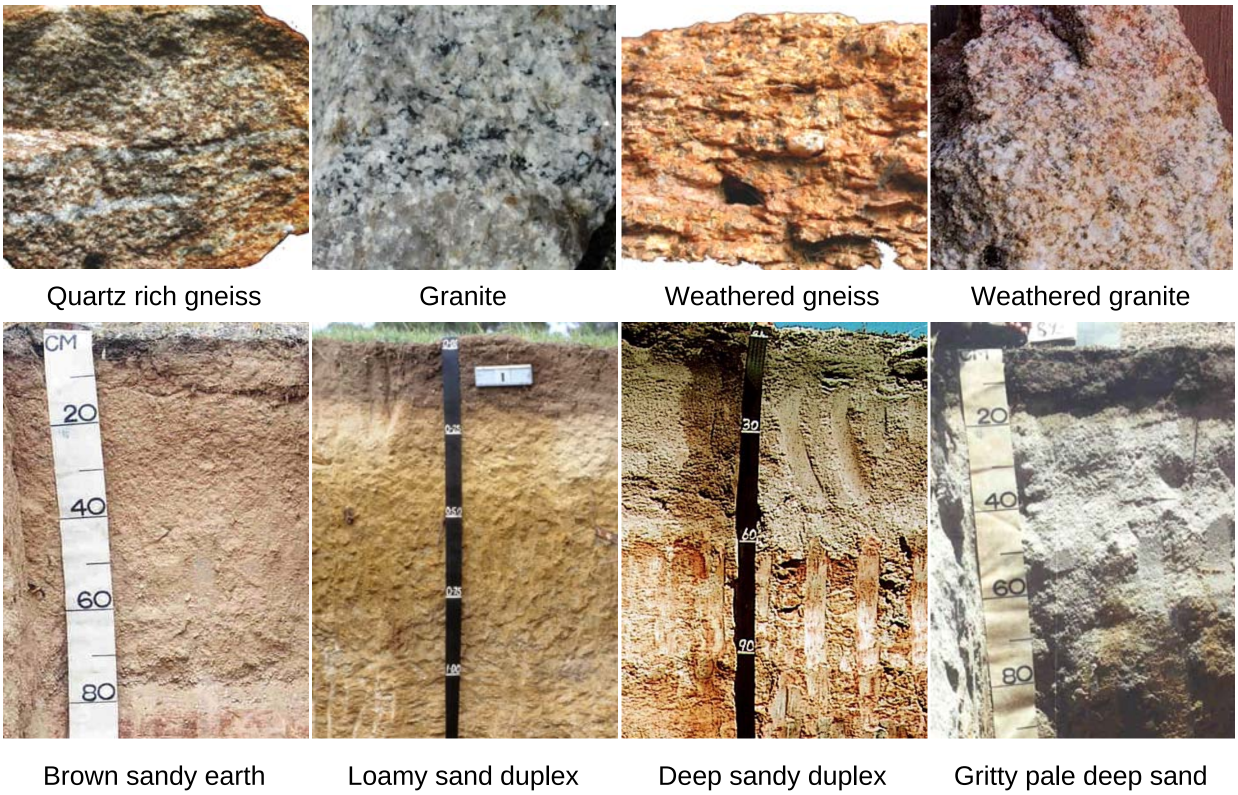


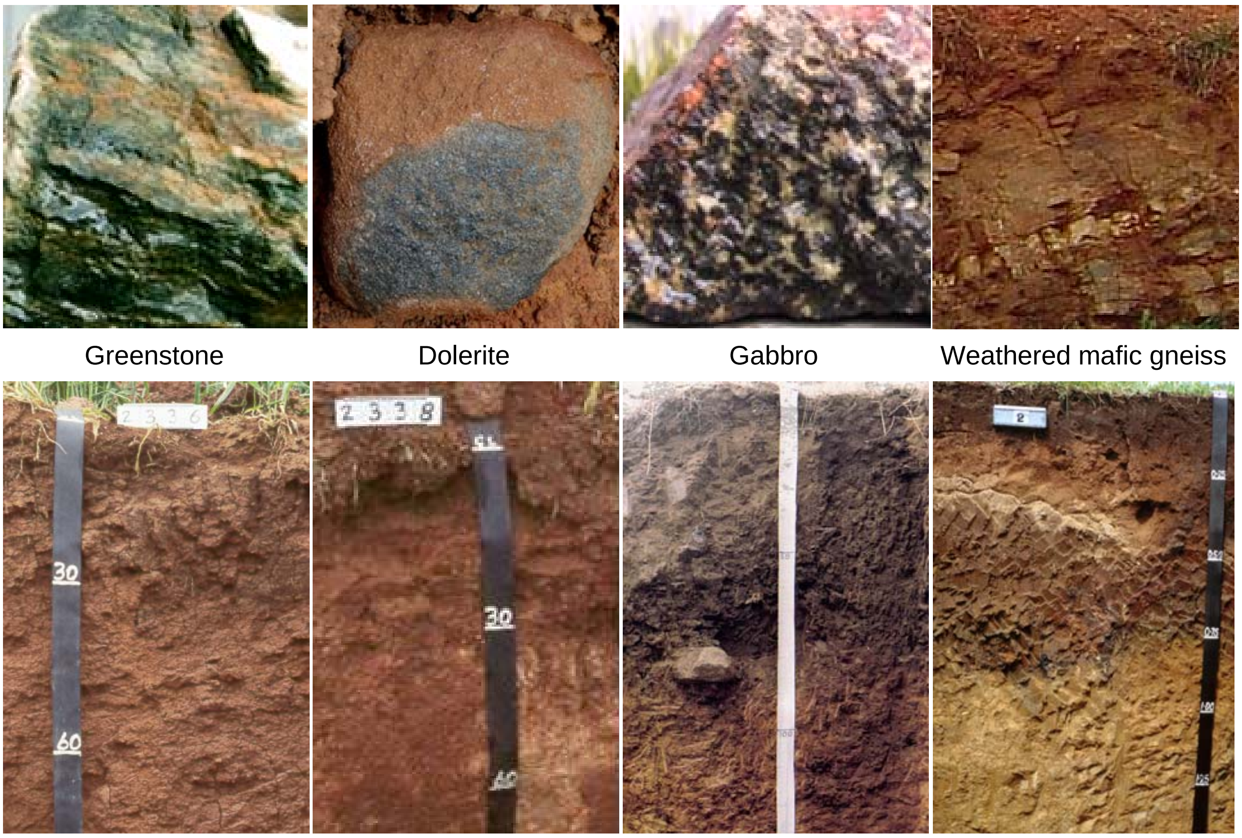

Figure 5 **Felsic (quartz rich) rocks and soils**

Mafic gneisses, as well as greenstones, dolerites and gabbros tend to form more clayey soils. Figure 6 shows a range of mafic (basic) rocks which typically contain large proportions of ‘dark’ minerals and high levels of calcium and iron. They typically weather to red-brown to brown clay loam to clay soils with alkaline and often calcareous subsoils.

In the Narrogin district, mafic areas occur in

1. The Avon Valley and down to about north Pingelly
2. The Corrigin soil landscape system that occurs from Corrigin to South Kumminin and south to about Jitarning
3. The Binneringie dyke suite is a band of mixed rocks from Quindanning, Williams, Narrogin Wickepin to Kulin. A part of this forms the Narrogin soil landscape system
4. A greenstone enclave at Boddington that is mined for gold.

Mafic rock is also scattered throughout the district, mainly as dolerite dykes.



Greenstone | Dolerite | Gabbro | Weathered mafic gneiss

Calcareous loamy earth | Calcareous loamy duplex | Brown loamy earth | Brown loamy duplex

More common to the east | More common to the west

Figure 6 **Mafic rocks and soils**

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. I will discuss this in the next chapter.

## Native Vegetation

In Western Australia, there is a very close relationship between soil types and the pre-European 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 7 shows soil variation on an upland sandy plain below a lateritic mesa, but soil gradation is common in all landscape positions.

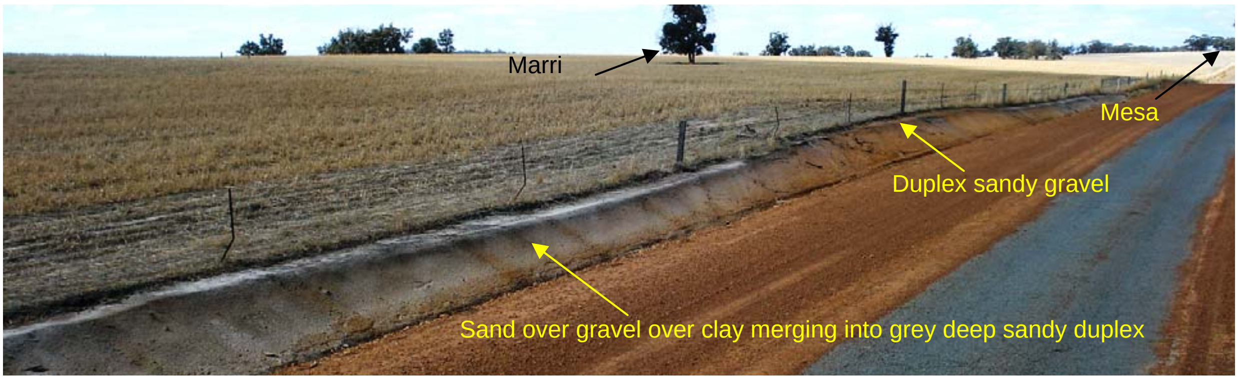



Figure 7 **Upland sandy plain NW of Narrogin with sandy gravels and remnant marri trees**

There is considerable evidence (Verboom, WH and Pate, JS (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.

Common examples in the district are:

- Laterite formation by many members of the *Proteaceae* family and *Allocasuarina* genus (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 which arise when roots shrink during heavy rain
- Lime deposits in subsoils of alkaline soils assist in soil water storage and may control access to soil phosphorus
- Plants such as brown mallet and powder-bark wandoo that create water-repellent topsoils and can direct water by their shape and bark characteristics into the subsoil.

Laterites are soils in which iron and aluminium have accumulated in the profile, usually as gravels. Laterite formation has been very widespread in well drained parts of the landscape and many present day soils have developed on laterite and lower levels of dissected laterite profiles. Sands gravels and duplex soils derived from intact and eroded laterites are very common in the Narrogin district.

Figure 8 shows a very old laterite developed on granite. Granitic laterites usually have a sandy surface overlying round gravel then a layer of blocky or layered ironstone (reticulite) followed by mottled clay and then a pallid zone ( sometimes referred to as 'pipe clay'.) Below this is saprock, a zone of partially weathered bedrock that is quite permeable for groundwater movement then granite. Laterites usually have shallower mottled and pallid zones than those in Figure 8.

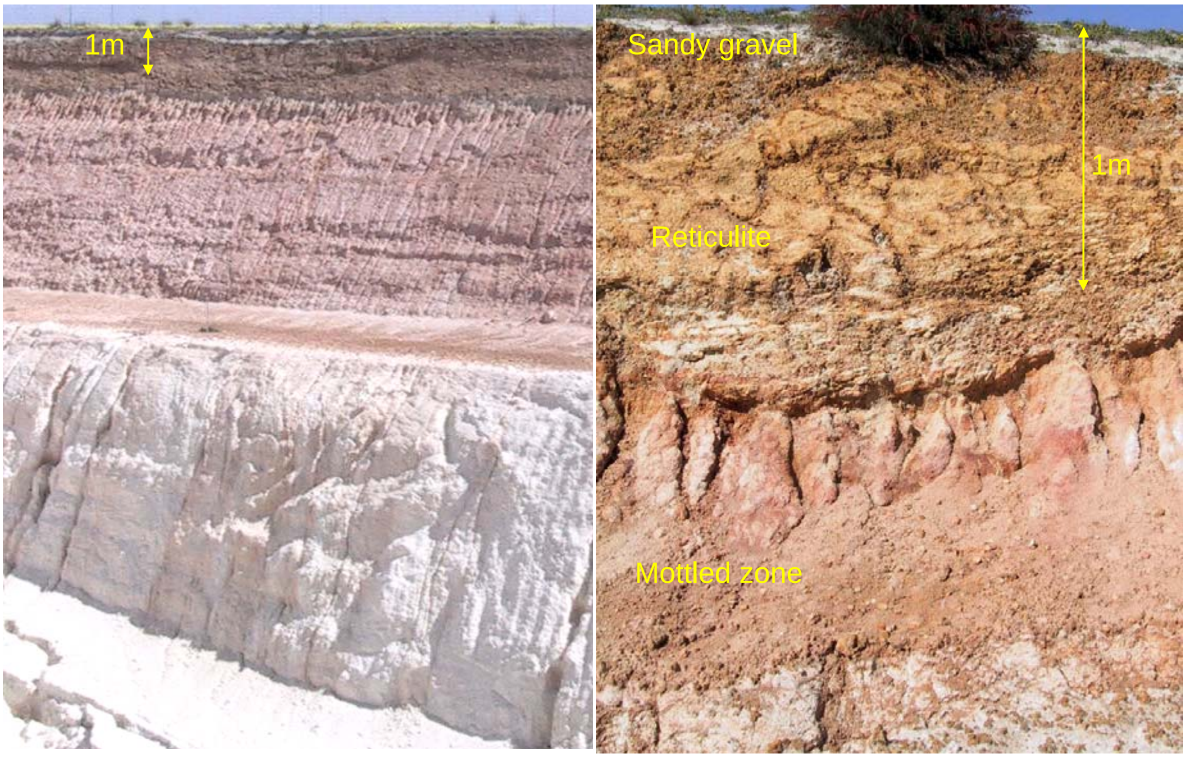



Figure 8 **Kaolin mine pit in a very old granitic laterite.(left); enlarged view of upper layers (right)**

Most laterite formation involves plants and bacteria, which accounts for the observations that different laterites occur under different populations of plants and that laterite is still forming where there is sufficient rainfall.

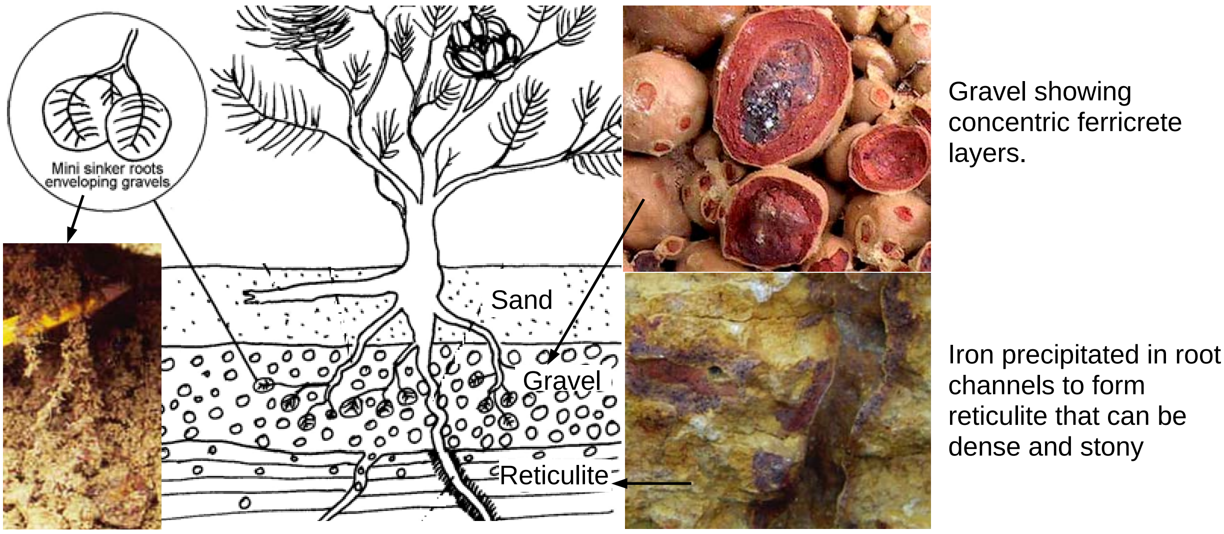



Figure 9 **Gravel and reticulite formation**

The following factors are required for laterite development:

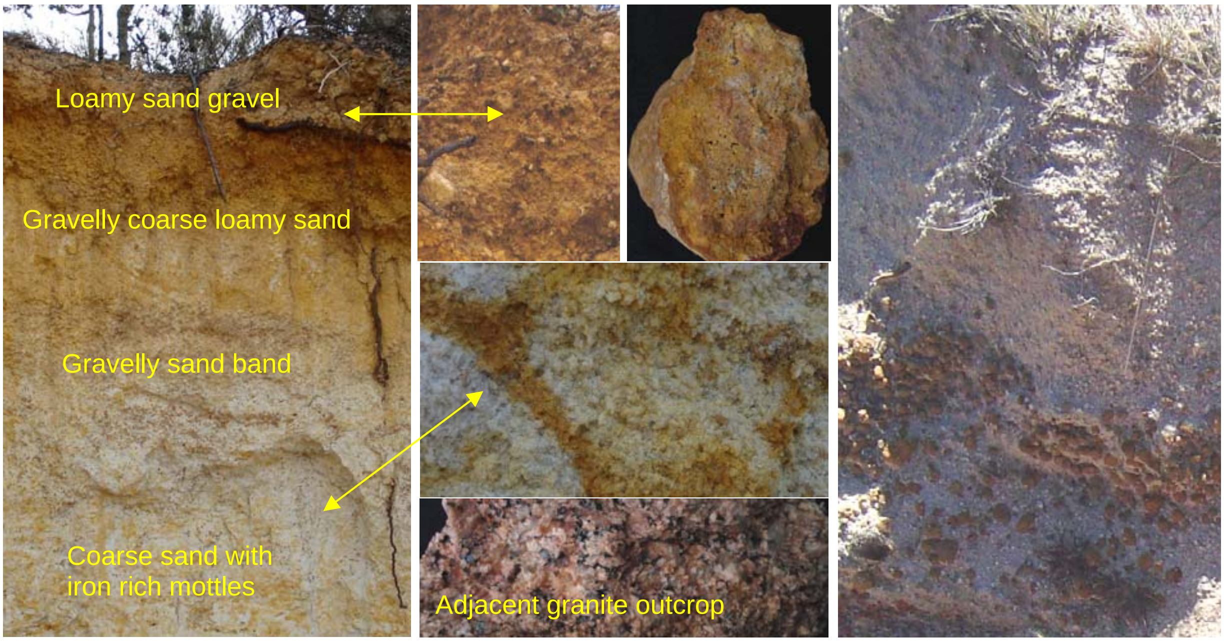
1. Plants with proteoid roots and associated bacteria: These secrete organic molecules of low molecular weight carboxylates (LMCs) which form a compound with phosphorus (and iron and other minerals such as aluminium and silica) that is soluble in water and can be absorbed by plant roots. Most of the 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 LMC's), 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.

2. 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.
3. 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.
4. 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 of the district, such as the Darling Range.

Laterites in the district vary due to:

- The type of parent material-for example mafic rocks, or quartz rich materials such as sandy deposits and quartz-rich granites that form sandy laterites. Most laterites have clay rich pallid zones, but in some sandy laterites like that in Figure 10, gravel and ironstone overlies sand. Mafic laterites have darker, heavier, more iron-rich ferricrete with more clay in the soil matrix. More information on mafic and sandy landscapes can be found in the landscape recognition guide (see page 41)

- Stage of laterite formation. Some laterites are very old but others have formed more recently with less well developed profiles that may lack a pallid or mottled zone. In Figure 11, a young mafic laterite has loamy gravel over reddish-brown clay then weathering dolerite. Dolerite often weathers to red-brown loamy duplex and clay, but lateritisation can't start until the soil becomes neutral. The much older profile in the Darling Range on the right has a "pink" zone in contrast to the pallid zone of the adjacent granitic profile. This profile is a truncated laterite on a mid slope where erosion has removed most of the original overlying gravel.




Sandy laterite from coarse granite on a mesa near Narrogin. Coarse sands, deep sandy duplex and granite outcrops occur downslope

Gravelly sand from laterite forming in colluvial sand.

Figure 10 **Sandy laterites**

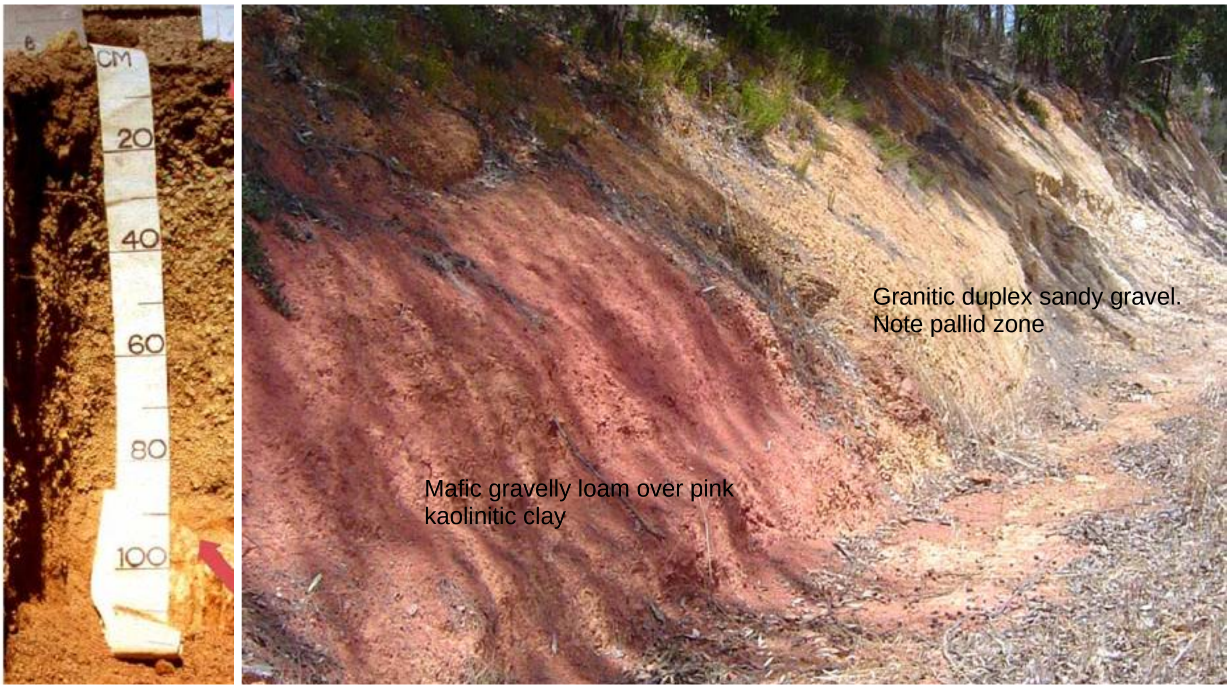



Figure 11 **mafic laterites; young loamy gravel laterite over clay (left); older profile (right)**

- Competition between native vegetation communities, often reacting to changes in climate, land relief and hydrology, or parent material. Intergrade soils are particularly common in the mallee zone, but sandy duplex soils in the Narrogin district often have a gravel band between the sand and clay.

Mesas called 'mallet hills' are a common feature of the RDZ.

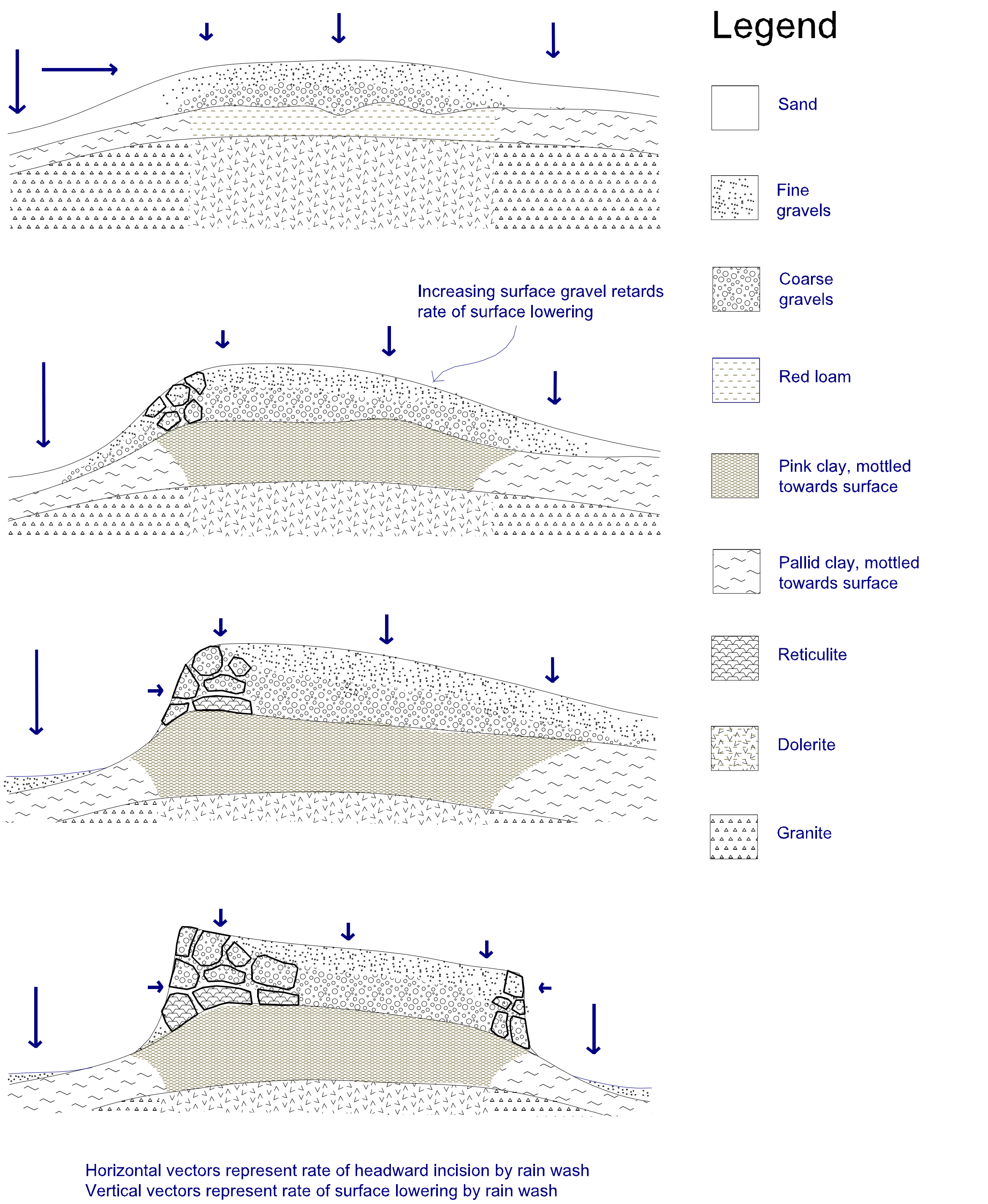



Figure 12 **A possible mechanism for mesa development by more resistant laterite formation on mafic dykes (from Verboom W H, Galloway P D 2000)**

Breakaways associated with these features together with lateritised ridges and spurs often have iron enriched laterites that coincide with mafic rocks. This is possibly due to the formation of more erosion resistant laterites over mafic rocks.

Eucalypts with associated hard setting or duplex soils tend to dominate in areas that don't favour laterite development. These include fertile soils, alkaline soils, and situations with restricted water movement through the soil, such as winter waterlogged, and heavy textured and poorly structured soils.

Most valleys in the Narrogin district have wandoo and or salmon gum grey duplex soils, but many uplands and slopes have a mosaic of soils.

## Climate

Climate changes cause changes in landscape and native vegetation. In the past 6 million years our climate has fluctuated greatly. In wetter 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 in lower slope areas.
During arid phases, the soil was barer and subject to erosion by flash floods. Sandplain development was favoured at the expense of gravels, particularly in the E/NE agricultural areas of Western Australia. Aridity may also have been associated with very strong winds and lower sea levels due to water being tied up as ice. Lower sea levels increased slope to the sea, which favoured water erosion. Winds moved materials out of dry rivers and lakes inland forming 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 have accumulated in the valleys where there was insufficient rainfall to flush salts out of the system in rivers or groundwater.

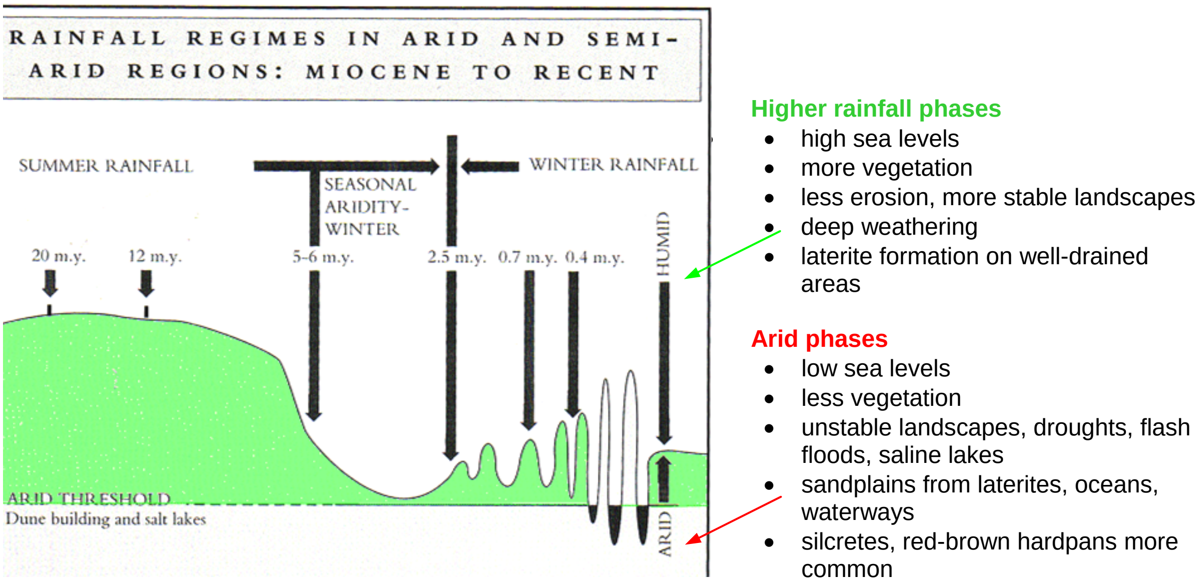



Figure 13 **Climate changes and landscape consequences**.

### Soil movement processes

Soil particles are sorted and transported by the following processes.

Colluviation is the most widespread process with soil movement down slopes and on to valleys in both arid and wet climates. The soil moves downslope by raindrop action, biological activity such as burrowing, by flash floods or just gravity acting on loose soil. Colluvial pale sands ("spillway sands") like the example in Figure 14, commonly occur in upland hollows and footslopes.

Alluvial processes (movement by water) were extensive in the major valleys more than 15 million years ago when the climate was wetter, but these deposits are often buried now by sediments originating from redistributed materials sweeping down from uplands. Recent alluvial soils are confined mainly to some flat trunk valleys and river terrace soils on major rivers. In reality, it is difficult to distinguish between alluvial and colluvial processes and there is also evidence of mixing of products from more than one mode of action. Soil profiles can also reveal complex sequences of differentiation where differing profiles overlay or overprint each other.

Pale sands in the West Kokeby area are relicts from an extinct river system.


Figure 14 **Colluvial sand at the base of a slope east of Wickepin**

Aeolian processes (wind) have been active in arid climatic times with sands and morrel loams being blown from ancient dry lakes, salt pans and river beds .These are mainly grey and yellow sands found on the east and south of large RDZ and ADZ valleys, but include morrel loams in similar positions in the ADZ. The West Kokeby, Kweda, Walyerming and Boscabel soil landscape systems (described in the next chapter), and the East Quairading case study have significant areas of aeolian sand covered areas.

Aeolian yellow sands generally have less clay with depth than lateritic yellow sandy soils, and have distinctive native vegetation. This includes banksias (particularly Acorn banksia), often with grevilleas, native pines, tamma (and woody pear in the north of the district).

Remnant vegetation tends to be similar on colluvial and aeolian pale sands, as these soils have similar 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.

Figure 15 shows a general grouping of the main laterite types in the Narrogin district. There is a general trend from deep stony laterites in the Darling Range though grey sandy laterites to the yellow sands of the eastern wheatbelt.

The grey sandy laterites further east have a grey sandy gravel or sand over gravel topsoils, with areas of deep pale spillway sand in hollows.

The yellow and white aeolian sandplain is mainly deep sands, gravelly sands and sand over gravels that were originally aeolian deposits. Their origin will be explained in more detail in the next section.

Pale sands and sandy gravels from old river deposits are derived from ancient river sands of an extinct river in the west Kokeby area.

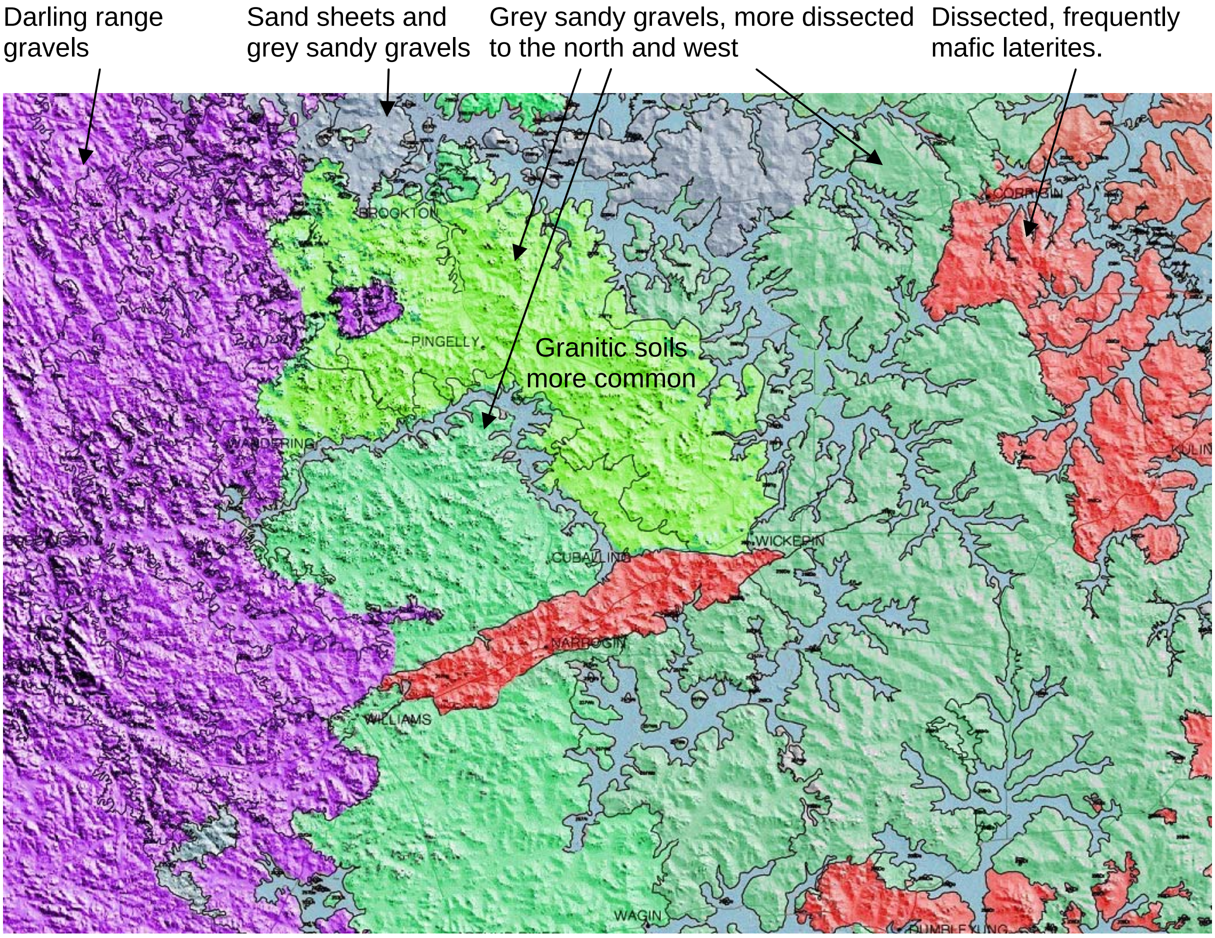



Figure 15 **Very general diagram of the main laterite types in the Narrogin district**

Interplay of the factors discussed above has resulted in a mosaic of soils, particularly on the uplands. This goes a long way to explaining the variation over short distances recorded by harvester yield monitors.

# Soil landscape systems in the Narrogin district

Soil surveys conducted for much of the district have characterised the main soils and grouped soil and landscape information into units often referred to as land units (or land surfaces.)

A land unit has single soil types or a group of soil types that correspond to broad topographical features such as valley floor, hill slopes, and sandplain, or to a sequence of soils to each other. Land units are useful for understanding the landscape at paddock to farm level.
More recently the WA Department of Agriculture and Food Western Australia has conducted land resource mapping in WA using soil landscape systems, and introduced a hierarchical classification system. Information is stored in a database to provide a uniform method of classification and information storage. (Schoknecht et al (2004). The relationship between the mapping methods is shown in Figure 16.

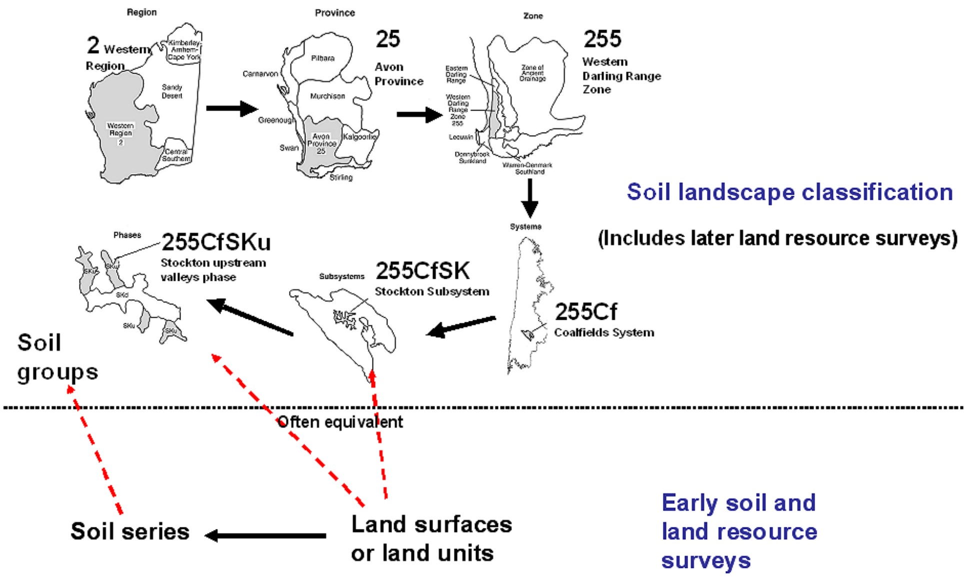



Figure 16 **Relationship between soil landscape systems and land units**

Soil landscape systems (also called systems here for brevity) consist of a range of land units. Different systems often contain the same land units, but in differing proportions.

Systems are more useful for gaining an overview of major landscape areas in the district, particularly for areas where there are large differences in the proportion of land surfaces (for example, areas of different laterite types, differences in geology, or more or less dissected).

This section is an introduction to the main upland systems in the form of a greatly simplified story about the development of the geology and geomorphology of the district
In reality, the situation is more complex, with unclear dates and often with events (for example, the uplift of the Darling Range) occurring as stages over long periods rather than as a single event. However, this approach helps us appreciate the factors that led to the development of the systems.

First consider the crystalline bedrock that underlies the district. Most of the district is underlain by granites that weather to sandy surfaced soils. NW/SE or E/W trending dolerite dykes have intruded the granite to form brown loam and clay soils, often in narrow strips.

Figure 17 **Red-brown loamy duplex slope and mafic laterite hills in the Corrigin system**

Areas in the district with enough mafic rock to comprise a system are:-

1. The Binneringie dyke suite is a large band of mixed mafic and granitic gneisses that passes through Quindanning, Williams, Narrogin, Wickepin and Kulin/Jitarning, and continues to Kalgoorlie. The Narrogin system is a part of this dyke with a greater proportion of soils formed from mafic rocks.

2. Areas with mixed mafic and granitic gneisses include the Corrigin system generally east and south of Corrigin, and the Datatine system in the Dumbleyung area.

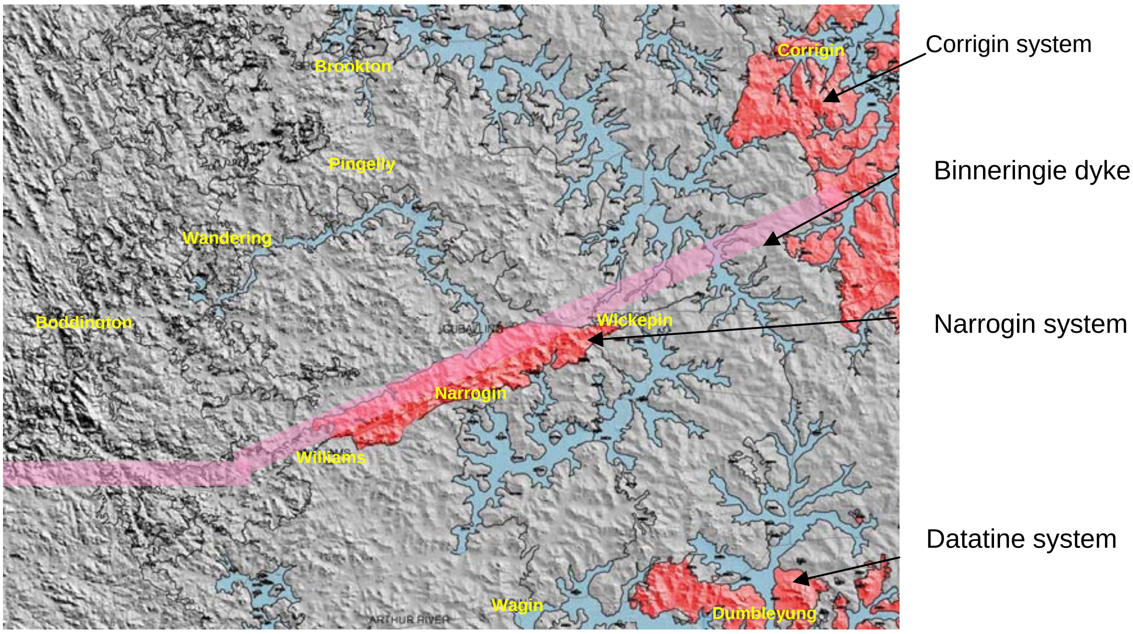



Figure 18 **Soil landscape systems with mainly mafic soils**

These systems tend to have dissected landscapes with very mixed (but often mafic) soils from truncated laterites and the underlying igneous rock. The mafic soils include stony and loamy gravels and red brown loamy duplex soils.

Soil landscape systems are described in more detail at the end of this section.

Australia was once a part of a supercontinent called Gondwana. When this split about 150 million years ago, processes started that culminated in the separation of Australia from

Antarctica and India. The extensive faulting and marginal uplifts that resulted from the rift caused marked changes to drainage patterns.

As the tectonic plate containing India gradually separated from the Western Australia, west-flowing rivers deposited sediments from the Yilgarn craton into a valley that is now the Swan coastal plain. There was also a rift developing on the south coast between Australia and Antarctica. A major ridge (the median watershed) separated east and south flowing rivers from those flowing west. This feature passes through the east of the Narrogin district

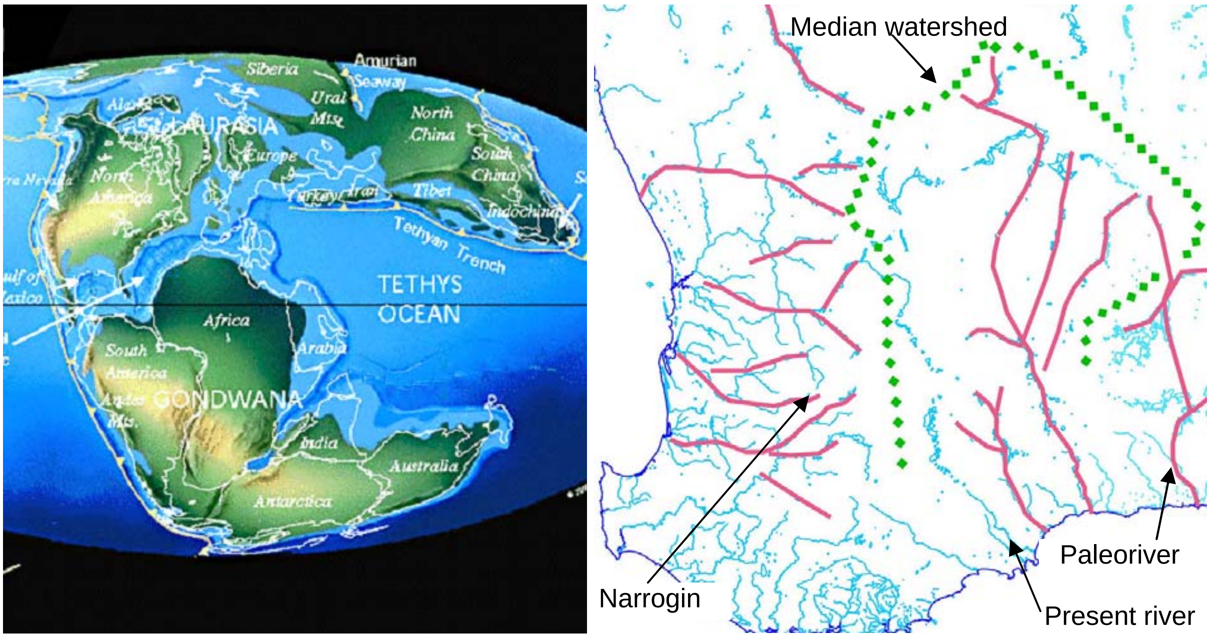



Figure 19 **Australia as a part of the Gondwana supercontinent from C.R. Scotese, (c( 2007)) (left); inferred paleorivers in the late Cretaceous period from Beard (1999) (right)**

A more detailed depiction in the Narrogin district is shown in figure 20. The Darkan paleochannel is a buried sandy river channel whose path is often independent of the overlying landscape. This contains artesian to sub artesian water.

North of Brookton, water flowed west to the Helena River rather than north in its present course. Apart from some deviations, the Hotham and Williams rivers still joined the Murray River, but the present upper Blackwood catchment was a tributary of the Collie River.

About 66 million years ago a low east-west rise near the south coast called the Jarrahwood axis formed. This and a fault called the Chin Smith lineament that runs SW/NE through Merredin, caused the lower part of the Yilgarn craton to tilt downward to the north. This caused previously south flowing rivers to reverse their flow. Water was then diverted down the Chin Smith lineament, and break through the median watershed SW of Kellerberrin to create the Salt River south of Quairading. This water joined the Helena river via Kokeby siding.

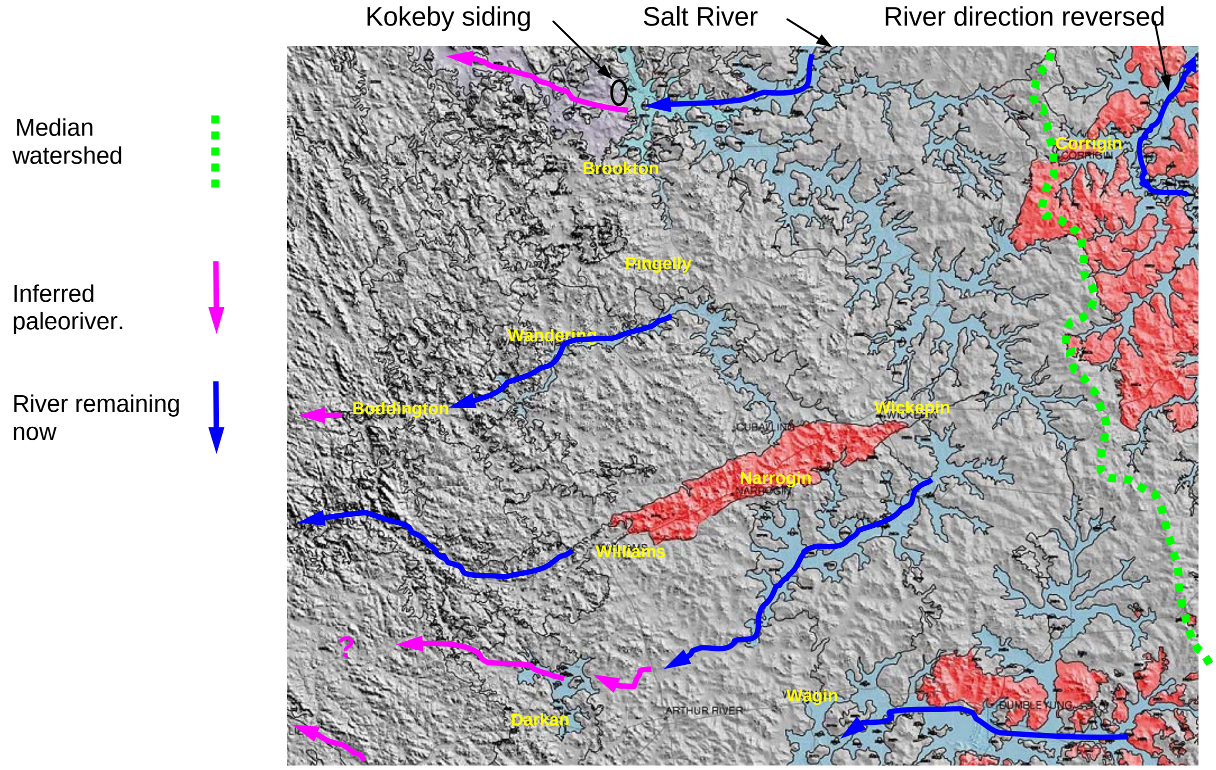



Figure 20 **Inferred paleorivers in the Narrogin district after Jarrahwood axis uplift**

Later, the Darling Range started rising as an uplifted plateau on the eastern edge of the Darling Fault. This was associated with a general upward tilting of the Yilgarn block to the west that reduced the grade of the west flowing rivers.

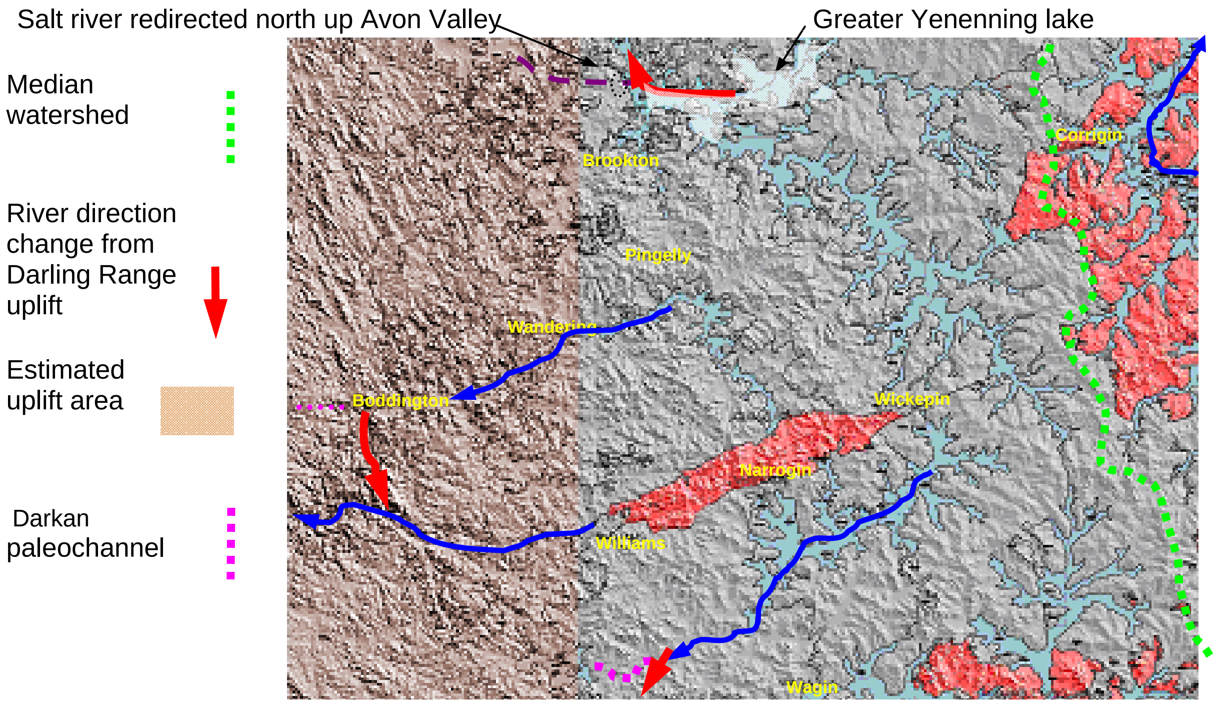



Figure 21 **Effect of Darling Range uplift on river direction**

With a general drying climate, this caused an accumulation of clay that has resulted in the present broad heavy textured river valleys in the ADZ and eastern RDZ.

In the north of the district the uplift blocked the Salt River to form a huge lake around the present Yenyenning lakes, until the river was redirected north along the Avon valley to Northam.
In the south of the district, the present day upper Blackwood catchment was separated from the Collie River, and possibly dammed near Moodiarup until the water was captured by the Blackwood River.

The Hotham River had some diversions but still flowed to Mandurah.

In following arid climate phases, sand was blown from lake beds and associated rivers to coat uplands to the south and east.

In the north, aeolian deposits are a feature of the following ADZ systems (see Figure22).

1. The Kweda system generally south east of Corrigin has a smooth landscape with extensive deep grey sands, gravelly sands, sandy gravels and deep grey sandy duplex soils.

2. The Walyerming system generally north west of Corrigin has more yellow sands, particularly in the east of the system. This is featured in the south east Quairading case study.

3. Sands and some morrel loams in parts of the Dongolocking system east of the Arthur River.

To the south of the district, grey sands were blown from the valley west of Moodiarup to coat uplands to the south west. This forms the Boscabel system that is described in the Katanning bulletin of this series.

Figure 22 shows upland ADZ systems.

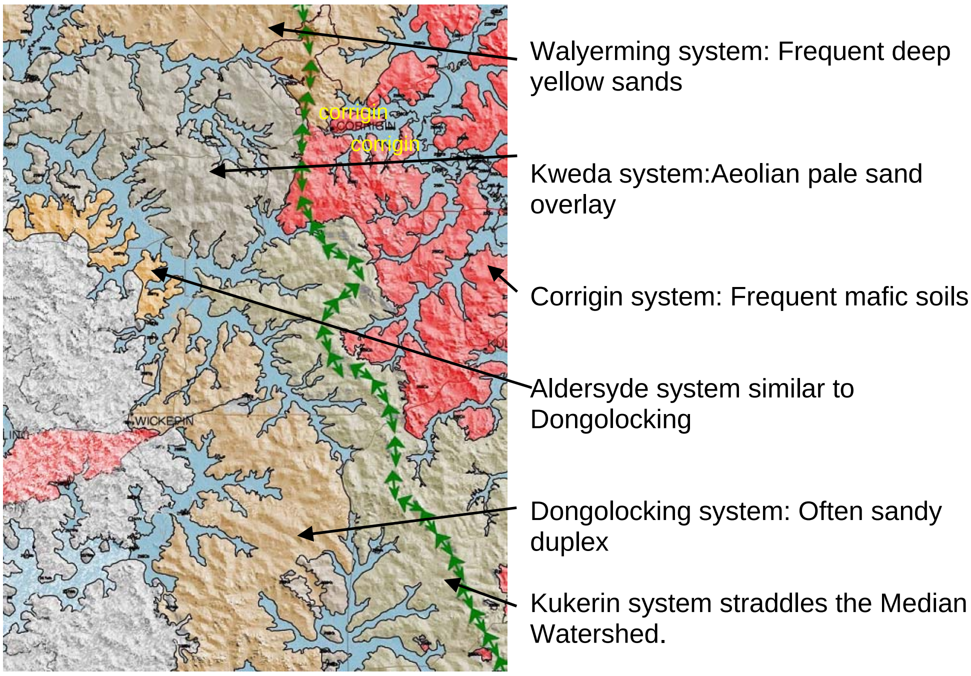



Figure 22. **Main upland ADZ soil landscape systems**

Generally south of the Kweda and Corrigin systems  are the Kukerin, Aldersyde, and Dongolocking systems. The Kukerin system straddles the median watershed and is a transition from wandoo sandy duplexes to mallee duplex soils. Soils are mainly grey lateritic and duplex soils formed from modified sandy laterites with intermixed mafic areas. The Aldersyde and Dongolocking systems to the west have more wandoo/rock sheoak grey deep sandy duplex soils. The East Wickepin case study features the eastern edge of the Dongolocking system, but with more mafic soils due to the influence of the Binneringie dyke suite.

Figure 23 shows upland Darling Range systems.

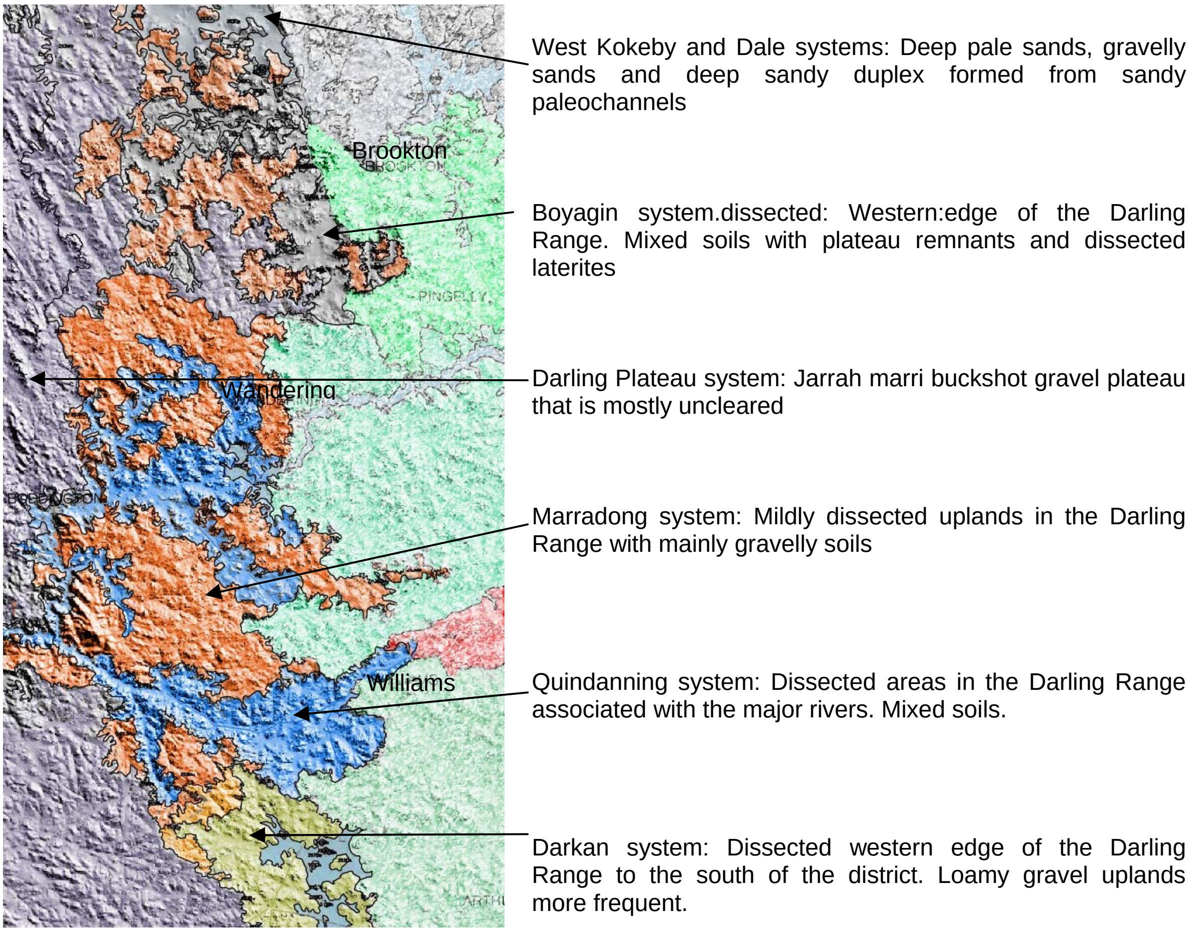



Figure 23 **Soil landscape systems in the Darling Range**

In the north, an uplifted extinct river east of Kokeby now forms the deep sands, gravelly sands and deep grey sandy duplex soils of the West Kokeby system. This system is featured in the south west York case study in the Northam bulletin of this series.

Between the DRZ and the ADZ, the RDZ tends to have more active upper waterways and hilly landscapes with very variable soils. Many waterways have a general NW/ SE orientation that was caused by extensive faulting associated with the Darling Range uplift. This and rejuvenation of the landscape by rivers cutting back through the Darling Range has been a major cause of the dissected landscape and active waterways that characterise this area.

The RDZ has been divided into soil landscape systems according to major river catchment and degree of dissection. Landscapes become smoother and less dissected with grey sandy surfaced soils increasing from north to south

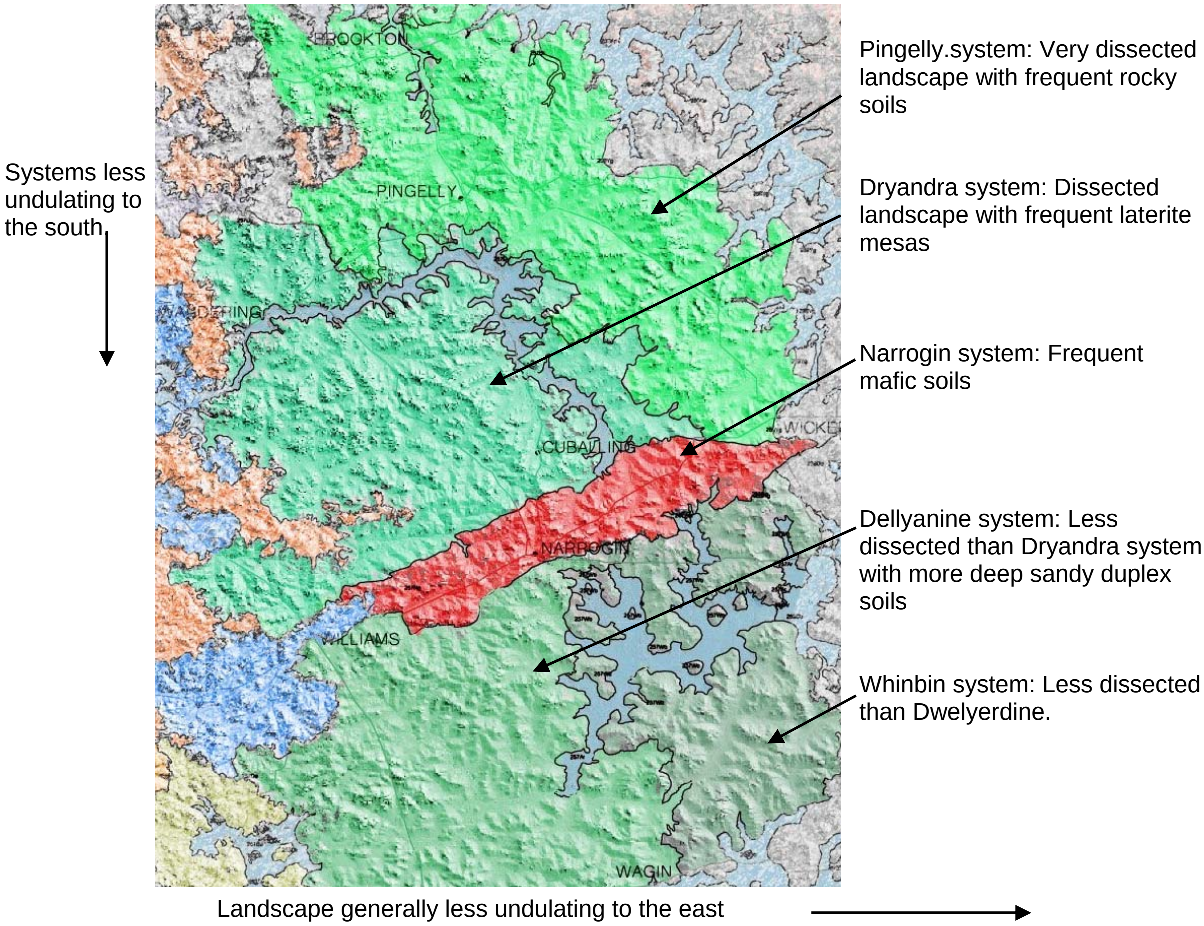



Figure 24 **Main upland RDZ soil landscape systems**

25B Pingelly system view with soils formed from both mafic and granitic rock

25A Dryandra system view with mixed soils and characteristic lateritic mesa

Figure 25 **Common Pingelly and Dryandra system views**

## Field tools

The following decision aids 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 clues can help—such as remnant vegetation, fragments on the surface, the shape of the landscape, topsoil colour, or man-made features such as banks, dams, roaded catchments and gravel pits.

Beware of reliance on road surface or road verge soil. Gravel has often been carted from gravel pits 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.

Five field tools are supplied:

- Landscape investigation sheet
- Guide for recognising indicator remnant vegetation in the district
- Landscape recognition guide
- Soil texturing card for use in the field to manually texture soils
- Common soils in the Narrogin district

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

Remnant vegetation is a very handy guide. However, note that there are exceptions and 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.

Figure 27. **Volunteer roadside vegetation: grey sandy duplex soil with original wandoo rock sheoak vegetation on the right, and dense volunteer rock sheoak on the left (top); old gravel pit with volunteer roadside tea tree on residual gravel (below).**

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

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

Surface clues include rock outcrops, fragments on the surface, and man-made structures like dams, roaded catchments and clusters of windmills.

There are many surface clues that can help you.

- Rock outcrops - weathered or relatively unweathered crystalline rocks (eg granites, gneisses, mafic rocks), banded ironstone or quartz ridges, or other rock types and exposed parts of the lateritic profile like mottled or pallid zones or silcretes.

- Fragments on the surface

    1. Crystalline rock fragments associated with younger soils

    2. Gravels, pallid zone, silcrete or red brown hardpan rocks

    3. Lime nodules on calcareous and alkaline soils

- Farm dams (dam colour and rocks excavated), roaded catchments, banks and drains give you clues on subsoils

- 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 low points in the landscape, or where less permeable clay or rock is coming closer to the surface

- Gravel and sand pits.

Table 2 **Narrogin District Soil/Landscape Investigation Sheet**

| | |
|---|---|
| **Soil landscape system**<br><br>*# soil landscape system précis*<br><br>page 23 | |
| **Indicator vegetation**<br><br>*# see Indicator vegetation guide*<br><br>page 31 | |
| **Where are you in the landscape?**<br><br>*# see landscape recognition guide.*<br><br>Page 41 | Look around and see where you are relative to other features.<br>Are you on a ridge a spur (a divide in a slope), or near a breakaway? These are water shedding areas that often have shallower and/or more gravelly soils.<br>Are you in an area where soils may accumulate like saddles (a basin on a ridge between high points). Smooth hollows, breaks of slope or valleys?<br>Is there evidence of aeolian activity? Is the area you are in sandy, mafic, or mafic influence? |
| **Fragments on the surface** | granite or gneiss, quartz, mafic (dark)rock, silcrete, saprock, sedimentary rock, laterite gravel or reticulite, mottled or pallid zone rocks, lime nodules |
| **Other clues** (eg dams, sand or gravel pits road cuttings, rock outcrops, erosion, salinity or waterlogging | |
| **Your conclusion on the landscape and soil(s)**<br><br>*Dig a hole, texture the soil* (page 50) *and identify the soil from the common soils list* (page 51). | |

# Indicator vegetation of the Narrogin district

**Tree -** single trunk, with branches that usually start more than1 meter 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.

**Malle**t - 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.

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

**Salmon gum** (*E. salmonophloia* left, RDZ and ADZ) and **gimlet** (*E. salubris* right, ADZ, note fluted stem) are common on clay, clay loam soils and loamy duplex soils on slopes and valleys. Salmon gums often dominate on loamy duplex and deep loam soils, and gimlets on heavier clay soils.

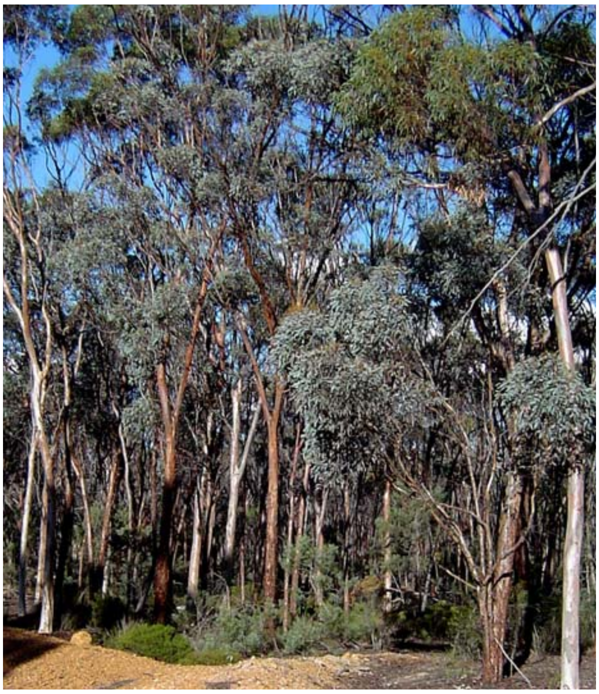
Buds and fruit can differentiate salmon gum from similar looking species like silver mallet.

Salmon gum | Silver mallet | Brown mallet | Blue mallet

**Silver mallet** (*E. argyphea*) grows on stony usually mafic gravel uplands, in the east of the district. It can be mistaken for salmon gum, but only occurs on upland gravels, has the characteristic mallet form, and distinctive buds.

**Blue mallet** (*E. gardneri*) often occurs with silver mallet, mainly on mafic stony uplands.

**Brown mallet** (*E. astringens*) is the most common mallet in this district. It is common below breakaways on poorly structured mottled zone soils ('mallet' soils), and may occur with silver and blue mallets.



Silver mallet (silver bark green shiny leaves) with blue mallet (brown bark dull blue green leaves)

Silver mallet (silver bark) with brown mallet (brown bark), both with shiny green leaves

**Red morrel** (*E. longicornis*) is an upright rough barked tree that occurs on the following aeolian or mafic soils

(1) Soils formed on mafic rock uplands in the RDZ and ADZ. Red brown stony and loamy gravels grading to gravelly loams with alkaline subsoils.

(2) Aeolian loamy soils usually on the west and southern sides of trunk valleys in the ADZ.

(3) Duplex soils with a brown subsoil on slopes.

York gum can be distinguished from red morrel by its generally rougher bark and more branching form. There are several species of trees and mallees with a stocking of rough bark that occur on alkaline valley soils (often aeolian loams), and red brown clay loam soils north and east of Harrismith. These include Yorrel (*E. yilgarnensis* syn Beard *E. gracilis)* , *E. myriadena* (syn Beard E. *ovularis*).

These species all have shiny leaves and rough bark, but can be differentiated from York gum by narrower leaves and smaller fruit.

DRZ = Darling Range Zone, RDZ = Rejuvenated Drainage Zone, ADZ = Ancient Drainage Zone

**York Gum** (*E. loxophleba*) has 3 types in the Narrogin district. They all have characteristic shiny green leaves but differ in their form and bark characteristics.

*Ssp. loxophleba* (tree with rough bark on whole stem) is the most common form and occurs mainly on loamy soils formed from crystalline rock (usually with jam *Acacia acuminata*).

*Ssp. lissophloia* is the smooth bark mallee form that occurs on lower slopes and valleys, generally on loams or loamy duplex soils often with salmon gum and gimlet east and north of Jitarning, and is common in the Merredin district.

An intergrade form that has rough bark part way up the stem is common in the Corrigin and Kukerin systems.

On the left is York gum *(E. loxophleba ssp. loxophleba)* with jam understorey.

York gum mallee *(E. loxophleba ssp. lissophloia.)*

Intergrade form

**Flooded gum** (*E. rudis* left) is a multi-branched tree that' occurs on winter wet soils that were originally non saline, mainly in valleys and granitic duplex slopes in the DRZ and western RDZ.

Many waterways with flooded gum have become mildly saline. These areas and fresh seepages have often been colonised by the introduced weed Spiny rush (*Dacutus spp*) below.

**Wandoo** (*E. wandoo subsp. wandoo).*is widespread, ranging from gravels (in association with dryandras, jarrah and marri), to valley duplex soils. Where wandoo is the dominant vegetation it often indicates deep or grey sandy duplex and gravelly duplex soils. With other vegetation, it usually becomes more dominant when the soil becomes more duplex. Wandoo is widespread on lower slopes and sandy duplex valleys, often in association with salmon gum and rock sheoak.

Salmon gums dominate on very shallow sandy duplex, clay or calcareous duplex soils, with wandoo being more common sandy duplexes in deeper sandy duplexes, and rock sheoak on very deep sandy duplex patches.

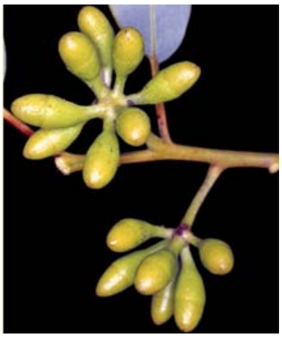
Salmon gums with their shiny leaves and layered foliage can be readily distinguished from dull leafed wandoos with bunchy foliage.

Sandy duplex wandoo woodland

Broad valley with salmon gum flanked by two wandoos

**Powder-bark wandoo** (*E. accedens* left) generally occurs in the west of the RDZ north of Williams on breakaways and stony ridges.
It often occurs near brown mallet.
Both are typical of highly water repellent soils.

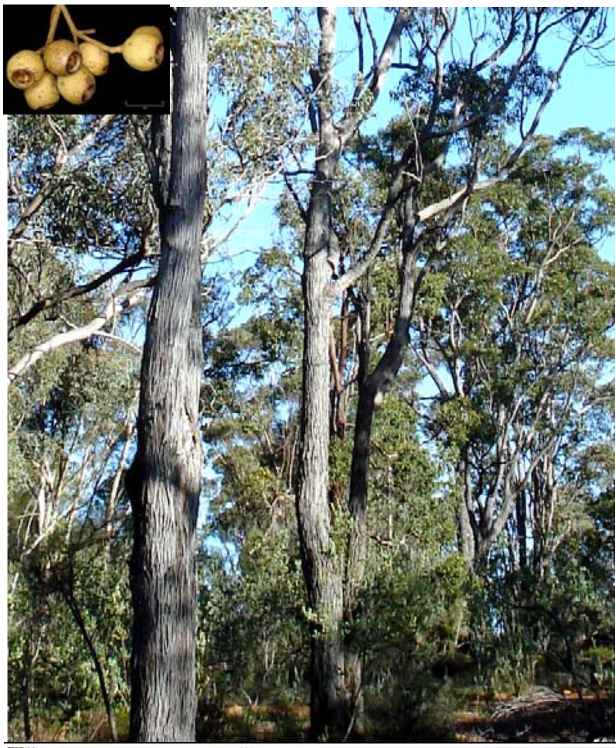
Powder-bark wandoo can be distinguished from wandoo by its powdery smooth bark, and much brighter white-seasonally pink bark. Wandoo bark colour is generally steel grey-yellow



Powder-bark wandoo

Wandoo

**Jarrah** *(E. marginata) (*below) occurs in the gravelly uplands in the DRZ and western RDZ
It indicates very gravelly and sandy gravelly soil, often with ironstone ridges, associated with marri and dryandras, but can also occur on deep pale sands.



**Marri** *(Corymbia calophylla)* occurs on gravelly rises and slopes in the DRZ and western RDZ, often down-slope of jarrah or dryandra ironstone ridges. It may be intermixed with jarrah on gravelly rises or wandoo on gravelly duplex soils. It generally grows on better water holding soils than jarrah, but can occur on deep grey sand over gravel.

Marri with parrot bush *(Banksia sessilis)* understorey


**Jam** (*Acacia acuminata*) often occurs with York gum and rock sheoak, and can dominate in shallow granitic and mafic soils, with another less common wattle (*Acacia saligna*.) Sometimes it can be scattered in lower slope sandy duplex soils in dissected landscapes.

**Manna wattle** (*Acacia microbotrya*) can be mistaken for jam, as they often occur together. However unlike jam, manna wattle can occur on a wide range of soils, including lateritic gravels and sands.

Plant differences are that jam has slender pointed leaves, rod shaped flowers, and flowers in spring; while manna wattle has broader sickle -shaped leaves, ball flowers and flowers in late autumn


**Mallees** are most common in the ADZ and eastern RDZ). The eastern edge of the district is the start of the mallee zone with widespread mallee duplex soils. Mallee scrub with melaleuca understorey usually indicates duplex or shallow soils( e.g. near breakaways, and rocky, or hard setting areas.

A few species - mottlecah (*E. macrocarpa)*, white mallee *(E. albida),* ridge fruited mallee *(E. incrassata),*and mallee white gum *(E. phaenophylla)* occur with sandplain and gravel heath

Apart from a few easily identifiable species like mottlecah, it is difficult to associate the many species with soil type without species identification keys. You can gain an idea of soil type by noting the type of understorey in conjunction with landscape clues like slope, rock fragments, and topsoil features.

**Mottlecah** (*E. macrocarpa*) is commonly found on yellow sandy soils and some pale gravelly sands in ADZ

**White mallee** (*E. albida*) is found in the same areas as Mottlecah on grey sandy laterites

**Mallee scrub;** shallow hard-setting mallee duplex soil with sparse understorey

**Mallee scrub;** shallow sandy duplex with dense melaleuca understorey

**Melaleucas** occur in all zones and many landscape positions. They are common on mallee duplex soils, or soils that can be winter wet. Where melaleucas are the dominant vegetation, they often indicate soils that are waterlogged in winter

The plants shown are from the frequently occurring *Melaleuca uncinata* group.

**Sheoaks** (small trees) and **Tammas** (mainly shrubs) have needle type foliage with separate male (pollen) and female ('nut') plants. Salt sheoak *(Casuarina obesa)* favours saline and wet areas, but the others are *Allocasuarina* species that indicate well drained sandy or gravelly soils.

Rock sheoak (*Allocasuarina huegeliana*) is widespread. Before agriculture, it was mainly on granitic sandy surfaced soils, sandy gravels and deep sandy duplex soils. However it has colonised many different well drained soils on roadsides.

Black tamma (*Allocasuarina acutivalvis*) occurs mainly on mafic and yellow stony and shallow gravels, in the east of the district.

Tamma, the most common tamma (*Allocasuarina campestris*) occurs with black tamma, but tends to be more common in deeper or loamier gravels and yellow earths.


Rock sheoak

Salt sheoak with samphire near a salt lake

Tamma

Black tamma

Male tamma with pollen and typical needle like foliage

## Sandy soil vegetation

**Roadside tea tree** (*Leptospermum erubescens*) is common on well drained sandy surfaced soil. Tea trees are common on deep grey sands, but are colonising species that have spread on well drained disturbed areas.

**Christmas tree (***Nuytsia floribunda* left) an indicator of deep grey sandy soils, with **sheoak** (*Allocasuarina fraseriana* right) that occurs on Darling Range sands and sandy gravels.

**Sandplain cypress** (*Actinostrobus arenarius*) often occurs in sandy soil, particularly yellow aeolian deep sands with Acorn banksia and woody pear

**Woody Pear** (*Xylomelum angustifolium*) occurs mainly on smooth slopes and crests and in dunes adjoining salt lakes and old drainage lines, mainly north and east of Pingelly.

It often occurs with banksias, sandplain cypress, roadside tea tree and sandplain heath. It indicates aeolian deep yellow sands. The image on the left shows woody pear with tamma**.**

**Proteaceous species** are major components of lateritic and sandy heaths, and as understorey species are a good guide to differentiating mallee duplex gravels from other duplexes.

**Banksias** are generally a good guide to sandy gravel and deep sandy soils.

Bull banksia (*Banksia grandis*) is a common tree on Darling Range gravels

Acorn banksia (*B. prionotes*) is a common tree on aeolian yellow sand

Sphere banksia (*B. sphaerocarpa*) is a shrub found in many sand and gravel heaths

Woolly banksia (*B. baueri*) is a feature of lateritic grey sandy soils to the east.

**Grevilleas** are also noticeable in lower rainfall sandplain heath, particularly yellow sand over gravel, but also occur on other well drained upland soils.

Flame grevillea (*G. eriostachya*) is a feature of yellow sandplain.

Hookers grevillea (*G. hookeriana*) is a feature of yelllow sand over gravel soils.

**Hakeas** have similar flowers to grevilleas, but have a persistent woody fruit (see below). They are very common on sandy gravel to shallow and loamy gravel soils, but can occur on a range of soils. Needle hakea (*Hakea preissii*) occurs on red clay soils)

Fan leaf hakea

*(Hakea brownei*)

Marble hakea

(*Hakea incrassata*)

Honeybush

(*Hakea lissocarpha*)

**Dryandras** (now in the *Banksia* genus) with their prickly vegetation are a noticeable feature of shallow gravel and sandy gravel soils.

Parrot bush (*Banksia sessilis*) is common on Darling Range gravels.

Prickly dryandra (*Banksia armata*) is widespread on shallow gravels

Dryandra rich shallow sand over gravel vegetation near Harrismith.

**Other sandplain *Proteaceae***

Stinkwood *(Jacksonia sternbergiana)* is common on deep grey sandy soils

Chittick (*Lambertia inermis*) is common on grey sand over gravel soils in the south east

Woolly bush (*Adenanthos sericea*) is also common on deep grey sandy soils.

## Landscape recognition guide

Long-term stability of the Yilgarn craton and lateritisation of most uplands have produced distinctive upland landscape patterns that are influenced by slope and underlying rock types. This guide can help you recognise these patterns in the field.

This guide distinguishes three upland landscape types that usually merge into one another.

- Sandy landscapes   quartz rich granites and gneisses, sandy sediments, and rocks with an aeolian sand overlay.
- Mafic influence landscapes   granites and gneisses with frequent dolerite dykes or bands of rock such as mafic gneiss or banded ironstone.
- Mafic landscapes   mafic gneiss, greenstone or large dolerite dyke areas.

**Table 3** Landscape type rules of thumb

| Sandy | Mafic influence | Mafic |
|---|---|---|
| Often upland plains and gentle slopes. Breakaways are generally small | Landscape varies according to rock composition and frequency of mafic dykes. Often mafic gravel ridges with frequent breakaways, mixed soils on surrounding slopes and less mafic rises | Hilly with active drainage and mafic ironstone or mafic rock outcrops |
| Sandy gravel or sandy duplex upper slopes and ridges. Can include shallow grey duplex and grey clays | Often similar mesas and mafic ridges on major ridges to mafic landscapes but these are usually interspersed with felsic rock areas, particularly on slopes and valleys | Dark stony and loamy gravel mesas on ridge tops that are often only isolated residuals in a dissected landscape with rocky red and brown loam and clay soils |
| Deep pale sand hollows on lateritic slopes | Mixed loamy and sandy gravels on lateritic backslopes, often with yellow to pale sandy hollows | Loamy gravel to yellow loamy sand on lateritic backslopes |
| Valleys often grey sandy duplex soils, and sometimes deep sands | Variable depending on the geology. Loamy, or more frequently, shallow sandy duplex colluvial valley soils but are often shallower, with more colour and better structured subsoils than sandy landscapes | Red-brown to brown loamy surfaced colluvial valley soils |
| Grey often coarse sandy surfaced soils in dissected areas, pale dam banks and often soaks and seepages | Variable soils in dissected areas, frequently with granitic, pallid clay dams. More shallow sandy duplex soils than sandy landscapes | Red-brown soils and dams in dissected areas |
| | Frequent gravel pits on mafic laterite ridges | |

### Sandy landscapes

These are either granite and quartz rich gneiss landscapes that may be intruded by narrow dolerite dykes (that are too narrow to have greatly affected the rest of the landscape), or landscapes formed on sandy deposits (eg Kweda, Walyerming, and West Kokeby systems.)

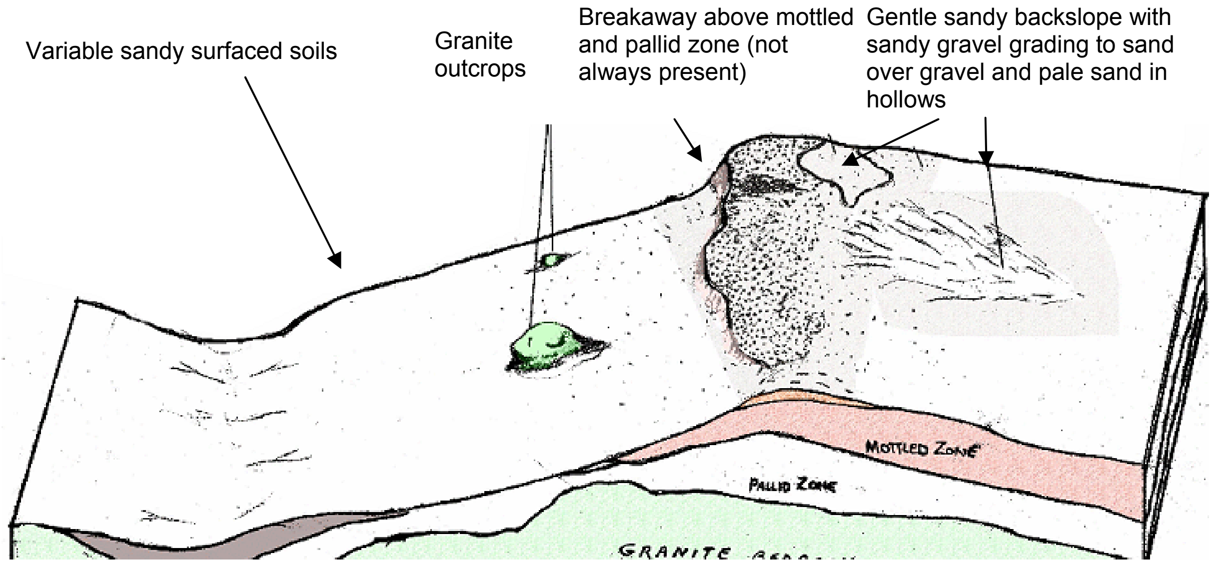



Figure 28 **Diagrammatic example of a sandy granite landscape**

Figure 29 features a typically gently sloping aeolian grey sandy landscape from the Kweda system. The east Quairading case study contains an aeolian yellow sandy landscape, and a Kokeby sandy landscape can be found in the south-west York case study in the Northam bulletin of this series.


Figure 29 **Aeolian grey sandplain in the Kweda system; deep sand and sandy gravel rises grading to grey deep sandy duplex valleys**

Figures 30 and 31 feature a range of sandy landscapes from the district.


30A Lateritic and granitic grey sandy duplex slope south east of Wagin


30B Deep grey sand and grey deep sandy duplex soils on a granitic hillside at Dardadine


30C Granitic grey deep sandy duplex soils on a hillside at Narrogin

Figure 30 **Dissected sandy granitic landscapes**


31A Upland grey aeolian sandplain south of Toolibin; tagasaste has been planted in the sand hollow


31B Sandy gravel slope west of Corrigin grading to a wandoo deep sandy duplex valley


31C Mildly dissected landscape with mixed sandy surfaced soils east of Harrismith

Figure 31 **Grey aeolian and lateritic sandy landscapes**

## Mafic influence landscapes

This is where rock types are too intermixed to form distinct sandy or mafic landscapes. They are very common as basement rocks vary and dolerite dykes have intruded most underlying granites and gneisses. These dykes are frequently associated with uplands as mafic ridges, often lateritic, but soils on slopes are very variable due to sudden changes in rock type and colluvial merging of soils formed from them.

Figure 32 is a conceptual diagram of a mafic influence landscape, and examples are shown in Figures 33 and 34. Note the characteristic hilly terrain and red brown mafic ridges.

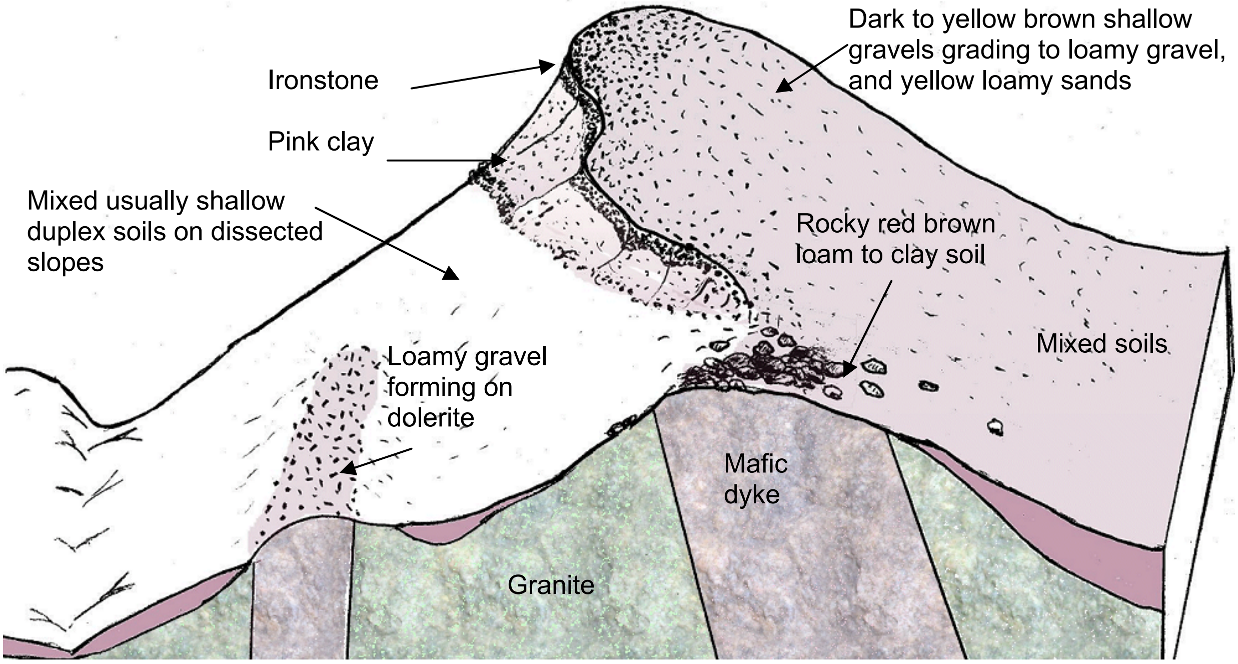



Figure 32 **Diagramatic view of a mafic influence landscape**

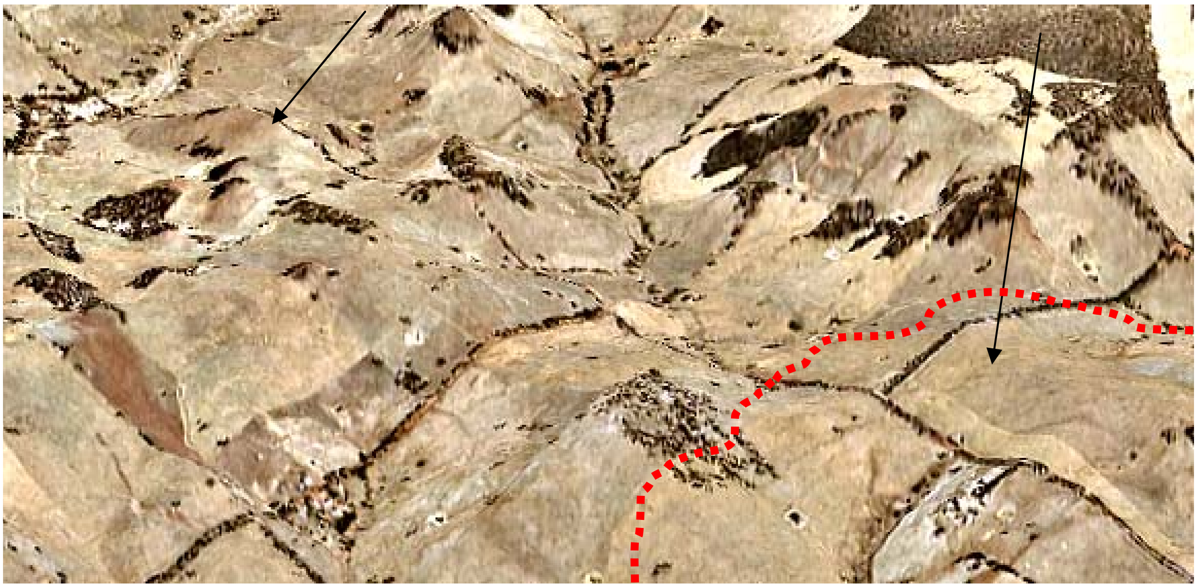



Figure 33. **Relief image of adjoining sandy granite and mafic influence areas west of Woodanilling**

Mafic rocks generally weather more quickly than quartz rich igneous rocks like granite, but mafic areas commonly coincide with dissected hilly uplands that stand above surrounding granitic surfaces.

Two factors are involved.

1. The contact layer between dykes and the surrounding rock are often more erosion resistant due to 'baking' by heat from the molten dyke.

2. Granitic laterites are less resistant to erosion then the dense iron rich mafic laterites. Differential weathering over long periods of time has left mafic ridges. When the dense mafic ironstone is penetrated, rapid erosion of the underlying clay layers result in steep slopes and incised waterways. Quartz rich igneous rocks and sandy laterites form sandy surfaced soils that create less runoff. This and less resistant ironstone create more subdued landscapes with sandy surfaced soils and often less active waterways. This is only a general guide as underlying rocks are variable and there are exceptions on poorly drained plains where heavy soils and waterlogging are more common, and there is insufficient slope for soil transport.

Figure 34 shows a relief map of an area east of Wickepin that illustrates a common pattern, with a smooth granitic laterite upland in the centre (within the dotted area) flanked by dissected areas of mixed geology. The colours show radiometric signals that are very useful for observing soil type patterns. In brief, red indicates potassium that is common in igneous rock feldspar minerals and associated soils formed from these rocks. Green indicates thorium and blue uranium, which are concentrated in laterites and clays. Dark colours indicate sandy surfaced soils, and green areas are more gravelly. This is only a general guide as white shading has also been used to emphasise landscape relief.

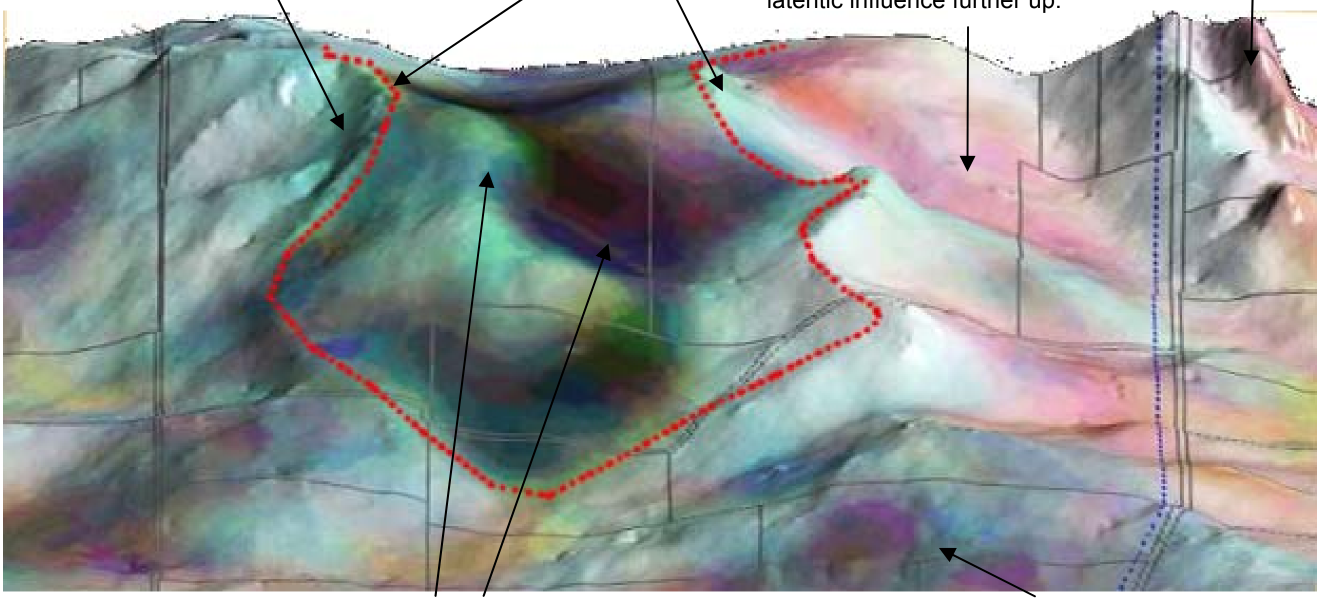
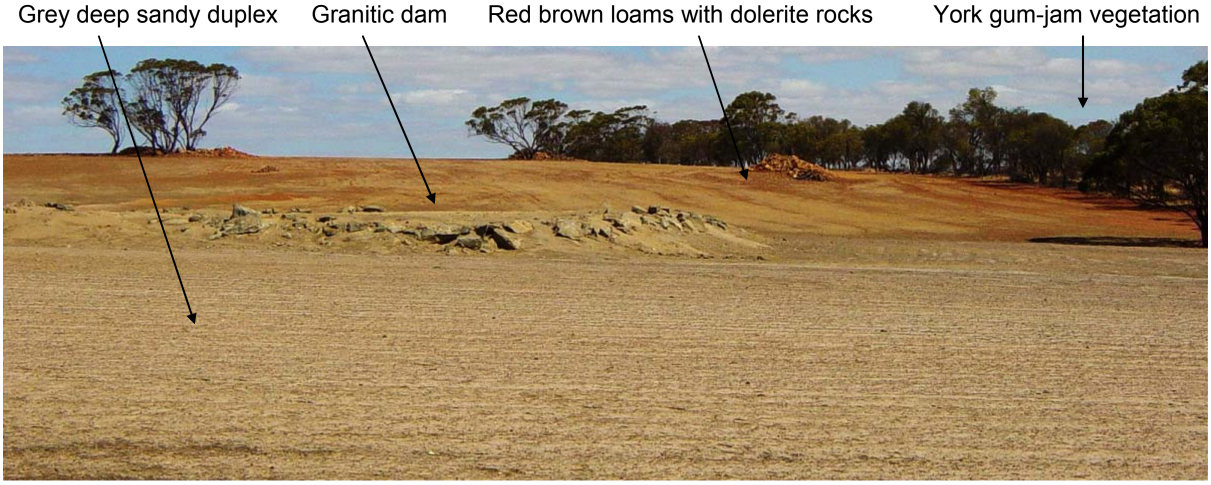
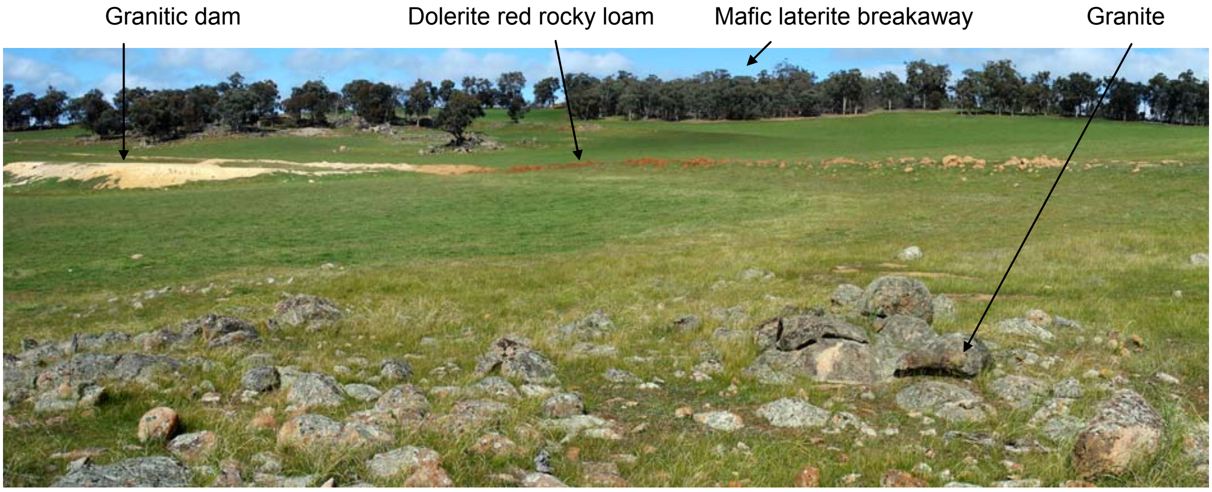


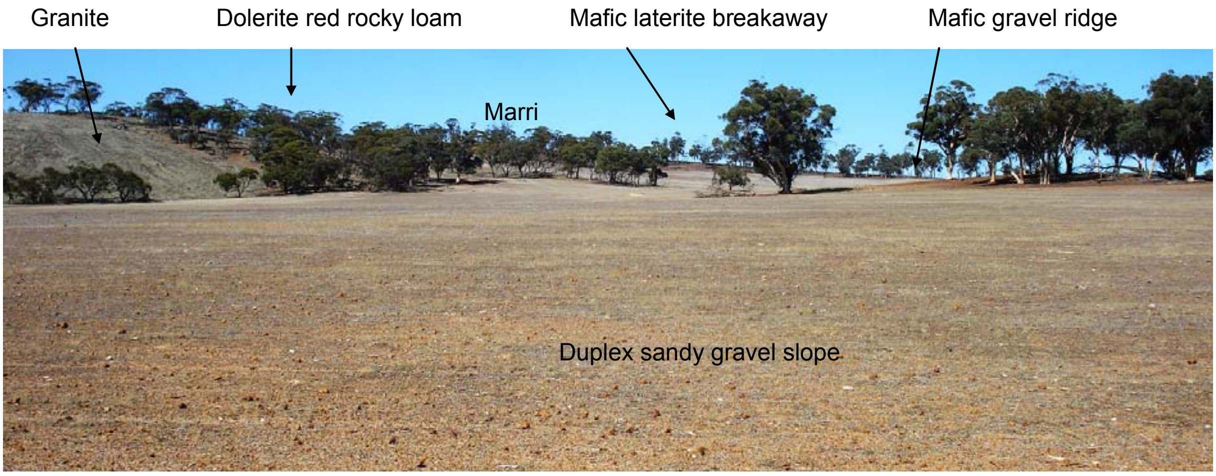

Figure 34 **Relief map with radiometric overlay of landscape components east of Wickepin**




35A Pingelly York gum mafic rocky loam ridge with granitic sandy duplex hollow




35B West Cuballing rocky landscape with mafic breakaway on the ridge and soils formed from granite (foreground) and dolerite dykes on the slope




35C Brookton mafic ridge with granite outcrop, duplex gravel and sandy duplex soils in the foreground

Figure 35 **Mafic influence landscapes**

## Mafic landscapes

These are often on hilly uplands with red brown soils with stony or loamy gravel residuals and alkaline and often calcareous loams, loamy duplexes and clays.

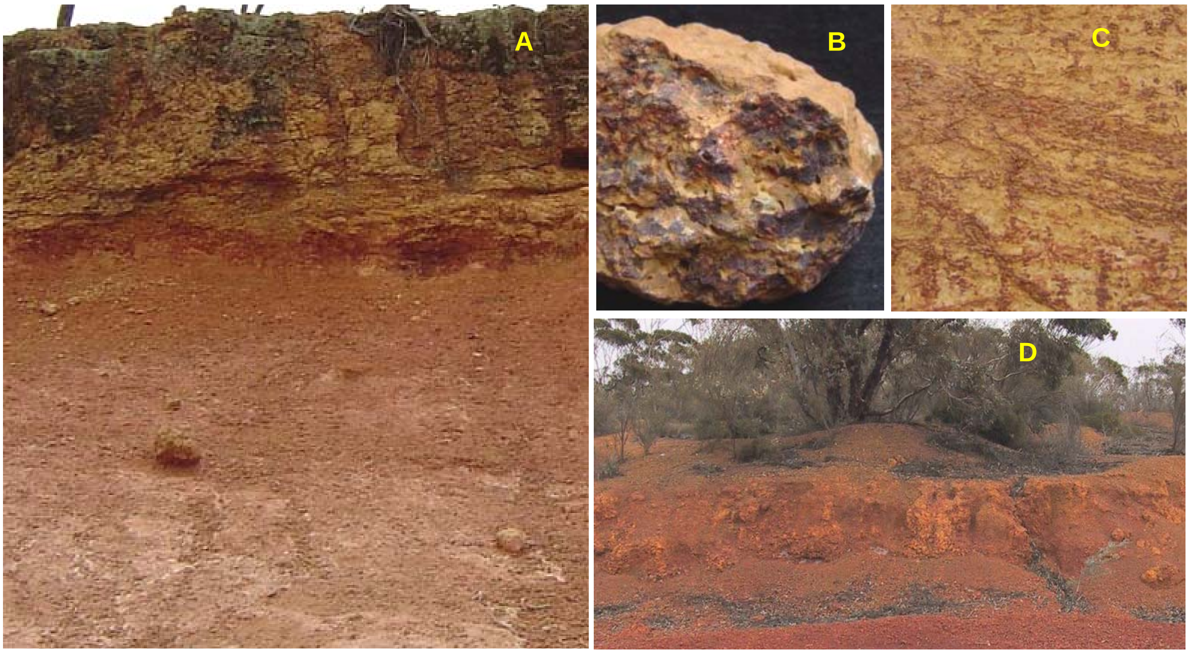
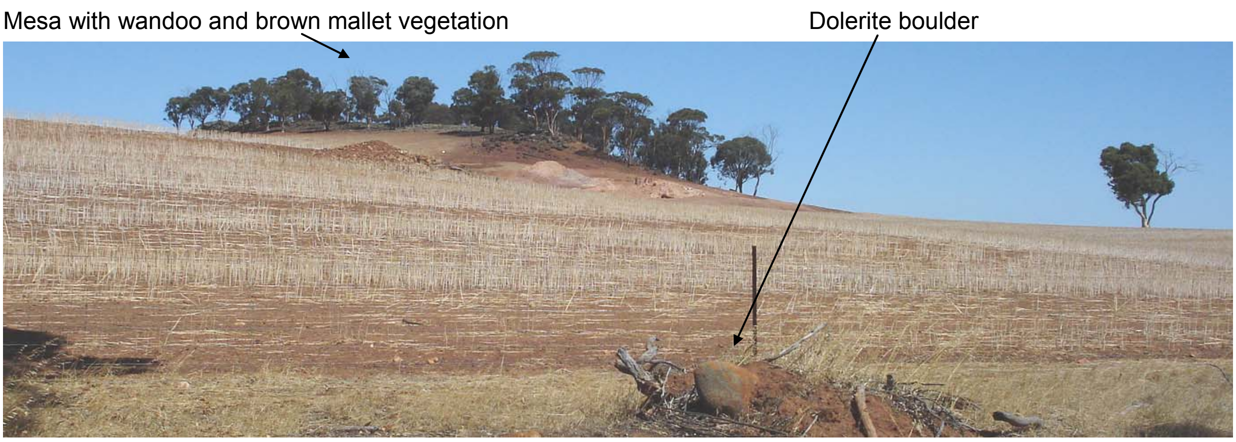



Figure 36 **Mafic laterites. Mafic breakaway (A); dense ironstone boulder (B); iron rich reticulite (C) loamy gravel in a mafic gravel pit at Kulin (D)**


Figure 37 **Mafic laterite surfaces east of Narrogin**

38A  Darling Range mafic loam with wandoo vegetation below a mafic breakaway


38B  East Wickepin mafic landscape with salmon gum-York gum-red morrel vegetation

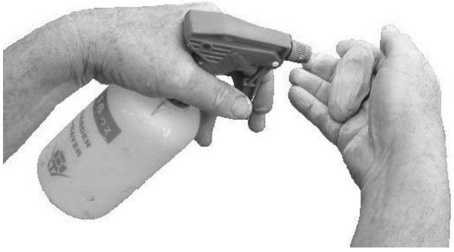



38C  East Cuballing mafic mesa

Figure 38  **Mafic landscape views**

## Soil field texture guide

The texture of a soil reflects the size distribution of mineral particles finer than 2 mm. If it is gravelly, remove the gravel by sieving.



Take a sample of soil that will sit comfortably in the palm of your hand from the layer of soil to be textured.

Form a *bolus* (ball) of soil by moistening the sample with water and kneading it. Knead the soil for 1–2 minutes while adding more water or soil until it just fails to stick to the fingers. The soil is now ready for shearing (ribboning). Note how the bolus feels when kneading it.

Press out the soil between the thumb and forefinger to form a ribbon. The ribbon should only be 2–3 mm thick.

The behaviour of the bolus and of the ribbon determines the field texture.
**Do not decide texture solely on the length of the ribbon.**

Table 4 **soil texture groups**

| Texture group | Subgroup | Behaviour of bolus and ribbon |
|---|---|---|
| CLAY | All clays | Plastic bolus like putty, smooth to touch, becomes stiffer as clay increases, forms ribbon of 50–75 mm or more |
| LOAM | Clay loam | Coherent plastic bolus, smooth to manipulate, forms ribbon of 40–50 mm |
| | Sandy clay loam | Coherent bolus, feels sandy, forms ribbon of 25–40 mm |
| | Loam | Coherent bolus, feels smooth and spongy, forms ribbon of about 25 mm |
| | Sandy loam | Weakly coherent bolus, feels sandy, ribbon of 15–25 mm. Sand grains may be visible |
| SAND | Clayey sand | Clay stain on fingers, very slightly coherent bolus, ribbon of 5–15 mm |
| | Loamy sand | Very slightly coherent bolus, dark staining of fingers, minimal ribbon of about 5 mm |
| | Sand | Cannot form a bolus, non-coherent |