Chapter 2: Geomorphology of the Swan Coastal Plain

2.1 Overview of geology

This introduction is not meant to be a comprehensive description of the geology of the Australian continent. The intention is to provide some very basic information that provides a framework upon which the geomorphology of the Swan Coastal Plain (SCP) can be understood. The key references for the discussion below are Bolland (1998), Department of Minerals and Petroleum Resources (Undated) and Seddon (1972).

The earth was a molten mass up until around 4,600 million years ago, at which time, the outside started to cool and solidify (crust) forming the first types of rocks/geological formations. The inner part of the earth (core) still remains molten today. The earth is constantly changing due to:

- On-going cooling and shape changing causing cracks and major faults;
- Molten rock emerging at the surface (volcanoes);
- Weather forces (rain, wind, ice) breaking rocks into smaller fragments; and
- The major plates upon which the continental masses sit and continuing to shift.

The rocks and soils that make up the surface of the earth are formed either by:

- Molten rocks cooling (igneous).
- Rocks being weathered (broken down into small fragments) by either rain, wind, salt (chemical), ocean waves and tides, and deposited on in other areas or in the ocean. These form soils and sands. If these sediments become consolidated into rocks (e.g. sandstone from compaction of sands, and limestone from chemical processes) these are called sedimentary rocks.
- If any of the above materiel is subject to renewed heat and pressure it will change into metamorphic rocks.

One of the key changes that have occurred over time as the earth has cooled has been the formation of deep basins where fault lines form and land either rises or falls either side of the fault lines (Figure 2).

Figure 2: The geological process of basin formation

1. Stable Igneous block
2. Faults appear as earth cools
3. Middle block slips forming basin.
4. Weathering occurs and basins fill with sediment from ocean and/or water courses – sedimentary basin (e.g the Perth Basin).
These basins can then fill with sedimentary material either from the oceans or from rivers and streams forming sedimentary basins. One of the key processes that form sedimentary basins has been the constantly changing sea levels as the climate has gone through various cycles of cooling and warming (the amount of ice on the surface strongly influences sea levels).

These basins are generally several hundreds of millions of years old and are geologically stable. The sediments that filled into these basins contained organic matter, which changed over the millions of years to form oil and gas deposits. The basins off the north of WA are particularly rich in gas deposits (Carnarvon and Browse).

The Perth basin began to form about 200 million years ago when the Darling Fault line became active and significant vertical movement occurred – the land to the west of the fault moved downwards. From that time on sea level changed several times which contributed to the build up of sediments west of the Scarp and a changing coastline growing gradually westwards. This sedimentary basin is called the Perth Basin, which is about 1000 km long, 65 km wide and up to 15 km deep. This basin extends out to the sea beyond the current coastline, and has been covered by more recent sediments at and near the existing coastline – the Swan Coastal Plain.

Whilst these sedimentary basins are stable, this doesn’t mean that change isn’t occurring. First, the ocean, through the activities of waves, is constantly breaking down the rocks at the coast and in shallow areas (reefs) creating millions of tonnes of sand every year. The ocean is also constantly moving this sand around (through the action of waves, tides and related sea breezes) and if the conditions are right this sand and other marine material can deposit at the near shore areas forming sandy coastal plains: the Swan Coastal Plain is one such example. These coastal plains are geologically very young (less than 30 million years) and are constantly changing, particularly at the coast where they may be either eroding or accreting (growing seaward).

As well, weathering processes are breaking down rocks. The constant heating and cooling of rocks as part of the daily day and night cycle will lead to cracks appearing, and, ultimately, the breaking down of large rocks into smaller ones. The wind adds to this process by picking up smaller particles and then pounding these into other rocks creating an abrasive process that further erodes the rocks. Rain has a similar effect, as the running water picks up smaller particles that create an abrasive processes similar to that of the wind. The speed of the wind and running water (as rivers) determines how much sediment is carried: the faster the speed the more sediment is carried. Consequently, when a river runs off the mountain and hilly landscape to either flat coastal plains or the ocean itself, the speed of the running water slows considerable. Much of the sediment load being carried, therefore, will be deposited in these locations.

There are, therefore, two processes depositing material in the coastal area: sediment bought to shore from the ocean and sediment from the upland areas bought by rivers. Sedimentary material from the oceans is called aeolian and sedimentary material bought from rivers and streams is called alluvial. Both these processes have occurred, and are occurring, on the Swan Coastal Plain.

### 2.2 Swan Coastal Plain (SCP)

#### 2.2.1 Overview

The SCP is a combination of sand and sediment that has been washed down from the Darling Scarp or deposited from the ocean, primarily the latter. The Plain in its entirety extends from near Geraldton in the north to Dunsborough in the south. In the near Perth Region, the Swan Coastal Plain’s eastern boundary is the Darling Scarp, approximately 25kms from the coast. The Plain lies over the Perth Basin.

The Swan Coastal Plain has four broad geomorphic units running roughly parallel to the existing coastline. Three of these units are formed primary from Aeolian deposits representing three separate geological ages increasing in age from the coast. The fourth unit is primarily alluvial in nature and is mainly found in the eastern part of the SCP. This unit began forming at the same time the aeolian part of the SCP began
to form. The main rivers that flow off the Darling Range – the Swan, Canning, Serpentine, Murray, Harvey, Collie and Brunswick Rivers - pre-date the SCP, and as the SCP began to form, these rivers continued to flow and find a way to the coast. As noted above, when these rivers met the SCP, their speed significantly reduced and they began to deposit alluvial material on top of the sand dunes. They also formed significant floodplains in some areas and these alluvial plain are very wide. This process continues today. Figure 3 shows these four land forms in the portion of the SCP around Perth.

**Figure 3: Swan Coastal Plain, (Source: Davidson 1995)**
2.2.2 Bassendean Dunal System

These dunes formed during the middle Pleistocene, which is from around 800,000 to 125,000 years ago. The dunes tend to be gently undulating made up of well-bleached white-grey sands (Plate 6). Because of their age, any chemicals (e.g. calcium carbonate, the base material for limestone) have long since been leached out and washed away. The soils of the Bassendean dunes are commonly called ‘gutless’ sands.

Plate 6: Bassendean dunes showing the typical Banksia woodland and the grey ‘gutless’ soils

2.2.3 Spearwood Dunal System

These dunes formed during the Pleistocene glacial and interglacial periods, around 40,000 years ago, and are made up of yellow brown sands of varying thickness over Tamala limestone. Because they are not as old as the Bassendean dunes, the soils of the Spearwood dunes still contain iron salts (the yellow/brown colour) and some calcium carbonate – i.e. the rain has yet to leach all of the nutrients out of the soil. (Plate 7). As noted earlier, the sand that makes up these dunes come from the ocean. Consequently, they would have originally had significant other marine material in them – notably the shells from dead molluscs. Plate 8 shows the sand on one of Perth beaches, with the presence of shells clearly visible. These shells are mostly calcium carbonate – the main component of limestone – and when they get buried by other sand, they slowly get dissolve as water (rain) passes through the sand. Deeper down in the soil the dissolved calcium carbonate can reform and come out of solution eventually forming solid limestone.

Plate 9 shows an eroding sand dune, and this has exposed the early stages of the calcification process described above. This is very young limestone – mostly sandstone.
Plate 7: Soils and vegetation typical of the eastern parts of the Spearwood dunes.

Plate 8: Beach sand showing the presence of marine deposits (shells).
Plate 9: Exposed sandstone in an eroding beach dune – formed from the marine shells deposited several hundred years previously.

Given the age of the Spearwood dunes, this calcification process is well advanced and much of the calcium carbonate originally in the soil has been leached out and formed limestone underneath the soil - Plate 10.

Plate 10: Exposed limestone under the Spearwood soils
This limestone will itself dissolve overtime – as they dissolve they may form underground caves. Thus, the Spearwood dunes closest to the coast, which are the youngest, still have limestone at or near the surface (Plate 10 above), whereas the soils to the east, which are older, have had more time for the limestone to dissolve and, consequently, the limestone is found much deeper i.e. the limestone that was near the surface has dissolved. Plate 7 shows this and Plate 11 below shows a sand quarry in a Spearwood dune and the depth of the soil is obvious. The limestone occurs at the base of the quarry and this is as deep as the sand extraction will go.

Plate 11: Sand quarry in a Spearwood dune showing the depth of the soil above the base limestone

The Spearwood dunes extend well west of the existing coast line. The off-shore islands (including Garden, Rottnest and Penguin Islands) and the near shore reefs are all part of the Spearwood dunal system, as is the now sea-bed in between. Sea levels during the height of the height of the last ice age were around 125m below what they are now (Yokoyama, De Deckker et al. 2001), and those island, reefs and sea-bed were all above sea level during this period.

As sea levels rose, the submerged soil was washed away leaving the limestone areas exposed. These are the reefs that are near the coast. The parts of these dunes that are too high to be submerged are the chain of islands that include Garden, Rottnest and Penguin. Where there has been significant erosion at the coast, the limestone is exposed as coastal cliff. Plate 12 is a photo of Cape Peron, and shows limestone at the coast, limestone reef just off shore, and a nearby island with its limestone base clearly obvious.
2.2.4 Quindalup Dunal system

These dunes began to form at the end of the last ice age, 10,000 years ago, and continue to be formed in some parts of the coast today. The dunes are made up of cream coloured calcareous sands (sands with marine shell material – see plate 8 above). These are the recent coastal sand dunes that overlay the Spearwood dunes (Plate 13). In most places, these dunes are less than a thousand years old, but there is a significant and wide Quindalup dunal system in Rockingham where the eastern most part of it dates back to the end of the ice age (10,000 years ago). This area called the Becher Plain. Figure 4 is a Google Earth photo showing the extent of the Becher Plain. Part of the old coastline still remains as the eastern shore of the two salt lakes - Lakes Cooloongup and Walyungup. The reason why these two lakes are salty is because the salt is of marine origin. It is thought that as the Becher plain was formed, the land to the west of the lake rose significantly, forming first an estuary very much like the Peel-Harvey estuary, and then the water body became completely land-locked, thus forming the two salt lakes.
Figure 4: Google Earth image showing coastline around 10,000 years ago and the Becher Plain.
2.2.5 Guilford Formation or Pinjarra Plain

This landform is the low lying and flat area found to the east of the SCP, mostly south of the Swan and Canning Rivers. As noted earlier, this landform is primarily of alluvial origin, formed by the major rivers that dissect the SCP. In effect, they are the floodplain of these rivers. Whilst the soils are primarily clay, there is also sand in the soils, which come from sand blown inland from the dunes in the west. This landform lies over the top of the eastern most Bassendean dunes. The clay nature of these soils and the generally low relief means that they are naturally poorly drained and hold surface water for most of winter (Plate 14).

Plate 14: Pinjarra Plain, showing its flat nature and the extent of surface water during winter
Given the clay content of these soils, this landform is much more fertile than the three sand based landforms of the SCP, and most of the Pinjarra Plain has been cleared for agriculture. However, to facilitate agriculture, many artificial drains have been constructed to help remove the excess water (Plate 15).

Plate 15: One of the many artificial drainage lines that dissect the Pinjarra Plain

2.3 Summary

The SCP is a combination of sand and sediment that has been washed down from the Darling Scarp or deposited from the ocean, primarily the latter. The Swan Coastal Plain has four broad geomorphic units running roughly parallel to the existing coastline. Three of these units are formed primarily from Aeolian deposits representing three separate geological ages increasing in age from the coast. The fourth unit is primarily alluvial in nature and is mainly found in the eastern part of the SCP. The four landform are:

- Bassendean,
- Spearwood,
- Qunidalup, and
- Pinjarra Plain

The sandy soils of the first three landforms do not hold water easily and most of the rainfall percolates into the groundwater rather than forms water courses, with the exception of the Pinjarra landform, which is made up of a mixture of clay and sand. This unit does not drain water very well.

Limestone (Tamala) underlays the Spearwood unit, which can be exposed at the coast and makes up the chain of islands and reefs off the coast of Perth.
2.4 References


Department of Minerals and Petroleum Resources (Undated). Perth Basin. Perth, Western Australia, Government of Western Australia.

Seddon, G. (1972). Sense of Place: A response to an environment the Swan Coastal Plain. Perth, Western Australia, University of Western Australia Press.


Dr Garry Middle, November 15, 2014

Email: garrymiddle@icloud.com