Great Southern Wine Region

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Geology, soils and climate of Western Australia's wine regions

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7 – Great Southern wine region

Regional snapshot

Size: 1.7 million hectares **Vine plantings area:** 2,853 hectares
Elevation range: 0–1,093 m AHD **Vine plantings range:** 6–371 m AHD
Geology: Felsic crystalline rocks of Yilgarn Craton in the north and the Albany–Fraser Orogen in the south
Geological age: Ranges from 1.1–2.8 billion years
Soil: Vines mainly grow on Ironstone gravels
Climate: The Great Southern has the coolest Mediterranean-dominated climate of all WA wine regions. The maritime influence of the Southern Ocean decreases further inland with increased daytime temperatures
Main grape varieties: White – Sauvignon Blanc, Chardonnay, Riesling, Semillon Red – Shiraz, Cabernet Sauvignon, Pinot Noir, Merlot, Malbec

Location and history

Registration of the Great Southern GI as a region took place in 1996. In area, it is the largest wine region in Western Australia and the second largest producer of grapes in WA. It lies on the southernmost part of the state, on Minang, Ganeang and Goreng Noongar Boodja (Country), who are the Traditional Custodians of the land.[134] Today, more than half the region is agricultural land, with the remainder covered in native forests, woodlands and heath, and boasting some areas of outstanding botanical diversity.

Albany is the main population centre in the Great Southern wine region. Other towns and settlements include Denmark, Walpole, Mount Barker, Rocky Gully, Frankland River, Cranbrook, Kendenup, Tenterden and Manypeaks (Figure 7.1).

The first recorded attempts at viticulture in the Great Southern region was in the Mount Barker area in 1859, when settler George Egerton-Warburton planted wine grapes on his St Werburgh's property and bottled his first vintage 2 years later.

Between the World Wars, viticultural pioneers such as Jack Mann and Maurice O'Shea identified the suitability of the region's climate.

After the Second World War, Professor Harold Olmo's (1956) and Dr John Gladstones' (1965) investigations confirmed the suitability of the Mount Barker, Kendenup and Rocky Gully areas for making table wines in the light, traditional European style, and the region's potential gradually became more widely recognised. The Pearse family and Bill Jamieson (the State Viticulturalist) attempted the first plantings at Forest Hill in 1965 (Beeston 2002). Although this failed due to waterlogging in the wet spring of that year, a second attempt the following year was a success.

In 1967, John Roche planted 2 ha of vines at Frankland River, which was the precursor to Westfield Vineyard. This evolved into the region's first large-scale plantings in the 1970s. Another small vineyard planted by Tony Smith at Denbarker around the same time became the Plantagenet vineyard, which produced its first wines at Mount Barker in 1975 (Beeston 2002). By the mid-1970s there were 7 vineyards between Mount Barker and Frankland River. Plantings in the Porongurups and around Denmark soon followed, with rapid expansion occurring in the late 1980s and into the 1990s.

In 2004, 2,071 ha of vines (wine grapes) were planted in the Great Southern region, increasing by 2019 to more than 2,800 ha (DPIRD 2019). Currently, most of the Great Southern region's vineyards are established within one of the 5 subregions: Frankland River, Mount Barker, Porongurup, Albany and Denmark (Table 7.1 and Figure 7.2). We describe the subregions in greater detail on the following pages.

[134] See https://www.noongarculture.org.au/wagyl-kaip/

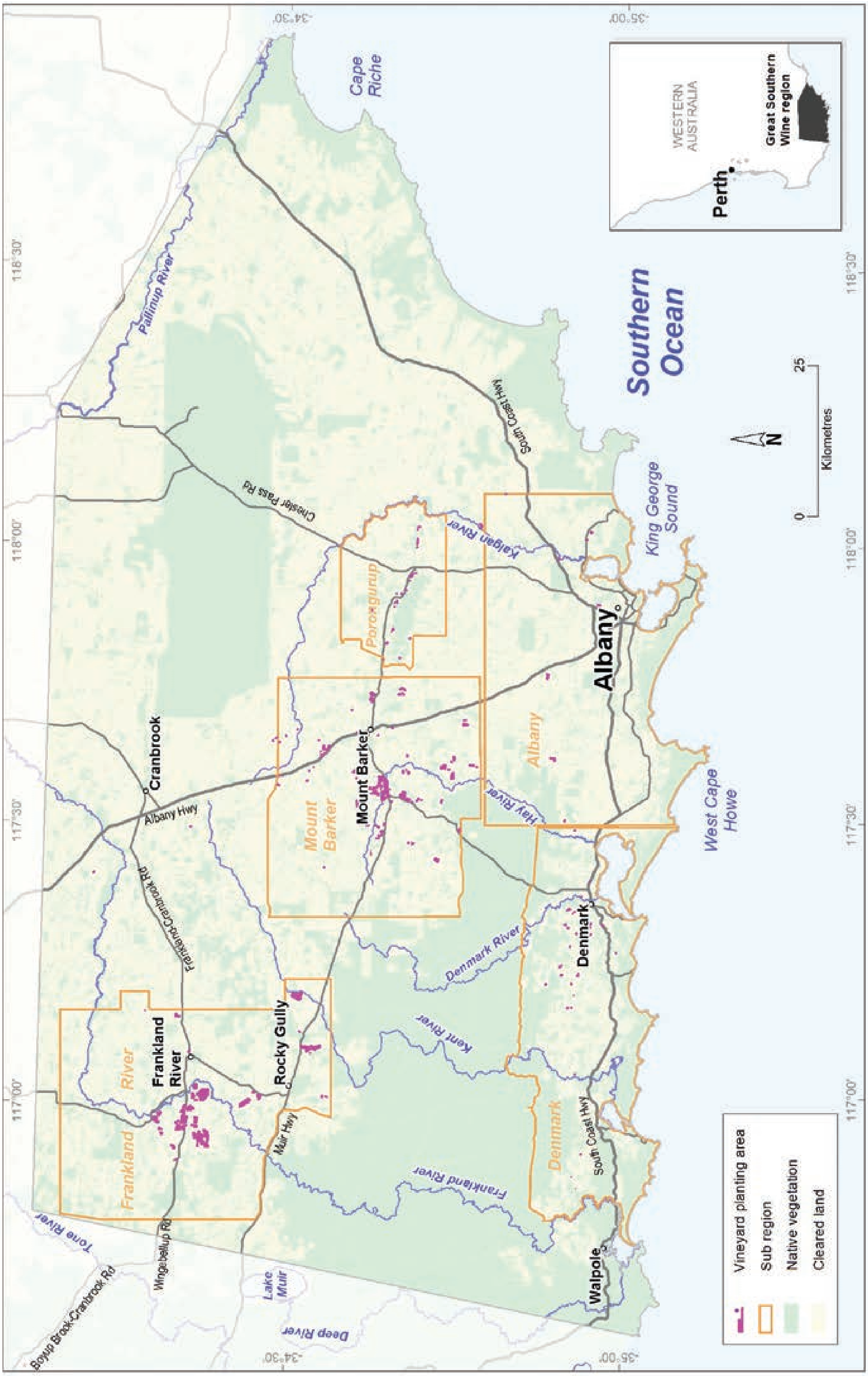


Figure 7.1: Great Southern wine region and subregions

Table 7.1: Great Southern wine region: Estimated area of vine plantings in each subregion (DPIRD 2019)

Subregion	Total area (ha)	Vines currently planted (ha)
Frankland River	143,679	1,526
Mount Barker	132,216	994
Porongurup	39,384	105
Denmark	115,558	102
Albany	157,338	94
Not in a subregion	1,080,322	32
Total	**1,668,497**	**2,853**

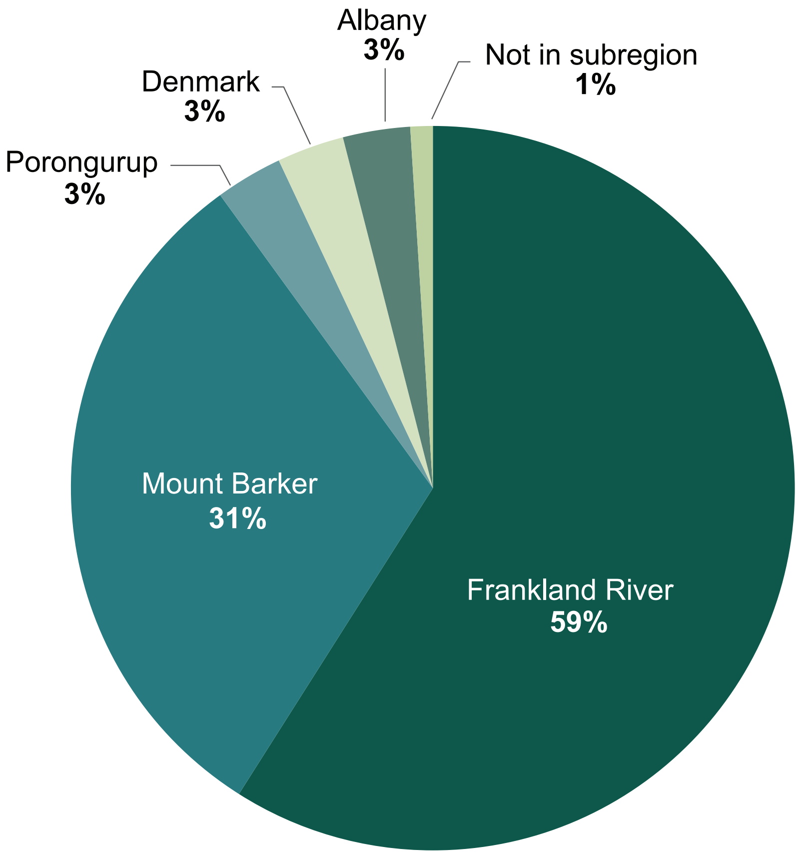


Figure 7.2: Great Southern wine region: Proportion of vine plantings in each subregion

Varieties and production

In 2021 the wine grape harvest from Great Southern wine region yielded 12,269 tonnes from more than 29 different varieties (APC 2022). This was up from almost 7,000 tonnes in 2002, with the range of varieties grown across the region increasing over that time.

In 2021 5,771 tonnes of white wine grapes were harvested—the dominant varieties were Sauvignon Blanc, Chardonnay, Riesling and Semillon. Pinot Gris and Gewürztraminer are becoming more important white varieties. The 2021 red wine grape harvest reached almost 6,500 tonnes—the dominant varieties grown were Shiraz and Cabernet Sauvignon. Pinot Noir, Merlot, Malbec and Tempranillo are increasingly common varieties.

Geology and physiography

The Great Southern region lies across the Ravensthorpe Ramp, where the southern part of WA gently tilts from the ancient central plateau down to the cool, windswept waters of the Southern Ocean. The development of the Ravensthorpe Ramp dates to the breakup of Gondwana, when the southern part of the Australian continent 'sagged' as it drifted away from the Antarctic continent (Cope 1975).

The southern extent of the ancient, deeply weathered Yilgarn Craton reaches the northern part of the wine region (Figure 7.3). Formed during the Archaean geological period more than 2.5 billion years ago, this is one of the oldest parts of the Earth's surface—a massive, stable area of Precambrian Shield measuring almost 750 km by 1,000 km (600,000 km^2). In the Great Southern region, the Yilgarn Craton comprises even-grained granite at an elevation of about 250–300 m AHD.

East of Cranbrook on the craton's southern margin (around 240 m AHD), the salt lake dotted plain gives way to the abrupt peaks of the Stirling Range, which rise to 500–1,000 m AHD. These peaks include Bluff Knoll, the highest point in the south of WA. The geology of the Stirling Range is completely different to its surrounds, comprising a complex of metamorphosed sandstone and shale, originally laid down as sediments in shallow marine waters.

South of the Stirling Range and the Yilgarn Craton, most of the remaining area of the Great Southern region overlies the high-grade metamorphic rocks of the Proterozoic Albany–Fraser Orogen.

Although the Albany–Fraser Orogen is not as ancient as the rocks of the Yilgarn Craton, it still dates from around 1.1 billion years ago. A blanket of more recent sedimentary deposits obscures the boundary between these significant formations.

The Albany–Fraser Orogen has 2 main components: north of Mount Barker is the Biranup Complex running from approximately between the Frankland River and Rocky Gully settlements eastward to Cape Riche, while south of Mount Barker, the Nornalup Complex underlies the remaining area of the Great Southern region.

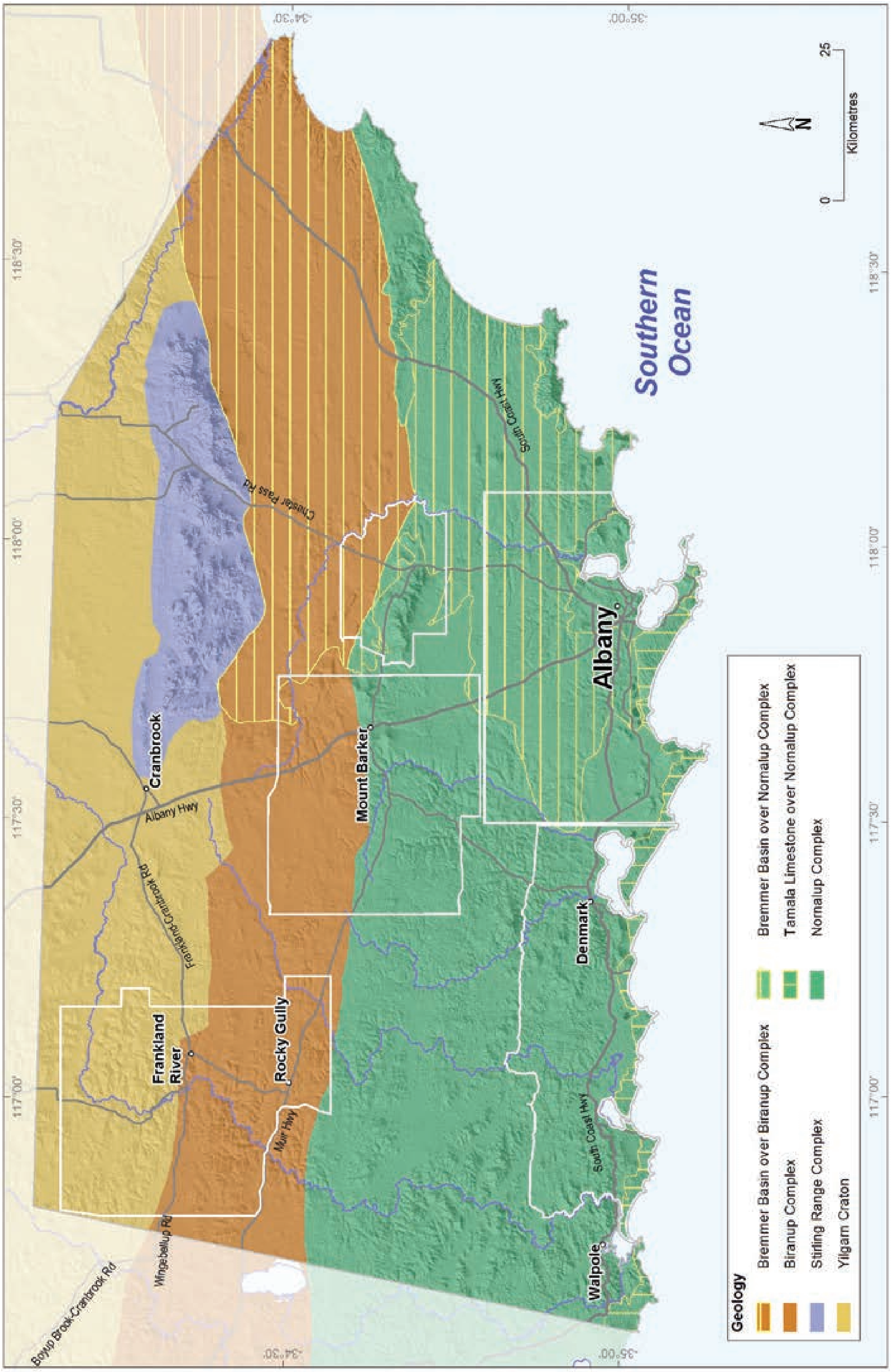


Figure 7.3: Great Southern wine region: Simplified geology

The rocks of the Biranup Complex are mainly gneiss, granitic orthogneiss and some even-grained granite. The rocks of the Nornalup Complex include layered quartz-feldspar-biotite gneiss, granitic orthogneiss, porphyritic granite and even-grained granite. The most prominent peaks emerging above the surrounding terrain tend to be found on the Nornalup Complex and include the Porongurup Range (rising to around 600 m AHD), Mount Frankland, Mount Manypeaks and Mount Barker.

In the eastern half of the region, the crystalline rocks of the Albany–Fraser Orogen are partly overlain by the Tertiary sediments of the onshore portion of the Bremer Basin (Clarke et al. 2003). These mainly include Eocene sedimentary rocks of the Plantagenet Group (pale spongolites and low-energy marine carbonate and light-coloured siltstone), deposited in several broad topographic depressions and shallow seaways, giving rise to the gently inclined landscape of the Albany Sandplain. Protruding granitic domes, including the Porongurup Range, sporadically outcrop above the sandplain sediments overlying part of the Nornalup Complex. The Albany Sandplain is also dissected by rivers and creeks, especially on its southern margins.

As evidence of its long geological history and deep weathering, a lateritic profile blankets much of the region's land surface, including parts of the Plantagenet Group sediments. The laterite varies from massive and cemented to loose uncemented stones, known as ferruginous nodules and pisolites (commonly called jarrah, forest or pea gravels).

Influenced by the tilted Ravensthorpe Ramp, the overall elevation trend is a gradual decline from the region's northern boundary to the south coast (Figure 7.4). This descent is interrupted by a series of 'shelves' as well as the prominent ranges and peaks. The shelves typically take one of two main forms: in some areas they are undulating lateritic plateau surfaces with some low emergent hills, dissected by river valleys; elsewhere they are flats where sediments were deposited during the Eocene by sluggish ancient river systems. These flats are often swampy and dotted with lakes.

Vine plantings range in elevation from near sea level on the south coast to nearly 300 m AHD in the north-west of the Frankland River subregion, and more than 350 m AHD on the slopes of the Mount Barker and Porongurup subregions (Table 7.2). Higher elevations exist within the region, such as the jagged peaks of the Stirling Range, which rise to more than 1,000 m, but these steep rocky peaks are in conservation reserves, unsuited to and unavailable for viticulture.

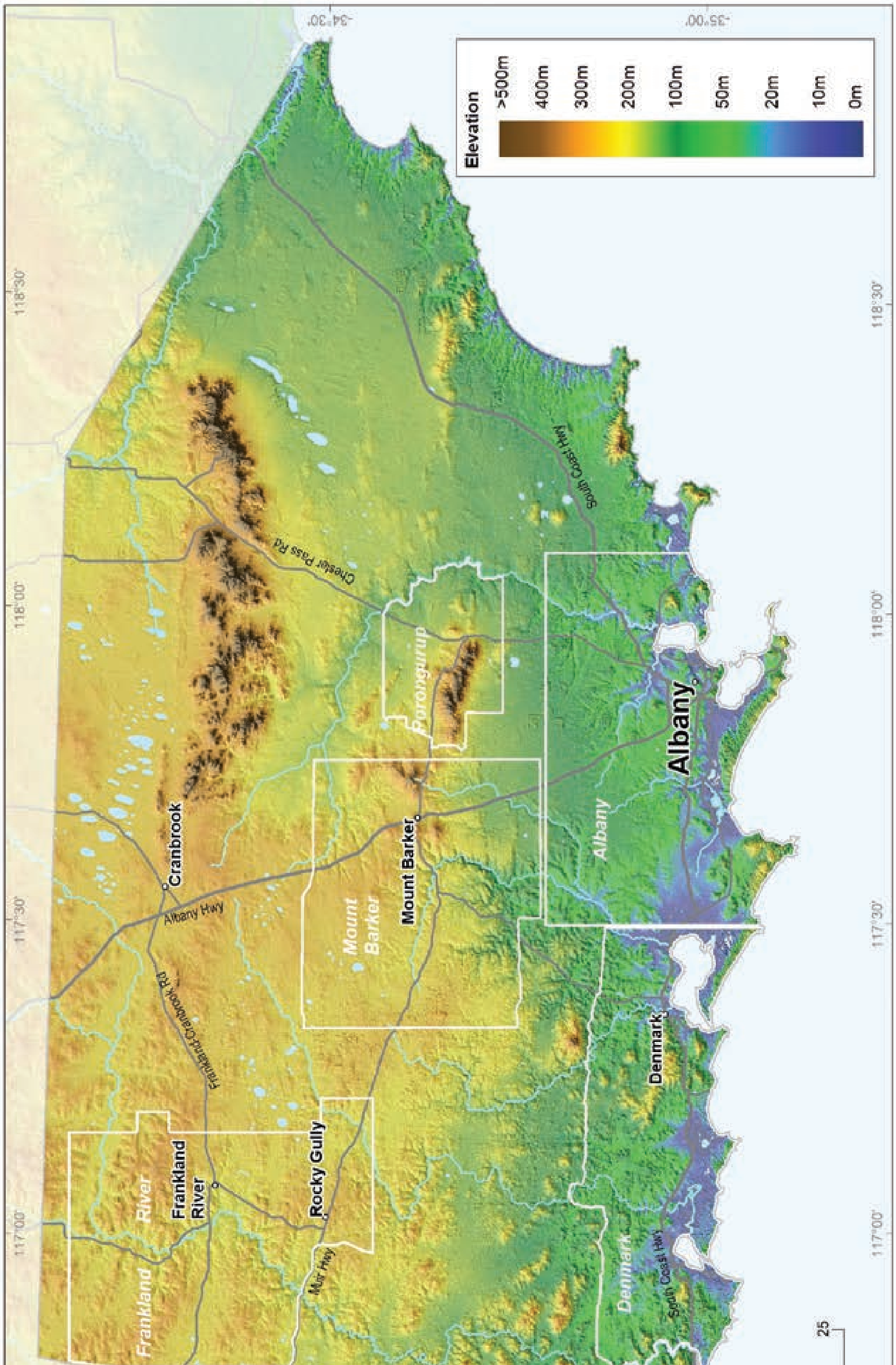


Figure 7.4: Great Southern wine region: Elevations

Table 7.2: Great Southern wine region: Elevation of the subregions and vineyards

	Total subregion elevation (m AHD)			Vineyards elevation (m AHD)		
Wine region	minimum	maximum	mean	minimum	maximum	mean
Albany	0	267	62	6	133	66
Denmark	0	308	62	10	219	102
Frankland River	155	331	237	184	291	228
Mount Barker	41	484	208	73	371	203
Porongurup	60	666	195	102	352	247

Soils and landforms

The section provides only a broad overview of the region's soils and landforms. For more detail, see the individual subregion descriptions that follow. Figure 7.5 presents the main soil types found across the Great Southern wine region with their distribution displayed on Figure 7.6.

The region's age and geology has had a strong influence on the soils. The blanket of laterite that formed across much of the area resulted in Ironstone gravels being the most prolific soil, particularly on the undulating terrain in the north-west of the region. The Ironstone gravels are especially prominent in the Frankland River and Mount Barker areas, but they are generally seen across the entire region, typically in association with other soils.

Many of the concentrations of Sandy duplex and Pale deep sands are related to the veneer of sediments (Plantagenet Group) deposited by shallow marine incursions in the eastern part of the region. After Ironstone gravels, Sandy duplexes are the next most widespread group of soils. These are particularly common near the Porongurup Range and other eminences, on gently sloping terrain around granite hills. They are also more typical on the subdued terrain north and west of Cranbrook, particularly north of the Gordon River, on the southern part of the Yilgarn Craton. The Sandy duplexes are frequently found in association with Ironstone gravels.

Pale deep sands occur sporadically across most of the region, often in a mix with other soils. The terrain south-east of the Stirling Range and east of the Porongurup Range has greater concentrations of Pale deep sands, associated with Plantagenet Group sediments. They are also often on valley slopes in the south of the region, usually with Ironstone gravel and Sandy duplex soils, and feature on windswept coastal dunes in a mix with other sands, usually over Tamala Limestone.

Heavy soils, seen in about 11% of the region, tend to be more frequent on the flat to gently undulating plain north of the Porongurup Range in a mix with Ironstone gravels. These soils are also related to the underlying sediments of Pallinup Siltstone (part of the Plantagenet Group).

Red–brown loams are typically associated with freshly weathered gneiss and granite on the hilly terrain of the Porongurup Range and in the south-west around the Mount Shadforth area. They are minor soils on cleared land in the region but are desirable for many activities.

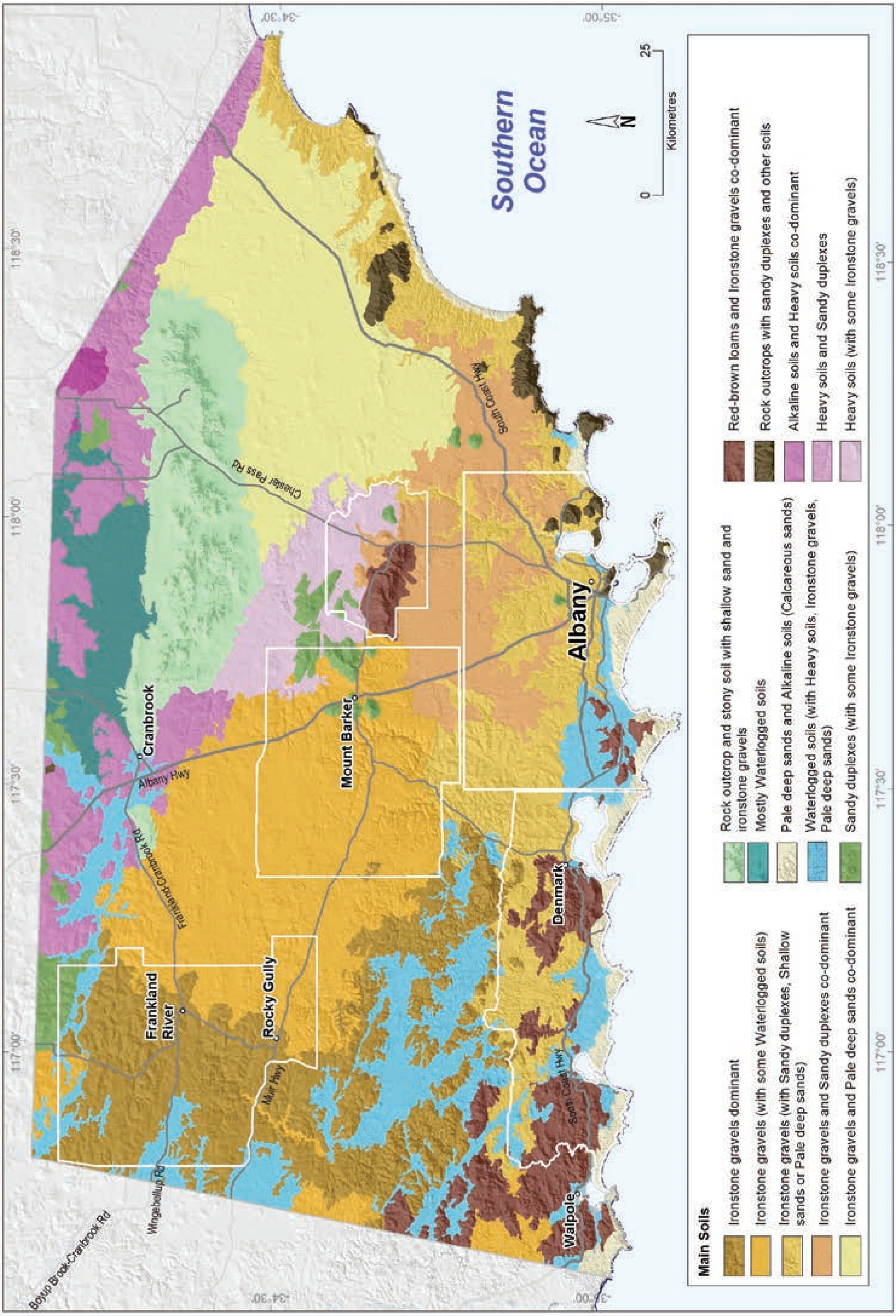


Figure 7.5: Great Southern wine region: Main soils

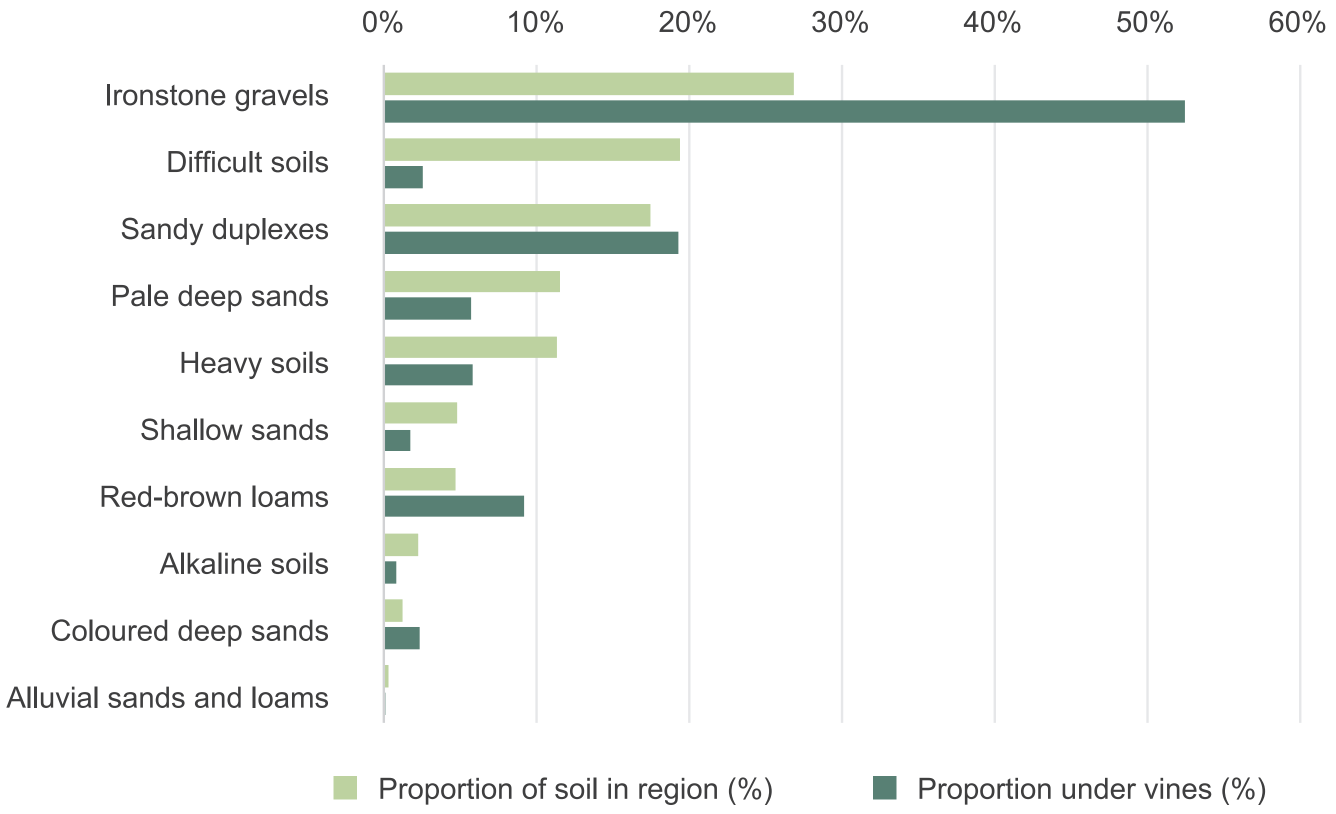


Figure 7.6: Great Southern wine region: Proportion of main soils in the region compared against main soils used for viticulture

The region has extensive areas of restricted drainage, which are mostly associated with Eocene sedimentary deposits found across the wide plain surrounding the Gordon River, on the undulating lateritic plain west of Mount Barker, and low-lying land leeward of the extensive coastal dunes. Areas of shallow soils and bare rock outcrops are also prominent in some locations. We grouped all these as Difficult soils, which make up about 19% of the region. These soils are typically unsuited for any form of agriculture but often occur in combination with more productive soils in various landscapes. Some have been altered (mounded, drained or rocks removed) to allow wine grape cultivation.

Soil-landscape mapping covering this region includes these surveys: South Coast and Hinterland (Churchward et al. 1988), Tonebridge-Frankland (Stuart-Street 2005), Tambellup-Borden (Stuart-Street and Marold 2009), and Jerramungup (Overheu [unpublished]); the mapping can also be viewed online at NRInfo.[135]

[135] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

Main viticultural soils of the Great Southern region

The most extensively planted soils across the Great Southern region are the Ironstone gravels (Figure 7.7). We estimate that about half of the region's vine plantings are currently on these soils, even though they cover less than 30% of the region. This may be partly because Ironstone gravels are typically found on better-drained landscapes but could also indicate the preference many growers have for gravelly soils.

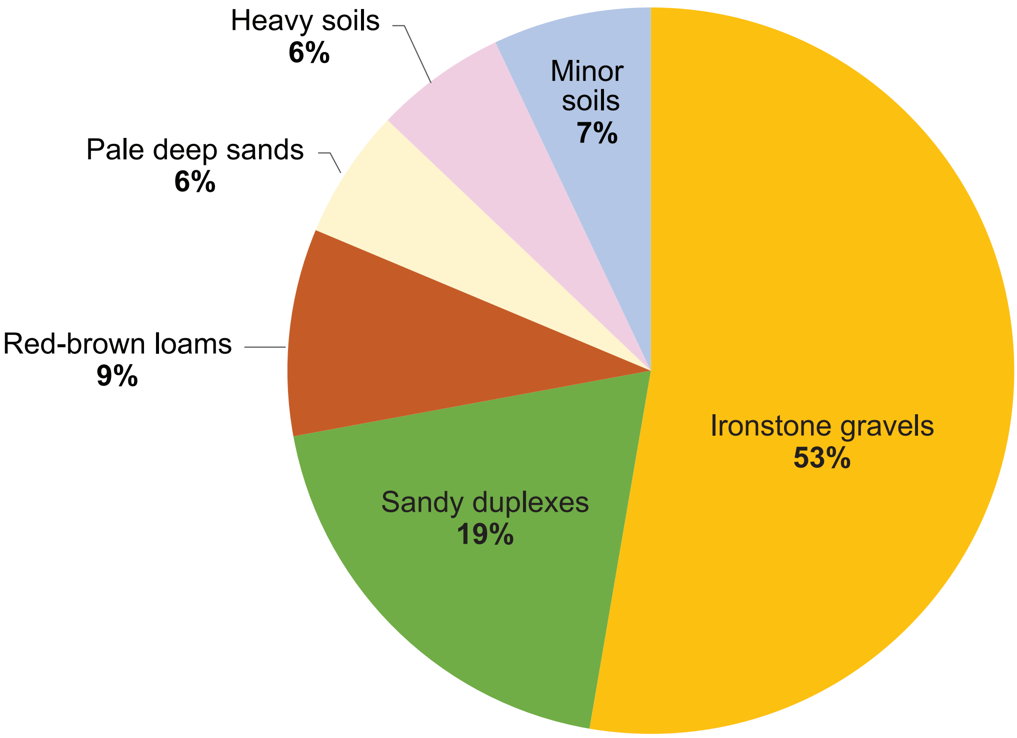


Figure 7.7: Great Southern wine region: Main soils used for viticulture (Minor soils include Shallow sands, Coloured deep sands and Alkaline soils)

The Ironstone gravels with clayey subsoils are the most widely planted on the lateritic plateau and undulating low hills in the region's north-west. In some areas where there is lower rainfall, they can have poorly structured, sodic clay subsoils. Before clearing for agriculture, many of these sodic soils originally supported wandoo (Eucalyptus wandoo) woodlands.

Sandy duplexes are also important soils, supporting almost 20% of the vines in the region. They usually have grey coloured sandy topsoils or less frequently, yellow to brown sandy topsoils, over clay. It is not uncommon to find a layer of ferricrete nodules and pisoliths sitting above the clay. If the vines are on Sandy duplexes close to granite hills, they may have rock fragments in the subsoil.

Almost 10% of the region's vines grow on well-structured Red–brown loams (often called 'karri loams'). These are generally near exposed or shallow areas of crystalline bedrock, often on steeper valley and hill slopes. These soils usually have brown (or less commonly, red or yellow) loamy topsoils over well-drained neutral clay subsoils.

The remaining soils supporting vines, particularly the Pale deep sands featuring deep bleached sands and Heavy soils with sandy loam topsoils and shallow reddish colour clay subsoils, are typically found among a mixture of other soils in vineyards.

Climate

The Great Southern wine region is large and has quite marked climatic differences from north to south and east to west. In general, the Great Southern's subregions are cool, with high humidity (similar to Margaret River wine region) and usually have low temperature variability. The inland areas feature occasional excessive heat events in summer and moderate frost risk in winter and spring. Specific details of each subregion's climate are in the following subregion descriptions.

According to Gladstones (1992), the Great Southern is WA's coolest winegrowing region, reflecting the strong influence of the Southern Ocean. Recent analysis by Remenyi et al. (2019) shows that it has the lowest mean growing season temperature of all WA wine regions. Gladstones (2021) identified that locations in the Great Southern region also have the lowest average daily sun hours and highest average cloud cover of all WA regions. The prominence of these moist coastal onshore south to south-east winds (especially from January to February) creates this coastal cloudiness, which typically dissipates about 20–50 km inland.

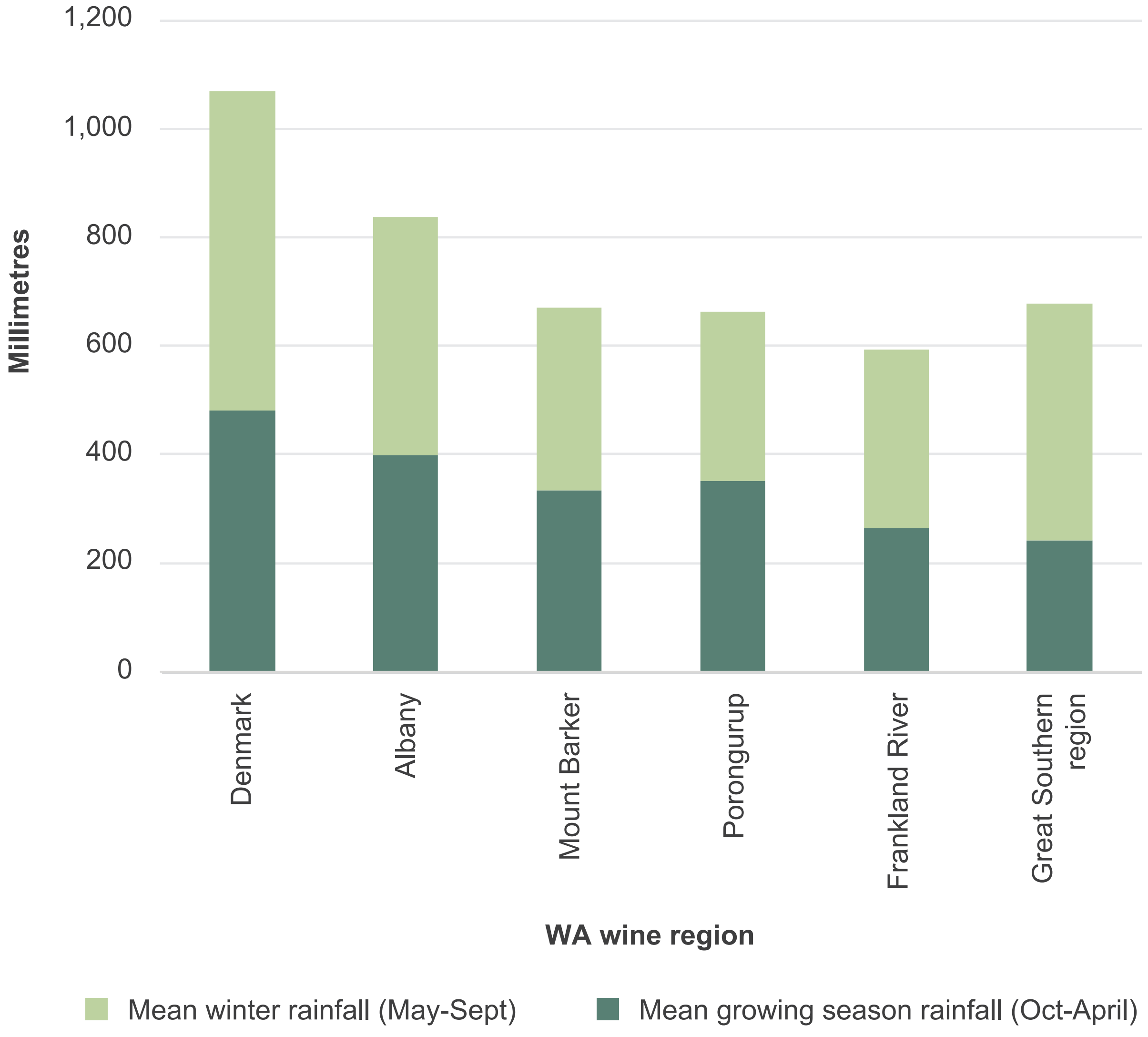
Mean annual rainfall ranges from more than 1,000 mm at Denmark on the coast in the south-west of the region to 450 mm in the north-east, reflecting the dominance of cold fronts from the Indian and Southern oceans bringing more rain to the west and south (Figure 7.8, Figure 7.9 and Table 7.3). A rain shadow effect north of the Stirling Range creates drier conditions east of Cranbrook[136] (Stuart-Street and Marold 2009). Mean 3pm October to April relative humidity ranges from 67% at Denmark to 49% at Rocky Gully and probably lower to the north (Gladstones 1992).

Table 7.3: Great Southern wine region: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	373	145
Maximum	1,257	427
Mean	677	242

136 As there is no official weather station in the Stirling Range National Park, the orographic effect of the Stirling Range is not captured on Figure 7.9.

What these single regional mean annual or seasonal rainfall figures do not capture is the range in rainfall experienced across the full extent of the Great Southern wine region. Despite the southern coast receiving some of the highest rainfalls experienced in WA's wine regions, the mean annual rainfall across the whole Great Southern wine region is one of the lowest of all regions (Figure 7.8).



Source: SILO (n.d.)[137]

Figure 7.8 Great Southern wine region: Variation of mean annual, winter and growing season rainfall for the subregions compared with the entire region (1989–2018)

[137] SILO (Scientific Information for Land Owners), https://www.longpaddock.qld.gov.au/silo/; Jeffrey et al (2001)

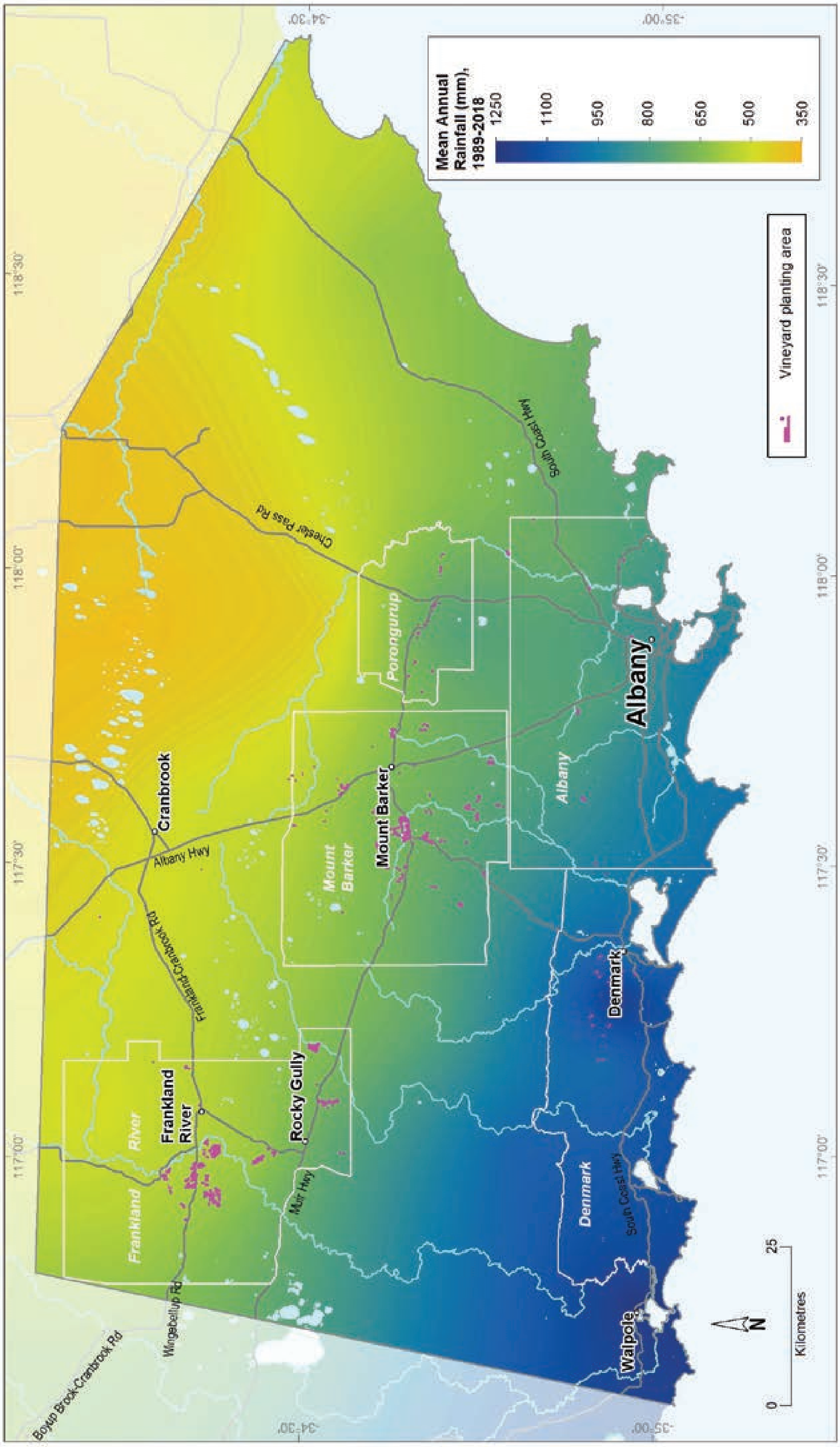


Figure 7.9: Great Southern wine region: Mean annual rainfall (1989–2018)

These factors also affect the ability and methods used to capture and store surface water supplies across the region—an issue compounded by the saline conditions in some of the lower landscape positions and valley floors that occur in some inland locations.

Mean temperatures and variability decrease from the north of the region to the south, with the increasing and cooling influence of the Southern Ocean (Table 7.4). As Halliday (2011a) states, the Southern Ocean has a strong hand in moderating temperatures in the Great Southern, although there are variations as you travel throughout the subregions. Inland, the summers are warmer and the winters are colder. Dry et al. (2004) identify Frankland River as the warmest subregion, and closer to the coast the Denmark and Albany subregions are the coolest and most influenced by maritime factors. Mount Barker and Porongurup are intermediate.

The relatively low spring rainfall, except along coastal areas, and moderate ripening temperatures are well suited to varieties such as Riesling and medium-bodied reds.

Table 7.4 summarises the temperature statistics for the Great Southern region, supported by maps on the following pages, including:

- mean growing season temperature (GST), which covers the months October to April (Figure 7.10). The Great Southern region has a mean GST range of 16.6 °C at Porongurup to 18.5 °C at Frankland River, with the overall mean of 17.9 °C being the lowest of all WA regions.
- mean January temperature (MJT), which represents the mean temperature throughout the day across the warmest month (Figure 7.11). The Great Southern region has a MJT ranging from 18.5 °C close to the coast to 21.5 °C in the north.
- growing degree days (GDD), which are a measure of heat (between 10 and 19 °C) accumulation[138] predicting the vines' development rates for the growing season months of October to April[139] (Figure 7.12). The Great Southern region has a range of 1,400 to 1,900 GDD units (°C), the second lowest of the WA wine regions.
- biologically effective degree days (BEDD), which are linked to the GDD calculation and adjusted for latitude/daylength and account for diurnal temperatures[140] (Figure 7.13). The Great Southern region has a range of 1,200 to 1,600 BEDD units (°C).
- diurnal temperatures, which are the mean of the daily range between the minimum and maximum mean daily temperature from October to April (Figure 7.14). The Great Southern region has a mean daily range of 8 °C in Albany to 14 °C in Frankland River, with the mean of 11.6 °C.

[138] These calculations use the base 10 method (Hall and Jones 2010).

[139] More recently, Jarvis et al. (2017) suggest that September to March may be more appropriate.

[140] Hall and Jones (2010)

Table 7.4: Great Southern wine region: Temperature statistics (1989–2019)

Measurement	Value
Mean January temperature (°C)	20.1
Mean growing season (October–April) temperature (°C)	17.9
Mean growing degree days (October–April)	1,693
Mean diurnal temperature (°C)	11.6
Average daily sun hours (October–April)*	7.2
Average (October–April) cloud cover (Okta)*	5.1

* Average estimates are from average measurements across the Great Southern region (Gladstones (2021).

Although Gladstones (2005) stated that the risk of spring frosts in the area has proved less than originally feared, frost can be a serious issue in the Frankland River, Mount Barker and Porongurup subregions and care is needed when selecting sites for planting.

Remenyi et al. (2019) has shown that a changing climate is influencing the region. They identified an increase in mean growing season temperatures (GST) over the past few decades and predict a further regional average increase to more than 19 °C in the next 20 years. They also observed a trend towards drier conditions, particularly in the western third of the region. They predict that the mean growing season rainfall for the region could fall below 190 mm over the next 20 years. These are all important factors to consider for the future viability of each vineyard, particularly in relation to water availability, planting and management.

For more information on the Great Southern region's climate see the descriptions for individual subregions below (Note: We have not created temperature maps for individual subregion descriptions).

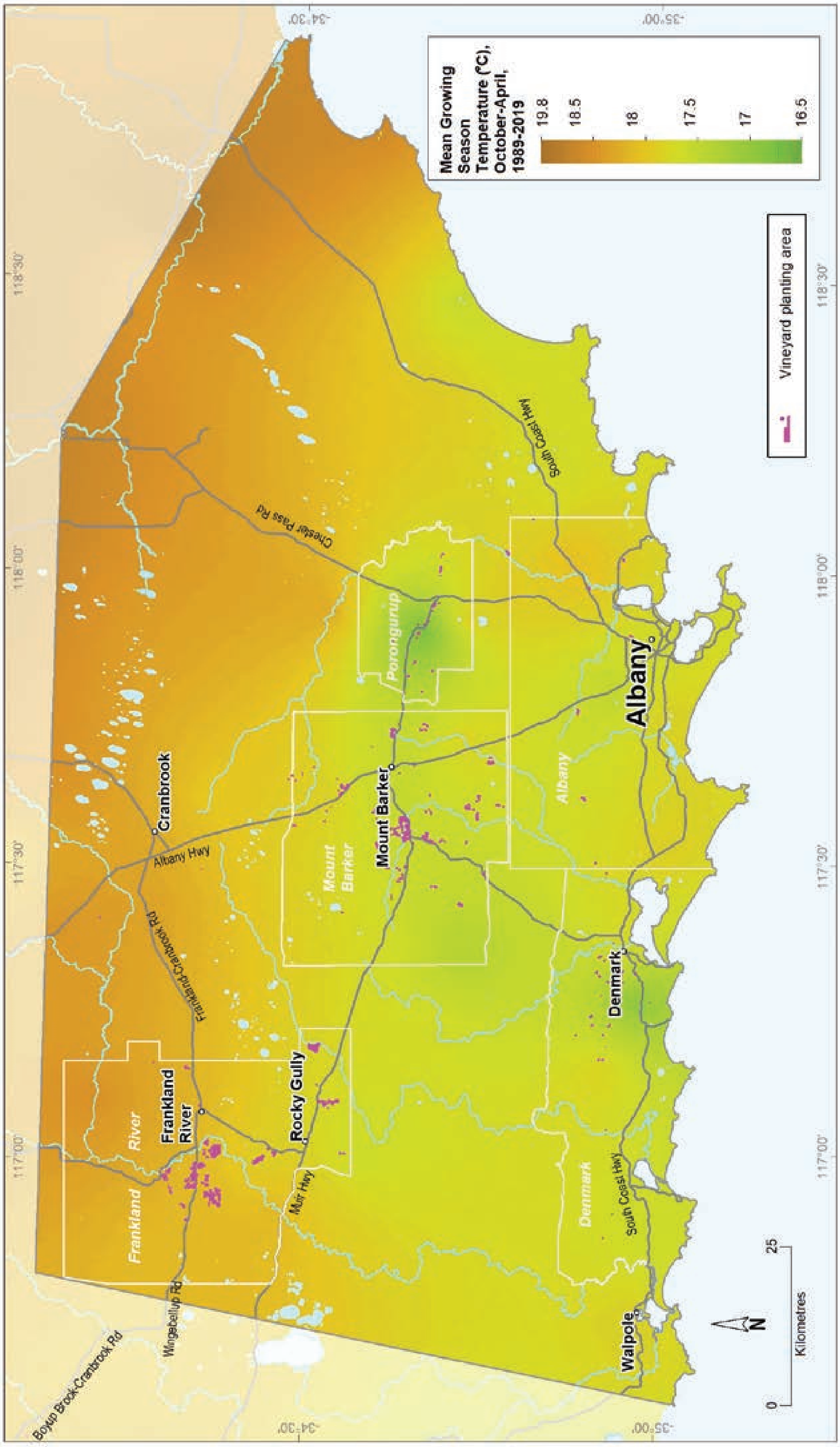


Figure 7.10: Great Southern wine region: Mean growing season temperature (October–April, 1989–2019)

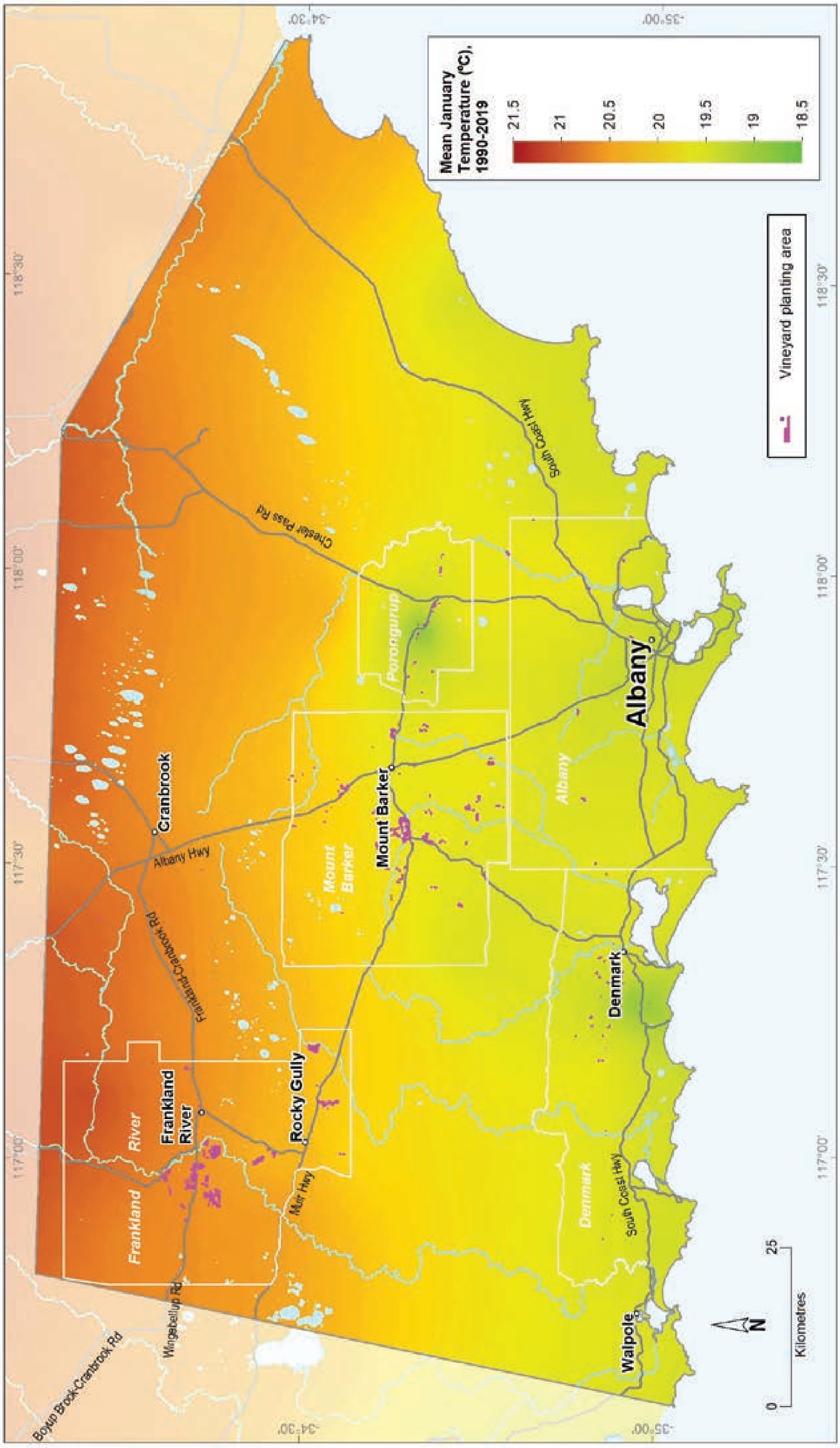


Figure 7.11: Great Southern wine region: Mean January temperature (1990–2019)

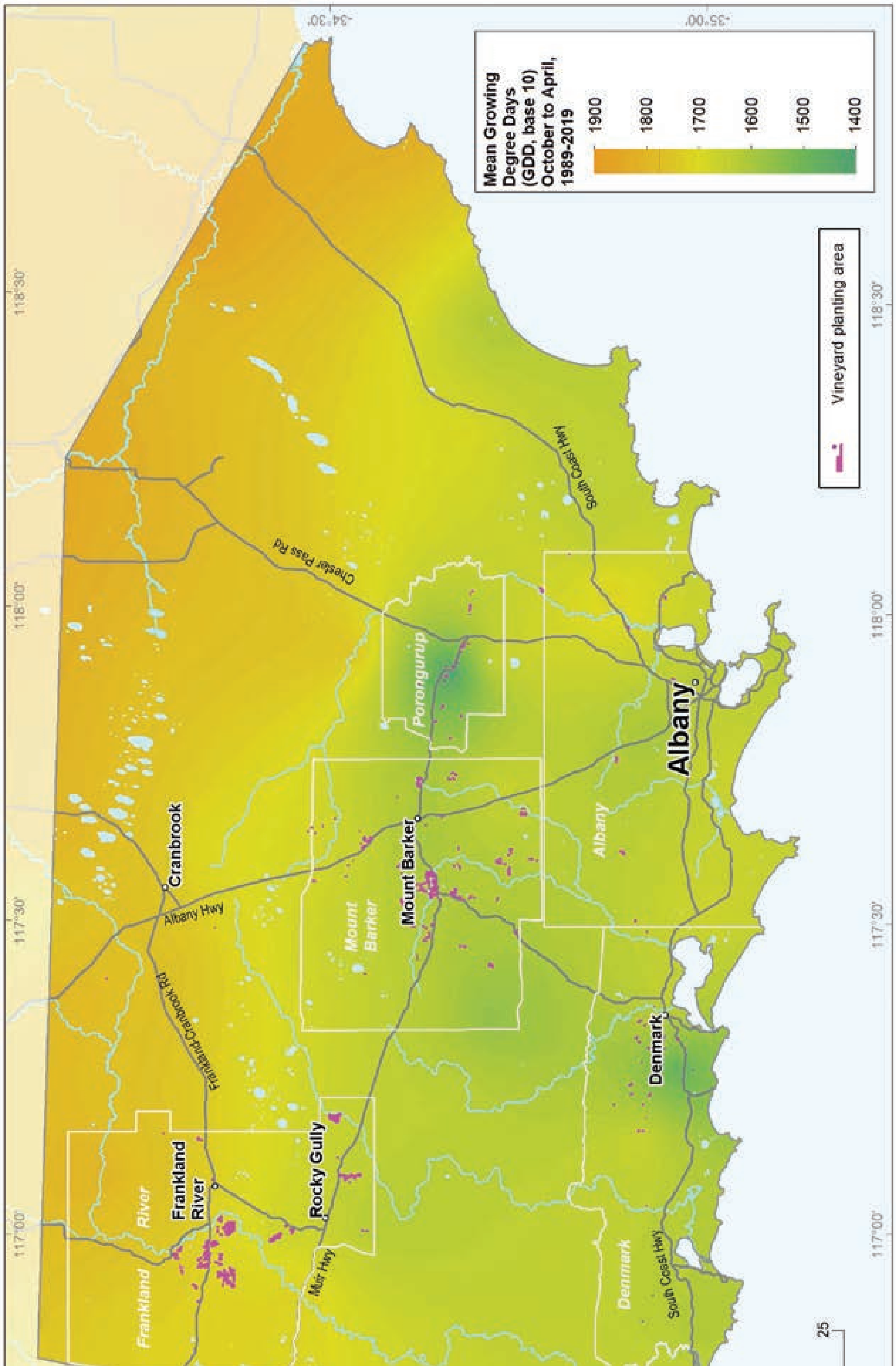


Figure 7.12: Great Southern wine region: Mean seasonal growing degree days (October–April, 1989–2019)

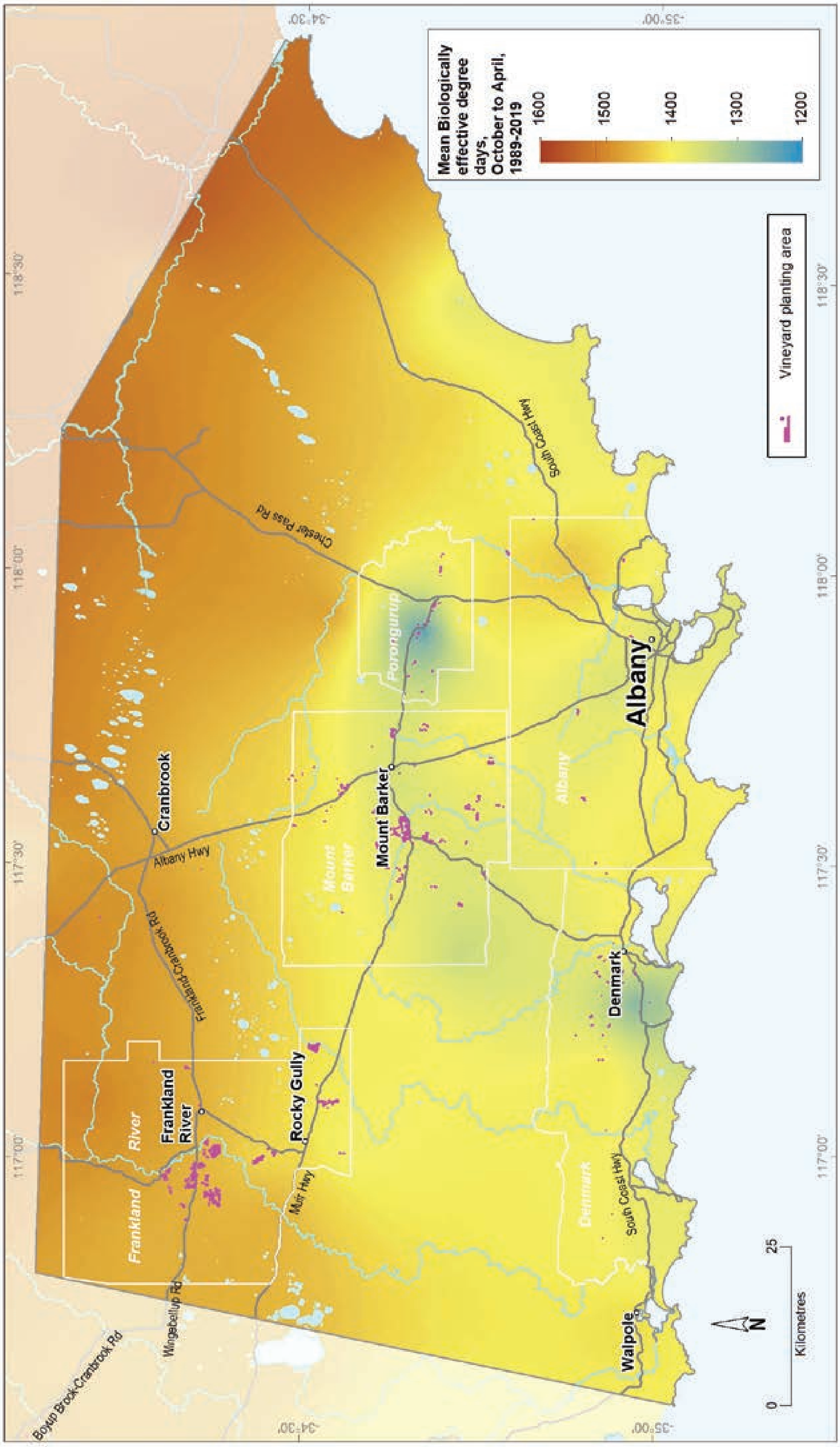


Figure 7.13: Great Southern wine region: Biologically effective degree days (October–April, 1989–2019)

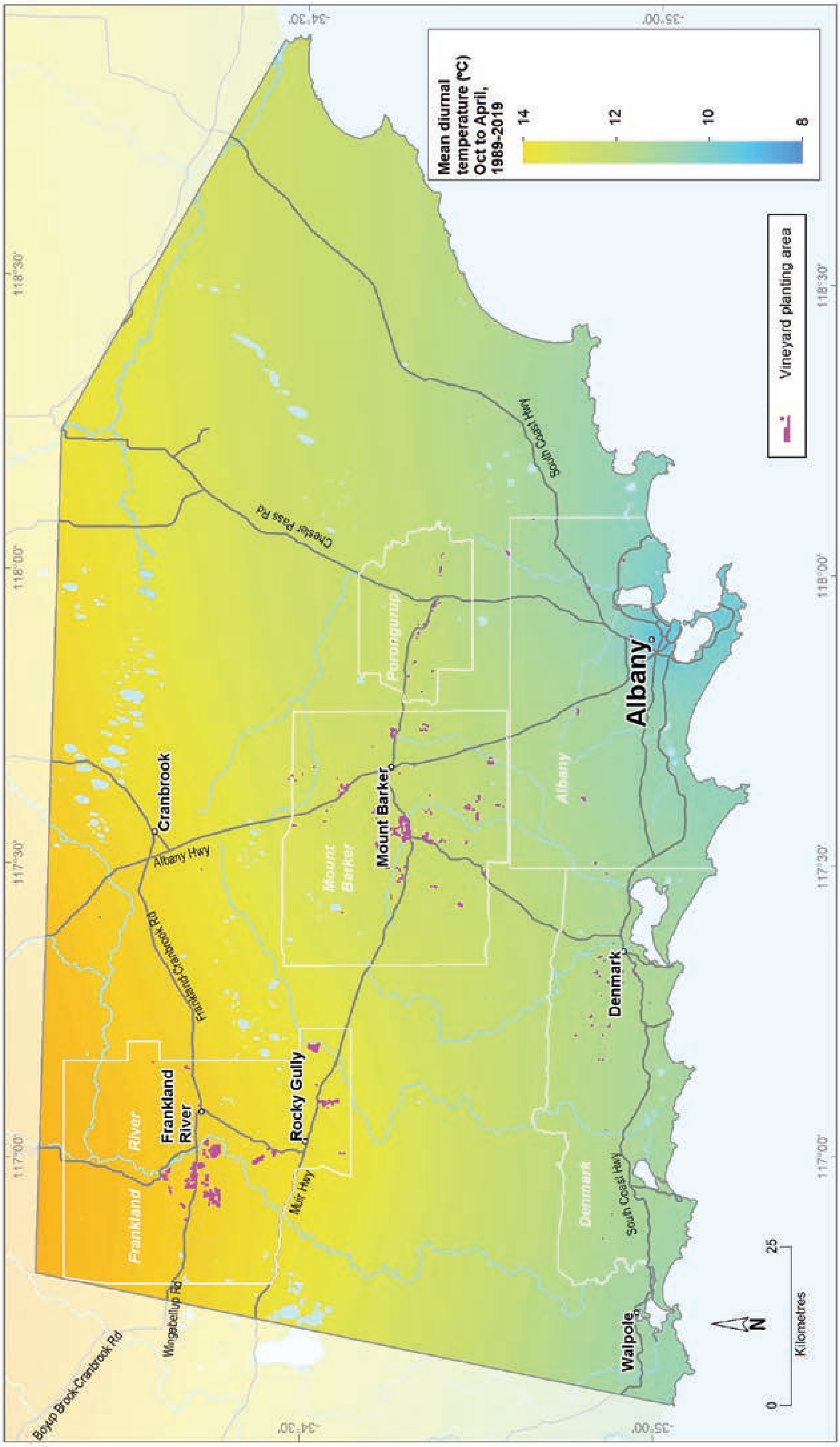


Figure 7.14: Great Southern wine region: Mean diurnal temperature (October–April, 1989–2019)

Frankland River subregion

The Frankland River subregion is in the north-west of the Great Southern region. It covers almost 143,700 ha and includes the towns of Frankland River and Rocky Gully (Figure 7.15). About three-quarters of the subregion is used for farming, with the remaining area cloaked by dense, tall jarrah, marri and wandoo forest, with low woodlands and heath on small areas of wetlands and swampy terrain.

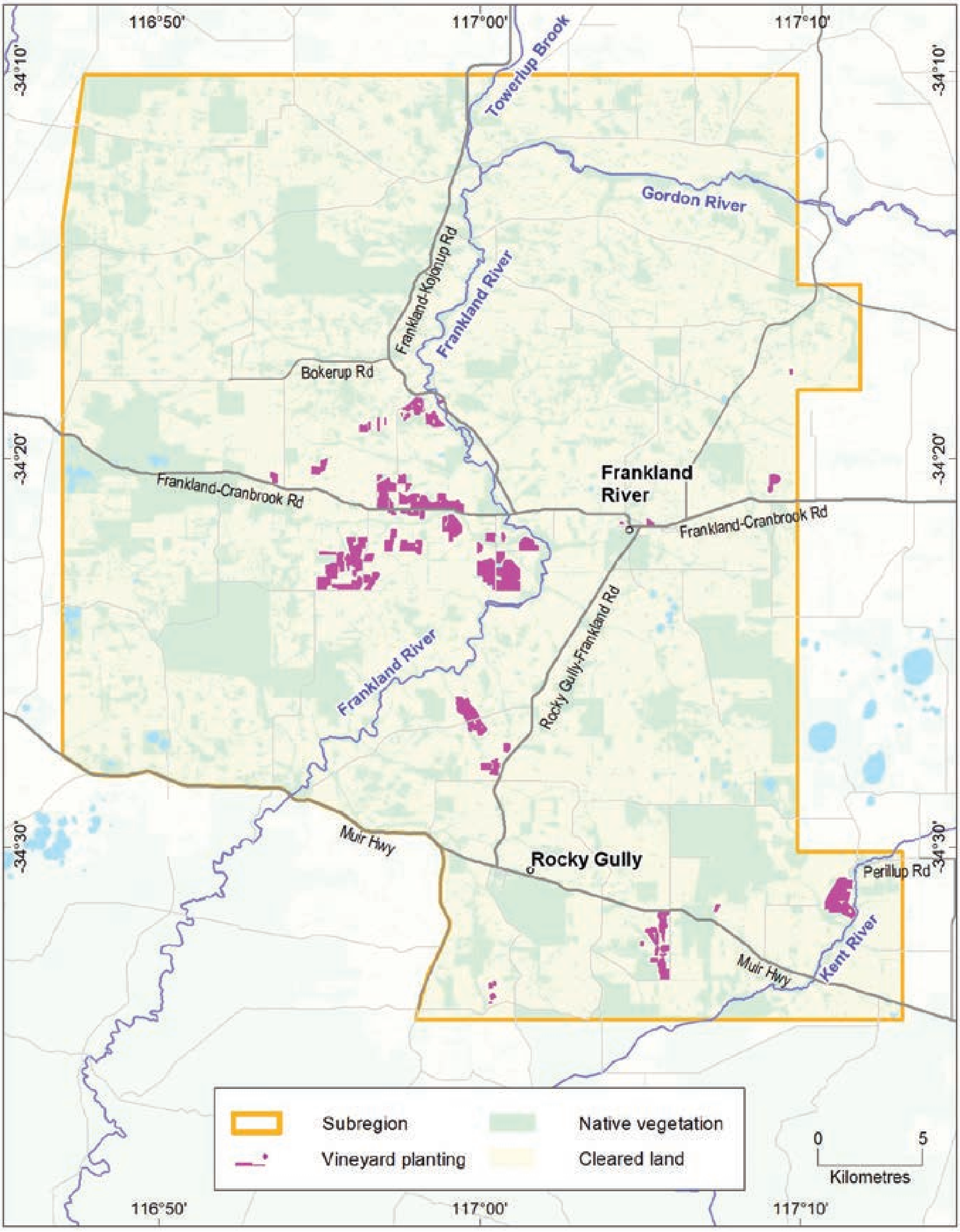


Figure 7.15: Frankland River subregion

The Frankland River area was promoted by State Viticulturalist, Bill Jamieson, with support and recommendations by visiting specialist, Professor Harold Olmo in 1955, who held the Frankland area in high regard for its table wine potential. In 1968, the first vineyard—Westfield—was established in the Frankland River subregion (Beeston 2002). In 1971, Merv and Judy Lange began developing the substantial Alkoomi Vineyard and Winery and by the end of the 1990s, the subregion had about 200 ha of vineyards.

The Frankland River subregion has the largest area of vines in the Great Southern region, with around 1,500 ha in 2019 (DPIRD 2019), making up about 59% of the region's entire plantings. Our data also suggests that this subregion has a higher proportion of large vineyards than any other region or subregion in WA. The average area of vines per viticultural property is 55 ha.[141] This probably reflects the size of the properties in this subregion, but also the relatively uniform soils and gently undulating topography that is ideal for large vineyards that can take advantage of economies of scale.

Geology and physiography

The Frankland River subregion has undulating low lateritic hills and rises that overlie granite and gneiss rocks dated at more than 1.6 billion years of age. It sits on a southward-tilting area known as the Ravensthorpe Ramp (Figure 3.2)—a slumping linked with the separation of the Australian continent from Antarctica during the breakup of Gondwana.

The subregion straddles 2 major geological bodies. North of the Frankland River settlement is the even-grained granite of the ancient Archaean Yilgarn Craton, one of the geological building blocks of south-west Australia. To the south is the layered gneiss of the Biranup Complex, a component of the Proterozoic Albany–Fraser Orogen (Figure 7.16).

Exposed to a long history of stability, these rocks—particularly the Yilgarn Craton—were subjected to deep weathering, which led to the development of the lateritic profile and ironstone gravel that blankets much of the surface of the Yilgarn Craton and large areas of the Albany–Fraser Orogen. In the Frankland River subregion, the laterite varies from massive and cemented blocks and boulders, to loose uncemented laterite stones known as ferricrete nodules and pisolites (commonly called jarrah, forest or pea gravels).

More recent sediments and deposits have formed over both the Yilgarn Craton and Albany–Fraser Orogen. Significant deposition took place across the area during a drier Eocene period when drainage became sluggish. This period of deposition led to the infilling of ancient valleys and depressions previously incised into the Albany–Fraser Orogen and the southern part of the Yilgarn Craton. The broad sandy flats around the Gordon River and the Muir–Unicup wetlands are examples of this.

141 In all other regions and subregions, the average area of vines per viticultural property is less than 20 ha, and Frankland River's neighbour Mount Barker has the next highest average at 19 ha.

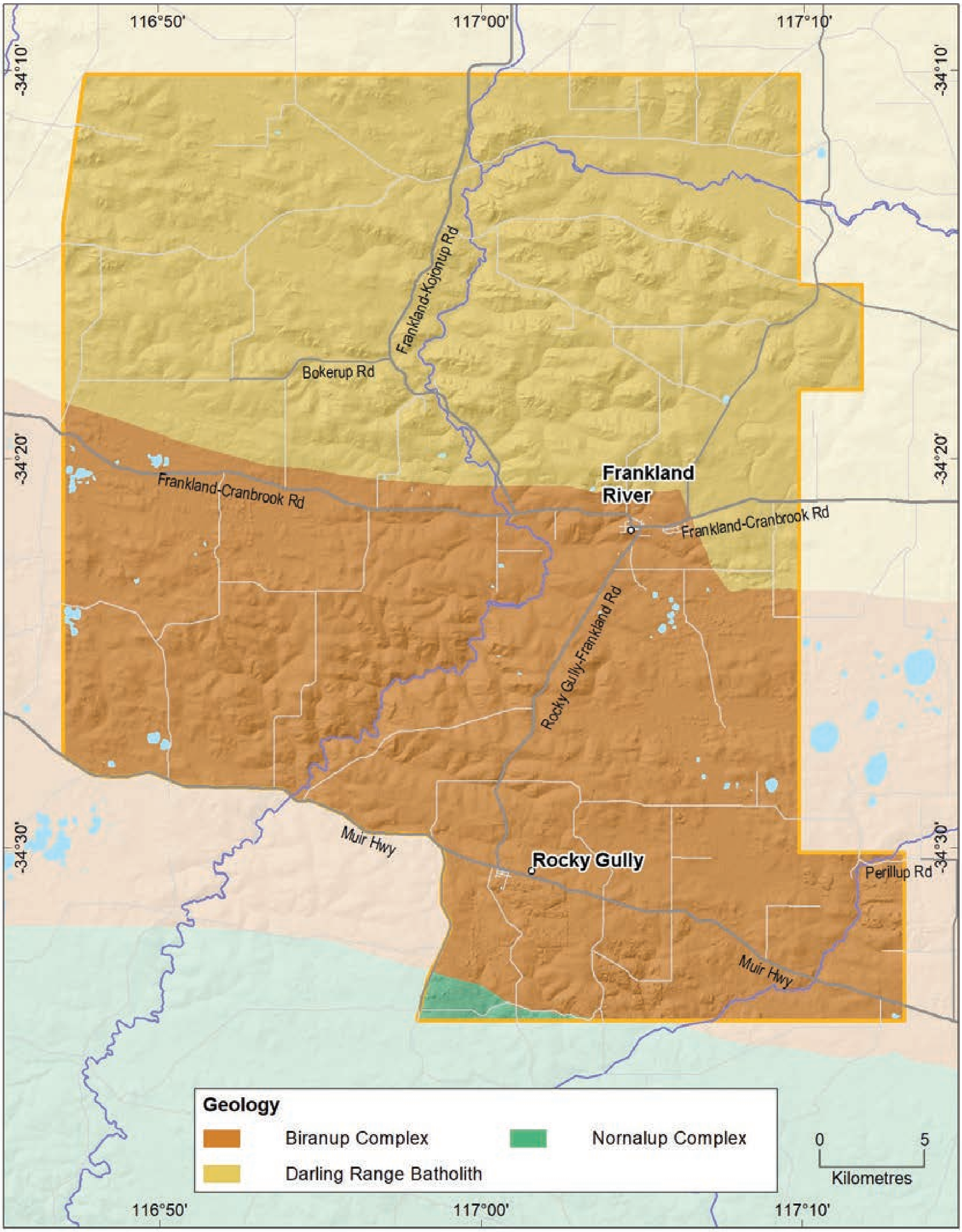


Figure 7.16: Frankland River subregion Simplified geology

The subregion is dissected by the broad, valley flats surrounding the Gordon River, which flows across from the north-east becoming the Frankland River as it arcs south and begins its journey towards the coast. The Kent River meanders across the gently undulating lateritic plain at the south-east corner. The region's elevation ranges from 155–331 m AHD, with the highest mean elevation in the Great Southern region, from 200 m on the floor of the Kent River in the south-east to 300 m on the hills around Frankland River to 330 m in the north-west corner. The elevation range of the vines is 184–291 m AHD.

Soils and landforms

Ironstone gravels are the most dominant soils across the Frankland River subregion, covering about half of the area. They can appear on the surface as cemented rocks and boulders or as the more familiar loose stones called ferruginous nodules and pisoliths and commonly known as jarrah or pea gravel (Figure 7.17).

Ironstone gravels are in most landscapes of the subregion, but they dominate on the broad hill crests and upper slopes of the undulating terrain. They frequently occur in combination with Sandy duplex and Red–brown loam soils.

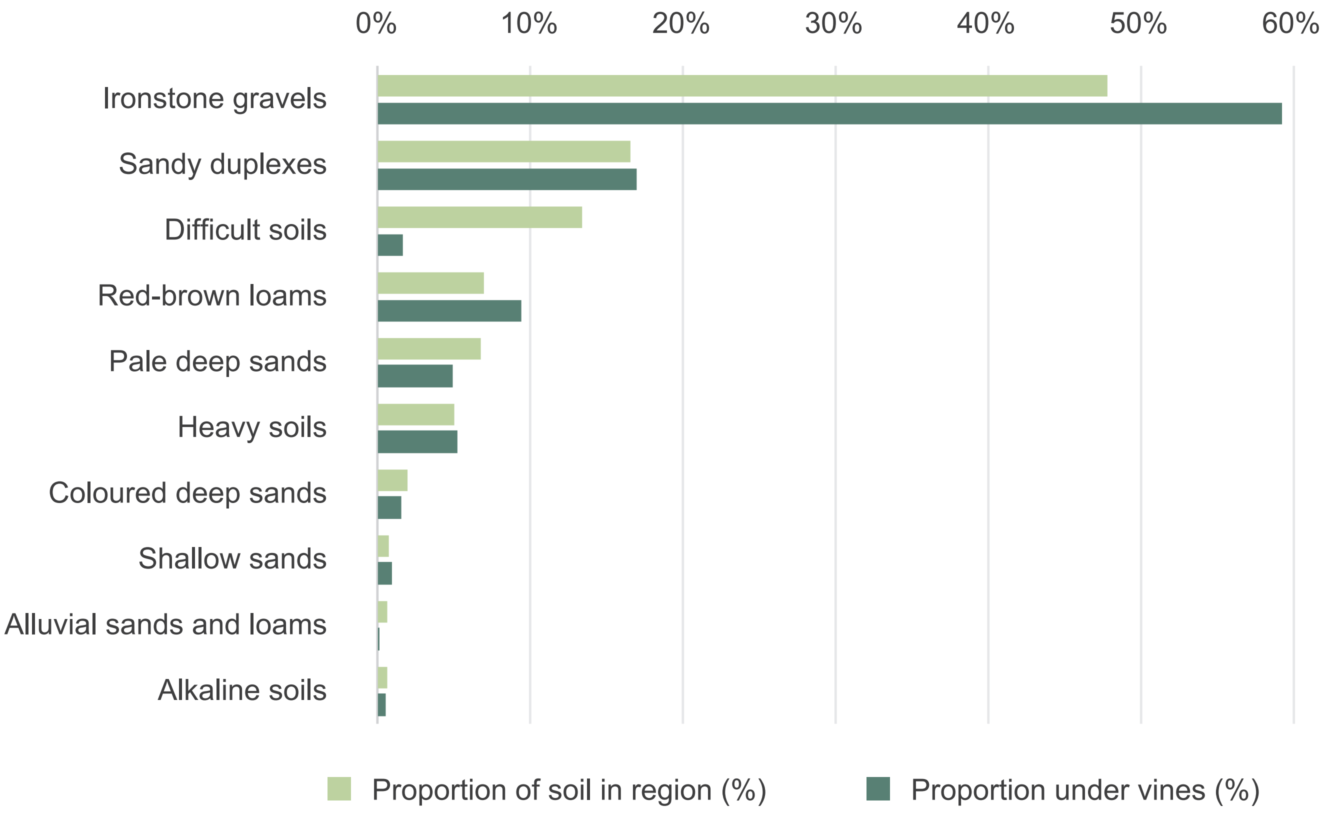


Figure 7.17: Frankland River subregion: Proportion of main soils in the subregion compared against main soils used for viticulture

Sandy duplexes are the subregion's second most common soils, found in about 17% of the area, mostly on gentle hillslopes, low rises or undulating plains. Sandy duplexes are more dominant in the north of the subregion and are associated with the weathered rocks of the Yilgarn Craton; in the remaining parts, they are in landscape combinations with Ironstone gravels, Red–brown loams and Pale deep sands (Figure 7.18).

Red–brown loams are not such common soils, found in less than 10% of the subregion. They tend to have brown, or occasionally red, loamy topsoils over clay subsoil. These soils are mostly on valley slopes surrounding the Frankland River and where freshly weathered rock is close to the soil surface or is exposed. The richer coloured soil profile is derived from underlying crystalline parent material such as gneiss of the Biranup Complex or mafic rocks such as dolerite dykes, more commonly seen on the Yilgarn Craton. These soils are often near outcrops of granite, or stony soils on hillslopes, or as isolated rises sitting above surrounding terrain and are frequently associated with Ironstone gravel and Sandy duplex soils.

Pale deep sands in the subregion can be found in patches in a mix with other soils on undulating hillslopes. They are more widespread in areas of flatter terrain with Eocene sediments, floodplains and undulating plains in lower landscape positions.

The remaining soils in the subregion are less common and are generally in a mixture with the Ironstone gravels, Sandy duplex and Red–brown loam soils.

We grouped together as Difficult soils those areas that can affect productivity such as the regularly waterlogged soils associated with valley flats, swamps and lakes; or where exposed or shallow rock, cemented laterite or stony soils are prevalent. These soils are typically unsuited for any form of agriculture but are often found in combination with more productive soils in various landscape positions. Many of these areas remain uncleared, making up about 13% of the subregion.

The soil-landscape mapping for this subregion is included in these surveys: Tonebridge-Frankland (Stuart-Street 2005) and South Coast and Hinterland (Churchward et al. 1988); the mapping can also be viewed online at NRInfo.[142]

Main viticultural soils of the Frankland River subregion

Ironstone gravels with grey–brown sand to loam topsoils containing abundant ferruginous nodules and pisoliths over well-structured, neutral, yellow–brown loam to clay subsoils are the most widely planted soils in the subregion (Figure 7.19). Currently, almost 60% of all plantings are on Ironstone gravels—the highest proportion of vines in these soils in the Great Southern region. If the crystalline bedrock is closer to the surface, the subsoil can be redder in colour. In areas where Ironstone gravels support jarrah and marri trees, they generally have reasonably well-structured subsoils, while those supporting wandoo vegetation typically have poorer structured, sodic or dispersive clay subsoils. The vine plantings are usually on hillslopes and undulating rises.

[142] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

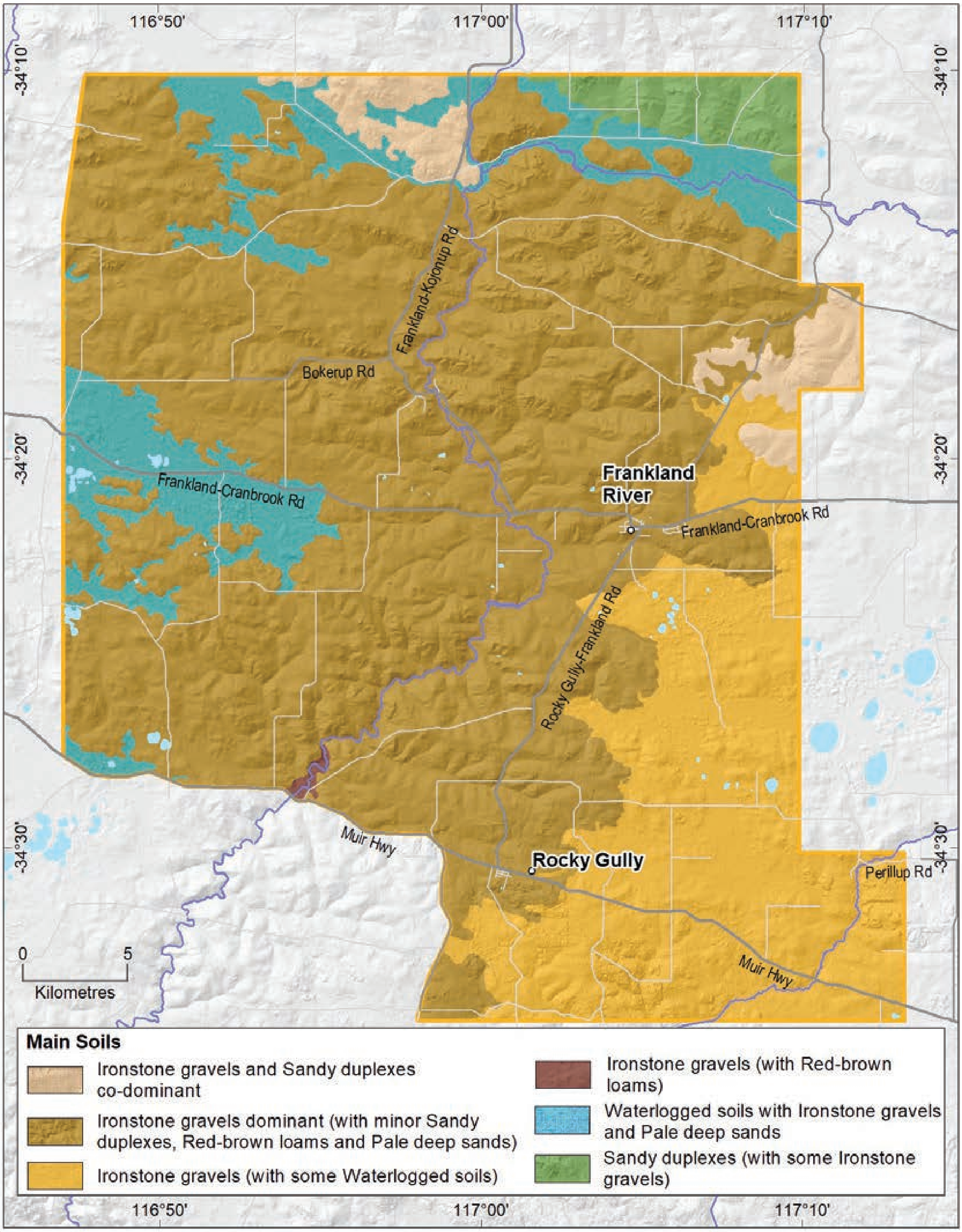


Figure 7.18: Frankland River subregion: Main soils

Almost 20% of vines grow in areas with Sandy duplex soils. They usually have grey coloured sandy topsoils or less frequently, yellow to brown sandy topsoils, over clay. It is not uncommon to find a layer of ferricrete nodules and pisoliths sitting above the clay. These soils are mainly on hillslopes and further east, on the broad, undulating rises of weathered gneiss of the Biranup Complex in the upper Kent catchment.

Almost 10% of the subregion's vines are planted on well-structured Red–brown loams generally near exposed crystalline bedrock or where it is close to the surface. These are often on steeper valley and hill slopes closer to the meandering course of the Frankland River. These soils usually have brown (or less commonly, red or yellow) loamy topsoils over well-drained neutral clay subsoils.

Smaller areas (about 5%) have vines growing on Pale deep sands. The sands are generally pale grey and extend more than 80 cm deep. Sometimes they contain ferricrete nodules and pisoliths below a sandy topsoil and in some cases, a clay layer can be found more than 80 cm below the sandy surface. These soils are generally not preferred for planting but often occur as small pockets amongst the better soils in vineyards.

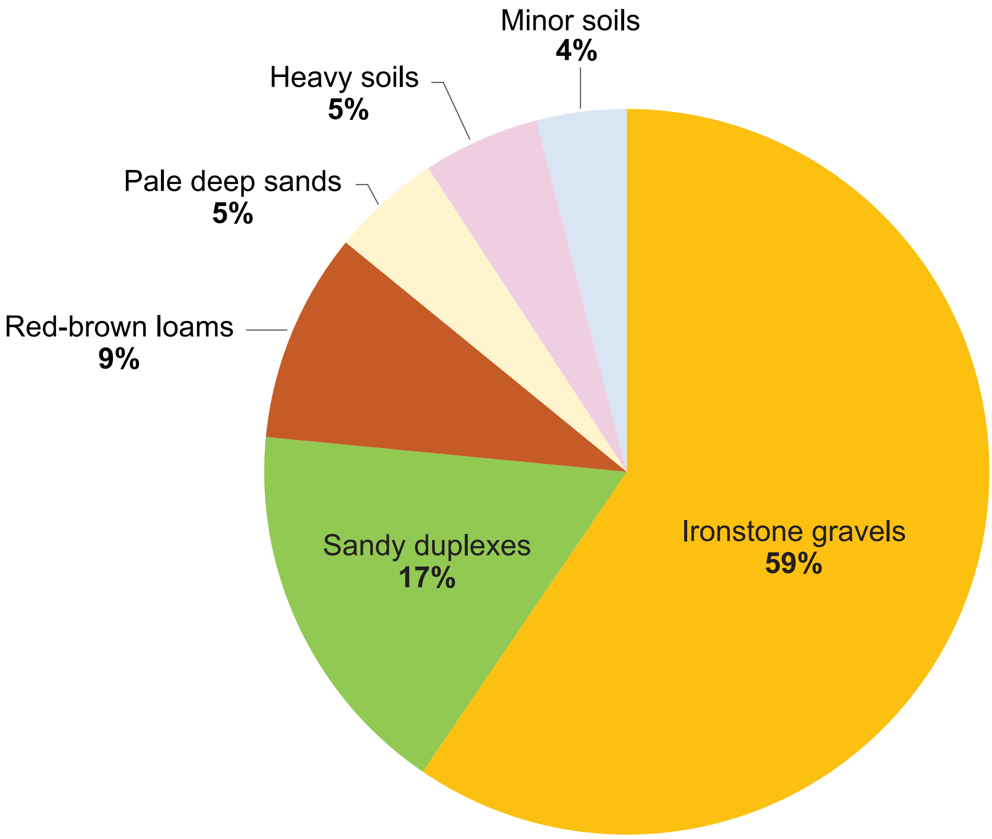


Figure 7.19: Frankland River subregion: Main soils used for viticulture (Minor soils are mainly Coloured deep sands and Shallow sands)

Climate

Smart and Dry's criteria (1980) classifies the climate in the Frankland River subregion as warm, moderately maritime, moderately sunny, arid and moderately humid. Halliday (2011a) describes the climate as still being Mediterranean in terms of rainfall but with greater continentality.[143]

Rainfall ranges from about 480 mm in the north-east to 790 mm in the south-west. Annual evaporation is greater than 1,400 mm in the south-west rising to almost 1,600 mm in the north-east. Mean 3pm October to April relative humidity is 49% at Rocky Gully and probably lower to the north (Gladstones 1992). The Frankland River subregion has the lowest mean annual rainfall of all the winegrowing areas in the south-west (Table 7.5), but the seasonal rainfall is like the Peel and Blackwood Valley regions.

Table 7.5: Frankland River subregion: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	481	151
Maximum	793	253
Mean	593	190

The subregion has the Great Southern region's warmest temperatures and greatest ripening period sunshine hours (Table 7.6). Temperature variability can be a problem with extreme high temperatures sometimes experienced, despite the low mean temperatures. Most heat extremes occur before ripening, reducing the impact on fruit quality. Spring frosts can also be a problem with temperatures below 2 °C that can extend into November so site selection is important.

Gladstones (2021) estimates that the Frankland River subregion has an average 7.6 daily sun hours (October to April) and an average October to April cloud cover, which are important considerations for temperatures and night-time cooling.

In spring, the dominant winds are about 17–20 km/h, swinging from the north-west in the mornings to the west and south-west in the afternoons. The characteristic summer sea breeze (the Albany Doctor) generally makes its way inland and cools the late afternoon temperatures by about 2 °C. These southerly afternoon winds are usually at speeds of 21 km/h, increasing in strength from the dominant warm, easterly morning winds of about 18 km/h.

Gladstones (2021) states that the sea breeze moderates hot summer temperatures in the subregion, bringing an increase in afternoon humidity, potentially reducing the period of cumulative afternoon stress and rapid loss of evaporative moisture and flavour volatiles from the berries.

[143] Continentality refers to a climatic effect that emerges because of the different range of temperatures for areas located in the interior of the continent away from the moderating influence of the oceans.

Table 7.6: Frankland River subregion: Temperature statistics (1989–2019)

Measurement	Value
Mean growing season (October–April) temperature (°C)	18.1
Mean January temperature (°C)	20.6
Mean growing degree days (October–April)	1,722
Mean diurnal temperature (°C)	13.3
Average daily sun hours (October–April)*	7.6
Average (October–April) cloud cover (Okta)*	4.8

* Average estimates are from a site at Westfield Vineyard, Frankland River (Gladstones 2021).

Due to the relatively low mean rainfall and warm temperatures in this subregion, supplementary irrigation of vines is essential to reduce stresses in summer. To avoid poor water quality often found in lower parts of the valleys, there are many extensive water catchment systems (such as roaded catchments) in upper parts of the landscape. These are designed to maximise the capture of better-quality run-off, with many vineyards relying on large dams to store water for more than one season.

Mount Barker subregion

The Mount Barker subregion lies south-east of the Frankland River subregion, north of the Albany subregion and west of the Porongurup subregion. It is 132,216 ha in size and includes the town of Mount Barker, the settlements of Narrikup and Pardelup, with Kendenup on the northern border (Figure 7.20). About 75% of the area is used for farming and other land uses. The local vegetation features low jarrah and marri forests and heathlands around poorly drained swampy areas.

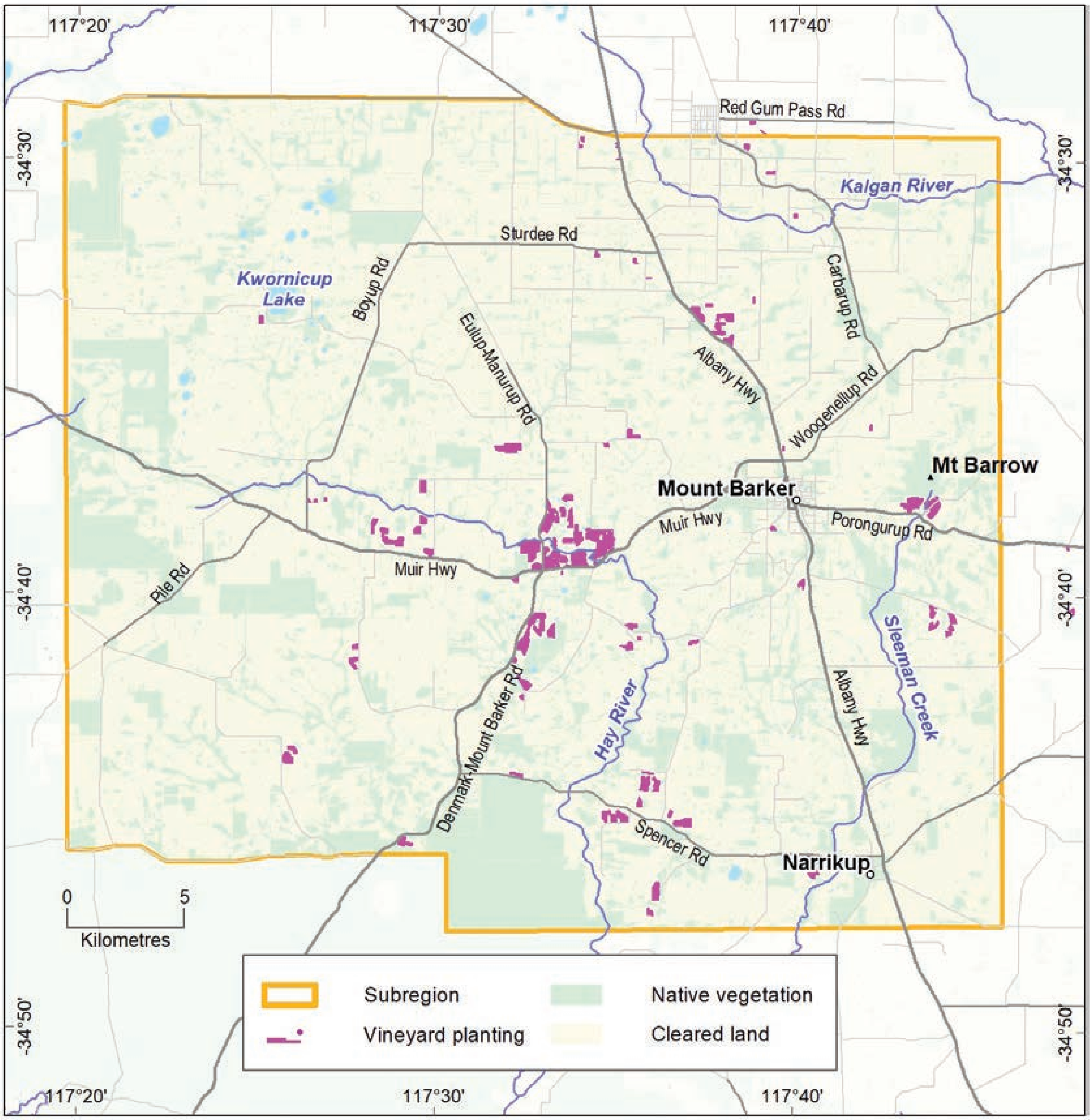


Figure 7.20: Mount Barker subregion

This area was the focus of early viticulture trials after Dr John Gladstones supported Professor Harold Olmo's suggestions for the potential of the Frankland River and Mount Barker areas for production of quality table wines (Gladstones 1965). Small trials were established here in the late 1960s—by 2019 more than 990 ha of vineyards were planted in the subregion (DPIRD 2019) making up almost one-third of the total region's plantings. This was the first subregion to gain GI recognition in Australia (Beeston 2002).

Geology and physiography

An undulating plateau dominates the landscape of the Mount Barker subregion, which is formed on deeply weathered rocks of the Albany–Fraser Orogen. The Orogen has 2 main components: north of Mount Barker is the gneiss and metasediments of the Biranup Complex, and to the south is the gneiss and granite of the Nornalup Complex. The prominent peaks at Mount Barker and Mount Barrow are part of the Nornalup Complex (Figure 7.21).

At the eastern edge of the subregion, the rocks of the Albany–Fraser Orogen are partly cloaked by the Tertiary sediments of the onshore portion of the Bremer Basin. These mainly include Eocene sedimentary rocks of the Plantagenet Group, commonly Pallinup Siltstone (pale spongolite and low-energy marine carbonate and light-coloured siltstone), originally deposited in several broad topographic depressions and shallow seaways.

These Tertiary sediments, along with the crystalline rocks of the Albany–Fraser Orogen, were subjected to deep weathering over long periods of geological stability, which led to the development of the lateritic profile and ironstone gravel that blankets many parts of the subregion. The laterite varies from massive and cemented blocks and boulders, to loose uncemented laterite stones known as ferruginous nodules and pisolites (commonly called jarrah, forest or pea gravels). The Hay River and its tributaries have carved a prominent route through this blanketing laterite to the bedrock of the Nornalup Complex in the southern part of the subregion. At the north-east corner is the Kalgan River catchment, with rocks of the Biranup Complex often exposed on valley slopes.

Influenced by the southward-tilting Ravensthorpe Ramp, the trend in elevation is for a gradual decline from the subregion's northern boundary towards the south coast. A series of topographic benches or shelves interrupts this descent, including the gently undulating lateritic plateau in the west of the subregion, dotted by low hills emerging above the plateau. Sluggish ancient river systems deposited sediments in some areas, forming poorly drained flats, which are often swampy with occasional wetlands (such as Lake Kwornicup).

The plateau landscape dominating the subregion rises gently from 140 m in the south-east to 240 m in the north-west. A few prominent hills rise above the plateau including Mount Barrow (485 m) and Pardelup Hill (312 m). Many of the vineyards are planted in valleys incised into the plateau. These include the Hay River, the floor of which drops from 180 m at the Muir Highway to 60 m on the southern margins of the subregion.

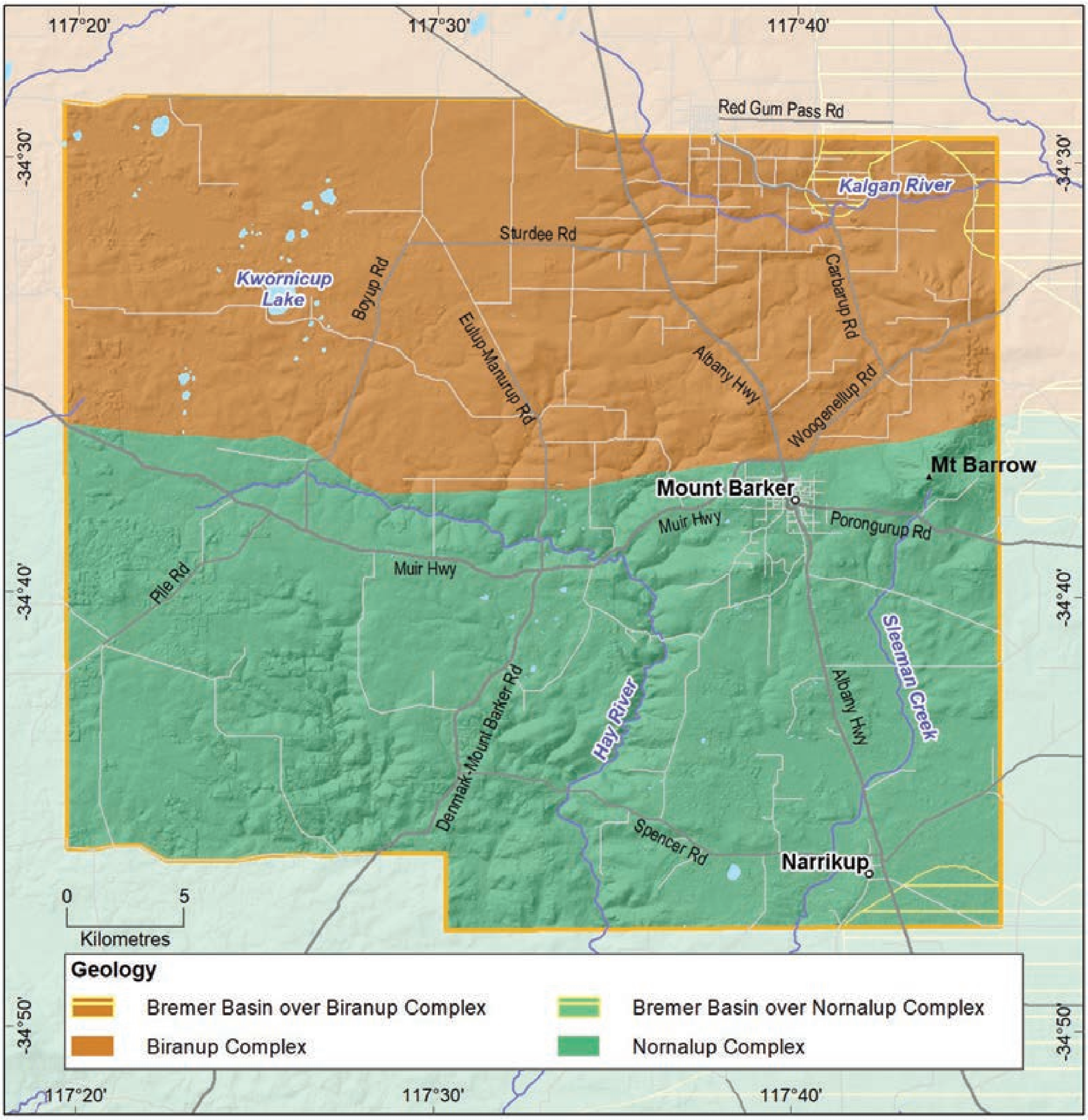


Figure 7.21: Mount Barker subregion: Simplified geology

Soils and landforms

Cloaking the ancient, deeply weathered felsic crystalline rocks of the Albany–Fraser Orogen is an undulating lateritic plateau that dominates the landscape of the Mount Barker subregion, with areas of alluvial plains and restricted drainage. Consequently, about one-third of the soils found in the Mount Barker subregion are Ironstone gravels (Figure 7.22 and Figure 7.23). They are mainly on broad, undulating rises or alluvial plains that sit above the sometimes poorly drained surrounding terrain. These soils are frequently found in combination with Sandy duplexes in many areas of the subregion.

Sandy duplex soils dominate in about 20% of the subregion, more so east of Mount Barker where influences from Eocene sediments and shallow bedrock are more marked. These soils are prominent in shallow valleys, on broadly undulating plateaux and are also associated with low granitic hills. They are often found in combination with Ironstone gravels and Red–brown loams.

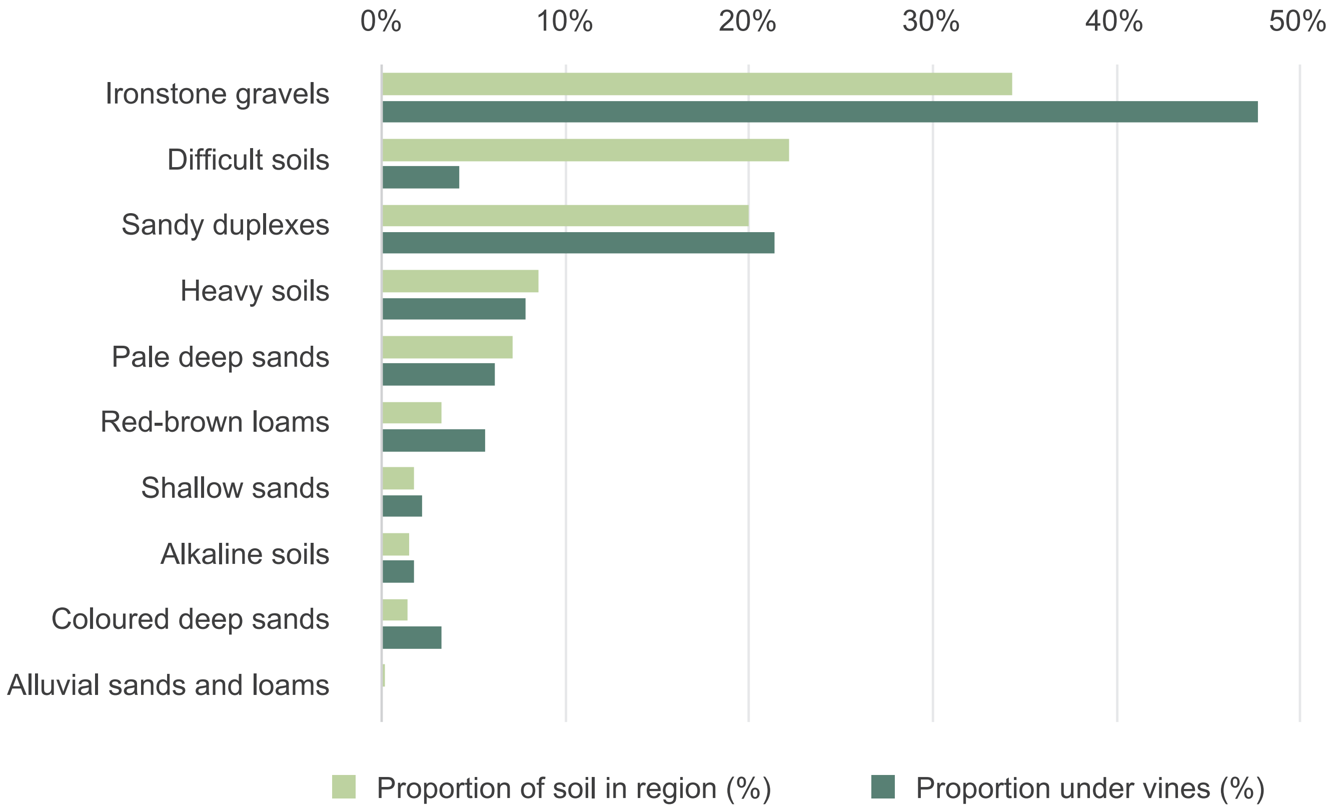


Figure 7.22: Mount Barker subregion: Proportion of main soils in the region compared against main soils used for viticulture

About 8% of the subregion's soils are described as Heavy soils, which are often found on alluvial plains around undulating low lateritic hills in the northern part of the subregion.

Pale deep sands, dominant in only 7% of the subregion, are generally found in patches in a mix with other soils. They can be more concentrated in low dunes close to swamps and shallow valleys, in depressions and on gently sloping uplands. They typically occur in combination with Sandy duplex soils, Ironstone gravels and outcrops of deeply weathered granite.

Red–brown loams are generally derived from the underlying crystalline parent material, mainly over the gneiss of the Nornalup Complex in this subregion. These soils are not widespread, found in only about 3% of the area. They often occur near outcrops of crystalline rock or stony soils on hillslopes or isolated rises sitting above surrounding terrain. The Red–brown loam soils are more common around the hills and peaks of the eastern half of the subregion at Carbarup Hill, Mount Barrow and Mount Barker. They are also associated with deeper valley slopes such as the Hay River.

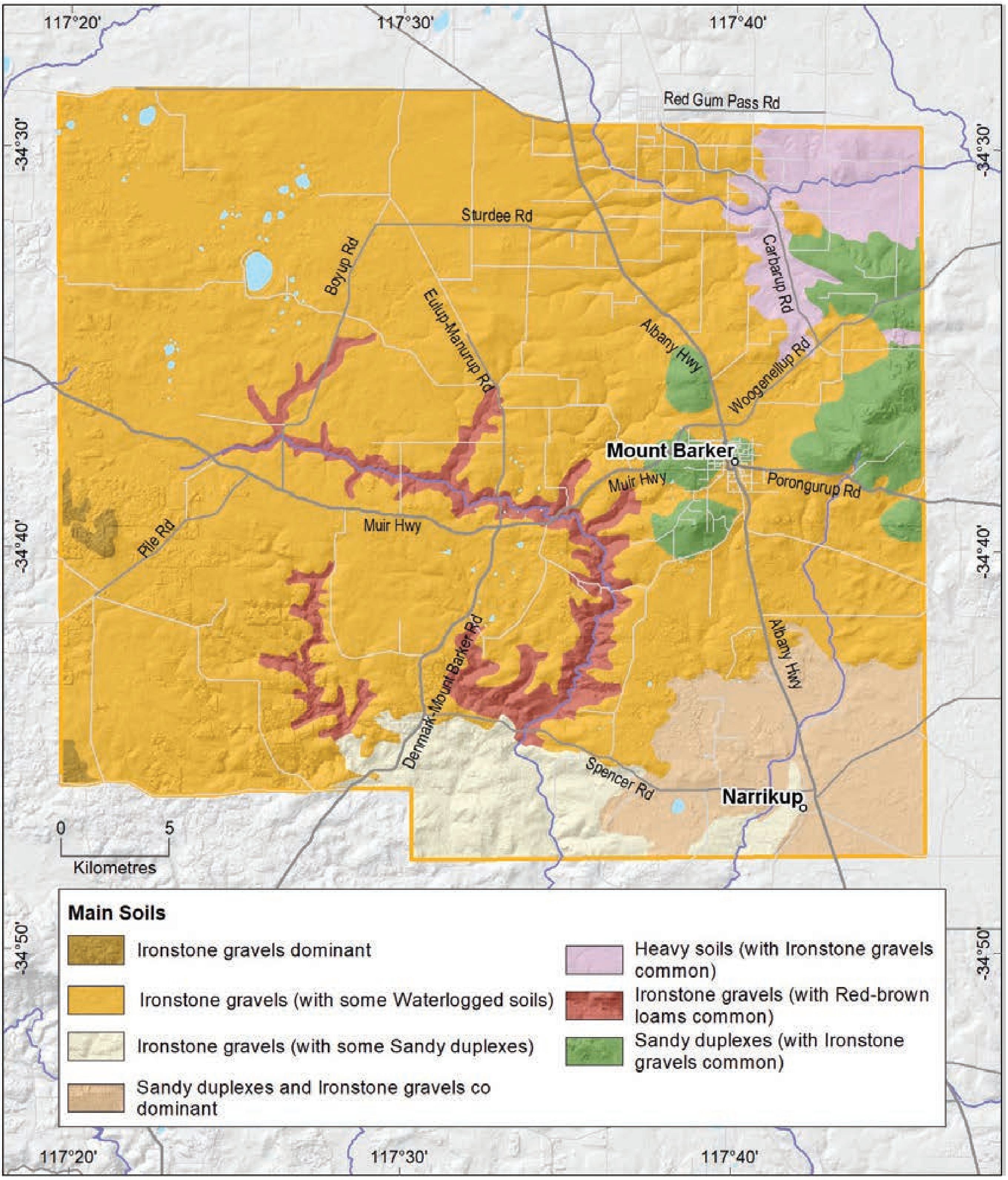


Figure 7.23: Mount Barker subregion: Main soils

About 20% of the subregion has patches of land with swamps and lakes, frequent waterlogging, rock outcrops and salt-affected waterways. We grouped these together into Difficult soils. They occur mainly in the low-lying alluvial terrain associated with the lateritic plateau west of Mount Barker and small areas of swampy plains in the south. The rocky peak of Mount Barker and other low granite rises, usually in the Nornalup Complex, also sit with this group. Difficult soils are typically unsuited for any form of agriculture but can combine with more productive soils in various landscapes.

The remaining soils in the subregion are minor (Shallow sands, Alluvial sands and loams and Alkaline soils) and generally occur intermittently in a mixture with the Ironstone gravels, Sandy duplex, Pale deep sand and Red–brown loam soils.

The South Coast and Hinterland survey (Churchward et al. 1988) contains soil-landscape mapping covering this subregion; the mapping can also be viewed online at NRInfo.[144]

Main viticultural soils of the Mount Barker subregion

Ironstone gravel soils are the most widely planted soils in the Mount Barker subregion, supporting about 48% of all the vines (Figure 7.24). These soils generally have grey sandy topsoils containing abundant ferruginous nodules and pisoliths overlying yellow–brown clay at depth. If the crystalline bedrock of the Albany–Fraser Orogen is closer to the surface, the subsoil clay is sometimes redder in colour. Ironstone gravels usually have reasonably well-structured subsoils with some exhibiting more poorly structured, sodic or dispersive clay subsoils.

The vines growing on Ironstone gravels are typically on the better-drained rises that emerge above the surrounding terrain. Some of the hill crests and upper slope positions feature patches of shallower Ironstone gravels over cemented laterites amongst the preferred soils. These are generally grey to pale yellow sands with abundant ferruginous nodules and pisolites over a cemented layer at less than 80 cm deep.

Almost one-quarter of all vines in the subregion grow in Sandy duplex soils. Most of these have pale grey to yellow–brown coarse- to medium-grained sandy topsoils over clay subsoils, which can be poorly structured. These soils are often associated with weathered felsic crystalline rocks on the slopes of granitic hills and valleys, as well as in a mix with Ironstone gravels and Pale deep sands.

About 8% of the subregion's vines grow in Heavy soils, which are more common on the alluvial plains surrounding the undulating lateritic rises in the northern part of the subregion. These soils usually have shallow, poorer structured subsoil clay beneath pale grey sandy or loamy topsoils. In some cases, the clay is over shallower areas of bedrock. In vineyards, these soils are often found amongst better soils, particularly Sandy duplexes.

About 9% of the subregion has vines growing on areas dominated by deep sands, collectively the Pale deep sands and Coloured deep sands, which are sometimes found together. Pale deep sands, with fine to coarse pale grey sand, tend to be more prominent on gentle slopes and minor valleys and depressions, sometimes with clay found below 80 cm. The Coloured deep sands are usually yellow in this subregion typically with fine sands over a deep clay layer beyond 80 cm. Deep sands (particularly Pale deep sands) are generally not preferred for planting in the subregion, but they often occur as small pockets amongst the better soils found in vineyards, such as Ironstone gravels and Sandy duplex soils.

[144] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

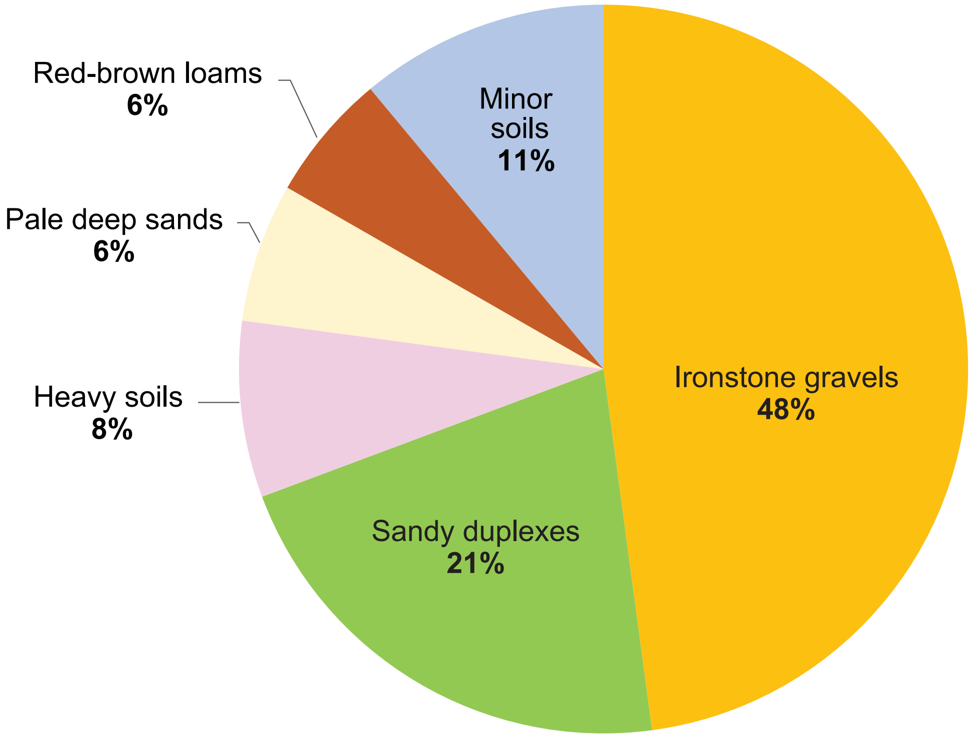


Figure 7.24: Mount Barker subregion: Main soils used for viticulture (Minor soils are Coloured deep sands, Shallow sands and Alkaline soils)

Red–brown loams supporting vines occur in about 6% of the subregion. They tend to be on valley slopes formed on the gneiss of the Nornalup Complex, such as at the Hay River (often in combination with Ironstone gravels). The Red–brown loams are also on footslopes of hills where crystalline bedrock is close to the surface or exposed, sometimes making the soil quite stony. These soils mainly have red–brown to yellow–brown loamy topsoils over well-structured loam to clay subsoils.

Climate

Smart and Dry (1980) classified the Mount Barker subregion climate as being warm, moderately maritime, sunny, not arid and moderately humid. At 50 km away from the Southern Ocean, climatic conditions in the subregion are like those in the Frankland River subregion, with slightly cooler temperatures, higher rainfall, fewer extremes and fewer sunshine hours (which increase from south to north, while relative humidity decreases) (Table 7.7 and Table 7.8). Annual evaporation is around 1,400 mm in the south-west rising to 1,500 mm in the north-east.

Frost is a risk in the Mount Barker subregion, with mean minimum temperatures below 2 °C experienced about 4 days per year, usually between May and October; frost risk is greatest in the north of the subregion.

Table 7.7: Mount Barker subregion: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	489	190
Maximum	845	305
Mean	670	249

Table 7.8: Mount Barker subregion: Temperature statistics (1989–2019)

Measurement	Value
Mean growing season (October–April) temperature (°C)	17.7
Mean January temperature (°C)	19.8
Mean growing degree days (October–April)	1,609
Mean diurnal temperature (°C)	11.5
Average daily sun hours (October–April)*	7.3
Average (October–April) cloud cover (Okta)*	4.7

* Average estimates for the Mount Barker subregion are from Gladstones (2021).

Spring winds are typically from the west and north-west at about 10–12 km/h. The winds swing around in the summertime, with mornings usually having east to south-east winds of about 9 km/h, followed by the afternoon southerly summer sea breeze (the Albany Doctor), which makes its way inland to cool temperatures with wind speeds of about 13 km/h.

To avoid poor water quality often found in lower parts of the valleys, there are many extensive water catchment systems (such as roaded catchments) now operating in upper parts of the landscape. These are designed to maximise the capture of better-quality run-off, with many vineyards relying on large dams to store water for more than one season.

Porongurup subregion

The Porongurup subregion is directly east of the Mount Barker subregion and covers almost 40,000 ha, including the rocky peaks and imposing karri forest (*Eucalyptus diversicolor*) of the Porongurup Range National Park. About 75% of the subregion is used for agriculture. The northern boundary is approximately Washpool Road, the eastern boundary follows the sinuous path of the Kalgan River to Kallamup, the western boundary follows Barrow, Watermans and Woodlands Roads, while the south extends to Yellanup locality (Figure 7.25).

Interest in viticulture grew slowly from the early 1970s (Beeston 2002), and by 2019 around 105 ha of vineyards were in the subregion (DPIRD 2019), comprising about 3% of the Great Southern region's plantings.

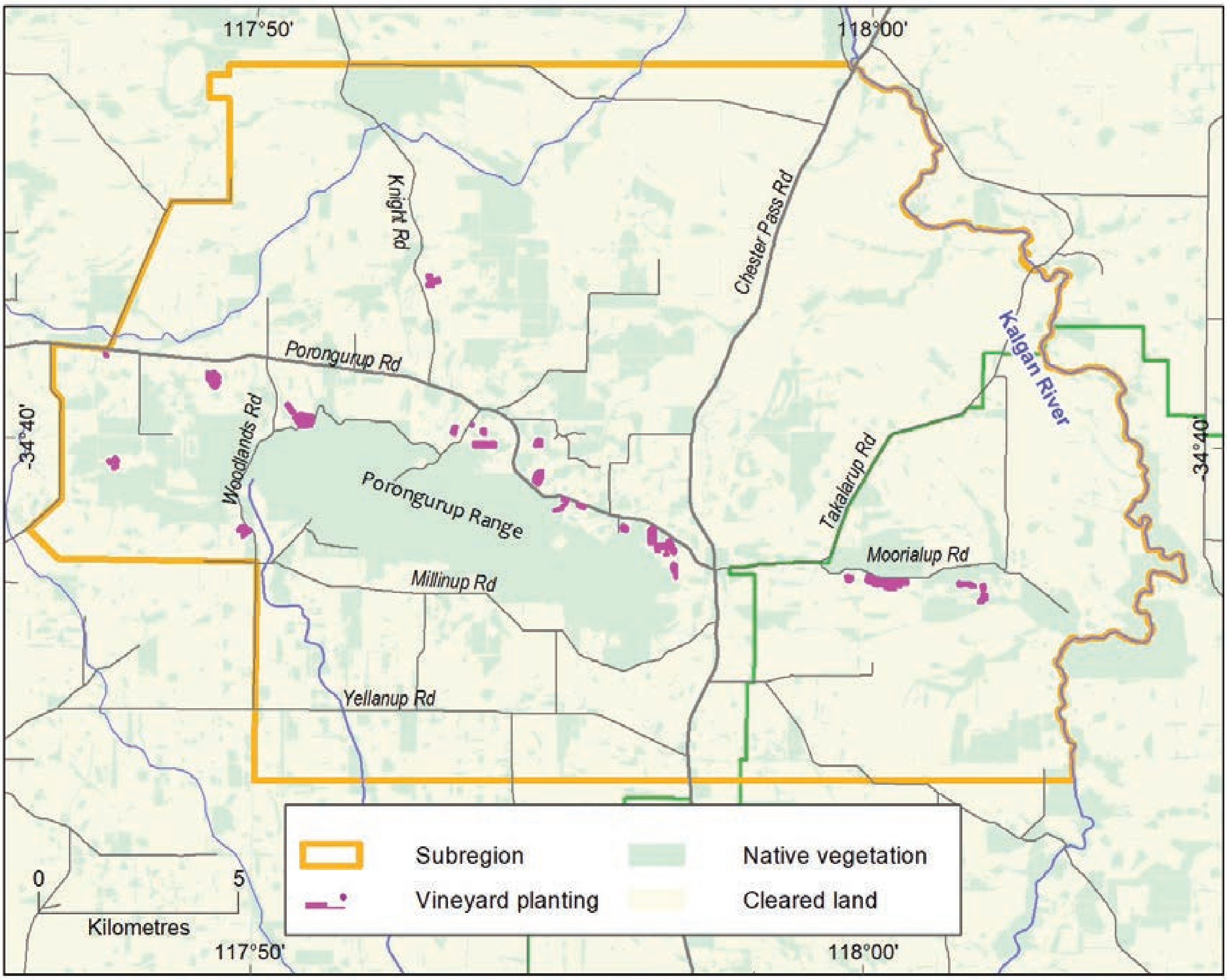


Figure 7.25: Porongurup subregion

Geology and physiography

The Porongurup subregion lies on the deeply weathered felsic crystalline rocks of the Albany–Fraser Orogen. In this area the Orogen features 2 main components: north of the Porongurup Range is the gneiss and metasediments of the Biranup Complex, and to the south is the gneiss and granite of the Nornalup Complex (Figure 7.26). The picturesque peaks of the Porongurup Range that rise abruptly above the surrounding terrain are part of the Nornalup Complex.

The elevated landscape of the range is almost an island of gneiss and granitic basement rock surrounded by a veneer of Eocene sedimentary deposits derived from the onshore extent of the Bremer Basin. These are sedimentary rocks of the Plantagenet Group, usually Pallinup Siltstone (containing pale spongolite, low-energy marine carbonate and light-coloured siltstone). The sediments were deposited in several broad topographic depressions and shallow seaways across this part of the Albany–Fraser Orogen. Over time, a lateritic mantle has formed on top of the sediments.

The peaks of the Porongurup Range rise to 670 m AHD above a plain, which is 100–130 m in the south and 160–200 m in the north. Vines are grown between 102 m and 352 m AHD, with a mean height of 247 m AHD, the highest in the Great Southern region.

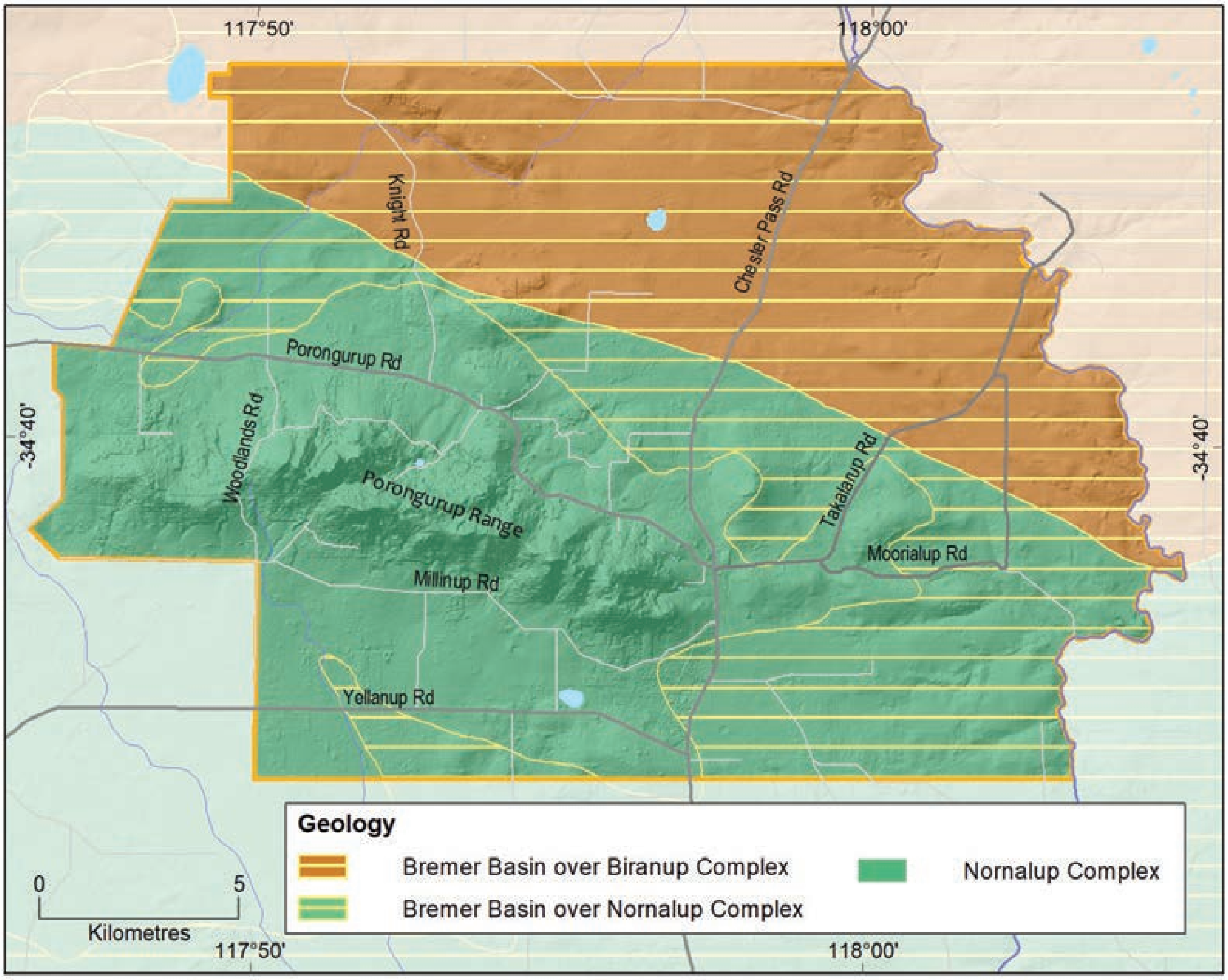


Figure 7.26: Porongurup subregion: Simplified geology

Soils and landforms

The soils of the Porongurup subregion strongly reflect the geology. Unlike other subregions in the Great Southern, the Sandy duplexes, which comprise about one-quarter of the soils in the area, are co-dominant with Ironstone gravels (Figure 7.27). This relates to the dominating presence of both the granitic bedrock and the surrounding Eocene sediments of the Plantagenet Group, both of which also have a lateritic mantle. The Sandy duplexes, along with the Ironstone gravels, are locally known as marri soils referring to marri (Corymbia calophylla), the prominent eucalypt supported by these soils. These soils are better-drained and suitable for viticulture. These are usually on the lower slopes of the granitic range and on the gently sloping footslopes surrounding the hills.

Ironstone gravels are dominant in about one-quarter of the subregion. These soils are most prominent on ridge crests and undulating rises, sometimes associated with granite, on areas surrounding the range, and in combination with Sandy duplex soils in many locations (Figure 7.28).

Heavy soils, found in about 16% of the subregion, tend to be more frequent on the flat to gently undulating plain north of the Porongurup Range, usually in a mix with Ironstone gravels. Underlain by Pallinup Siltstone, the Heavy soils tend to be sandy or loamy duplexes with poorer structured clay or clay loam subsoils within 80 cm, and in many cases, within 30 cm, which can impede root growth and water movement.

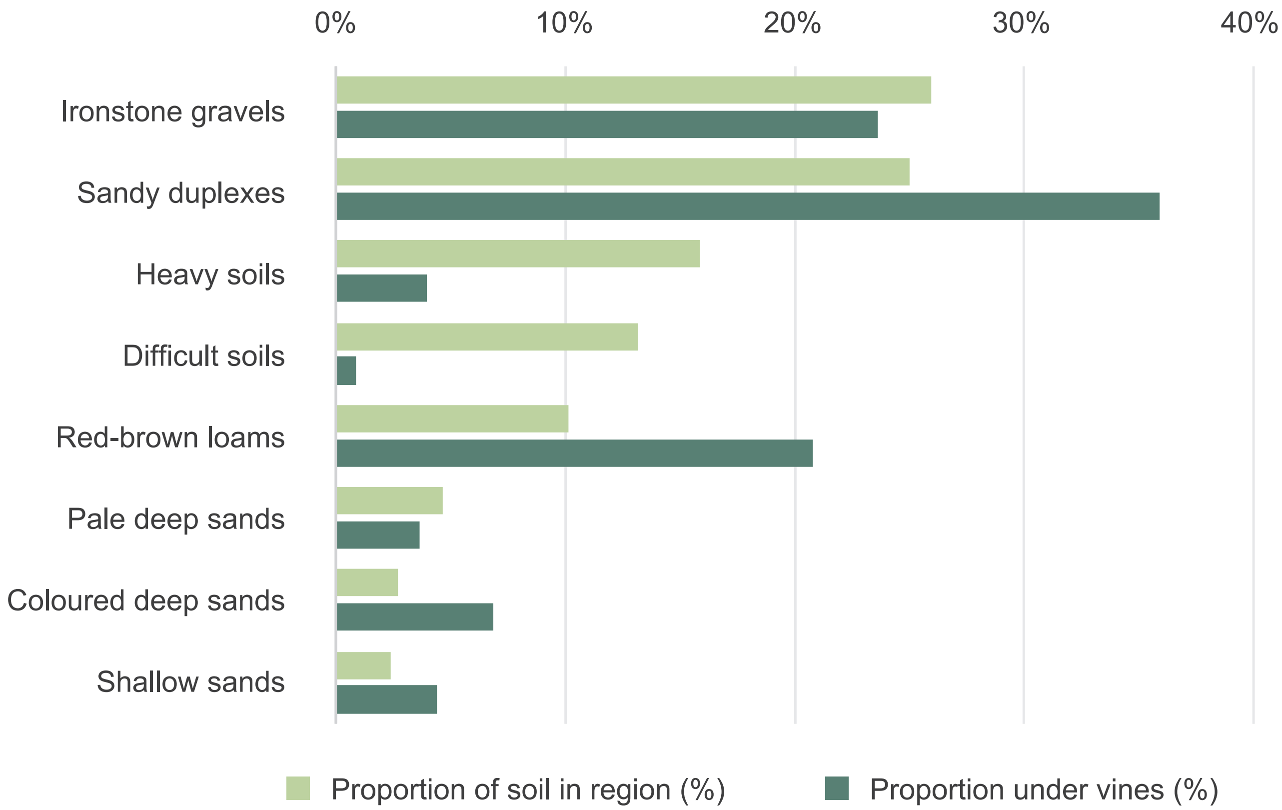


Figure 7.27: Porongurup subregion: Proportion of main soils in the region compared against main soils used for viticulture

Red–brown loams occur in only about 10% of the subregion. They are associated mainly with shallower granitic bedrock on the lower slopes of the range, near rock outcrops or stony soils on hillslopes or on isolated rises sitting above the surrounding terrain. They are often found in combination with Sandy duplex soils.

Deep sands are minor soils here, covering only about 8% of the area, with Coloured deep sands being slightly more common than Pale deep sands. Pale deep sand is usually in small patches across the subregion, occasionally as hummocky dunes close to the Kalgan River and on the undulating plateau north of the Porongurup Range. To the south they are also found in broad depressions. Coloured sands are generally found in areas on lower slopes surrounding granitic hills and around the valley slopes of the Kalgan River.

In terrain where swamps, waterways and rock outcrops dominate, we grouped them together as Difficult soils. These terrains comprise about 13% of the subregion and include the rocky peaks of the Porongurup Range and other low granite rises, as well as small areas of swampy plains south-east of the range. These Difficult soils usually occur in combination with better-drained, more arable terrain.

The South Coast and Hinterland survey (Churchward et al. 1988) contains soil-landscape mapping covering this subregion; the mapping can also be viewed online at NRInfo.[145]

[145] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

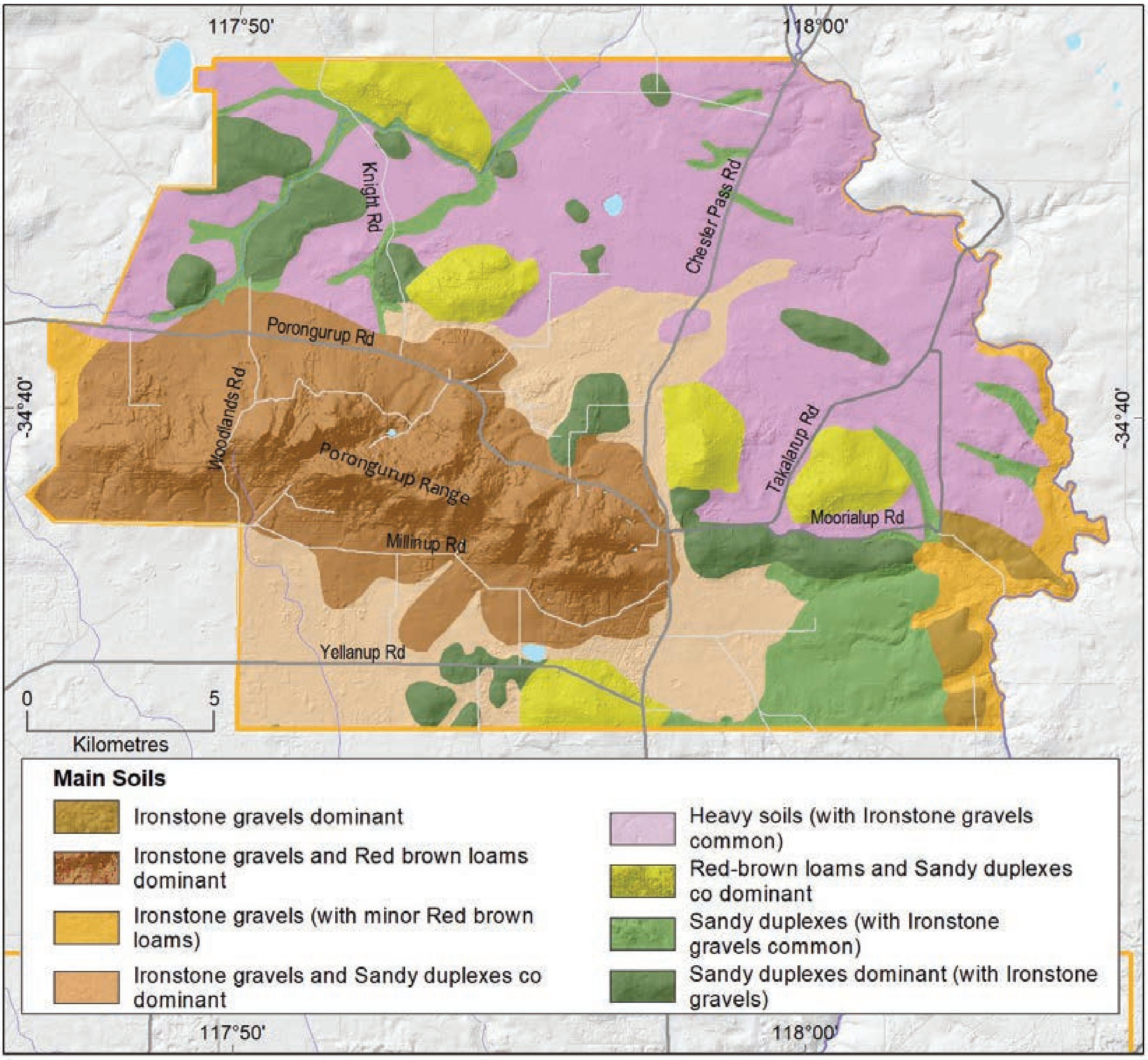


Figure 7.28: Porongurup subregion: Main soils

Main viticultural soils of the Porongurup subregion

Most of the plantings in the Porongurup subregion are fringed by the spectacular karri forests on the lower northern footslopes of the granitic Porongurup Range that rises dramatically above the surrounding terrain.

The most widely planted soils in the subregion are Sandy duplexes (Figure 7.29). These tend to have yellow–brown moderate to fine sandy topsoils over well-structured yellow to yellow–brown mottled clay subsoils below 30 cm. Less often the sandy topsoils are grey or grey–brown coloured. On the hillslopes it is not unusual to encounter shallow granitic rock within 80 cm. The Sandy duplexes on the undulating plateau areas often feature a layer of ferruginous nodules and pisoliths above the clay.

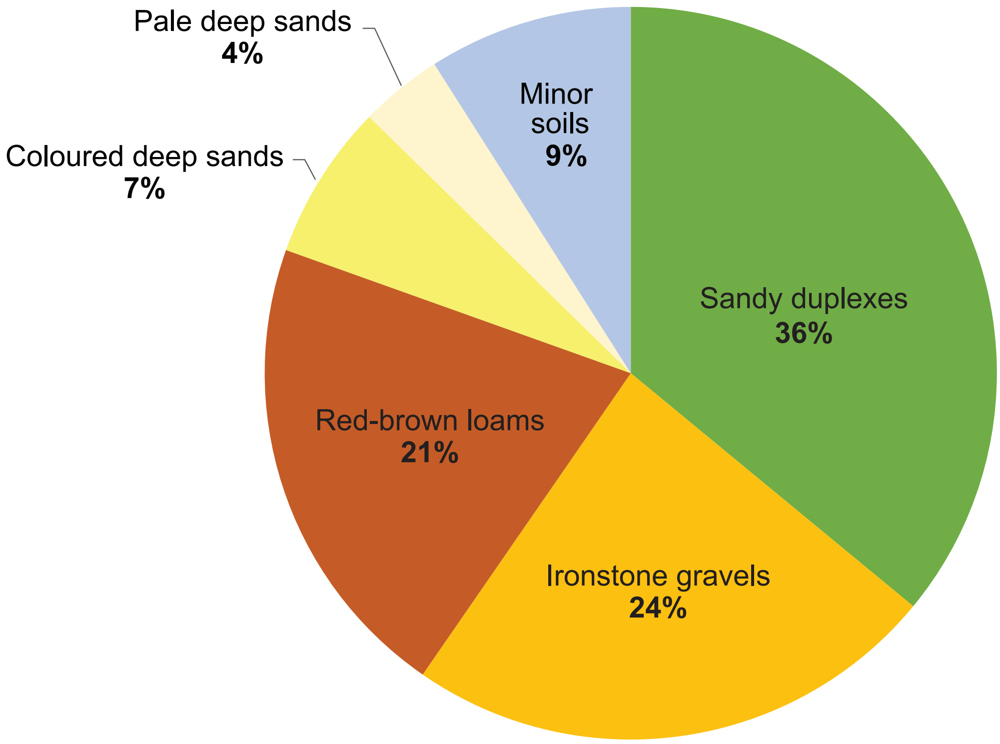


Figure 7.29: Porongurup subregion: Main soils used for viticulture (Minor soils are Heavy soils and Shallow sands)

Almost one-quarter of the subregion's vines grow in Ironstone gravels with sand to loam topsoils containing abundant ferruginous nodules and pisoliths over well-structured neutral yellow clayey subsoils. Many of the Ironstone gravels on the granitic slopes are brownish red coloured indicating shallower bedrock.

Red–brown loams are popular for viticulture in the subregion, and with the redder Ironstone gravel soils, they are known locally as 'karri loams' after the towering karri trees (*Eucalyptus diversicolor*) that frequently grow in these areas. Although Red–brown loams only occur in about 10% of land in the entire subregion, more than 20% of vines grow on these soils. The Red–brown loams usually have brown to red–brown loamy topsoils over well-structured loam to clay subsoils. Areas of rocky or stony soils are not uncommon amongst these soils and they can also contain some ferricrete nodules and pisoliths.

Coloured deep sands are also somewhat preferentially planted with vines, making up about 7% of plantings, even though these sands occur in just 3% of the subregion. These soils typically have more than 80 cm of fine deep yellow sand, usually over yellow–brown clay or coffee rock beyond that depth. They are generally found on the lower slopes of some hills and can be associated with Ironstone gravel soils.

A small area of the subregion's vines grown in Pale deep sands. These deep, pale grey to grey–brown sands extend beyond 80 cm in small patches on lower hillslopes. These sands are not generally preferred for viticulture but often occur in vineyards in combination with other more desirable soils.

Climate

Gladstones (2021) indicates that the subregion's vineyards have distinctive and highly favourable air drainage patterns because they are on the lower slopes of a strongly isolated small mountain range (Table 7.9). This subregion's overall temperatures are lower, making aspect an important consideration. Most vineyards are on the north side of the Porongurup Range, where the slope aspect is warmer and better for ripening later varieties and fuller-bodied reds.

The Porongurup subregion's mean annual rainfall is second lowest of the subregions, after the Frankland River. Conversely, its mean seasonal rainfall is one of the highest, after the Denmark subregion. Annual evaporation is around 1,450 mm.

Table 7.9: Porongurup subregion: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	522	210
Maximum	769	309
Mean	663	269

To improve rainfall capture for supplementary irrigation requirements, water catchment systems (such as roaded catchments) are placed in upper parts of the landscape. These are designed to maximise the capture of better-quality run-off, with many vineyards relying on large dams to store water for more than one season.

Much of the Porongurup subregion is at a higher altitude than the Mount Barker subregion, with temperatures probably 1 °C cooler with less variability during ripening. Its mean diurnal temperature range is higher than coastal locations, but lower than other inland subregions (Table 7.10). The Porongurup subregion has the lowest mean seasonal growing degree days (GDD) of all the Great Southern subregions, and a mean January temperature (MJT) about the same as the Albany and Denmark subregions and lower than the remainder.

Table 7.10: Porongurup subregion: Temperature statistics (1989–2019)

Measurement	Value
Mean growing season (October–April) temperature (°C)	16.8
Mean January temperature (°C)	19.5
Mean growing degree days (October–April)	1,566
Mean diurnal temperature (°C)	11.0

The slopes of the Porongurup Range exhibit good air drainage, although spring frosts can still be a problem. Halliday (2011a) describes a feature of the climate in the Porongurup subregion as having a night-time thermal zone, which is created by a layer of warm air rising above the denser cold air that slides down the hillslopes and settles on the lower valley floors.

Albany subregion

The Albany subregion is south of the Mount Barker and Porongurup subregions and abuts the wild coastline of the Southern Ocean. It covers 157,338 ha surrounding the town of Albany and the settlements of Torbay, Kalgan and King River. About 60% of the land is used for agriculture and other activities (Figure 7.30).

The Sippe family at Redmond Vineyard planted the first vines in the subregion in 1975, followed by Wignalls Wines who planted their first vines in 1982 (Beeston 2002). By 2019 the subregion had about 94 ha of vineyards (DPIRD 2019), which contribute about 3% of the Great Southern region's plantings.

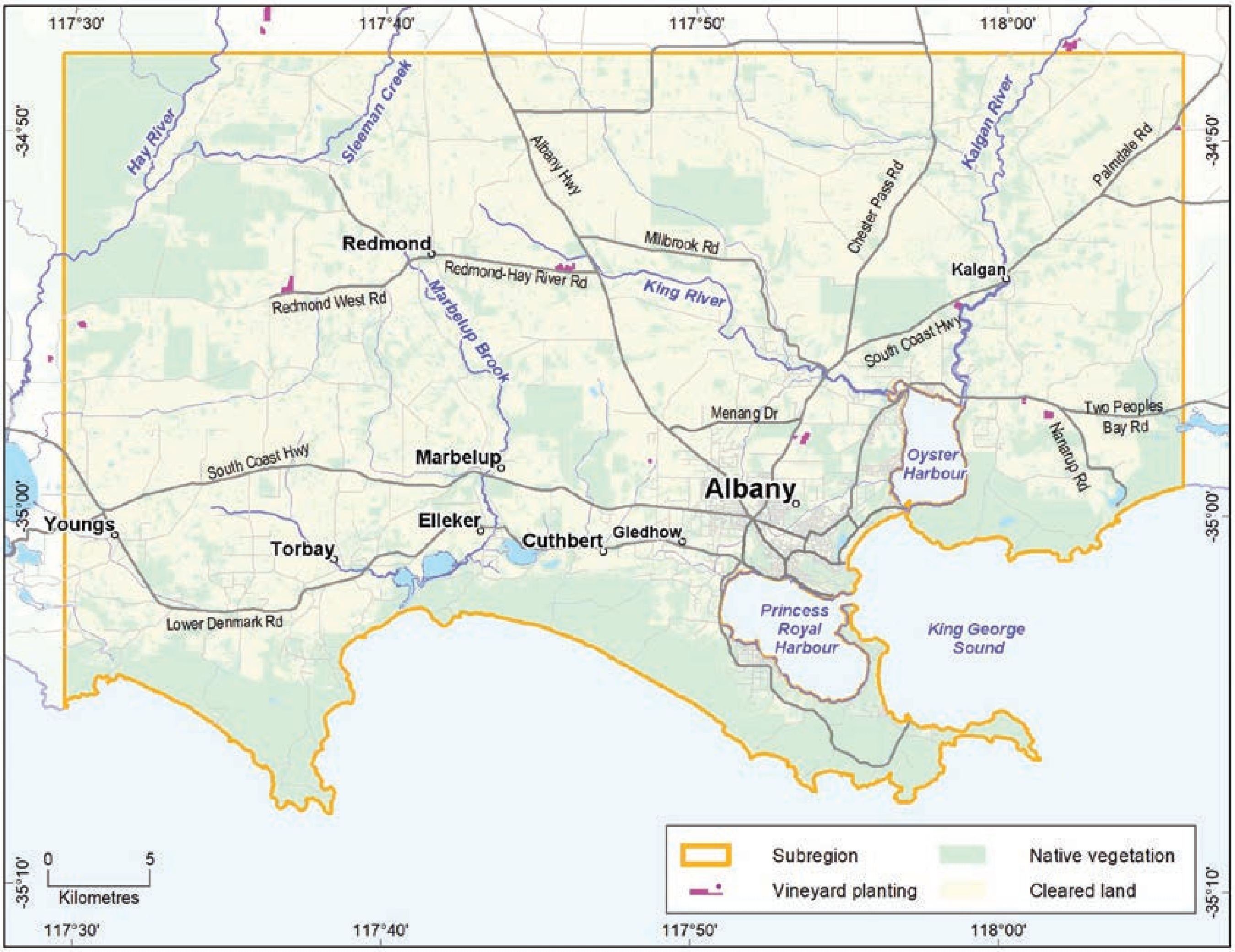


Figure 7.30: Albany subregion

Geology and physiography

The Albany subregion sits entirely within the Nornalup Complex of the Proterozoic Albany–Fraser Orogen (Figure 7.31). These crystalline basement rocks are mainly gneiss and granite.

Shallow marine waters and other sediments encroached onto this part of the Albany–Fraser Orogen in the later Eocene period (around 40 million years ago). The waters eventually receded around the end of the Eocene leaving behind a relatively smooth veneer of sediments known as Pallinup Siltstone (siltstones and spongolite as part of the Plantagenet Group), which cover a large part of the Albany subregion. A covering mantle of laterite formed on much of the Pallinup Siltstone over time. The land of higher relief, including the domes of weathered felsic crystalline rock found closer to the south coast, are often surrounded by the sediments. In many places, the Hay, Kalgan and King Rivers, with their tributaries, have also carved sinuous paths through large parts of the laterite and Eocene sediments down to the crystalline bedrock.

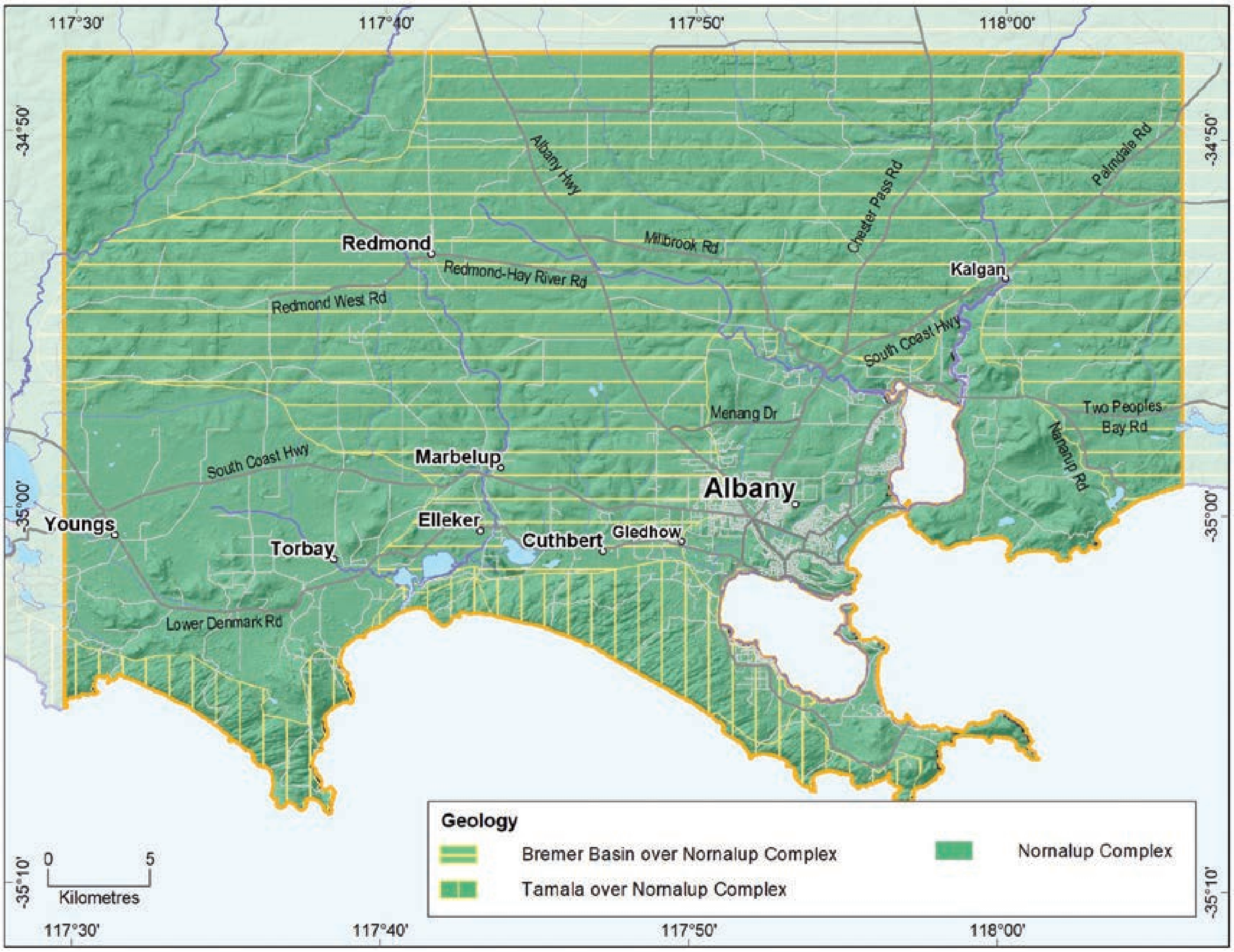


Figure 7.31: Albany subregion: Simplified geology

The imposing granite and gneiss headlands and coastal eminences of the Nornalup Complex at the south coast of the subregion are frequently overlain by broad ridges of Tamala Limestone. Large, windswept parabolic dunes cover the limestone in many areas. The limestone ridges and dunes often act as barriers behind which are areas of swamps with alluvial and estuarine deposits.

Elevation ranges from near sea level at the coast to just over 100 m AHD in the north.

Soils and landforms

The lateritic mantle cloaking the Eocene siltstone and sandstone sediments is the source of the Ironstone gravels found across much of the Albany subregion's hinterland (Figure 7.32). Ironstone gravels are the dominant soils in more than one-quarter of the area and frequently occur in combination with Sandy duplex and Pale deep sandy soils.

Over eons, rivers and other watercourses have carved into the gently sloping upland sandy plain that dominates the northern part of the subregion. This created a dissected landscape at the plain's southern edge and leaving low undulating hills with long spurs and ridges that feature more concentrated areas of Ironstone gravels, particularly on crests and upper slopes (Figure 7.33).

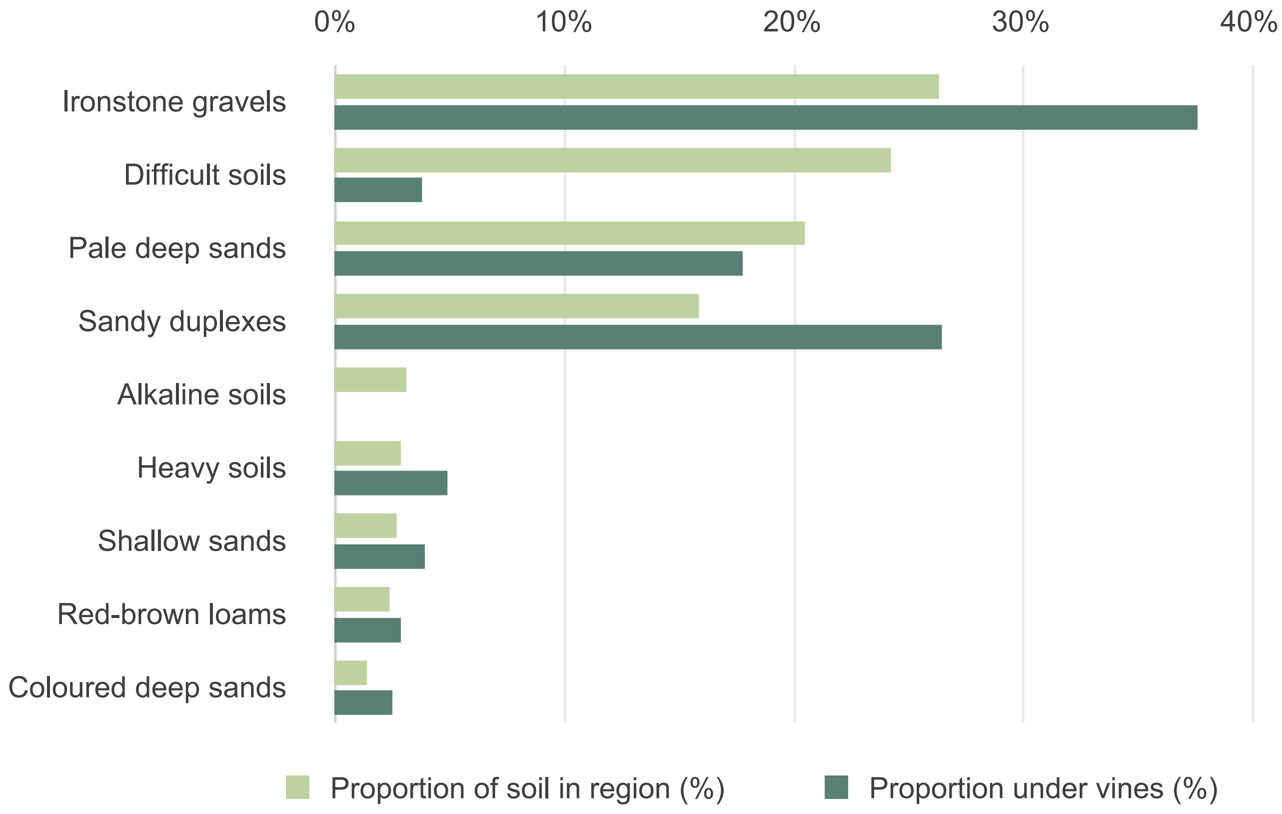


Figure 7.32: Albany subregion: Proportion of main soils in the subregion compared against main soils used for viticulture

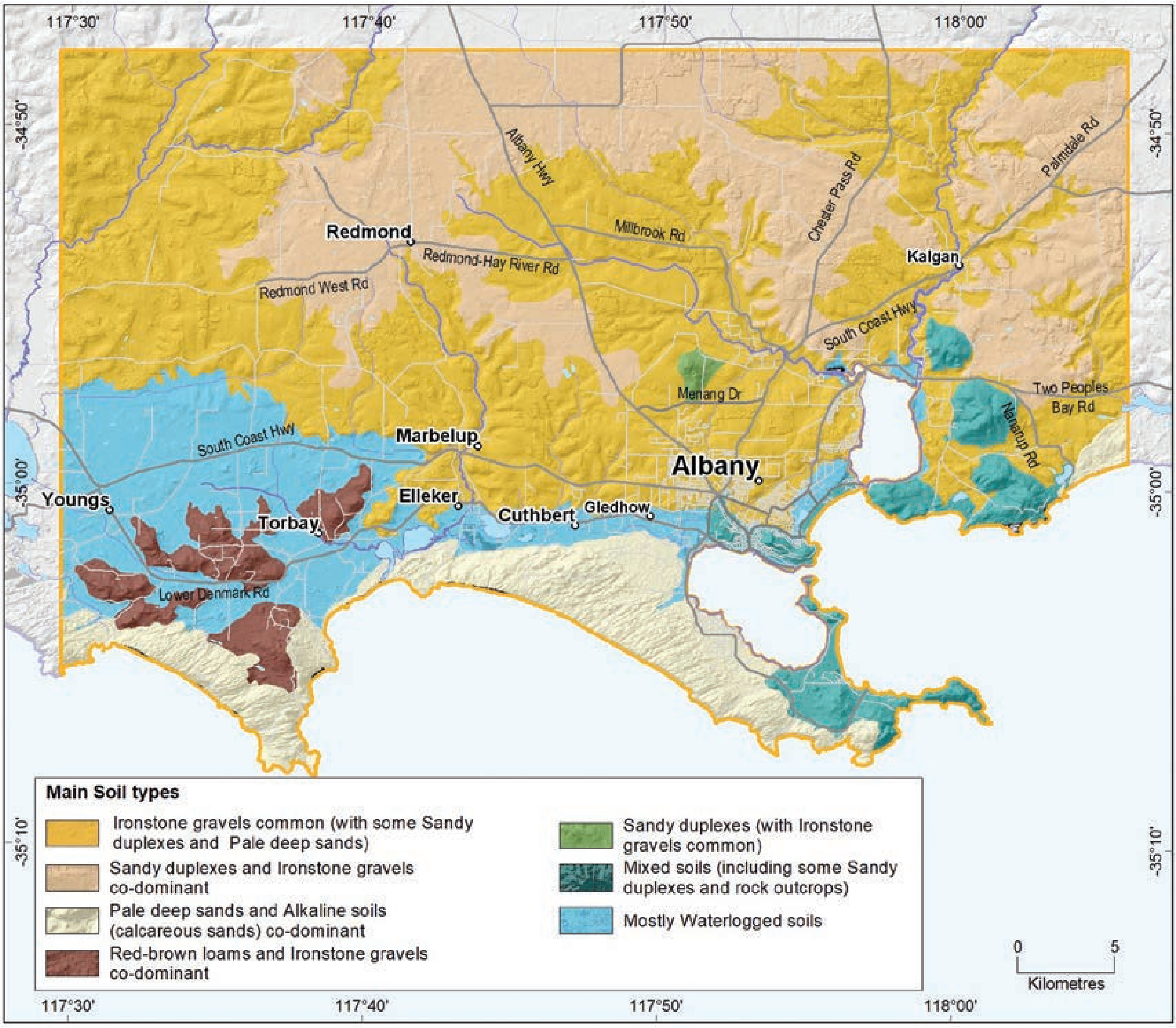


Figure 7.33: Albany subregion: Main soils

Pale deep sands occur on about 20% of the land across the subregion, generally in patches mixed with Sandy duplex and Ironstone gravel soils. In some landscapes these sands are dominant, including in shallow valleys and depressions over sandstone and siltstone. Most significantly, however, they fringe the southern coastline, in association with imposing sand dunes over Tamala Limestone and granite.

Sandy duplex soils are the next most prominent in the subregion and are related to the deep weathering of the sedimentary rocks. These soils mainly occur on the broadly undulating plateau in the subregion's north and in smaller upland plains above valley slopes. They are also more common on lower slopes around granite hills fringed by sedimentary rock. Sandy duplex soils are often found in combination with Ironstone gravels and Pale deep sand.

Where swamps, waterways and rock outcrops dominate the subregion's soils, we have grouped them together as Difficult soils. Found in about one-quarter of the subregion, these soils tend to be found on valley floors and scattered lakes and swamps dotted on the inland plateau area that are prone to waterlogging. Closer to the coast are broad areas of flat swampy plains and lakes that lie behind impressive coastal dunes and vast domed granitic headlands.

The South Coast and Hinterland survey (Churchward et al. 1988) contains soil-landscape mapping covering this subregion; the mapping can also be viewed online at NRInfo.[146]

Main viticultural soils of the Albany subregion

The highest concentration of the Albany subregion's plantings is on land dominated by Ironstone gravels, which support more than one-third of all the vines (Figure 7.34). These soils are located mainly on broad crests of sandy and lateritic spurs and ridges and upper north-facing slopes on dissected terrain.

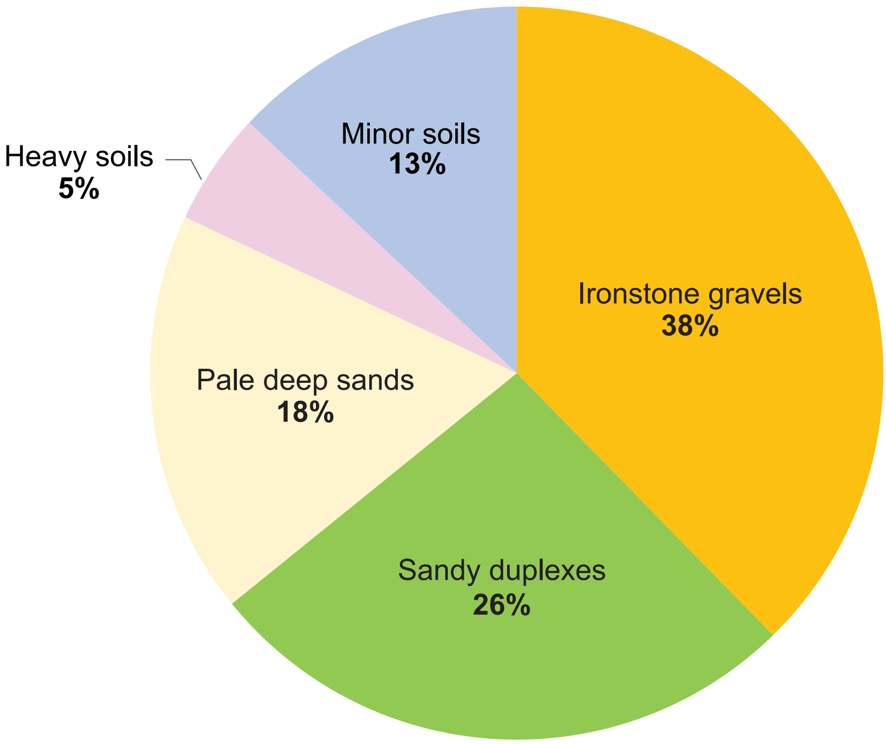


Figure 7.34: Albany subregion: Main soils used for viticulture (Minor soils are Shallow sands, Red–brown loams and Coloured deep sands)

The most common Ironstone gravels usually have pale yellow–brown to pale grey sand topsoils containing abundant ferruginous nodules and pisoliths over yellow clay subsoils. The clay is usually above 80 cm, but occasionally deeper. Hard, cemented ironstone layers or other rocks are common on hill crests.

[146] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

Sandy duplexes are the next most frequently planted soils, supporting over one-quarter of the subregion's vines. These are generally on the undulating plateaux, on broad valley slopes and at footslopes of the granitic hills emerging above the surrounding terrain north-east of Oyster Harbour.

Sandy duplex soils commonly have light grey–brown coloured coarse- to medium-grained sandy topsoils over yellow clay subsoils, or less often, the sandy topsoils are coloured yellow–brown. They are more common around the lower footslopes of some granitic outcrops.

Pale deep sands can be co-dominant with Sandy duplex soils in many of the Albany subregion's landscapes, particularly on slopes of broad valleys that have carved into sedimentary rocks. They tend to be pale grey–brown fine- to coarse-textured sand extending more than 80 cm deep, often with a yellow–brown clay layer below that depth. In some cases, a cemented laterite or coffee rock layer is found deep below the deep sand.

About 5% of the region's vines grow in Heavy soils, which typically have shallow grey coloured loamy sand topsoils over poorer structured subsoil clays within 30 cm below the surface. These, like the other minor soils, generally occur in patches amongst Ironstone gravels, Sandy duplex and Pale deep sands in various landscapes.

Climate

Because of its proximity to the Southern Ocean, the Albany subregion is cooler than the more northerly subregions of the Great Southern region, with a greater maritime influence. The coastal location brings warm humid winds with afternoon sea breezes (the Albany Doctor) and summer drizzle, which is rarely experienced in other areas of WA (Table 7.11). For this reason, soils tend to remain moister than elsewhere and fungal diseases and over-vigorous vine growth need to be managed.

Table 7.11: Albany subregion: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	690	227
Maximum	1,003	318
Mean	836	294

The Albany subregion's sunshine hours are similar to those experienced at Mount Barker; however, the moderating effect of the ocean reduces temperature variability, particularly for vineyards closer to the coast (Table 7.12). Halliday (2011a) states that moderate humidity in summer assists ripening by reducing stress on the vines. Diurnal temperature range is minimal. Annual evaporation is between 1,300 and 1,400 mm.

Table 7.12: Albany subregion: Temperature statistics (1989–2019)

Measurement	Value
Mean growing season (October–April) temperature (°C)	17.8
Mean January temperature (°C)	19.5
Mean growing degree days (October–April)	1,626
Mean diurnal temperature (°C)	9.9
Average daily sun hours (October–April)*	7
Average (October–April) cloud cover (Okta)*	5.6

* Average estimates for the Albany subregion are from Gladstones (2021).

Beeston (2002) suggests that the release of heat accumulated during the day by the Albany subregion's numerous granite outcrops has a further moderating effect on evening temperatures.

The maritime influence also means that frost risk is low, with temperatures in Albany rarely dipping below 2 °C in July.

Wind exposure can be a problem in coastal areas and shelter from the wind is an important management consideration to prevent damage to tender shoots and buds. Morning winds have a mean speed of 14 km/h, increasing to about 19 km/h in the afternoons. On summer afternoons, the humid, cooling Albany Doctor usually increases to about 21 km/h.

Denmark subregion

The Denmark subregion covers 115,558 ha and hugs the coastline of the Southern Ocean west of the Albany subregion. Towering karri forest (Eucalyptus diversicolor) cloaks much of the subregion; less than half the land is used for farming or other land uses. The Denmark subregion includes the town of Denmark and the settlements of Nornalup, Peaceful Bay and Bow Bridge (Figure 7.35). By 2019, the Denmark subregion had around 102 ha of vineyards (DPIRD 2019) making up about 3% of the Great Southern region's plantings.

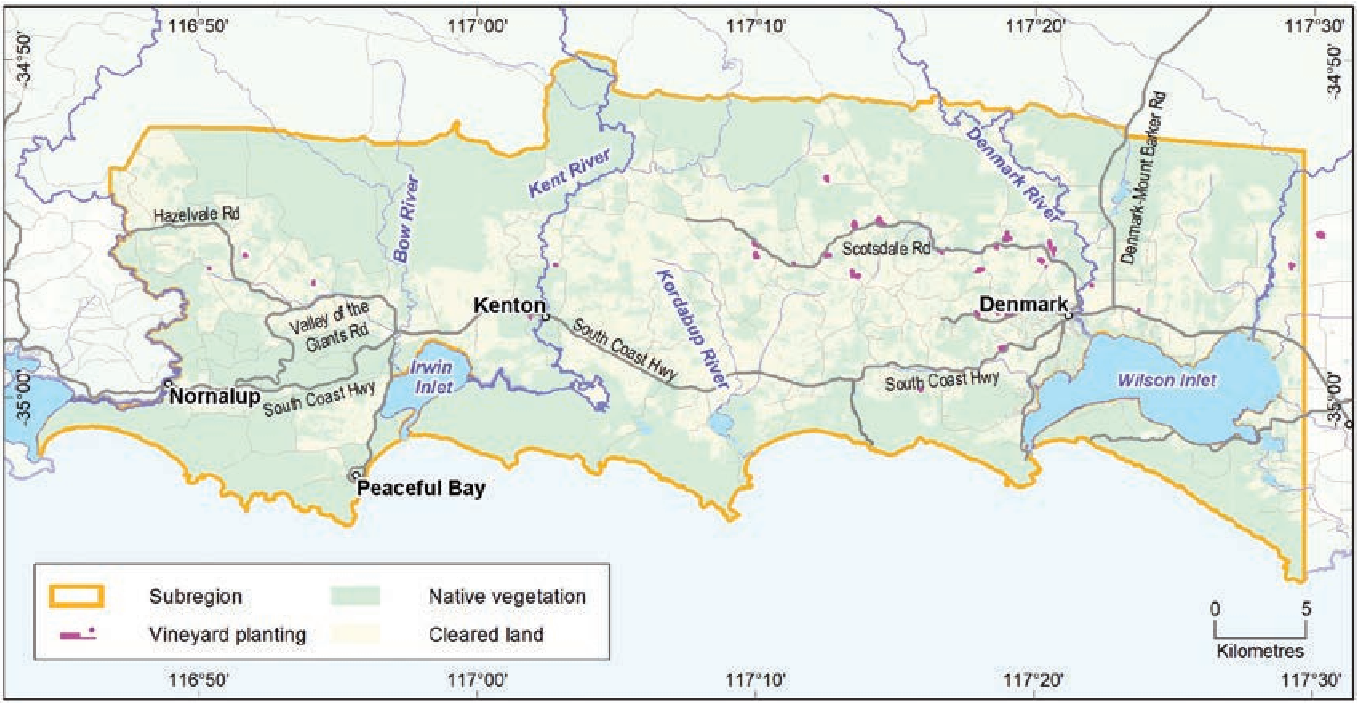


Figure 7.35: Denmark subregion

Geology and physiography

The Denmark subregion sits entirely within the Nornalup Complex of the Proterozoic Albany–Fraser Orogen (Figure 7.36). These ancient, deeply weathered felsic crystalline rocks are mostly gneiss and granite. In many areas these rocks are covered with a mantle of laterite, varying from massive and cemented blocks, to loose uncemented laterite stones known as ferruginous nodules and pisolites (commonly called forest or pea gravel).

The powerful Southern Ocean pounds the coastline at the lower edge of the subregion where outcropping domes of the Nornalup Complex form spectacular headlands and coastal eminences. Broad, imposing ridges of Pleistocene-aged Tamala Limestone overlie the coastal fringe of these prominent coastal domes, often cloaked by large windswept parabolic dunes. The coastal limestone ridges and dunes often act as barriers behind which lie areas of swamps with alluvial and estuarine deposits.

North of the coast, steep hills of the deeply weathered granite and gneiss alternate with broad swampy corridors and sandy deposits underlain by fine-grained sandstone. Many river valleys and tributaries have carved paths through this terrain, including the lower reaches of the Hay and Denmark rivers and Scottsdale Brook in the east and the Kent, Bow and Frankland rivers in the centre and west of the subregion.

Elevation ranges from near sea level at the coast to 310 m on the peak of Mount Shadforth. Most vineyards are at elevations lower than this, but much of the Bennett Range, north-west of Denmark, is more than 100 m.

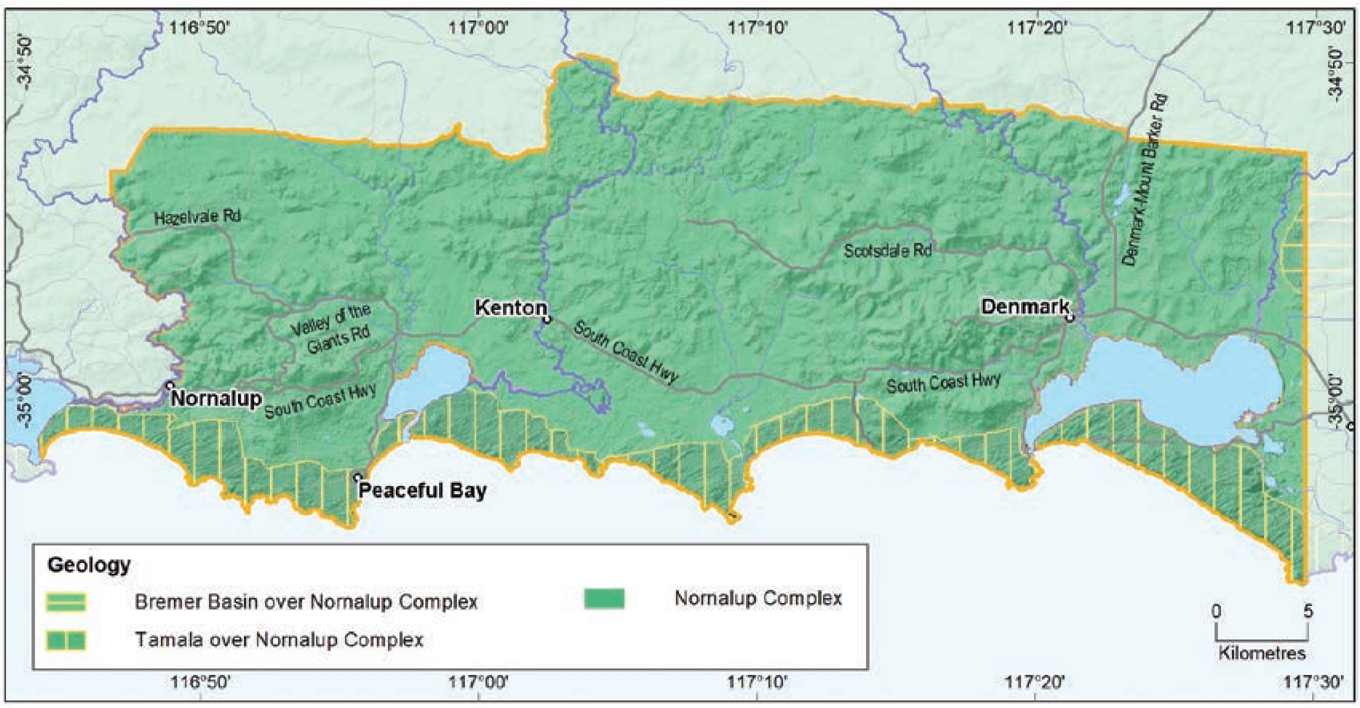


Figure 7.36: Denmark subregion: Simplified geology

Soils and landforms

The subregion's landforms (and soils) appear to be somewhat defined by the route of the South Coast Highway, which is a broad indicator of the area's topography.

Ironstone gravels are dominant in the Denmark subregion, comprising almost one-quarter of all the soils. These gravels usually occur on hill crests, ridges and upland plateau remnants, and on valley slopes in granitic terrain, mainly all north of the highway (Figure 7.37).

We grouped together as Difficult soils the areas where productivity may be affected by seasonally high watertables; valley floors, swamps and lakes; or where exposed or shallow rock or cemented laterite or stony soils are prevalent. These soils occur in about one-quarter of the subregion (Figure 7.38), often in combination with more productive soils in various landscapes. Difficult soils are more frequent closer to the coast, and often south of the highway.

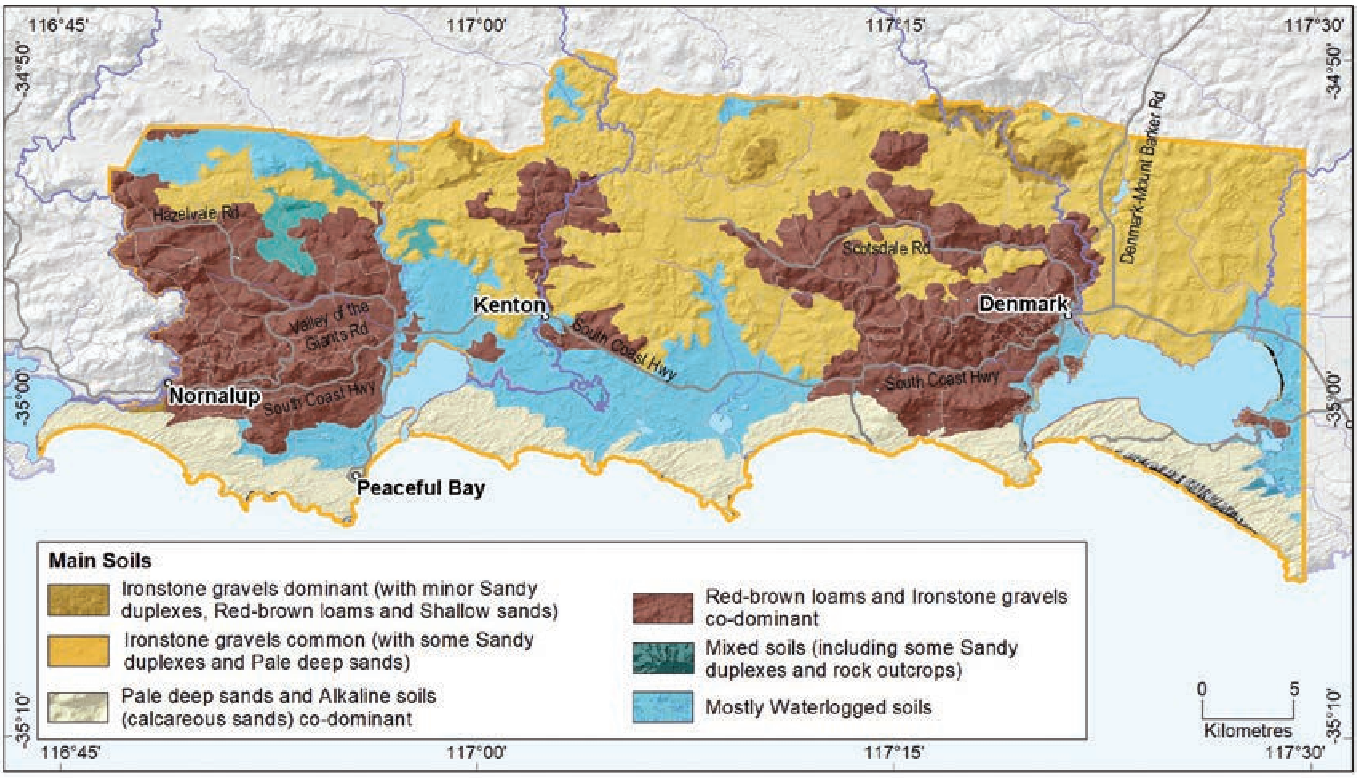


Figure 7.37: Denmark subregion: Main soils

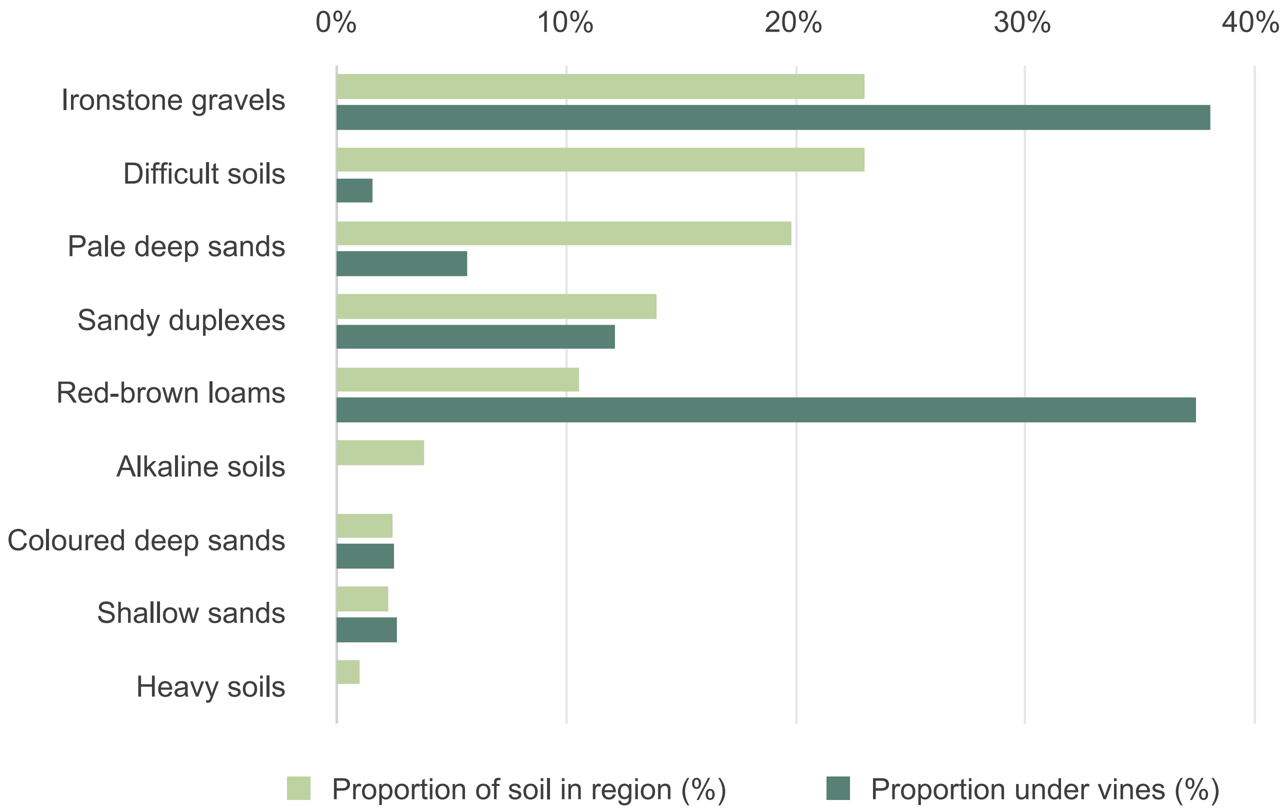


Figure 7.38: Denmark subregion: Proportion of main soils in the subregion compared against main soils used for viticulture

About 20% of all the soils are Pale deep sands, making it a more common soil in this subregion than any other in the Great Southern. North of the highway, these soils are mainly on gently undulating terrain and hillslopes, broad drainage floors and sloping flats. In a few areas they are on hill crests and catchment divides.

South of the highway, Pale deep sands are mostly on the ragged edge of the southern coastline, in association with large dune systems pushed inland by strong winds.

Sandy duplex soils are prominent in about 14% of the subregion and are mainly found north of the highway. These soils are more common on gently undulating sandy terrain and weathered sandstone fringing granitic hills, as well as on low hills. They are frequently found in combination with Ironstone gravels and Pale deep sand.

Only about 11% of soils in the Denmark subregion are Red–brown loams. These soils are typically in areas associated with the shallow granitic bedrock of the Nornalup Complex such as the hills around Mount Shadforth. They are generally on broad hill crests and slopes as well as the major valleys, mainly north of the highway. They are often associated with Ironstone gravel soils.

The South Coast and Hinterland survey (Churchward et al. 1988) contains soil-landscape mapping covering the Denmark subregion; the mapping can also be viewed online at NRInfo.[147]

Main viticultural soils of the Denmark subregion

Despite being a relatively minor soil in the Denmark subregion, Red–brown loams are as popular for growing wine grapes as the more common Ironstone gravels, with both supporting almost three-quarters of all plantings (Figure 7.39). Most of the subregion's viticulture is on these soils, fringed by karri forests and on undulating granitic hill country north of the highway between Denmark and Walpole.

The Ironstone gravel soils most favoured for growing vines in the Denmark subregion are on the granitic slopes. Commonly called 'karri loams', these soils generally have loamy or sandy red–brown topsoils (indicating shallower bedrock) containing abundant ferruginous nodules and pisoliths, and gradually increase in clay with depth. The well-structured clay loam to clay subsoils are usually red–brown or yellow–brown in colour.

Other Ironstone gravels also support a good proportion of the Denmark subregion's vines. These generally have sandy grey–brown topsoils containing abundant ferruginous nodules and pisoliths over yellow–brown subsoil clay.

The main Red–brown loams supporting vines are soils with friable brown or red loamy topsoils (and sometimes yellow–brown) over well-structured red or brown clay loam to clay subsoils. These soils are all associated with the deeply weathered bedrock of the Nornalup Complex where rock outcrops and stony soils are common. These soils are also collectively called 'karri loams'.

Sandy duplexes, supporting about 12% of vines, usually have yellow–brown or grey–brown coloured coarse sandy topsoils over neutral yellow clay subsoils.

[147] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

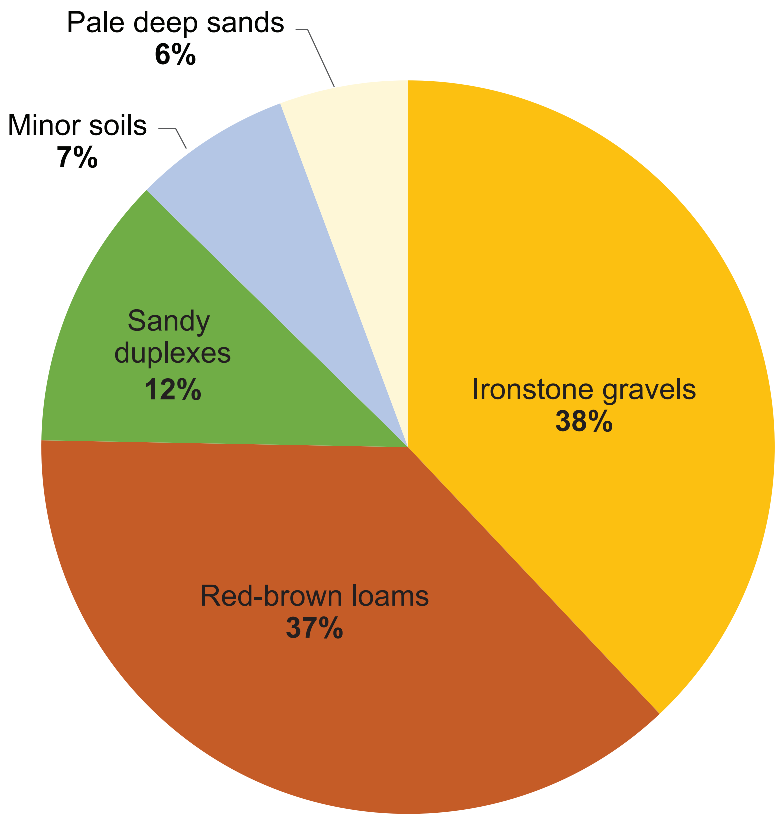


Figure 7.39: Denmark subregion: Main soils used for viticulture (Minor soils are Shallow sands and Coloured deep sands)

Small areas (about 6%) have vines growing on Pale deep sands. These soils are generally pale grey and extend more than 80 cm deep. Sometimes they contain ferricrete nodules and pisoliths below a sandy topsoil and in some cases, a hard layer of rock or cemented laterite occurs more than 80 cm below the sandy surface. These soils are generally not preferred for planting but often occur as small pockets amongst the better soils in vineyards.

Climate

Gladstones (1992) described the Denmark subregion as one of the few parts of WA capable of producing true cool climate wine styles.

Rainfall and relative humidity are higher here than elsewhere in the Great Southern region (Table 7.13). Halliday (2011a) suggested that the subregion is wetter and marginally cooler than Albany, but the differences are not significant. The high rainfall also brings abundant potential for surface storage of good quality water. Like the Albany subregion, proximity to the Southern Ocean brings warm humid winds with afternoon sea breezes and summer drizzle, which carries a risk of fungal disease for the vines and fruit, requiring careful management.

Annual evaporation is between 1 200 mm and 1,350 mm and the mean 3pm October to April relative humidity is 67% at Denmark (Gladstones 1992).

Table 7.13: Denmark subregion: Rainfall statistics (1989–2019)

Value	Annual rainfall (mm)	Seasonal (October–April) rainfall (mm)
Minimum	900	313
Maximum	1,221	427
Mean	1,070	348

The Denmark subregion has temperature statistics similar to other cooler climate regions in Australia (Remenyi et al. 2019), with mean growing degree days comparable with Tasmania (Table 7.14).

Table 7.14: Denmark subregion: Temperature statistics (1989–2019)

Measurement	Value
Mean growing season (October–April) temperature (°C)	17.6
Mean January temperature (°C)	19.5
Mean growing degree days (October–April)	1,594
Mean diurnal temperature (°C)	10.3
Average daily sun hours (October–April)*	6.7
Average (October–April) cloud cover (Okta)*	5.2

* Average estimates for the Denmark subregion are from Gladstones (2021).

Proximity to the Southern Ocean brings a moderating maritime influence. The mean diurnal temperature in the Denmark subregion is low, similar to the Albany subregion and slightly lower than the Margaret River region, with a narrower temperature range. This subregion also has the lowest average daily sun hours and the highest average cloud cover of all WA winegrowing areas (Gladstones 2021).

Inland from the coast, there is an increased risk of frost between May to October where temperatures can fall below 2 °C about 6 days per year, which brings some risk of cold air ponding in areas. Temperature variations are related to altitude, slope and aspect of the vines. Plantings of varieties like Chardonnay and Pinot Noir are often on the warmer north- and west-facing slopes to enhance early ripening.[148]

Like the Albany subregion, wind exposure can be a problem in coastal areas of the Denmark subregion. Morning winds have a mean speed of 13 km/h. On summer afternoons, the humid, cooling effect of the sea breeze is usually stronger. Exposure to strong ocean winds, particularly in spring, can damage new shoots and flowers (thus reducing fruit set), making the degree of protection from the sea wind by the landscape and the towering forest an important factor for the vines.

[148] Jim Campbell-Clause, AHA Viticulture (personal communication, 27 June 2022)

Appendices

A Areas of wine grapes planted in regions and subregions

B Geological age data

C Main Soils in relation to other soil classifications

D Areas of Main Soils for each region and subregion

E Accuracy of area estimates for Main Soils

F Climate indices for WA wine regions

Appendix A

Wine grapes planted in regions and subregions

Table A1: Total area of each wine region and area planted to wine grapes

Zone	Wine region	Total area (ha)	Area planted to wine grapes (ha)	Area planted to wine grapes % of total
South-west Australia	Margaret River	212,006	6,035	50
	Great Southern	1,668,682	2,853	24
	Geographe	553,220	822	7
	Pemberton	205,345	459	4
	Blackwood Valley	592,952	382	3
	Manjimup	224,910	250	2
Greater Perth	Swan District	358,882	883	7
	Perth Hills	327,577	197	2
	Peel	769,627	79	1
Total		**4,913,201**	**11,960**	

Table A2: Total area of each wine subregion and area planted to wine grapes

Zone	Wine subregion	Total area (ha)	Area planted to wine grapes (ha)	Area planted to wine grapes % of total
Great Southern	Frankland River	143,679	1,526	54
	Mount Barker	132,216	994	39
	Porongurup	39,384	105	4
	Denmark	115,631	102	3
	Albany	157,451	94	3
	Not in a subregion	1,080,322	32	1
Total		**1,668,683**	**2,853**	
Greater Perth	Swan Valley	8,940	624	70
	Not in a subregion	349,942	263	30
Total		**358,882**	**887**	

Appendix B

Geological age data

Although the age of the sedimentary rocks found across WA's wine regions is well known, less data is available on the age of the older crystalline rocks.[195] In the past, greater attention has been given to the geology of some less-populated parts of WA (where the most economically important mineral resources are located); however, a program to improve our knowledge of the south-west is currently underway.

We created the map in Figure 3.4 by overlaying the digital linework of the 1:500,000 Cenozoic Geology on the 1:500,000 Interpreted Bedrock Geology (GeoVIEW.WA, Department of Mines, Industry Regulation and Safety n.d.). We obtained both from the WA Department of Mines, Industry Regulation and Safety in 2016. The map units were then correlated to units shown on the *Geological map of Western Australia* (Martin et al. 2015)[196] and the age ranges obtained from its map legend. In some cases, the ages were adjusted to reflect the ages shown in GeoVIEW.WA in September 2022.

We intersected the combined mapping with the boundaries of the wine regions and our mapped distribution of vines to generate the data used to create Table 3.2 and Figure 3.5.

When the current geological investigations are completed and published, the information in the section titled 'Ancient ground' can be updated. It may eventuate that some of the crystalline rocks underlying the wine regions will be even older than suggested in this bulletin.

195 The geological age of rocks can be a complex (and sometimes contentious) issue. This is especially true when it comes to metamorphic rocks for which the age relates to when the rock was last significantly altered. The age of the igneous or sedimentary rock from which the metamorphic rock originated is not considered.

196 The correlation was based on the units from the Interpreted Bedrock Geology except where these were overlain by units from the Cenozoic Geology. This linework can be viewed on the GeoVIEW.WA website.

Appendix C

Main Soils in relation to other soil classifications

The Main Soils used in this bulletin are based on the Soil Groups of Western Australia (Schoknecht and Pathan 2013). This is because WA Soil Groups are identified in the soil-landscape mapping across the combined area of the WA's wine regions (see NRInfo[197]).

Each of the Main Soils comprises multiple WA Soil Groups. However, we split some of the Soil Groups between the Main Soils according to their Soil Group Qualifier.[198] For example, the Main Soil into which most of the Grey shallow sandy duplex Soil Group has been placed is Heavy soil. The exception is those with a 'good neutral subsoil' qualifier, which we placed into the 'Sandy duplex' Main Soil.

We also split some WA Soil Groups between the Main Soils based on their landscape position. We placed any Soil Group that would otherwise qualify as a 'Red–brown loam' or 'Coloured deep sand', into the Main Soil 'Alluvial sands and loams' if it occurs in an alluvial landscape.

All the Semi-wet soils have been placed into the 'Difficult soils' group except those with a 'deep sandy duplex' or 'sandy earth' Soil Group Qualifier which are found in elevated or sloping landscape positions.

Table C1 lists the main soils described in this bulletin in relation to the WA Soil Groups, the Australian Soil Classification[199] (Isbell and National Committee on Soil and Terrain 2021) and the World Reference Base[200] for Soil Resources. This table contains only the common classifications for each Main Soil.

[197] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

[198] Soil Group Qualifiers are explained in Section 4.3 in Schoknecht and Pathan (2013) at https://researchlibrary.agric.wa.gov.au/rmtr/348/

[199] See https://www.soilscienceaustralia.org.au/asc/

[200] See https://www.fao.org/3/i3794en/I3794en.pdf

Table C1: Common classifications for the most widespread soils

WA Soil Group	Australian Soil Classification	World Reference Base
Ironstone gravels		
*Duplex sandy gravel**	Ferric Chromosol or Ferric Sodosol	Abruptic pisoplinthic Acrisol or Abruptic pisoplinthic Lixisol
*Loamy gravel**	Ferric Kandosol	Pisoplinthic Ferralsol
Shallow gravel	Ferric-Petroferric Tenosol	Petric, pisoplinthic Plinthosol
Deep sandy gravel	Sesqui-Nodular Tenosol	Pisoplinthic Cambisol
Sandy duplexes		
*Grey deep sandy duplex**		
*Yellow/brown deep sandy duplex**	Yellow, Grey or Brown Chromosol or Sodosol	(Albic) Abruptic Acrisol or Abruptic Lixisol
Grey shallow sandy duplex[201] *Yellow/brown shallow sandy duplex*[202]	Yellow, Grey or Brown Chromosol or Sodosol	Abruptic Acrisol or Abruptic Lixisol
Pale sandy earth		
Semi-wet soil[203]	Grey Kandosol or Chromosol	Dystric Cambisol
Red–brown loams		
*Brown loamy earth**	Brown Kandosol or Brown Dermosol	Leptic and/or Skeletic, Dystric or Eutric Cambisol
*Brown deep loamy duplex**	Yellow or Brown Chromosol	Abruptic Lixisol or Abruptic Acrisol
*Friable red/brown loamy earth**	Red or Brown Dermosol or Red or Brown Kandosol	Ferritic and/or Acric or Lixic or Haplic Ferralsol or Chromic and/or Dystric or Eutric Cambisol
Yellow/brown shallow loamy duplex[204]	Yellow or Brown Chromosol	No information
Stony soils[205]	No information	No information
Red deep loamy duplex		
Red shallow loamy duplex[206]	Red Chromosol or Red Sodosol	Abruptic Chromic Lixisol or Abruptic Chromic Acrisol
Pale deep sands		

* One of the most common WA Soil Groups.

(Table C1 continued following page)

[201] Where a Grey shallow sandy duplex has a 'good neutral subsoil' qualifier.
[202] Where a Yellow/brown shallow sandy duplex has a 'good neutral subsoil' qualifier.
[203] Where a Semi-wet soil has a 'deep sandy duplex' qualifier.
[204] Where a Yellow/brown shallow loamy duplex has a 'good neutral subsoil' qualifier.
[205] Where a Stony soil has a 'loamy soil matrix' qualifier.
[206] Where a Red shallow loamy duplex has a 'good neutral subsoil' qualifier.

Table C1: Common classifications for the most widespread soils

WA Soil Group	Australian Soil Classification	World Reference Base
*Pale deep sand**	Bleached Arenosol, Grey Arenosol, Yellow or Grey Chromosol	Albic Arenosol or Pisoplinthic, Dystric Cambisol
Gravelly pale deep sand	Sesqui-Nodular Tenosol	Pisoplinthic, Dystric Cambisol
Alluvial sands and loams		
*Brown deep sand** *Red deep sand*	Red or Brown Arenosol	Dystric Fluvic Arenosol or Dystric Orthofluvic Fluvisol (Arenic)
Brown loamy earth *Friable red/brown loamy earth*	Red or Brown Dermosol or Red or Brown Kandosol	Eutric Fluvic Cambisol (loamic or clayic) or Eutric Orthofluvic Fluvisol (loamic or clayic)
Brown sandy earth *Red sandy earth*	Red or Brown Kandosol	Dystric Fluvic Cambisol (loamic) or Dystric Orthofluvic Fluvisol (loamic)
Coloured deep sands		
*Yellow deep sand**	Yellow Arenosol	Dystric Arenosol
Yellow sandy earth	Yellow Kandosol	Xanthic? Cambisol
Brown deep sand	Brown Arenosol	Brunic Arenosol or Dystric Arenosol
Red deep sand	Red Arenosol	Chromic Arenosol or Dystric Arenosol

* One of the most common WA Soil Groups.

Appendix D

Area of Main Soils for each region

Table D1 presents an estimate of the area covered by each of 10 Main Soils across the combined area of the nine south-west WA wine regions, rounded to the closest 100 ha. Estimates of the area planted to wine grapes are also shown, rounded to the closest 10 ha.

Table D1: Estimate of area of Main Soils of Western Australia's wine regions and proportion used for viticulture

	Total area		Area under vines	
Location	**(ha)**	**(%)**	**(ha)**	**(%)**
Ironstone gravels	1,629,100	33	5,280	44
Sandy duplexes	568,700	12	2,730	23
Red–brown loams	534,600	11	1,310	11
Pale deep sands	548,000	11	720	6
Coloured deep sands	271,200	6	610	5
Alluvial sands and loams	39,600	1	470	4
Heavy soils	258,400	4	330	3
Difficult soils	848,900	17	260	2
Shallow sands	131,000	3	220	2
Alkaline soils	83,500	2	30	<1
Total	**4,913,000**		**11,960**	

Table D2: Approximate area of Main Soils in each of Western Australia's wine regions and proportion used for viticulture

Region	Main Soils	Total area in region		Total area under vines	
		(ha)	(%)	(ha)	(%)
Margaret River	Ironstone gravels	54,900	26	2,750	45
	Difficult soils	43,400	20	200	3
	Sandy duplexes	42,900	20	1,750	29
	Coloured deep sands	20,550	10	150	2
	Pale deep sands	19,800	9	350	6
	Alkaline soils	11,400	5	0	0
	Shallow sands	8,050	4	150	3
	Red–brown loams	4,850	2	300	5
	Alluvial sands and loams	4,150	2	450	7
	Heavy soils	2,050	1	40	1
Great Southern	Ironstone gravels	447,900	27	1,500	52
	Difficult soils	324,350	19	50	3
	Sandy duplexes	292,000	17	550	19
	Pale deep sands	192,100	12	150	6
	Heavy soils	188,700	11	150	6
	Shallow sands	80,400	5	50	2
	Red–brown loams	79,050	5	250	9
	Alkaline soils	37,900	2	20	1
	Coloured deep sands	20,650	1	50	2
	Alluvial sands and loams	5,650	0	1	<1
Geographe	Ironstone gravels	176,000	32	300	34
	Difficult soils	102,450	19	20	2
	Red–brown loams	99,000	18	250	32
	Pale deep sands	69,350	13	100	10
	Coloured deep sands	38,450	7	50	6
	Sandy duplexes	27,200	5	50	5
	Heavy soils	12,100	2	50	6
	Alluvial sands and loams	10,300	2	50	4
	Shallow sands	9,750	2	2	<1
	Alkaline soils	8,700	2	10	1

(Table D2 continued following page)

Table D2: Approximate area of Main Soils in each of Western Australia's wine regions and proportion used for viticulture

Region	Main Soils	Total area in region		Total area under vines	
		(ha)	(%)	(ha)	(%)
Pemberton	Ironstone gravels	94,700	46	300	61
	Red–brown loams	59,000	29	150	30
	Difficult soils	19,600	10	1	<1
	Pale deep sands	11,300	6	10	1
	Coloured deep sands	10,400	5	50	8
	Sandy duplexes	7,500	4	0	0
	Shallow sands	2,050	1	0	0
	Heavy soils	600	<1	0	0
	Alkaline soils	150	<1	0	0
	Alluvial sands and loams	100	<1	0	0
Blackwood Valley	Ironstone gravels	278,400	47	150	41
	Red–brown loams	117,850	20	150	41
	Difficult soils	80,750	14	10	2
	Sandy duplexes	48,600	8	50	8
	Pale deep sands	33,050	6	15	4
	Coloured deep sands	2,450	4	10	2
	Alluvial sands and loams	5,250	1	10	2
	Shallow sands	3,200	1	0	0
	Heavy soils	2,200	<1	0	0
	Alkaline soils	250	<1	0	0
Manjimup	Ironstone gravels	116,350	52	150	65
	Difficult soils	38,550	17	5	3
	Red–brown loams	25,000	11	50	16
	Sandy duplexes	16,300	7	15	6
	Pale deep sands	13,950	6	10	4
	Coloured deep sands	12,200	5	15	7
	Heavy soils	1,550	1	0	0
	Shallow sands	850	<1	0	0
	Alluvial sands and loams	100	<1	0	0

(Table D2 continued following page)

Table D2: Approximate area of Main Soils in each of Western Australia's wine regions and proportion used for viticulture

Region	Main Soils	Total area in region		Total area under vines	
		(ha)	(%)	(ha)	(%)
Swan District	Sandy duplexes	11,550	3	300	34
	Coloured deep sands	92,100	26	200	24
	Alluvial sands and loams	6,000	2	150	14
	Ironstone gravels	9,150	3	100	11
	Heavy soils	8,600	2	50	6
	Pale deep sands	122,350	34	50	6
	Difficult soils	75,900	21	20	2
	Shallow sands	15,100	4	10	1
	Red–brown loams	2,150	1	5	<1
	Alkaline soils	15,950	4	1	<1
Perth Hills	Ironstone gravels	171,500	52	50	21
	Red–brown loams	57,000	17	100	47
	Sandy duplexes	31,750	10	10	6
	Difficult soils	24,900	8	5	2
	Coloured deep sands	14,200	4	10	6
	Pale deep sands	11,350	3	20	12
	Heavy soils	11,050	3	10	5
	Shallow sands	5,800	2	2	1
	Alkaline soils	15	<1	0	0
Peel	Ironstone gravels	280,250	36	20	25
	Difficult soils	139,050	18	2	3
	Sandy duplexes	90,900	12	15	17
	Red–brown loams	90,000	12	10	16
	Pale deep sands	74,800	10	20	22
	Coloured deep sands	38,650	5	10	12
	Heavy soils	31,600	4	5	4
	Alluvial sands and loams	9,450	1	1	1
	Alkaline soils	9,150	1	0	0
	Shallow sands	5,750	1	1	2

Table D3: Area of Main Soils in each of Western Australia's wine subregions and proportion used for viticulture

Subregion	Main Soils	Total area in subregion		Total area under vines	
		(ha)	(%)	(ha)	(%)
Frankland River	Ironstone gravels	68,600	48	900	59
	Sandy duplexes	23,750	17	250	17
	Difficult soils	19,250	13	25	2
	Red–brown loams	9,950	7	150	9
	Pale deep sands	9,550	7	100	5
	Heavy soils	7,200	5	100	5
	Coloured deep sands	2,700	2	25	1
	Shallow sands	1,000	1	15	1
	Alluvial sands and loams	850	1	1	<1
	Alkaline soils	750	1	5	<1
Mount Barker	Ironstone gravels	45,400	34	500	48
	Difficult soils	29,300	22	50	4
	Sandy duplexes	26,450	20	200	21
	Heavy soils	11,250	8	100	8
	Pale deep sands	9,350	7	50	6
	Red–brown loams	4,300	3	50	6
	Shallow sands	2,300	2	50	2
	Alkaline soils	1,950	1	20	2
	Coloured deep sands	1,850	1	50	3
	Alluvial sands and loams	200	0	0	0
Porongurup	Ironstone gravels	10,213	26	50	24
	Sandy duplexes	9,845	25	50	36
	Heavy soils	6,256	16	5	4
	Difficult soils	5,184	13	1	1
	Red–brown loams	3,991	10	25	21
	Pale deep sands	1,817	5	5	4
	Coloured deep sands	1,064	3	10	7
	Shallow sands	925	2	5	4
	Alluvial sands and loams	57	0	0	0
	Alkaline soils	33	0	0	0

(Table D3 continued following page)

Table D3: Area of Main Soils in each of Western Australia's wine subregions and proportion used for viticulture

Subregion	Main Soils	Total area in subregion (ha)	Total area in subregion (%)	Total area under vines (ha)	Total area under vines (%)
Albany	Ironstone gravels	41,500	26	50	38
	Difficult soils	38,200	24	5	4
	Pale deep sands	32,250	20	20	18
	Sandy duplexes	25,050	16	25	26
	Alkaline soils	5,000	3	0	0
	Heavy soils	4,600	3	5	5
	Shallow sands	4,250	3	5	4
	Red–brown loams	3,800	2	5	3
	Coloured deep sands	2,250	1	5	3
	Alluvial sands and loams	650	0	0	0
Denmark	Difficult soils	27,050	23	5	2
	Ironstone gravels	26,250	23	50	38
	Pale deep sands	22,950	20	10	6
	Sandy duplexes	16,150	14	15	12
	Red–brown loams	12,200	11	50	37
	Alkaline soils	4,400	4	0	0
	Coloured deep sands	2,800	2	2	2
	Shallow sands	2,600	2	3	3
	Heavy soils	1,150	1	0	0
	Alluvial sands and loams	100	<1	0	0
Swan Valley	Sandy duplexes	3,000	34	300	46
	Alluvial sands and loams	1,300	14	150	20
	Ironstone gravels	850	9	100	14
	Heavy soils	750	8	50	8
	Pale deep sands	850	9	50	6
	Difficult soils	1,600	18	15	2
	Coloured deep sands	300	3	15	2
	Shallow sands	50	<1	2	<1
	Red–brown loams	350	4	1	<1

Appendix E

Accuracy of area estimates of Main Soils

We have more confidence in the estimates of the areas of Main Soils found across each wine region than our estimates of the areas of vines planted to each of the Main Soils.

The broadscale soil-landscape mapping compiled by DPIRD was used to generate this data and can be viewed on NRInfo.[207] This mapping is sufficiently detailed to typify the soil pattern within individual wine regions and subregions.

Each wine region covers at least 200,000 ha, with the smallest subregion (the Swan Valley) covering almost 9,000 ha. The soil-landscape mapping in most areas is at a scale of 1:100,000 but ranges between 1:25,000 and 1:250,000.

We calculated the area of each soil-landscape mapping unit within each wine region. We then multiplied this area by the proportional area of each Soil Group of Western Australia found within that map unit (as shown in the summary of soils in NRInfo).[208] By adding the area of each Soil Groups for each map unit we calculated the total area for each region. We then converted the Soil Group into Main Soils with the aid of the Soil Group Qualifiers (see Appendix C).

The boundaries of the individual vine plantings were mapped at much more detailed scale (1:5,000) than the soil-landscape map units. Most of the individual blocks of vines mapped range in size between 1 and 15 ha, with only 5 of the 960 blocks mapped exceeding 50 ha.

There is no consistent mapping available at the level of detail[209] that shows intricate soil patterns within the individual blocks. Instead, to make our estimates of the area of soils planted to vines, we had to rely on the broadscale soil-landscape map units. We calculated the area of soil-landscape map units underlying each block of vines. We then multiplied the area by the average proportion of WA Soil Groups soils across that map unit and converted them into Main Soils as described above.

Most soil-landscape map units on which vineyards are located have a combination of soils better and less suited to viticulture. Where possible, viticulturists will select the better soils and avoid the less suitable soils. But our calculations assume that the soils are planted in the same proportion as they occur within the map unit.

For this reason, Figure 4.2 and Figure 4.3 most likely underestimate the area of the favoured soils planted to vines (such as Ironstone gravels, Red–brown loams and Alluvial sands and loams) and overestimate the area of poorer soils (such as Pale deep sands).[210]

[207] See https://www.agric.wa.gov.au/resource-assessment/nrinfo-natural-resource-information-western-australia

[208] These data show a proportional area for each combination of WA Soil Group and Qualifier present within the map unit. We also used the available data on the landscape position of these combinations.

[209] No detailed soil mapping is available for most vineyards, although detailed mapping of some vineyards has been completed over the years. However, this mapping is not always available in a consistent format, and it would be a major task to relate the mapping to the Main Soils.

[210] For the Difficult soils only, we reduced our estimates of the area planted.

The proportion of Sandy duplex soils planted to vines may also be overestimated. Most of these are from the Margaret River wine region, where our estimates show almost 30% of the soils planted to vines are Sandy duplexes. In the Margaret River region, some of the major mapping units planted contain a complex of Sandy duplexes and Ironstone gravels. On the Swan Coastal Plain, a complex of Sandy duplexes and Alluvial sands and loams occurs. Although some of the Sandy duplexes have been planted, our observations suggest that the Ironstone gravels are preferentially selected in many cases.

Difficult soils was the only Main Soil for which our estimates of the area planted do not directly reflect the proportion of soils in the underlying map unit. Vineyards are rarely established primarily on these soils, but small patches surrounded by suitable soils can be found within some plantings. Elsewhere, remedial works, such as installing drainage, have been adopted to make these soils productive. Based on these circumstances, we reduced our initial estimates of the area that each map unit is planted to Difficult soils by 70% and added this area to areas of the other Main Soils found within the map unit in proportion to their occurrence.

Appendix F

Climate indices for WA wine regions

Table F1: Mean annual rainfall for WA wine regions (highest to lowest)

WA wine region	Mean annual rainfall (mm)
Pemberton	1,111
Margaret River	977
Geographe	854
Perth Hills	828
Manjimup	797
Peel	737
Blackwood Valley	701
Great Southern	677
Swan District	660

Table F2: Mean growing season temperatures and Growing Degree Days for WA wine regions (highest to lowest)

WA wine region	Mean growing season temperature (Oct–Apr) (°C)	Mean Growing Degree Days
Swan District	21.88	2,522
Perth Hills	21.60	2,464
Peel	20.42	2,212
Geographe	19.50	2,017
Margaret River	18.71	1,851
Blackwood Valley	18.61	1,828
Manjimup	18.09	1,718
Pemberton	18.03	1,704
Great Southern	17.83	1,662

Table F3: Mean seasonal diurnal temperatures (October–April) for WA wine regions (highest to lowest)

WA wine region	Mean diurnal temperature (Oct–Apr) (°C)
Perth Hills	14.70
Blackwood Valley	14.65
Geographe	14.43
Peel	14.28
Swan District	14.08
Manjimup	13.08
Great Southern	12.25
Pemberton	12.02
Margaret River	10.85

Table F4: Mean January temperatures for WA wine regions (highest to lowest)

WA wine region	Mean January temperature (°C)
Swan District	24.7
Perth Hills	24.4
Peel	23.3
Geographe	22.3
Blackwood Valley	21.4
Margaret River	20.7
Manjimup	20.5
Great Southern	20.1
Pemberton	20.0

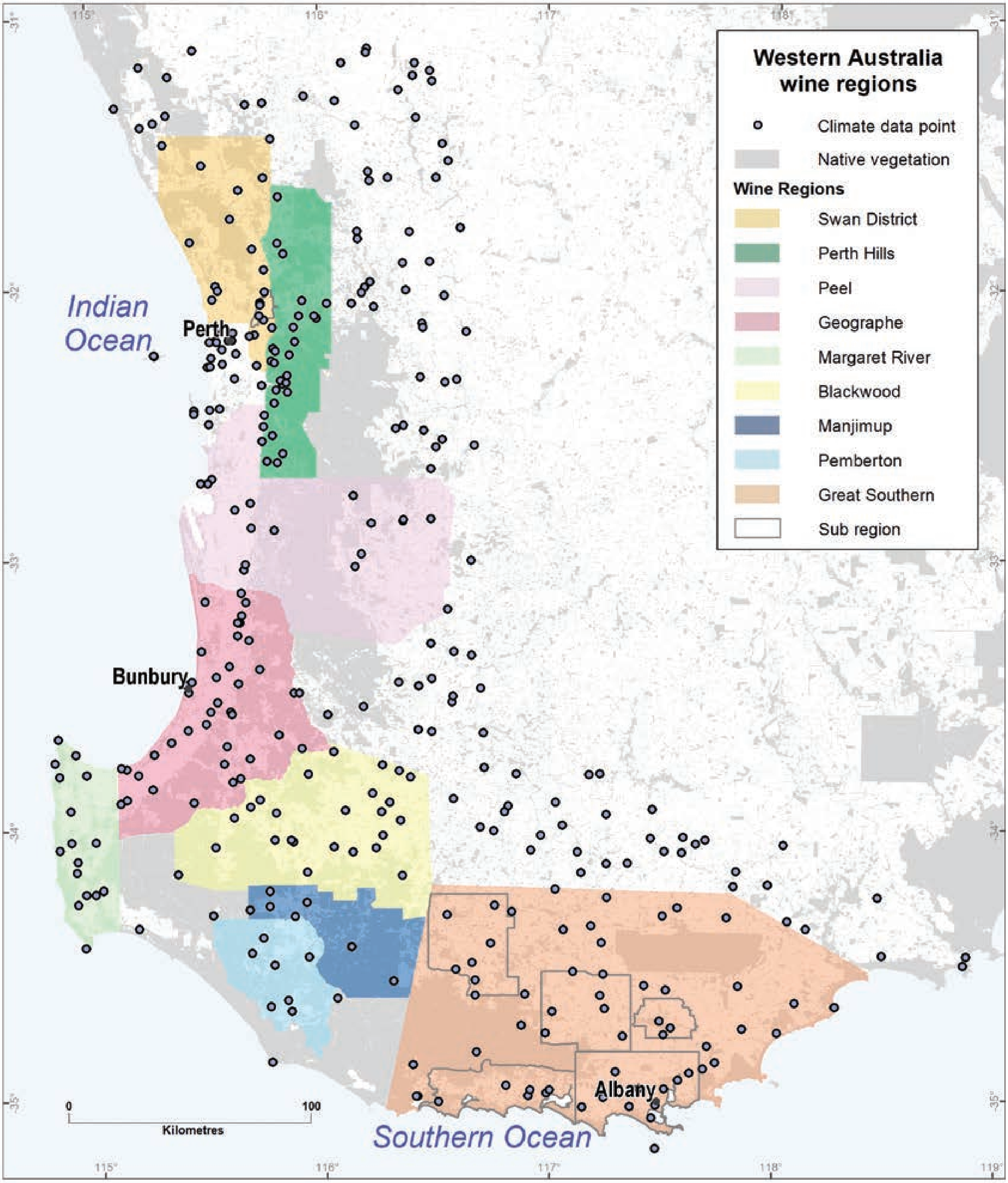


Figure F1: Climate data points for the wine regions of WA

Shortened forms

Short form	Long form
AHD	Australian Height Datum
BEDD	biologically effective degree days
BoM	Bureau of Meteorology
Ca	calcium
cm	centimetre
Cu	copper
DPIRD	Department of Primary Industries and Regional Development
Fe	iron
Ga	giga annum or billions of years
GDD	growing degree days
GI	Geographic Indication
GST	growing season temperature
ha	hectare
IOCI	Indian Ocean Climate Initiative
K	potassium
km; km^2	kilometre; square kilometre
m	metre
Ma	mega annum or millions of years
Mg	magnesium
MJT	mean January temperature
Mn	manganese
Mo	molybdenum
N	nitrogen
Na	sodium
P	phosphorous
pH	The acidity or basicity of a solution.
S	sulfur
WA	Western Australia
WST	Western Standard Time (Australia)
Zn	Zinc

Glossary

Acidity: A figure derived from the measure of the soil pH on a logarithmic scale from 1 to 14 where 7 is neutral and lower values (1–6) are acidic.

Aeolian: Relating to, or arising from, the action of the wind.

Alkaline: A figure derived from the measure of the soil pH on a logarithmic scale from 1 to 14 where 7 is neutral and higher values (8–14) are alkaline.

Amphibole: any of a group of common rock-forming silicate minerals. Amphiboles are found principally in metamorphic and igneous rocks.

Archean: The Archean Eon is a geological period that covers the second of four eons of Earth's history, representing the time from 4,000 to 2,500 million years ago.

Basin: A low area in the Earth's crust, of tectonic origin, in which sediments accumulate.

Batholith: A large intrusion of igneous rock, usually granite, formed deep beneath the surface so the rock cooled very slowly.

Biotite: A form of black mica widely distributed in igneous rocks (particularly in granites) as lustrous black crystals. In composition, it is a complex silicate, chiefly of iron and magnesium, together with potassium and hydroxyl.

Calcareous: Soil with the presence of carbonate (lime) as segregations or fine earth.

Carbonaceous: Rocks or sediments consisting of, or containing, carbon or its compounds.

Chalk: A soft, white, porous, sedimentary carbonate rock.

Claystone: A sedimentary rock that is composed primarily of clay-sized particles

Complex: A lithodemic unit comprising 2 or more lithodemes of more than one genetic class (metamorphic, igneous or sedimentary). Lithodeme: A body of intrusive, pervasively deformed, or highly metamorphosed rock, generally nontabular and lacking primary depositional structures, and characterised by lithic homogeneity.

Conglomerate: A coarse-grained sedimentary rock composed of rounded fragments embedded in a matrix of cementing material such as silica.

Craton: An old and stable part of the continental crust that has survived the merging and splitting of continents and supercontinents for at least 500 million years.

Cretaceous: a geological period spanning 145.5 million years ago to 66 million years ago. The Early Cretaceous period is considered as 145 – 100.5 million years ago.

Cryogenian: A geologic period that lasted from 720 to 635 million years ago.

Crystalline: (rock): Rock made up of interlocking crystals. Igneous and metamorphic rocks are almost all crystalline, as are salt deposits.

Darling Fault: One of the longest and most significant faults in Australia, extending for at least 1,500 km in a north–south orientation near the west coast of southern Western Australia.

Darling Plateau: The gently undulating plateau surface of the Darling Range, excluding river valleys.

Darling Range Batholith: A section of the Yilgarn Craton, it is the major geological unit underlying the plateaus and valleys of much of the Darling Range.

Darling Range: A general collective term for the plateau and valley landscapes east of the Darling Scarp; often used interchangeably with the term 'Perth Hills'.

Darling Scarp: A low escarpment, formed by the Darling Fault, running north to south-east of the Swan Coastal Plain and Perth.

Duplex: Soil that has an abrupt increase in clay content over a short vertical distance.

Eocene: Relating to or denoting the second epoch of the Tertiary period, between the Paleocene and Oligocene epochs.

Feldspar: A common mineral in igneous and some metamorphic rocks.

Felsic: Silicate minerals, magmas and rocks enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium. The term is a mnemonic adjective for igneous rocks having light-coloured minerals derived from 'feldspar' and 'silica'.

Ferric/ferruginous: Soil with abundant ferruginous (ironstone) nodules or pisoliths.

Garnet: Any member of a group of common silicate minerals that have similar crystal structures and chemical compositions. They may be colourless, black, and shades of red and green

Glauconite: An iron potassium phyllosilicate mineral of characteristic green colour which is very friable and has very low weathering resistance. Glauconitic sandstone contains sufficient grains of glauconite to impart a marked greenish colour to the rock.

Gneiss: Coarse-grained, metamorphic rock often showing a 'banded' texture due to separation of pale and dark-coloured minerals containing abundant feldspar with quartz, mica, hornblende, and garnet.

Goethite: The most common iron oxide in soils and is widely distributed in WA – it weathers to produce the distinctive brownish yellow colour of many soils.

Granite: Light grey or pinkish, coarse-grained, igneous rock, cooled slowly in large intrusions.

Granitic orthogneiss: Gneiss derived from granite.

Granofel: Medium to coarse grained metamorphic rock.

Granodiorite: A coarse-grained intrusive igneous rock similar to granite but containing more plagioclase feldspar than orthoclase feldspar.

Greensands: A sand or sandstone which has a greenish colour. This term is specifically applied to shallow marine sediments that contain noticeable quantities of rounded greenish grains.

Haematite: An iron oxide widely found in rocks and soils, recognised and named because of its distinctive 'blood red' colour. In WA, haematite is often associated with goethite in soils.

Holocene: The current geological epoch. It began approximately 11,650 years before present, after the Last Glacial Period, which concluded with the Holocene glacial retreat.

Hornblende: An important rock-forming mineral of complex composition, essentially a silicate of calcium, magnesium and iron, with smaller amounts of potash, soda and hydroxyl. Hornblende crystallises in the monoclinic system and occurs as black crystals or grains in many different types of igneous and metamorphic rocks.

Igneous: Formed from magma, either erupted from a volcano or cooled below ground in an intrusion.

In situ: Situated in the original, natural, or existing place or position in which it was originally formed.

Ironstone: See Ferric/ferruginous

Kaolinite: A layered silicate clay mineral which forms from the chemical weathering of feldspar or other aluminium silicate minerals. It is usually white.

Limestone: Sedimentary rock composed largely of calcium carbonate (fizzes with dilute acid), usually formed from the remains of living organisms.

Lineament: A linear feature in a landscape which is an expression of an underlying geological structure such as a fault.

Mafic: A dark-coloured silicate mineral or rock that is rich in magnesium and iron.

Marl: An earthy material rich in carbonate minerals, clays, and silt.

Matrix: Refers to all the solid particles found in soil that include the soil particles, organic matter, and other inorganic materials.

Mesoproterozoic: The Mesoproterozoic Era is a geological time period spanning 1,600 to 1,000 million years ago. It is one of the three subdivisions of the Proterozoic Eon.

Mesozoic: The era of geological time including the Triassic, Jurassic and Cretaceous ages.

Metabasalt: A low-grade, mafic metavolcanic rock with preserved evidence of its original basaltic character.

Metamorphic: A rock that has recrystallised because of heat and/or pressure.

Metasandstone: See metasediment

Metasediment: A class of metamorphic rocks where the original rock was sedimentary.

Mica: Any of a set of minerals that crystallise in the monoclinic system.

Migmatite: Rock composed of a metamorphic (altered) host material that is streaked or veined with granite rock; such rocks are usually gneissic (banded) and felsic rather than mafic in composition.

Miocene: A geological time period spanning 23.03 to 5.3 million years ago.

Monadnock: An isolated hill or ridge or erosion-resistant rock rising above a plain.

Mottle: Spots, blotches or streaks of colours in soil that are different to the main soil colour.

Muscovite: The most common mineral of the mica family. It is an important rock-forming mineral, present in igneous, metamorphic, and sedimentary rocks.

Non-wetting: Water-repellent soils

Orogen: A zone of crustal collision generally formed when continents collide, where a belt of the Earth's crust is involved in the formation of mountains.

Orthoclase: A silicate of potassium and aluminium, which crystallises in the monoclinic system and occurs as an essential constituent in granitic and syenitic rocks and as an accessory in many other rock types.

Orthogneiss: Gneiss derived from igneous rock (such as granite).

Paleoproterozoic: The Paleoproterozoic Era is a geological time period spanning 2,500 to 1,600 million years ago, is the first of the three sub-divisions of the Proterozoic Eon. The Paleoproterozoic is also the longest era of the Earth's geological history.

Pedology: The study of soils in their natural setting and includes the study of soil genesis and soil classification.

Permian: The Permian is a geological period that lasted from 299 to 251 million years ago and was the last period of the Paleozoic Era.

Phyllite: Any of a set of argillaceous rocks in a condition of metamorphism between slate and mica schist.

Pisolith: A pea-sized (usually ferruginous) nodule or concretion. See Ferric/ferruginous

Plagioclase hornblende: A combination of minerals found in some medium-grained, moderately well foliated gneiss (hornblende – dark-coloured silicate mineral; plagioclase – white or grey coloured mineral).

Pleistocene: The geologic epoch that lasted from about 2,588,000 to 11,700 years ago, spanning the world's recent period of repeated glaciations. The Pleistocene is the first epoch of the Quaternary Period and the sixth epoch of the Cenozoic Era.

Profile: A vertical section of soil from the ground surface downwards, usually divided into layers called horizons.

Proteaceous: Relating to the Proteaceae, a family of flowering plants.

Proterozoic: The Proterozoic is a geological eon following the Archaen eon, spanning the time interval from 2,500 to 538.8 million years ago.

Quartz: Hard, resistant mineral (grey/white/glassy) in granite, many metamorphic rocks and sandstones. Most sand grains are made of quartz, a very hard and chemically resistant mineral.

Quartzite: A very hard, usually almost white, sandstone made up of quartz grains cemented together by silicon dioxide. Quartzite is always associated with other metamorphic rocks, while cemented sandstone is always associated with other sedimentary rocks.

Quaternary: The Quaternary is the current and most recent of the three periods of the Cenozoic Era. It follows the Neogene Period and spans from 2.58 million years ago to the present.

Sandstone: Medium-grained, sedimentary rock comprising mainly sand grains that have been cemented together.

Schist: A metamorphic rock with a shiny, foliated, medium-grained texture, often containing much mica.

Sediment: Material deposited by water, wind or ice. Includes pebbles, sand, mud, organic remains (e.g. shells) and salts left by evaporation.

Sedimentary rock: Any rock made up of sediment grains; for example, mudstone, sandstone, limestone, rock salt, coal.

Shale: Mudstone that has been compressed to form a fine-grained, flaky, dark-coloured sedimentary rock.

Siliceous: Material containing abundant silica.

Siltstone: Fine-grained sedimentary rock comprising consolidated silt.

Spongolite: A light and porous stone made almost entirely from fossilised sponges.

Terra rossa: A reddish-brown soil with favourable drainage characteristics, found as a mantle over limestone bedrock.

Terroir: The complete natural environment in which a particular wine is produced, including factors such as soil, topography, and climate.

Tertiary: The geologic time period from 66 million to 2.6 million years ago.

Texture contrast: See Duplex

Truncated: A soil profile that has lost all or part of its upper horizons through erosion.

Unconsolidated sediments: Sediment that is loosely arranged or unstratified, or whose particles are not cemented together, found at the surface or at depth.

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