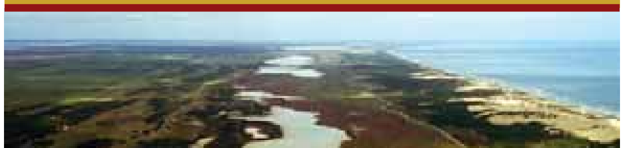
COORONG
Geological trail

A self-drive geological trail



Government of South Australia
Primary Industries and Resources SA

Introduction

This field guide illustrates the effects of ice ages, global warming and sea-level changes in the Coorong region of southeastern South Australia. From about 30 000 to 18 000 years ago global climate favoured expansion and maintenance of glaciers. Ice sheets covered much of North America and Europe, the Antarctic ice sheet was at its maximum thickness and extent, while glaciers formed in Tasmania and on the southern highlands of eastern Australia (Barrows et al., 2002 and references therein). The most extreme parts of this climatic event and the time of its occurrence are commonly referred to as 'The Last Glacial Maximum' (Fig. 1) which spanned the period 23 000 to 19 000 years ago (Yokoyama et al., 2001). With so much of Earth's water frozen in place on the continents, sea-levels were 120–130 m lower than they are today (e.g. Ferland et al., 1995; Murray-Wallace, 2007). The local shoreline was south of what is now Kangaroo Island, at the outer edge of the continental shelf (Fig. 2). Backstairs Passage became a seaway, isolating Kangaroo Island only about 10 000 years ago.

With the passing of the Last Glacial Maximum and transition to global warming, the ice sheets and glaciers began to melt and sea-levels rose, transgressing over the formerly exposed parts of the continental shelf and flooding into Gulf St Vincent and adjacent Spencer Gulf. This event is known as the 'Postglacial Marine

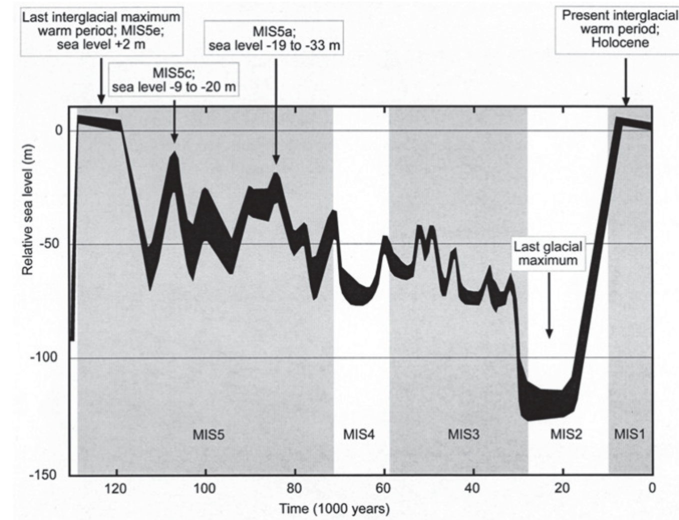


Figure 1 *Sea level curve for the past 130,000 years, in relation to Marine Isotope Stages 1 to 5, derived from observations of flights of coral terraces on the uplifting Huon Peninsula, Papua New Guinea; adapted from Lambeck & Chappell (2001). The thickness of the line of the curve is an expression of the degree of uncertainty of the calculated sea-levels. Numbers 1 to 5 refer to episodes of time (stages) defined by marine oxygen isotopes. The Last Glacial Maximum, when sea level was about 120 m lower than at present, is shown within Stage 2. The Last Interglacial warm period (within Stage 5) occurred about 130 000 to 120 000 years ago, when sea level was about 2 m higher than at present. The present interglacial warm period (Stage 1) has existed for little more than the past 10 000 years. The rapid rise in sea level during the transition from Stage 2 to Stage 1 is known as the Postglacial Marine Transgression. The last 10 000 years (approximately) constitutes the Holocene Epoch.*

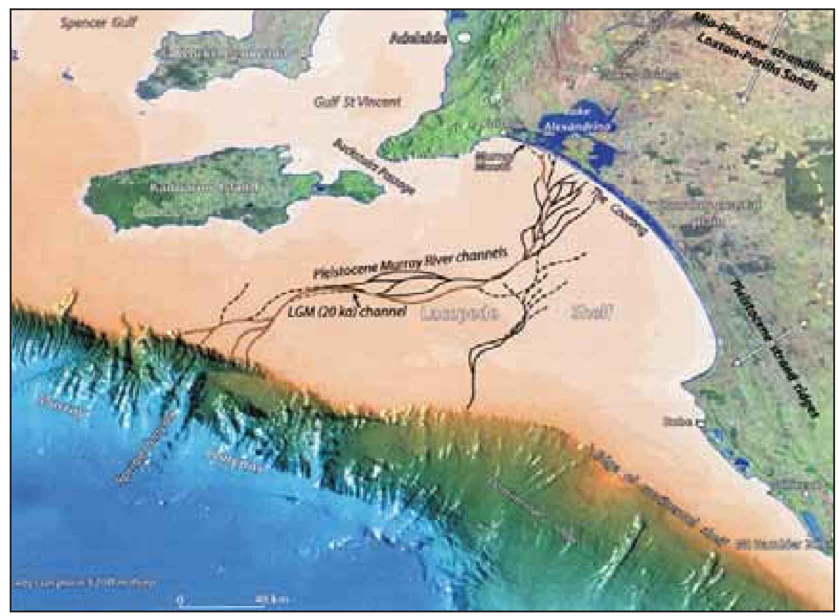


Figure 2 *Three dimensional, oblique view, looking north, over the Lacepede Shelf region and River Murray palaeochannels; Last Glacial Maximum (LGM) channel in brown. The wide continental shelf (light brown/fawn colour) dips very gently seaward to a depth of about 200 m at the shelf edge, beyond which the continental slope, deeply incised by canyons, descends steeply to a flat abyssal plain at 5200 m. During major glaciations in the Pleistocene, the Lacepede Shelf was an expansive coastal plain across which the palaeo-River Murray flowed initially southward, then roughly west-southwest and into the head of Sprigg Canyon (Hill et al., 2009). Centre of plan approximately -36.39°, 138.38°.*

Transgression'. There is every reason to suppose that these conditions were witnessed by local populations of coastal-dwelling humans, who retreated landwards as sea-levels rose. Earliest evidence of a human presence on South Australian coasts is dated at about 8000 years ago (e.g. near Robe; Cann et al., 1991), the rising sea having covered any older artifacts or midden materials. Sea-level rise due to deglaciation culminated about 7000 years ago. Subsequent changes in relative sea-level have been minor and are due, at least in part, to physical adjustment of the continental margins to the loading of additional water following deglaciation (Binnie and Cann, 2008 and references therein).

Table 1 *Estimated sea-levels in southern Australia from 125 000 years ago to present; after Belperio (1995). *MIS refers to the Marine (oxygen) Isotope Stages (Fig. 1). MIS 5 includes three warmer times of higher sea-level, 5a, 5c and 5e; sub-stages 5b and 5d were cooler and sea-levels were lower; MIS 5e is known as the time of the Last Interglacial.*

MIS 5e*	125 000 yr BP	+2 m
MIS 5c	100 000 yr BP	-8 m
MIS 5a	80 000 yr BP	-14 m
MIS 2	20–30 000 yr BP (Last Glacial Maximum 23 000 to 19 000 yr BP)	-120 to -130 m
MIS 1	present sea level from ca. 7000 yr BP (Subsequently little change; sea levels thought to have fallen during the past 2000 years; relative sea levels have both risen and fallen in many coastal localities)	

The Younghusband Peninsula

Younghusband Peninsula (Figs 3, 4) is a Holocene beach-dune-barrier complex which originated as the rising postglacial sea transported sandy sediment shoreward from the exposed Lacepede Shelf. It stabilised at the culmination of the postglacial marine transgression, at the same time isolating a narrow back-barrier lagoon (The Coorong) from the direct impact of the Southern Ocean. The peninsula extends from the mouth of the River Murray some 180 km towards the southeastern town of Kingston. Transgressive dune systems are characterized by unvegetated active dune sheets, large-scale parabolic and transgressive dunes up to ~40 m in altitude, and deflation hollows (coastal blow-out dunes) that extend down to sea level. However, large parts of the dune complex are now fixed by vegetation, principally species of *Acacia* (coastal wattle), *Leptospermum* (tea tree) and *Melaleuca* (paper bark).

Figure 3 *Oblique aerial view of the Younghusband Peninsula, looking towards the southeast, showing both vegetated and unvegetated transgressive sand dunes. The Coorong Lagoon is a back-barrier lagoon isolated from the direct influence of the Southern Ocean. Centre of image approximately -35.62°, 139.03°.*

The Coorong

The Coorong (Figs 3, 4) is the name given to a back-barrier lagoon that is confined by the Younghusband Peninsula on the seaward side, and on the landward side by the Last Interglacial (MIS 5e; Fig. 1; Table 1) shoreline of 125 000 years ago. The lagoon is narrow (<4 km wide), shallow (<4 m deep) and ~150 km long, and consists of a number of interconnected basins that become increasingly restricted, hypersaline and ephemeral towards the southeastern end. Lagoon waters are derived from the Southern Ocean (seawater) via the mouth of the River Murray, from the River Murray (freshwater), runoff from Salt Creek and from seasonal rainwater and from unconfined groundwater. Salinity and water levels in the lagoon are subject to the alternating dominance of winter rainfall and summer evaporation, and climatic influences (e.g. prolonged drought in the Murray-Darling catchment). Studies of cored sediments recovered from the lagoon indicate that, following European settlement, water circulation became increasingly restricted as sedimentation progressed and hypersaline conditions subsequently developed in the southeastern parts. In the latter part of last century, to the south of The Coorong, a network of channels was constructed to drain swamp waters directly into the Southern Ocean. Overflowing surface swamp water, a consequence of heavy winter rainfall, no longer flows into the lagoon, and thus may have contributed to increasing salinity. Lagoon sediments are mostly derived from shelly organisms. Of the molluscs, the small cockle *Spisula (Notospisula) trigonella*, and an even smaller snail, *Coxiella striata*, are particularly evident. At a microscopic scale there are distinctive species of foraminifera and ostracods.

Figure 4 *Google Earth image showing the spatial relations of the Southern Ocean, the unvegetated sand dunes of the Younghusband Peninsula and the Coorong Lagoon. Note that the ocean waves are parallel with the beach, effectively precluding longshore transport of sand and signifying that the coast and coastal processes are in a state of equilibrium. Centre of image approximately -35.66°, 139.09°.*

Lakes Alexandrina and Albert

The River Murray flows directly into Lake Alexandrina which, in turn, is connected to Lake Albert (Fig. 5). These lakes are essentially bodies of freshwater, now effectively isolated from marine influence by barrages that were

Figure 5 *Google Earth image showing the spatial relations of Lakes Alexandrina and Albert, the inflowing River Murray and Murray Mouth, and the Coorong Lagoon. Blind Creek marks the site of a former embayment in Lake Alexandrina when water levels were higher than they have been in historic time. Centre of image approximately -35.50°, 139.19°.*

constructed between 1935 and 1940 along the Last Interglacial shoreline and in the Goolwa Channel. Water levels and water quality in the lakes depend largely on the inflow from the River Murray. A consequence of prolonged drought conditions in the Murray-Darling catchment, and excessive exploitation of river water by irrigators, has been lower levels of water in the lakes, increased salinity of lake water and exposure of pyritic sediments that oxidized to form acid sulfate soils with a low pH.

The Field Trip

This field guide to the Coorong Lagoon and related water bodies assumes a self-drive use of a motor vehicle, commencing at the town of Goolwa and proceeding to Salt Creek via the ferry at Wellington and the town of Meningie on the shore of Lake Albert.

1 Goolwa and surrounding area (Fig. 6)

The town of Goolwa is situated on the lower estuary of the River Murray. It is a town of historic interest in terms of its former place in the river boat trade. It may be convenient to stay overnight in this town, commencing the field trip from here the following morning.

Things to do and see:

- drive to the Goolwa barrage, between Sir Richard Peninsula and Hindmarsh Island;
- drive across the bridge from Goolwa to Hindmarsh Island; a lookout on the southern side of the island allows a view of the Murray Mouth;
- visit the Murray Mouth; there are commercially operating cruises taking passengers from Goolwa to the Murray Mouth and upper Coorong; access may be restricted at times of low water levels.

On leaving Goolwa, follow road signs towards Wellington.

2 Ferry at Wellington (Fig. 7)

Wellington is a small township adjacent to the River Murray. There is no bridge; transport across the river is by vehicular ferry; there is no charge for this service.

On leaving Wellington, drive 2 km to an intersection with the Princes Highway; turn right towards Meningie and drive 11.5 km to Stop #3, Blind Creek.

3 Blind Creek (Figs 5, 8)

Blind Creek (roadside sign post) is an area of low relief that marks the site of a former embayment of Lake Alexandrina, when sea-levels were ~2 m higher than they are known to have been in historic times. There are several possible explanations that can be considered here (Cann et al., 2000b and references therein).

- In mid Holocene times it is established that the climate in southeastern Australia was appreciably wetter than that of today; e.g. volcanic crater lakes in Victoria that are today saline and at a low water level, were filled to overflowing with fresh water. Thus inflow of fresh water from the River Murray would have been greater and consequently the water level in Lake Alexandrina would have been higher.
- There is some evidence to support the notion that mid Holocene sea-levels were ~2 m higher than those of today. If that were the case, water levels in the estuary of the River Murray and the adjacent lakes would have conformed to that higher sea-level.
- Following the Postglacial Marine Transgression, the extra weight of water on the continental shelf caused the area of the Lacepede Shelf to subside slightly, and this generated a compensatory uplift inland. The significance of this process, known as hydroisostasy, has not been thoroughly investigated for this area, but at Port Augusta, at the head of Spencer Gulf, an uplift of 4.5 m has been attributed to the same cause (Belperio, 1995; Cann et al., 2000b)

Continue on the Princes Highway towards Meningie; drive a further 17.5 km to Stop #4; at the top of the hill, safe parking is available on the gravel road to the left:

4 Lookout over nested saline lakes (Fig. 9)

This cluster of saline lakes and related features mark the site of a former embayment of Lake Albert, equivalent

Figure 6 Google Earth image showing the Goolwa Channel at the southern end of Lake Alexandrina, extending in a loop around the town of Goolwa to the mouth of the River Murray. The Goolwa barrage separates the freshwater, downstream flow of the river from incoming seawater via the Murray Mouth. Centre of image approximately -35.53°, 138.83°.

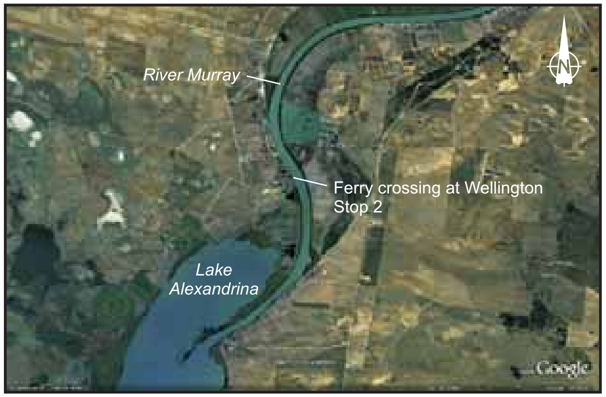


Figure 7 Google Earth image showing the location of the ferry crossing at Wellington, Stop 2. Centre of image approximately -35.33°, 139.38°.

Figure 8 Google Earth image of Blind Creek, a feature which marks the site of a former embayment of Lake Alexandrina when water levels with the lake were higher. Centre of image approximately -35.38°, 139.49°.

Figure 9 *Google Earth image showing nested saline lakes in a former embayment of Lake Albert; the white lake beds indicate dry conditions; coloured lakes signify the presence of the alga* Dunaliella salina. *Centre of image approximately -35.38°, 139.37°.*

to the site of Blind Creek for Lake Alexandrina. From the lookout, in summer time, many of the lakes appear pink in colour due to the presence of algae known as *Dunalliela salina*. At the bottom of the hill the road crosses the floor of one of these lakes where there is a small car park. From here it is possible to directly view the crystalline mineral salt which has resulted from evaporation of saline groundwater.

Continue on the Princes Highway; drive a further 13 km to Meningie.

5 Meningie

The township of Meningie is situated on the shore of Lake Albert. In the main street there is a lakeside park where there are grassed areas and toilets. Take away food can be purchased from shops opposite.

When inflowing water from the River Murray has been plentiful, water levels in Lake Albert have been consistently high, as indicated by the short jetties extending from the shore. However, in recent times of drought within the Murray-Darling catchment, inflow of freshwater into the shallow lake has not been sufficient to keep pace with evaporation, and the jetties have been left high and dry by the retreating shoreline. The remaining waters became increasingly saline and evaporation exposed acid sulfate lake sediments.

On departing Meningie, leave the Princes Highway towards the end of the main street; turn right into Narrung Road, which follows the Lake Albert shoreline; after 8 km turn left into the unsealed Seven Mile Road. After 2 km this road passes a National Park Centre where a range of maps and pamphlets are available for purchase. A further 2 km along is a signposted lookout over The Coorong.

6 Lookout over the Coorong Lagoon (Fig. 10)

The elevated lookout provides excellent views of the lagoon. The site is part of the Last Interglacial shoreface, formed 125 000 years ago (MIS 5e) when sea-levels were about 2 m higher in southern Australia than those of today. Abraded, large scale, beach face sedimentary structures, which can be viewed from the lookout, indicate that the environment was probably very similar to that existing on the modern shoreface of Younghusband Peninsula, i.e. a beach facing the Southern Ocean with associated transgressive sand dunes. The elevated sandy sediments have been heavily cemented in places by calcium carbonate, forming a material known as calcrete (also caliche and kunkar). Calcrete typically forms in areas which experience alternating wet winters and dry evaporative summers, leading to pronounced changes in sediments containing calcium carbonate; repeated solution and precipitation cements the sediment into consolidated rock.

On leaving the lookout, continue southwards along Seven Mile Road to rejoin the Princes Highway, which follows the elevated Last Interglacial shoreline. Drive for 23 km to Stop 7 (Fig. 11).

Figure 10 *Google Earth image of an area southeast of Meningie, showing the landward shore of the Coorong Lagoon. Centre of image approximately -35.75°, 139.26°.*

Figure 11 *Google Earth image showing the spatial relations of the Last Interglacial shoreline (MIS 5e), known as the Bonney Coastline, which is the landward margin of the Coorong Lagoon, and the modern Younghusband Peninsula on the seaward side. The spatial placement of the linear islands in the centre of the lagoon is in accord with their likely formation during MIS 5c, about 100 000 years ago, when sea-level was about 8 m lower than that of today (Cann and Murray-Wallace, 2012). Centre of image approximately -35.95°, 139.47°.*

7 Lookout over islands in the Coorong Lagoon (Fig. 11)

An off-road lookout on the elevated Last Interglacial shoreline, close to the intersection of Princes Highway and Field Road, is well signposted. This vantage point east of the highway provides a clear view across the lagoon to the Younghusband Peninsula, and a linear group of islands within the lagoon that are parallel with both the modern ocean beach and with the MIS 5e shoreline (the Bonney Coastline). The parallel arrangement of the linear islands in the centre of the lagoon is in accord with their likely formation during MIS 5c, about 100 000 years ago, when sea-level was about 8 m lower than that of today. However, at the time of preparation of this text, no materials from the islands have been subjected to any dating analyses.

Continue along Princes Highway for a further 5 km.

8 Beach on the landward side of the Coorong Lagoon (Figs 12–16)

Although not signposted, the location of this site is easily recognised as the road and the lagoon beach are in very close proximity; a narrow unmade track leads off to the right; this is a convenient place to park a motor vehicle. Beach sediment at this location includes abundant shells of the bivalve *Spisula (Notospisula) trigonella* and a small snail *Coxiella striata*.

Figure 12 *Google Earth image showing the distribution of shelly beach sediments on the landward shore of the Coorong Lagoon. Centre of image approximately -35.96°, 139.51°.*

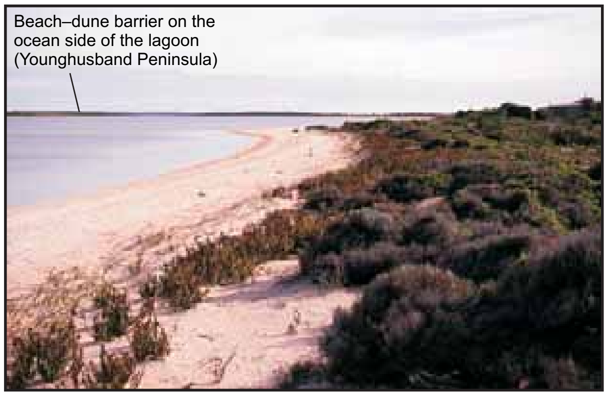


Figure 13 *Beach comprised of shelly sand on the landward shore of the Coorong Lagoon; view to northwest.*

Figure 14 *Detail of Coorong Lagoon beach sediment; left, strand lines along the beach; right, sediment is comprised of shells of bivalves, mostly* Spisula (Notospisula) trigonella *and a snail,* Coxiella striata, *which is responsible for the orange-pink colour of the sediment; view to northwest.*

Drive on a further 23 km to Salt Creek where there is a road house; food, fuel and toilets are available.

9 Salt Creek (Fig. 17)

At this locality, the elevated Last Interglacial barrier is dissected by Salt Creek. Upstream east of the roadhouse, shelly sediments of Last Interglacial age (125 000 years, MIS 5e) outcrop prominently. This rock was quarried to construct the supporting pylons of a bridge that once spanned Salt Creek. While the main structure of the bridge is no longer in place, the rock supports remain evident and can be easily accessed from the roadhouse carpark. The rock is a well cemented, shelly limestone; planar cross-bedding structures are consistent with beach-face sedimentation.

Leaving the roadhouse, after crossing Salt Creek, take the gravel road obliquely to the right. This road provides access to a series of lakes that are nested between the Last Interglacial barrier and younger (MIS 5c?), calcreted dunes. From here southwards, the Coorong Lagoon is confined to the seaward side of this younger (MIS 5c?) barrier.

10 Milne Lake (Figs 18–21)

This lake, the most elevated and removed from marine influence, has always been separated from the main Coorong Lagoon. The lake fills with water each winter and, around November, a milky turbid suspension forms, adding to the annual cycle of precipitation of the minerals dolomite and magnesite. Surficial carbonate muds have the consistency of yoghurt; lumpy algal mats and large ostracods are common. Surface sediments consist of approximately equal proportions of magnesite and dolomite, but the proportion of magnesite decreases with depth of sediment until only dolomite is present from 30 cm. Below 50 cm, sediment cores reveal a dark, laminated, foul-smelling, pelletal sand. The slightly higher elevation of this lake results in more extreme drying of the sediment above the lowered, summer-time water table, and more extensive development of brittle, indurated carbonate crust around the lake margin. Magnesite and dolomite crusts and intraclastic breccias occur with well developed tepees, polygonal structures (Fig. 21), mudcracks and animal tracks (Belperio et al., 1996).

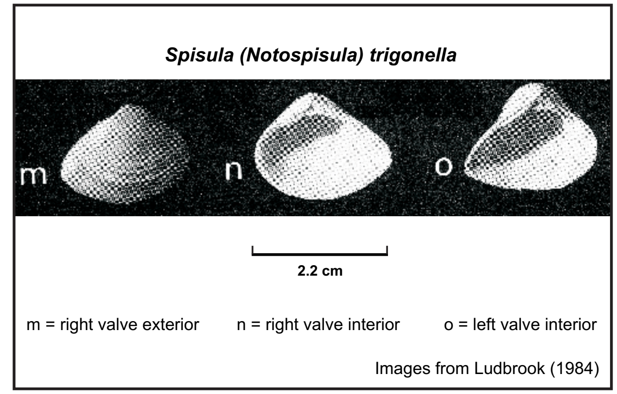


Figure 15 Spisula (Notospisula) trigonella

Figure 16 Coxiella striata. *Image from www.jandmgrist.com*

Figure 17 *Google Earth image of the Salt Creek area showing the location of outcropping shelly sediment of Last Interglacial age (MIS 5e). This rock was quarried to construct the pylons of a former bridge across Salt Creek. Centre of image approximately -36.12°, 139.64°.*

11 Halite Lake (Figs 18–20, 22)

This lake is close to the main Coorong Lagoon and is subject to marine seepage; evaporation leads to the formation of gypsum and an annual summer-time crust of halite (Fig. 22). The marginal carbonate crust includes shells of bivalves, suggestive of a former marine connection. Underlying sediments comprise laminated gypsum and hydromagnesite mud (Belperio et al., 1996).

__Figure 18__ Google Earth image showing the spatial arrangement of lakes with respect to the Last Interglacial barrier, elevation 40 m, and the barrier thought to be of MIS 5c age, elevation 17 m. The Coorong Lagoon is on the seaward side of this supposedly MIS 5c barrier. The Younghusband Peninsula (not labelled), which separates the Coorong Lagoon from the Southern Ocean, is the modern equivalent of these older barriers. Centre of image approximately -36.15°, 139.65°.

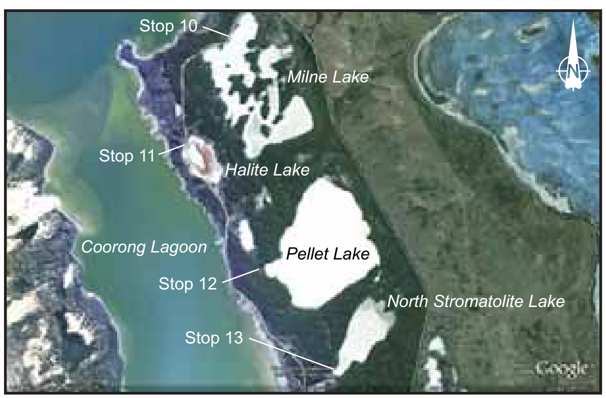


__Figure 19__ Google Earth image showing the spatial arrangement and names of the lakes also shown in Fig. 18. Centre of image approximately -36.15°, 139.65°.

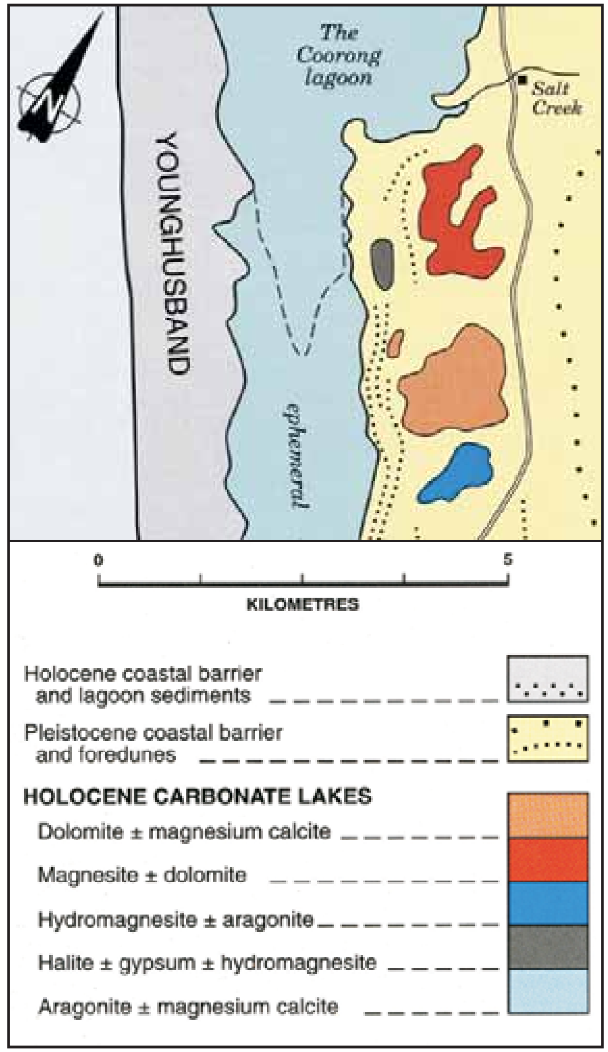


__Figure 20__ Map of the lakes area showing the composition of the lake sediments; from Belperio et al. (1996), based largely on the work of von der Borch (1965, 1976a, 1976b, 1981), von der Borch and Lock (1979) and Warren (1988). Note orientation of north. Centre of image approximately -36.15°, 139.65°.

12 Pellet Lake (Figs 18–20)

Access to Stop #12 is via a walking trail around the shore of a much smaller unnamed lake between the road and Pellet Lake. Alternatively, a walking trail from Stop #13 leads directly to the southern shore of Pellet Lake. This lake is so named because organisms burrow, ingest and

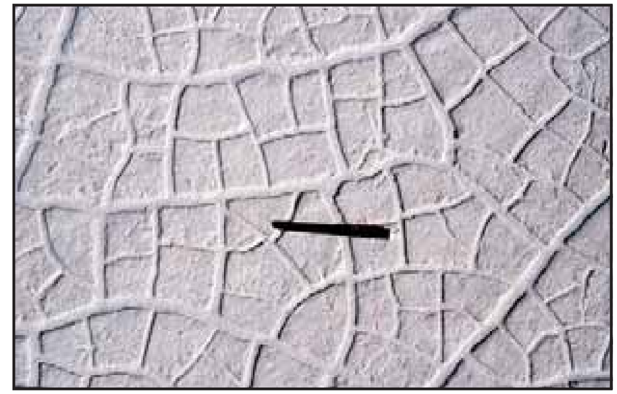


__Figure 21__ Milne Lake (approximately 36.14°, 139.65°): 'mudcracks' in carbonate sediment; groundwater strengthens the sediment along the cracks; wind deflation preferentially erodes the sediment within the polygons.

pelletize the carbonate mud, which otherwise has the consistency of yoghurt. Environmental interpretation of sediment cores, up to 5 m long taken from this lake, reveal a sedimentary succession from a marine setting, to a restricted lagoon and finally the ephemeral saline lake of today. A sedimentation rate of 0.2 mm/year has been determined for these sediments (Belperio et al., 1996, and references therein).

13 North Stromatolite Lake (Figs 18–20, 23, 24)

Access to this locality is via an area previously excavated for road-making material. Shell beds exposed in the bulldozer scrapes signify a former connection between the lake and the Coorong lagoon. These deposits are dominated by *Spisula (Notospisula) trigonella*, but underlying sediments contain shells indicating a more open marine association, e.g. the intertidal cockle *Katelysia* sp. The lake is an ephemeral, groundwater dominated lake reflecting the final phases of upward shoaling and isolation from the marine system. Surface sediments are yoghurt-like carbonate mud, with abundant ostracods and small snails. Seasonal exposure results in cementation and formation of marginal carbonate crusts which preserve structures such as tepees, polygons, mudcracks and footprints. Groundwater discharge from the adjacent dunes (Fig. 23) is a contributing factor in the development of carbonate crusts around the lake shore (Fig. 24; Belperio et al., 1996).

Figure 22 Halite Lake (approximately 36.15°, 139.64°; summer-time strand lines of halite.

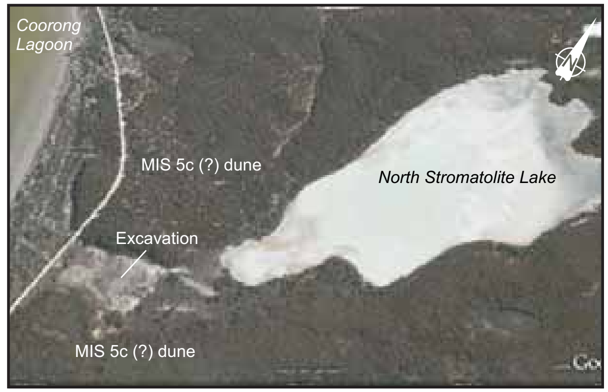


Figure 23 Google Earth image showing the location of North Stromatolite Lake. Centre of image approximately -36.16°, 139.66°.

Figure 24 North Stromatolite Lake; tepee structure in carbonate crust at the lake shore. Centre of image approximately -36.16°, 139.66°.

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Figure 25 *Location of stops along the Coorong self-drive geological trail.*

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Be prepared for your drive:

- ensure that your vehicle is roadworthy and has sufficient fuel for the distance to be travelled
- allow an entire day to travel the route at a leisurely pace
- drive safely and be traffic-aware when stopping at the designated places
- carry adequate food and drinking water for yourself and your passengers
- be aware of and practise conservation etiquette in the Coorong National Park – 'leave nothing but footprints; take nothing but photographs'
- when walking around the lakes, wear sturdy shoes and a hat; sunscreen should be used even in winter and insect repellent may be required
- weather conditions can change quickly; ensure that appropriate wet weather clothing is available in your vehicle.

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