A Guide to the Geological Heritage of Kangaroo Island

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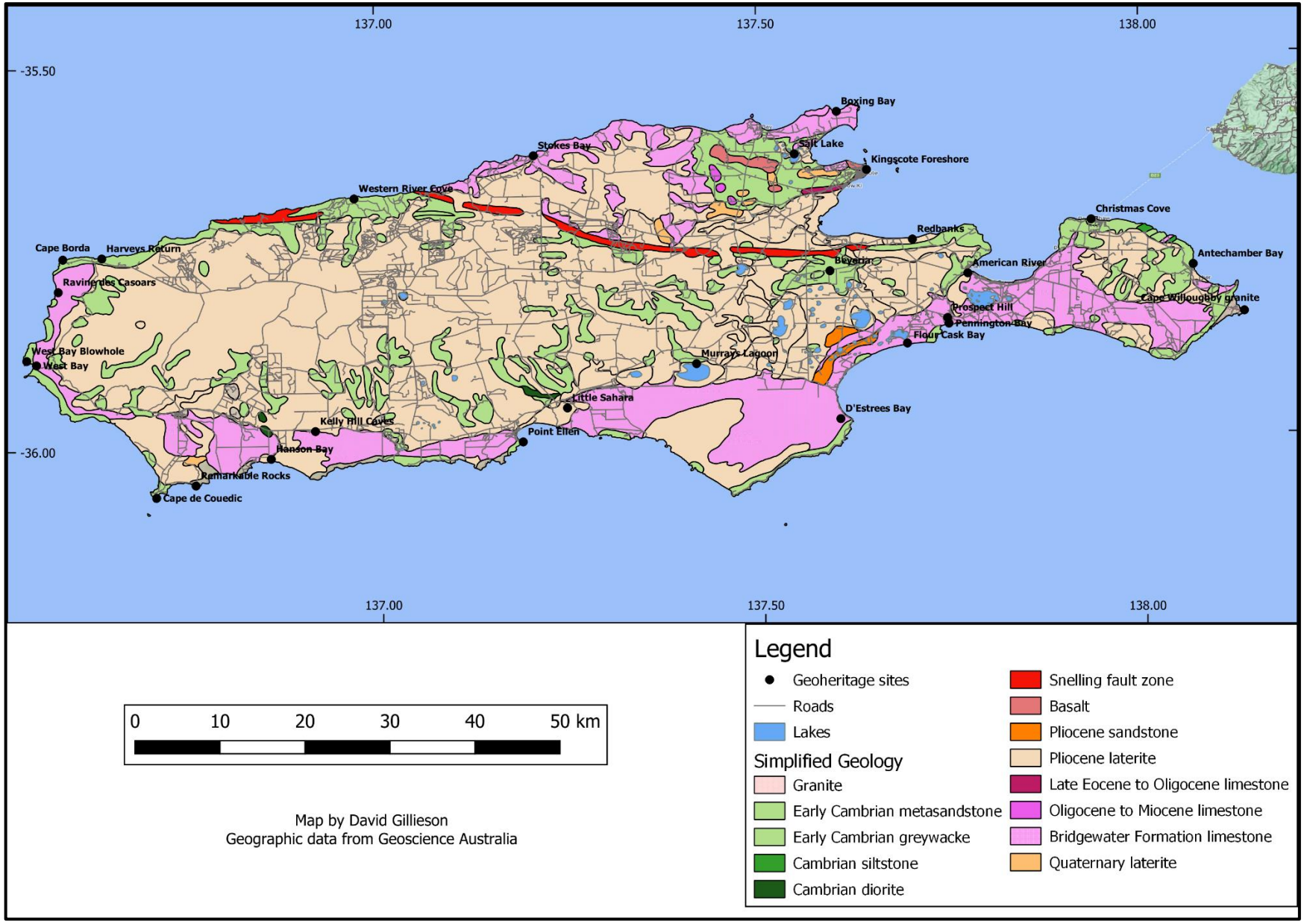
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Salt Lake
Kingscote Foreshore
Western River Cove
Christmas Cove
Redbanks
Cape Borda
Harveys Return
Ravine des Casoars
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Bridgewater Formation limestone
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Introduction

Welcome to Kangaroo Island. This booklet is designed to help visitors explore the island's rich geological heritage, its rocks of almost unimaginable age, its landscapes and their treasures. It should also help you to understand some of the events responsible for its formation through millions of years of Earth history.

Geodiversity refers to the variety of geological elements of nature, such as rocks and minerals, soils, fossils and landforms, and active geomorphological processes. Kangaroo island is a very geodiverse place, as well as an important place for biodiversity. Together they make up our natural heritage that is worthy of conservation.

Geoheritage is made up of the elements of geodiversity which are of significant value to humans, for purposes which do not diminish their intrinsic or ecological values. This implies a distinction between the utilitarian resource values of rocks, landforms and soils, and their conservation values as heritage in their natural state.

There are currently 21 sites on the South Australian geoheritage register for Kangaroo Island (Table 1). These can broadly be grouped into: a limited outcrop of Proterozoic rocks; Cambrian granites, sandstones and metasediments, with some fossil sites; Permian glacial deposits and striations; Jurassic basalt; and Holocene dune fields.

Table 1: Existing SA Heritage Sites on Kangaroo Island. Grid references in map grid UTM zone 53S

Site	Easting	Northing	Feature
Big Gully	733500	6060700	Cambrian White Point conglomerate and Boxing Bay formation; richly fossiliferous
Cape D'Estaing	725100	6059400	Cambrian sediments and fossils well exposed
Emu Bay	727000	6058700	Cambrian Emu Bay shale fossils; trilobites
Smith Bay	722300	6058200	Permian shales and glaciated pavements
Stokes Bay	699800	6055600	Pleistocene dune limestone overlying Early Cambrian rocks
Old Government Quarry	739200	6051800	Jurassic Wisanger basalt overlying Permian sediments in quarry
Kingscote foreshore	738600	6050600	Eocene bryozoal Kingscote Limestone in cliffs
Christmas Cove	765500	6043300	Cambrian rocks overlain by Permian glacial deposits, excellent glaciated pavement
Snapper Point	773800	6041000	Neo-Proterozoic metamorphic rocks of Adelaide geosyncline
Harveys Return	648200	6042700	Metamorphosed Cambrian sediments with zebra rock (contorted bedding)
Ravine des Casoars	642900	6038000	Pleistocene limestone; flank margin caves
Cape Willoughby granite	781800	6031500	Cambrian granite overlying Early Cambrian Middleton sandstone
Wilson River dune	765200	6028600	Holocene dune overlying floodplain deposits, bedding very clear
West Bay	639800	6027300	Cambrian Middleton sandstone with sedimentary structures
D'Estrees Bay	736100	6024000	Pleistocene dune limestone of Last Interglacial age
Little Sahara	702500	6018800	Mobile Holocene dunefield
Cape Gantheaume	713600	6014700	Mobile Holocene dunefield
Point Ellen	697100	6014100	Cambrian igneous migmatites with granite melts, overlain by Pliocene shell beds
Remarkable Rocks	658300	6009300	Cambrian granite weathering, xenoliths
Cape de Couedic	653600	6007700	Cambrian metasandstones, dune limestones

How to use this book

There are many sites which you can visit easily by car, bike or on foot. For each site I provide a simple description of the geology and geomorphology. You can combine these sites into an itinerary over several days. The sites are listed in clockwise order round the island starting at Penneshaw, where ferries arrive. There is also a list of accessible further reading if your curiosity is stimulated.

Geological Overview of Kangaroo Island

Kangaroo Island is made up of a diverse association of both rocks and landforms that reflect a long and varied geological history. The broad geology of Kangaroo Island is made up of a central plateau capped with deeply weathered soils called laterites, with abundant ironstone nodules. The laterites overly Cambrian sandstones, about 500 million years old, that are exposed at the coast in many places. The gritty sandstones have been tilted and folded so that the original bedding is now almost vertical. The Cambrian sandstones and siltstones were deposited in a deep oceanic trench and as sediments accumulated, the depression of the crust allowed molten magma to reach the surface around 400 million years ago. These are today represented by a number of granite outcrops along the south coast, most noticeably at Cape Willoughby and the Remarkable Rocks.


Steeply dipping beds of Cambrian sandstone at American River

After a long period of erosion when Australia was part of the supercontinent Gondwana, most of Australia became covered by glaciers. At this time, in the Permian period around 280 million years ago, Australia was much closer to the South Pole. Glacial ice flowed northwards carving a trough more than 500 m deep where Pelican Lagoon and Backstairs Passage are today. Glacial ice carved also grooves in the rocks at Christmas Cove and Smith Bay, while polished granite boulders at Boxing Bay were transported by the ice from Cape Willoughby. During the Pleistocene, during the last 2 million years, high sea levels facilitated the formation of dunes made of carbonate-rich shelly sand on the island, and the carbonate cemented the dunes into limestone. Karst features such as caves and sinkholes are widespread on the dune limestone; in excess of two hundred and fifty caves have been explored and mapped by cavers. Guided tours are available at the Kelly Hill Caves near Flinders Chase National Park.


Left photo: Glacially rounded granite boulder, Boxing Bay. Right photo: Dune limestone bluffs at Pennington Bay

Christmas Cove, Penneshaw

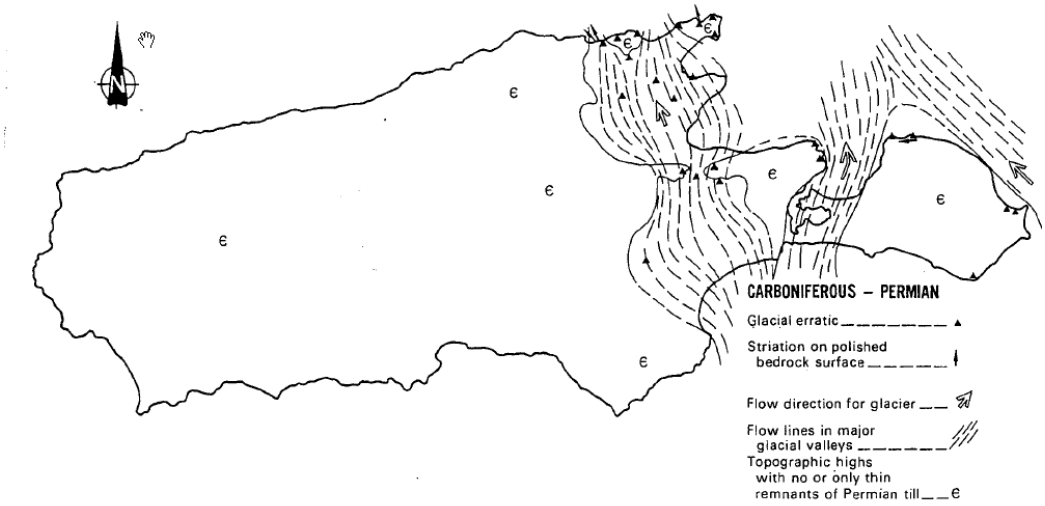
Christmas Cove on the western side of Penneshaw reveals several features of the extensive Permian (290 million years ago) glaciation that covered most of Australia. At that time Australia was part of the supercontinent Gondwana and was much closer to the South Pole, about the latitude of subantarctic Macquarie Island some 12 degrees from the pole.

Glaciers carved deep valleys into the bedrock, principally in Backstairs Passage and the Pelican Lagoon area where a now-buried glacial valley was probably more than 500 m deep. At Christmas Cove, ice polished and grooved sandstone bedrock is exposed on the northwest side of the cove opposite the marina. The bedding in the sandstone is very steep, similar to many other places on the island, and the grooves and scratches cut right across it close to water level. Elsewhere on the island large boulders and layers of glacial clay or *till* were dumped. Erratic boulders transported by the ice are anomalies where they have lodged, and are mostly granite, porphyry and sandstone. Several can be seen on the beach at Boxing Bay.

Evidence of past glaciation is best seen from the breakwater at low tide

Glacial striations (abraded grooves) just above water level

Continental ice sheet, till and an erratic boulder in the Vestfold Hills, Antarctica. Photo by David Gillieson



Directions of glacial ice flow over Kangaroo Island. From Belperio, A.P. (1995) Guide to the Geology of Kangaroo Island, Geological Survey of South Australia.

Antechamber Bay

This expanse of unspoiled white sand is one of the best beaches on Kangaroo Island. It can be accessed from the Lashmar Conservation Park campsite at the mouth of the Chapman River, off the Cape Willoughby road. At the northern end of the beach is a low rocky headland with an excellent exposure of the Cambrian metasandstones which here have been folded and are dipping at about 60°. The bedding forms ribs of stone in the tidal zone and extend for about 100 m. At the southern end of the beach is a band of well-rounded boulders of the sandstone which have been tumbled in the surf for thousands of years. Further south along the beach, at the base of a low cliff of dune limestone, is the keel of the steamer *Kona* which was wrecked here in 1910. You can still see rusted steel bolts protruding from the massive block of wood which is about 20 m long.

The Chapman River drains Lashmars Lagoon and provides good canoeing on sheltered waters. Lashmars Lagoon itself would have been an inlet of the sea during the last interglacial period some 125,000 years ago, but is now isolated by a Holocene sand barrier. Today the lagoon is a very valuable bird habitat providing an important feeding refuge for waterbirds and migratory wader species. It also provides suitable habitat for at least fifteen species of waterbird to breed.

Folded Cambrian sandstone at the northern end of iconic Antechamber Bay

Boulder beach at Redhouse Bay, Cape St Albans in the distance

Keel of the steamer Kona, wrecked at Redhouse Bay in 1910

Cape Willoughby Granite

The lighthouse at Cape Willoughby sits on top of a large outcrop of granite, with the wave washed deep gorge of the Devil's Kitchen just to the west of the site. Granite is usually a crystalline mix of three minerals: quartz (white and pale blue), feldspar (pink plagioclase) and mica (brown biotite). The granite formed from molten magma deep in the Earth's crust, about 5-10km below the surface. This happened back in the Cambrian (470-500 million years ago) when the crust was depressed due to the weight of accumulated sediments in a deep ocean trench. Granite landscapes tend to weather to produce rounded boulders called tors. In cliff faces, the blocky appearance results from deep cracks and veining associated with the cooling of the magma, and then folding and faulting.

From the lighthouse, a marked circular walk leads down to a boulder beach and old landing place with nicely rounded granite boulders. Just west of the Devil's Kitchen and over a stile, a rough track leads along the cliff tops outside the sheep fence for about 1 km to Windmill Bay, where a field of large rounded granite boulders meets the clean white sandy beach and an impossibly clear blue sea.

Jointed granite cliffs with characteristic blocky weathering

Looking along the cliff tops to Windmill Bay

Cape Willoughby lighthouse and the Devil's Kitchen gorge

Pennington Bay

There are very good exposures of Pleistocene dune limestone along the coast of iconic Pennington Bay. On the shore platform there are sporadic outcrops of Cambrian (500 million years old) metasandstones, some finely laminated muddy siltstones (Petrel Cove Formation) of similar age, and Early Pleistocene fossiliferous limestone with *Ostrea* shell moulds. These are overlain by a 50m thick sequence of Pleistocene dune limestone (Bridgewater Formation). Over the last two million years, during periods when sea level was higher, coastal shelly dunes migrated inland under the influence of strong southwesterly winds. These became cemented into limestones, separated by calcrete fossil soils. The limestones here have been dated by strontium isotope analysis to 1.23, 1.18 and 0.52 million years ago. In places Oligocene (34 to 23 million years old) flint cobbles with sponge spicules are washed onto the coast. These were prized by First Nations people for making stone tools with durable sharp edges, and have been found in many places along the shores of Kangaroo Island.

Solutionally sculpted dune limestone remnant on the beach

Looking west along Pennington Bay to Point Reynolds cliffs

Stone tools made from Oligocene chert

Dune limestone bluff overlying Cambrian sandstone

Prospect Hill Lookout

The summit of Prospect Hill (also known as Mount Thisby) provides a really good view of Pennington Bay, Pelican Lagoon and surrounding country, and rises about 90m above the countryside. The hill is the culmination of a series of recent sand dunes blown off the south coast in the last 10,000 years (known as the Holocene), now stabilised by mallee vegetation. The sand is partially cemented by shell fragments and other marine organisms, and provides a modern analogue for the extensive Pleistocene (< 2 million years) dune limestones that mantle much of the southern coastline of Kangaroo Island, including Pennington Bay. Prior to that there was a deep open channel through here, excavated by glacial ice during the Permian (285 million years ago). Immediately east of Pelican Lagoon is New Lake or Gobell's Lagoon, which was mined for salt and gypsum during the nineteenth and twentieth centuries. This can be viewed from Mitchell Drive which links Hog Bay Road and Island Beach.

Flour Cask Bay

This lovely stretch of coast, part of D'Estrees Bay, is reached down Old Salt Lake Road, off Hog Bay Road near the American River turnoff. From the vehicle turnaround at the end of the road, walk east through a gate in the fence and follow the sandy track down to the beach. The area is best explored at low tide. To the east is a 60m cliff in dune limestone with numerous caves at different levels, due to recent uplift of the terrain. To the west a shore platform has formed in Pliocene (2-5 million years old) limestone of the Point Hart Formation. This limestone is dark in colour and very hard, with numerous solution cavities due to the action of sea spray and aerated seawater. There are also a couple of nice sea stacks along the coast. Follow the shore platform to several nice pocket beaches that lie below the 50-60m cliffs in dune limestone.

Flour Cask Bay was once a whaling station in the 1830s and the people there raised old flour casks, painted white, on poles to attract the attention of passing ships when they ran out of flour, rum and tobacco. The Old Salt Lake was mined

for both salt and gypsum from 1905 to 1955. Both were quite pure and of very good quality. There are remains of the old salt works on the northern shore. A railway line ran from there to the Muston jetty and the remains of the track, a raised ridge, can be seen on the east side of the road just south of the KI Tru Thai restaurant entrance.

View from top of track

Calcified root casts at top of cliff

Sea stacks in limestone

Pocket beach and shore platform in limestone

Murray Lagoon

Murray Lagoon is part of the Cape Gantheaume Conservation Park and lies off South Coast Road on the way to Flinders Chase. It is the largest freshwater body on the island and is an important wildlife refuge and feeding site for water birds and migratory species.

The lagoon is bounded on the south by a high ridge of dune limestone of Pleistocene age, which provides an upper limit of 2 million years for the age of the basin to the north. Timber Creek flows off the laterite plateau into the lagoon and its large catchment provides plenty of water. The maximum depth is 3 m and large areas become dry in summer, although some fresh to brackish water is always present. On the eastern side of the lagoon there are several low ridges up to 2 to 3 m high and composed of *Coxiella* shells from the lagoon, creating several nested basins 3-5 m higher. This suggest that the lagoon was once much larger. Unlike most of the small lagoons and lakes on Kangaroo Island, Murray Lagoon lacks lunette ridges composed of clays blown out of dry lake floors during the Last Ice Age. This suggests it held water throughout that cold dry time, and Aboriginal artefacts have been found around the shore of the lagoon.

The Curley Creek walk follows the northern shore of the lake for 5 km, and at the eastern end the Bald Hill walk leads to a viewing platform with a fine view of the lake. The Timber Creek walk follows one of the shelly ridges for about 2 km

and is a good place to spot waterbirds. Birds present include Cape Barron geese, Black swans, Hoary headed grebes and Black shouldered kites.

Panorama of Murray Lagoon from Bald Hill lookout

Panorama from Timber Creek walk

Little Sahara

Little Sahara is a naturally occurring dune field which covers 250 hectares and lies about 4 km from the south coast of Kangaroo Island, near Seal Bay. It is privately owned and was placed on the Australian geological heritage list in 1979. The white sand dunes are composed of fine shelly sand which was blown off the continental shelf during low sea levels in the Last Ice Age, about 22,000 years ago. Today the highest part of the dune complex is 70 m above sea level.

During the Last Ice Age sea level was about 125 m lower than present and very strong south-westerly winds blew for several thousand years. On Kangaroo Island conditions were also very cool and dry, so many lakes dried out completely. Sediments were blown from the lake bed to accumulate on the eastern shore as curved ridges known as lunettes. While most of these have now stabilised under native vegetation, Little Sahara continues to move slowly and steadily eastwards. Within the dune field, fine sand grains are lifted into the air and suspended for short distances before falling back to the surface, creating an ever-changing pattern in the dune ridges.

Point Ellen, Vivonne Bay

Point Ellen, on the western side of Vivonne Bay, is reached on the road that leads past the jetty to an automatic navigation light. Here there is a sequence of limestones and metasandstones exposed in the low cliff of the point. The wide shore platform is formed in Cambrian metamorphosed sandstones and migmatites from melting, with extensive folded and fractured quartz and feldspar veins. There are small platy fragments of brown muscovite mica and dark green to black tourmaline crystals associated with the veins. Above this is the Point Ellen limestone (Pliocene, about 2 million years old), which contains abundant bivalve shell fragments of *Anodonta* species as well as rounded boulders of

the sandstone. This suggests that the Point Ellen limestone was formed in shallow water and subject to wave action eroding the sandstone. This limestone is capped by a thin and partly eroded red soil or *terra rossa*, suggesting a long period of stability above the reach of waves. A thick dune limestone of Pleistocene age (less than 2 million years old) covers the red soil and extends seawards to cover the metamorphic rocks in places, with the sea having eroded the Pliocene limestone to form a low cliff.

The point has a shallow cave in it, which today is within reach of storm waves. It appears to be a breached flank margin cave with several deeper cavities at the same level along a ledge. This implies that it formed at the junction of fresh water and sea water when sea level was higher. The most likely age is about 125,000 years ago – known as the Last Interglacial – when sea level was 3m higher and the climate was much warmer and wetter than today. Marine benches of this age and elevation are widespread on the south coast of Kangaroo Island.

View towards shore platform and cave from Point Ellen

Contact between Point Ellen limestone (below) and Bridgewater Formation dune limestone (above)

Contact between Cambrian metamorphic rocks (below) and Pliocene shelly limestone (above)

Breached flank margin cave with solution tubes

Aerial view of Point Ellen, from SA Government


Intensely folded and faulted Cambrian metamorphic rock on shore platform

Kelly Hill Caves

Kelly Hill Cave is a well decorated system just outside Flinders Chase National Park. Today the SA National Parks Service runs guided tours through the cave, which is well worth visiting. The cave has formed in the Bridgewater Formation dune limestone, which is of Pleistocene age (< 2 million years ago). During high sea levels coastal sand dunes formed and were cemented by the shelly material within the sand. The formation of the dune limestone impeded the central plateau's existing drainage and led to the development of a shallow lagoon along the contact with the limestone. Overflow from this drained into the dune limestone at three points. It is likely that a process of mixing corrosion was involved, with most cave development occurring at the interface of the swamp water and rainwater infiltrating down through the limestone. Both water types are acidified by soil carbon dioxide and humic acids from the plant roots, dissolving the dune limestone. This resulted in passages forming at the water table, enhanced by the porous nature of the limestone allowing water to move laterally and leading to the formation of wide, low chambers in a maze.

Over time the water table lowered, removing the support for the cave roof and some collapse occurred. This has been stable for a very long time as stalagmites thousands of years old have formed on top of the collapse blocks. Rainwater passing through the soil picks up carbon dioxide from plant roots and bacterial activity, dissolves the dune limestone and when it enters the cave as drips it precipitates calcite crystals. Over time these form stalactites and unusual formations called helictites, decorations that grow in random directions. As well is the beauty of the crystal formations, Kelly Hill Cave is a very important palaeontological site where fossils of extinct marsupials have been found dating to the Last Ice Age. A current project is also analysing stalagmites to reconstruct a long-term fire history for Kangaroo Island.

The Kelly Hill Cave is open daily for tours run by the SA National Parks and Wildlife Service. There are also walking tracks linking the carpark and the cave, as well as the walking track between Kelly Hill and Hanson Bay. There are numerous sea caves which can be explored at low tide at Vivonne Bay, Hanson Bay and West Bay.

Straw stalactites and stalagmites growing on flowstone surfaces in Kelly Hill Cave

Pristine white formations in Kelly Hill Cave, including helictites

Remarkable Rocks

These spectacular granite rocks have unusual weathering shapes reminiscent of the sculptures of Henry Moore. The rock itself is about 440 million years old (Cambrian), and is one of a series of granite outcrops along the south coast that include Cape Willoughby. Granite is a coarse-grained intrusive rock which rises from great depth as a molten mass through weaknesses in the Earth's crust. It is made up of blue-white quartz, pink feldspar and black or brown micas in roughly equal proportions. The granite here also includes fragments of the older Cambrian sandstone through which it was thrust up.

Once the granite is near to the surface, pressure release in the rock occurs due to removal of overlying rock and soil, or expansion of water in fissures and crevices as steam after summer thunderstorms. This results in the formation of joints or crevices parallel to the ground surface or penetrating deep into the rock mass. Platy fragments of granite also spall off the rock surfaces. More resistant parts of the granite remain intact as *corestones*. The entry of water into the joints facilitates chemical weathering in which some parts of the rock dissolve. This occurs when dilute carbonic acid and other acids, present in rain and soil water, alter the feldspar in a process called hydrolysis. The feldspar crystals weather to form clays and silica in solution, which are removed by running water. The crystals that do not weather, mostly the quartz, forms a coarse sand called *grus*. The vertical runnels down the sides of the boulders are due to this solution process, while the unusual pockets and cavities, called *tafoni*, reflect chemical weathering under the soil.

Remarkable Rocks before the 2020 bushfires

Cavernous weathering or tafoni on a granite corestone

Sub-soil weathering pockets and cavities on granite corestones

Vertical solution runnels on a granite boulder

Admirals Arch, Cape de Couedic

Below the lighthouse is a famous cave known as Admirals Arch. Here on the point, sloping Cambrian sandstone shore platforms are overlain by Pleistocene (less than 2 million years old) dune limestone of the Bridgewater Formation. To the east in Weirs Cove the steep limestone cliffs contain a number of breached flank margin caves at levels up to 35m altitude, suggesting recent uplift.

The Arch is not solely due to wave action. Initially a flank margin cave formed when sea level was higher, possibly around 125,000 years ago. At that time with sea level 3m higher, solution of the limestone occurred at the interface between fresh and salt water. There are solution pockets in the north wall of the arch which would have formed below the water table, and the original floor of the Arch is preserved as a level bench of dune limestone on the north side as well. That floor has been mostly stripped away by modern wave action ramping up the sloping sandstone platforms. Thus Admirals Arch appears to be a breached flank margin cave, which has been modified by wave action during higher sea levels. There are abundant stalactites which probably formed while the cave was still sealed and thus protected from wave action.

Other flank margin caves are visible on the nearer of the two Casuarina Islets (The Brothers) facing Admirals Arch. Remnant stalactites and stalagmites can be seen as well, suggesting these caves were sealed in the past prior to breaching by wave action.

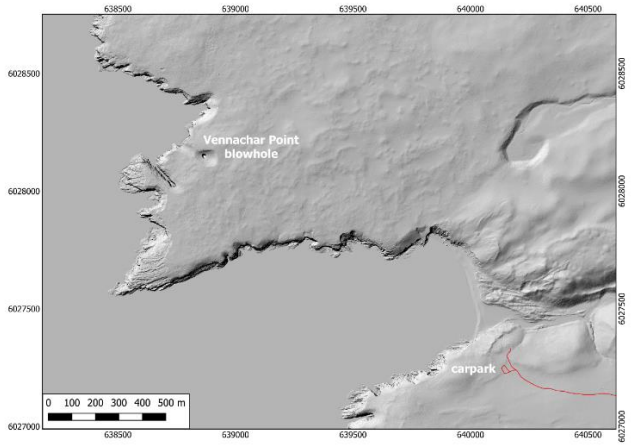
Admirals Arch from Weir Cove, with the Casuarina Islets in background

Pleistocene dune limestone lies above Cambrian sandstone slabs. Pale band of limestone on right side marks original floor of the cave.

Vennachar Point and West Bay

At the extreme western end of the island, West Bay is a deep harbour regularly used by yachts. To the north of the bay is Vennachar Point, the site of the 1905 wreck of the *Loch Vennachar* wool clipper. Wreckage from this ship was spread along the southwest and south coasts of the island; there were no survivors. In the days of sail ships frequently came to grief on this cliffed coast, fully exposed to westerly winds and the Southern Ocean waves. To the north of the point are deep gulches or *geos* cut into the Cambrian sandstone, and capped with Pleistocene dune limestone. The massive sandstone dips gently to the northwest and forms tall cliffs and shore platforms.

Walk north along the beach and follow a rough track up onto the cliff top, then head west along the coast for 1.5 km to Vennachar Point itself. From here head north along the cliff tops for another 500m. There are several deep geos to circumvent, then you reach a deep trench with the surf booming hypnotically below. A little further on you will reach a wide bare limestone pavement with a deep shaft in the middle. This is the Vennachar Point blowhole, which has been descended for 30m and links to the sea by a narrow cleft with a boulder beach. Be sure to stay well back from the edge of the shaft.



Location of Vennachar Point Blowhole, West Bay. LIDAR data from SA Government

Aerial image of geos and blowhole north of Vennachar Point. Image sourced from Location SA viewer http://location.sa.gov.au/viewer/

Large geo at lower edge of aerial image

Blowhole shaft 30m deep connects to the sea through a cleft with surf audible

Baudin's Cave, Ravine des Casoars

The 7km return walk begins on the Ravine des Casoars Road, 7 km south of the Playford Highway, near Cape Borda Lighthouse. The Ravine was first named by the French explorer Nicholas Baudin in 1802, who thought the now extinct dwarf emus there were cassowaries. From the carpark, the track descends from the laterite plateau through outcrops of the Cambrian (500 million year old) sandstone which forms the basement of the island. After a creek crossing the track passes below a cliff formed in the Pleistocene (2 million year old) dune limestone. Dune limestone forms when a beach dune stabilises under native vegetation and the shelly fragments in the sand dissolve in rainwater, then form a cement which binds the grains together. The cliffs here have several large flank margin caves. These shallow maze caves form at or near sea level where the limestone dissolves at the interface of fresh water and salt water. There are two caves, so bring a torch each with you! The seaward cave has two entrances linked by a flat sandy floor which is awash at high tide. At low tide a short daylight passage leads around the headland to a nice pocket beach. It was also home to a group of shipwrecked French sailors in 1815, who left an engraving on a flat rock within the dark zone. The landward cave has a well decorated entrance zone and a steep rockfall and a small chamber at the rear. There are several other big rocks and flank margin caves in the north wall of the valley near this cave. Their shade makes for a cool lunch spot!

View from the seaward cave entrance

Flank margin cave upstream of caves

Entrance chamber and inner collapse dome

Solution slot due to mixing corrosion at interface between fresh and salt water

Harvey's Return

The walking track begins at the Harvey's Return campground, about 4km east of Cape Borda lighthouse. The track descends gradually to the old winch site, where a horse drawn capstan brought supplies up from the cove below for the lighthouse keepers. Beyond this point the track descends very steeply down to the cove. At the cove there are spectacular outcrops of "zebra rock", intensely folded and faulted layers of Cambrian sandstone (pale cream) and quartz-biotite schist (black), a metamorphic rock. This part of Kangaroo Island has been folded and faulted at least four times, with the rocks generally dipping to the south. The zebra rock reflects the original layering of the sedimentary rock as it was laid down in a deep oceanic trench, with ripples and small troughs.

A sealing gang under Joseph Murrell was based at Murrell's Landing (Harvey's Return) from 1806 to 1808; they arrived back in Port Jackson on 16 April 1808 aboard the colonial vessel *Eliza* with 500 seal skins and about 1,000 kangaroo skins. During their stay on the island, they had subsisted entirely on wild animals, as their supplies had been exhausted after three months. Murrell was also familiar with the large freshwater lagoon known to sealers and early settlers as Murrell's Lagoon, now known as Murray's Lagoon Conservation Park.

Intensely folded zebra rock and the cove at Harvey's Return

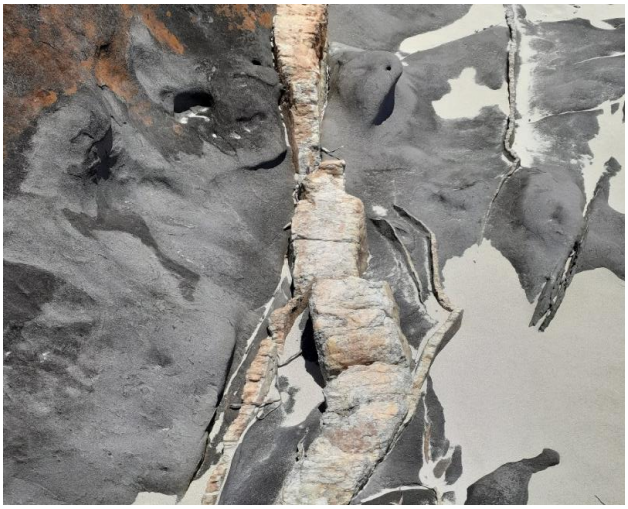
Western River Cove sea caves

Western River Cove lies on the north coast to the west of Snelling's Beach. Here the Snelling Fault reaches the coast creating a shear zone, with curved and contorted rock strata. Fine-grained metamorphic rocks (containing small beads of golden muscovite mica) are visible in contact with underlying Cambrian sandstones. There are several sea caves of geological interest. The caves have either formed at the contact between metamorphic rocks and sandstones, or are formed along the near-vertical jointing in the metamorphics. Some of the caves have narrow passages extending into the hillside, with penguin tracks and a strong fishy smell.

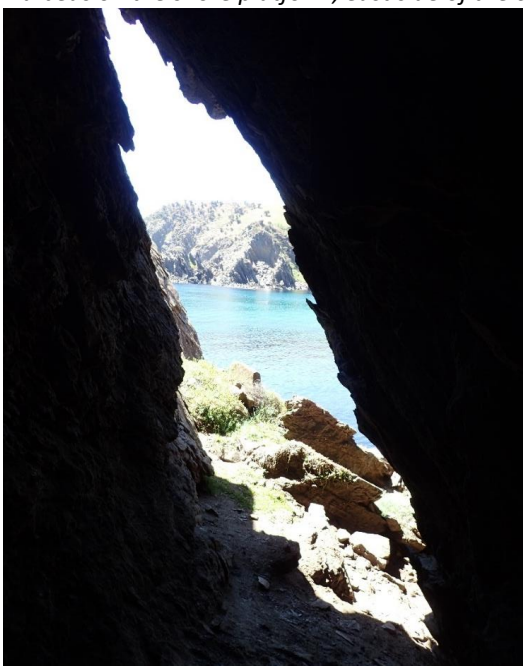
The sandstones also have interesting bedding known as a Bouma sequence, where thick fine-grained beds alternate with thinner coarser sandy beds. These can be seen on shore platforms on either side of the cove. The fine sediments were deposited by persistent turbidity currents in deep water on the continental slope, while big rivers also brought coarser sands in seasonal floods. At that time, about 500 million years ago, the sea floor would have been home to trilobites. Trilobites were among the most successful of all early animals, existing in oceans for almost 270 million years. Their closest living relatives are the horseshoe crabs found in southeast Asia, scorpions and spiders.

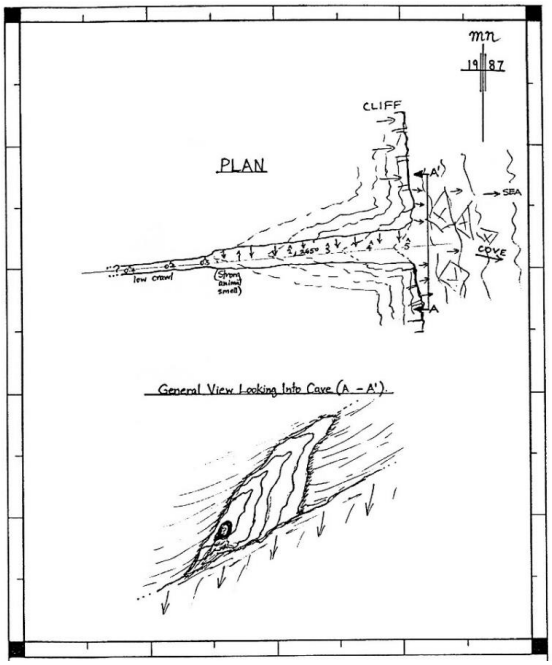
Looking west to sea caves in Western River Bay, on contact of metamorphics and Cambrian sandstones

Bouma beds on the shore platform, east side of the cove



Bands of quartz in folded and faulted sandstone



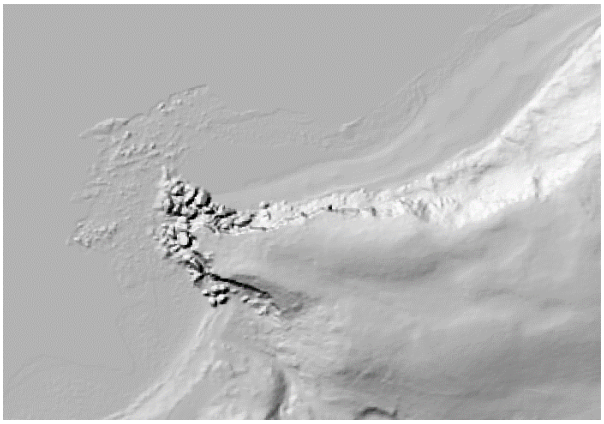


Entrance of cave K61 developed along jointing in metamorphics. Map courtesy of Kevin Mott and CEGSA.

Stokes Bay

A popular tourist destination on the North Coast of KI, Stokes Bay has been voted one of the most beautiful of Australia's beaches. From the car park a path leads through narrow crevices which form a cave and emerges onto a beautiful sandy beach with a naturally enclosed wading pool. The crevices separate large collapsed blocks of Bridgewater Formation dune limestone. It is overlies the Cambrian metasandstone which is the basement rock over most of Kangaroo Island.

Google satellite image of Stokes Bay



LIDAR hillshade image of the same area.
Source: SA Government

Large collapse blocks of dune limestone and old sea caves

Enjoying the beach at Stokes Bay

If you walk along the beach to the north you will cross steeply dipping ribs of the metasandstone with narrow tidal channels between them. On the cliff at the rear of the beach several small faults cross the steeply dipping dune limestone. These are probably associated with one limb of the Cygnet-Snelling fault that runs across the island from east to west. At the crevices the dune limestone has been weakened by the faulting and undercut by wave action, with the orientation of the large blocks consistent with the strike of the underlying metasandstone. There is a horizon of solution cavities in the main limestone cliff which may relate to a higher sealevel during an interglacial period, some 125,000 years ago. The surfaces of the limestone blocks show many small solution holes due to the enhanced dissolving of the limestone in sea water.

Boxing Bay

This lies on the western side of Point Marsden and is reached by following North Cape Road. The road first follows the

shore of the Bay of Shoals, and then turns west to cross the peninsula. Half way along, Turner Drive to the right leads to a good viewpoint over the Bay of Shoals and Kingscote. The last kilometre of the road is a bit rough, so slow down and you will reach a vehicle turnaround point. From here follow the shore to the north to a rocky headland. The first few hundred metres is a boulder beach, mostly composed of Cambrian sandstone but careful inspection will reveal some large rounded boulders of granite. These were transported by glacial ice during the Permian, some 285 million years ago, when most of Australia was covered by ice as Antarctica is today. The glaciers carved deep channels heading north-west, and as well as the granite boulders also transported clays and pebbles. These can be seen as a band at the back of the beach and also underlie the extensive plain around Cygnet River. At the northern end of the beach the rocks are of the Cambrian Boxing Bay formation, pink and grey sandstones and conglomerates, and contain small trilobite fossils at Bald Rock. Further on Big Gully is a protected geological site.

Boulder beach at Boxing Bay, looking towards Bald Rock

Polished granite boulder transported by glacial ice in the Permian

Salt Lakes near Emu Bay

Two salt lakes lie quite close to the north coast road near the Emu Bay turnoff. Salt was and still is a very important commodity for people, and salt was one of Kangaroo Island's first exports in the early nineteenth century. Before refrigeration salt was used to preserve meat and vegetables, and cure skins used for boots and hats. Salt was dug from these lakes, bagged and carried to ships anchored in the nearby Bay of Shoals. In 1814 the sloop *Fly* arrived in Port Dalrymple, Tasmania with a cargo of seal and kangaroo skins, and salt from these lakes on Kangaroo Island. In the early twentieth century they were investigated for gypsum mining, used in plasterboard, but the reserves were not large enough to make it viable. One lake is a dazzling white and the other is a hot pink. Both are highly saline, up to ten times saltier than seawater. It is safe to wade in pink lakes, but not to drink it owing to the effects of hypersalinity on the human body, and the possibility of harmful micro-organisms. After heavy rain the dilution of the salt changes the colour to a dark green.

Pink lakes owe their colour to two different groups of micro-organisms. *Dunaliella salina* is a green alga that can tolerate salinity up to 35% (seawater is about 3%). Under high salinity, temperature and light, *Dunaliella* produces a red carotenoid pigment (same colour as carrots) which acts as a natural sunscreen coating the algal cells. Another micro-organism thought to produce the pink colour is *Halobacterium salinarum*, one of the primitive archaean bacteria. Halobacteria are single-celled, rod-shaped micro-organisms that are among the most ancient forms of life and first appeared on Earth billions of years ago.

Salt lakes near Emu Bay.
From https://www.placesandfoods.com/2013/08/salt-lakes-in-kangaroo-island-pictures.html

Harvesting salt from the salt lake in the 1950s.
From Bauer, F. H. (1959) Regional geography of Kangaroo Island, unpubl. PhD thesis, ANU.

Kingscote Foreshore walk

A pleasant walk along the foreshore between Reeves Point and the Ozone Hotel reveals a quite varied geology. At the Old Government Quarry, columns of basalt overly a gravelly sand. A lava flow from the west reached here in the Jurassic period (150 million years ago) and flowed down a river valley which started under the Wisanger Hills, whose flat tops reflect the top of the basalt flow. In the 1840s basalt was quarried here, shipped to Adelaide and used to surface the road between the growing town and Port Adelaide, which passed through swampy ground.

Further south along the shore is a *diamicton* or debris flow deposit which is of Permian age (280 million years ago) and is composed of pebbly mudstones and a very gritty sand derived from glacial activity. Near the jetty this deposit is overlain by thin beds of Eocene (40 million years ago) limestone which forms low coastal cliffs extending to the south of the town near the yacht club and swimming pool. The limestone is full of fossils such as mollusc shells and echinoderms such as feather stars, brittle stars, sea urchins and sea cucumbers.

Basalt columns at the Old Government Quarry, Kingscote. Photo from Belperio (1995).

Beyeria Conservation Park

This small Conservation Park with mallee eucalypt vegetation provides a good example of the landscape of the central plateau of Kangaroo Island prior to vegetation clearance. Reached on Wilson Road, a loop walking track can be followed for half an hour and has signs identifying the native plant species present.

The central plateau of the island is mantled with a deeply weathered lateritic soil profile which probably developed in a warmer and wetter climate during the Pliocene (2 to 5 million years ago). The deep soil profile developed on the Cambrian metasandstones that form the basement for the island. A typical lateritic profile has an organic surface soil developed under native vegetation, quite often sandy in profile. Below this, at the upper limit of seasonal water table variations, is a layer of pea-sized iron oxide pebbles. These concretions build up with concentric layers over time as they are wetted and dried. Below this is a mottled soil zone with red and orange oxidised clays and bleached reduced patches. This marks the range of water table fluctuations and below this is a pallid zone of bleached heavy clays. In most cases the organic surface soil has been lost by erosion, leading the ironstone gravels as a surface layer. This kind of surface can be seen throughout the Beyeria Conservation Park and over most of the central plateau of the island. Many roads are surfaced with this material which can act like ball bearings. Slow down!

The term *laterite*, which is Latin for a brick, was first used in India in the early 19th century by Francis Buchanan, a Scottish geologist. He noticed that local people mined the pallid zone of lateritic soils to make house bricks, which then oxidised and hardened in the sun. Some of the Moghul palaces in India, built in the 16th century from these bricks, are still standing. Similar bricks were also used around 1000CE to build the temples of Angkor Wat in Cambodia.

Yacca (grass tree or Xanthorrhoea) and narrow-leaved mallee eucalypts at Beyeria CP

Surface of ironstone pebbles and pea gravel, with a rather large weevil

Redbanks cliffs, Nepean Bay

These spectacular coastal cliffs are reached either from the eastern end of Min Oil Road off Hog Bay Road, or from a carpark at the end of Flea Castle Road, off Redbanks Road. They are best explored at low tide. The red cliffs are 20 to 30 m high and have formed in Pleistocene alluvium. There is a prominent shore platform, low-energy beaches and sand flats. The alluvium is a deeply weathered laterite enriched in nodular iron and aluminium oxides, which in turn overlies a mottled and pallid sandy clay due to water table fluctuations in the past. Deep gullies have been cut in the alluvium and in places form solution pipes exposed in the cliffs. The cliffs are undercut by wave action forming shallow caves. Iron minerals in the alluvium show that the Earth's magnetic polarity was reversed when they were laid down, making them more than 780,000 years old. Elsewhere in South Australia similar alluvium contains fossil remains of *Diprotodon*, the giant wombat, and giant kangaroos such as *Procoptodon* and *Sthenurus*. Fossils of these animals have been excavated at Black Swamp in Flinders Chase.

Redbank cliffs of red lateritic alluvium with solution pipes and shore platforms

Wave cut cave showing mottling in the alluvium due to water table fluctuations

History of Earth Science on Kangaroo Island

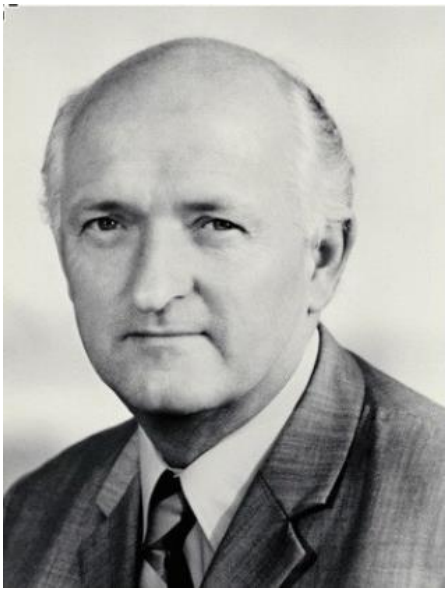
In 1802 and 1803 the Baudin expedition mapped the coasts of Kangaroo Island for the first time. Captain Nicholas Baudin led a team of twenty natural scientists whose work provided the first descriptions of many terrestrial and marine species.

Amongst the scientific staff of the expedition were the geologists Louis Depuch and Joseph Bailly. Their work provided the first detailed descriptions of the major rock types on Kangaroo Island and along the margins of the Australian continent. They concluded that Australia was built on a foundation of granite, overlain by a variety of sedimentary rocks and fringed by extensive sand dunes of recent origin. Although Baudin did not survive to see the publication of the scientific work of the expedition, this was completed in 1807 by François Peron and a second edition in 1816 by Peron and Louis Freycinet. At the time most geologists believed that crystalline rocks, including basalt, had been precipitated from solution in a sea covering the entire globe. This was known as the Neptunian view of the origin of the Earth. They recognised four types of rocks: terrains of precipitation including granite; sedimentary terrains unquestionably of marine origin; terrains of transport formed from alluvium derived from the first two categories; and volcanic terrains composed of material ejected from deep within the Earth. Evolutionary theory had not yet emerged and most people conformed to a view of creation in which the age of the Earth was less than 6000 years old and that the flood of Noah had covered the planet. Archbishop Ussher of England calculated the age of the Earth, using genealogies from the Bible, and concluded the Earth was created in 4004 BC, at 10:30am on the 23rd of October.

Following the establishment of the South Australian colony in 1836, the task of investigating the geology of the new colony was given to Johannes Menge, an idiosyncratic German who was employed as the “mine and quarry agent and geologist”. He was required to explore the natural productions of the colony above and below ground, the working of quarries, boring for water and the availability of useful minerals. He was primarily a mineral collector with considerable experience and followed the Neptunian doctrine. However he took an inherently mystical approach to science under the influence of the Nature Philosophers, a German Romantic movement of which Goethe himself was a leader. Mr Menge was clearly not fitted to be a company employee and was soon dismissed from service. Afterwards he commenced years of solitary wandering in the bush of Kangaroo Island and the Mount Lofty ranges, acting as a freelance mineralogist. He certainly built a reputation by alerting the colonists to the mineral potential of those areas.

In 1882 Henry Y L Brown was appointed as South Australia's first government geologist and commenced a dynamic phase of geological exploration. Brown toured widely in the State, mostly on horseback or by camel. He was soon able to produce an advanced geological map of about 80% of the State and defined the geology of the Adelaide geosyncline from Kangaroo Island to the northern Flinders Ranges. He was also involved in the investigation of salt and gypsum deposits on Kangaroo Island. Following him R Lockhart Jack became assistant government geologist from 1912 to 1931. He also investigated the Cambrian rocks and was the first to recognise the Permian glaciation of South Australia. In the late 1870s Reverend Walter Howchin emigrated to Adelaide, to improve his health in a dry climate. In Britain he had suffered from tuberculosis, but in SA he recovered and in 1901 he was offered the Lectureship in Geology at Adelaide University. In 1918 he published the textbook “The Geology of South Australia” which was the most advanced work of its day.

Dr R C Sprigg, known as Reg, trained as a geologist in Adelaide and was greatly influenced by close contact with outstanding geologists Sir Douglas Mawson and Dr Cecil Madigan. He joined the South Australian Geological Survey in 1944 and until 1954 he led geological surveys over large areas of the State, including Kangaroo Island. In 1954 he established the consulting group Geosurveys of Australia, mainly involved in oil and gas exploration.



There was extensive seismic exploration and some drilling on Kangaroo Island, hence the name Min Oil Road near Nepean Bay. Dr Sprigg's main contributions lay in three areas of geology: the Ediacaran formation in the Flinders Ranges, with some of the earliest jellyfish fossils on earth; the evolution of beach ridges in south-eastern South Australia, and the extensive Cambrian sandstones that make up the Kanmantoo Group in the Adelaide geosyncline

Dr Tony Belperio has been very active in the mapping of the geology of Kangaroo Island and has produced several comprehensive publications, which are listed in Further Reading. In particular he has defined the geological evolution of the southern margin of the Gawler Craton and the complex sequence of Cambrian sedimentary rocks on Kangaroo Island and the adjacent mainland. He has 35 years' experience in a variety of geological disciplines, including marine geology, environmental geology and mineral exploration including copper-gold exploration. In 2010 he was awarded the Bruce Webb medal by the South Australian branch of the Geological Society of Australia for his contributions to the earth sciences.

Further Reading

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Online resources

Brochure 2007 Guide to geology of Kangaroo Island

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