NATURAL HISTORY
OF
EYRE PENINSULA

Editors:
C.R. Twidale, M.J. Tyler and M. Davies

Royal Society of South Australia (Inc)

Issued November 1985

National library of Austra;ia car number and
ISBN 0 9596627 3 1

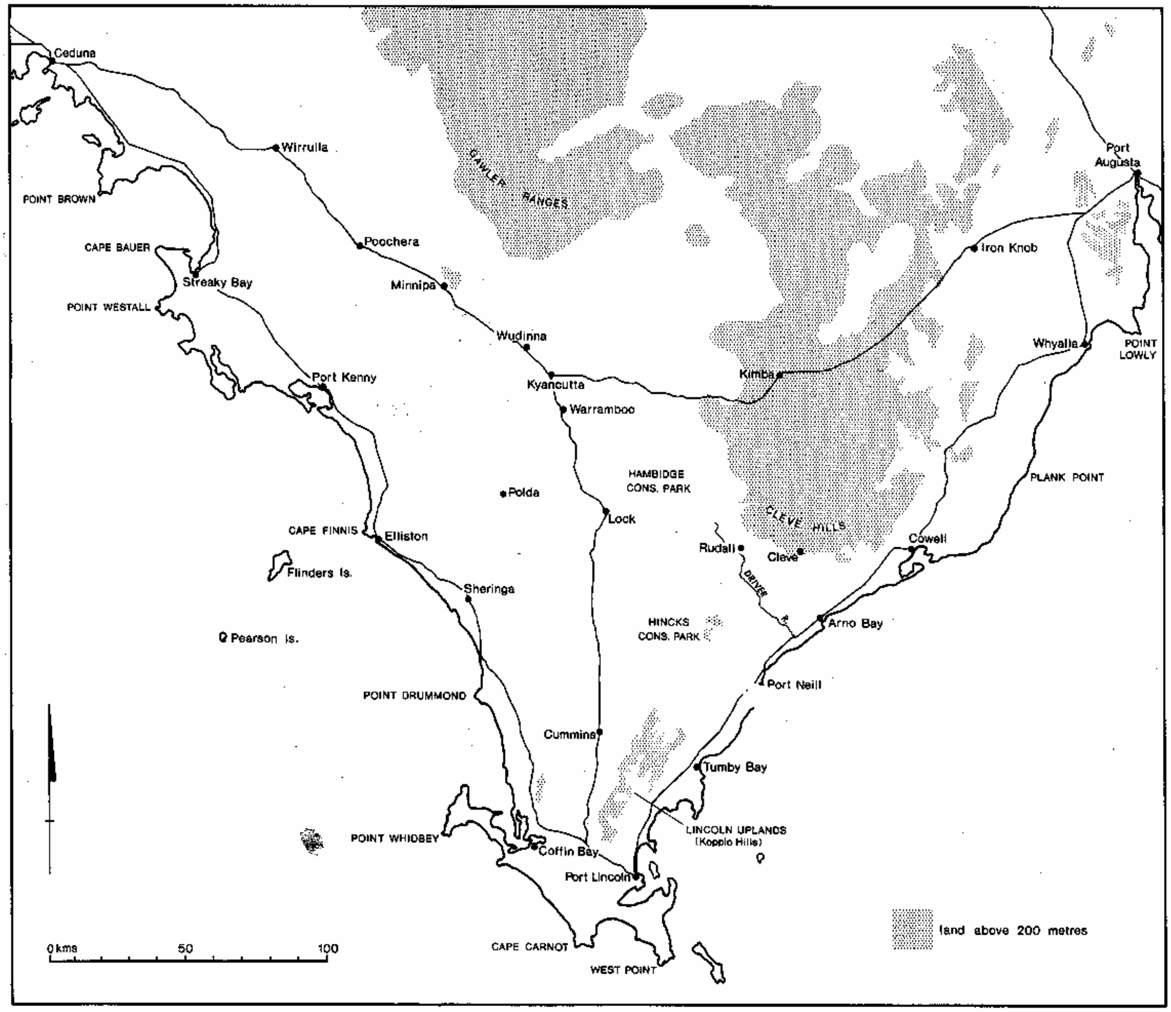
Occasional Publication of the Royal Society of South Australia Inc.

No. 1 Natural History of the Adelaide Region (1976)
No. 2 Natural History of Kangaroo Island (1979)
No. 3 Natural History of the South East (1983)
No. 4 Natural Histroy of Eyre Peninsula (1985)

Cover: Pt Drummond on the west coast of Eyre Peninsula

Digitised in July 2020 with pagination maintained as in the orginal book

Original book printed by Graphic Services Pty Ltd, 516-518 Grand Junction Road, Northfield



Eyre Peninsula—principal localities mentioned in the text.

Contents

Contributors

R. M. Berndt, Dept of Anthropology, University of Western Australia, Nedlands, W.A. 6009.
E. M. Campbell, Dept of Geography, University of Adelaide, G.P.O. Box 498, Adelaide, SA 5001.
H. J. Eckert, South Australian Museum, North Terrace, Adelaide, SA 5000.
C. M. Fanning, Australian Mineral Development Laboratories, P.O. Box 114, Eastwood, SA 5063.
R. H. Fisher, 21 Seaview Road, Lynton, SA 5062.
R. B. Flint, Dept of Mines and Energy, P.O. Box 151, Eastwood, SA 5063.
C. J. M. Glover, South Australian Museum, North Terrace, Adelaide, SA 5000.
L. M. B. Heard, Dept of Environment & Planning, G.P.O. Box 1782, Adelaide, SA 5001.
R. K. Johns, Dept of Mines and Energy, P.O. Box 151, Eastwood, SA 5063.
P. J. Lang, Dept of Environment & Planning, G.P.O. Box 1782, Adelaide, SA 5001.
R.T. Lange, Dept of Botany, University of Adelaide, G.P.O. Box 498, Adelaide, SA 5001.
J. K. Ling, South Australian Museum, North Terrace, Adelaide, SA 5000.
E. G. Mathews, South Australian Museum, North Terrace, Adelaide, SA 5000.
P. B. McQuillan, Dept of Agriculture, St John's Avenue, New Town, Tasmania 7008.
B. Miller, 10 Yarrow Crescent, Hope Valley, SA 5090.
A. M. Olsen, 11 Orchard Grove, Newton, SA 5074.
A. J. Parker, Dept of Mines and Energy, P.O. Box 151, Eastwood, SA 5063.
S. Parker, South Australian Museum, North Terrace, Adelaide, SA 5000.
J. R. W. Reid, Dept of Environment & Planning, G.P.O. Box 1782, Adelaide, 5001.
A. C. Robinson, Dept of Environment & Planning, G.P.O. Box 1782, Adelaide, SA 5001.
T. D. Schwaner, South Australian Museum, North Terrace, Adelaide, SA 5000.
P. Schwerdtfeger, Institute for Atmospheric and Marine Sciences, Flinders University of South Australia, Bedford Park, SA 5042.
R. G. Shepherd, 56 Northumberland Street, Tusmore, SA 5065.
C. R. Twidale, Dept of Geography, University of Adelaide, G.P.O. Box 498, Adelaide, SA 5001.
M. J. Tyler, Dept of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, SA 5001.
C. H. S. Watts, South Australian Museum, North Terrace, Adelaide, SA 5000.
W. D. Williams, Dept of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, SA 5001.
M. J. Wright, CSIRO Division of Soils, Private Bag, Glen Osmond, SA 5064.

Acknowledgements.

The production of this volume was made possible by the assistance of individuals. We particularly wish to thank Liz Campbell for substantial help in the editorial work and Max Foale, Debbie Haggar, Ruth Evans and Chris Crothers who expertly drafted or redrafted Maps. Noreen Shepherd and Sandra Lawson typed several chapters and also the preliminary pages to the volume.

C.R. Twidale
Michael J. Tyler
Margaret Davies

1: *History of Exploration and Settlement*

by C.R.TWIDALE and E.M.CAMPBELL

INTRODUCTION

Eyre Peninsula was named after the explorer Edward John Eyre (Gawler 1839), and today is an integral and vital part of the South Australian economy. In reasonable years almost 40% of the State's grain and 15% of its wool are produced there. The iron ore of the Middleback Range and the associated steel industries of Whyalla are well known (see Chapter 3). Marine industries are increasingly important at several centres (see Chapter 14). The tourist attractions of Port Lincoln and other coastal resorts are highly developed and inland sites are being promoted.

Yet the perceptions and reports of early explorers were far from encouraging. Eyre, though doubtless honoured by having the region named after him, had a poor impression of most of the Peninsula. The rocky hills, limestone plains, relic dunes, deep sand and thick scrub did not compare favourably with the green pastures of mother England. Eyre described parts of north western Eyre Peninsula as, "a perfect desert" (Eyre 1845, p. 199). Others referred to the interior lands as barren and desolate. The landscapes they encountered were beyond their experience and understanding, and their adverse reports arguably retarded development and settlement. Major changes in perceptions, and gains in experience and technology, were required before the potential of the region could be realised.

Who were the explorers and what physical constraints have been overcome in order to transform the "perfect desert" into the present fertile productive lands? Indeed have the various problems posed by the physical character of the Peninsula really been resolved? (see Chapter 4).

THE NAVIGATORS

The Dutchman, Francors Thyssen, in the *Gulden Zeepaard* was the first explorer to touch the South Australian coast. In 1627 he pushed eastwards across the Bight as far as the Nuyts group of islands, named after the then Councillor Extraordinary of the East India Government of Batavia, Pieter Nuyts, who was a passenger on board Thyssen's ship. But Thyssen turned back from the inhospitable coast and more than 150 years passed before any other European is known to have approached it (Someryille 23.xi.1934).

During the search for the French explorer La Perouse, who had disappeared on a voyage of discovery intended to take him round the world, D'Entrecasteaux, in the ships *La Recherche* and *L'Esperance,* sailed eastwards along the coast of the Bight late in 1792, praised the accuracy of the earlier Dutch navigator, and on 2 January 1793 was in the vicinity of the island of St Francis, in the Nuyts Archipelago. Because of the lack of water and supplies, and without landing or making new discoveries, he headed for Van Diemen's Land. Describing the western shores of South Australia D'Entrecasteaux wrote:

> "The shore was either a steep calcareous cliff of equal height or low and sandy with a few naked hillocks behind" (Somerville 7.xii.1934), "and it is not astonishing that Nuyts has not recorded any details of this sterile coast whose aspect is so uniform that the most fertile imagination could find nothing to say about it" (Somerville 30.xi.1934).

The exploration and mapping of the coast of Eyre Peninsula was left to the Englishman Flinders and his crew who arrived aboard the *Investigator* at Fowlers Bay on 28 January 1802. Flinders began his mapping of the 'Unknown Coast' at Cape Nuyts which he named after the earlier visitor whose charts of the coast, and those of D'Entrecasteaux further west, he praised highly. He proceeded in an easterly direction charting the outline of the Peninsula and establishing beyond doubt that there was no oceanic link between the Southern Ocean and the north coast of Australia. Flinders named many features after places in his native Lincolnshire, e.g. Kirton Point, Spalding Cove, Spilsby Island, Stamford Hill and Sleaford Bay and Mere; after members of his party on the *Investigator,* e.g. Thistle Island, Point Westall and Point Brown; after events which occurred on the voyage, e.g. Cape Catastrophe where the Master of the *Investigator,* Thistle, and seven crewmen were drowned, and Memory Cove to commemorate those lost; from the way the features appeared to him, e.g. Smoky Bay, Streaky Bay, Denial Bay and Anxious Bay; and after the supporters of the voyage, e.g. Coffin Bay after Vice Admiral Sir Isaac Coffin and Mount Greenly after Coffin's fiancee.

The *Investigator* left the Eyre Peninsula region on 19 March 1802 but continued charting the coast eastwards until 8 April. In Encounter Bay Flinders met *Le Géographe,* a French corvette commanded by Captain Nicholas Baudin, who was charting the coast westwards from Cape Banks. After discussing their separate discoveries, Flinders continued eastwards, arriving in Sydney on 9 May 1802, and Baudin continued in a westerly direction as far as Murat Bay where he abandoned the coast and headed for Port Jackson.

Le Géographe returned to France and the official account of the expedition published in 1807 contained over 380 French names, ignoring those of Flinders to the west of Encounter Bay and of Grant in the South East. Flinders was detained by the French on Mauritius, and it was not until 1814 when he published his *Voyage to Terra Australis* that Flinders' rights as a discoverer were altered. On Eyre Peninsula there remain, especially in the area around Murat Bay where haze prevented Flinders carrying out his coastal survey, and further south, numerous French names: Murat Bay, Cape Thevenard, Decres Bay, Cape D'Estree, Cape Carnot, etc., but the majority of the names are those given by Flinders, making it unlikely that it will ever be forgotten who discovered and mapped the coastal fringe of Eyre Peninsula.

Following Flinders, whalers and sealers, especially from the United States and France, worked and no doubt explored the coast and the immediate hinterland even if only in search of fresh water. For example in 1815 and 1816 a Captain Peter Dillon in the *Spring* killed 500 seals on Kangaroo Island and 100 on Althorpe Island. He reported the land around Port Lincoln as fertile and productive. He located Flinders' wells, which he cleaned out, but found no water there in February (Dillon pp. 64-67 in South Australian Association 1834).

Captain Goold visited the area in 1827 and 1828 to investigate the possibility of establishing a seal factory. He found a spring of fresh water west of Point Boston. He declared that:

> "the harbours, soil, climate, position for commerce and vicinity to excellent fishing grounds, renders the formation of a colony there, in my opinion, highly desirable" (Goold pp 59-63 in South Australian Association, 1834).

In about 1831 a Captain Hart examined the islands off the coast and found several of them to be inhabited by escaped convicts (Somerville 29.iii.1935).

In 1837 Frederick Hamborg was at Spalding Cove in the brig *Socrates* and reported black whales, seals, fish, a good harbour, fresh water and friendly natives (Hamborg pp 70-71 in South Australian Association 1834). Between 1832 and 1834 the Henty family investigated the Port Lincoln area and nearby islands looking for farming land and a site for a whaling station. No land in the area was selected, Portland, Victoria, being preferred (Somerville 29.iii.1935). A Kangaroo Island whaler, George Meredith is reported to have abducted a Port Lincoln Aboriginal woman (Sal) in about 1834 (Somerville, 22.iii.1935), and this together with the reported activities of Newell and Manning may have caused at least some of the later referred revenge attacks by the Aborigines (Somerville 22.iii.1935). Thus there was considerable activity around the coast before Colonel Light made the preliminary survey of Port Lincoln in 1836 with a view to selecting a site for the capital of the future colony of South Australia.

About the time of the foundation of Port Lincoln in March 1839, and afterwards, there were minor voyages of exploration which added to the knowledge of the coast. Early in 1839 Captain F.A. Lees in the *Nereus* made one (possibly two) voyages up the west coast of the Peninsula. On board were Flaxman, Stephens and McLaren looking for land suitable for a 'Special Survey.' Theirs was the first exploratory journey (as opposed to the whalers' and sealers' trips) since Flinders' and Baudin's voyages of 1802 and 1803. They reached as far as Point Westall noting various physical features en route, naming Mt Prospect for its commanding and extensive view and surveying Coffin Bay (Somerville 5.vii.1935, 23.v.1940, 30.v.1940, 6.vi.1940).

In the same year Robert Cock, acting on behalf of a group of Adelaide speculators, sailed down the coast from present day Yatala on Yorke Peninsula to south of Point Lowly. Cock reported the country as exceedingly barren, and departed for Boston Bay. He made further journeys on land (see later) but his mentors took no further action (Somerville 19.vii.1935).

John Cannon in the *Ranger* was to meet Eyre at Streaky Bay with supplies in September 1839, but arriving early he took the opportunity to survey the areas to the west before making his rendezvous. He reported good harbours in Streaky Bay, Denial Bay and Smoky Bay, but considered the area, from the barrenness of the land and the scarcity of fresh water, to be useful only for whaling (Somerville 9.viii.1935).

At about the same time Stephens and Hill in the *Rapid,* representing the Secondary Towns Association, penetrated to the western limit (132°) of the province and reported several good harbours but a poor hinterland (Somerville 2.viii.1935, 6.vi.1940).

As late as 1858, Captain Bloomfield Douglas was sent by the Government to check on the surveys of Flinders and Baudin of the western shores of Eyre Peninsula, to select good anchorages and an adjacent town site to cater for the pastoralists who might take up land in the area as a result of the surveys of Hack in the Gawler Ranges, and of Miller and Dutton north of Denial Bay (see below) and to explore for guano. Douglas praised Flinders' charts, prophesied that Streaky Bay would become "the western port of the Province", being backed by fine pastoral districts, but failed to find worthwhile guano deposits (Douglas 1858).

Interesting as these minor explorers are, they added nothing major to what had been discovered previously, and Flinders' charts remained the best available for many years; this was true of many parts of the Australian coast until well into this century.

THE FOUNDING OF PORT LINCOLN

A little more than two years after the founding of the Colony of South Australia, a party set out in the vessel *Abeona* under Captain Hawson to establish a settlement on the shores of Boston Bay on southern Eyre Peninsula, or what was then known as the Port Lincoln Peninsula (Fig. 1). The area had been surveyed in 1836 by Light, who was seeking a site for the capital of the new province. But Light approached the harbour in a gale, found the land around to be of an inferior quality, and therefore decided on a site near Holdfast Bay. Hawson's party had better luck; leaving Adelaide on **11** March 1839 they landed on the shores of Boston Bay on the 19th. There were about 120 settlers in this first wave. A few

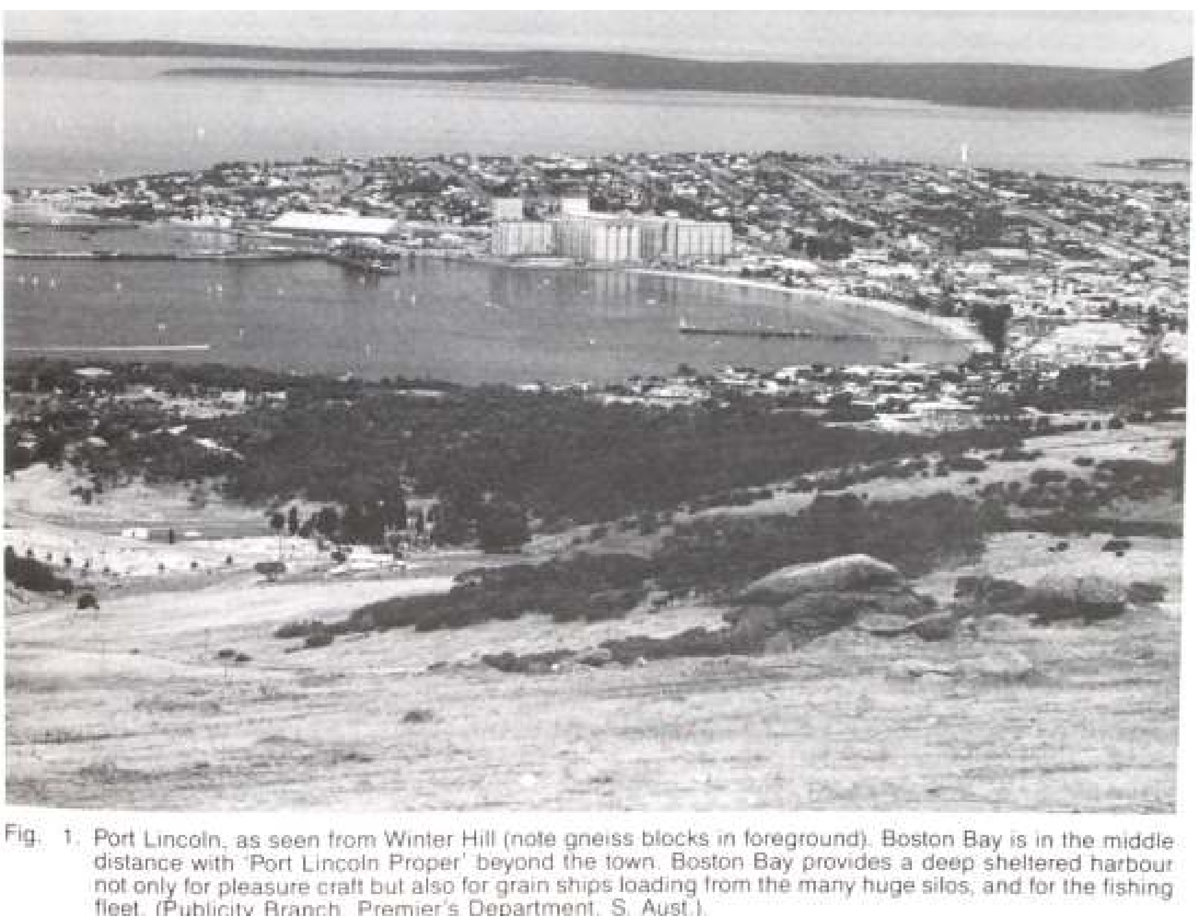


Fig. 1. Port Lincoln, as seen from Winter Hill (note gneiss blocks in foreground). Boston Bay is in the middle distance with 'Port Lincoln Proper' beyond the town. Boston Bay provides a deep sheltered harbour not only for pleasure craft but also for grain ships loading from the many huge silos, and for the fishing fleet. (Publicity Branch, Premier's Department, S. Aust.)

weeks later Dutton arrived in the Dorset and commented on the splendid harbour:

"Much as I admire Port Jackson as a harbour, the capabilities of which I had ample time for exploring during a five year residence in Sydney, I readily yield the palm to Port Lincoln. In having two bold entrances the latter harbour has the advantage over the former, as ships can enter in any weather and at any time without the aid of a pilot, whereas Port Jackson possesses only one narrow entrance with shoal water, and dangerous rocks immediately at the mouth of the harbour" (Dutton 1839, p. 2).

With this opinion many, including Mr Porter, a merchant, and Captain Johnston, of the *Recovery,* agreed (Johnston 1839). Mr Porter's confidence was demonstrated by his purchase of five of the original allotments in the town and a half share in another. He built at Kirton Point and in 1839 had already planted:

"a quantity of orange, lemon, bananas, vines and other rare plants, which are all looking remarkably healthy" (Dutton 1839, p. 2).

He cultivated turnips on-Boston Island. He had: "sunk a well upon one of his half acre frontages, and has met with a ... spring at a depth of only twelve feet ... " (Dutton 1839, p.2).

Others too had been successful with early plantings. There were splendid crops of potatoes, and though, due to his neglecting to fence, Mr Hawson's eight acres of wheat and potatoes had been partly destroyed by foraging animals "Mr Piddington's maize looks exceedingly fine as well as everything else growing in Happy Valley" (Johnston 1839, p. 126).

Dutton believed that:

"Upon the ranges behind the town, terraced vineyards may and eventually must rise one above the other, while the orange, lemon, olive, fig, pomegranate, banana, quince and pineapple will luxuriate in the deep alluvial deposits which are to be found in the valleys" (Dutton 1839).

Water was essential and here too the new settlement was fortunate, for springs were numerous and prolific.

There was freestone on the spot; fish was abundant, mackerel in particular having already been taken in great quantities; a reconnaissance survey had revealed a promising country in the hinterland. All in all Dutton was very favourably impressed and he too purchased an original town allotment.

The town itself expanded, In 1840 Eyre noticed many improvements since his visit the previous year. There were many neat cottages and some gardens were cultivated and doing well. There was a church and the congregation, though small, seemed respectable and suitably devout (Eyre 1845). Two newspapers were published. *The Egotist* published by Joseph Barnett for Charles Smith on 14 and 18 May 1839 did not survive. *The Port Lincoln Herald* was first published by George Delane in November 1839 and on the 16th reported the launching of the first ship built in Port Lincoln, the cutter *Alice.* On its maiden voyage on 27 November it carried salted fish and three bales of wool to Port Adelaide. There was tremendous optimism concerning the future of Port Lincoln.

By October 1841, J. B. Neales, another of the owners of an original town plot, reported that 4000 acres had been surveyed and selected in and near Port Lincoln. Another 6000 acres had been surveyed but not selected. In the town itself and in an area of 40 miles radius the population had attained 195, living in what Neales called eight first class houses, 20 second class houses and 20 cottages. There were government officers in the form of a harbourmaster, resident magistrate (Matthew Smith) and a clerk who doubled as postmaster and collector of customs, as well as a sergeant of police and four constables. Dr Harvey and Mr White cultivated vines. In the surrounding countryside were 6600 sheep, 450 cattle, 18 horses and about 100 pigs and goats. Wheat, oats, barley, turnips and mangel wurzel were grown, and ducks and other water fowl, mutton birds, oysters, seal and whale were hunted and collected. Wool, oil, skins, whalebone, potatoes, corn, fish, wood, stone, lime, feathers, butter and cheese are listed as "exports" from Port Lincoln (Neales 1841).

But not all the reports were optimistic. Neales complained, as did Eyre, that American and French whalers were working the coast and robbing the colony of those riches. George French Angas in a letter published in London in the *Colonies* in 1877, but based on a sojourn in Port Lincoln and environs in 1840, referred to Port Lincoln as "Sleepy Hollow". At the time of his visit the inhabitants had been without news or outside contacts for several weeks and were anxiously awaiting the next vessel-any vessel-to bring news of the outside world. Isolation from the rest of South Australia was keenly felt. This feeling persisted for many years for Mrs Nellie Kettle, posted to a one-teacher school at Coorabie, north of Fowlers Bay, in 1913 recalls the settlers on Eyre Peninsula referring to the "mainland" even as late as World War I, and the term was used at that time even in Government publications (Coleman

1917). The isolation of the early settlers was apparently matched by the opinion of the early inhabitants of Adelaide, who felt that Adelaide was the centre of activity in South Australia – “a fertile island" in a sea of desert. This idea was reinforced by the unfavourable reports of the early explorers from the surrounding areas including Eyre Peninsula, and by the true nature of the conditions not being understood (Price 1924).

Angas claimed that this sense of isolation was also felt by visitors as there were no inns or public places of accommodation (Mr Smith ran an establishment, but this was a tavern for the bar trade only), though the abundant and generous hospitality offered by the settlers more than compensated for the deficiency (Angas 1877).

In addition, Eyre in 1840, although noting many improvements, concluded that Port Lincoln could never become a large or important place because of its isolation except by sea, and because of a lack of local resources (Eyre 1845). He noted that the population had decreased and that many of the cottages were unoccupied;

> "Those who remained were principally persons who had lost everything and who could not well get away, or who on the other hand, had invested their property in the place, and could not leave it except at the sacrifice of almost everything they possessed. No one seemed to be doing well but the innkeeper who thrived at the expense of the whalers and other seamen. The stockholders, living a few miles from the town ... were getting dissatisfied at the many disadvantages around them, and everything wore a gloomy aspect" (Eyre 1845, pp. 160-161).

Certainly some of the earliest and most enthusiastic settlers departed. Mr Porter left disillusioned. Some of the early pastoralists sought better conditions. A Mr S. W. White who in 1840 had become a member of the board of licensing publicans, had, with his two sons, taken land at Tallala about 45 km north of Port Lincoln. But supplies and communications were uncertain and the Whites departed. The White property was taken over by Tennant who overlanded sheep from Adelaide but lost 3000 out of 10 000 (and two shepherds) en route.

Apart from isolation and difficult communications, there were troubles with the Aborigines. The small community was shocked by the fatal spearing of 10 year old Frank Hawson at Little Swamp on 5 October 1840 (Somerville 22.xi.1935). The barbed spears could not be removed and the boy took several days to die. The attack on the boy, utterly unprovoked in terms of European logic, marked the end of a period of peaceful co-existence and the beginning of an unhappy few years.

That there had not been open warfare from the beginning does great credit to the Aborigines. They had, after all, been treated abominably by some of the whalers who preceded the settlers. The settlers themselves, though committing no physical violence (or at least such actions were not officially condoned) were nevertheless intruders who as Eyre (1845) pointed out, tended to take the best land and to monopolise the watering sites. Eyre's views were enlightened, but how typical of the day is not clear. He hints that Frank Hawson's murder may have been a referred revenge: retribution for an offence committed by another European on an Aborigine at some other place and time (Eyre 1845). Whatever the case, two years of violence ensued after Hawson's murder; sheep were stolen, fences burned, settlers attacked and some of them killed. Brown, who had supplied sheep to Eyre, was killed with a Mr Lovelock in March 1842; Rolles Biddle and two of his servants, Fastin and Stubbs, were also murdered that month (Somerville 6.xii.1935, 27.iii.1936). Retribution, if not justice, followed. Apart from local settlers (vigilante groups), troops and police were sent in pursuit of the offenders, real or imagined. Some natives were shot during these pursuits. Some of those captured were tried and jailed, others put to death, either by hanging or beheading-the latter overtly *pour encourager les autres.* But even at the time it was widely considered that some of those executed were innocent.

Though racial disharmony persisted in other parts of the Peninsula as settlement spread, peace soon returned to the Port Lincoln district and by March 1845 Aborigines were reported to be employed on farms on southern Eyre Peninsula.

THE EXPLORERS

On 10 March, 1839, the morning after the first settlers landed on the shores of Boston Bay, a party under Robert Tod and comprising the surveyor Winter, and Messrs Fenn and Stephens headed NNW from Happy Valley and ascended what was to become Winter Hill. The view was splendid. Tod waxed enthusiastic about the harbour, but expressed reservations about the carrying capacity of the hill country. They travelled to Little Swamp, came across Duck Pond Creek, and returned to Happy Valley. On the 23rd Tod, Fenn and Stephens, together with Crouch, Austin, Phillipson and Williams, an unnamed servant and two Adelaide tribe Aborigines embarked on a slightly longer excursion; travelling north along the coast to the promontory that separates Boston and Louth bays, they discovered the Tod. Tod modestly records that while he was investigating the promontory, the rest of his party:

> "fell upon a river about 100 feet wide and 6 to 8 feet deep. They acquainted me that they had named it the River Tod, in compliment to the individual under whose direction they had placed themselves" (Tod 1839, p. 116).

They also climbed and named Mt Gawler, after the then Governor. They went a short distance west into Cowan Vale (which, it transpired, was drained by the headwaters of the Tod) and then returned to the settlement having been out for four days (Somerville 12.vii.1935).

On the 30th March 1839 C. C. Dutton, with Captain Hawson, and Messrs T. Hawson, R. Stevens, Mitchell, Dennis, T. Whybell and T. Harrison made an eight day journey west to Coffin Bay, naming Mt Dutton and Hawson's (now Marble) Range, and thence north and east to reach the east coast near Mt Gawler (Dutton 1839).

Charles Christian Dutton's early impressions of Port Lincoln have already been cited. He was born in 1811 in England of a well-to-do family. He arrived in Sydney in the *Platina* in 1833 and in partnership with his brother ran a general merchandising business in Maitland. They ran to a city office and Dutton was evidently at this time largely resident in Sydney. But he developed the wanderlust in 1837. He sailed to Java and Mauritius before returning to Australia-to Hobart, where on 5 March he boarded the schooner Abeona bound for Port Lincoln. He walked into Adelaide, and was soon appointed clerk of the Supreme Court, and then, in May, Sheriff of the province of South Australia. He married Ellen (?) White in June of 1838, but remained unsettled. He was one of the owners of a town allotment in Port Lincoln, and by April 1839 he was the "late Sheriff of the Province" (Dutton 1839). On 1 October 1840 Eyre recorded that he and his party travelling southward down the east coast reached Mr Driver's station where Mr Dutton was manager. Dutton managed Pillaworta Station owned by Mr Driver near the Hill of the same name just inland from what is now Tumby Bay township. Dutton's second child and eldest daughter, born 6 June 1840, was christened Emily Piliwarta.

Dutton assessed the area immediately to the southwest of Port Lincoln as "very fair sheep country" and beyond the ranges surrounding a lagoon he noted rich agricultural land. To the north of Coffin Bay:

> "a magnificent country opened upon us, the trees growing in clusters interspersed about a rich park-like flat, in the centre of which there was a large lagoon covered with black swans" (Dutton 1839, p. 2).

This was probably Lake Wangary. After a few more kilometres and upon ascending a slight eminence "a still more beautiful country stretched out before us". Dutton and his companions climbed Hawson's Range and though camping without potable water (though finding much that was brackish) he was much impressed with some of the country he saw in this area inland from Port Lincoln. Of one area west of Mt Gawler he wrote:

> " ... I certainly never saw finer agricultural land in New Holland than this tract. The undulating hills which bound the vallies covered with a fine light soil shaded with gum and she-oak trees, are peculiarly adapted for sheep runs, and as wool always partakes of the nature of the soil over which it runs, a fine bright description of that staple may be grown here, partaking of the Saxon character, and certainly equal to the Bathurst and Argyle wool in New South Wales, which is grown upon a similar soil. Any quantity of cattle would find excellent feed in the vallies and water in abundance ... " (Dutton 1839, p. 3).

In May 1839 Robert Cock, on behalf of the Adelaide Survey Association, proceeded to Coffin Bay from Port Lincoln, travelling through barren, stony country. He reported some good sheep country west of Boston Point. He also visited Franklin Harbour where the party suffered from heat and lack of water. As a result of his reports the Adelaide Survey Association left Eyre Peninsula severely alone (Somerville 26.vii.1935).

Dr J. B. Harvey in October 1839 travelled south to Sleaford Mere where he found plentiful supplies of fresh water and land adapted for sheep and cattle. He also found good garden ground at the western end of Sleaford Bay and collected stones from the South Australian native peach (Somerville 23.viii.1935).

Captain Hawson, William Smith, Innes and two other men left Port Lincoln on 17 October 1839, using horses as means of transport, and explored the country north of Mt Gawler to around the present Pillaworta Hill. Hawson reported excellent land for agriculture and pastoral purposes:

> "During the whole of our excursion we did not meet with five miles of unavailable land, nor did we ride two hours without water ... " (Somerville 16.viii.1935).

He named a stream Mississippi after a French whaling vessel in port and a well watered vale, Rossiter, after its captain. These names are however no longer used.

Captain Rossiter's ship was the first overseas vessel to enter Port Lincoln harbour after settlement (8 October 1839). He had spent several days in Coffin Bay and reported a large lake, probably Lake Greenly, which encouraged further exploratory journeys (Somerville 16.viii.1935).

In December 1839 a party made up of Matthew Smith, Solicitor, Dr J. B. Harvey, Collector of Customs, Charles Driver, C. C. Dutton and Capt. Johnson of the *Recovery,* set out to inspect the country around Port Lincoln for the purpose of reporting to the Assistant Commissioner, Capt. Charles Sturt. They too reported excellent agricultural and pastoral land (Somerville 23.viii.1935).

There was also more than basic living in these country areas even in the earliest days of settlement, for during his brief excursion into the countryside early in 1840 George French Angas recollected that at Wangaree Lake (Lake Wangary) the "rosy damsels" he had earlier seen milking cows and churning butter, at dinner (roast goose) "made their appearance arranged in garments of white muslin with sashes of cerulean blue, and the orthodox white stockings and sandalled shoes of the period" (Angas 1877, p.39).

Thus within a short time of the arrival of the first settlers, good pastoral and agricultural land had been located. The early explorers made no secret of their optimism and enthusiasm. Dutton summed it up best when, considering the area: "a great extent of good country in the immediate neighbourhood of Port Lincoln for agricultural as well as pastoral pursuits covered with an abundance of fine she-oak which splits exceedingly well for fencing ... " (Dutton 1839, p. 2).

Unfortunately Dutton was not to live long enough to participate in the development he felt sure would occur. He left Port Lincoln in late June of 1842 intending to drive cattle overland to Adelaide around the top of Spencer Gulf, but he and his four companions (Messrs Cox, Haldane, Graham and Brown) disappeared (Somerville 31.i.1936). Though some of the cattle were traced and Dutton's horse returned to Pillaworta no sign of the men or their dray was ever found. Three months passed before the alarm was raised. Several parties went in search of them mostly on land but including at least one expedition based on a small boat edging up the coast and sending parties inland in search of tracks. The boat party found Dutton's tracks near Mt Middleback but none to the north. One of the land parties was headed by Eyre (Eyre 1842) who reported that though there were no dray tracks in the vicinity of Point Lowly, he did cross them between Refuge (Secret) Rocks and Mt Olinthus. Eyre was short of water and could not follow the tracks to the nortneast. It was particularly unfortunate because in retrospect it seems that Eyre must have been reasonably close to the site of Dutton's end. However Eyre was not to know this and he together with the rest of the community assumed that Dutton and his party had died of thirst; thus Eyre (1845, p. 154) stated that "Dutton and his party perished in the desert (as supposed) from want of water". Certainly Eyre and others engaged in the search found water to be at a premium in late October and early November 1842.

Later information however suggested that they may have been attacked and killed by Aborigines somewhere near and, bearing in mind Eyre's sighting of the dray tracks, possibly a few kilometres west of the Middleback Range. This is consistent with their having passed north of Cleve but not having attained the latitude of Point Lowly. Quite clearly Dutton was not following the coast but was cutting inland, taking the shortest route he could reasonably follow.

Nathaniel Hailes who was resident in Port Lincoln at the time and had participated in the search, took information from an aborigine in the Middleback region about a party of white men who had been slaughtered by the natives. The informant managed to convey to Hailes a description of the four Europeans indicating their height, build and colouring as well as indicating for example that one of them had a pock-marked face. This was true of Cox and this sort of unusual detail together with the correspondence between the native's general descriptions and the four men in question persuaded Hailes that the account was true. Hailes took the Aborigine to the court house at Port Lincoln where the testimony was recorded. According to the Aborigine, as related by Hailes and with the latter's speculations and comments, this is what happened:

> "One day toward sundown Dutton and Cox were in advance of the party. It was the custom of one or both to precede the dray and cattle, after the mid-day meal, in search of a suitable camping place for the night. On this occasion they must have been later than usual in halting, probably because they could not readily find water. They arrived at a party of native women making preparations for a night's lodging, from which circumstances they would know that water was not far off. The women taken by surprise, darted off like startled hares, all except one, whom Dutton

> detained by the wrists. The whole of them vociferated that shrill piercing shriek which they utter on such occasions, and which I have heard, in the stillness of the evening, at a distance of four miles. It resembles the railway whistle more than any other sound I am acquainted with. The men from all sides, abandoning their game, their apparel and spears, rushed to the rescue, and killed the two white men with their waddies. Haldane then came up with the dray and shared the same fate. The tragedy was completed on arrival of Graham and Brown with the cattle the fatal waddies being inflicted also on them" (Hailes no date).

However while these local excursions were being made in southernmost Eyre Peninsula, the man after whom the Peninsula is named was accomplishing the first of three overland journeys which, though not adding anything spectacular to the map, provided the first indications of the character of the region and, more importantly, coloured the views of South Australians for decades to come. This was Edward John Eyre.

Edward John Eyre

Eyre was born in 1815 at Hornsea, Yorkshire, the son of a clergyman. He was educated at Sedburgh, Yorkshire, and Louth, Lincolnshire, and emigrated to NSW. in 1833. In 1838 he drove cattle overland to Adelaide and was appointed magistrate and Protector of Aborigines in the lower Murray district. He bought a town allotment at Port Lincoln in 1839 and engaged in exploration in South Australia, in the Flinders Ranges and adjoining areas, on Eyre Peninsula, and along the southern coast of South Australia and Western Australia. For his heroic trek across the Nullarbor, culminating in his fortunate salvation at the hands of a French whaler, Eyre was awarded the Founder's Gold Medal of the Royal Geographical Society of London. Eyre returned to England in 1845 but returned briefly to the Antipodes as Lieutenant Governor of New Zealand. He then served successively as Governor of St Vincent and of Antigua in the British West Indies, and then in 1861, Acting Governor, and in 1864, Governor of Jamaica. There was a negro insurrection there in 1865, harshly or firmly suppressed by Eyre according to one's point of view. In any event his handling of the situation was controversial, and he was compelled to resign and return to England where he was the subject of vicious attacks to the end of his days. He was twice tried for his actions in Jamaica, but twice acquitted. Though he received a government pension the acrimony did not disappear, and what had been a brilliant public career ended in the shadows. Eyre died in retirement in Devonshire in England in 1901.

No matter what Eyre did or did not do in the Antilles however, he will always be remembered in Australia as a courageous and able explorer. His journal gives a splendidly graphic account of events and places and it is possible to plot within close limits the route he followed on Eyre Peninsula.

On 1 May 1839 Eyre left Adelaide and travelled north to what became his depot near Mt Arden, north of Port Augusta. Whilst travelling further northwards Eyre noticed a distant range to the southwest and sent his overseer Baxter to investigate. Baxter discovered a large lake which was named Lake Gilles by Eyre and the range was named after its discoverer. Baxter's report of the country was not very heartening and although he and Eyre followed down the western shore of Spencer Gulf, for a short distance, the journey further south was abandoned as "impracticable at so unfavourable a season as the present" (Somerville 6.ix.1935), and they returned to Adelaide.

On 8 July 1839 Eyre left Adelaide in the *Porter* for Port Lincoln. From there he departed on 5 August for Streaky Bay, arriving on 25 August having travelled through low, barren country. He had an agreement to provide the South Australian Company with information to enable it to request Special Surveys (Somerville 6.vi.1940). From Streaky Bay, Eyre attempted exploring westward hoping to reach the Head of the Bight, but found the country to be "low, barren, sandy and densely covered with scrub" (Somerville 6.ix.1935). He reached only as far as Point Bell where he was forced to return to Streaky Bay due to lack of water and grass. Meanwhile Baxter was sent to explore in the vicinity of Mt Sturt where he reported water at intervals, but the supply was derived from recent rains and was diminishing rapidly. A boat with supplies for the party had been promised at Streaky Bay by the Governor, but this was overdue and Eyre decided on returning to his former depot at Mt Arden and thence to Adelaide. Thus Eyre crossed the broad northern base of Eyre Peninsula in September 1839. He travelled across an area of relict Pleistocene dunes with a few scattered granite outcrops, and then across the Corrobinnie Depression with its deep dune sands, numerous salt lakes and thick scrub. The going was difficult, and Eyre judged that the trip was made possible only by the recent falls of rain.

He passed under the southern peaks of the Gawler Ranges which he named after the then

Governor of the Province and after further explorations from Mt Arden, during which Eyre discovered and named Lake Torrens, the party returned to Adelaide on 15 October 1839.

Eyre's next trip was by sea to Albany in Western Australia with a consignment of sheep and cattle. On his return to Adelaide the public was clamouring for an overland route to be tried between South Australia and the west, but Eyre was of the opinion that a journey northward would be more advantageous. The trip was planned and the party with Eyre as leader set out in June 1840. The journey northwards was stopped at Mt Hopeless where Eyre found himself surrounded on all sides but the south by a sheet of water. Rather than give up Eyre decided to cross to Streaky Bay and from there attempt to discover a route to the interior. Eyre sent Baxter and most of the party across the Peninsula to Streaky Bay retracing Eyre's 1839 journey. Scott and Eyre, with one man and a native boy, travelled down the east coast passing west of Iron Knob and the Iron Baron Range to Port Lincoln for supplies. This is waterless country and Eyre was compelled to send Mr Scott and the rest of the depleted party with the dray back to their base at Baxter Hills, near the present Corunna Station, for water. Eyre camped alone on the night of 19-20 September and quite without Eyre's knowing it Aborigines crept close to him and stole his horizon glass. He promptly cleared a defensive circle of scrub 3-4 metres radius fearing another attack. But nothing untoward occurred and Scott rejoined him next day with replenished water supplies. They passed through "dreadful country" (Eyre 1845, p. 145) composed of dense scrub and heavy sand ridges with some salt water channels and beds of small dry lakes. Thus they were glad to find water in the rock holes at Refuge (Secret) Rocks. They pushed down the east coast "passing over a wretched country" (p. 148) via Mt Hill and Pillaworta (Mr Driver's Station) to Port Lincoln. Apart from the green valleys with rich soil and luxuriant pasturage in the south, Eyre passed through rocky, dry, sandy country with salt water lakes and salty creeks. Fresh water supplies were very limited, and of course some of the country on that eastern traverse, for instance around Verran, is still notorious for its frequent drifting sand.

After material, social and spiritual refreshment in Port Lincoln, on 24 October Eyre resumed his journey northeastwards passing by Mt Wedge which he named "from its shape" (Eyre 1845, p. 189). (It is mere coincidence that Wedge is the name of the uncle with whom J. C. Darke emigrated to Tasmania: the feature was named four years before Darke reached the site-see below). Eyre named lakes Hamilton and Newland after friends, Mt Hall after George Hall, the Governor's private secretary, and Mt Cooper after Charles Cooper, a judge of the Colony of South Australia. He rejoined his party at Streaky Bayon 3 November 1840. He formed a favourable opinion of the well-watered pastures around Lake Newland, but considered the area, as a whole, uninviting; the area between Streaky and Smoky bays for instance he described as "this worse than desert region" (Eyre 1845, p. 210). It is true however that he thought the land north and northwest of Streaky Bay was improving with time, implicitly as a result of climatic change resulting in the scrub being replaced by grassland (Eyre 1845).

Eyre travelled westward from Streaky Bay through heavy, sandy, arid country with a scarcity of pasture for the horses and dense brush making travel difficult, and in the heat of summer-it was 17 November when he arrived at Fowlers Bay and made camp with supplies from the *Waterwitch.* From here he made three attempts to round the Head of the Bight, but each time was forced back because of the difficult country and lack of water. Eyre was pushing westward hoping to find a point on the coast from which it was possible to penetrate far into the interior. But he found none and the local natives reported that there was no water inland. Failing to find a northerly route to the interior Eyre decided to attempt a crossing to the west as originally desired by the colonists (Somerville 8.xi.1935).

He decided to reduce his party and take only pack horses and not drays for transporting provisions. Thus on 25 February 1841 (Eyre 1845), he embarked on the most horrific and epic stage of his journey, across the Nullarbor, during which his foreman Baxter was killed by natives. On 2 June 1841 he was saved by a French whaler the *Mississippi* under Capt. Rossiter-which had earlier visited Port Lincoln and which was lying at anchor in Thistle Cove near Esperance. After resting he continued on to Albany arriving on 7 July. On 13 July Eyre returned in the *Truelove* to Adelaide arriving on 26 July when he was enthusiastically received.

Eyre had not discovered any areas of perceived productive land, nor had he made any other important discoveries. But as well as his courage and ability as an explorer indicated by these voyages, Eyre showed for the first time the nature of the country crossed.

Cummings and Harris

In late August 1843 two former seamen, Cummings and Harris left the whaling station at Fowlers Bay to walk to Port Lincoln, which they thought was about 320 km away (in reality it is about twice that distance). Carrying 10 days' supply of food the two men called at the whaling stations opposite St Peter's Isle and at Streaky Bay and then set out for the south, at first sticking to the coast. But they found water scarce, and so, at Anxious Bay struck inland, passing by Lake Newland and after two days came to Mt Wedge. There was running water and the park-like green grasslands there and for 80 km to the south greatly impressed Cummings and Harris. They reached Point Drummond where they fell in with the *Governor Gawler* which took them to Port Lincoln after a journey of more than three months. Their report of excellent country helped revive interest in the Peninsula and in time remove the prevailing impression that the country was barren and unsuitable for habitation. It stimulated speculation as to the nature of the interior: the coastal areas were known, and were considered of mixed merit, but what of the 34 000 or so square kilometres of the inland south of the Gawler Ranges (South Australian Register 16 and 20 December 1843; South Australian 15 December 1843; Smith 1843).

John Charles Darke

With the Peninsula evidently unfavourable, the settlers' eyes turned to the north, to the Gawler Ranges, and two expeditions, those of Darke and Hack, were sent to prospect. But they travelled by way of the Peninsula and so added to the knowledge of the interior regions. Darke (circa 1806-1844) was born in England and emigrated to Tasmania in 1824. He studied surveying and went to a sheep station in the Geelong area of Victoria but returned to his profession, being appointed assistant surveyor of South Australia in 1838. He later went into private practice and was appointed to head a privately financed expedition to Eyre Peninsula and the Gawler Ranges in 1844. The expedition was to "proceed to the country lately described by the whalers J. Cummings and J. Harris and thence Northward crossing the Gawler Range and in such directions as in the judgement of the gentleman in charge may be thought desirable ... " It was intended that Darke's party should "determine the nature and capabilities of the land in order to determine the propriety of taking stock to, and forming communions at the various harbours of the extensive portion of South Australia" (South Australian Register 14 August 1844).

The funds whereby to finance the expedition were to be raised by public appeal. In the advertisements Darke was described as a "gentleman of great talents and experience" but this was apparently not enough for although £150 ($300) was required only £90 ($180) had been raised by the time Darke left Adelaide and by the end of the year with the expedition long since over and Darke dead, the organisers were still £20 ($40) short of the target.

Darke is an enigmatic minor figure in the history of exploration. His journal is poor, and no map of his journeys survived the expedition. He did not carry out instructions concerning the aims of the expedition. He may have been talented and experienced but to proceed into country that had not been travelled before, but which was likely deficient in supplies of fresh water, without horses, was insane. Nevertheless his gory end attracted sympathy, and the ambiguities of his published journal (compounded by the lost route map-for surely as a surveyor he must have made one) the disappearance of the original day to day records, and the unjustifiable speculations of later workers, all combine to make Darke's expedition one of some little interest.

Darke's grandly named North Western Exploratory Expedition left Adelaide on 12 August 1844, and is commemorated by a plaque on the CBA Building on the western side of King William Street, between North Terrace and Hindley Street. Proceeding by ship to Port Lincoln (where in Flinders Court a memorial to Darke reads "speared by natives at Waddikee Rocks, 23 October 1844"), the party, consisting of Darke, Theakston as his second-in-command, two other men and a bullock-drawn dray, left the little seaport on 29 August and travelled northwest, at first through known territory, by way of Lake Wangary, Marble Range, Lake Hamilton and Sheringa to Wedge Hill (Mt Wedge) which they reached on 10 September without any serious difficulties (Twidale 1974). In a way it is a pity that he did not have problems for it might have persuaded him to get horses, without which he lacked the flexibility to reconnoitre ahead for water and good going, while he was in settled districts. He had learned nothing from Eyre's experiences which though not yet published must surely have been a talking point in the isolated Australian community.

Nevertheless, at this stage all was well. Like Dutton and Eyre before him Darke liked what he saw west and northwest of Port Lincoln: he noted "a very rich piece of land", and a lake "surrounded by an excellent land". Only a short distance to the north, near Marble Range he was talking of "barren country", and "barren sandy country", but the "whole of the country between Mt Greenly and Wedge Hill, a distance of 40 miles (64 km) to the west appeared to be an excellent sheep and cattle country" *(South Australian Register* 13.xi.1844).

After burying a cache of two bags of flour against the anticipated return journey Darke proceeded toward a high peaked hill located "north 30° east" of Mt Wedge. On arrival he found it to be of granite and named it after his friend, a Mr Southam. He then continued on to Granite Mount situated about 32 km from the Gawler Ranges and with excellent feed and water. Subsequent events make it clear that Darke's Granite Mount is Mt Wudinna but, and this is a good example of Darke's propensity for ambiguity, it is this hill and not Mt Southam that bears 30° east of north from Mt Wedge. There is no other prominent peaked granite hill along the bearing. Mt Southam is generally reckoned to be Cocata Hill (and it may well be, though the nearby Ucontitchie Hill better fits the description of peaked) but it does not bear 30° from Mt Wedge. Almost certainly Darke sighted Mt Wudinna from Mt Wedge and knowing that water is frequently to be found in association with hills, made for it. He did not proceed directly across the mallee plains, where water was likely to be scarce or absent, but rather made a dog-leg by going to Mt Wudinna by way of another group of hills, which include Ucontitchie and Cocata, where he hoped for water. Unfortunately Darke did not record events in his journal, only his overall intentions.

Further confusion was introduced long after Darke's death by Harris who, summarising the journal as published in the *South Australian Register* of 13 November 1844-the original diary was evidently in the keeping of J. B. Neales of Port Lincoln but cannot be traced-stated that the party travelled on a bearing of 3° north from Mt Wedge. This was roughly the bearing of the first leg of the dogleg to Mt Southam, but he did not continue on it for he definitely went to Mt Wudinna. He made it the base from which he journeyed on into the Gawler Ranges, and, after his return, from which he departed for the east coast and, hopefully, Port Lincoln. To suggest otherwise makes nonsense of the rest of the diary. Nevertheless Harris (1909) has Darke and his companions marching just a little east of north from Mt Wedge, and despite the lack of corroboration in the diary entries, through the Minnipa district with its numerous granite outcrops and associated water supplies (see below) to a high porphyritic hill named by Stephen Hack, Mt Granite, and taken by Harris to be Darke's Granite Mount; but the porphyritic hill described by Hack was in the southern crawler Ranges, not south of it as it must have been in order to fit Darke's schedule.

After recuperating at Mt Wudinna for a few days on the soak there and also allowing his bullocks to take advantage of the good natural pastures, Darke and his party set off northwestwards toward a high peak of the southern Gawlers, Mt Sturt. They had to battle through deep sands and thick scrub, as well as negotiate the boggy margins of salt lakes. It was hard going and the party made only 32 km in three days. But on 7 October they crossed Eyre's 1839 dray tracks just south of Mt Sturt and they spent eight days exploring the Gawler Ranges before retracing their steps to Mt Wudinna. It is not known precisely where they went in the Gawlers, but they saw huge salt lakes and were not favourably impressed by the country. Returning to Mt Wudinna, they again recuperated and on 20 October left the base that had served them so well, as it had served the Aborigines much longer. Instead of heading for their cache at Mt Wedge, however, Darke evidently thought that the prominent group of uplands comprising Caralue Bluff, Carappee Hill and Darke Range visible from the crest of Mt Wudinna, were table topped peaks described by Eyre on his 1840 trip down the east coast. Darke no doubt thought to join his track and return to Port Lincoln through country which if not exactly known had at least been travelled before and therefore held no startling surprises. He headed south 55° east, and apart from heading for the landmarks, this bearing also took them along easy going country in the corridors between the NW-SE trending fixed dunes. On 21 October the party deviated eastwards from this route to take advantage of water to which they were led by an Aborigine. They watered next morning and then went on until about 2 o'clock in the afternoon when they came to:

> "a large gritstone rock where I found an abundance of feed and water on a plain about 200 yards (180 m wide) by a half a mile (0.8 km) long surrounded by thick scrub" *(South Australian Register* 13.xi.1844).

About 8 o'clock next morning Darke was speared three times-one spear entered his abdomen and passed right through his body-and he died late next day near Darke Range whence his party, now under the command of Theakston were heading, and where Darke was buried. Theakston and the others continued on toward the east coast and following Eyre's tracks during the later stages

,

arrived in Port Lincoln on the last day of October 1844.

Fig. 2. Plaque from memorial to J. C. Darke at Waddikee Rocks.

Traditionally Waddikee Rocks is the site of the fatal spear attack, and there is indeed a monument and plaque alongside the Eyre Highway at Koongawa (Fig. 2). But comparing the journal and the landscape, and the landscape and the schedule as indicated by the journal, it is clear that Waddikee Rocks is the place Darke and his party watered on the morning of the 22nd-the soak is still there though it is, deliberately, well hidden-and Middle Rock, which fits the diary description perfectly, is where Darke had his last camp on the night of 22-23 October, and where he was so inexplicably and brutally attacked.

The North Western Exploratory Expedition achieved little and ended in tragedy. The expedition was badly planned and left much to be desired in execution; but Darke emerges as a courageous and tenacious figure who for all his faults deserves praise and sympathy.

Stephen Hack

With his elder brother, John, Stephen Hack migrated from Gloucester, England to South Australia in 1836, arriving in February 1837. He had a chequered career and retired to his birthplace and died there in 1874, aged 78.

Hack led an expedition to examine the northwestern interior of the province of South Australia. His fee was £300 ($600) with a further allowance of up to £300 "proportionate to the value the Government may attach to the result of the expedition" (Hack 1857).

In May of 1857 Hack journeyed up the west coast of the Peninsula from Port Lincoln. He listed the places through which he passed and apart from mentioning good water-except one well near Cooeyana, the water from which was "not drinkable by Christians unless in extremity" (Hack 1857, p. 3)-and feed, what is interesting is that he mentions that in several areas, e.g. Lake Wongaree (Wangary) and Kyana Swamp the feed was already "eaten bare by sheep" (Hack 1857, p. 3). He was hopeful of finding good land to the north:

> "from all the information I can gather, I am convinced of the existence of a fine country in the interior but I imagine it is situated a considerable distance to the north" (Hack 1857, p. 2)

On 22 June he left his base near Streaky Bay and travelled east to Parlia. He explored the Minnipa district, where he mapped and recorded (Fig. 3) the native names of several of the well known granite hills of that area: Tcharkledoo or Tcherlkedoe or Tcharkulda (here and in other instances different spellings are used on the map and in the text - the hill in question is also known as Tcharkuldu), Yarwandutta or Yarwondutta, Minnepah or Minnipe (Minnipa), Warwar or Wauwau or Wow Wow, Pidinna or Podina, Chilpuddie, Moolje and Peldubba or Peeldubba or Gemini Rocks (Pildappa). He then travelled north along the western border of the Gawler Ranges to Yarlbinda where he was advised by his native guide that there was insufficient water for horses for a very long distance northward. Hack's route therefore diverted to the east in search of a large lake reported by the natives which took him through the Gawler Ranges to the shores of Lake Gairdner and along the western shore of which he hoped to find a passage to the north. The natives refused to go northwards and Hack was forced to leave the "unlikely looking country" (Hack 1857, p. 9), and try to discover a practical route for stock from Port Augusta to the good pasture he had discovered to the west and south of the Gawler Ranges.

He continued through the southern Gawler Ranges past Yardea, Mt Nott and Mt Ive, naming a Freeling Range to the south (probably Uno Range) before passing the Baxter Hills and Iron Monarch en route to Port Augusta, Mt Remarkable on 19 September, and thence to the settled areas.

Hack regarded this expedition as preliminary to the exploration of the interior. He was satisfied that the true route to the interior would be found between Lake Torrens and Lake Gairdner. During this journey, however, he found and noted on the map, extensive and good country with sufficient water to warrant its immediate occupation as pasture land (Hack 1857).

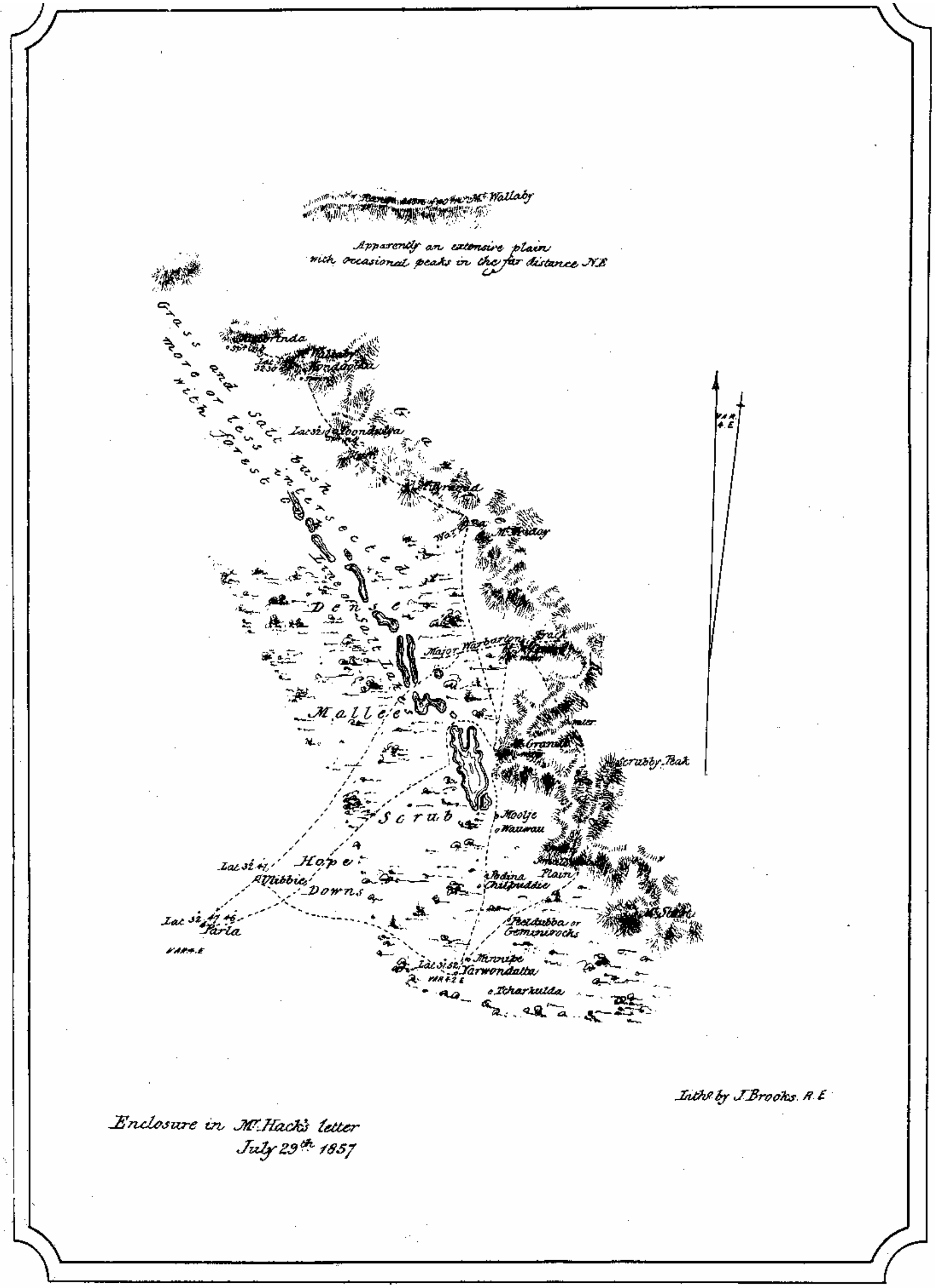


Fig. 3. Stephen Hack's map of the present Minnipa district depicts several features that are instantly recognisable—high hills in the south-western Gawler Ranges such as Mt Sturt, Mt Granite and Mt Centre; the line of salt lakes standing in the Corrobinnie Depression; and several well-known inselbergs such as Yarwondutta, Chilpuddie, Tcharkulda and Peeldubba (Pildappa). (From SAPP 156, 1857).

Warburton, in 1858, travelled from Mt Wedge northwards to the Gawler Ranges and beyond. He reported poor grass on these parts of Eyre Peninsula, but the main limiting factor was the very poor supply of water for stock. He discounted Hack's prediction of pasture for thousands of sheep and judged:

> "the experiment far too hazardous for any but a man who had more sheep than he knew what to do with" (Warburton 1858, p. 40).

The seasonal conditions varied resulting in the opposing reports of the value of the land.

Similarly varying seasonal conditions resulted in contrasting reports of the area north of Denial Bay. Miller and Dutton explored this area in 1857. Their journey was reported by Harris (1858) who spoke highly of the grass seen but noted that permanent water was absent away from the coast. In the following year Geharty was sent to check on these findings and he gave an opposite report of the same country under different seasonal conditions (Somerville 3.vii.1936).

Between 1860 and 1900 little disturbed the natural landscape of Eyre Peninsula. True, farming prospered in the south and in the coastal regions. Shepherds took their flocks inland. Two pastoral stations, at Kolballa and Mt Wudinna (Weedinna), were established inland, both on natural soaks related to granite inselbergs. But the vast interior remained essentially untouched and untapped.

SUBSEQUENT DEVELOPMENT

Apart from the better watered southern areas and some of the coastal zones that were readily accessible by sea and (in the west) possessed fairly accessible supplies of underground waters, the greater part of Eyre Peninsula was perceived as being barren and useless. Even Goyder's Line drawn in 1865 suggested that much of the northeast was unsuitable for agriculture (Fig 4)

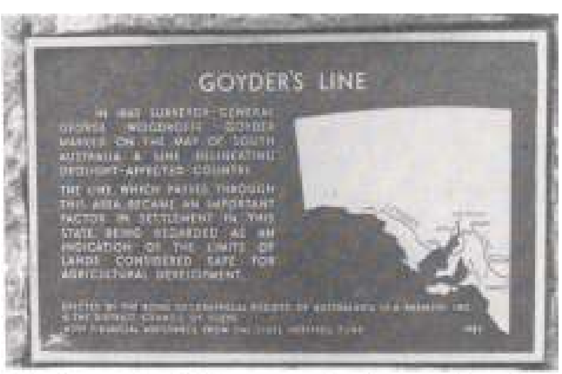


Fig. 4. Goyder's Line as depicted on a plaque just west of Cleve.

That this interpretation was ill conceived, based as it was on ignorance of the true nature of the land and in values and attitudes that had their foundations in the very different physical landscapes of Britain and Western Europe is now abundantly clear. One has only to subject Eyre Peninsula to a casual inspection to appreciate that here is one of the most productive areas in South Australia.

What caused the change in attitude implied in the contrast between the explorers' view of Eyre Peninsula and the present reality? Three factors are mainly responsible: human ingenuity, honest sweat and the experienced gained in other mallee lands in the State. The opening up of Yorke Peninsula, the Adelaide Plains and the western Murray plains demonstrated that agriculture could be a paying proposition in such areas. As in other mallee lands the desert dunes are a relic of the past and do not reflect the modern climatic mean. The soils are not naturally fertile, but though commonly stony, they are, by and large well drained and of good texture. The thick scrub presents no problems that are not soluble by hard work and modern machinery.

Given reliable supplies of water for stock (which in the early years of settlement included the draft animals that provided the power in the paddocks) much was possible, but the situation was not promising at first sight. The markedly seasonal rainfall, the long dry and hot summer, and the uncertainty of even the winter rains, posed serious problems for both the pastoralist and the would-be farmer. It will be recalled that as early as 1857 Hack had reported that at Lake Wangary, Kyana Swamp, Sheringa and Gum Tree Flat the feed had been eaten bare by the sheep (Hack 1857), testimony not only to the lack of soil moisture but to the poor quality of the natural pastures. Water was available at shallow depth in the limestone areas of the west coast, and there were supplies to be had also in the gnammas or rock basins of the granite inselbergs of the northwest. Some soaks such as those at Mt Wudinna and Kolballa were permanent, but even taken together such supplies were limited in amount and unreliable: they formed no fit basis for settlement and development.

Another problem was posed by the distance of much of the interior from the coast. A way had to be found of transporting any produce to the ports and harbours, and of taking imported goods to the townships and homesteads that the visionaries saw being established inland amongst the fields of grain.

These impediments to progress were tackled head on by the State Government of the day. As

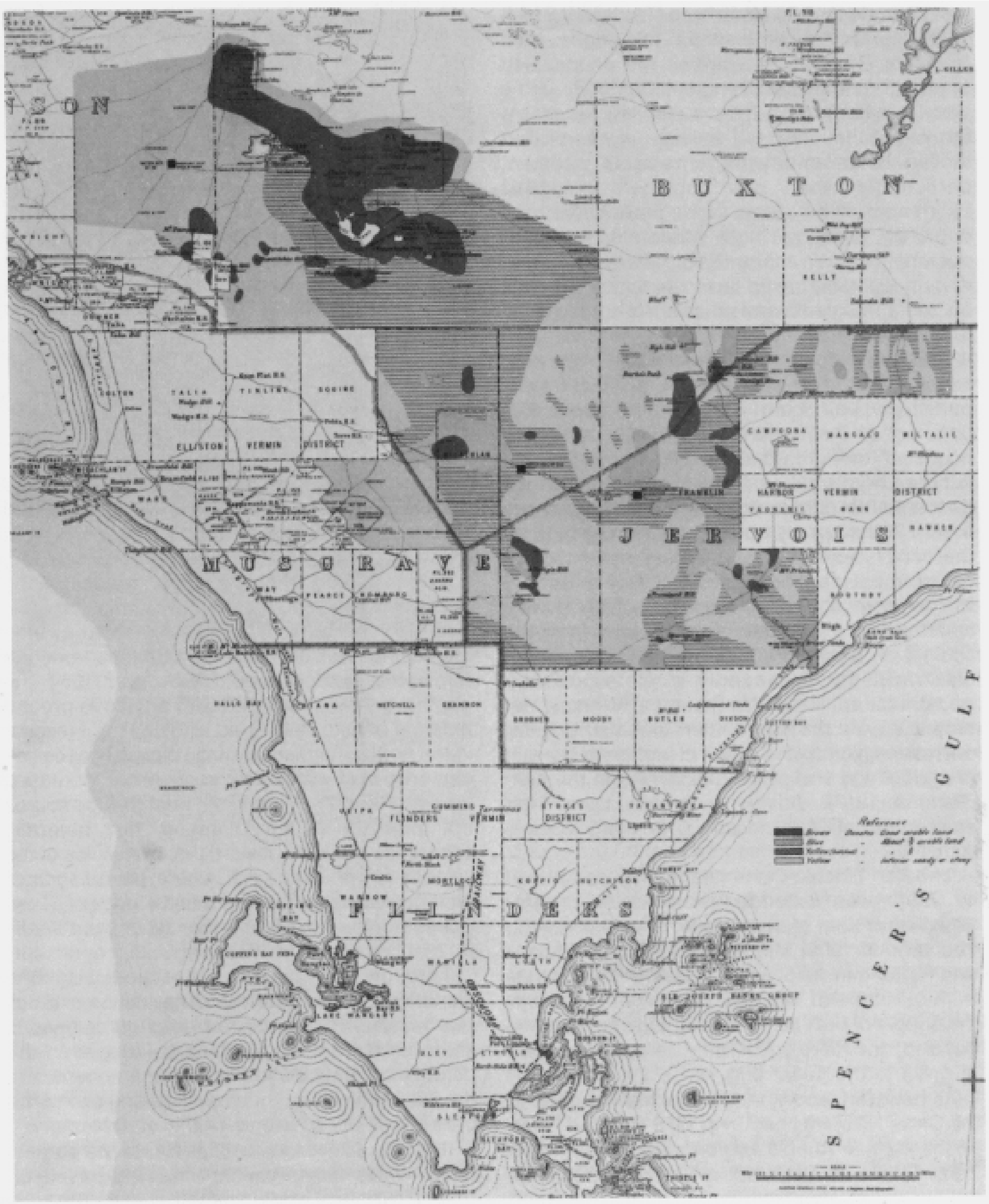


Fig. 5. E. B. Jones' map of 1906, showing his assessment of the mallee lands of northern Eyre Peninsula: the darkest shading depicts what he thought were the best lands, the light shading the poorer, and the lined areas are of intermediate quality. Jones' assessment proved astute. (SAPP 58 1906).

has been described elsewhere (Twidale & Smith 1971) the Government sent E. B. Jones, then Surveyor General, to examine the unoccupied lands of central Eyre Peninsula in 1906, with a view to establishing their suitability for arable farming. Stimulated by developments in other mallee lands and with remarkable acumen, particularly when one considers the little information at his disposal, he produced a map depicting areas of high, moderate and .poor potential (Fig. 5; Jones 1906). His assessment was undoubtedly based on the experience gained on Yorke Peninsula and elsewhere, but his good opinion was encouraged by the assessments of those few agriculturalists and pastoralists with experience of the inland areas. W. A. Barns in particular was both enthusiastic about the potential of the region and realistic as to the needs of the area before development could succeed. (It is interesting to note that Barns' descendants continue to make a living in the area!). Water supply and transport were high on the list of prerequisites for development. The Government went further and helped materially in three ways, for in addition to building a railway, constructing a pipe line to carry water from the Tod River Reservoir and utilising many local catchments for local supply, it also established an Agricultural Research Station at Minnipa, not only to advise the new settlers but also to carry out research on a wide range of problems relevant to agricultural and pastoral activities in the area (Perkins 1917). Advisory centres were later established at Port Lincoln, Cleve and Streaky Bay.

The Port Lincoln-Cummins railway, completed in 1907, was extended northwards roughly equidistant from east and west coasts, reaching Yeelanna in 1909, Minnipa in 1913 and Ceduna and Penong in 1915, and an eastern branch was built to Kimba in 1913, thus facilitating not only the supply of bulk items to the inland settlements but also, and more importantly, allowing transport of grain to the coast (Fig. 6).

As to water supply, the Yeldulknie Scheme, in the Cleve Hills, was begun in 1913. The Tod River, in the higher rainfall region of southern Eyre Peninsula, was dammed in 1922 and pipelines built to carry water from the reservoir so formed to the dependent areas of the north. The pipeline reached Minnipa in 1926, Ceduna in 1929 and Kimba as recently as 1973. This pipeline served the region well. But it was constructed of cast iron, and placed underground. Very quickly it, and especially the trunk section between Knotts Hill and Minnipa, became costly to maintain, for the pipe had been corroded from the inside by the infamous "hard" or saline waters of the Tod supply and from the outside by alkaline soil moisture. Between 1936 and 1968 attempts were made to recondition the pipeline by putting in a concrete lining that although reducing the diameter nevertheless improved flow. Even this was not enough however. Demand was increasing as agriculture extended on the Peninsula, and between 1961 and 1964 the original line was replaced with an above-ground pipeline of mild steel lined with concrete (except in the north where some of the pipe is of asbestos cement), and with many sections of increased diameter (Fig. 7). In the south near the Tod source the pipe is 84 cm diameter but naturally decreases gradually toward the extremities of the system-save near Lock where for reasons of historical accident there is a bottle-neck of 51 cm diameter pipe-to 69 cm, then 61 cm and finally to 25.4 cm diameter.

Fig. 6. The railways constructed on Eyre Peninsula proved essential to the development of the cereal industry, and silos as well as 'temporary' storages (see here at Wudinna) have been built at numerous settlements, large and small, along the iron road.

Through the nineteen twenties also the Department undertook the construction of small but locally important conservation schemes, some using run off in natural valleys, as in the Yeldulknie, Ullabidinie and Ulbana schemes in the Cleve Hills (Fig. 8), others making use of the bare granite catchments of the northwest.

It is interesting to note that two of the earliest small water conservation schemes based on granite hills were at Minnipa Hill where a reservoir to supply the railway's steam engines was constructed in 1913, and at nearby Yarwondutta Rocks where a reservoir was established in 1916 on the Agricultural Research Station to provide water for the draft animals.

These minor but locally significant conservation schemes were and remain minor engineering delights. The water is prevented from spreading

Fig. 7. The provision of water for stock and for other purposes was another boost to the settlement and development of the Peninsula. But the waters of the Tod Reservoir proved too corrosive for the first pipeline constructed, and it has been gradually replaced and enlarged. The two, the old and the new, are seen side by side here between Minnipa and Ceduna. (E and W S Department).

from the bare rocky hillslopes on to the adjacent plains by low retaining walls so levelled that the water runs under gravity into channels and thence into huge tanks, usually of 2275 million litres (0.5 million gallons) capacity (Fig. 9).

Though some of the early schemes (Kolballa, Yarwondutta) had the reservoir close up to the hill base (Fig. 10), this was found to be less suitable from an engineering point of view than placing them downslope and building a circular tank wholly or largely above ground. Such schemes were constructed at many sites during the twenties and for a few years before and after that decade of the Depression-at Pildappa (Fig. 11), Mt Wudinna, Peella, Cocata, Pinbong, Poldinna, Polda, Tcharkulda, Pygery and so on. What a pity that so many of these schemes have been allowed to fall into disrepair! The Government initiative has been emulated however by many farmers who have constructed reservoirs (most of them close to the hill base) at such sites as Ucontitchie, Dumonte, Chilpuddie and so on. Many of these private schemes are of relatively recent date but one at Kolballa is amongst the earliest on the Peninsula.

On the other hand an area around Cummins had too much water, and again the Government intervention was necessary, there in the construction of drains to run water out of the fields.

Later underground supplies were tapped by the Engineering and Water Supply Department in various basins including Uley-Wanilla, Lincoln, Polda, Robinson and Bramfield basins, to augment the Tod Scheme (Chapter 7).

Scientific agriculture has come to the fore since World War II (Bicknell 1970). New techniques have been evolved for clearing scrub quickly and efficiently (though not cheaply). New pastures such as the medics have been developed that are especially suitable for sandy country. Application of superphosphate is now standard practice. Insect pests have been retarded if not eradicated, and fungal diseases also have been tackled with varying degrees of success. The clearing of sand ridges is now controlled in the interests of soil conservation. Mechanisation of farming has allowed the areas cultivated to be increased ten or twenty fold since World War II with all that that implies for farm size, social organisation of settlements and so forth. Thus the many abandoned homesteads one sees on the Peninsula in part reflect the capability of farmers to work larger areas, with consequent increase in farm size; but social and economic expectations also play a part in this process. Some abandoned homesteads are a reflection of the consolidation and increase in farm size. Others are reminders of bad times, notably the Depression of the late 'twenties' and 'thirties' when many were driven from the land, but then the great community spirit of the West Coast showed through, not least in neighbour helping neighbour, and in the extended credit allowed some lucky farmers by store-keepers in such centres as Cowell, Streaky Bay and elsewhere.

In addition to farming, fishing has developed apace especially in the areas of tuna and abalone. Oyster farming (at Coffin Bay) is also noteworthy for the gastronome. There were several small mining ventures for gold and copper in the Lincoln Uplands in the early years but none amounted to anything (Chapter 3). But on the other hand, the mining of iron began at Iron Knob in 1899 and led to the development of a large industrial complex at Whyalla as well as to an export trade. The jade quarries in the Cleve Hills form the basis of a small but interesting industry. The most notable recent development however

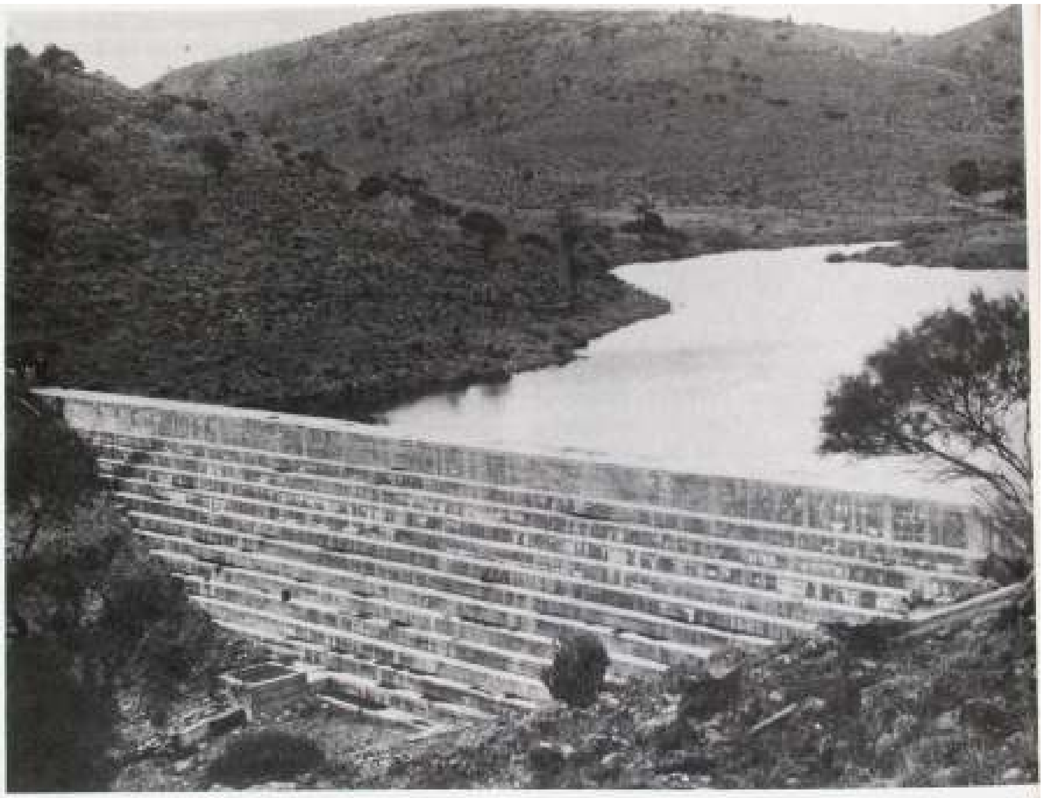


Fig. 8. The Ulbana Reservoir is a small but locally important water storage constructed by the State Government in the Cleve Hills. (E and W S Department).

Fig. 9. Many of the granite outcrops of northwestern Eyre Peninsula provide excellent catchments, for the massive rock of which they are made is essentially impermeable. The State Government utilised many of them for water conservation and supply. Pildappa Hill is a typical example of such a local but important conservation scheme. Low walls have been built around the lower margins of the hill. Run off is thus diverted into channels carefully levelled so that the water runs under gravity into large tanks or storages.

Fig. 10. This small storage was built at the base of Kolballa Hill. Though it leaks it nevertheless still holds water for many weeks and is therefore useful in this dry country.

Fig. 11. Ruins of abandoned homestead, south of Minnipa. Note the materials used—corrugated iron and local split timbers, and of course the rain tank.

is the development of the tourist industry for the scenery of Eyre Peninsula, and especially its coastal scenery, and opportunities for fishing and other sports, are a major attraction.

In the following chapters various aspects of the various and varied natural environments of the Peninsula are discussed in some detail They form an essential background to any consideration of the present economy of the Peninsula for they place constraints on man's use of the area as well as offering opportunities for the willing and able.

REFERENCES

Angas, G. F. (1877). Port Lincoln in the Olden Times. "Colonies" London *In Royal Geographical Society of Australia,* SA *Branch Proceedings,* 21, (1920-21), 35-39.

Bicknell, K. G. (1970). Agticulture in South Australia: Lower and Eastern Eyre Peninsula. *S.A. Dept. Agriculture Extension Bulletin* **34**, 70.

Coleman, F. (1917). Report of chairman of Advisory Board of Agriculture. SA *Parliamentary Paper* **43A**, 6

Douglas, B. (1858). Survey of Coast between Point Fowler and Kangaroo Island. *S.A. Parliamentary Paper* **120**, 2-5.

Dutton, C. C. (1839). Port Lincoln. SA *Gazette and Colonial Register* 20.iv.1839, 2-3.

Eyre, E. J. (1842). Report of Mr Eyre's Expedition in Search of C. C. Dutton of Port Lincoln. *South Australian* 11.xi.1842.

Eyre, E. J. (1845). 'Journals of expeditions into Central Australia' Vol. 1 (Borne, London).

Gawler, G. (1839). Letter to Edward John Eyre. SA *Government Gazette* 7.xi.1839, p. 1.

Hack, S. (1857). Explorations by Mr Hack. SA *Parliamentary Paper 156.*

Hailes, N., no date. Manuscript on the South Australian aborigine. Part C. The Search for C. C. Dutton's party. SA Archives, 20M.

Harris, C. H. (1909). SA Lands Dept. Docket *434/09.* Harris, W. G. (1858). Report of journey by Miller and Dutton. SA *Parliamentary Paper* ***192.***

Johnston, (1839). Letter to Captain Walker *In* Some Notes relating to the First Settlement of Port Lincoln. *Royal Geographical Society of Australia,* SA *Branch, Proceedings* **17** (1917), 113-133.

Jones, E. B. (1906). SA Parliamentary Paper **58**, p. 1.

Neales, J. B. (1841). Port Lincoln and its neighbourhood. *South Australian Magazine,* November 1841.

Perkins, A. J. (1917). Report of Director of Agriculture. 1915-16 Season. SA *Parliamentary Paper* **43**, p. 10.

Price, A. G. (1924). 'Foundation and settlement of South Australia 1829-1845' (Preece, Adelaide). p. 147.

Smith, M. (1843). The Country Westward of Port Lincoln. *Southern Australian* 22.xii.1843.

Somerville, J. D. (1934-1940). Early Days of Eyre Peninsula. *Port Lincoln Times.*

South Australian Register, 16.xii.1843. Progress of Discovery Westward of Port Lincoln. 20.xii.1843. Progress of Discovery Westward of Port Lincoln. 13.xi.1844. The Late Mr John Darke's North Western Exploratory Expedition.

South Australian Association (1834). 'Outline of the Plan of the Proposed Colony to be found on the South Coast of Australia.' (Ridgway & Sons, Piccadilly, London). (Facsimile: Austprint 1978 Hampstead Gardens, S. Aust.).

Tod, R. (1839). Some Notes relating to the First Settlement of Port Lincoln *in Royal Geographical Society of Australia, S.A. Branch, Proceedings* **17** (1917), 113-133.

Twidale, C. R. (1974). J. C. Darke's North Western Exploratory Expedition of 1844. J. *Royal Australian Historical Society* **60**, (1) 28-47.

Twidale, C. R. & D. L. Smith (1971). A 'Perfect Desert' Transformed. The Agricultural Development of NorthWestern, Eyre Peninsula, South Australia. *Australian Geographer* XI, 5, 437-454.

Warburton, P. E. (1858). Report of Tour of Inspection by Major Warburton. SA *Parliamentary Paper* ***25,*** 38-42.

2: Geology

by A.J. PARKER, C.M. FANNING and R.B. FLINT

INTRODUCTION

Early descriptions of the geology of Eyre Peninsula by Tate (1882), Brown (1908), Jack 1914, 1922) and Tilley (1920a, b; 1921a, b) recognised the antiquity of crystalline rocks forming the hills in the Port Lincoln, Tumby Bay and Cowell-Cleve regions. They noted the complex geological processes to which those rocks have been subjected, and Tilley's work in particular demonstrated that the rocks had once been deeply buried within the earth's crust, and subjected to very high temperatures and pressures. The region has since been uplifted at least once to form mountain chains, then subsequently eroded, and the sediments transported and deposited in basins such as in the Adelaide Geosyncline 1100-600 million years ago, then recycled and deposited in Spencer and St. Vincent Gulfs.

Numerous refinements have been made to this concept (Miles 1955; Johns 1961) but none so dramatic as those resulting from newly developed concepts and techniques in structural geology and isotopic dating. These developments have allowed a relatively precise determination of the absolute age and evolution of the rocks.

The following account is a summary of the geological evolution of Eyre Peninsula. However, even now, over 100 years after the first descriptions of the area, many questions remain unanswered about the geological history of this fascinating region which contains some of the most ancient and valuable mineral deposits in South Australia.

TECTONIC SETTING

Eyre Peninsula is part of a major tectonic province known as the Gawler Craton. The Gawler Craton includes Yorke Peninsula, the Gawler Ranges (from which it derives its name) and that vast region of central South Australia extending west of Lake Torrens north to Marla, and as far west as Ooldea. The Gawler Craton extends southwards to the outer edge of the continental shelf, but, prior to the break-up of Gondwanaland, was linked to Antarctica near Commonwealth Bay.

The Gawler Craton is defined as a geologically stable part of the Earth's crust that has not been subjected to major tectonic forces since 1450 Ma (Ma=million years before present). Its boundaries are defined by those crustal regions which have been active or deformed since that time: the Adelaide Geosyncline or Adelaide Fold Belt represented by the Mt Lofty and Flinders Ranges: was tectonically active until about 460 Ma and defines the eastern margin of the Gawler Craton; the Musgrave Block has been active since 1450 Ma and defines the northern margin; the edge of the continental shelf, formed about 125 Ma defines the southern margin.

The evolution of the Gawler Craton can be traced back to at least 2700 Ma. Older rocks are not known either on Eyre Peninsula or anywhere else In the Craton. The oldest gneisses of the region probably were formed from sedimentary rocks deposited on the margin of a much older craton that was possibly connected to the Yilgarn Block In Western Australia. Subsequently younger sediments and volcanics were accumulated essentially from west to east. When the Gawler Craton was stabilised about 1450 Ma ago the processes of accretion continued progressively further to the east, first in the Adelaide Geosyncline and then in the Tasman Fold Belt that constitutes much of eastern Australia.

GEOLOGICAL HISTORY

The geological evolution of Eyre Peninsula spans 2700 million years and represents the most complete record preserved in South Australia. The oldest rocks on Eyre Peninsula are of late Archaean to earliest Proterozoic age (about 2700 - 2300 Ma) and are known as the Sleaford Complex. They are similar to Archaean rocks known from other parts of the world and have suffered a number of complex metamorphic, igneous and deformational events that have transformed them into a series of contorted gneisses.

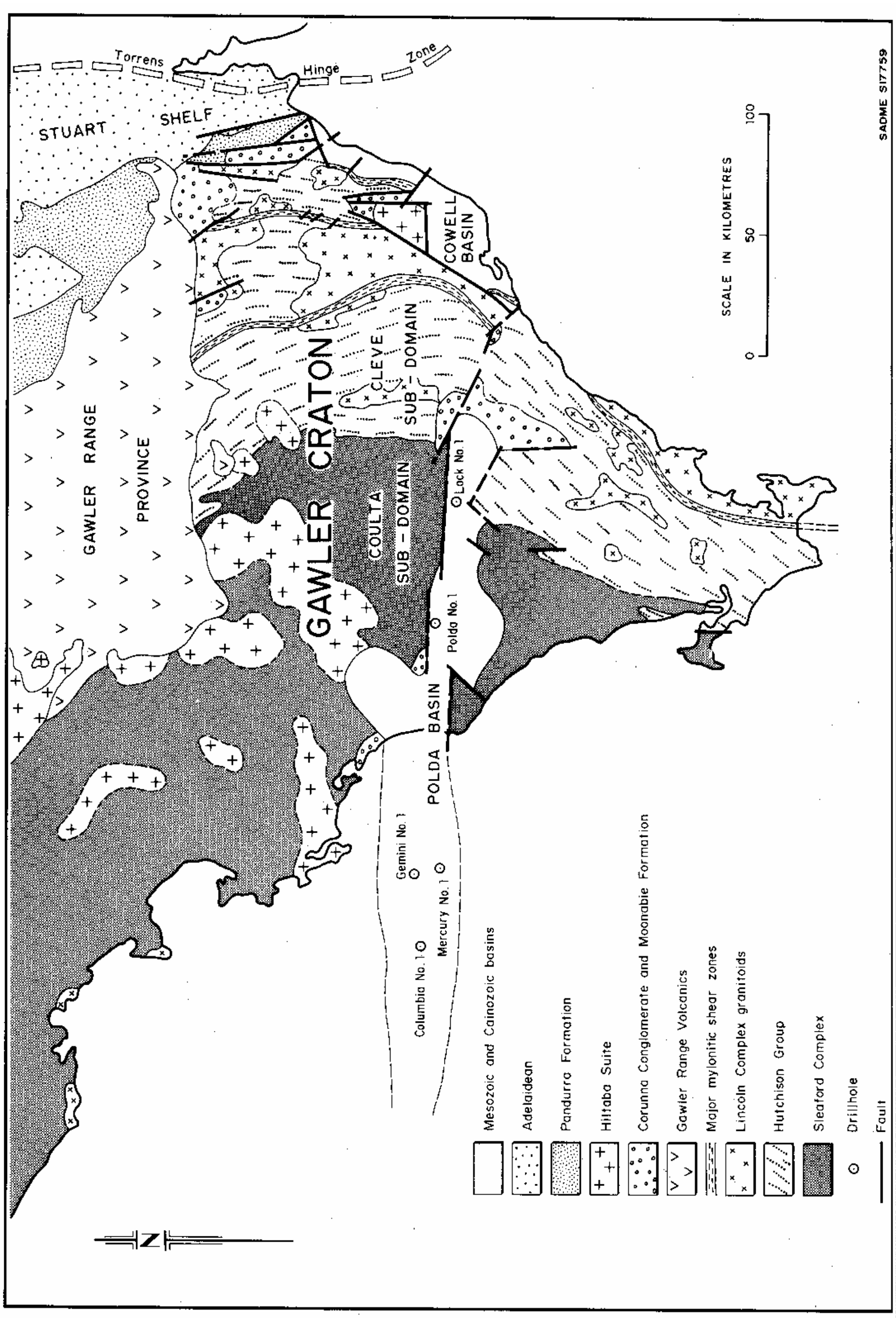
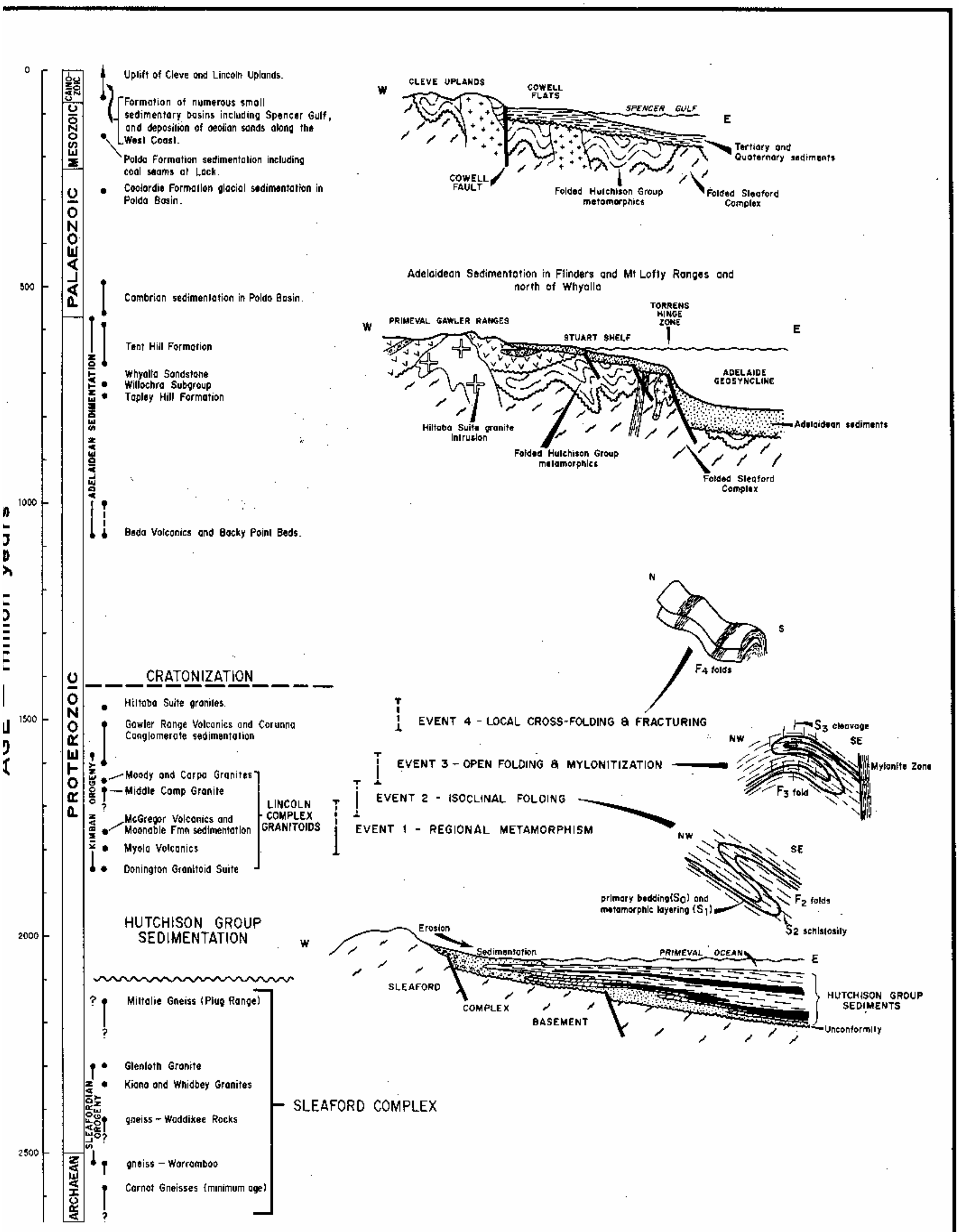


Fig. 1. Tectonic sketch of Eyre Peninsula.



2. Geological evolution of Eyre Peninsula based on Rb-Sr age determinations.

These gneisses are overlain by a sequence of iron-bearing sediments known collectively as the Hutchison Group (Table 1). Iron ore of the Middleback Range is well known but the rocks re also prospective for many other minerals and metals including jade, marble, copper, lead, zinc, silver, uranium and manganese.

Stratigraphic relationships between the Hutchison Group and Myola Volcanics in the immediate vicinity of Iron Baron are not known,

Table 1. PRECAMBRIAN STRATIGRAPHY OF EYRE PENINSULA.

AGE		WEST COAST	SOUTHERN EYRE PENINSULA	CENTRAL EYRE PENINSULA	NORTHERN EYRE PENINSULA: MIDDLEBACK RANGE	NORTHERN EYRE PENINSULA: KIMBA/WUDINNA REGION	
ADELAIDEAN	UMBERATANA GROUP				Tent Hill Formation Whyalla Sandstone Willochra Subgroup Tapley Hill Formation		
ADELAIDEAN	CALLANNA GROUP				Beda Volcanics Backy Point Beds	dolerite dykes	
MIDDLE PROTEROZOIC					Unconformity Pandurra Formation Unconformity		
MIDDLE PROTEROZOIC			dolerite dykes	dolerite dykes	rhyolite dykes	rhyolite dykes	
MIDDLE PROTEROZOIC		Hiltaba Suite		Charleston Granite	Charleston Granite / Hiltaba Suite	Hiltaba Suite	
MIDDLE PROTEROZOIC			CORUNNA CONGLOMERATE	Blue Range Beds	breccia (Cowleds Mbr) quartzite (Nilgenee Mbr) conglomerate	Yardea Dacite "Older" Gawler Range Volcanics	GAWLER RANGE VOLCANICS
MIDDLE PROTEROZOIC		acid volcanics granite	Unconformity	Unconformity	Unconformity		
EARLY PROTEROZOIC	LINCOLN COMPLEX	Bungalow Granodiorite	Bungalow Granodiorite	Bungalow Granodiorite	Moonabie Formation McGregor Volcanics Wandearah Metasiltstone Unconformity		
EARLY PROTEROZOIC	LINCOLN COMPLEX	granite gneissic granite migmatite gneiss	Moody Suite Spilsby Suite Donington Granitoid Suite	Carpa Granite Middle Camp Granite Minbrie Gneiss	Wertigo Granite Broadview Schist Myola Volcanics Unconformity	granite gneissic granite Volcaniclastics	
EARLY PROTEROZOIC	HUTCHISON GROUP / MIDDLEBACK SUBGROUP		Middleback Subgroup Equivalents	Yadnarie Schist		Middleback Subgroup Equivalents	
EARLY PROTEROZOIC				Upper Middleback Jaspilite (Mt. Shannan Iron Fm)	Upper Middleback Jaspilite		
EARLY PROTEROZOIC				Cook Gap Schist (Mangalo Schist and local amphibolite)	Cook Gap Schist		
EARLY PROTEROZOIC				Lower Middleback Jaspilite	Lower Middleback Jaspilite		
EARLY PROTEROZOIC				Katunga Dolomite	Katunga Dolomite		
EARLY PROTEROZOIC	HUTCHISON GROUP		Warrow Quartzite (basal pebble beds)	Warrow Quartzite (Local calcsilicate at base)	local quartzite and leucogneiss	Warrow Quartzite	
ARCHAEAN	SLEAFORD COMPLEX		DUTTON SUITE Whidbey Granite Kiana Granite Coulta Granodiorite	Miltalie Gneiss			
ARCHAEAN	SLEAFORD COMPLEX		Wangary Gneisses Carnot Gneisses			garnet gneiss	

but the latter are likely equivalent to the Moonta Porphyry which hosts the copper deposits of Yorke Peninsula.

Like the Sleaford Complex, the Hutchison Group and Myola Volcanics were complexly deformed and metamorphosed during the Kimban Orogeny. Zones of extremely high strain containing mylonitic rocks (that form due to relatively rapid, severe movements within the earth's crust) resulted from this period of deformation.

Granites were emplaced during and after the Kimban Orogeny. They underlie much of Eyre Peninsula and, apart from their value as building stone, contain traces of such metals as tungsten and uranium. Those granites intruded during the orogeny belong to the Lincoln Complex, a series of granitic, migmatitic and gneissic rocks.

The early Middle Proterozoic era (about 1600-1400 Ma) was a period of extensive volcanism on northern Eyre Peninsula and was accompanied by widespread, predominantly fluvial sedimentation. Volcanics occur at Moonabie, Mt Cooper, the Nuyts Archipelago and throughout the Gawler Ranges, together constituting one of the largest acid volcanic complexes known anywhere in the world. The occurrence of volcaniclastic grits at Moonabie and tuffaceous beds at Corunna attest to the contemporaneity of volcanism and fluvial (and locally lacustrine and shallow marine) sedimentation.

There was a local, relatively weak deformation event following deposition of the Corunna Conglomerate and extrusion of the Gawler Range Volcanics, heralding a change in the tectonic environment of Eyre Peninsula and leading to formation of the Gawler Craton.

Sedimentation on the Gawler Craton to the end of the Precambrian (about 570 Ma) was largely controlled by faulting and the relative rise and fall of sea level. On Eyre Peninsula the record of this sedimentation was restricted essentially to the northeastern area between Whyalla and Port Augusta.

Palaeozoic tectonic events which moulded the Adelaide Geosyncline into the fold belt as we now know it did not affect Eyre Peninsula. Possible Cambrian red beds and evaporites were deposited in the Polda Basin, and Permian glacials certainly occur there in the subsurface, but elsewhere on Eyre Peninsula there is no record of Palaeozoic sedimentation. The same is also true of Mesozoic sedimentation; the Jurassic coal-bearing formations near Lock in the Polda Basin constitute the only record of this era on Eyre Peninsula. Deposition of these sediments coincides with initial separation of the Australian continent from Antarctica; a more complete Mesozoic succession occurs along the continental shelf offshore.

During the Cainozoic era Eyre Peninsula was blanketed by a veneer of fairly thin, largely alluvial sediments. Several small basins developed around the margins of the Peninsula and some of these contain uraniferous lignites below marginal marine sands and limestones. However, the aerially most extensive deposits that we now see today, the surficial deposits, were formed during the last one million years of earth history. Extensive aeolian dune sands, alluvial sands, silts and conglomerates, and thin but often very tough, calcareous layers form a thin veneer rarely more than a few metres thick covering almost the entire Peninsula.

EARLY PRECAMBRIAN RECORD

Ancient Archaean to very Early Proterozoic crystalline rocks of the Sleaford Complex are exposed mainly around the southern and southwestern coastlines. They occur sporadically in the interiors west and northwest of Kimba, and between Kimba and Cowell are interfolded with Hutchison Group rocks (Parker 1983).

Along the southern coastline the Sleaford Complex is composed of two distinct elements-a highly metamorphosed, supracrustal sequence (the Carnot Gneisses, Fanning *et a/.* 1981), and a slightly younger, higher crustal-level suite of granitoids known as the Dutton Suite (Parker *et a/. 1981).*

The Carnot Gneisses (Table 2) form an extensive layered sequence consisting dominantly of thinly layered, garnetiferous quartzofeldspathic gneisses (Fig. 3). These are often intimately intercalated with thin layers of leucogneiss, biotite-garnet gneiss, hypersthene bearing felsic gneiss and basic granulite. Other less abundant but noteworthy felsic lithologies include augen gneiss, plagioclase gneiss, cordie rite-garnet gneiss and coarse to medium, even-grained, garnetiferous granite gneiss. Minor calc-silicate gneiss is also present.

Banded iron formations, which occur in similar lithologies northwest of Tarcoola (Daly *et a/. 1978),* are notably absent from the Carnot Gneisses. However near Kyancutta in the Warramboo WD1 drill hole, magnetite-bearing horizons occur within a sequence of layered garnetiferous quartzofeldspathic gneisses that could represent a more northerly occurrence of the Carnot Gneisses (Fig. 4).

Table 2. LITHOLOGICAL CHARACTERISTICS AND AGE RELATIONSHIPS OF THE EARLY PRECAMBRIAN SLEAFORD COMPLEX.

Stratigraphic unit		Lithology	Structural/Stratigraphic Relationships	Metamorphic features	Age*
SLEAFORD COMPLEX – DUTTON SUITE	Whidbey Granite	*Massive*, even-grained *granite* (locally gneissic)	Weakly foliated; relationship with Kiana Granite uncertain.	Coarse-grained granoblastic to locally porphyritic; microcline + plag + qtz + biot (or chl + sph).	2337 ± 71 Ma (Four Hummocks)
	Kiana Granite	Coarse-grained, porphyritic, *tabular feldspar*, gneissic *granite*	Foliation variable from weak alignment of tabular feldspars to augen texture; intrudes Coulta Granodiorite.	Perthite + microcline phenocrysts (up to 5 cm) in coarse-grained matrix of Kspar + plag + qtz + musc + biot	2334 ± 109 Ma (Marble Range)
	Coulta Granodiorite	Medium to coarse-grained *granodiorite* with abundant mafic xenoliths	Foliated.	Zoned plag. phenocrysts + qtz + orthoclase + biot; Xenoliths typically hbl + plag ± qtz, biot.	
	Miltalie Gneiss	Grey to pink, medium-grained, migmatic, *granodiorite gneiss* (with comformable amphibolites)	Strongly foliated parallel to banding and to D_2 axial planes; unconformably overlain by Warrow Quartzite.	Equigranular granoblastic; qtz + perthitic microcline + plag + biot ± zircon, gnt, sill.	1697 ± 65 Ma (Plug Range area) 2315 ± 175 Ma (Minbrie Springs)
	Wangary Gneisses	Massive and *layered*, grey *quartzo-feldspathic gneiss*	Foliated and locally mylonitized; intruded by Kiana Granite but relationship with Carnot Gneisses unknown.	Inequigranular granoblastic; mirco kspar + plag + qtz + biot ± musc + acc.	
	CARNOT GNEISSES	*Basic granulite*	Concordant but boudinaged; possibly originally intrusive; foliated.	Equigranular granoblastics; Opx + Cpx + labradorite + mag + ilm + qtz; retrograde hbl + biot.	
		Magnetite-bearing gneiss	Poorly banded but concordant with garnetiferous felsic gneisses; possibly original B.I.F.	Medium-grained granoblastics; plag + kspar + qtz + mag (5-30%) + biot + oord + gnt + sill.	2520 ± 163 Ma (Warramboo WDI)
		Felsic gneisses —Layered garnetiferous quartzofeldspathic gneiss	Dominant lithology of supracrustal gneisses; foliated and folded.	Granoblastic; perthitic Kspar + plag + qtz + gnt (almandine-pyrope) + biot ± zircon, mag, sill, etc;	2428 ± 94 Ma (Waddikee Rocks)
		—Augen gneiss	Coarse Kspar augen which may or may not be oriented parallel to regional foliation.	Inequigranular granoblastic; similar composition to garnetiferous gneiss.	2586 ± 131 Ma (Cape Carnot)
		—Biotite garnet gneiss	Isolated pods within augen and layered garnet gneiss.	Biot (10-20%) and gnt (up to 25%) rich ± cord, sill.	
		—Cordierite garnet gneiss	Foliated; local pegmatite veins (with up to 20% sill.).	Dark green cordierite porphyroblasts + gnt + sill + qtz + Kspar + plag.	2412 ± 72 Ma (Cape Carnot)
		—Leucogneiss	Foliated; intimately interlayered	Kspar + plag + qtz ± biot, gnt.	
		—Hypersthene gneiss	Foliated (parallel compositional layering).	Kspar + plag + qtz + hyp + gnt + biot.	

*Rb-Sr radiometric ages after Fanning *et al.* (1981), Cooper *et al.* (1976) and Webb *et al.* (in press).

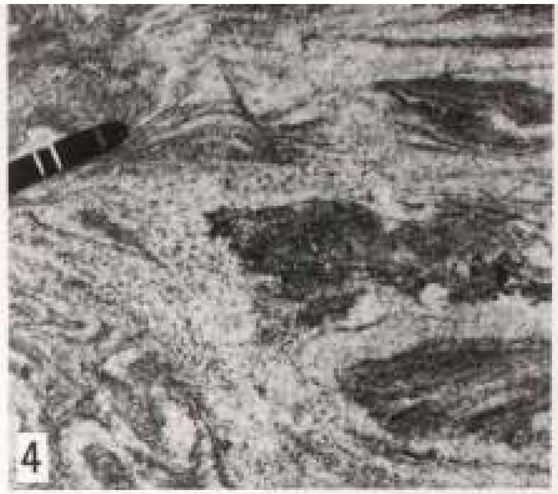


Fig. 3. Layered, garnetiferous and cordierite-garnet gneisses of the Carnot Gneiss (Sleaford Complex) exposed at Cape Carnot.

Fig. 4. Migmatitic garnetiferous gneisses (Sleaford Complex) at Waddikee Rocks. The gneisses have a Rb-Sr isochron age of 2428 ± 94 Ma.

Fig. 5. Porphyritic Kiana Granite, with its characteristic large tabular feldspars, intruding the xenolithic Coulta Granodiorite (Dutton Suite) at Mt Hope.

High-level granitoids of the Sleaford Complex, the Dutton Suite, crop out in the southwest of Eyre Peninsula and offshore in the Whidbey Islands (Webb & Thomson 1977; Fig. 5). These granitoids are intrusive into layered quartzofeldspathic gneisses (Wangary Gneisses) on Coffin Bay Peninsula and west of Lake Hamilton but their relationship with the Carnot Gneisses has not been observed. The Wangary Gneisses could represent less-metamorphosed equivalents of the Carnot Gneisses.

The Sleaford Complex is represented in the Cowell-Cleve-Kimba region by the Miltalie Gneiss, a variably migmatized, grey, medium-grained gneiss of granodioritic composition containing numerous concordant amphibolites. In the Plug Range area, the Miltalie Gneiss is structurally overlain by the Warrow Quartzite and although the gneiss has an isochron age of 1697 ± 65 Ma, it is considered to be the northern equivalent of the Wangary Gneisses or Carnot Gneisses, the Rb-Sr age in this case reflecting isotopic resetting during the Kimban Orogeny.

Table 3. STRATIGRAPHY AND LITHOLOGICAL CHARACTERISTICS OF THE EARLY PROTEROZOIC HUTCHISON GROUP AND ASSOCIATED ROCKS.

Stratigraphic Unit	*Lithology*	*Structural/stratigraphic Relationships*	*Mineralogy/Petrography*
Unnamed Unit	Fine-grained, thin-bedded, feldspathic *quartzite.*	Weakly foliated, thin dark layers of iron oxides, zircon and tour.; conformable with silvery schists; stratigraphic facing uncertain.	Equigranular granoblastic subpolygonal; qtz (55-65%) + kspar (20-35%) + musc (10-20%) ± plag (<20%) + biot + opaques + acc.
Broadview Schist	Fine to very fine-grained, silvery grey *schist* or phyllite.	Strong slaty schistosity, sometimes crenulated; conformable with Myola Volcanics; rare, primary compositional banding.	Equigranular granoblastic to lepidoblastic with local micro-augen of qtz; musc (60-70%) + biot/chl (5-15%) + qtz/plag (10-30†) + acc (rare andalusite).
	Massive fine-grained *amphibolite.*	Foliated and often lineated; conformably interbedded with schists (and also Myola Volcanics); recrystallized former mafic volcanic or dolerite	Relatively equigranular-granoblastic; plag (40-55%) + hbl (30-50%) + minor opaques ± kspar ± qtz ± sph ± biot + acc.
Myola Volcanics	Grey to pinkish grey, *porphyritic rhyolite* and *rhyodacite.*	Foliated and often strongly lineated.	Phenocrysts of kspar, plag, lesser qtz and rare mafic in a fine to very fine grained, recrystallized ground mass of felds + qtz.
	Fine-grained, pink *felsic gneiss.*	Foliated and lineated; inter-layered with rhyolites; local flattened augen of recrystallized qtz + felds.	Equigranular granoblastic metamorphic textures; kspar (25-45%) + qtz (50-25%) + plag (15-25%) + minor mafics + acc.
	Fine-grained, greyish-pink, *quartz feldspar amphibole gneiss.*	Foliated with local elongate augen of recrystallized qtz + amphib + felds; developed along strike from rhyolites.	Relatively equigranular granoblastic; kspar (35-45%) + plag (20-40%) + amphib (10-20% hbl) + qtz (25-40%) + acc.
Unconformity			
HUTCHISON GROUP: Yadnarie Schist	Fine-grained, locally quartz-veined quartzose *schist* with interlayered psammitic bands several cm thick.	Strongly foliated and often crenulated; layering of mixed primary and tectonic origin; top of unit not exposed.	Equigranular granoblastic subpolygonal (to lepidoblastic); musc (30-50%) + qtz (30-40%) + biot (10-25%) + felds + acc.
HUTCHISON GROUP, MIDDLEBACK SUBGROUP: Upper Middleback Jaspilite	*Mixed silicate* and *carbonate facies banded iron formation* with local oxide facies banded iron formation in the Middleback Range and graphitic quartzite in western regions.	Regularly banded; gradational into units above and below.	As for Lower Middleback Jaspilite
HUTCHISON GROUP, MIDDLEBACK SUBGROUP: Cook Gap Schist	*Layered,* medium to fine-grained, quartz veined garnetiferous *gneiss* and*schist.*	Strongly foliated; layering of mixed primary and tectonic origin; multiply deformed.	Equigranular granoblastic sub-polygonal; qtz (av. 45%) + plag (20%) + musc (20%) + biot (15%) + kspar + gnt ± sill + acc.
	Layered garnetiferous migmatite gneiss with coarse grained quartzo feldspathic segregations.	Strongly foliated parallel to quartzo feldspathic segregations; migmatized, high metamorphic grade equivalent to layered gneiss and schist.	Inequigranular granoblastic interlobate; qtz (av. 40%) + kspar (40%) + plag (15%) + biot (15%) + sill + gnt ± musc (trace) + acc.
	Massive *amphibolites* (equigranular medium-grained schistose amphibolite and minor porphyroblastic amphibolite.	Strongly foliated, concordant bodies, 2-50⁺ m thick within layered gneisses; either intrusive sills or quartz tholeiite volcanic flows.	Granoblastic polygonal to porphyroblastic with xenoblastic porphyroblasts (up to 5 mm) of hbl in a schistose matrix; hbl (45-65%) + plag (An_{15}-An_{100}) ± qtz ± biot ± cpx + opaques + acc.

HUTCHISON GROUP	MIDDLEBACK SUBGROUP	LOWER MIDDLEBACK JASPILITE	Long Gully Member*	*Mixed silicate facies iron formation* and *schist.*	Gradational with units above and below.	
			Knight Member*	*Mixed silicate* and *carbonate facies banded iron formation.*	Gradational with lower members.	As per Duke Member.
			Duchess Member*	*Oxide facies banded iron formation* (magnetite quartzite).	Regularly banded and locally laminated; base is gradational into silicate facies iron formation.	Fine to medium grained and essentially equigranular; granoblastic interlobate textures; qtz + mag (±hem.) ± minor amph ± trace carbonate.
			Duke Member*	*Silicate facies banded iron formation* (amphibole magnetite quartzite).	Regularly banded and strongly foliated; interbanded with carbonate facies iron formation and ferroan dolomite; base is gradational but contains abundant iron sulphides.	Fine to medium grained, granoblastic interlobate to decussate textured; qtz + mag (±hem.) + amph (grunerite or cummingtonite) ± cpx (hedenbergite) ± py ± pyrrh + acc.
				Carbonate facies banded iron formation (talc magnetite schist, carbonate "ore" and talcose carbonate magnetite jaspilite).		Medium grained but inequigranular with iron oxides finer grained; mag (±hem) + carbonate (calc, dol, sid and ferrodol) ± talc, ± trem ± py ± pyrrh ± acc.
			Poor-namoo-kinnie Member*	*Graphitic quartzite.*	Thin and regularly banded with thin (<1 mm) bands of amphibole; foliated; probably originally a graphitic chert.	Granoblastic subpolygonal; fine grained; qtz (80-90%) + graph (5-10%) + amphib (5% tremolite-grunerite) ± felds + acc.
		Katunga Dolomite		Massive to poorly banded *dolomitic marble* and minor, banded calc-silicate gneiss.	Conformably overlies pelitic schist at top of Warrow Quartzite; very weakly foliated; banding (original) now defined by serpentine nodules + calc-silicates	Medium-grained holocrystalline; dol + calc (combined 60-98%) + serp ± phlog ± diop ± trem ± plag ± sph + opaques + acc; serp occurs after forsterite.
	Warrow Quartzite			Pale brown to grey, silvery, *mica schist.*	Interlayered with flaggy quartzite in units a few mm to several metres thick.	Medium to fine grained, crenulated, lepidoblastic; musc. (40-70%), + biot + qtz + felds + gnt + tour + sill (<20%) + acc.
				Flaggy, medium-grained, *feldspathic micaceous quartzite.*	Strongly foliated and banded; locally lineated (qtz rodding); dominant lithology in upper Warrow Quartzite.	Granoblastic equigranular interlobate; qtz (70-90%) + micro + musc (1-5%) + biot + plag + sill + acc.
				Massive, medium to coarse-grained *feldspathic quartzite.*	Foliated but generally only very weakly banded (as defined by thin aggregates or trains of feldspar); dominant lithology in lower Warrow Quartzite.	Granoblastic interlobate qtz (85-95%) + micro + biot + musc ± sill ± acc; local bands up to 15 mm thick of diop + trem (near base of unit).
				Quartz-pebble conglomerate.	Beds from a few cm to several metres thick at or near base in western outcrops.	Pebbles up to 6 cm in size of very coarse grained quartz in a massive feldspathic quartzite; originally clast supported.
				Podded *sillimanite gneiss.*	Associated with calc-silicates in Cowell-Cleve region.	Pods (5-15 mm) of fibrolite in medium grained, inequigranular groundmass of micro (40-50%) + plag + qtz + biot + sill
				Banded calc-silicate gneiss and massive dolomitic *marble.*	Developed on unconformity in Cowell-Cleve region.	Interbanded dol ± calc and calc + plag (anorthitic) + cpx + hbl + trem + kspar ± phlog ± ol ± serp ± sph ± acc.
	Unconformity					

*Informal names

EARLY PROTEROZOIC RECORD

Hutchison Group

The Hutchison Group is a mixed clastic (sand, silt, shale) and chemical (limestone, iron formation) sedimentary sequence consisting of a basal quartzite unit, the Warrow Quartzite, interlayered clastic, carbonate and iron formation facies, the Middleback Subgroup, and an upper psammopelitic unit, the Yadnarie Schist (Table 3).

At Marble Range and Coles Point on southern Eyre Peninsula and at Caralue Bluff and Darke Peak on central Eyre Peninsula, Warrow Quartzite unconformably overlies gneisses of the Sleaford Complex. Contacts are for the most part obscured by scree but cross bedding and quartz-pebble beds at or near the base confirm structural relationships.

To the east in the Tumby Bay and Cowell-Cleve region, sedimentary features have not been observed. More intense deformation and metamorphism may account for the apparent lack of these features, but it is more likely that their absence reflects a change in sedimentary palaeoenvironments. At the base of the Warrow Quartzite northwest of Cowell, there are local calcsilicate/dolomite/podded sillimanite gneisses while in the upper Warrow Quartzite there are pelitic schist interbeds. This led Parker & Lemon (1982) to believe that the Warrow Quartzite represents a fluvial to marginal marine, sandy arkose sequence with fluvial sediments represented in the west and more distal, progradational marine sediments represented in the east.

Mixed chemical and clastic metasediments of the Middleback Subgroup represent a number of cyclic transgressions and regressions of the sea either across a continental shelf or within a major basin deepening to the east. Pelitic schist interbeds (formerly shales) at the top of the Warrow Quartzite represent the first transgression. Local sequences from quartzite into pelitic schist, dolomite, carbonate facies iron formation, silicate facies iron formation and oxide facies iron formation (Table 3) are believed to represent progressively deepening water and more distal sedimentary facies. These facies variations within the Katunga Dolomite and Lower Middleback Jaspilite can also be traced across the former shelf or basin and may indicate more distal facies to the east in the Middleback Range. In the Cleve region for example, both the Lower and Upper Middleback Jaspilites are relatively depleted in iron but enriched in carbonate by comparison with classical sections in the Middleback Range. Furthermore, graphitic quartzites which were originally carbonaceous cherts before metamorphism, occur north of Cleve at the same stratigraphic level as iron-rich jaspilites in the Middleback Range.

A major influx of clastic sediments represented by the Cook Gap Schist (Fig. 6) followed deposition of the Lower Middleback Jaspilite. Parker & Lemon (1982) suggested that this possibly represented eastwards regression of the shoreline across the shelf or basin. Alternatively the influx of clastics from the west may represent a change in the source region reflecting either renewed tectonic uplift or volcanism.

Deposition of the Upper Middleback Jaspilite occurred in almost identical sedimentary environments to those in which the lower iron formation was deposited. This might represent a second major transgressive cycle while the overlying Yadnarie Schist represents a return to clastic sedimentation similar to that which formed the Cook Gap Schist.

Minor local perturbations superimposed on these macroscopic facies variations are clearly evident by the "meso-banding" so well developed in the Upper Middleback Jaspilite at Mangalo Creek northwest of Cleve. Here alternating dolomite and jaspilitic chert bands several millimetres thick represent minor cyclic pulses superimposed on the regional cycle. This "mesobanding" may be analogous to mesobanding in classical Hamersley Group and Lake Superior-type iron formations (e.g. Trendall 1976), and may represent annual or seasonal perturbations in sedimentation and diagenesis.

Definite volcanics are absent in the Hutchison Group but there are numerous conformable amphibolites in the Cook Gap Schist. These are of quartz tholeiite composition and probably represent either mafic volcanic extrusions or mafic sills intruded very early before deformation. Similar amphibolites occur in the Willyama Supergroup at Broken Hill and Olary. Acid gneisses of possible volcanic origin like the Potosi Gneiss at Broken Hill (Laing *et al.* 1984) are absent, which may account for an apparent lack of Broken Hill-style silver-lead-zinc mineralization. Instead, most of the silver-zinc mineralization on Eyre Peninsula is intimately associated with dolomitic carbonates and calc-silicates such as the Katunga Dolomite, carbonate and graphitic facies of the Lower and Upper Middleback Jaspilites, and calc-silicates at the base of the Warrow Quartzite.

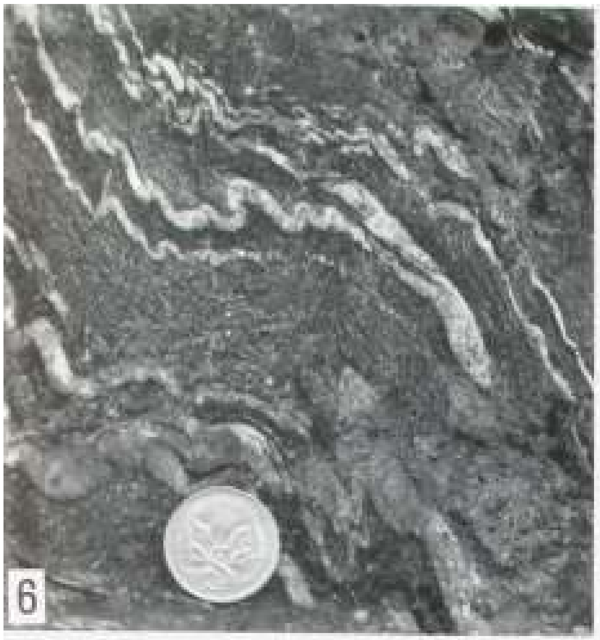


Fig. 6. Style of folding and refolding developed in the Cook Gap Schist (Hutchison Group) in Mangalo Creek. Quartz veins have been isoclinally folded by F_2 folds and subsequently refolded about a subvertical F_3 fold axial plane.

Fig. 7. Megacrystic granite gneiss of the Donington Granitoid Suite at Cape Donington displaying large, zoned feldspar phenocrysts and narrow mylonitic shear zones.

Fig. 8. Multiple intrusions of foliated granites, and aplitic and granitic dykes (Kimban Orogeny granitoids) near Smooth Pool.

Fig. 9. Memory Cove Charnockite near Wanna containing younger, north-south trending dolerite dykes.

Myola Volcanics and Associated Rocks

Although acid volcanics have not been identified within typical Hutchison Group sequences anywhere on Eyre Peninsula, east of the Middleback Range there is a prominent sequence of weakly metamorphosed rhyolites and rhyodacites known as the Myola Volcanics (Parker 1980b; Table 3). These are associated with gabbroic amphibolites, fine-grained laminated quartzites, and slaty schists, the Broadview Schist unit. There is no obvious connection between these units and the Hutchison Group but, because of the absence of acid volcanics elsewhere from the Hutchison Group, and because of their lower metamorphic grade, the Myola Volcanics and Broadview Schist are believed to represent a younger volcanosedimentary sequence, possibly formed early during the Kimban Orogeny. Texturally the rhyoliteslrhyodacites resemble acid porphyries from the Moonta district, inviting direct correlation. The conventional association of Moonta Porphyry with the 1510-1600 Ma Gawler Range Volcanics is not valid in terms of textural and fabric evidence and, furthermore, Rb-Sr dating of deformed acid volcanics from Wardang Island gives an age of about 1735 Ma (Fanning 1985)'.

Deformation

Two major periods of complex deformation, metamorphism and plutonism have been recognised in the southern Gawler Craton. They are the Sleafordian Orogeny which culminated about 2300 Ma and the Kimban Orogeny which extended from about 1850 Ma to about 1580 Ma (Webb *et al*). The Sleafordian Orogeny affected Archaean rocks throughout Eyre Peninsula and was a high-metamorphic-grade gneiss-forming event accompanied by both mafic (early) and acid (late) plutonism. Because of overprinting by the subsequent Kimban Orogeny, resolution of the exact nature of the Sleafordian Orogeny has not yet been possible, although some specific plutonic events forming the Dutton Suite granitoids have been dated (Table 2).

The Kimban Orogeny locally affected western Eyre Peninsula, but was most intense in the east. In the Cowell-Cleve region, the Tumby Bay - Cummins region and the Middleback Range, three main tectonic events can be identified (Fig. 2): an early high-grade upper amphibolite to locally granulite facies metamorphic event, M,; a high-grade, isoclinal fold event possibly with associated thrusting, D_2; and a lower-grade, open fold event, D_3, with associated development of major mylonite zones, D_M. Principal structural characteristics of each of these events are outlined by Glen *et al.* (1977) and Parker & Lemon (1982) but briefly they are as follows:

Event 1 (M_1)-a high-grade fabric-forming event not obviously related to folding but producing a layer parallel foliation, S_1 defined by the crystallographic alignment of mica and sillimanite, and by inclusion trails in garnet and andalusite porphyroblasts. S_1 commonly is only observed in the hinge zones of F_2 folds; elsewhere it is parallel to and indistinguishable from S_2 (see below).

Event 2 (D_2)-a high-grade deformational metamorphic event characterized by very tight to isoclinal folds F_2 with pervasive axial planer fabrics S_2 developed. These fabrics include a strong mica (or amphibole) schistosity, a local segregation schistosity or metamorphically differentiated layering, the platy alignment of elongate or discoid sillimanite aggregates, garnet, feldspar and quartz, and an often quite strong, quartz-rod lineation. Transposition on a mesoscopic scale is frequent and may also be important on a macroscopic scale.

Event 3 (D_3)-a lower-grade, retrogressive, deformational event characterized by broad, tight to open folds F_3 and crenulations, and local, highly-strained, mylonite zones. By contrast to F_2, D_3 folds generally lack a strong axial planar schistosity, but within the mylonite zones (Figs 10, 11) there is variable fabric development from weak incipient mica orientation to strong slaty ultramylonite (Parker 1980a).

The macroscopic tectonic effects of these combined events on the shaping of Eyre Peninsula were enormous. It is estimated that the shelf region upon which the Hutchison Group was deposited, was originally very wide. A conservative estimate from unfolding D_3 folds would suggest that Cowell and Cleve would have been at least 1.5 times further apart and that unfolding of D_2 folds would at least double that figure. Therefore the former continental shelf represented now by the Cowell and Cleve region may have been originally more than 100 km wide.

The mylonite zones also had a significant regional effect (Fig. 1). The Kalinjala Mylonite

---

(U-Pb zircon dating, undertaken by the authors since writing this chapter, confirms that the Myola Volcanics and Moonta Porphyry formed during the Kimban Orogeny about 1795-1735 Ma. The McGregor Volcanics are also of this age whereas the Gawler Range Volcanics define a very precise 1593 Ma age.)

Fig. 10. Mylonitic gneisses containing melanocratic boudins of amphibolite, Kalinjala Mylonite Zone at Port Neill.

Fig 11. Mylonite and ultramylonite at Port Neill showing relic feldspar augen, and tails and ribbons of recrystallised quartz and feldspar.

Zone which extends from just west of Port Lincoln north through Port Neill to just west of the Middleback Range is locally over 2 km wide yet is only one of many, there being at least three such zones between Whyalla and Kimba. If lateral movement along these zones was important in their formation then the rocks in the Middleback Range may have been formed much further south of their present position, near Cowell or even Port Lincoln.

East of the Middleback Range and in the zone extending under Spencer Gulf to upper Yorke Peninsula, the various units record varying degrees of deformation. The Broadview Schist and Myola Volcanics are clearly deformed by D_3 folds and crenulations, but while D_3 deforms a strong layer-parallel slaty schistosity, there is no obvious evidence of D_2 or M_1. It is considered however that the slaty schistosity is probably related to D_2. McGregor Volcanics and Moonabie Formation grits are locally deformed (open folds) suggesting that they may have been deformed by D_3 but not D_2.

Metamorphism

As discussed above, two main periods of complex deformation and metamorphism have been recognized on Eyre Peninsula-the Sleafordian Orogeny and the Kimban Orogeny. It is difficult to ascertain the specific nature of the Sleafordian Orogeny, since for the most part the inferred metamorphic conditions bear a close resemblance to those induced by the younger Kimban Orogeny.

In southernmost Eyre Peninsula, the Carnot Gneisses were subjected to a prograde granulite facies event at about 2400 Ma (Fanning *et al.* 1981). Pressure-temperature estimates for this Sleafordian event are 800-900°C at a total pressure of 7-9 Kb. The Wangary Gneisses in southwestern Eyre Peninsula perhaps reached low to middle amphibolite facies during this time, but this is uncertain due to the extent of Kimban overprinting, in particular shearing during D_3.

The metamorphic conditions that prevailed in the Cowell-Cleve area during the Sleafordian Orogeny similarly are uncertain. However, one could suggest similar metamorphic conditions to those proposed for the Wangary Gneisses. Equivalents of Carnot Gneisses at Waddikee Rocks by contrast reached upper amphibolite to granulite metamorphic facies.

The metamorphic development of the Kimban Orogeny is far better preserved due to the stabilization of the Gawler Craton not long after the orogeny. Parker (1978) established the structural and metamorphic history in the Cowell - Cleve region where M, and M_2 were both high-grade, pervasive metamorphic events of upper amphibolite facies and estimated P-T conditions ca 600-700°C at a total pressure of 5-7 Kb. M_3 and M_4 were retrograde events and lower P-T conditions ca 450-550°C at a total pressure of 2-4 Kb are evident.

The peak, prograde, metamorphic conditions in southern Eyre Peninsula particularly east of the Kalinjala Mylonite Zone tend to be higher for the M_2 events of the Kimban Orogeny. Mortimer *et al.* (1980) propose that primary crystallisation of the Donington Granitoid Suite took place at about 900°C and about 8 Kb, conditions very similar to those estimated for the Carnot Gneisses. However, it is more likely that most of southern Eyre Peninsula was subjected to somewhat lower pressure and temperature conditions early in the Kimban Orogeny, about 650-750°C and 4-6 Kb as suggested by Flook (1975). Retrogression during the M_3 and M_4 events is similar to that proposed for the Cowell-Cleve region although pressure and temperature conditions may have been locally higher adjacent to the syn- to late tectonic granite intrusives such as the Moody Suite (Coin 1976).

Granitoids

Even during the early days of geological mapping on Eyre Peninsula, a complex plutonic history was recognized. Jack (1914) on central Eyre Peninsula and Tilley (1921a, b) on southern Eyre Peninsula both identified multiple granite intrusions, but only in recent times, through the application of isotopic dating techniques, have temporal relationships been established (Table 4).

On southern and central Eyre Peninsula four temporally distinct granitoid suites have been identified-the Late Archaean/Early Proterozoic Dutton Suite, the Early Proterozoic Donington Granitoid Suite, and the Early to Middle Proterozoic Spilsby and Moody Suites. The Dutton Suite granitoids form part of the Sleaford Complex (see Table 1) whereas the Donington, Spilsby and Moody Suites are collectively known as the Lincoln Complex. (For ease of regional geological mapping the Lincoln Complex also contains some other non plutonic units such as highly migmatized remnants of the Sleaford Complex and Hutchison Group).

The Donington Granitoid Suite consists of a broad spectrum of mantle-derived ("I' type) granitoids ranging from quartz gabbronorite, through to hypersthene granite and late-stage leucogranite (Figs 7 & 9). Mortimer *et al. (1980)* consider that these granitoids evolved through a crystal fractionation process at about 1810 Ma during the first tectonic event of the Kimban Orogeny. The deformation has resulted in the development of a folded gneissic fabric and variable retrogression of the primary pyroxenes to hornblendes.

In the Cowell region and west of the Middleback Range in the Secret Rocks region, the Donington Granitoid Suite is represented by early tectonic granites known as the Minbrie Gneiss. This is composed of a broad spectrum of granitoids but many of the migmatitic gneissic granites are believed to have formed largely *in situ,* and to represent deformed magmas derived from melting of crustal rocks ("S" type granitoids).

Spilsby Suite granitoids outcrop in the Sir Joseph Banks Group of islands located in Spencer Gulf east of Port Lincoln and in the Cowell-Cleve region where they are represented by the foliated Middle Camp Granite. In the Sir Joseph Banks Group, the Spilsby Suite is composed of massive to foliated hornblende granite and tabular feldspar granite which both intrude more deformed, megacrystic granites of the Donington Granitoid Suite. The Middle Camp Granite. is folded by D_3 folds which implies emplacement possibly during the D_2 tectonic event, but certainly prior to the D_3 tectonic event of the Kimban Orogeny; a date about 1700 Ma is envisaged.

Granite, porphyritic granite (with tabular feldspars), adamellite, leucogranite and syenite comprise the Moody Suite. These granitoids crop out northwest of Tumby Bay (e.g. at Moody Tank), in the Cowell-Cleve region (Carpa Granite), in the Middleback Range area (Wertigo Granite and Cooyerdoo Granite) and along the coast and coastal islands of western Eyre Peninsula (e.g. foliated granites of Smooth Pool (Fig. 8) and Point Brown). The granitoids form a series of related plutons that vary from massive to weakly foliated with aligned tabular feldspar phenocrysts. The Moody Suite is characterised by xenoliths or schlieren of gneissic material and garnet is common. Intrusion of these late Kimban Orogeny granitoids spans an interval of time about 1670-1600 Ma and encompasses, at least locally, the D_3 tectonic event.

Table 4. LITHOLOGICAL CHARACTERISTICS AND AGE RELATIONSHIPS OF THE SYN- AND POST-KIMBAN OROGENY GRANITOIDS. GEOCHRONOLOGY AFTER WEBB (1978), WEBB *ET AL.* (IN PRESS), COOPER *ET AL.* (1976) AND MORTIMER *ET AL.* (1980).

	Stratigraphic unit	Lithology and age (Ma)	Structural relationships	Petrographic features
HILTABA SUITE	—	*Porphyritic leucogranite*; white pink. 1489 ± 15 Ma; 1466 ± 79 Ma	Intrudes acid volcanics in Nuyts Archipelago.	Abundant phenocrysts of perthitic kspar and qtz (<10 mm) in fine-grained recrystallised qtz mosaic.
	—	Massive, *pink-red granite*; coarse grained with pinkish-red feldspars. 1456 ± 26 Ma; 1478 ± 38 Ma	Intrudes Gawler Range Volcanics in southern Gawler Ranges; "type" lithology of Hiltaba Suite.	Perthitic kspar (50-70%) + zoned plagioclase (10-15%) + qtz (20-40%) and biot (<5%)
	Charleston Granite	Massive, homogeneous, coarse-grained, *Megacrystic granite.* 1445 ± 39 to 1556 ± 30 Ma	Intrudes Corunna Conglomerate and older units; non-foliated; semi-circular pluton.	Large kspar phenocrysts (30-40%) + greenish plag (10-15%) + biot + qtz + acc.; some phenocrysts are zoned.
	—	Massive, *hornblende* ± pyroxene *granite*; medium-grained to porphyritic. 1478 ± 15 Ma	Intruded by rhyolite dykes in Nuyts Archipelago; non-foliated.	Dominantly graphic qtz + kspar, minor plag, minor mafics are aegirine and/or hornblende
LINCOLN COMPLEX — MOODY SUITE	—	*Granodiorite*; pale grey, medium-grained, equigranular. 1601 ± 14 Ma	Massive to weakly foliated dykes in Bungalow BD2 drillhole, E of Buckleboo and in the Streaky Bay area.	Microscopically deformed and partially recrystallised; plag + qtz + micro + biot + acc.
	—	*Coarse grained granite*; also foliated megacrystic granite	Weakly to strongly foliated and intruded by granodiorite dykes in the Streaky Bay region.	Perthitic microcline (30-40%) + plag. (30-40%) + qtz (20-25%).
	Burkitt Granite	Massive, even-grained, *hornblende granite/quartz syenite*; locally porphyroblastic. 1655 ± 61 Ma	Intrudes Hutchison Group and is overlain by Corunna Conglomerate; elliptical pluton elongate parallel S_3, maybe equivalent to Chinmina Syenite.	Ortho perthite (40-60%) + plag (20-25%) + qtz (10-15%) + hbl (5-15%) ± biot + sphene + acc.
	Carpa Granite	Massive, medium-grained, weakly foliated *granite.* 1677 ± 125 Ma	Equivalent to granite at Moody Siding (type locality for Moody Suite).	Microscopically deformed/ recrystallized qtz (30-45%) + kspar (30-60%) + plag (10-40%) + biot + musc + gnt + acc.
	Wertigo Granite	Massive, medium-grained *gneissic granite* with schlieren of meta-sedimentary gneiss.	Intrudes Myola Volcanics and contains an S_3 foliation; type locality is Wertigo Rockhole.	Equigranular, qtz (20-30%) + kspar (25-40%) + plag (20-30%) + biot (5-10%) + acc; locally granodioritic.
LINCOLN COMPLEX — SPILSBY SUITE	Middle Camp Granite	Medium-grained *gneissic granite/granodiorite* with abundant pegmatite veining. 1650 ± 35 Ma	Well foliated with foliation and pegmatite veins folded by D_3 folds; local xenoliths of Hutchison Group marble.	Qtz (20-25%) + plag (45-60% and 20-30%) + kspar (10-25% and 35-50%) + biot + sphene + acc.
	—	Medium-grained *hornblende granite* and *tabular feldspar granite.* 1576 ± 199 Ma	Massive to foliated with local D_3 shear zones intrudes Donington Granitoid Suite on Sir Joseph Banks Group islands.	Micro (35-40%) + plag (15-25%) + qtz (20-30%) + hbl (<7%) + biot + acc.
LINCOLN COMPLEX — DONINGTON GRANITOID SUITE	—	*Even-grained granite gneiss*; medium-grained. 1816 ± 10 Ma	Foliated and folded by D_2 and D_3 folds; grades into megacrystic granite gneiss at Kirton Point but intrudes hypersthene granitoids at Cape Donington.	Microcline + plag (andesine) + qtz + biot + acc.; granoblastic serriate textures.
	—	Mafelsic *megacrystic granite* gneiss grading into augen gneiss.	Strongly foliated and folded; local xenoliths of mafic material.	Zoned void plag + ortho/micro megacrysts (<40 mm) in a coarse grained groundmass of qtz + felds + biot + hbl + opx
	Memory Cove Charnockite	Medium to coarse-grained *hypersthene granite gneiss.*	Intruded by even-grained granite gneiss at Cape Donington.	Plag + hyp + orthophenocrysts in a partly recrystallised groundmass of felds + qtz + biot + hbl + acc.
	—	Coarse-grained *quartz gabbronorite gneiss.*	Xenoliths in even-grained granite gneiss; probable earliest intrusive phase of Donington Granitoid Suite.	Zoned plag phenocrysts (oligoclase) + augite + hyp + biot + qtz + acc + secondary hbl.

MIDDLE PROTEROZOIC PERIOD

Stratigraphy

For the purpose of this discussion the Middle Proterozoic sediments and volcanics on Eyre Peninsula are taken as those formed during the period about 1615-1300 Ma. They include the McGregor Volcanics[1], Moonabie Formation[1], Corunna Conglomerate, Gawler Range Volcanics, Pandurra Formation and lateral equivalents of these units (Table 1).

The McGregor Volcanics (formerly referred to as Moonabie Volcanics and Moonabie Porphyry) occur as a steeply-dipping sequence in Moonabie Range, southwest of Whyalla, and were formed at about 1615 Ma (Webb *et al*). They are bimodal, consisting of acidic, welded, ashflow tuffs derived from melting of a lower crustal source, and basaltic lava flows derived from a mantle source (Giles *et at. 1980).*

Interlayered with, but mostly overlying the McGregor Volcanics, are volcaniclastic grits of the Moonabie Formation (formerly Moonabie Grit). The volcaniclastic grits contain a mixture of volcanic and chert clasts in an immature matrix and indicate rapid erosion of the underlying volcanic pile. Rare heavy mineral beds are locally preserved (e.g. at Mt Young).

Overlying the Moonabie Formation is the Corunna Conglomerate which is thought to have been deposited synchronously with the Gawler Range Volcanics. The conglomerate contains acid volcanic clasts similar to the Gawler Range Volcanics, yet is intruded by plugs and dykes representing the final phase of Gawler Range Volcanics. In the Tarcoola region there is evidence of extensive syn-depositional volcanism.

The Corunna Conglomerate is composed mainly of fluviodeltaic conglomerates and sandstones (Fig. 12). However in Moonabie Range, basal fluvial conglomerates are overlain by a marine sandstone (Nilgenee Member), which intertongues to the east with a rapidly deposited talus breccia (Cowleds Member). The breccia coarsens eastwards, containing angular clasts up to 0.5 m diameter. It was probably deposited near an ancient escarpment perhaps coinciding with the present day Moonabie Scarp.

Equivalent to the Corunna Conglomerate are the Blue Range Beds which outcrop from Gibbon Point on Spencer Gulf, through Blue Range and the Cleve area on central Eyre Peninsula to Mount Wedge and Talia Caves on the west coast. This chain of outcrops suggests an east-west oriented depositional basin.

Also equivalent to the Corunna Conglomerate is a sequence of grey, laminated carbonaceous siltstones and sandstones encountered during drilling in the Uno area. These appear to correlate with similar carbonaceous siltstones in the Tarcoola region and are of likely lacustrine origin.

The depositional age of the Corunna Conglomerate is not clearly defined; a minimum age is given by the intrusive rhyolite dykes (1457 ± 22 Ma according to Webb *et al.*) whereas a maximum age is given by the underlying McGregor Volcanics in the Moonabie Range. Isotopic ages derived for the Corunna Conglomerate fit within these constraints but are too young relative to the disputed age of the Charleston Granite (viz. 1556 Ma, after Compston *et at.* 1966) which intrudes the conglomerates near Moonabie.

For the purposes of this discussion the Gawler Ranges are excluded from Eyre Peninsula. However there are isolated outliers of Gawler Range Volcanics scattered throughout northern Eyre Peninsula. In the Corunna area and west of Iron Baron there are north-northwest trending rhyolite dykes which intrude the Corunna Conglomerate and Hutchison Group respectively but which represent the very latest phase of Gawler Range volcanism. Similar dykes occur elsewhere around the southern margin of the Gawler Ranges and also in the Mt Sturt-Buckleboo region where there are also outliers of both the lower Gawler Range Volcanics (porphyritic dacites and flow-banded porphyritic rhyolites) and the lowermost unit of the upper Gawler Range Volcanics (the highly porphyritic dacite of Mt Sturt). Other outliers of Gawler Range Volcanics or equivalents thereof, occur at Mt Cooper (porphyritic and locally flow-banded rhyolites) and in the St Francis Isles of the Nuyts Archipelago. The latter include porphyritic rhyolites and rhyodacites and dykes of flow banded rhyolite and black dacite. The porphyritic rhyolites are most likely equivalent to the lower Gawler Range Volcanics.

At Roopena northwest of Whyalla, a sequence of amygdaloidal basalts interbedded with conglomerate, volcaniclastic sandstone and laminated siltstone overlies acid volcanics, brecciated siltstone, and volcaniclastic sandstone of the Moonabie Formation. Previous workers have correlated the basalts with basal Adelaidean volcanics but recent work (Mason *et at.* 1978; Giles & Teale 1979) suggests that the Roopena Volcanics are analogous to basalts from the Gawler Range Volcanics.

Deposition of the Corunna Conglomerate, extrusion of the Gawler Range Volcanics,

Fig. 12. Steeply dipping, fluvial conglomerates and sandstones of the Corunna Conglomerate, Moonabie Range.

Fig. 13. In Moonabie Range, the Charleston Granite (massive with large microcline phenocrysts) intrudes the Corunna Conglomerate.

postorogenic granitic intrusion (see below), and local deformation (D_4) represent the final events leading to stabilization of the Gawler Craton.

The Pandurra Formation is generally regarded as the final pulse of intracontinental sedimentation on the Gawler Craton. It unconformably overlies the Roopena Volcanics and is, in turn, disconformably overlain by the Beda Volcanics and Backy Point Beds. The Pandurra Formation is a fluvial sequence of sandstones, commonly feldspathic, kaolinitic and exhibiting characteristic fossil liesegang weathering bands. It was deposited in a series of northwest-trending grabens or fault-bounded troughs, reaches a maximum thickness exceeding 600 m and was possibly deposited about 1420 Ma (Fanning et al. 1983).

Granitoids

Middle Proterozic post-tectonic granitoids, the Hiltaba Suite, are extensively developed throughout northern Eyre Peninsula and form some of the very prominent landforms in that region (e.g. Mt Wudinna). In and adjacent to the Gawler Ranges and in the Nuy1S Archipelago, the granitic intrusives are mainly shallow, flat-roofed leucogranites rich in alkalis and occurring in close spatial relationship with rhyolites and rhyodacites. The granites represent high-level intrusions derived essentially from "S” type magma sources in the lower crust and except for the older pink leucogranite of Nuyts Archipelago and maybe the Charleston Granite (Fig. 13), were intruded mainly in the period 1500-1450 Ma (Table 4).

Deformation

Throughout Eyre Peninsula there is local evidence for minor post-Kimban Orogeny tectonism in the form of cross folding, fracturing and the development of major lineaments andlor shear zones. This event (D_4) is known as the Wartakan Event and affected not only basement (Sleaford Complex) but also the Corunna Conglomerate. The latter is well displayed at Mt Laura where folding of quartzites believed to represent Corunna Conglomerate occurs about northwest-southeast trending axes. In the Middleback Ranges and the Cowell-Cleve region major, often quartz-veined lineaments are associated with cross-folding about east-west and northwest-southeast trending axes. Nephrite jade at Cowell was formed during this event (Parker 1981).

Subsequent tectonism on the southern Gawler Craton is largely restricted to local tensional tectonics such as graben development during the Pandurra Formation, dolerite dyke intrusion probably during the Late Proterozoic, and block faulting or graben development periodically during the Phanerozoic. Cratonization of the Gawler Craton is believed to have occurred about 1450 Ma so these later tensional effects were intracratonic.

ADELAIDEAN (LATE PROTEROZOIC) RECORD

The only known Adelaidean or Late Proterozoic rocks on Eyre Peninsula occur north of Whyalla. Around the Cultana Inlier and in bores on the southernmost Stuart Shelf (Mason *et al.* 1978) the lowermost basal Adelaidean of this region is represented by partially hematised, pink to buff coloured quartzofeldspathic sandstones and conglomerates (Backy Point Beds), interbedded with hematised and sericitised amygdaloidal basalts (Beda Volcanics). The basaltic lavas are of spilitic association and at least 14 flows (1-55 m thick) have been identified (Mason *et al. 1978).* Isotopic dating of the volcanics suggests an extrusive age of 1076 ± 33 Ma (Webb *et al. 1983).*

Overlying the Beda Volcanics, but rarely exposed, is the Tapley Hill Formation: a sequence of dark grey, laminated, carbonaceous and dolomitic siltstones and slates. Deeply weathered, kaolinized siltstones occur in dams and in a small quarry north of Whyalla but occur predominantly in drillholes throughout the Myall Creek-Port Augusta region where they attain a thickness about 140-210 m and where they locally contain anomalous lead-zinc mineralization.

The presence of Tapley Hill Formation directly overlying Beda Volcanics represents a major break in sedimentation from about 1050 Ma to about 750 Ma (Webb *et al.* 1983), the period of time during which the Burra Group and Sturtian glacials were deposited in the Adelaide Geosyncline only a few tens of kilometres east. The line across which this dramatic change in early Adelaidean sedimentation took place is the Torrens Hinge Zone. This extends from the western side of Gulf St Vincent through the Cultana area just northeast of Whyalla, and northwards along the length of the western side of Lake Torrens.

In the Pt Augusta-Myall Creek region the Tapley Hill Formation is overlain by very thin and patchy beds of Brighton Limestone and pink to marooncoloured, dolomitic shales and sandstones of the Willochra Subgroup. These in turn are overlain by the pink, feldspathic Whyalla Sandstone which is characterized by well-rounded, frosted quartz grains. The Whyalla Sandstone in this region is about 20-60 m thick. It correlates with Elatina Formation sandstones and glacials of the Adelaide Geosyncline.

Overlying the Whyalla Sandstone, and forming the base of the very prominent mesas in the Port Augusta-Whyalla region, is the Tregolana (or Woomera) Shale Member of the Tent Hill Formation. This unit and the overlying Corraberra Sandstone Member are equivalent to the Brachina Formation and consist of red and to a lesser extent green, laminated shales with thin sandy interbeds grading up into maroon, flaggy to thick bedded, sandy siltstone and sandstone of the Corraberra Sandstone Member. Together these two members attain a thickness about 150-200 m in the Port Augusta area.

The Corraberra Sandstone Member is overlain by the Simmens Quartzite Member which consists of massive, white, thin-bedded, cross·bedded sandstones and quartzites forming the "Arcoona Plateau" (Johns 1968) where it caps the mesas. Just south of Port Augusta the Simmens Quartzite Member has been intruded by relatively young (?Jurassic) kimberlite pipes that may be related to diamond-bearing kimberlites in the Adelaide Geosyncline.

PALAEOZOIC RECORD

Early Palaeozoic

Early Palaeozoic units are restricted to the Polda Basin-a narrow east-west graben less than 25 km wide but extending for 350 km from Rudall in the east to 220 km offshore from Elliston. It is an intracratonic graben flanked by Archaean-Middle Proterozoic rocks and is totally veneered by Tertiary and Quaternary sediments. One of the Quaternary units (Bridgewater Formation) is a major freshwater aquifer which was originally used by J. I. Miller (E & WS) in 1928 to define the Polda Basin. Since then, the term has also incorporated older sedimentary sequences, even though ideally these infra· basins represent distinct and separate cycles of sedimentation.

Early Palaeozoic sediments have been intersected in two drillholes: Mercury No.1 and Columbia No. 1 (Fig. 14, Table 5); both were drilled by Australian Occidental Pty Lld in 1981-1982 when evaluating the hydrocarbon potential of offshore portions of the Polda Basin.

Mercury No. 1 intersected 2375 m of pre Permian sediments, and three sequences were identified (McClure 1982a, Fig. 14). The basal

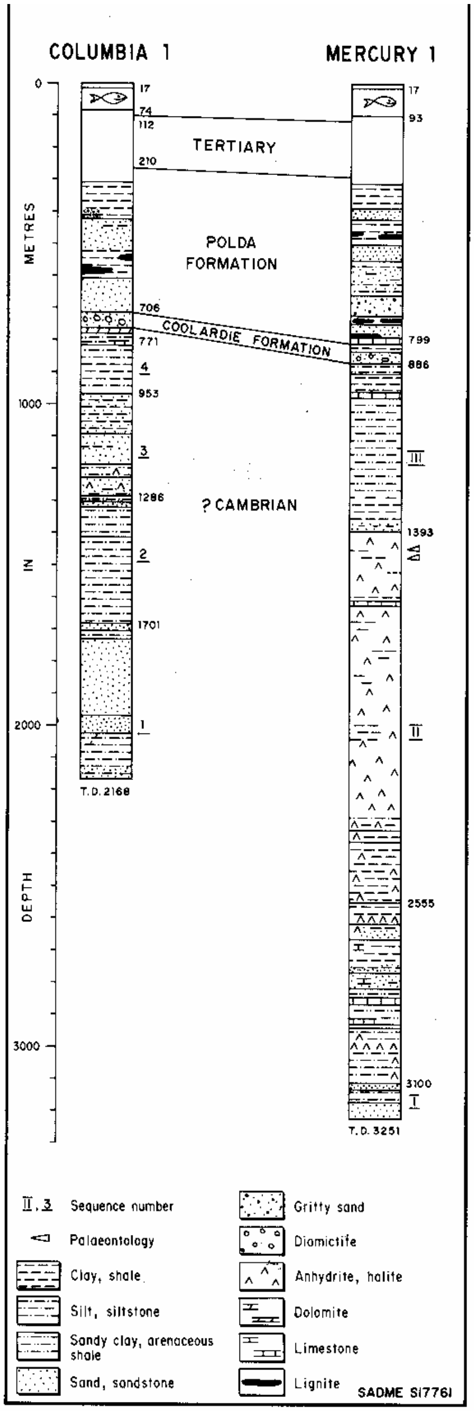


Fig. 14. Stratigraphic sequences in the eastern portion of the Polda Basin

unit (sequence I) is >151 m thick and consists of interlayered white quartzose sandstone, reddish-brown siltstone and silicified sandy siltstone. The overlying Sequence II is 1707 m thick and consists predominantly of massive rock salt. The clear to milky-coloured salt had been predicted from seismic profiling and the drill hole was located on the crest of an interpreted salt dome with an upper areal closure of 24 km^2. Interbedded with the salt are red-brown shale, siltstone, medium to coarse-grained sandstone and carbonate-cemented fine sandstone which contain abundant euhedral dolomite and anhydrite crystals. Within this sequence are 11 m of black stylolitic limestone and black shale, from which was recorded the only gas show to date from the Polda Basin. Unfortunately, it was a very minor 40 ppm of methane and source rock analysis indicated a very low total organic carbon content of 0.06%. The upper unit (Sequence III) consists of red beds, similar to those in Sequences I & II.

Columbia No.1 intersected 1397 m of reddish brown shale, siltstone, sandstone and minor limestone-dolomite similar to those in Mercury No.1, 35 km east-southeast. The sequence has been subdivided into four units (McClure 1982b, Fig. 14). Although it lacks the thick salt sequence, silicified siltstone and quartzose sandstone at the top of Sequence I are correlated with similar lithologies in Sequence I of Mercury No.1 (McClure 1982b).

It has not been possible to determine palaeontologically the age of oxidised red beds and salt. Two cuttings samples examined from Mercury No.1 contained only downhole contamination of foraminifera and microflora (Lindsay & Cooper 1982). However, the sediments have broad lithological similarities to those in the eastern Officer Basin: particularly a halite-bearing red-bed sequence in Wilkinson No.1 (Gatehouse 1979a) and red beds in Murnaroo No.1 (Gatehouse 1979b), which are believed to be Cambrian. By analogy, the sequence of red beds and salt in Mercury No.1 and Columbia No.1 have an interpreted ?Cambrian age. Similar sediments occur in deeper onshore sections of the Polda Basin where they are associated with mafic volcanics.

Late Palaeozoic

Extensive exploratory drilling for Jurassic coal by the Department of Mines and Energy and ETSA during 1976-1978 in the Lock area resulted

Table 5. STRATIGRAPHY AND LITHOLOGICAL CHARACTERISTICS OF PALAEOZOIC, MESOZOIC AND TERTIARY SEDIMENTS

Age	*Stratigraphic Unit*	*Lithology*	*Depositional Environment*	*Comment*
Pleistocene -Pliocene	Gibbon Beds	Orange-brown qtz sands, sandy clays, mottled clayey sands and conglomerates. laterite nodules common.	Alluvial.	Probably laterally equivalent to Uley Formation (Cummins and Uley Basins) and Pantoulbie Formation (polda and Robinson Basins). 50 m max. thickness.
Pliocene -Miocene	Unnamed	Sands, sandy clays, brown-green- grey clays, dolomites.	Lacustrine.	Restricted to eastern Polda Basin, e.g. Tuckey No. 1 and Polda No.9.
	Unnamed	Yellow-buff fossiliferous limestones, sandy limestcnes.	Marine.	Includes both Pliocene and Miocene limestones of Fishery Bay and Miocene limestones at Deep Creek (Melton Limestone equivalent).
Eocene (Middle-late)	Poelpena Formation	Brown-grey, quartz sands, silts and clays-carbonaceous, micaceous, pyritic and uraniferous.	Fluviatile-paludal.	Equivalent to Pidinga Formation (northern Eyre Peninsula) and Wanilla Formation (Uley-Wanilla-Cummins Basins). Thickness varies e.g. 110 m Tuckey No.1 and 178 m Mercury No.1.
		Carbonaceous and sapropelic clays.	Marginal marine.	Deposition synchronous with separation of Australia and Antarctica.
Jurassic (Late)	Polda Formation	Dark grey carbonaceous fine to coarse grained sands, silts and clays interbedded with sub- bituminous lignites.	Fluviatile -paludal.	Restricted to Polda Basin; type section in Polda NO.1. Max. thickness onshore is 170 m (Lock No.1) to an interpreted 511 m offshore in Mercury NO.1. Deposition synchronous with initial rifling between Australia and Antarctica.
Permian-Carboniferous	Coolardie Formation	Brown, grey, green diamictites, mudstones, sandstones.	Glacial-marine	Restricted to Polda Basin. Max. thickness 181 m in type section Lock No.1. Equivalent to Cape Jervis Beds of Troubridge Basin. Top of unit, below Jurassic sediments, weathered and kaolinised.
?Cambrian	Unnamed	Massive rock salt, red-brown shales, siltstones with anhydrite and dolomite crystals. Minor dolomite and carbonate-cemented sandstones.	Arid fluviatile- playa lake	Restricted to Polda Basin. Only intersected in Columbia No. 1 and Mercury No.1, though also expected to occur in onshore portion of the trough.

in the discovery of pre-Mesozoic sediments. Palynological examination of two drill holes in this programme (Polda No. 8 and No. 37) indicated a Carboniferous-Permian age (Harris 1979, Gatehouse 1980) and supported by subsequent investigations on Lock No. 1 (Cooper *et al* 1982). Microflora includes *Cycadopites cymbatus* and *Parasaccites gondwanensis.*

These Carboniferous-Permian sediments (Coolardie Formation) consist dominantly of diamictite and mudstone. Diamictite is brown, grey or green in colour and has a muddy-sandy matrix containing dispersed clasts (Kwitko 1982). Coolardie Formation was deposited in a glacial environment, though one foraminiferan present in contaminated cuttings in Mercury No. 1 and probably derived from this unit suggests some marine influence in the western portion of the Polda Basin (Lindsay & Cooper 1982).

Distribution and thickness of the Coolardie Formation are not well known as only a few drillholes are deep enough to fully penetrate the unit. However the Coolardie Formation is likely to be extensive in the Polda Basin with 87 m known from Mercury No.1 and at least 181 m in Lock No.1.

MESOZOIC RECORD

Interest in coal in Eyre Peninsula dates from 1923 when a sheep herder recognised spoil of coal fragments from a water well at "Win Gully" 15 km west of Lock. The Central Eyre Peninsula Coal and Oil Company then deepened the well but no significant quantity of coal was found. Subsequent hydrogeological drilling revealed grey lignitic silts and clays which yielded a Jurassic microflora (Harris 1964). Polda No. 1 stratigraphic bore, drilled in 1965, was the first drillhole to penetrate the entire Jurassic Polda Formation (Harris & Foster 1974; Gatehouse & Cooper 1982).

The Polda Formation was deposited in fluvial swampy environments and consists of grey to dark-grey, fine to coarse-grained clayey sand, dark grey claystone and lignite (Table 5). The sub-bituminous Lock coal deposit of 260 million tonnes (measured-indicated and *in situ)* has been delineated near "Win Gully". It is elongate east-west, 2-4 km long and has 50-130 m of overburden. Individual seams of high-ash coal are up to 6 m thick with a maximum cumulate coal thickness of 17 m.

Distribution of the Polda Formation is reasonably well known and has been intersected in numerous holes throughout the Polda Basin. Thickness varies from a maximum of 170 m onshore in Lock No.1 to an interpreted 511 m in offshore Mercury No.1.

Palynology of the unit was reviewed by Harris & Foster (1974) who used the presence of *Dictyotosporites* complex and other evidence to determine a Late Jurassic age, correlating with unit J6 of Evans (1966). This age coincides with the initial rifting that occurred prior to the separation of Australia and Antarctica. Rejuvenation of tectonism within the Polda Basin occurred along pre-existing faults within this intracratonic trough, resulting in deposition of the Polda Formation.

No marine or nonmarine Cretaceous sediments are known from the Polda Basin.

TERTIARY RECORD

Tertiary sediments represent a variety of lithologies, ages and depositional environments. They include Middle-Late Eocene fluviatile and marginal-marine sediments, Miocene-Pliocene lacustrine clay and dolomite with marine limestone, and Pliocene-Pleistocene alluvials (Table 5). They are widely distributed over Eyre Peninsula occurring in basins and shallow channels on an irregularly eroded palaeosurface over Precambrian rocks.

Middle-Late Eocene sediments are present in the Euley-Wanilla-Cummins Basins (Wanilla Formation), Polda and Robinson Basins (Poelpena Formation), palaeochannels in the western Corrobinnie Depression (Pidinga Formation), and the Cowell Basin. Lithologies in the various basins and channels are similar, consisting mostly of brown-grey, fine to coarsegrained sand, silt and clay. Some sediments are uraniferous, others are carbonaceous with minor lignitic horizons. A rich and varied assemblage of spores and pollen, including *Proteacidites asperopolus* and P *pachypolus,* were used by Harris (1964), Harris & Foster (1974) and Lindsay & Harris (1975) to define a Middle-Late Eocene age for these fluviatile to paludal sediments.

Marginal-marine carbonaceous sand, silt, and sapropelic silty clay are found within the Wanilla and Poelpena Formations (Ludbrook 1963; Lindsay 1974). Glauconite may be present sparsely, and also rare bryozoal fragments, foraminifera, sponge spicules, ostracod valves, echinoid and ?mollusc fragments. Generally sparse planktonic foraminifera in the Cummins and Wanilla Basins have been dated as Late Eocene.

Thin, yellow-buff, fossiliferous, marine limestone crops out along the Randell Fault Scarp, at Deep Creek, and near Murninnie Mine southwest of Whyalla (Miles 1952; Ludbrook *in* Miles 1955). The presence of the foraminifera *Austrotrillina howchini* is diagnostic of a Miocene age (Lindsay 1970), and the unit correlates with the Melton Limestone on Yorke Peninsula.

At Fishery Bay, similar Miocene limestone is overlain by a thin conglomeratic sandy limestone (Johns 1957, 1961), which contains moulds and casts of molluscs including *Anodontia sphericula.* A Pliocene age was inferred by Ludbrook (1959) for the molluscan assemblage in this upper unit, although A. *sphericula* is now known to range from Middle Miocene to Early Pleistocene (Ludbrook 1973a)

Restricted to the eastern end of the Polda Basin is an unnamed sequence of sand, carbonaceous grey to green clay and minor dolomite. Little is known about its thickness and distribution, but the sediments probably were deposited in a lacustrine-fluviatile environment. The clays contain a sparse microflora including *Nothofagidites mataurensis* and *Haloragacidites harrisii* which suggest a Miocene-Pliocene age (Harris in Morgan 1974)

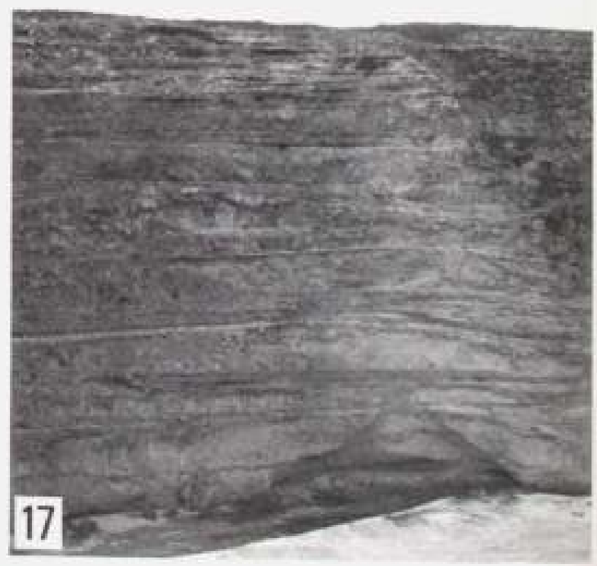


Fig. 15. Coastal cliff exposure of the Bridgewater Formation near Elliston featuring a 12 m thick sequence of nodular calcrete (oldest horizon), an overlying aeolianite with large foresets and solution pipes (note geohammer for scale), silty clay and basal calcrete clasts, and upper aeolianite.

Fig. 16. Aeolianites and calcretes of the Bridgewater Formation overlying wave-washed platform of Middle Proterozoic Blue Range Beds near Talia Caves.

Fig. 17. 130 m high cliff at Cape Wiles displaying alternating cross-bedded aeolianite and calcrete horizons (Bridgewater Formation).

The Uley Formation (of the Cummins and Uley Basins) and equivalent Pantoulbie Formation (Robinson Basin) are fluviatile-regolithic sediments consisting of orange-brown quartz sand, sandy clay, clay and rare gravel with abundant laterite nodules (Barnett 1978). Ferruginised gravelly sand grading through to clay, cropping out over granite along the west coast are likely to be of similar age as are the Gibbon Beds south of Whyalla (Parker 1983). In all cases, fossil evidence is absent, though stratigraphic relationships suggest a ?Pliocene-Pleistocene age.

Many inland Archaean-Proterozoic outcrops have been kaolinised and/or ferruginised and may have a capping of silicified conglomerate (silcrete). silicified sandstone or laterite. These weathering events generally are regarded as being Tertiary, but their precise relationships to the palynologically dated sequences are unknown.

QUATERNARY RECORD

Thin veneers of Quaternary sediments mask many of the earlier Phanerozoic sediments and Precambrian rocks on central and western Eyre Peninsula. Most prominent are Pleistocene calcrete and carbonate-cemented aeolianite (Bridgewater Formation, Figs 15-17), which form cliffs along the southern and western coasts and Pleistocene-Holocene inland longitudinal dunes and sand spreads (Wiabuna Formation and Moornaba Sand).

Aeolianite of the Bridgewater Formation contains large dune-size cross beds and consists dominantly of comminuted shell fragments in a micrite cement. Also present are numerous calcrete horizons (the Ripon and Bakara Calcretes of Firman 1967; 1975) which vary in form from intraclast breccia, to nodular, massive and laminated calcrete. Calcretization is by progressive dissolution and replacement of comminuted shell fragments and gradual development of nodular to laminar fabrics (Warren 1983a).

Carbonate-cemented root casts, elliptical calcareous cases of the weevil *Leptopius duponti* (Lea 1925) and fossils of the land snail *Bothriembryon barretti* (Ludbrook 1973b, 1984) commonly occur within the aeolianites.

Laterally equivalent to Bridgewater Formation are carbonate-cemented marine shell beds exposed at or just above present-day sea level (the Glanville Formation of Firman 1967) which are characterised by the mollusc *Anadara trapezia* and the foraminiferan *Marginopora vertebra lis.* Neither fossil is present in the modern fauna of South Australia. Belperio *et at. (1984),* from amino acid racemization and thermoluminescence dating, suggested a Late Pleistocene age of about 110 000 years for the Glanville Formation.

Younger Late Pleistocene-Holocene sediments include Pleistocene orange-fawn clayey sand which forms the cores to inland longitudinal sand dunes (Wiabuna Formation) and the capping white sands, sand dunes and spreads of the Corrobinnie Depression (Holocene Moornaba Sand) (Firman 1974; Twidale *et at. 1976).* Equivalent Holocene coastal white sands are known as the Semaphore Sand, whereas beach sand, mangrove, samphire and supratidal sediments formed within the last 6500 years are St Kilda Formation (Belperio *et at.* 1983). Near coastal salt lakes and inland salinas contain saline mud, gypsum silt, crystalline gypsarenite and selenite (Yamba Formation). Lake MacDonnell, west of Ceduna has the largest and purest gypsum deposit yet mined in Australia (Warren 1983b).

REFERENCES

Barnett, S. J. (1978). Late Tertiary sediments on Eyre Peninsula. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **67***,* 1-4.

Belperio, A. P., Hails, J. R. & Gostin, V. A. (1983). A review of Holocene levels in South Australia. *In* Hopley, D. (Ed.), 'Australian sea levels in the last 15000 years: A review.' Monograph series, Occasional paper No.3. James Cook University of North Queensland, 37-47.

Belperio, A. P, Smith, B. W, Polach, H. A., Nillrouer, C. A., DeMaster, D. J., Hails, J. R. & Gostin, V. A. (1984). Chronological studies of the Quaternary marine sediments of northern Spencer Gulf, South Australia. *Marine Geol.* **61**, 265-296.

Brown, H. Y. L. (1908). 'Record of the mines of South Australia.' (Adelaide).

Coin, C. D. A. (1976). A study of the Precambrian rocks in the vicinity of Tumby Bay, South Australia. Unpubl. Ph.D. thesis, Univ. of Adelaide.

Compston, W, Crawford, A. R. & Bofinger, V. M. (1966). A radiometric estimate of the duration of sedimentation in the Adelaide Geosyncline. *J. geol. Soc. Aust.* **13**, 229-276.

Cooper, B. J., Harris, W K. & Meyer, G. M. (1982). The Late Palaeozoic Coolardie Formation, Polda Basin. Q. *geol. Notes, Geol. Surv.* S. *Aust.,* **81**, 9-13.

Cooper, J. A., Fanning, C. M., Flook, M. M. & Oliver, R. L. (1976). Archaean and Proterozoic rocks on southern Eyre Peninsula, South Australia. *J. geol. Soc. Aust.* **23**, 287-292.

Daly, S J, Webb, A. W & Whitehead, S. G. (1978). Archaean to early Proterozoic banded iron formations in the Tarcoola region, South Australia. *Trans. R. Soc.* S. *Aust.* **102**, 141-149.

Evans, P R. (1966). Mesozoic stratigraphic palynology in Australia. *Australas. Oil Gas J.* **12**, 58-63.

Fanning, C. M. (1985). Comments on Rb-Sr total rock measurements for Wardang Volcanics, Yorke Peninsula. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **93**, 1-6.

Fanning, C. M., Flint, R. B. & Preiss, W V. (1983). Geochronology of the Pandurra Formation. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **88**, 11-16.

Fanning, C. M., Flint, R. B. & Preiss, W V. Rb-Sr geochronology on clays from the Pandurra Formation. Q. *geol. Notes, Geol. Surv.* S. *Aust.*

Fanning, C. M., Oliver, R. L. & Cooper, J. A. (1981). The Carnot Gneisses, southernmost Eyre Peninsula. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **80**, 7-12.

Firman, J. B. (1967). Stratigraphy of Late Cainozoic deposits in South Australia. *Trans. R. Soc.* S. *Aust.* **91**, 165-180.

Firman, J. B. (1974). Upper Cainozoic stratigraphic units of the Gawler Block and Eucla Basin in South Australia. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **52**, 2-4.

Firman, J. B. (1975). Australia-South Australia. */n* Fairbridge, R. W (Ed.), The Encyclopedia of World regional geology, Part 1-western hemisphere. (Hutchinson & Ross Inc, Stroudsburg, USA), 61-81.

Flook, M. M. (1975). The geology and geochronology of high grade metamorphic rocks at Kirton Point and Cape Donington, Southern Eyre Peninsula. Unpubl. B.Sc. Hons thesis, Univ. of Adelaide.

Gatehouse, C. G. (1979a). Well completion report for Murnaroo NO.1. S. Aust. Dept. Mines & Energy report 78/152 (unpubl.).

Gatehouse, C. G. (1979b). Well completion report, Wilkinson NO.1. S. Aust. Dept. Mines & Energy report *79/58* (unpubl.).

Gatehouse, C. G. (1980). A report on the relinquished areas of EL 280 outside the area of EL 434. S. Aust. Dept. Mines & Energy report *80/56* (unpubl.).

Gatehouse, C. G. & Cooper, B. J. (1982). The Late Jurassic Polda Formation, Eyre Peninsula. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **81**, 13-16.

Giles, C. W, Goode, A. D. 1. & Lemon, N. M. (1980). Middle Proterozoic volcanism and sedimentation in the Moonabie area. *J. geol. Soc. Aust.* **27**, 53.

Giles, C. W & Teale, G. S. (1979). A comparison of the geochemistry of the Roopena Volcanics and the Beda Volcanics. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **71**,7-13.

Glen, R. A., Laing, W P, Parker, A. J. & Rutland, R. W R. (1977). Tectonic relationships between the Proterozoic Gawler and Willyama Orogenic Domains, Australia. J. *geol. Soc. Aust.* **24**, 125-150.

Harris, W K. (1964). New and redefined names in South Australian Lower Tertiary stratigraphy. Q. *geol. Notes, geol. Surv.* S. *Aust.* **20**, 1-3.

Harris, W K. (1979). Palynology of the Lock coalfield: synoptic report. S. Aust. Dept. Mines & Energy report 813 (unpubl.).

Harris, W K. & Foster, C. B. (1974). Stratigraphy and palynology of the Polda Basin, Eyre Peninsula. *Min. Resour. Rev.* S. *Aust.* **136**, 56-78.

Jack, R. L. (1914). The geology of the County Jervois and portions of the Counties Buxton and York, with special reference to underground water supplies. *Bull. Geol. Surv.* S. *Aust. 3.*

Jack, R. L. (1922). The iron ore resources of South Australia. *Bull. Geol. Surv.* S. *Aust. 10.*

Johns, R. K. (1957). Eyre Peninsula. *In* Glaessner, M. F. & Parkin, L. W (Eds), 'The geology of South Australia.' J. *geol. Soc. Aust.* **5**(2), 61-70.

Johns, R. K. (1961). Geology and mineral resources of southern Eyre Peninsula. *Bull. Geol. Surv.* S. *Aust.* **37**.

Johns, R. K. (1968). Geology and mineral resources of the Andamooka:forrens area. *Bull. Geol. Surv* S. *Aust.***41**.

Kwitko, G. (1982). Lock No.1 well completion report S. Aust. Dept. Mines & Energy report 811109 (unpubl.).

Laing, W P, Sun, S. S. & Nesbit, R. W (1984). Acid volcanic precursor to Potosi Gneiss at Broken Hill and its implications for ore genesis. *In* Geoscience in the development of natural resources. *Geol. Soc. Aust. Abst.* **12**, 318-321.

Lea, A. M. (1925). Notes on some calcareous insect puparia. *Rec.* S. *Aust. Mus.* **3**, 35-36.

Lindsay, J. M. (1970). Melton Limestone: multiple mid· Tertiary transgressions, southeastern Gawler Platform. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **33**, 2-10.

Lindsay, J. M. (1974). Marine foraminifera from Eocene carbonaceous sediments, Polda, Cummins and Wanilla Basins, Eyre Peninsula. *Min. Resour. Rev.* S. *Aust.* **136**, 46-51.

Lindsay, J. M. & Cooper, B. J. (1982). A.O.P Mercury-1 well, palaeontological examination of cuttings samples. S. Aust. Dept. Mines & Energy report 820 (unpubl.).

Lindsay, J. M. & Harris, W K. (1975). Fossiliferous marine and non-marine Cainozoic rocks from the eastern Eucla Basin. *Min. Resour. Rev.* S. *Aust. 138,* 29-42.

Ludbrook, N. H. (1959). A widespread Pliocene molluscan fauna with *Anodontia* in South Australia. *Trans. R. Soc.* S. *Aust.***82**, *219-234.*

Ludbrook, N. H. (1963). Correlations of the Tertiary rocks of South Australia. *Trans. R. Soc.* S. *Aust.* **87**, 5-15.

Ludbrook, N. H. (1973a). Distribution and stratigraphic utility of Cenozoic molluscan faunas in southern Australia. *Spec. Vol. Sci. Rep. Tohoku Univ., Ser. 2 (Geol.), (Hatai Memorial Vol.),* **6**, 241-261.

Ludbrook, N. H. (1973b). Stratigraphic range of the Bulimulid land snail *Bothriembryon* in the Fowlers Bay area. S. Aust. Dept Mines & Energy report *73/51* (unpubl.).

Ludbrook, N. H., (1984). Quaternary molluscs of South Australia. *Handbook* S. *Aust. Oept Mines and Energy.* **9**.

Mason, M. G., Thomson, B. P & Tonkin, D. G. (1978). Regional stratigraphy of the Beda Volcanics, Backy Point Beds and Pandurra Formation on the southern Stuart Shelf, South Australia. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **66**, 2-9.

of the Middleback Range area. *Bull. Geol. Surv.* S. *Aust.* ***33***.

Morgan, P. J. (1974). Final report, exploration of EL 37, Lock area-South Australia. S. Aust. Dept Mines & Energy open file Env. 2256 (unpubl.).

Mortimer, G. E., Cooper, J. A. & Oliver, R. L. (1980). Petrological and petrochemical evolution of the 1.82 by Donington Granitoid Suite of the southeast Eyre Peninsula. *J. geol. Soc. Aust.* **27,** 50.

Parker, A. J. (1978). Structural, stratigraphic and metamorphic geology of Lower Proterozoic rocks in the Cowell/Cleve district, eastern Eyre Peninsula. Unpubl. Ph.D. thesis, Univ. of Adelaide.

Parker, A. J. (1980a). The Kalinjala Mylonite Zone, eastern Eyre Peninsula. Q. *geol. Notes, Geol. Surv.* S. *Aust.* **76,** 6-11.

Parker, A. J. (1980b). The six 1:100000 compilation sheets of WHYALLA-A progress report. S. Aust. Dept Mines & Energy report 80/93 (unpubl.).

Parker, A. J. (1981). Structural and metamorphic controls on the origin of nephrite jade near Cowell, South Australia. S. Aust. Dept Mines & Energy report 81/114 (unpubl.).

Parker, A. J. (1983). WHYALLA map sheet, Geological Atlas of South Australia, 1:250000 series. Geol. Surv. S. Aust.

Parker, A. J., Fanning, C. M. & Flint, R. B. (1981).
Archaean to Middle Proterozoic geology of the southern Gawler Craton, South Australia. EPIC excursion guide. S. Aust. Dept Mines & Energy report 81/91 (unpubl.).

Parker, A. J. & Lemon, N. M. (1982). Reconstruction of the Early Proterozoic stratigraphy of the Gawler Craton, South Australia. *J. geol. Soc. Aust.* ***29,*** 221-238.

Tate, R. (1882). Notes on geology about Franklin Harbour, west side of Spencer's Gulf. *Trans. R. Soc.* S. *Aust.* **4**, 143-144.

Tilley, C. E. (1920a). Metamorphism of Precambrian dolomites of southern Eyre Peninsula. *Geol. Mag.* **57**, 449-462.

Tilley, C. E. (1920b). The metamorphism of the Precambrian dolomites of southern Eyre Peninsula, South Australia. *Geol. Mag.* **57,** 492-500.

Tilley, C. E. (1921a). The granite gneisses of southern Eyre Peninsula and their associated amphibolites. Q. *J. Geol. Soc. Lond.* **77,** 75-134.

Tilley, C. E. (1921b). Precambrian paragneisses of southern Eyre Peninsula. South Australia. *Geol. Mag.* **58,** 251-259.

Trendall, A. F. (1976). Geology of the Hamersley Basin. 25th Int. geol. Congr. Excursion guide 43A (unpubl.).

Twidale, C. R., Bourne, J. A. & Smith, D. M. (1976). Age and origin of palaeosurfaces on Eyre Peninsula and in the southern Gawler Ranges. Z. *Geomorph.* ***20,*** 28-55.

Twidale, C. R., Bourne, J. A. & Smith, D. M. (1976). Age and origin of palaeosurfaces on Eyre Peninsula and in the southern Gawler Ranges. Z. *Geomorph.* **20*,*** 28-55.

Warren, J. K. (1983a). Pedogenic calcrete as it occurs in Quaternary calcareous dunes in coastal South Australia. *J. Sed. Petrol.* **53,** 787-796.

Warren, J. K. (1983b). A review of gypsum reserves at Lake Macdonnell, Eyre Peninsula. *Min. Resour. Rev.* S. *Aust.* **152,** 12-18.

Webb, A. W. (1978). Geochronology of the younger granites of the Gawler Craton and its northwestern margin. S. Aust. Dept Mines & Energy open file Env. 1582 (unpubl.).

Webb, A. W., Coats, R. P, Fanning, C. M. & Flint, R. B. (1983). Geochronological framework of the Adelaide Geosyncline. In Adelaide Geosyncline: sedimentary environments and tectonic settings. Geol. Soc. Aust. Abst. **10**, 7-9.

Webb, A. W. & Thomson, B. P (1977). Archaean basement rocks in the Gawler Craton, South Australia. Search **8**, 34-36.

Webb, A. W., Thomson, B. P, Blissett, A. H., Daly, S. J., Flint, R. B. & Parker, A. J. Geochronology of the Gawler Craton, South Australia. Aust. J. Earth Sci.

3: Mining and Mineral Resources

by R.K. JOHNS

INTRODUCTION

Mining activity on Eyre Peninsula dates from early 1860s when copper ores were produced Lipson Cove, Port Lincoln, Mount Liverpool and Murninnie mines, all in Precambrian rocks exposed in the Lincoln Uplands. In the decade that followed, lead with silver and, occasionally, copper were discovered in the Cleve Hills but production of metallic ores had almost ceased by end of the century. All base metal prospects proved to be short-lived with economic mineralisation being confined to near-surface oxidised, and production of hand-picked material amounted to several thousand tonnes only.

Iron ores were won for a short time from Iron Mount mine and Wadella Springs in the Tumby Bay area for use as smelter flux, but these were soon eclipsed by exploitation of rather more substantial resources.

The major mineral resources development project in South Australia to date has been based on outcrops of iron ore in the Middleback Ranges. Mining operations, coupled with the establishment of a fully integrated steelworks and ship building yards (for a period), all operated by Broken Hill Proprietary Co. Ltd (BHP) supports the industrial city of Whyalla which has a population 34000. The importance of these deposits in South Australian economy cannot be over-emphasised. Mining of iron ore has been the foundation of the Australian steel industry and associated industries and has added materially to the welfare of the State.

The Lake MacDonnell gypsum deposit located on northwestern Eyre Peninsula, west of Ceduna been worked since 1919 and represents the largest single Australian deposit of gypsum. It supplies 50% of domestic requirements for plaster and cement, and also is shipped overseas.

Production of other non metallic and industrial minerals currently includes salt at Whyalla, lime sand at Coffin Bay, dolomite at Iron Prince, silica near Iron Knob, jade in the Cowell district and granite at Calca for building and monumental stone (Johns 1961; Hiern 1972).

A diversity of minerals occurs on Eyre Peninsula and several are significant suppliers for domestic requirements and for export. Exploration undertaken over the past 20 years has encouraged the belief that the province has potential for hosting a variety of economic metals and minerals, and the search for petroleum has far from exhausted prospectivity of basins offshore.

IRON ORE

The Middleback Sub-Group has been strongly folded along north-south axes and crops out in the Middleback Ranges as a discontinuous line of prominent ridges extending southerly for 60 km from Iron Knob, and comprises iron-rich rocks with local concentrations of high grade iron ore as hematite. Jaspilite, consisting of magnetite, hematite and limonite with quartz and silicate-carbonate-sulphide minerals, host not only localised high grade iron enrichment but also large low grade iron resources (Miles 1955).

Iron formations comprise a conformable sequence overlying metasediments which outcrop on the lower slopes of the ranges. The lowermost unit of the Middleback Sub-Group, Katunga Dolomite, outcrops discontinuously along the flanks of the ranges; it has been intersected in drill holes and has been exposed in quarrying operations. Dolomite, 200 m thick, often is ferruginous and manganiferous, and grades upwards into either carbonate facies or silicate facies iron formation. Dolomite has been quarried from Iron Prince since 1982 for use as blast furnace flux.

Middleback Jaspilite, 200 m thick, comprises carbonate facies iron formation at the base grading upwards into an oxide facies iron formation (including talc/magnetite) and thence into a silicate facies (jaspilite). These are succeeded by Cook Gap Schists.

The sequence outlined above is cut by intrusive amphibolites emplaced during an early folding phase, post ore. The ore bodies are also intersected by a later generation of crosscutting doleritic dykes.

Iron enrichment is considered to be related to 'preparation' of favourable stratigraphy (carbonate facies iron formation) by faulting along the flanks of the ranges. Removal of carbonate through percolation of groundwaters resulted in enrichment of hematite in other favourable structural locations also, as in the keels of synclinal folds, by the process of supergene enrichment over a long period of geological time (Miles 1955; Owen & Whitehead 1965; Furber & Cook 1976).

Production is based on the principal deposits at Iron Knob (Fig. 1), Iron Monarch (Figs 2-4), Iron Prince, Iron Baron, Iron Queen and Iron Cavalier. Planning is in hand for development of Iron Duke and Iron Duchess; Iron Knight, Iron Chieftain and Iron Warrior will probably follow in due course. Close grade control is maintained in mining operations through production scheduling and blending of output from the various quarry faces. Ore may be hard and massive or friable and granular. Deleterious impurities include alumina, silica, sulphur, phosphorus, manganese and zinc.

As high grade iron ore from Iron Baron mining area is soft and unsuitable for charging directly to the blast furnace, it is pelletised at Whyalla. The blast furnace is charged with iron ore pellets and high grade lump ore from the Iron Knob mining area in a 4:1 ratio.

Mineral leases were first acquired by BHP at Iron Knob in 1898 for the production of iron ore for use as a flux at the lead smelters at Port Pirie. Mining commenced in 1900 when ore was carted by bullock wagons to Port Augusta, and thence by rail to Port Pirie until a tramway was constructed from Iron Knob to Whyalla and wharves were opened in 1903 to handle larger scale production, with barges carrying ore directly to the smelters.

Mining operations expanded considerably after 1915 to feed company steelworks at Newcastle and, for 50 years, iron ore for this and the Port Kembla plant was derived principally from the Middleback Ranges.

A blast furnace built in Whyalla in 1941 was shut down in 1981 after producing ten million tonnes of iron. A second blast furnace was tapped in 1963. A pellet plant for processing finely divided ore came on stream in 1968 and the commissioning of a new bank of coke ovens in the same year marked the final phase in establishment of a fully integrated steelworks. Work began on a shipyard in 1940 and 66 ships were built before closure in 1978. A magnetite plant for the upgrading of low grade ore was constructed at Whyalla in 1974 but it was decommissioned in 1976.

During the period 1920-1977, iron ore was the principal commodity mined in South Australia. In the 25 years of peak production between 1950 and 1975, more than 100 million tonnes of high grade iron ore, valued at $900 million, were mined. Total production to 1984 was 175 million tonnes. Output of high grade iron ore (+64% Fe) totalling 1112 million tonnes annually now sustains the requirements of the Whyalla steelworks; only small tonnages (100 000 tpa) are being shipped to New South Wales and overseas. Recoverable reserves amount to approximately 80 million tonnes.

Exploration for iron elsewhere on Eyre Peninsula has been undertaken by the Department of Mines and the private sector in areas of shallow Quaternary cover. Drilling of magnetic anomalies located by airborne and detailed ground surveys failed to disclose other than sub-economic concentrations of limonitic iron-the most significant perhaps being those of the racecourse area at Iron Knob and at Warramboo.

GYPSUM

The Lake MacDonnell gypsum deposit is the largest and most important in Australia, capable of supplying domestic and overseas requirements for many generations. At Lake MacDonnell, gypsum accumulated in a shallow depression adjacent to the coast through the refluxing and evaporation of sea brines during the Holocene period. Sea water which seeped through porous Pleistocene aeolianite (Bridgewater Formation) separating the salina from the sea was evaporated each summer to the point where gypsum crystallized. The deposits are markedly laminated with thin, regular layers reflecting seasonal precipitation of calcium carbonate alternating with deposits of gypsum.

Rock gypsum (selenite) which accumulated in the floor of the ancestral Lake MacDonnell is succeeded by seed gypsum (crystalline gypsarenite); the surface is now mantled by a thin cover of flour gypsum (gypsite) as a weathering product Average thickness of the gypsum deposit is 3.87 m. Indicated reserves of 575 million tonnes at an average grade of 91.3% $CaS0_4.2H_20$ are expected to yield 525 million tonnes of refined product; much of the deposit has a gypsum content in excess of 95% $CaS0_4.2H_20$. The major impurity is calcium carbonate (average 3.7% $CaC0_3$) as calcite and aragonite, with lesser sodium chloride.

Both rock and seed gypsum are mined from the former lake bed; seed gypsum is stripped and pushed into stockpiles by bulldozer. Exposed rock gypsum is drilled, blasted and excavated from flooded workings by dragline, crushed and screened on site. Stock piles are monitored during exposure for one to two years, to enable rainwater leaching to reduce the salt content before being railed 90 km to Thevenard for export to the eastern States and overseas. Gypsum is used for plaster of Paris, wall board, chalk, casting plaster, cement, flux, and glass filler-the product grade approaches 97% $CaS0_4$.2Hp. Since mining began in 1920, to the end of 1984, 9 520 000 tonnes of gypsum have been produced. A new company, Gypsum Resources Australia Pty Ltd, was formed in 1984 to combine the gypsum operations of Waratah Gypsum (Boral Ltd wholly owned subsidiary) and CSR Ltd at Lake MacDonnell.

Drilling has indicated reserves of gypsarenite of 58 million tonnes averaging 2.18 m thickness occupying two lakes 32.3 km^2 in area, 20 km SSE of Streaky Bay. Average grade is 87.5% gypsum with 9.0% calcium carbonate and 2.2% sodium chloride. Several other lakes and associated dunes contain significant accumulations of gypsarenite along the coast and inland. The Moonabie deposits covering an area of 26 km^2 to the west of the Middleback Ranges 64 km west of Whyalla were operated during the period 1947-1952 by BHP.

SALT

Upper Spencer Gulf enjoys special natural advantages as a source of solar salt including high net evaporation, low rainfall, and being based on high salinity seawater. Evaporating pans and crystallizers were constructed on swamp lands adjacent to the coast immediately north of Whyalla by BHP and, since 1951, production has amounted to 1 120 000 tonnes. Most of the feed water is channelled to evaporation ponds from cooling systems in the steelworks; the balance, approximately 10%, is pumped directly from the waters of Spencer Gulf.

Halite is deposited seasonally in Lake MacDonnell where natural brine inflows via Blue Lake are augmented by pumping make-up water from nearby gypsum workings. Since 1968, 1 160 000 tonnes of salt have been harvested by Waratah Gypsum Pty Ltd for shipment from Thevenard.

LIME SAND

During the Pleistocene, calcareous dune sand accumulated adjacent to the west coast of Eyre Peninsula, as a conseqence of lowered sea levels and exposure of vast expanses of the continental shelf to sub-aerial erosion. While the dunes have been stabilised through cementation of the constituent grains through downward percolation of rainwater, 'blowouts' of derived unconsolidated lime sand extend over a large area near Coffin Bay and elsewhere.

Deposits of finely divided limestone were sought by the BHP for use as flux in blast furnaces in order to utilise the soft iron ore from the Middleback Ranges. A regional survey of the State in 1959 identified Coffin Bay deposits as being the most attractive based on chemical purity, physical state and accessibility to the seaboard. Drilling in 1961-1963 outlined 750 million tonnes of comminuted calcareous sand. Sampling established uniformity of grade of these extensive deposits, containing 95% $CaC0_3$, 2.2% $MgC0_3$ and 1.0% $Si0_2$ which have been mined since 1966 by BHP for use as a flux in steel making (discontinued in 1974) and in BHAS Pty Ltd lead smelters at Port Pirie.

Lime sand is loaded by electric shovel into trucks for storage in tramway loading bins at the terminal, 35 km west of Port Lincoln. A stockpile storage bin and shipping facilities are located on the shores of Porter Bay for loading cargoes as required. Production to the end of 1984 totalled 3 070 000 tonnes.

The parent aeolianite, similarly, comprises enormous resources of high grade limestone; drilling and sampling from Coffin Bay to Uley was undertaken by BHP from 1965 to 1975.

JADE

Australia's only major nephrite jade deposits are located in the hills north of Cowell. Lenticular masses of nephrite jade up to 65 m long and 3 m wide are associated with dolomitic marble and calc-silicate of Hutchison Group Archaean gneiss in the Mount Geharty area. Since discovery in 1965 more than 100 discrete deposits have been located.

Cowell Jade Pty Ltd was established in 1976 to mine, process and market the product which is sawn and graded according to colour and quality. A variety ·of jewellery, ornaments and carvings are fashioned at Cowell and Unley workshops. The jade commonly is dark green, often with colour zoning; black jade constitutes the highest grade material. To the end of 1984, approximately 1000 tonnes had been mined.

SILICA

High grade quartz is being mined by BHP from a reef which crosses the Whyalla-Iron Knob road

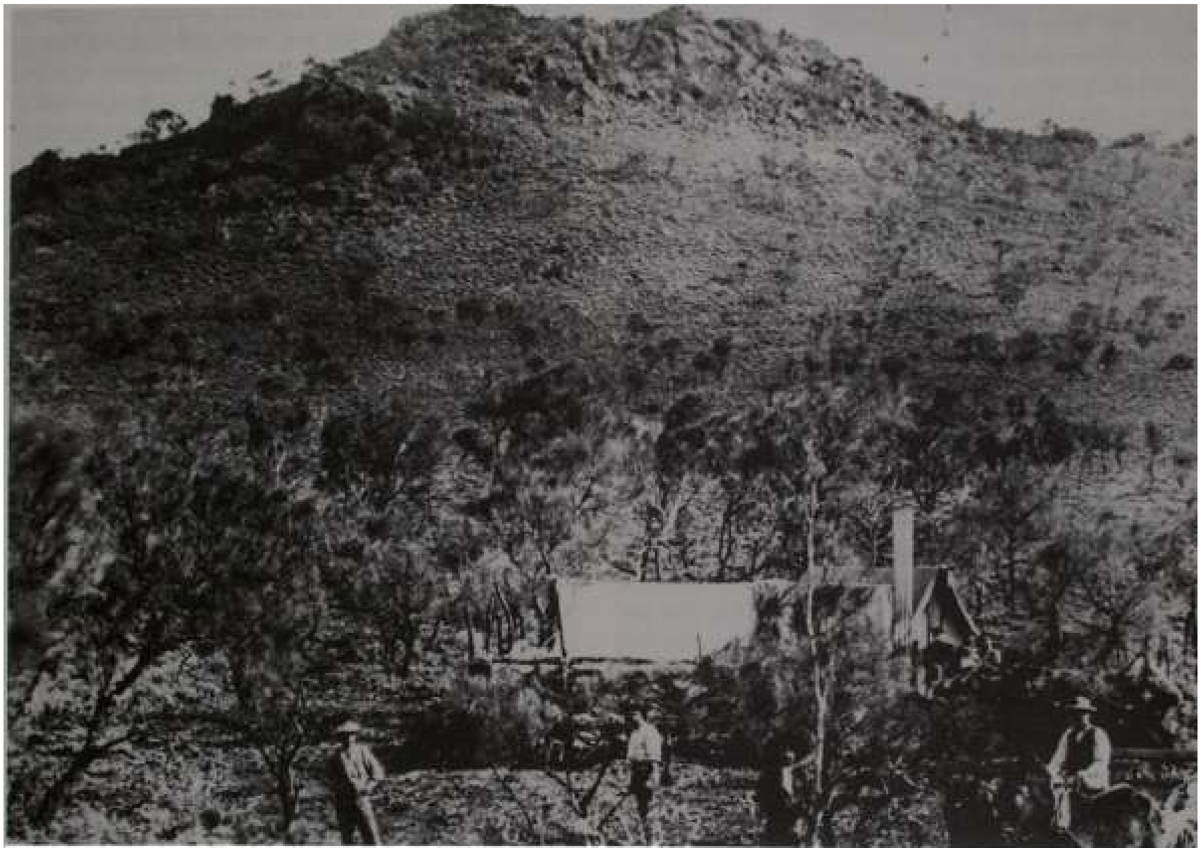


Fig. 1. Iron Knob, view South, 1900, prospector's hut.

Fig. 2. Figs 2-4. Blasting at Iron Monarch, 1966.

Fig. 3.

Fig. 4

36 km from Whyalla. A quarry has been opened about one km north of the road where the reef is 20 m wide. Hard brittle lump silica is shipped to Bell Bay (Tasmania) for the manufacture of ferrosilicon. Specifications include +99% $Si0_2$ and less than 1% Al_20_3 + Fe_20_3. Since quarrying began in 1949 to and including 1984, 250 000 tonnes have been produced.

Since 1970, BHP has mined coarse grained well sorted rounded quartz sand from the peach at Baird Bay for soakage pit bed sealer.

AGGREGATE, CONSTRUCTION MATERIALS

Coarse aggregate for road and railway construction and for concrete are derived from a variety of rocks, dependent on availability and suitability of materials. Calcrete is widespread and constitutes the only useful rock over much of the region, though pisolitic iron (laterite) is used in the Lincoln Uplands. The principal aggregate quarries are based at Whyalla (quartzite), Moonabie (grit), Ferns (dolomite), Uranno (granite), Port Lincoln (granite gneiss), Darke Peak (quartzite), Tooligie (quartzite), Minnipa (granite), Mount Cooper (rhyolite), Coorabie (granite), Ceduna (calcrete) and Paney (porphyry).

Sandstone of pleasing appearance and ready workability has been utilised from two quarries as building stone at Whyalla. Monumental and building stone is being produced from red granite at Calca, near Streaky Bay. Middle Camp (red) and Minnipa (pink) granites have been quarried on a small scale in the past and Charleston (pink and green) and Moody (grey) granites have potential use. Dolomite from deposits near Cowell and in the Tumby Bay area have been utilised in terrazzo ware.

GRAPHITE

Disseminated flake graphite occurs in several localities in the Cleve Hills and on southern Eyre Peninsula where flake size is coarser. Mining was conducted at Uley and at Koppio; production amounted to 800 tonnes of refined graphite which was used in crucibles and mould facings in foundries, and in dry cell batteries, lubricants, carbon brushes and paints.

At Uley a bed of graphitic schist up to 10 m thick was exploited on the crest of an anticlinal fold by shafts which connected to three principal working levels and, in due course, an open cut. During 1866-1950 over 550 tonnes of graphite were produced, containing 58-84% carbon. A mill and refinery were erected at Uley in 1928 for recovery of refined flake graphite by flotation. Competition from abroad, however, forced closure in 1951.

Since 1981 there has been renewed interest in the Uley deposits and work undertaken to define extensions under shallow cover.

BROWN COAL

Lignite has been intersected during drilling in Tertiary basinal sediments but the only deposits of brown coal of any significance that have been identified are preserved in the Polda Basin, 15 km west of Lock.

Drilling undertaken from 1977 to 1980 by the Department of Mines and Energy in conjunction with the Electricity Trust of South Australia disclosed 260 million tonnes of brown coal amenable to open cast extraction, and which would be suitable for combustion in conventional thermal power stations. Sub-bituminous coal of Late Jurassic age is interbedded with sand and clay of Polda Formation and is overlain by Tertiary sand and clay with lignite and Quaternary sand, clay, gravel and calcrete.

Lock coal measures are confined to an elongate narrow east-west trending basin, 2-4 km wide and 15 km long, comprising numerous flat to gently dipping seams of high ash (23%), high moisture content (26%) coal, 0.5-6 m thick. Cumulative coal thickness attains 17 m, but is usually 5-15 m. Overburden ranges 35-230 m, but is generally 50-130 m.

Sodium/ash ratio and sulphur content are the lowest of the known South Australian sub·bituminous coals and heat value is comparable with that of Leigh Creek coal. Problems with exploitation of this deposit include proximity to the Polda groundwater basin and higher cost of recovery than for some other deposits.

TALC

Mining began in 1909 on a number of small irregular talc lodes near Lipson, 14 km northwesi of Tumby Bay. Output of high quality white, powdery, cosmetic grade talc selectively mined from irregular underground workings serviced by some 50 shafts up to 25 m deep reached a peak during 1941-1950; about 12 000 tonnes of talc have been produced. The talc, in two parallel northeasterly trending lines of lode, is generally less than 10 m wide, with masses of jasper and pegmatite, adjacent to a bed of dolomite.

Because of limited reserves, dark green, fine grained, homogeneous masses of talc in the Cowell district at Minbrie and at Mount Geharty, are used only in ornamental carving.

OTHER MINERALS

A variety of other minerals has been identified in the region but, because of their limited size or indifferent grade, they are of limited commercial interest.

Narrow pods of high grade dense white magnesite are associated with graphitic beds. Small production was limited to the Stokes-Koppio area.

Mount Whyalla barite deposits, 4 km north of Mt Whyalla yielded 2 188 tonnes of high quality material (96% $BaS0_4$) for use in paint during 1938-1967. A series of lenses was exploited along a vertical fracture zone for a distance of about 800 m in now-abandoned workings of what was known as Turner's Mine. The veins ranged up to 1.5 m wide; the host rocks are gently dipping Pandurra Formation sandstone.

Lenses of high quality barite averaging 0.5 m wide occupy a fracture zone in quartzite of the Moonabie Formation at Mount Laura. There has been small production. Quartz-barite veins intrude Burkitt Granite and Corunna Conglomerate, 12 km northwest of Corunna.

White kaolinitic clay derived from weathering of felspars in the pallid zone related to lateritic weathering of Precambrian rocks is widespread. Testing of clay from Stokes and Salt Creek gave some encouragement for use in fireclays as a constituent of whiteware pottery bodies. Deposits located near Mount Hope and at Mount Sturt have been investigated for use in paper coating.

A number of deposits of white clay have been identified between Whyalla, Iron Knob and Port Augusta which have been derived principally from weathering of the Tregolana Shale Member of the Tent Hill Formation and shale of the Moonabie Formation and have been utilised by BHP for brick making and as fireclay.

Avian guano and phosphate rock derived from reaction with underlying calcrete was recovered from a number of islands off the coast of southern Eyre Peninsula for application directly to the soil as an agricultural fertilizer during 1890-1912. The low grade deposits mark the former nesting sites of sea birds and were often preserved in cavities in Pleistocene limestone. Licences for production were issued over islands of Spencer Gulf, particularly Sir Joseph Banks Group, in Coffin Bay, and off the West Coast.

Amazonite was mined from a pegmatite in the Koppio area during the period 1965-1974.

Semi-precious amethyst has been exposed in veins up to 1 m wide, and in crystal-lined vughs in quartzite, 22 km southeast of Kimba. Black quartz crystals (morion) have been recovered from the Kathleen Patricia deposit 26 km north west of Cowell.

Finely banded gem quality agate, with alternating red and white laminae with shades of grey, occurs as cavity fillings in Gawler Range Volcanics and as detrital fragments on the surface at Pandurra; there has been limited production.

Pink thulite (clinozoisite) which has been found near Cowell nephrite jade deposits has potential for use as ornamental stone.

There has been small production of chrysotile asbestos from thin veinlets in serpentinised dolomite in the Cowell area and west of Tumby Bay.

Sampling has indicated the availability of metallurgical grade dolomite in the Cleve Hills, at Mangalo and Carpa.

Production of 200 kg of wolfram was reported from Langton Island during the period 1942-1944.

In 1963, molybdenite associated with scheelite was discovered on the southernmost extremity of Spilsby Island. Drilling indicated approximately 250 000 tonnes of rock containing 0.25% combined $MOS/W0_3$ but the mineralized zone is of too low grade to support a mining operation.

Small tonnages of manganese as pyrolusite derived from weathering of banded ironstone formations were recovered in the Tumby Bay locality late last century. The iron ores of the Middleback Ranges, particularly at Iron Monarch, were sufficiently high in manganese to warrant selective recovery for production of high manganese steels. Iron ore high in zinc and manganese has been marketed interstate and overseas for use as high density aggregate to clad pipelines offshore.

Copper mining was initiated in the Lincoln Uplands but reserves of near-surface, secondarily enriched, carbonate ores in the district were limited. The lodes are tabular quartz veins, confined to near-vertical, narrow shears in Hutchison Group metasediments. Production of about 1000 tonnes of ore, hand picked to about 25% copper, is recorded from the Tumby workings which penetrated to 75 m. Primary chalcopyrite was encountered in the lowermost levels of Tumby Bay and Liverpool mines and at the Lipson Cove prospect. Bismuth was a minor constituent at the Burrawing mine.

In the Cleve Hills, secondary ores of copper are associated with lead, silver and minor zinc in narrow lodes, concordant with enclosing dolomitic meta-sediments, or in association with pegmatites. Production of hand-picked ore from the numerous prospects was probably less than 1000 tonnes. Mining extended to depths of about 40 m at several mines. Drilling failed to indicate lode extensions at Miltalie, Calcookra and Yalpoudnie mines.

Lead is associated with copper at Miltalie, Yalpoudnie and Poonana mines, and lead with silver was mined at Mount Miller, Cleve, Elson and Davey's prospects. Rich silver ore was recovered from Atkinson's Find.

About 1 000 tonnes of copper ore with bismuth were raised from Murninnie mine during 1862-1900.

Galena and sphalerite with minor copper, silver and gold were recovered at the Lady Franklin and Moonlight mines.

RECENT EXPLORATION ACTIVITY

The search for stratiform base metal mineralisation since 1969 has utilised geochemical and geophysical methods based, principally, on a concept of association with banded iron formations where exploration targets are lead-zinc-copper-silver deposits of the Broken Hill type. Other geological environments in which copper anomalism has been disclosed include the Tapley Hill Formation in the Tregolana.-Tent Hills area and in the Roopena Volcanics structural zone. These efforts have been rewarded with the discovery of significant base metal mineralisation at several centres.

Uranium is associated with copper mineralisation in the Cleve Hills at the Poonana, Calcookra, Boards and Emu Plains mines, while a number of points of anomalous radioactivity have been located by aerial and ground surveys elsewhere in the region. Pitchblende with secondary uranophane and gummite is concentrated in thin, concordant, steeply dipping, tabular bodies in granite gneiss in the Port Lincoln area but drilling has indicated that extent is limited.

The occurrence of uranium in crystalline basement rocks suggests that there is potential for its redistribution from such sources and to be concentrated in marginal Tertiary basinal sediments.

Exploration for sandstone-type uranium mineralisation undertaken by Carpentaria Exploration Co. Pty Lld in 1979-1982 revealed a major Tertiary palaeochannel system. The main palaeo-channel (Narlaby Channel), more or less coincident with the Corrobinnie Depression, is 170 km long, up to 10 km wide and is infilled with up to 80 m of Eocene fluviatile sediments overlain by up to 100 m of Pliocene to Recent fluviatile and lacustrine deposits. The Hiltaba Granite which margins the depression is considered to be the source of the uranium. Low grade uranium mineralisation is associated with a complex series of redox fronts in the western part of the channel. Groundwaters are extremely saline and acidic and in places contain very high concentrations of uranium, but the mineralisation located to date is too patchy to be economic.

During 1964-1984, 64 companies have been engaged in the search for a variety of minerals on Eyre Peninsula in 231 Exploration Licences. During the course of exploration 9 550 holes have been drilled, aggregating 294 000 m; expenditure reported in compliance with commitments totalled $16 490 000.

Offshore, the search for hydrocarbons over the Continental Shelf is at a preliminary stage and only four wells have been drilled. Potoroo 1 and Apollo 1 were dry holes drilled in the Great Australian Bight Basin and Echidna 1 and Platypus 1 in the Duntroon Basin, southwest of Port Lincoln. Likewise, drilling of Gemini 1, Mercury 1 and Columbia 1 which have been drilled in the offshore Polda basin failed to disclose hydrocarbons. Excessive water depth (plus 1000 m) has inhibited testing the Ceduna Terrace where seismic surveys have indicated a number of large exploration plays.

Since exploration was initiated in 1969, 17 companies have been engaged in petroleum exploration offshore; $50 million have been expended on 14 licences during the ensuing 15 years.

The geological setting of sedimentary basins off Eyre Peninsula is considered to be favourable for the generation and accumulation of hydrocarbons. They conform to a passive continental margin tectonic model associated with deposition of predominantly non marine Mesozoic sediments during a rift development phase prior to the separation of Australia from Antarctica. In this respect, a common tectonic history is shared with the Bass and Gippsland Basins, such that source and reservoir beds and structural trapping mechanisms are likely to be similar. The Polda Basin is exceptional to the above, having a geological history which predates the Mesozoic through Tertiary rift and post-rift tectonic phases.

A new importance was conferred on northern Spencer Gulf when Stony Point (20 km east of Whyalla) was selected to be the coastal terminal for petroleum liquids produced in the north east of the State from the Cooper and Eromanga Basins. An 80 000 barrels per day capacity pipeline, 659 km long, connects the Moomba processing plant with fractionation plant, storage facilities, and a loading out jetty 2.4 km long at Port Bonython. Crude oil and condensate were first produced for export in February 1983 and production of LPG (propane and butane) for domestic and overseas markets began in June 1984. The volume of throughput amounts to about 7 million barrels of crude oil, 5 million barrels of condensate and 600 000 tonnes of LPG, annually.

REFERENCES

Furber D. V. & Cook J. N. (1976). Middleback Ranges Iron Ores, *In:* 'Economic Geology of Australia and Papua New Guinea', Vol. 1, Metals, Monograph Series No.8, (Aust. Inst. Mining & Metallurgy, Melbourne), 945-951.

Hiern, M. N. (1972). Mineral Resources of the Eyre Planning Area. *Mineral Resour. Rev.* S. *Aust.,* **133**, 11-28.

Johns, R. K. (1961). Geology and Mineral Resources of Southern Eyre Peninsula. *Bull. Geol. Surv.* S. *Aust.* **37**, 101 pp.

Miles, K. R. (1955). The Geology and Iron Ore Resources of the Middleback Range Area: *Bull. Geol. Surv. S. Aust.* **33**, 198 pp, 5 append.

Owen, H. B. & Whitehead, S. (1965). Iron Ore Deposits of iron Knob and the Middleback Ranges, *In:* 'Geology of Australian Ore Deposits' Vol. 1 Eighth Commonwealth Mining and Metallurgical Congress, Australia and New Zealand, 1965, 301-308. (Aust. Inst. Mining & Metallurgy, Melbourne).

4: The Form of the Land Surface

by C.R. TWIDALE and ELIZABETH M. CAMPBELL

EVOLUTION OF THE LAND SURFACE

From a geomorphological point of.view, and in many other ways, Eyre Peninsula epitomlses the western half of the Australian continent: the major outlines of features are directly and closely related to the nature of the underlying crust; the region is dominated by plains, some of them at or close to present baselevel (sealevel), but with remnants of others preserved high in the relief; many of the forms are of considerable antiquity.

The triangular shape of Eyre Peninsula is due to the intersection of two major fault (fracture) zones (Fig. 1). One, the Lincoln Fault or lineament runs southwest from the vicinity of Port Augusta. This fault zone effectively determines the trend of the east coast, though it is complicated in detail by local fracture patterns, as for instance between Cowell and Whyalla and Whyalla where the faults form an angular *en echelon* pattern; by lithological contrasts that give rise to bay and headland; and by alluvial and coastal deposition as for instance around Franklin Harbour where there are extensive mangrove flats. The faults are still active (Sutton & White 1968) and account for the straightness of the coast in broad view, for the abrupt rise of the Lincoln Uplands and Cleve Hills from the coastal plains, and for the occurrence of dirt scarps in the Cowell-Whyalla region. On the west coast the general linearity of the coast and the occurrence of earthquake epicentres argue the presence of a broad fracture zone or lineament trending northwest-southeast. Demonstrated faults run near the coast in the south, but the northwest, north of the Polda Basin inferred and offset fractures parallel the coast but are located close to the edge of the continental shelf.

In the north, too (Fig. 1), the Peninsula is effectively separated from the Gawler Ranges by the northwest-southeast trending Corrobinnie Depression (Bourne *et al.* 1974). Another northwest-southeast trending depression, of such straightness as to be almost certainly fault-related, runs southwest of Minnipa and Wudinna and is occupied in part by Lake Yaninee, Kappakoola Swamp and other ephemeral lakes. The abrupt western margin of the Cleve Hills also is almost certainly associated with crustal fractures. It is the site of earthquake epicentres, and their distribution (Sutton & White 1968) also suggests another NE-SW trending fracture zone that partly defines the Lincoln Uplands on their western side.

Though it is not evident at the surface there is an east-west fault-bounded structural depression (possibly a rift valley or graben now occupied by Mesozoic sediments) crossing the continental shelf and slope west of Elliston and extending into the heart of the Peninsula south of the Darke Range (Smith & Kamerling 1969). There are indications of other possible east-west fracture zones in the south of the Peninsula (see below).

Rock type also plays an important part in determining topography. The oldest rocks exposed on the Peninsula are those of the Lincoln Uplands and Cleve Hills. These metamorphic rocks are folded and the contrasted rock types, of differing resistance to weathering and erosion, typically give rise to patterns of ridge and valley that closely reflect the pattern of folding (Fig. 2). Exposures of granite rocks give rise to forms that are characteristic of the rock type not only in gross form (inselbergs, boulders) but also in the suite

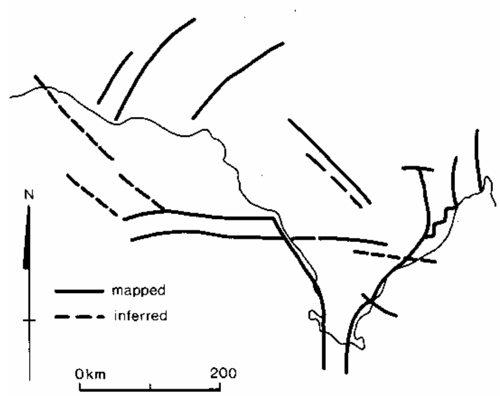


Fig. 1. Major fractures on and near Eyre Peninsula. Modified from Tectonic map of South Australia 1982. (Geol. Surv. S. Aust.).

of minor forms developed (see e.g. Twidale 1982a). Similarly the riverless character of the centre and west of Eyre Peninsula reflects the permeability and perviousness of the limestone that underlies these regions.

The oldest landforms known from Eyre Peninsula-and they include some of the oldest dated land surfaces known-are preserved in the uplands of the east and south (Twidale *et al.* *1976).* The most distinctive feature of the Lincoln Uplands is the lateritised plateau which, though tilted down to the west and extensively dissected, dominates the landscape. Laterite is the oldest of several duricrusts preserved on Eyre Peninsula.

A duricrust is a tough, hard, resistant concentration of a particular mineral or minerals formed as a result of weathering and now desiccated and forming a hard encrustation or capping on the land surface. Such duricrusts are of interest not only because of their economic significance - calcrete is a useful road metal for instance-but also because they afford clues as to the age of the land surfaces on which they occur, and to the climatic and other conditions that existed at the time of their development.

Today laterite is forming on plains in humid tropical (optimally in monsoon) lands, in such areas as southern India, Malaysia and Indonesia (Prescott & Pendleton 1952; Maignien 1966) and

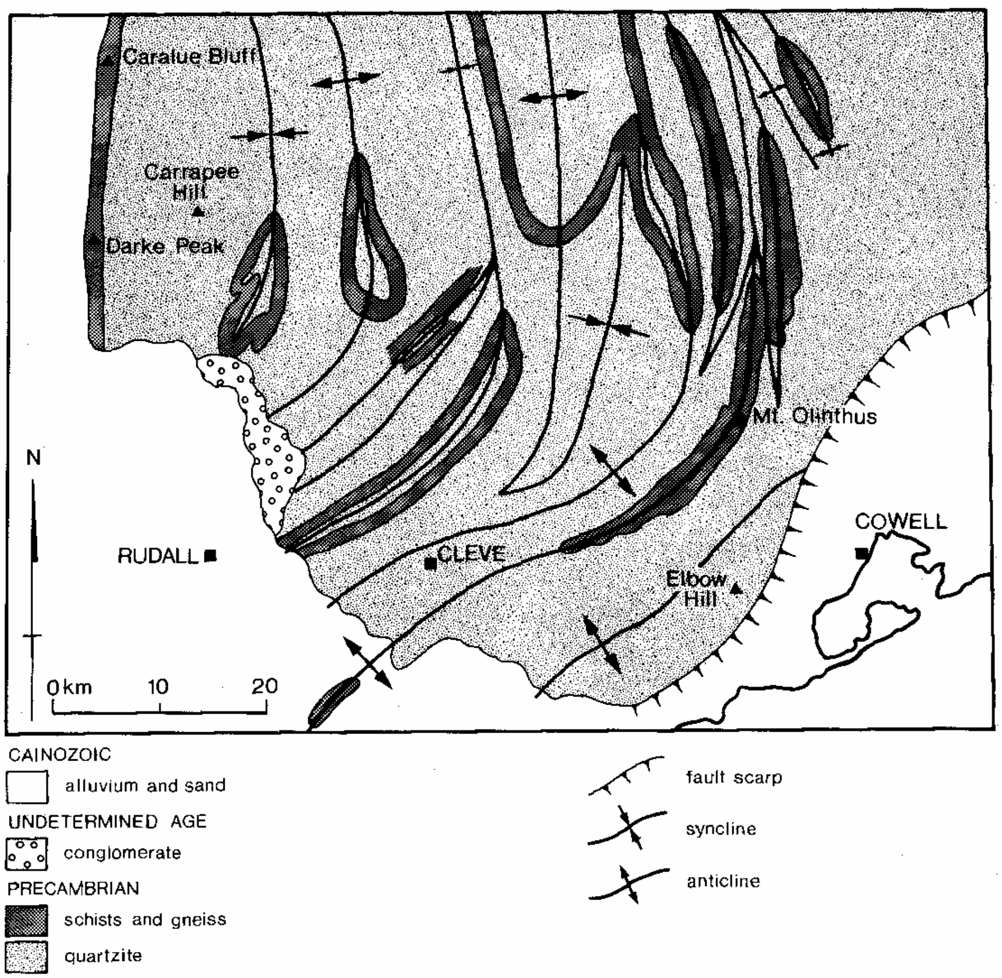


Fig. 2. Pattern of folds in the Cleve Hills. (After Johns 1961)

presumably similarly torrid conditions and low relief prevailed when the laterite of southern Eyre Peninsula formed.

The laterite is widely preserved on the Lincoln Uplands (Johns *et al.* 1958) but it is not as extensive as might at first sight seem to be the case, for the ferruginous pisolitic (pea-like) capping of this old weathering profile is widely used in road construction, and is found for instance on Winter Hill, overlooking Port Lincoln, where the bedrock is a granite gneiss and where no laterite occurs *in situ.* There is no direct evidence as to the age of the laterite on Eyre Peninsula, but a similar high plain capped and protected by pisolitic ironstone occurs on Fleurieu Peninsula and on Kangaroo Island. In the latter area the laterite is developed on Precambrian, Cambrian and Permian rocks. The weathering profile appears to be buried by basalt (Fig. 3) of Middle Jurassic age (Daily *et al.* 1974; Daily *et al.* 1979). Thus the laterite must be younger than the Permian, but older than the Middle Jurassic, and the best estimate of its age, bearing in mind the palaeontological evidence, is that it is Triassic, i.e. of the order of 200 million years old. There is no evidence of its having been buried and preserved in that way; on the contrary the sands that commonly overlie the ironstone are part of the soil profile. How the old soil and associated surfaces have survived so long is a considerable mystery. The ironstone hardens irreversibly on desiccation (Alexander & Cady 1962), and reinforcement effects -the fact that once uplifted the hills shed water, the main agent of erosion (Twidale *et al.* 1974)- would also assist, but their persistence at the land surface remains an enigma (Twidale 1976).

The laterite extends as far north as Blue Range and possibly to one site between Kimba and Kyancutta, about 40 km ESE of the last named settlement (but see also below), but is not preserved on the prominent summit plains of the Cleve Hills and Tent Hills. Both of these high plains and plateaux are erosional in origin, though very little in the way of soil (or saprolith) is preserved on either upland. In the Cleve Hills, as for example just north of Glenville Homestead (east of Cleve) there are pockets of ferruginous pisolite but they are thin and of limited extent. Nonetheless they suggest that the surface may have been subjected to the same type of weathering as the lateritised area to the south, and that the weathering may have taken place at the same time in the two areas. But the paucity

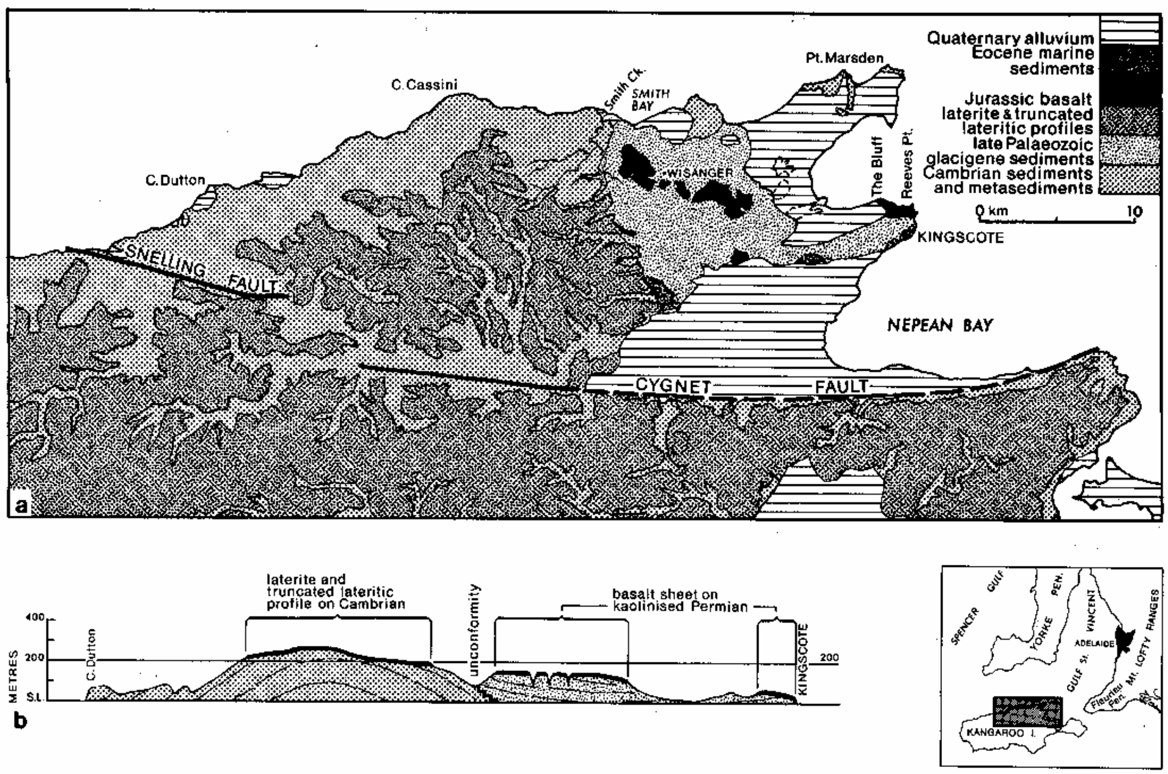


Fig. 3. East-west section west of Kingscote, Kangaroo Island, showing relationship between basalt and lateritised Palaeozoic and Proterozoic rocks (after Daily *et al.* 1974).

of the lateritic material in the Cleve Hills suggests that if it were ever present it has been stripped off by later erosion so that the surface now exposed and underlain essentially by the local, unweathered bedrock, is of etch type (Wayland 1934; Willis 1936; also Jutson 1914). The summit surface of the Tent Hill region, which also lacks a lateritic cover, was evidently disrupted by the late Cretaceous faulting that caused the initiation of the Lake Torrens basin, as well as the formation of the St Vincent and Spencer gulfs (Twidale *et al.* 1970). These uplifts may well have caused stream rejuvenation and renewed dissection and the stripping of the earlier developed saprolith.

The reduction of large areas of varied and resistant and contorted rock to plains of low relief, and the concomitant development of a saprolith that was manifestly, on the evidence of the remnants in the Lincoln Uplands and adjacent regions in Fleurieu Peninsula and Kangaroo Island, of considerable depth, argue a long period or periods of relative standstill, when the land surface changed only slowly in response to stability of the crust and of climatic conditions.

During the Mesozoic such deep weathering presumably extended over the entire Peninsula as water penetrated deep below the then land surface. The rocks were rotted, though not uniformly, for particularly resistant compartments or masses remained virtually unscathed and, as now, stood as projections above the surface or as projections within the saprolith (Fig. 4).

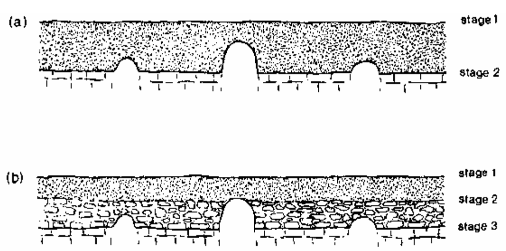


Fig. 4. Diagrammatic section showing relationship of inselbergs to weathering front, and possibilities of (a) single and (b) multiple phases of weathering and erosion.

Whether this differential weathering was achieved during one extended (Mesozoic) period of landscape stability, or whether several periods of weathering and erosion were involved, is not known. As the weathered cover has been eroded these resistant masses have become exposed and then more exposed to become the various inselbergs or island mountains, the isolated hills and ranges, some granitic, some quartzitic, that stand so dramatically above the plains of the central western and northeastern areas. The various bevels and platforms preserved on and near the summits of such hills at Mt Wudinna, Carappee Hill (Twidale & Bourne 1975a; Twidale 1982b), Mt Hope and the North and South Blocks and Marble Range may be remnants of such once extensive higher plains (Fig. 5).

Fig. 5. Carappee Hill is a high (490 m above sealevel and 270 m above the plain) inselberg of granite gneiss and with a stepped morphology: there is for example a prominent platform located some 90 m above the base.

The lowering of the plains took place in stages, with pauses between the various phases of erosion during which the uplands came to stand higher and higher in the relief. These pauses are marked by the development of different duricrusts, and by intense weathering in the then scarp foot zones of the uplands, weathering that at some sites resulted in the development of the flared slopes (Twidale 1962) that are such dramatic features of some inselbergs (Fig. 6).

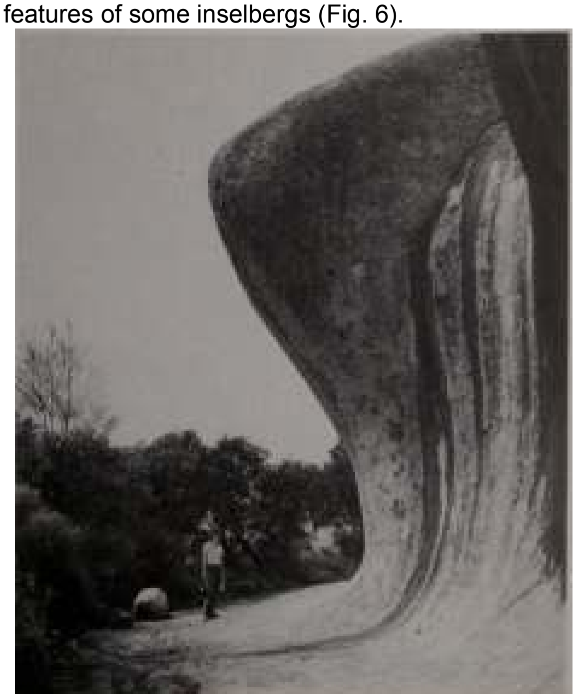


Fig. 6. This distinctly overhanging flared slope occurs on a minor spur on the western side of Ucontitchie Hill.

Thus after the dissection of the Mesozoic landscape or landscapes, large areas of the north, centre and west of the Peninsula had by later Tertiary times, some 20 million years ago, been reduced to a plain of low relief on which a silcrete was widely developed.

Silcrete (see Hutton *et al.* 1978) is a highly siliceous duricrust typically grey or yellow brown in colour (though red and white patches are common), with a glassy look, greasy feel and well developed conchoidal fracture-hence its widespread use by Aborigines for tool making. In hand specimens the rock is fine grained with large crystals of quartz set in a fine siliceous matrix. The silcrete, like laterite, seems to have formed under warm humid conditions but it is preserved in aridity. No certain contemporary developments have been recognised. During the late Tertiary, the silcreted plain of Eyre Peninsula was dissected by rejuvenated streams and only remnants of this surface are preserved in the northeast, for example on Long Sleep Plain, north of Whyalla; on the Pandurra Range; around Uno Range, and in the scarp foot zones and on the plains around the Tent Hills.

Then during Pliocene times about 2-8 million years ago, another plain was developed standing about 5 m higher than the present surface, and a ferruginous carapace, an iron encrustation was formed. Ferricrete is another duricrust rich in iron oxides. It lacks the sandy A-horizon and the kaolinitic C-horizon of laterite. Many examples are of depositional origin and were laid down in valley floors although they now commonly cap ridges -an example of relief inversion. In some areas ferricretes are derived from the dissection of laterites. On Eyre Peninsula ferricrete occurs patchily in the north and northeast (e.g. between Kimba and Kyancutta, some 40 km ESE of Kyancutta -though it could be a true laterite- and some 7 km north of Mt Bosanquet), and is the saprolith well displayed at many sites on the west coast, and at Louth Bay, preserved beneath the dune limestone. Evidence from Yorke Peninsula suggests that these ferricretes are of Pliocene-early Pleistocene age, i.e. about two million years old (Horwitz & Daily 1958).

Associated with this period of weathering that resulted in ferruginisation of the surface, are the flared slopes prominently displayed around the bases of many of the granitic inselbergs of the northwest, for these concave bedrock forms are demonstrably due to subsurface moisture attack in the piedmont zone, followed by preferential erosion of the weathered rock, and exposure of the flared weathering front, or limit of weathering.

This surface was in turn dissected though considerable elements of the older plain still remain, but new plains have been eroded especially around the inselbergs in the zones of rotten bedrock, and the whole surface has acquired a crust of lime, or calcium carbonate, and known as kunkar or calcrete.

Calcrete is a pedogenic limestone (Milnes & Hutton 1983). Initially small nodules of lime form in the soil, then grow and coalesce to form honeycomb calcrete, more or less massive sheets, and eventually hard pans. Calcrete develops in arid or semiarid conditions and is widely developed and preserved throughout the Peninsula. It is part of a complex sheet of carbonate widely accumulated in southern Australia, and sporadically in the centre and north of the continent during the Pleistocene.

During these extended periods of Cainozoic erosion the Corrobinnie fault zone was also exploited by streams (Bourne *et al.* 1974; Binks & Hooper 1985). During the Eocene, some 40-60 million years ago, the main Corrobinnie Channel extending from the vicinity of Kimba to the Wirrula district, was eroded and river deposits laid down (Fig. 7). The river was reactivated during the Pliocene, 2-5 million years ago and, in addition, a channel extending north from Narlaby was developed. It extended an unknown distance to the north on the western side of the Gawler

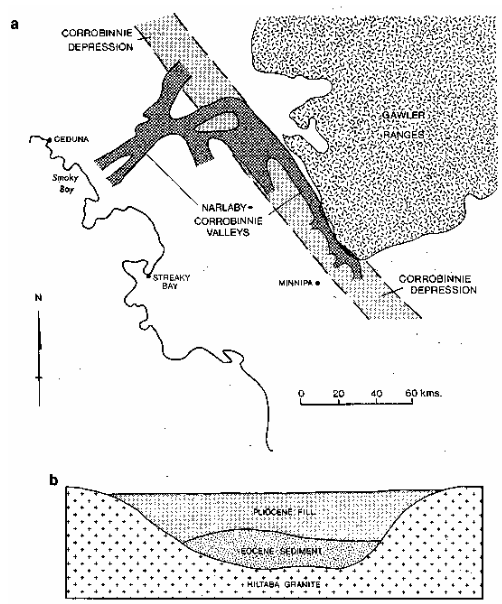


Fig. 7. (a) Plan and (b) typical cross-section of the Corrobinnie Depression and associated old river channels (after Binks & Hooper 1985).

Range, and a tributary evolved in the (fracture controlled) valley now occupied by Lake Gilles. The Corrobinnie and Narlaby channels joined in the vicinity of Wirrula and ran southwest to the then coast and through the present Smoky Bay. Odd though it may seem, this old major river channel was blocked as a result of sea level lowering during the late Cainozoic, consequent upon the formation of vast sheets of ice at high latitudes. Then the continental shelves were exposed, and sand and fragments of shells were blown inland under the influence of onshore winds, and particularly on the west coast of the Peninsula, under the influence of the westerlies. Huge coastal dunes of limestone or aeolianite (Crocker 1946) were formed behind the beaches. As can be seen at many sites along the west coast, the old dunes extend well below present sea level, for much of the late Cainozoic ice has melted, allowing water to return to the ocean basins.The old dunes effectively blocked the outlets of several late Cainozoic rivers, including the Corrobinnie-Narlaby channel which thus became a depression without a mouth, an area where sediments and water from the southern Gawler Ranges and much of northern and northwestern Eyre Peninsula gathered. The result is the Corrobinnie Depression, with its many salt lakes and the Kwaterski Dunefield, a region of parabolic, U-shaped or festoon dunes (Fig. 8).

Coastal dunes are still actively forming in many areas and attain considerable size. In two southern regions also the dunes are of parabolic form and these two areas-McLachlan and Tooligie, are distinguished on that basis (see below).

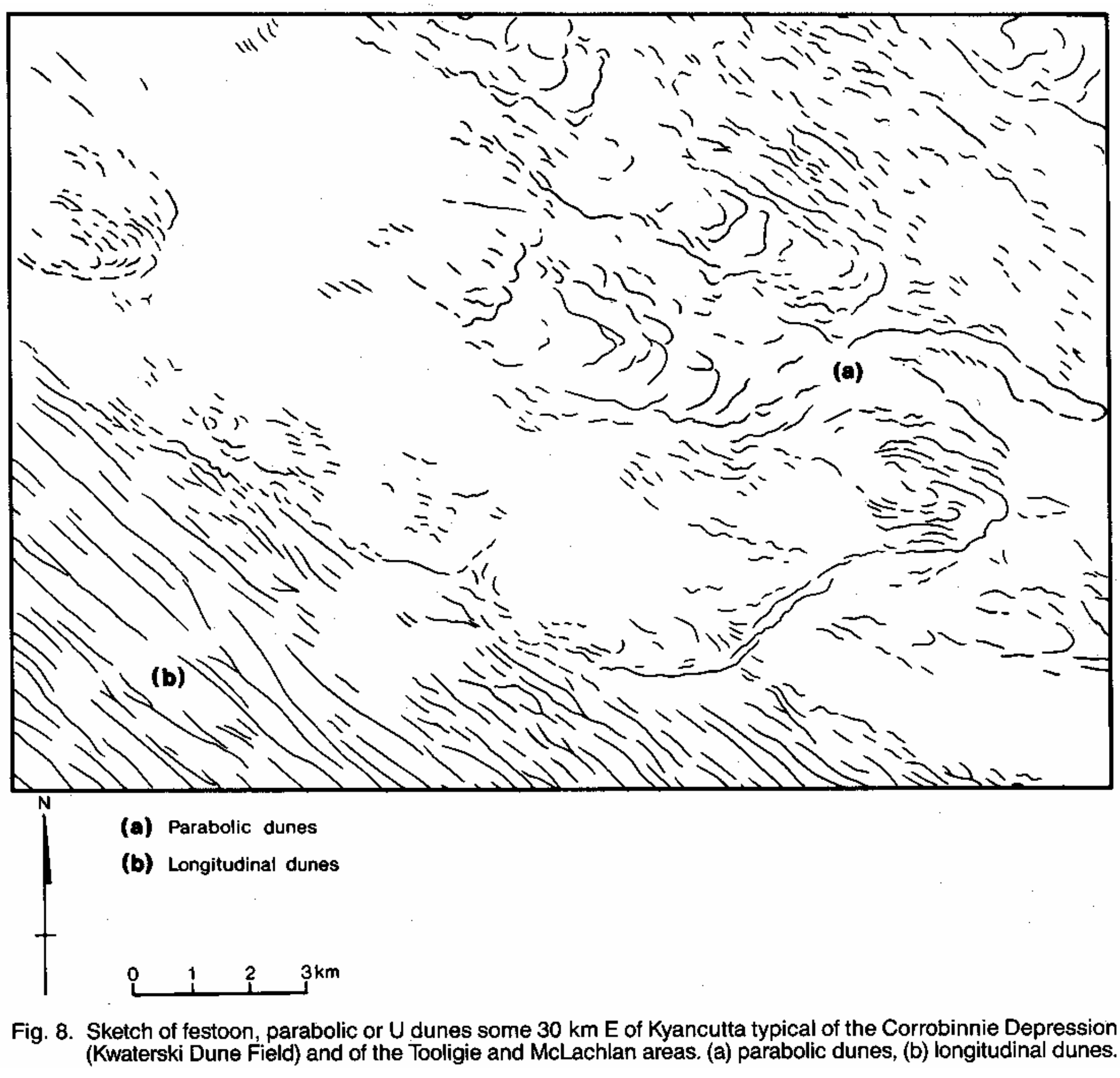


Fig. 8. Sketch of festoon, parabolic or U dunes some 30 km E of Kyancutta typical of the Corrobinnie Depression (Kwaterski Dune Field) and of the Tooligie and McLachlan areas. (a) parabolic dunes, (b) longitudinal dunes.

The fields of parabolic dunes are probably developed in areas of abundant sand, and probably in topographic depressions, possibly in old east-west trending (fault controlled?) river valleys now blocked by the coastal dune fields.

Besides being areas of accumulation of sand, these topographic depressions were also wetter than the surrounding areas. Thus vegetation flourished with the result that the dunes were partly stabilised. In particular the lower slopes were made stationary, whilst the crests were blown out by the wind. The open end of the U faces upwind, though rather than a simple U, the dune form is often complex with rake-like and circular forms common.

Dunes of another type also extended across vast areas of the north of Eyre Peninsula during the late Cainozoic glacial periods (for northeast of Franklin Harbour calcareous cores of desert dunes extend below sealevel, showing that they were active when sealevel was lower-see Van Deur 1983). Longitudinal or seif dunes similar in all essential respects to those of the present Simpson Desert and other arid lands spread southeastwards across the Peninsula. There is considerable debate as to the origin of longitudinal dunes. Some workers consider that they are due to horizontal vortices or spirals of wind, while others are of the opinion that they form under the influence of a bidirectional wind regime, in the case of Eyre Peninsula, strong sand-moving winds from the northwest.

Whatever their origin however it is apparent that they are initiated in the lee of mounds that accumulate on the lee side of playas, salinas and alluvial plains. The wind passing over such mounds develops an increased turbulence, and tails of sand develop in the dead, or low velocity, areas between these short lived but important vortices. These tails extend and merge to become part of the regional dune field (Twidale 1972, 1981).

The dunes of Eyre Peninsula, like those of Yorke Peninsula, the Murray Mallee, the Wimmera, and the Adelaide Plains, formed some 10 000-30 000 years ago when the climate was more arid than it now is.

As in the Simpson Desert, the dunes, built of siliceous or quartz sand vary in density, i.e. the number per unit distance measured normal to dune trend. They trend NW-SE except in the vicinity of major topographic obstacles such as Darke Range (Fig. 9). These old dune fields occupy topographic and structural depressions and they are virtually absent from the higher ground with numerous granite outcrops (as for instance in the Minnipa-Wudinna district).

Related to the mounds on the lee side of playas from which the longitudinal dunes developed under more arid conditions during the pleistocene are lunettes which are well developed on Eyre Peninsula as they are throughout southern Australia.

These fixed dunes occur on the lee side of depressions which are the source of the material from which the dunes are made. They are thought to have formed in the recent past, but in some areas are still developing. Splendid examples border Lake Baird, Lake Yaninee and Kappakoola Swamp.

The most recent event of geomorphological importance has been the settlement of the region by European man. Though most farmers are conscious of the importance of the soil, land clearance and grazing by animals, especially sheep, have nevertheless inevitably rendered the surface vulnerable to erosion by both water and wind (see Smith *et al.* 1975). The exposure of the calcrete, the pedogenic lime, over vast areas of the western part of the Peninsula, gullying, sand drift and landslips (like that on Mt Dutton) are the result of this human activity (Fig. 10).

Thus various factors have determined the present face of Eyre Peninsula. Basically they involve the interplay of climatically induced processes (rivers, the wind) and the crust of the earth, a crust that is partly recurrently active as shown by earthquake activity, but which is also

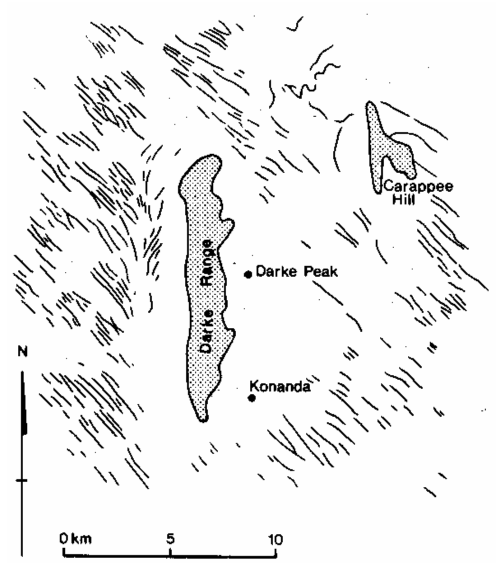


Fig. 9. Longitudinal dune pattern deranged by interference to wind pattern by Darke Range.

Fig. 10. The Kappakoola Dune was formed as a consequence of the clearing of mallee from a lunette or sandy fixed dune on the southern side of Kappakoola Swamp in 1916 or thereabouts. During the 'twenties strong northerly winds scoured the northern slope of the lunette and the sand so eroded was deposited a few score metres away to the south to form the dune. Certainly it was in existence by 1929. It is a well-known source of good building sand (see Smith *et al.* 1975).

passive with its weaknesses exploited by the external agencies. The interplay of internal and external forces has resulted in the development of various more-or-less distinctive geomorphological regions, which are described below.

GEOMORPHOLOGICAL REGIONS

A geomorphological map of the northern two thirds or so of Eyre Peninsula was produced by Bourne (1974). Several of her regions such as the Cleve Hills, the Tent Hills and the Corrobinnie Depression have been retained, though their interpretation has in some cases been refined. Others have been reconsidered and subdivided; for example the 'Sheringa Plain' has been subdivided into the Talia Hills and the undulating Chandada Plain. But the essential framework remains much the same, with extensions into the southern part of the Peninsula that she did not consider in her study.

The primary subdivision is made on the basis of whether the land surface is predominantly due to erosion or to deposition. Further distinctions reflect the degree of erosion-whether upland or plain-underlying structure, type of deposition (e.g. dunefield, lake plain) and so on. A map showing various topographic and geomorphologic regions is shown in Fig. 11.

Tent Hills (A1)

The Tent Hills region is a dissected plateau, a series of mesas and buttes with flat tops and steep bounding slopes bordered by pediments. The mesas are capped by resistant Simmens Quartzite with Tregolana Shale beneath. The sediments are generally flat-lying but have a gentle northerly dip. In different areas the summit surface, which is part of the summit surface of the Arcoona Plateau is preserved on different members of the quartzite sequence. Corraberra Hill and the Sugarloaf are interesting last remnants of this plateau surface in which the resistant quartzite capping has all but been removed. The mesas (Fig. 12a) typically stand about 100-130 m above the plains and about 300 m above sea level, Simmens Hill (278 m), Corraberra Hill (310 m). The bounding scarps of the mesas are marked by minor benches coincident with outcrops of thin quartzite beds. Scarp foot valleys are well developed, for example west of El Alamein Camp (Fig. 12b) and around South Tent Hill. Between the mesas the plains are pediments, remarkably smooth surfaces cut in bedrock, and well seen for instance in Lincoln Gap. Occasional low mesas capped by silcrete stand above the pediments, while in and near the stream channels alluvium is deposited. West of Port Augusta some old desert dunes are preserved.

Lincoln Uplands (A2a)

The Lincoln Uplands consist of folded Precambrian sediments and metasediments. The dominant feature is the dissected lateritised summit surface which is tilted down to the west. The upland is bordered on the east by a steep though dissected fault scarp. The structural grain of the Precambrian rocks is NE-SW and this is reflected in the trend of the major ridges and valleys. The high points-such as Pillaworta Hill (322 m), Knott Hill and Bald Hill (each 282 m) and Mt Gawler (249 m)-are generally composed of gneiss and/or quartzitic rocks. The valleys are underlain by schists. The Tod River and its tributaries form a trellis pattern as does, though in lesser degree, the Salt Creek drainage system. Within the uplands some alluviation and gullying presumably due to European settlement, land clearance, and grazing by domesticated animals, has occurred. Blue Range, Verran Hill and Cobbler Hill are small uplands with laterite cappings that can be regarded as outliers of the main Lincoln Uplands.

Cleve Hills (A2b)

The Cleve Hills (Fig. 13) are a dissected upland developed on quite extensively folded Precambrian sediments and metasediments which during the Mesozoic were eroded to a surface of low relief. Quartzite and gneiss ridges were left upstanding whilst weaker rocks, mainly schists, were eroded to form valleys. The fold axes trend NE to SW swinging to N-S in the north. The

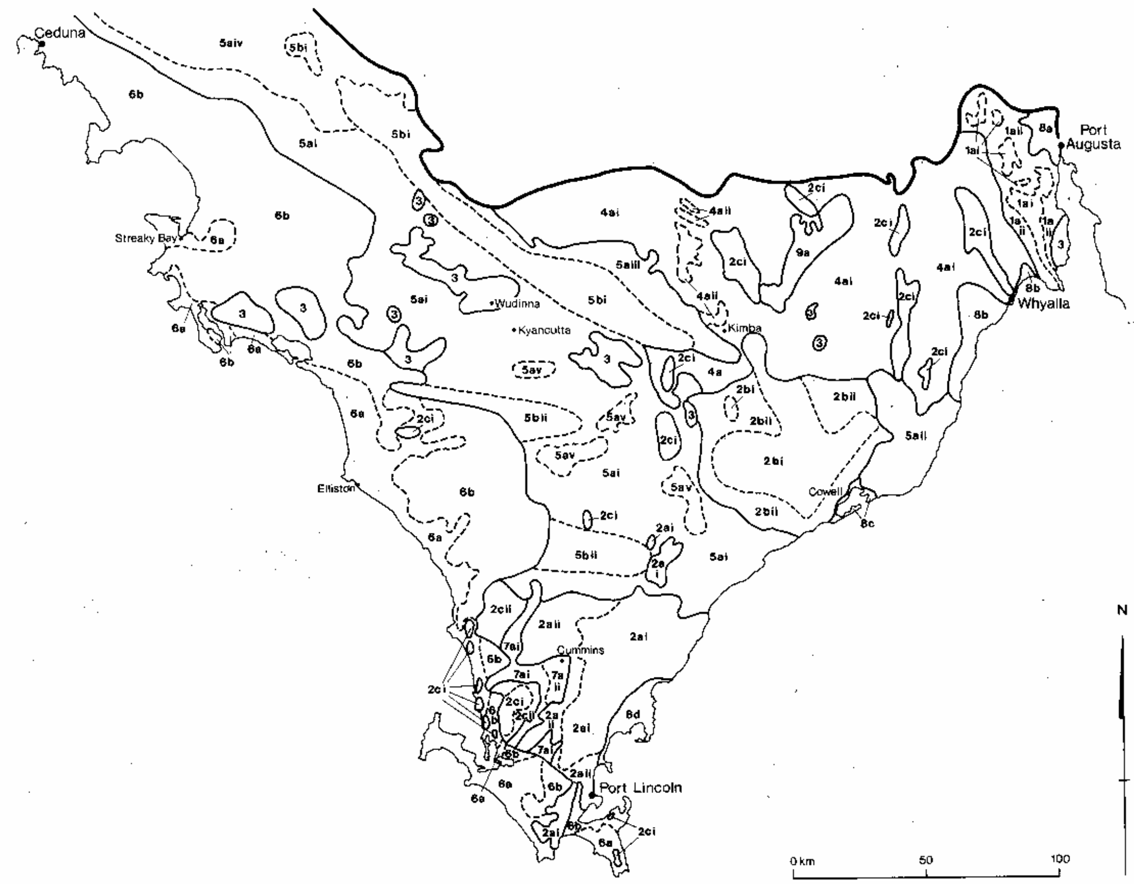


Fig. 11. Physiographic regions. A. Erosional forms. 1. Plateaux or high plains (a) Tent Hill region (i) plateau surface (ii) scarps and adjacent plains; 2. Fold mountain ranges: uplands developed on folded sediments and metasediments (a) Lincoln Uplands (i) high plains (ii) scarps and adjacent plains (b) Cleve Hills (i) high plains (ii) scarps and adjacent plains (c) remnants or outliers of uplands (i) ranges (ii) scarps and adjacent plains; 3. Granitic plains and isolated hills (inselberg landscapes) 4. Peneplains: rolling or undulating plains cut in bedrock (a) Kimba Peneplain (i) rolling plain (ii) plain with old dune fields superimposed. B. Depositional forms; 5. Siliceous sand ridge plains (a) longitudinal dunes (i) Tuckey Plain (ii) Mitchellville Plain (iii) Pinkawillinnie Plain (iv) Nunnyah Plain (v) Lock Plain (b) Parabolic or U-shaped dune fields (i) Kwaterski Dune field of the Corrobinnie Depression (includes major salinas) (ii) Tooligie and McLachlan dune fields; 6. Calcareous sand dunes (old coastal foredunes) (a) Talia Hills (b) Chandada Plains; 7. Swampy plains (a) Cummins Plains (i) seasonal lakes and swamps (ii) clay plain; 8. Coastal plains (a) Port Augusta Plain (b) Whyalla Plain (c) Cowell Plain (d) Louth Plain; 9. Lake Plain (a) Gulles Plain.

massif is bounded on the east and south by prominent fault scarps and in the west there is a low scarp, leading to undulating hills, but in the north the massif merges gradually with the surrounding plains.

Outliers of the major uplands (A2c)

Many isolated hills and ranges stand above the plains of southwestern, central and northern Eyre Peninsula. Underlain by dipping sediments or metasediments they can best be regarded as outliers of the Cleve Hills and Lincoln Uplands. They lack either a lateritic capping or a planate summit surface (save for Mt Hope) though many of them have distinct shoulders or benches on their flanks. Examples include Marble Range (414 m), North Block and South Block (373 m), Frenchman (160m), Mt Hope (171 m) and Mt Dutton (274 m) in the south; Tooligie Hill and Mt Wedge (250 m) in the centre; and in the northeast such quartzite uplands as Barna Hill (415 m), Curtinye Hill (440 m), Darke Range (445 m), Uno Range (393 m), Caralue Bluff (495 m, with gneiss exposed at the northern end, and with typical boulders and platforms) and Baxter Hills (388 m). The Moonabie Hills and Middleback Ranges are uplands in Banded Iron Formation.

Fig. 12. (A) Typical view of Tent Hills near Lincoln Gap and (B) scarp foot valley near El Alamein Army Camp.

Fig. 13. Low hilly country typical of much of the Cleve Hills region.

Granitic Hills (3)

Outcrops of granitic rock are widespread on Eyre Peninsula, but few are large enough to be mapped as separate regions. Especially in the northwest of the Peninsula, the granite occurs as isolated hills, mainly small in area, and these and the detailed landforms associated with them are discussed below under features of special interest.

The Cultana Hills is an area of massive rounded hills developed on old volcanic rocks similar to those exposed in the Gawler Ranges, and in some small measure on granitic rocks. They stand up to 130 m above sea level; a well-defined summit surface is also preserved (Fig. 14). Carappee Hill is a prominent inselberg in granite gneiss rising 270 m above the plain and 490 m above sealevel. The residual is stepped (Fig. 5). A well developed bench at about 350 m above sea level marks the level of a once extensive high plain of erosion. There is a prominent north-south lineation in the rock. Minor features characteristic of granite such as sheet structure, flared slopes, A-tents, rock basins or gnammas and tafoni are well developed.

Secret Rocks is a small group of low gneiss domes with basins, gutters and flared sidewalls, most notable for its connection with Eyre.

The Investigator Group includes Flinders Island, a low mass of granite, boulders on its flanks, but capped by limestone. In the south are the Pearson Islands. These are true inselbergs, a series of high granite islands rising abruptly from the eastern section of the Great Australian Bight (Fig. 15). The islands are strongly joint controlled, rising to 240 m above sealevel. They take the form of domes which are rounded and boulder strewn on the upper slopes, with massive curvilinear sheets on the lower levels. Flared slopes and tafoni are well developed. The western exposed shores are strongly cliffed. On the east remnants of dune limestone are preserved.

In the northwest there are several areas essentially devoid of sand ridges, though surrounded by or adjacent to dune fields. These slightly higher areas consist of rolling plains cut in granite, with quite numerous outcrops, including prominent hills. The plains are underlain by 25-45 m of weathered rock, and in depressions calcrete or limestone is well developed, Nevertheless the soils are quite clayey and are fertile; moreover the granite hills provide good catchments and the possibility, frequently realised, of water conservation. Hence many farms, including some of the earliest established in the district, are to be found in these areas.

The Wudinna-Minnipa area is such a region, with fertile plains and several notable hills or inselbergs surrounded by rolling plains, and the Koongawa-Waddikee Rocks-Middle Rock area is another notable for its outcrops. Colley Hill (116 m), Mt Hall (190 m), Cash Hill, Freeman Hill (119 m) and Murphy Haystacks are similar, but being nearer the coast the dunes are calcareous, and the hills carry a mantle of lime. But what we see is a landscape much like that around Wudinna at the present time, but buried under coastal dunes a few tens of thousands of years ago and since partly exhumed, with the crests of the hills re-exposed. Mt Cooper (204 m) is a broad but high rise underlain by Gawler Range Volcanics, which are also exposed in Nuyts Archipelago.

Kimba Peneplain (A4)

Cut in granite and gneiss the Kimba Peneplain is an extensive plain of low, broadly rolling relief (Fig. 16). The plain is underlain by weathered rocks (seen white and kaolinised in excavations) and much of the surface carries a veneer of calcrete. Residual hills, some granitic and some

Fig. 14. The Cultana Hills are high rounded hills of dacite; in the background can be seen the Tent Hills (S.A. Department for the Environment).

Fig. 15. The Pearson Islands are literally inselbergs or island mountains. As seen here they are very like their terrestrial counterparts with well developed sheet structure, bouldery slopes, etc.

Fig. 16. The Kimba Peneplain is an extensive area of low rolling relief eroded in granite and gneiss, carrying a veneer of limestone (calcrete) and with a few residual hills standing above plain level. This view is of the plain seen east of Kimba and the rounded quartzite hill is one of several in the Curtinye area.

quartzitic, and some (like Caralue Bluff) a mixture of the two, stand above the plain. Of these, several are sufficiently notable to warrant separate mention, but one, Red Rock, near Roopena Station is a splendid example of a steep-sided sandstone mesa with cliff foot caves and undercut sidewalls.

There are areas of linear dune development (Fig. 11) and occasional dune developments elsewhere. In particular considerable mounds of sand have accumulated against the northern slope of the Cleve Hills.

Siliceous sand ridge plains (B5)

The sand ridge plains of northwest and central Eyre Peninsula are characterised by fields of siliceous (quartz) dunes, some longitudinal trending NW to SE, and some parabolic, superimposed on low rolling plains cut in granitic rocks. The granite may well be the source of the quartz grains of which the dunes are built. The dunes are essentially stabilised by' vegetation. The interdune corridors contain massive calcrete or limestone and, quite commonly, small pans or salt "lakes". In the areas of longitudinal dunes the sand has travelled from NW to SE as indicated by the encroachment of dunes on the northwest margins of playas such as Agars Lake and Kappakoola Swamp.

In the Tuckey, Mitchellville and Pinkawillinnie dune fields, all similar but separate, the dunes are typically 10 m high and 2-4/km. In the Nunnyah dune field the dunes are 10-15 m high and run 5-6/km, though they are sparser on the granite rises.

The Corrobinnie Depression occupies a prominent NW-SE fracture zone. Several uplands-Mt Sturt (porphyry) and Corrobinnie Hill and Peella Rock (granitic)-stand in isolation above the general level of the Depression. The Kwaterski Dune Field of fixed parabolic dunes of quartz sand occupies the major part of the Depression. Salinas occur in the lower parts of the Depression. The Tooligie and McLachlan Dune fields are also characterised by parabolic dunes.

Calcareous dune sand (B6)

Enormous spreads of calcareous dune sand were blown inland in Pleistocene times. The lime of which these dunes are predominantly composed has cemented the forms with the result that they persist over vast areas of the west of the Peninsula, for the most part hilly near the coast where the dune forms are well preserved-the Talia Hills-and undulating plains for many kilometres east of this-Chandada Plains. The Talia Hills have a relief amplitude of about 50 m. Because of the permeability and perviousness of the old dune limestone there is no surface drainage (Fig. 17) although there are rare valleys suggestive of a higher water table and possibly of higher rainfall in the past. Subsurface water occurs at shallow depths. Some dolines or sink holes are present.

Fig. 17. Dune limestone covers the area near the west coast of the Peninsula, so that there are no surface streams, though there are a few dolines or sinkholes and some old valleys. The rolling or low hilly relief seen here north of Elliston largely reflects the shape of the original dunes.

The Chandada Plain is generally located inland, i.e. to the east of the Talia Hills and is of similar origin. The area is a low undulating limestone plain with no surface drainage. The relief amplitude is 20 m or less. Isolated granite peaks such as Parla Peak (160 m) protrude from the limestone cover, similar to the more extensive rises of the Mt Cooper and Mt Hall areas.

Depositional Plains (B7, 8, 9)

The Cummins Plain is developed in the Cummins Basin including alluvia derived from the surrounding higher areas. Areas of undulating plain are crossed by stretches of lowlying swamp and lake, such as Lake Malata, the drainage from which is impeded by coastal dunes. Around Cummins an area of clays becomes very sticky and impermeable when wet. There is now a system of open drains dug to deal with excess winter water, but in the past many farmers were forced to migrate north to drier, more readily tilled areas.

Depositional plains of various extent occur along the east coast near Port Augusta, Whyalla, Cowell and Louth. They are underlain by alluvium (including some alluvial aprons) derived from the backing uplands. The Gilles Plain is a lake and alluvial plain deposited marginal to Lake Gilles and includes the gypsum-covered bed of that lake.

FEATURES OF SPECIAL INTEREST

The Coast

The most notable feature of the coast is the contrast between west and east. The west coast faces the Bight and is open to long-travelled waves blown by the dominant westerlies. As described earlier, sand derived from the fragmentation of the shells of various marine organisms left stranded on the exposed sea floor was blown from the beaches to form huge coastal dunes, and spread far inland, blanketing the preexisting relief. The dunes have since been eroded on the seaward side. Stages in the building of the dunes with pauses in construction marked by old soils are visible in cliff sections. Cross-bedding related to the wind action responsible for forming the dunes is also commonplace.

Many of the towering cliffs of the west coast are built entirely of such old limestone dunes (Fig. 18), but at many sites the base of the limestone can be seen to rest on older, Precambrian rocks and particularly granite or gneiss, though at Talia Caves an old sandstone with beautifully developed cross-bedding but of unknown age is exposed: the joints in the sandstone (Fig. 19) have been exploited by waves to form splendid caves after which the site is named.

Joint clefts are also to be seen in some of the crystalline rocks as for instance north of Cape Carnot, where Theakstone Crevasse is a well known example. The crystallines, however, more commonly form more or less bouldery promontories, though in some areas, platforms of remarkable smoothness have been developed. That at Smooth Pool, near Streaky Bay is a notable example (Fig. 20). It and all of the crystalline forms have a complex origin for they are not merely due to wave attack (Twidale *et al.* 1977). Exposures at Point Drummond clearly indicate their nature for there it can be seen that what is being attacked by waves is not a simple mass of granite or gneiss, but crystalline rock which, before being buried by the dune sand, was weathered (Fig. 21). What we see beneath the dune limestone at Point Drummond and elsewhere (Point Westall, Point Brown and Louth Bay on the east coast) is an old land surface developed in the crystallines and with a ferruginous soil or saprolith several metres thick well developed. That the mottled and reddish soil is derived from the weathering of the granites and gneisses is most clearly demonstrated by the fact that quartz veins that intrude the crystallines and which are very resistant to weathering can be traced through the old soil profile, and at Point Drummond to the contact with the limestone above. What happened is that quite by chance the unconformity between the Precambrian and the Pleistocene rocks occurs in the present tidal zone, with the result that waves have eroded the soil, exposing the fresh rock beneath. The rock surface we see was originally the base of the significant weathering, the weathering front, and the exposed rock face is an etch or subcutaneous surface.

Fig. 18. Towering limestone cliffs typical of much of the west coast, and seen here west of Pt Kenny. The minor cliff present near the top of the slope is due to the development of calcrete (a soil limestone). Note the huge blocks that have been undermined by the strong wave attack and slumped to the base of the cliff, where they remain until broken down and evacuated by the waves and by solution (S.A. Department for the Environment).

Fig. 19. At Talia the dune limestone that forms prominent cliffs is underlain by a coarse sandstone of as yet undetermined age. But the prominent vertical joints in the sandstone have been exploited by waves to form clefts or geos as they are called when they occur on coasts.

Platforms are also formed in the limestone. Indeed they are formed at several levels in relation to the tidal range (Fig. 22). Some, usually narrow but distinct, occur on promontories, and there are many near high tide levels. Some platforms occur well above high tide, even high storm tide level. Thus at Cape Wellesley, near Elliston, there are many narrow platforms 6-7 m above high tide level. They stand within the spray zone, and fragments of shells as well as halite (common salt) derived from the sea water, can be seen on them. They are due to weathering (mainly solution) by spray collected in crevices. The water changes the rocks with which it comes into contact to form flat floored pools that eventually merge to form quite extensive platforms.

Where the dunes were never very high or where they have been breached, large embayments have been formed. Streaky, Venus and Coffin bays are examples. Waterloo Bay, at Elliston is especially interesting because of its rounded shape (Fig. 23). It has been suggested that it is a meteorite impact crater but supporting evidence is lacking. There are small dolines due to solution and collapse in the Talia Hills region, but this is much larger than anything known from the area and due to such processes. It is most likely due to waves entering the bay and being refracted, so giving rise to a smooth arcuate outline to the eastern shoreline.

Between the cliffed promontories and headlands there are long, though because exposed, often dangerous beaches. Behind these beaches coastal dunes have been built, dunes that achieve a height of up to 10 m and are spreading inland, as for instance south of Streaky Bay.

But the west coast is notably dramatic and beautiful, with high cliffs, in places complex

Fig. 20. Smooth Pool, southwest of Streaky Bay is an important scientific site because there the shore platform in granite is of extraordinary width—for granite. It has a complicated history for it is clear (see Twidale *et al.* 1977) that the platform is really due to weathering of the granite before the dune limestone was laid down over it. Subsequently the waves have not only eroded the dunes but have also stripped the soil or saprolith from above the granite, exposing the weathering front or base of weathering as a platform.

Fig. 21. The promontory at Point Drummond looks complicated but basically the situation is the same as that at Smooth Pool. The bouldery platform is the exposed weathering front. Part of the old saprolith is preserved in the promontory (red and white soils but with quartz veins running through it from the bedrock below) which is capped by a thin remnant of limestone, though the cliffs behind the promontory are largely of the dune limestone.

geology and morphology, and long sweeps of sandy beaches.

The east coast is much lower though basically similar; and being sheltered in Spencer Gulf, its splendid beaches are safer. The coast is backed by plains underlain by alluvium and alluvial fans. There are the same alternations of headland and bay that can be seen on the west coast, but the whole topography is lower. There are rocky headlands with Precambrian crystalline rocks exposed (and with old saproliths exposed and exploited as at Louth Bay) and beaches with coastal dunes developing behind them. But the high old cemented dunes are absent. The whole coast is on a smaller scale.

Nevertheless there are features of interest. Whereas mangroves on the west coast are limited to a small area near Streaky Bay, there

Fig. 22. Shore platforms occur within a considerable vertical range and include some well above even high tide level. Here at Yanerby south of Streaky Bay the main platform cut in limestone is at or about high tide level.

Fig. 23. Waterloo Bay is a curious feature, a circular embayment that has been interpreted in various ways. It is however almost certainly due to the refraction of waves that penetrate the narrow entrance of the feature.

Fig. 24. Yarwondutta Reservoir was excavated in 1916 in order to ensure a water supply for the then newly established Minnipa Research Farm. The weathered rock was removed to expose the weathering front, which is obviously concave upward and comparable to the flared slopes that are such a prominent feature of the inselbergs here and elsewhere.

are extensive stands in and near Franklin Harbour, and north of Point Lowly, and to a lesser degree near Tumby Bay. There are beautifully preserved shingle beaches at Fitzgerald Bay and also near Port Augusta (Hails & Gostin 1978). And north of Franklin Harbour near Plank Point and Lucky Bay there are calcified cores of desert dunes.

Granite Hills

Eyre Peninsula is well known for its granite hills or inselbergs -literally island mountains, because they rise abruptly from the plains like islands from the sea. Some are especially important from a scientific point of view, for not only are the various detailed forms of interest but there is evidence bearing on the general origin of such hills the world over. While it would be invidious to say that such and such a hill is more important than the rest there are several that are particularly important by virtue of the evidence they present.

Of these Yarwondutta Rock may well be considered by scientists the world over to be especially important and interesting; certainly many overseas and interstate scientists make a point of visiting the site. It is important for a number of reasons (Twidale & Bourne 1975a; Twidale 1981, 1982a, b, c). First there is exposed in the reservoir (Fig. 24) clear evidence as to the nature of the flared slopes that are so characteristic not only of the lower slopes of inselbergs on Eyre Peninsula, but also of some higher zones and of other areas such as the southwest of Western Australia (e.g. Wave Rock, Hyden) and Ayers Rock. Second the northern slope is stepped (Fig. 25), that is there is a series of flats separated by flared slopes, and these suggest that the inselberg has survived several phases of weathering and erosion and that it has grown as a relief feature through time, and not diminished as is suggested by accepted theory. Third there is exposed in the nearby quarry a superb example of a weathering profile with calcrete superimposed on the granite saprolith and with a well developed zone rich in iron oxide near the base of the weathering: for added measure there are silicified tree roots at this weathering front. Fourth there are splendid examples of inverted grooves or *Rillen,* tafoni or caverns, fracture controlled clefts, a drainage network developed in solid rock, sills, large rock basins, and so on-a host of minor forms.

Ucontitchie Hill (Fig. 26) is also spectacular, rising to 170 m above sea level and 50 m above the surrounding plain. Here, there is clear evidence of the basic reason for the inselbergs being upstanding. They are made of the same rock as the granite that underlies the plains, but as seen in the quarry north of the Schmucker homestead the rock of the hill is massive whereas that of the plains is well jointed. There are also marvellous exposures of sheet structure, flared slopes (Fig. 6) and platforms, multiple flared slopes, fracture patterns, *Rillen,* tafoni (Fig. 27)

Fig. 25. Stepped northern slope of Yarwondutta Rock, evidence of the inselberg having been exposed as a hill in several phases each marked by the development of a flared slope in the subsurface at the hill plain junction.

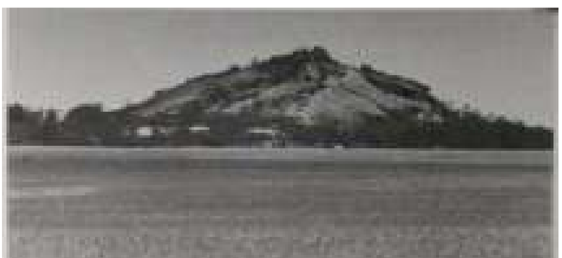


Fig. 26. General view of Ucontitchie Hill, an inselberg standing above the plains of central Eyre Peninsula.

and so on, as well as forms thought to be associated with the release of compressive stress.

In the Wudinna area one can see a wide range of forms related to the release of compressive stress, for at Mt Wudinna and Little Wudinna there are A-tents, vertical wedges and displaced slabs (Twidale & Sved 1978). A-tents (Fig. 28) are fairly widely developed and can be seen on several of the west coast inselbergs, including Freeman and Cash hills as well as on Carappee Hill.

Pildappa Hill is another notable inselberg, with especially well developed gnammas or rock basins, but with also beautiful flared slopes, taloni, and clear evidence of fracture control of the major outlines. The best cylindrical basins occur on the less well known Myrtle and Kwaterski rocks. Pildappa is also notable for evidence that minor forms (in this instance grooves or *Rillen)* are initiated at the weathering front beneath the soil cover, but similar evidence can be seen at Crowder Rocks, and especially at Dumonte, near Wudinna (Fig. 29; see also Twidale & Bourne 1975b).

Tcharkulda Hill is notable for its large boulders, tafoni, platforms and especially its polygonal cracking; Murphy Haystacks for the large boulcjers, tafoni and flares (Twidale & Campbell 1984).

Murphy Haystacks perhaps warrant further mention, partly on account of their aesthetic appeal, partly because of their name. Hearsay has it that they were given their curious name by coachmen who pointed out these curious formations standing near a hill crest west of the Port Kenny-Streaky Bay road. With their comparatively narrow bases, swelling upwards to rounded crests, the coachmen thought they looked like haystacks (Fig. 30); they were on the Murphy's property; hence the name. Seen close to, the various large boulders and pillars are elegant and, to some at least, aesthetically pleasing. In this regard it is worth noting that similar forms, sculpted by Henry Moore, are considered so appealing by their maker that they stand in his garden at Much Hadham in Hertfordshire. Murphy Haystacks belie their rather mundane name!

Eyre Peninsula has a considerable aesthetic appeal, especially in its coastal scenery, though the intricate sculptures of the various granite hills are coming more and more to be appreciated. But the Peninsula is even more widely known for its landforms seen through the eyes of the scientist

Fig. 27. Tafoni at Ucontitchie Hill.

Fig. 28. A massive A-tent on Mt Wudinna (scale from hammer).

.

Fig. 29. Dumonte Reservoir north of Wudinna, showing the channels of the naturally exposed rock, continuing in the natural subsurface.

Many of its upland plains are of great antiquity. The extensive plains themselves are worthy of interest. The shore platforms in granite exposed on the west coast, and notably that at Smooth Pool, are unusual by virtue of their width, and the nature and the flights of platforms cut in the coastal limestone is also of interest and importance. Finally the granite inselbergs are well known because of the evidence they offer relevant to the solution of general problems of inselberg development.

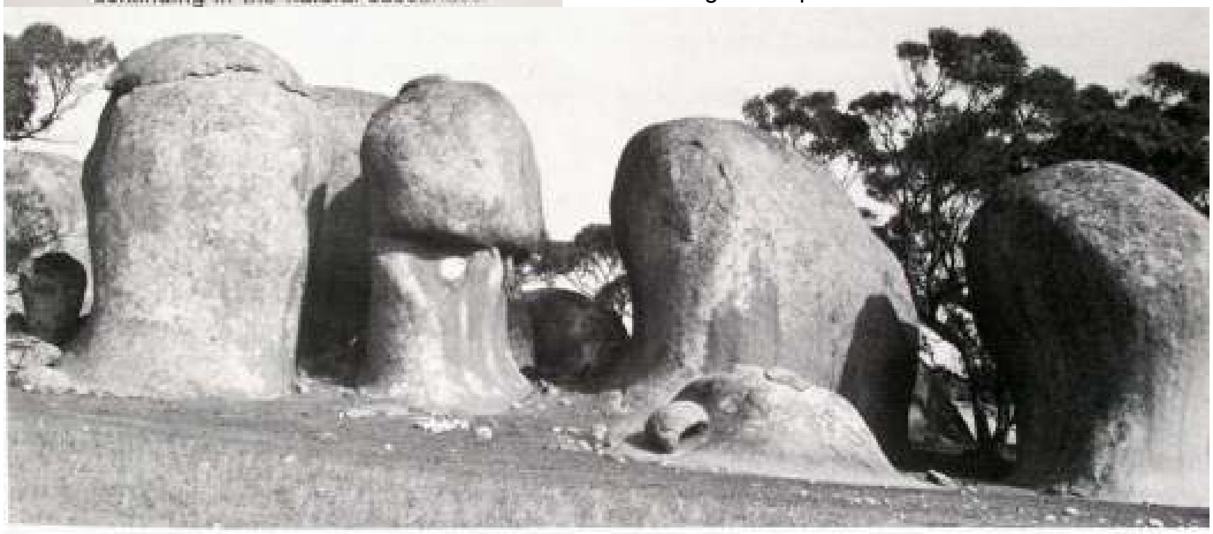


Fig. 30. Large flared boulders or pillars at Murphy Haystacks, between Streaky Bay and Port Kenny, northwestern Eyre Peninsula.

REFERENCES

Alexander, L. T. & Cady, J. G. (1962). Genesis and hardening of laterite in soils, *U.S, Dept. Agric. Tech. Bull,* **1282**

Binks, P. J, & Hooper, G, J. (1984), Uranium in Tertiary Palaeochannels, 'West Coast Area', South Australia, *Proc, A'Asian Inst. Min. Metall.* **289**(8), 271-275,

Bourne, J, A. (1974). *Chronology of denudation of Northern Eyre Peninsula, South Australia,* M.A. Thesis, University of Adelaide, Unpubl.

Bourne, J, A., Twidale, C. R. & Smith, D. M. (1974), The Corrobinnie Depression, Eyre Peninsula, South Australia. *Trans. R. Soc,* S. *Aust.* **98**, 139-152.

Crocker, R, L. (1946), An introduction to the soils and vegetation of Eyre Peninsula, South Australia. *Trans. R, Soc,* S. *Aust.* **70**, 83-107.

Daily, B., Twidale, C, R. & Milnes, A, R, (1974), The age of the lateritised summit surface of Kangaroo Island and adjacent areas of South Australia, *J. geol. Sac, Aust.* **21**, 387-392.

Daily, B., Milnes, A. R., Twidale, C. R. & Bourne, J, A. (1979), Geology and geomorphology, pp. 1-39 *In* (M, J, Tyler, C, R, Twidale & J. K, Ling, Eds.) *'Natural History of Kangaroo Island:* (Royal Society of South Australia, Adelaide).

Hails, J. R, & Gostin, V. A, (1978), Stranded shingle beach ridges, upper Spencer Gulf, South Australia: evidence for high wave energy dissipation during the late Pleistocene, *Trans, R. Soc.* S, *Aust,* **102**, 169-173.

Horwitz, R, C, & Daily, B. (1958). Yorke Peninsula. pp, 46-60 *In* (M, F. Glaessner & L, W. Parkin, Eds,) *'The Geology of South Australia',* (Melbourne Univ. Press, Melbourne),

Hutton, J, T., Twidale, C, R, & Milnes, A. R. (1978), Characteristics and origin of some Australian silcretes *In* (T, Langford-Smith, Ed,) 'Silcrete in Australia', (Univ, New Engl. Press, Armidale) pp. 18-39.

Johns, R, K, (1961), Geology and mineral resources of southern Eyre Peninsula, *Geo/. Surv.* S. *Aust. Bull. 37,*

Johns, R. K., Thatcher, D. & O'Driscoll, E, S. (1958). Lincoln Sheet 1 *53/11, Geo/. Surv*. S. *Aust,* Adelaide,

Jutson, J, T. (1914). An outline of the physiographical geology (Physiography) of Western Australia. *Geo/. Surv,* W *Aust. Bull.* **61**,

Maignien, R. (1966), Review of research on laterites. *Nat, Resources Rev.* IV, (UNESCO, Paris).

Milnes, A. R. & Hutton, J. T. (1983). Calcretes in Australia. pp. 119-162. *In* Soils: an Australian Viewpoint. Division of Soils, C.S.I.R.Q. (Academic Press, Melbourne).

Prescott, J. A. & Pendleton, R. L. (1952). Laterite and laterite soils. *Comm. Bur. Soil Sci. Tech. Comm.* **47**.

Smith, R. & Kamerling, P. (1969). Geological framework of the Great Australian Bight. *Austr. Petrol. Explor. Assoc. Jour.* **9**, 60-66.

Smith, D. M. Twidale, C. R. & Bourne, J. A. (1975). Kappakoola dunes-aeolian landforms induced by man. *Austr. geogr.* **13**, 90-96.

Sutton, D. J. & White, R. E. (1968). The seismicity of South Australia. J. *geol. Soc. Aust.* **15**, 25-32.

Twidale, C. R. (1962). Steepened margins of inselbergs from northwestern Eyre Peninsula, South Australia. *Z. Geomorph.* **6**, *NB. 51-69.*

Twidale, C. R. (1972). Evolution of sand dunes in the Simpson Desert, central Australia. *Trans. Inst. Brit. geogr.* **56**, 77-109.

Twidale, C. R. (1976). On the survival of palaeoforms. *Amer.* J. *Sci.* **276**, 77-94.

Twidale, C. R. (1981). Age and origin of longitudinal dunes in the Simpson and other sand ridge deserts. *Die Erde* **11**, 231-247.

Twidale, C. R. (1982a). *'Granite Landforms'.* (Elsevier, Amsterdam).

Twidale, C. R. (1982b). Les Inselbergs a gradins et leur signification: l'exemple de l'Australie. *Ann. Geogr.* **91***,* 657-678.

Twidale, C. R. (1982c). The evolution of bornhardts. *Am. Scientist,* ***70***, 268-276.

Twidale, C. R. & Bourne, J. A. (1975a). Episodic exposure of inselbergs, *Geol. Soc. Am. Bull.* **86**, 1473-1481.

Twidale, C. R. & Bourne, J. A. (1975b). The subsurface initiation of some minor granite landforms. *J. geol. Soc. Aust.* **22**, 477-484.

Twidale, C. R., Bourne, J. A. & Smith, D. M. (1974). Reinforcement and stabilisation mechanisms in landform development. *Rev. Geomorph. Dynam.* **23***,* 115-125.

Twidale, C. R., Bourne, J. A. & Smith, D. M. (1976). Age and origin of palaeosurfaces on Eyre Peninsula and in the southern Gawler Ranges, South Australia. Z. *Geomorph.* **20**, 28-55.

Twidale, C. R., Bourne, J. A. & Twidale, N. (1977). Shore platforms and sea level changes in the Gulfs region of South Australia. *Trans. R. Soc.* S. *Aust.* **101**, 63-74.

Twidale, C. R. & Campbell, E. M. (1984). Murphy Haystacks, Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **108**, 95-103.

Twidale, C. R., Shepherd, J. A. & Thomson, R. M. (1970). Geomorphology of the southern part of the Arcoona Plateau and of the Tent Hill region west and north of Port Augusta, South Australia. *Trans. R. Soc.* S. *Aust.* **94**, 55-67.

Twidale, C. R. & Sved, G. (1978). Minor granite landforms associated with the release of compressive stress. *Austr. geogr. Studies* **16**, 161-174.

Van Deur, W. J. (1983). 'Submerged dunes of northeastern Eyre Peninsula.' MA Thesis, University of Adelaide, Unpubl.

Wayland, E. J. (1934). Peneplains and some erosional landforms. *Geol. Surv. Uganda Ann. Rept. Bull.* **1***,* 77-79.

Willis, B. (1936). 'East Africa Plateaux and Rift Valleys' (Studies in Comparative Seismology). Carnegie Inst., Wash. D.C. Publ. 470.

5: Soils

by M.J. WRIGHT

HISTORICAL PERSPECTIVE

In comparison with other agricultural regions of South Australia, Eyre Peninsula is relatively neglected in terms of soil investigations, particularly detailed and semi-detailed surveys. There has been no work on Eyre Peninsula to parallel, for example, the soil association mapping of Blackburn (1959, 1964) and others in the South East. Rather there has been a series of broad compilations based on limited field work, in some of which soils considerations are incidental to either vegetation or landform studies.

The first study that involved a significant collection of field data is due to Crocker (1946a). While his main interest was aligned more, perhaps, to the history of landscape development and to plant ecology, he nevertheless delineated the major soil 'types' of Eyre Peninsula on a map at a scale of approximately 1:3 000 000. In fact his five map units show the distribution of seven "major soil groups" based on the great soil group concept as advanced by Prescott (1944). This map marked a significant advance on the pioneering Continent-wide soil maps of Prescott (1931, 1944) that were the precursors of the maps of Stephens (1961) and Northcote *et at. (1960-68),* all of which include Eyre Peninsula. Prescott's earlier version, at a scale of approximately 1:20 000 000, having been compiled with the least accumulated experience and field knowledge, shows the major part of Eyre Peninsula as covered by "mallee soils" and bounded to the north by "desert steppe soils". Stephens (1961) expanded this to nine great soil groups at a scale of 1:5000000 but, in contrast, Northcote *et at.* (1960-68), with the benefit of another 30 years accumulated knowledge after Prescott, and further field inspections, delineated, at a scale of 1:2000000, no less than 31 general, or compound soil landscapes (Fig. 1) for the same region. The compound soil landscapes are composed of 34 or more PPFs (the principal profile forms of Northcote 1979a). Some PPFs may recur in different compound soil landscapes but if they do they are in comparable landscape positions.

Between the different generations of Continent wide soil maps French (1958), spurred no doubt by the practical needs of agricultural development in the region, produced a soil map of Eyre Peninsula at a scale of just over 1:1 000000. Vegetation was related to the soils but not mapped separately. The map units were essentially associations of great soil groups in particular types of landscape (e.g. undulating country) or topographic position, or were areas dominated by surface features of significance to land use. These latter units included, for example, "outcropping limestone", which is further subdivided into "hills or plain".

A quite different approach was the landscape mapping of Laut *et al.* (1977) in which LANDSAT imagery was used to map the whole of South Australia into combinations of landforms in units termed "environmental associations". Soil occurrences were indicated according to landscape positions termed "environmental units". The soil information appears to have been derived from the Continental soil map of Northcote *et at.* (1960-68) although this is not stated; nor is it clear whether further field work was carried out. Sixty-two environmental associations were delineated within the region.

Other significant pedological work in the region was achieved by Jessup & Wright (1971). The Cainozoic stratigraphy of approximately 1200 km^2 north and west of Whyalla was elucidated from the examination of profiles exposed in 82 backhoe trenches. Inferences were drawn about the climates responsible for the sequence of soils, sediments and erosional episodes revealed.

In other studies such as those of Smith (1963) in lower Eyre Peninsula, and Mowling (1979), soil mapping has been peripheral to other interests in both these cases plant ecology. Studies in related disciplines, such as those of Bourne *et at.* (1974), Twidale & Smith (1971) and Twidale *et al.* (1976), all have a degree of relevance to the patterns of soil distribution within the Eyre Peninsula region. Other work in this general category includes surveys such as. those of Wetherby *et at.* (1983) of wind erosion, and Wetherby (1984) of water repellent sands.

Finally, a few detailed and semi-detailed studies have been made, for example the Tod River soil survey of Wetherby *et al.* (1982); a survey of soils near Wharminda and Stokes, by King & Alston (1975); and soil surveys of parts of the Hundred of Wanilla, County Flinders, by Stephens (1943) and Downes (1944). A survey of 11 000 km^2 of north-west Eyre Peninsula has been recently completed by the author and colleagues but, apart from a conference poster paper (Billing *et al.,* 1984), the material remains unpublished.

SOIL LANDSCAPES OF THE REGION

Eyre Peninsula lies at the southeastern margin of the Gawler Platform, a part of the ancient shield of Australia that has remained stable since its formation around 1500 Ma ago (see Chapter 2). Apart from sedimentation in the Polda Basin during the Jurassic, no sediments older than Eocene have been recorded overlying the Proterozoic rocks of the Gawler Platform anywhere within the region. Thus there is a gap in sedimentation exceeding 1400 Ma until shallow basins, some tectonic (Bourne *et al.* 1974) such as the Corrobinnie Depression, in the basement and between granite highs were filled with lignitic and carbonaceous sands of Middle to Upper Eocene age (Harris 1979).

Extensive exploratory drilling in recent years, reported by Binks & Hooper (1984), has shown substantial deposits of Eocene sands, silts and clays in extensive palaeodrainage systems, the largest of which is contiguous with the Corrobinnie Depression until it swings away at right angles to reach the present coastline at Smoky Bay. As well, the Eocene sediments have been extensively eroded during the Pliocene when substantial deposition also took place. Thus, in the main palaeochannel (170 km long and up to 10 km wide), a maximum of 80 m of Eocene fluviatile sediments on the granite basement are overlain by up to 100 m of Pliocene to Recent fluviatile and lacustrine deposits.

The Quaternary has also been an obviously eventful period with the emphasis on development of soil landscapes primarily by aeolian (wind) activity. The pioneering and incredibly intuitive work of Crocker (1946a, b) in relation to aeolian landscapes in particular can scarcely be faulted in broad principle almost 40 years later. Along with other pioneering pedological studies such as that of Northcote (1951), his work played a major role in achieving an adequate understanding of the genesis of the aeolian landscapes that are so widely preserved in southern Australia.

But to elucidate the landscapes of the region further, it is preferable to divide it into five sub regions (Fig. 1), which not only are distinct in terms of landform but also reflect the broad patterns of soil distribution.

The first of these divisions is here termed the ranges and hills sub-region. It covers the "spine" which runs down the east coast, except for a narrow coastal plain. These hills and ranges are underlain by rocks of Lower Proterozoic age (Geo!. Survey S. Aust. 1969) and include the iron formations of the Middleback Range. From Cowell northwards these ranges and hills curve inland. This sub-region is typified by duplex (sand over clay) soils, one exception being where lower portions of the ranges have allowed dune tracts to break through from the west. Here siliceous sands dominate. The other exception is in the drier northern extensions, for example, the Middleback Range, where shallow compact loamy soils are prominent. But in the typical areas, red duplex soils (loam over reddish clay B horizon) are characteristic as in the Cleve-Mangalo hills and outwash plains and the Yeelanna rolling lands. Yellow duplex soils (sandy loam over yellowish clay B horizon) predominate in the Koppio and Yallunda undulating to hilly lands and associated areas, and the Carpie Puntha hilly lands, but here, because of the occurrence of dunes, the duplex soils are sandy surfaced.

The second division is referred to as the plains and tablelands sub-region. These are the plains, low hills and tablelands that occur in the northeast portion of the region on Adelaidean cover rocks. These are flat-lying rocks of Middle to Upper Proterozoic age that formed where sedimentation on the Stuart Shelf overlapped the Gawler Platform.

Soil development in this sub-region is affected by two factors. First, the basement rocks are extsnsively covered by Quaternary fluviatile and aeolian sediments. Second, annual precipitation is so low that pastoral pursuits are the only possible land use. As well, soil development is minimised to the extent that soils in this sub region are more closely akin to soils of the arid zone than to those of the remainder of the region.

The main area of crusty red duplex soils is that in which the flat-bedded Adelaidean rocks occur. Such soils occur both on the crests of these tablelands and on the steeper flanking slopes where red cracking clays occur as well in gilgai depressions. Shallow loamy soils are associated on the crests.

The low hills and undulating plains of this sub region have mainly shallow calcareous loamy

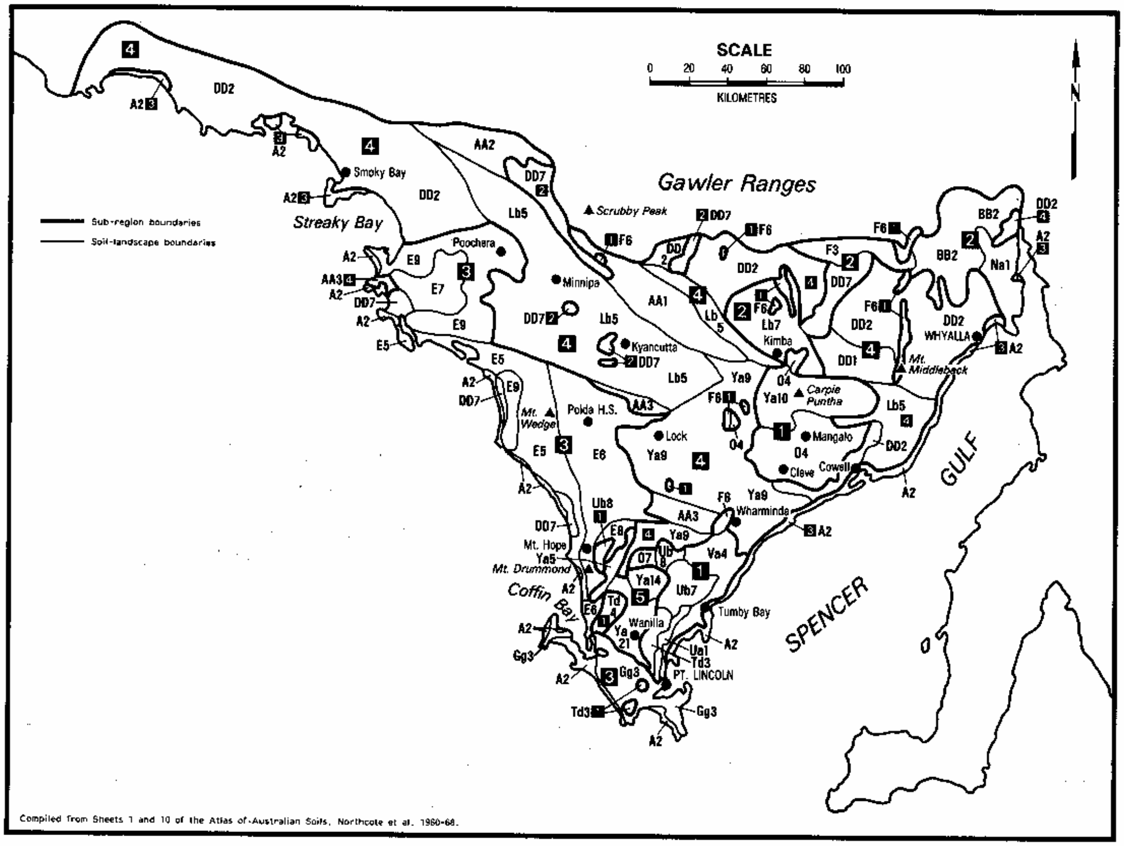


Fig. 1. Generalised soil-landscapes of the Eyre Peninsula region.

1 Ranges and hills sub-region

Unit	Landscape	Dominant Soils
F6	Hills and ranges	Um5.41 and rock outcrops
04	Hills with outwash plains	Dr2.23, Um5.41, Dy3.43
07	Rolling hills	Dr2.23, Uc6.13
Td3,4	Undulating to hilly	Dy3.61, Dy5.61
Ua1	Rolling hills	Dy3.22, Uc6.11, Dy3.43
Ub7,8	Undulating to hilly	Dy3.42, Dy3.43
Va4	Undulating outwash plains	Dy3.43, Dy5.43
Ya10	Broken-hilly with dunes	Dy5.43, Uc2.2, Uc6.11

2 Plains and tablelands sub-region

BB2	Hills, tablelands, valleys	Um5.11, Dr1.13, Dr1.33
F3	Flanking plains	Dr1.33, Gc1.12
DD7	Plains and lake basins	Saline Gc and Dr1 variants
Lb7	Undulating	Gc1.12, Dr2.23, Dr2.33
Na1	Dissected tableland	Dr1.13, Dr1.33, Ug5.3

3 Calcarenite plains sub-region

A2	Coastal dunes and plains	Uc1.11, Uc1.33, Gc1.1
E5	Limestone hills	Uc1.33, Uc6.13, Um6.24
E6	Limestone plain	Uc6.13, Uc6.12, Uc5.11
E7	Plain	Um1.43, Uc1.43, Um6.24
E8	Plain	Uc6.13, Dy5.43, Dy5.83
E9	Plain	Uc1.33, Uc1.43, Gc1.12
DD7	Plains and swamps	Saline Gc, Uc1.1, Uc1.33
Gg3	Broken, undulating	Um6.24, Um6.21, Uc6.13

4 Dunefields sub-region

AA1,3	Jumble and teardrop dunes	Uc5.11, Uc2.21, Dy4.83
AA2	Low, broad dunes	Uc5.11, Uc5.12, Gc1.12
DD1	Dunes with small plains	Gc1.12, Gc1.22, Uc2.21
DD2	Plains with dunes	Gc1.12, Uc2.21, Dr1.43
Lb5	Plains with dunes	Gc1.12, Uc1.33, Dy4.43
Ya9	Plains with dunes	Dy5.43, Uc2.2, Uc6.13

5 Basin plains sub-region

Ya5	Lake and swamp plains	Dy5.43
Ya14	Basin plain	Dy5.43, Dr2.23, Dr2.33
Ya21	Basin plain	Dy5.43, Dy5.83

soils and calcareous earths with, in places, sporadic but significant areas of sandy red earths. Some large salinas and associated lunettes and dunes occur in low parts of the landscape.

The third division can be termed the calcarenite (Calcarenite is the preferred term for a limestone consisting predominantly (more than 50%) of detrital calcite particles of sand size. In this case the particles have been derived by the breakdown of marine shells) plains sub-region of the west coast. Topographically these consist of gently undulating plains and low hills, but the high cliffs in the stretch of coastline from Streaky Bay to Port Lincoln are included. The inland extent of this sub-region is highly variable but reaches as far as Poochera, in the northern sector, and Lock, in the central sector, for example.

The common feature of these landscapes is an almost continuous exposure of dense, hard calcrete (see explanation of calcrete formation below) often expressed as a very subdued dunelswale landscape. In this case the crests sometimes have an extremely thin (<10 cm) remnant veneer of white siliceous sand which, on aerial photographs, gives them the erroneous appearance of belonging to a dunefield. Soil cover is discontinuous and shallow with shallow red sandy soils the most common, although shallow calcareous loamy soils and calcareous earths do occur. Shallow red duplex soils are found in isolated patches and their occasional association with ferruginous gravels suggests that they represent relicts of the landscape now universally covered by the dense, hard calcrete.

A key proposal of Crocker (1946b) was that during Pleistocene glaciations sealevel was lowered exposing large areas of continental shelf and allowing the subsequent on shore accumulation of vast amounts of aeolian calcarenite that now occupies more than 5000 km^2. The calcarenite has since been subjected to pedological processes with the result that calcrete was formed over these wide areas by downward leaching and redeposition, at depth, of calcium carbonate derived from the calcarenite. It was considered that a leached siliceous residue remained above the calcretes wherever they formed. This residue subsequently became unstable during Recent arid phases and was swept inland, being piled into the extensive dunefields that will be considered next as sub region 4.

Recent work of Milnes & Ludbrook (1985) shows clearly that while Crocker's thesis was broadly correct, the detail may well have been rather different. From the identification of microfossils they show that much of the aeolian calcarenite contains a significant component that dates from the Miocene. They argue that marine transgression may have been rather more extensive at that time than there is presently evidence to confirm. Much of the Miocene microfossil material shows extensive re-working. They consider it possible that there have been several accessions of calcareous materials since the Miocene, from a coast-line standing essentially at its present position. In this respect tectonic stability is much more likely on Eyre Peninsula than was the case in the South East of South Australia where many stranded coastlines occur (Blackburn *et al.* 1965; Sprigg 1952, 1959).

Milnes & Ludbrook (1985) also suggest that the calcarenite had been transported well inland by aeolian activity before extensive leaching and formation of calcretes took place. In this respect they were able to find Miocene marine microfossils in calcretes as far inland as Yarwondutta Rock near Minnipa. This, of course, helps to explain the widespread presence of calcretes in swales and even beneath dunes in such hinter· land locations.

Finally, in better watered portions of this sub region it appears that the shallow red sandy soils, in particular, may currently be developing by weathering of the calcretes. There are also shallow loamy soils developed on thin freshwater limestones containing gastropod fossils, as in the area between Mt Wedge and Polda Homestead.

The fourth division is here referred to as the dunefields sub-region and includes associated calcreted plains of the far west, north-west and central portions. It is the most extensive of the sub-regions, stretching as it does from the north·west corner to the south-central coast, right across Eyre Peninsula. Crocker (1946a) considered that the sands of these dunefields were derived by the stripping of profiles developed on the aeolian calcarenites of sub-region 3, at least in the central and south-central dune tracts.

Crocker (1946b) postulated that in the north and north-west portions the sands were derived from the Nullarbor Plain. While this contention may be partly correct there are doubtless areas where the sands came from a localised source such as the Corrobinnie Depression. More recent evidence (Binks & Hooper 1984) of the relatively widespread occurrence of Eocene and Pliocene sands suggests that these have contributed in large part to the dunefields.

Again, this is a rather complex sub-region in terms of soil distribution. In the northern parts the dunes are somewhat less leached than further south and swales are dominated by calcareous earths and deep calcareous loams. In the drier parts some crusty red duplex soils also occur in the swales. In the central tract, on the other hand, swales are strongly calcreted with shallow redbrown sandy or loamy soils and shallow calcareous sands. Dunes are more strongly leached here and there are areas where yellow duplex soils that normally occur only on dune flanks also occur on the crests of some low dunes.

The south-central tract, like the north-eastern, has less calcrete in the swales but the soils of the swales are dominantly yellow duplex or shallow red-brown sandy soils where calcrete does occur. The dunes consist of strongly leached sands although some areas of jumbled or teardrop dunes of dominantly brown sands occur on the west side of this particular tract. Ferruginous gravels derived from the ranges and hills of sub region 1 are apparent in places. It should be mentioned too that these dunefields range widely in elevation from a little above sea level near the coast to about 300 m above sea level in the vicinity of Mt Bosanquet, but mostly they have skirted the higher country. In parts of the Gawler Ranges on the northern boundary of the region, for instance near Scrubby Peak, dunes have piled against, and finally crossed, rocky ridges standing nearly 200 m above the nearby plain.

The fifth and final division is one of limited area covering the low-lying basin plains of the southern central portion and is thus termed the basin plains sub-region. These plains occur in an area between the main range of the east coast (sub region 1) and the outlying White Range and lines of hills such as Mt Greenly, Mt Hope and Mt Drummond on the west side of the Peninsula, north of Coffin Bay.

This sub-region is by far the smallest but is nevertheless quite distinctive in terms of landscape features. It is, at least in part, the surface expression of the Wanilla portion of the Uley-Wanilla groundwater basin, developed in Eocene lignitic and carbonaceous sands and clays (Johns 1961).

The generally low-lying aspect coupled with a moderately high rainfall have contributed to the formation of the widespread yellow duplex soils many of which exhibit subsurface waterlogging. Some of these soils also contain ferruginous gravels derived from nearby highlands. Areas of red duplex soils occur in better drained locations while grey cracking clays and various saline soils occupy drainage ways that are commonly sluggish and ill-defined. The chief remaining variants are shallow red-brown sandy soils in limited locations where calcretes persist.

PREDOMINANT SOILS OF THE REGION

Calcareous sands[2] (Great soil group[3]; Calcareous sands: Soil Taxonomy: Xeropsamment/Xerochrept)

There are two major and distinctive groups of these soils, firstly the shelly sands of the coastal margins (Ucl. 11). They are generally deep soils, although shallow versions on calcrete do occur. Their profiles show only rudimentary alteration of whitish to pale yellow sands, often consisting principally of marine shell fragments. There is usually some darkening by organic matter of the uppermost 10-30 cm.

Such soils characteristically have low water holding capacity, are deficient in plant nutrients, particularly the micro-nutrient metals such as copper, zinc, molybdenum and manganese (Table 1), and are prone to wind erosion when devegetated. Cobalt is usually needed for animal production. Shortages of phosphates and nitrogen are common to all soils in the region so that a forage legume is an essential part of the cropping system, together with regular top dressings of superphosphate.

The second group is common further inland, usually associated with dense, thick calcretes whether these be on the sub-coastal aeolian calcarenite plains of sub-region 3 or in the swales between the dunes of sub-region 4. These Ucl.33 soils vary greatly in thickness, from < 20 cm to over 1 m. They are firmer soils than Ucl.11 and shell fragments are no longer apparent. Rather, their obvious feature is abundant calcareous rubble throughout, but often increasing with depth. Otherwise, organic darkening of the topmost 10-20 em is the only sign of pedological organisation. Such soils appear to grow adequate crops in seasons when water is not limiting, particularly in the case of the shallower members. No plant nutrient data are obtainable but, drawing on experience of similar calcareous sands, it is most likely that their availability is both marginal and variable.

Bleached Sands with a colour B-horizon (Podzols: Xeropsamment/Xerochrept/Haploxeralf)

These Uc2.21 soils that French (1958) called deep leached sands are the common soils of the dunes in the inland dunefields. They occur throughout the length of the region but vary from south to north. In the south, with higher rainfall, they are acid to neutral, highly leached and impoverished and thus extremely susceptible to drifting when disturbed. Consequently many of the larger dunes have not had vegetation cleared from their crests. Similarly, some of the larger dune tracts have been conserved, e.g. the Hincks, Hambidge and Pinkawillinie conservation parks.

Characteristically these soils have minimal darkening by organic matter to form a rudimentary greyish to light brown A_1 horizon over a deep (often > 1 m) A_2 horizon of leached white sand, which in turn overlies a B horizon of yellow sand, above a dune core of yellow-brown sandy loam to sandy clay in the south and east of the region.

[2] The descriptive names of Northcote et al. (1975) are given first.

[3] The great soil group names of Stace *et al.* (1968) and of Soil Taxonomy (Soil Survey Staff 1975) are in parentheses.

Table 1. SOME PROPERTIES OF SOILS OF THE EYRE PENINSULA REGION.

Soils		Usual Occurrence			Morphological Properties		Chemical Properties		
PPF'	GSG[2]	Location(sub-region)	Landscape	Generalised Parent Material	A horizon	B horizon	SRT[3]	Exch. Cats[4]	Deficiencies Reported6
Uc1.11	CS	3	Coastal dunes	Calcareous sands	A, only	none	Alkaline	6-7	N, P, K, Cu, Co, Zn, B, Fe, Mn, Mo
Uc1.33	UCS	3,4	Plains and swales	Calcareous sands	A, only, coherent	none	Alkaline	9-12	No data
Uc1.43	L	3,4	Plains and swales	Calcrete/calc. sands	A, only, firm	none	Alkaline	11-12	N, P, K, Cu, Zn, Mn
Uc2.21	P	4	Dunes and sandsheets	Siliceous sands	A, and A_2	none	Acid/Alkaline	5-6	N, P, K, Ca, Mg, CU, Zn
Uc6.13	UT-R	4	Plains	Calcrete/calc. sands	A, only, weakly pedal	none	Alkaline	5_7[5]	N, P, K, Cu, Zn, Mn
Um1.43	UT-R	3,4	Plains and swales	Calcrete/calcareous	A, only, firm	none	Alkaline	25-27	N, P, K, Cu, Zn, Mn
Um6.24	T-R	3,4	Plains	Calcareous	A, only, pedal	Pedal	Alkaline	20-30	N, P, Zn, Cu, Mn
Gc1.12	SB	2,3,4	Plains, slopes and swales	Calcareous	Calcareous throughout	horizon of CaC03 maxima	Alkaline	18-25	P, N, Zn, Mn, Fe, Cu
Gc1.22	SB	2,3,4	Plains, slopes and swales	Calcareous/finer grained	Calcareous throughout	clay and CaC03 maxima coincide	Alkaline	20-25	P, N, Zn, Mn, Fe
Dr1.13	DL	2,4	Plains and slopes	finer grained: saturated base	A, only, crusty	Red pedal clays	Alkaline	No data	No data
Dr1.33	DL	2,4	Plains and slopes	finer grained: saturated base	A, crusty and A_2	Red pedal clays	Alkaline	20-35	No data
Dr1.43	DL	2,4	Plains and slopes	finer grained: saturated base	A, crusty and A_2	Red pedal clays	Alkaline	No data	No data
Dr2.23	RB	1,2	Slopes and valleys	finer grained: felspar rich	Hardsetting A, and A_2	Red pedal clays: calcareous	Alkaline	15-28	N, P, Zn
Dr2.33	RB	1,2	Valleys and slopes	finer grained: felspar rich	Hardsetting A and A_2,	Red pedal clays: calcareous	Alkaline	15-30[5]	N, P, Zn
Dy3.22	GP		Slopes	Coarser grained: quartz rich	Hardsetting A and A_2,	Mottled yellow pedal clays	Neutral	10-20[5]	N,P
Dy3.42	S		Slopes	Coarser grained: quartz rich	Hardsetting A and A_2,	Mottled yellow pedal clays	Neutral	5-20[5]	N, P, K, Ca, Mo, S, Cu, Zn
Dy3.61	LP/YP		Ridge crests	Deep weathering profile	Hardsetting A, and A_2	Mottled yellow clays	Acid	5-10[5]	P, N, K, Mo, Cu, Zn
Dy4.43	SS	4	Low rises and sand- sheets	Coarser grained: quartz rich	Sandy A, and A_2	Yellow pedal clays	Alkaline	20	N, P, Cu, Zn, Mo
Dy4.83	SS	4	Low rises and sand- sheets	Coarser grained: quartz rich	Sandy A, and A_2	Yellow clays	Alkaline	7	N, P, Cu, Zn, Mo
Dy5.43	SS	1,3,4	Slopes and plains	Coarser grained: quartz rich	Sandy A, and A_2	Mottled yellow pedal clays	Alkaline	6-18[5]	N, P, K, Zn, Cu, Mo ,Ca
Dy5.61	LP		Crests and slopes	Deep weathering profile	Sandy A, and A_2	Mottled yellow clays	Acid	5-10[5]	N, P, K,Mo, Cu, Zn
Dy5.83	SS	1,3,4	Slopes and plains	Coarser grained: quartz rich	Sandy A, and A_2	Mottled yellow clays	Alkaline	6-18[5]	N,P,K,Zn,Cu, Mo,Ca

Notes:
1. Principal profile forms (Northcote, 1979a).
2. Nearest equivalent great soil group (Stace *et a/.,* 1968). CS=Calcareous sands; L=Lithosols; P=Podzols; T-R=Terra-rossas; SB=Solonized brown soils; DL=Desert loams; RB=Red- brown earths; GP=Grey-brown podzolic soils; S=Soloths; LP=Lateritic podzolic soils; YP=Yeliow podzolic soils; SS=Solodized s%netz and S%dic soils.
3. SRT=Soil Reaction Trend.
4. Total metal cations (Ca+Mg+K+Na) in m.e. per 100 g soil for upper B horizon where present.
5. Data from similar soils elsewhere.
6. Some information from outside of region.

From south to north these dune profiles become progressively more alkaline so that from near Kyancutta north and northwestwards they have calcareous dune cores and surface horizons that are neutral to alkaline throughout. They are, therefore, less satisfactorily classed as podzols. In the more northerly dunefields where swales often have shallow soils on dense, hard calcrete, the dunes are generally cleared and, if not actually encouraged to drift, no preventative measures are taken, in order to achieve a deeper, albeit sandy, seedbed on the calcretes of the swales, at the expense of the dunes.

Major and micronutrients, as mentioned for the calcareous sands, are essential for any degree of productivity from these soils, as are adequate management to minimise drift, and the build-up of organic matter in order to increase their water holding capacity. The water repellent nature of their sandy surfaces can be a significant problem.

Weakly structured sandy soils (Terra rossa soils: Xerochrept/Haploxeroll/Calcixeroll/Palexeralf)

These soils are represented widely throughout the region by Uc6.13 and to a lesser extent by their finer textured counterparts the Um6.24 soils. The lithosols Uc1.43 and Um1.43 are common too, and have a similar profile form in that they are shallow, uniform-textured and non-calcareous red soils developed on calcrete. French (1958) called them shallow terra rossa soils. The Uc6 soils are distinguished by a very weak structure and a slight clay increase with depth while the Um6 soils have loamy textures and more pronounced structure.

While all these soils occur over large areas they are limited in extent in that they tend to be restricted to small flats between calcrete rises. The Uc6 and Um6 soils are most prevalent on the aeolian calcarenites of sub-region 3 while the Uc1 and Um1 soils are common in the swales of subregion 4. These soils are all generally satisfactory for cereal growing and pasture production, particularly the deeper ones, their main constraint being their close association with outcropping calcrete. Moreover they require the correction of deficiencies of copper, zinc and sometimes manganese (Table 1). Some of them have been excavated extensively for use as road-dressing material, particularly in areas of dense sheet calcrete.

Calcareous earths (Solonized brown soils: Calcixeroll/Palexeroll)

These soils are mainly represented by the highly calcareous Gc1.12 soils, although there are minor occurrences of the less calcareous Gc1.22 soils. They are the co-dominant soils of sub region 4 along with the siliceous sands of the dunes; they form a significant component of sub region 2, and are relatively minor in sub-region 3.

The calcareous earths have gradational texture profiles that are calcareous throughout, and indistinct horizons with gradual changes down the profile. They range from non-sodic to strongly sodic and may also have moderate to high soluble salt contents. Surface soils are commonly dark reddish brown with textures ranging from sand to clay loam. Calcium and magnesium carbonates occur both in the fine earth and as hard segregations which may dominate the middle portions of the profiles, being at times cemented into a continuous pan. These soils are usually structureless and may be powdery and loose when dry, particularly after being disturbed.

The redder and more clayey members of the Gc1.12 soils occur almost universally as a sloping "halo" wherever there are significant granite outcrops. As well, they occur on rising ground where granite does not, or barely outcrops and in other cases it is not clear whether rises are granite based or not. A minor proportion occurs on small plains or very low rises associated with tracts of dunes. Here they may be sandier and greyer.

These soils are among the deeper ones of the region so have been highly sought after for cropping, especially where their association with granite highs allowed the harvesting of extra, good quality water, shed from the granite surfaces. The sandy members particularly may nevertheless be subject to some deficiencies (Table 1), notably of zinc, manganese, iron and copper.

Red duplex soils (Desert loams and Red brown earths: Natrargid/Paleargid/Natrixeralf/Palexeralf)

This group is so named on account of the strong texture contrast between their surface soils and their red-brown to red clay subsoils. As indicated by the great soil group names, there are two distinct and important forms of red duplex soils that occur if! the region. The crusty red duplex soils (Dr1.13, 1.33 and 1.43; Desert loams) are restricted to the drier, pastoral portions, specifically sub-region 2 and the more northerly portions of sub-region 4.

The second group, the hard pedal red duplex soils (Dr2.23 and 2.33; Red-brown earths) occur widely scattered throughout the region but are most important in sub-region 1, particularly on the slopes and outwash plains about the hills and ranges from Tumby Bay to Cummins, and in valleys and on slopes in the Cleve-Mangalo-Kimba areas. Recent work by the author and colleagues (unpublished data) has shown that the widespread surface on which these soils occur in the north and northwest of the region pre-dates the deposition of aeolian calcarenites. Most such profiles contain ferruginous gravels and are clearly related to the occurrence of granites, in the subsurface at least. They are to be found in sub-regions 2, 3 and 4. Younger forms are developed on calcretes in sub-region 3 and in valley alluvia in sub-region 1.

In the low-lying basin plains of sub-region 5 there are hard pedal red duplex soils formed in alluvia derived from the hills and ranges of sub region 1. In sub-region 3 there are limited areas where these soils were, and technically still are, palaeosols, but they are being exhumed as a result of the current dissolution of overlying calcretes.

The distinguishing features of the crusty red duplex soils are a surface crust which always reforms after being disturbed and can be readily separated from the rest of the soil revealing an undersurface characterised by large (1-4 mm) smooth-surfaced vesicles. The remainder of a generally loamy and thin A_1 horizon rests abruptly on a moderately to strongly pedal, often prismatic, reddish clayey B horizon. A surface pavement of gravels, pebbles or stones is a common feature of these soils and may consist of resistant country rock such as quartzite, or be derived from other pedogenic materials such as ferricrete or silcrete. These soils generally occur in areas of < 250 mm rainfall and their use is thus confined to pastoral pursuits i.e. the grazing of natural vegetation. Infiltration of water is fairly slow because of the surface crust, although runoff is retarded by the surface pavement. These soils mostly contain gypsum and/or calcium carbonate at shallow depth, as well as high contents of soluble salts. Subsoils, in fact, are generally highly saline; even surface soils may contain >0.1% NaCl. Little is known of their micronutrient status because they are neither cropped nor carry improved pasture, but inherent fertility is low.

The hard pedal red duplex soils, on the other hand, are among the most highly regarded agricultural soils of South Australia. They normally have a thicker and hardsetting surface horizon in contrast to the Dr1 soils, and a distinct texture contrast to moderately to strongly pedal reddish clayey B horizons. Calcium carbonate is common in the lower B horizon.

Some of the Dr2.23 soils occur in the <250 mm rainfall zone, which indicates their use for grazing alone but elsewhere they are highly suitable soils for cereal growing and, indeed, for more intensive purposes, if required. The Dr2.33 soils, however, because of a degree of sodicity, tend to have more problems such as extreme hardsetting in summer and waterlogging in winter with the attendant likelihood of salinity problems.

Nutrition is not usually a problem with these soils (Table 1) except where they contain excess quantities of ferruginous gravels, when higher than normal applications of phosphates are essential. In some of these soils copper supply can be marginal.

Yellow duplex soils (lateritic podzolics, solodized solonetz, solodics, soloths, grey brown podzolics and yellow podzolics: Palexeralf/Natrixeralf/Haploxeralf)

Again there is a marked contrast in texture between the surface soils and the clay subsoils, but the latter are dominated by yellow colours, indicating their poorer aeration and drainage as compared with the red duplex soils. The string of great soil group names suggests much greater differences than in fact exist. Indeed, in this region these soils are best considered in three groups. These are the hard and sandy apedal mottled-yellow duplex soils (Dy3.61 and 5.61; lateritic podzolics or yellow podzolics); the hard pedal mottled-yellow duplex soils (Dy3.22 and 3.42; grey-brown podzolics or soloths); and the sandy pedal and apedal mottled-yellow duplex soils (Dy5.43 and 5.83; solodized solonetz or solodic soils).

Most of these soils are confined to sub-regions 1 and 5 where rainfall is high enough to provide the extra moisture necessary for the development of mildly waterlogged clay subsoils, indicated by yellow colours and mottling. The last group also has members in sub-regions 3 and 4 where they occur on the flanks of dunes, or on rises within swales. In the drier parts of sub-regions 3 and 4 these soils are replaced by equivalents with unmottled clay B horizons (Dy4.43 and 4.83; also solodized solonetz or solodic soils).

The chief features of the first group are a strong texture contrast between loamy or sandy A horizons and clayey B horizons that are dominantly yellow and mottled. The A horizons have organic darkening in the upper part and are pale yellow or light grey below, with much ferruginous gravel down to the contact point with the B horizons. This first group comprises acid soils that are usually associated with the breakdown of lateritic plateaux in southern Australia (Northcote 1979b). Their clayey subsoils restrict drainage so that they are prone to develop perched watertables in the winter months, a factor that can lead to severe erosion on steeper slopes. Coupled with this physical constraint their dominantly kaolinitic clays mean that inherent fertility is low. Apart from phosphorus and nitrogen, in some areas copper, molybdenum and zinc (Table 1) are required.

The second group, of hard pedal mottled-yellow duplex soils, differs in three major respects; they are moderately well structured, have a neutral reaction trend, and contain less ferruginous gravel than the foregoing soils. In practical terms, then, they are much better drained soils, and while inherent fertility is not particularly high, they require lighter fertilizer applications for a similar response. The Dy3.22 soils are stable but the Dy3.42 soils are less well drained and therefore somewhat of an erosion risk on steeper slopes.

The third group, apart from having the general mottled-yellow duplex properties, are sandy surfaced soils with an alkaline reaction trend and either have a structured B horizon (Dy5.43) or are massive throughout (Dy5.83). In the higher rainfall portions, e.g. sub-regions 1 and 5, these soils may contain ferruginous gravels, but in their drier distribution range, as in sub-regions 3 and 4, they do not. In these drier parts their main constraints are low fertility (deficiencies can include phosphorus, nitrogen, copper, zinc and molybdenum), sodic subsoils and a tendency for the sandy surfaces to drift if poorly managed.

CONCLUSIONS

Eyre Peninsula still offers unsolved problems for the pedologist and soil chemist. Some of the most highly calcareous parent materials and soils in Australia occur in the region. Their variety is not yet satisfactorily encompassed by current classification schemes although one such has been proposed specifically for calcium carbonate layers (Wetherby & Oades 1975); nor do we adequately understand the role that calcium carbonate plays in the soil in respect of plant nutrition and water holding capacity. It is clear that much of this calcium carbonate may occur in the silt and clay sized fractions, but as yet there are no figures to quantify this occurrence as there are for Coomealla where it was shown by Northcote (1951) that more than 90% of the carbonate can occur in these fractions.

These highly calcareous parent materials and soils rest in places on an older landscape that was leached and "acid". Calcium carbonate is readily soluble so that it is being redistributed in these and other landscapes at a rapid geological rate by both water and wind; locally by solution in rainwater and reprecipitation at greater depth, and on a wider scale by wind winnowing of finer particles.

It is clear that both wind and water have played a major role in fashioning the present face of the region, and these agencies continue their activities today. Despite man's desire to the contrary, soils and landscapes are not static entities but are in a constant state of change. How man manages the soils and landscapes that he uses can determine the rate and direction of such change. Land clearing alone alters a long established balance and leads to the redistribution of soil materials within landscapes, largely by water erosion in the higher rainfall areas, and by both wind and water (principally wind) in the drier parts.

It is obvious that on Eyre Peninsula, while it should not be used as cause for complacency, a huge refashioning of the landscape had been achieved by wind long before man arrived on the scene and that his attempts to initiate a renewed round are puny by comparison.

Finally, there remains the question of soil fertility. While most of the early work on the subject of trace elements was carried out in the upper and lower South-East (Marston *et al. 1938;* Tiver 1955; McKenzie 1959), a great deal of attention has been paid to the question on Eyre Peninsula in recent years, particularly in regard to cereal nutrition (Harris & Cartwright 1980; Cartwright & Harris 1980). At the same time the clover-ley side of the rotation has certainly not been forgotten because of the prominent and integral part that it plays in the whole cereal nutrition story. As well, strong evidence has appeared (B. Cartwright pers. comm.) that in addition to the nutrient and micronutrient deficiencies, there is a widespread boron toxicity present in the aeolian calcarenite landscapes. Work continues to relate these findings sensibly to the pattern and variety of soils.

ACKNOWLEDGEMENTS

I thank my colleagues Dr A. R. Milnes, Mr J. R. Harris and particularly Dr K. H. Northcote for helpful comments and suggestions on the first draft of this paper. I thank Mr G. E. Rinder for the design and drafting of Fig. 1.

REFERENCES

Billing, N. B., Wright, M. J. & Thompson, J. M. (1984). The evolution of the soil-landscapes of western Eyre Peninsula (Abs.) Proc. National Soils Conf. Brisbane. Aust. Soc. Soil Sci. p. 145.

Binks, P J. & Hooper, G. J. (1984). Uranium in Tertiary palaeochannels "West Coast area" South Australia. *Proc. A'Asian Inst. Min. Metall.* **289**, 271-275.

Blackburn, G. (1959). The soils of County Grey, South Australia. *CSIRO Divn Soils, Soils and Land Use Ser.* No. 33.

Blackburn, G. (1964). The soils of Counties Macdonnell and Robe, South Australia. *CSIRO Divn Soils, Soils and Land Use Ser.* No. 45.

Blackburn, G. (1983). Soils. *In:* Tyler, M. J., Twidale, C. R, Ling, J. K. & Holmes, J. W. (Eds) 'Natural History of the South East'. (Royal Society of South Australia, Adelaide).

Blackburn, G., Bond, R. D. & Clarke, A. R. P (1965). Soil development associated with stranded beach ridges in south-east South Australia. *CSIRO Soil Publ.* No. 22.

Bourne, J. A., Twidale, C. R. & Smith, D. M. (1974). The Corrobinnie Depression, Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **98**(3), 139-152.

Cartwright, B. & Harris, J. R. (1980). A survey of the nutrient resources of cereal-producing soils on Eyre Peninsula, South Australia. *Intern. Cong. Dryland Farming.* Adelaide 1980.

Crocker, R L. (1946a). An introduction to the soils and vegetation of Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **70**(1), 83-106.

Crocker, R. L. (1946b). Post-Miocene climatic and geologic history and its significance in relation to the genesis of the major soil types of South Australia. *Bull. Coun. Sci. Ind. Res. Aust.,* No. 193.

Downes, R. G. (1944). A soil survey of blocks 5, 3Wand 49, Hundred of Wanilla, South Australia. *CSIR Divn Soils, Divnl Rep.* No. 3/44.

French, R J. (1958). Soils of Eyre Peninsula. *Dept Agric.* S. *Aust. Bull.* No. 457.

Geological Survey of South Australia (1969). Handbook of South Australian Geology. L. W. Parkin (Ed.) (A. B. James, Govt Printer, Adelaide).

Harris, J. R. & Cartwright, B. (1980). Supply and demand for nutrients: differences between crops in soils of low fertility. *Intern. Cong. Dryland Farming.* Adelaide, 1980.

Harris, W. K. (1979). Streaky Bay town water supply. Palynology of carbonaceous clay from For 20A. *Dept Mines and Energy, Rept Bk* No. *79/91.*

Jessup, R. W. & Wright, M. J. (1971). Cenozoic sediments, soils and climates at Whyalla, South Australia. *Geoderma,* **6,** 275-308.

Johns, R. K. (1961). Geology and mineral resources of southern Eyre Peninsula. *Geol. Survey* S. *Aust. Bull.* No. 37.

King, P M. & Alston, A. M. (1975). A survey of soils near Wharminda and Stokes, Eyre Peninsula, South Australia. *Dept. Agric.* S. *Aust. Special Land Description Ser.* SB5.

Laut, P, Heyligers, PC., Keig, G., Loftier, E., Margules, C., Scott, R. M. & Sullivan, M. E. (1977). Environments of South Australia, Province 4, Eyre and Yorke Peninsulas. CSIRO Aust. (Division of Land Use Research, Canberra).

Marston, H. R., Thomas, R. G., Murnane, D., Lines, E. W. L., McDonald, I. W., Moore, H. O. & Bull, L. B. (1938). Studies on coast disease of sheep in South Australia. *Bull. Coun. Sci. Ind. Res. Aust.,* No. 113.

Milnes, A. R. & Ludbrook, N. H. (1985). Provenance of microfossils in aeolian calcarenites and calcretes in southern South Australia. *Aust. J. Earth Sci.* (in press).

McKenzie, R M. (1958). Trace elements in some South Australian Terra Rossa and Rendzina soils. *Aust.* J. *Agric. Res.* **10,** 52-57.

Mowling, F. A. (1979). The natural vegetation of Eyre Peninsula. (NCSSA Inc., Adelaide).

Northcote, K. H. (1951). A pedological study of the soils occurring at Coomealla, New South Wales. *Bull. Coun. Sci. Ind. Res. Aust.,* No. 264.

Northcote, K. H. (1979a). A factual key for the recognition of Australian soils. 4th Ed. (Rellim, Glenside).

Northcote, K. H. (1979b). Soils. *In:* Tyler, M. J., Twidale, C. R & Ling, J. K. (Eds) 'Natural History of Kangaroo Island'. (Royal Society of South Australia, Adelaide).

Northcote, K. H., with Beckmann, G. G., Bettenay, E., Churchward, H. M., van Dijk, D. C., Dimmock, G. M., Hubble, G. D., Isbell, R. F., McArthur, W. M., Murtha, G. G., Nicolls, K. D., Paton, T. R., Thompson, C. H., Webb, A. A. and Wright, M. J. (1960-68). Atlas of Australian Soils. Sheets 1-10 with explanatory booklets. (CSIRO and Melb. Univ. Press, Melbourne).

Northcote, K. H., Hubble, G. D., Isbell, R. F., Thompson, C. H. & Bettenay, E. (1975). A description of Australian Soils. (CSIRO, Melbourne).

Prescott, J. A. (1931). The soils of Australia in relation to vegetation and climate. *Bull. Coun. Sci. Ind. Res. Aust.,* No. 52.

Prescott, J. A. (1944). A soil map of Australia. *Bull. Coun. Sci. Ind. Res. Aust.,* No. 177.

Smith, D. F. (1963). The plant ecology of lower Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **87,** 93-120.

Soil Survey Staff (1975). Soil taxonomy-a basic system of soil classification for making and interpreting soil surveys. (USDA, Washington, D.C.)

Sprigg, R. C. (1952). The geology of the south-east province, South Australia, with special reference to Quaternary coast-line migrations and modern beach developments. *Geol. Survey* S. *Aust. Bull.* No. 29.

Sprigg, R. C. (1959). Stranded sea beaches and associated sand accumulations of the upper southeast. *Trans. R. Soc.* S. *Aust.* **82,** 183-193.

Stace, H. C. T, Hubble, G. D., Brewer, R., Northcote, K. H., Sleeman, J. R, Mulcahy, M. J. & Hallsworth, E. G. (1968). A handbook of Australian soils. (Rellim, Glenside). Stephens, C. G. (1943). A soil survey of part of Hundred of Wanilla, County Flinders. *CSIR Divn Soils Divnl Rep.* No. *22/43.*

Stephens, C. G. (1961). The soil landscapes of Australia. *CSIRO Soil Publ.* No. 18.

Tiver, N. S. (1955). Deficiencies in South Australian soils. J. *Dept Agr.* S. *Aust.* **59**, 100-113.

Twidale, C. R., Bourne, J. A. & Smith, D. M. (1976). Age and origin of palaeosurfaces on Eyre Peninsula and the southern Gawler Ranges, South Australia. *z'f. Geomorph. N.F* **20,** 1: 28-55.

Twidale, C. R. & Smith, D. L. (1971). A "perfect desert" transformed: the agricultural development of northwestern Eyre Peninsula, South Australia. *Aust. Geograph* II, **5**: 437-54.

Wetherby, K. G. (1984). The extent and significance of water repellent sands on Eyre Peninsula. *Dept. Agric.* S. *Aust. Tech. Rept* **47**.

Wetherby, K. G., Davies, W. J. & Matheson, W. E. (1983).Wind erosion on Eyre Peninsula, 1975-1979. *Dept. Agric.* S. *Aust. Tech. Rept* **31**.

Wetherby, K. G., Moore, S. D. & Sinclair, J. A. (1982). The Tod River soil survey. *Dept. Agric.* S. *Aust. Tech. Paper* **2**.

Wetherby, K. G. & Oades, J. M. (1975). Classification of carbonate layers in highland soils of the northern Murray Mallee, S.A., and their use in stratigraphic and land-use studies. *Aust. J. Soil Res.* **13**, 119-132.

6: Climate

by PETER SCHWERDTFEGER

INTRODUCTION

Eyre Peninsula is a prominent triangular coastal projection of South Australia. It is virtually equilateral with vertices approximately 450 km part located at the head of Spencer Gulf and Streaky Bay respectively, both at about latitude $32^0$30'S, and Cape Catastrophe in the south at approximately 35°S, 136°E. This area of almost 0000 km^2 is thus bounded by the open waters of the Great Australian Bight and Southern Ocean toward the southwest, Spencer Gulf to the southeast and the interior of the Australian continent in the north. These three contrasting bounding regions lend some of their characteristics to passing air masses, and have a great influence on the climate of Eyre Peninsula, the nature of which is therefore by no means uniform.

From the air, the overall visual impact of the peninsula is essentially one of a vast plain, punctuated only by a few isolated peaks and flanked to the north, east and south by low discontinuous ranges.

RAINFALL

The western coastline of the Peninsula is exposed to the atmospheric pressure systems of lows and accompanying fronts that move in from the west during winter. Their recession to higher latitudes in summer and concomitant decrease in rainfall lead to a well defined mediterranean climate. As revealed by Fig. 1, the mean annual rainfall falls off steadily with distance from the west coast and decreasing latitude: factors which also are associated with reduced reliability of precipitation. The topographic influence on rainfall is by no means obvious, in marked contrast to the situation in the Adelaide region, which lies in similar latitudes to those of the southern part of the Peninsula. While the mean annual records suggest some orographic rainfall in the Lincoln Uplands region west of Tumby Bay, the effect of the Gawler Ranges and the Cleve hills is extremely marginal, even during winter, as seen in Fig. 2. During summer, orographic effects are still important, particularly in the Lincoln Uplands, in spite of their low altitude (Fig. 3). Compared with the winter situation, the mean summer precipitation is relatively uniform over the entire Peninsula, the absence of frontally induced rain to the north and east being compensated by more thunderstorms. An analysis of the fraction of annual precipitation which falls during the three summer months in shown in Fig. 4 which illustrates the systematically varying nature of rainfall-producing mechanisms over the Peninsula. The orientation of the contours suggests that while the movement of relatively cool air from over the ocean in the southwest may still be important during the summer, neither frontal nor orographic effects are sufficient to have any impact, while thunderstorm mechanisms appear to develop in proportion to the distance from the west coast, as the air becomes heated over increasingly warmer land surfaces. The monotonic pattern of this systematic change becomes disturbed near Whyalla and Port Augusta, presumably because of the proximity of the southern Flinders Ranges close to the eastern shore of Spencer Gulf.

All of the four rainfall maps referred to above have been compiled using rainfall data archived by the Australian Bureau of Meteorology in 1978 for stations with time-series extending over periods of 20 years or more.

Rainfall data for a few locations such as Port Lincoln have been recorded for over a century. However, no records are available for naturally vegetated areas prior to the wave of agricultural land clearance. Thus even though the plough brought significant changes in the surface temperature regime and albedo (akin to the reflectivity), as is obvious from the aerial view shown in Fig. 5, no direct evidence of the hydrologic consequences is available. Nevertheless, it is of interest that Colonel Light's brief inspection of the country around Port Lincoln (1839), left him unimpressed about potential water resources. Recent comparative measurements of precipitation over bush and farmland, extending over three years, are too brief to be conclusive, especially in the light of observed trends in

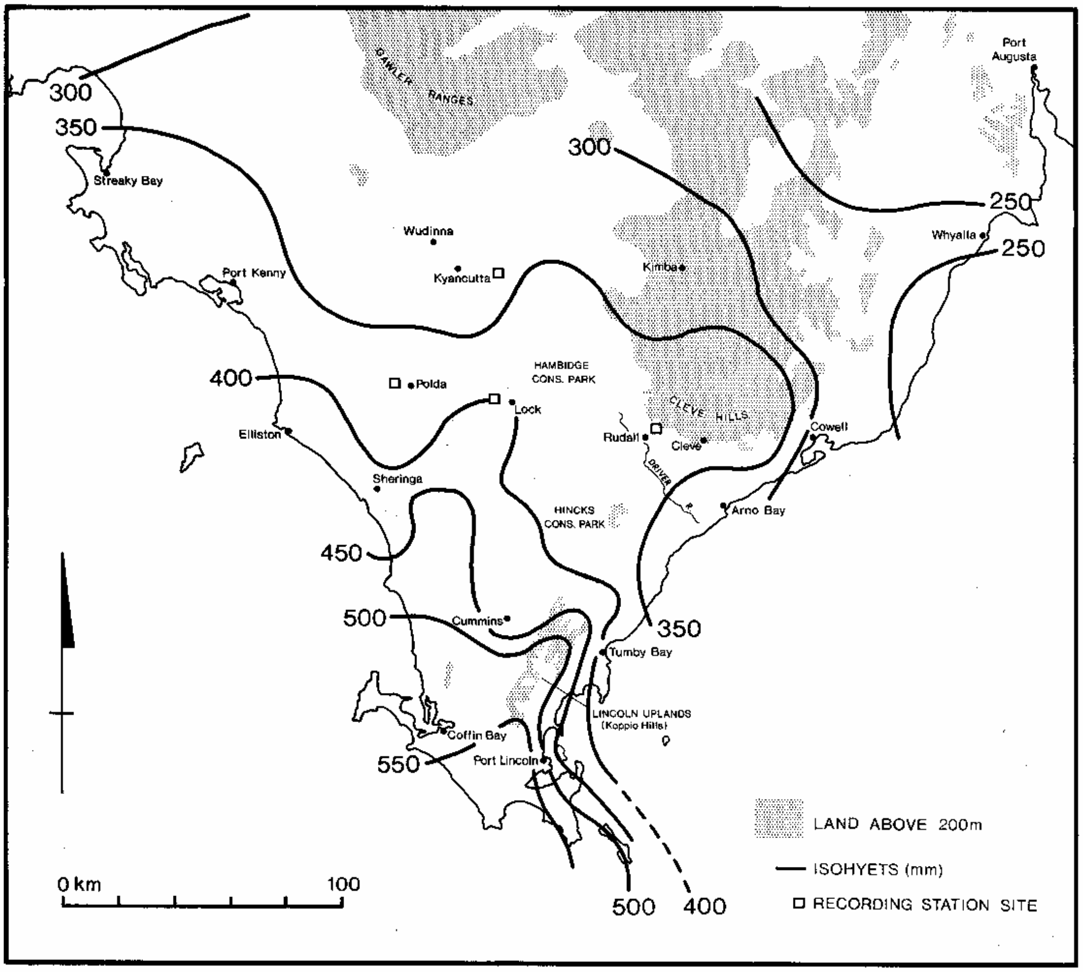


Fig. 1. Mean annual rainfall on Eyre Peninsula from Bureau of Meteorology data.

decadal means. For example, at Yeelanna, an area at about 34°S which has been substantially cleared for over 50 years, 30 years of rainfall records by V. Modra (pers. comm.) from about 1940, reveal increasing levels of total precipitation each successive decade! This more general climatic trend makes difficult the detection of rainfall changes which might be associated with large scale land clearance.

The magnitude of potential evaporation on the Peninsula everywhere exceeds the mean annual rainfall, a fact which emphasises the importance of the region's underground water resources.

RADIATION

Over the central portion of Eyre Peninsula, the mean solar irradiance ranges from approximately 85 Wm^{-2} (or 7.3 $MJm^{-2}d^{-1}$) ± 50% in winter to 310 Wm^{-2} (or 26.8 $MJm^{-2}d^{-1}$) ± 22% in summer[1]: values comparable to those on the Adelaide Plains. The relatively large uncertainties result from varying levels of cloudiness and, to a lesser extent, atmospheric turbidity.

As seen in Fig. 6, the agricultural and natural bushland areas on the Peninsula show a great contrast in albedos. Measurements over several years and seasons have revealed a remarkable constancy of albedo for bushland sites, where observations were made with pyranometers (visible wave-length radiometers) mounted on 7 m towers approximately 4 m above most of the canopy. At two sites, in Hincks Conservation Park and an area of regenerated mallee near Rudall, the albedo was found to lie consistently within the

([1] Wm^{-2} = watts/m^2; MJm^{-2} = megajoules/m^2/day)

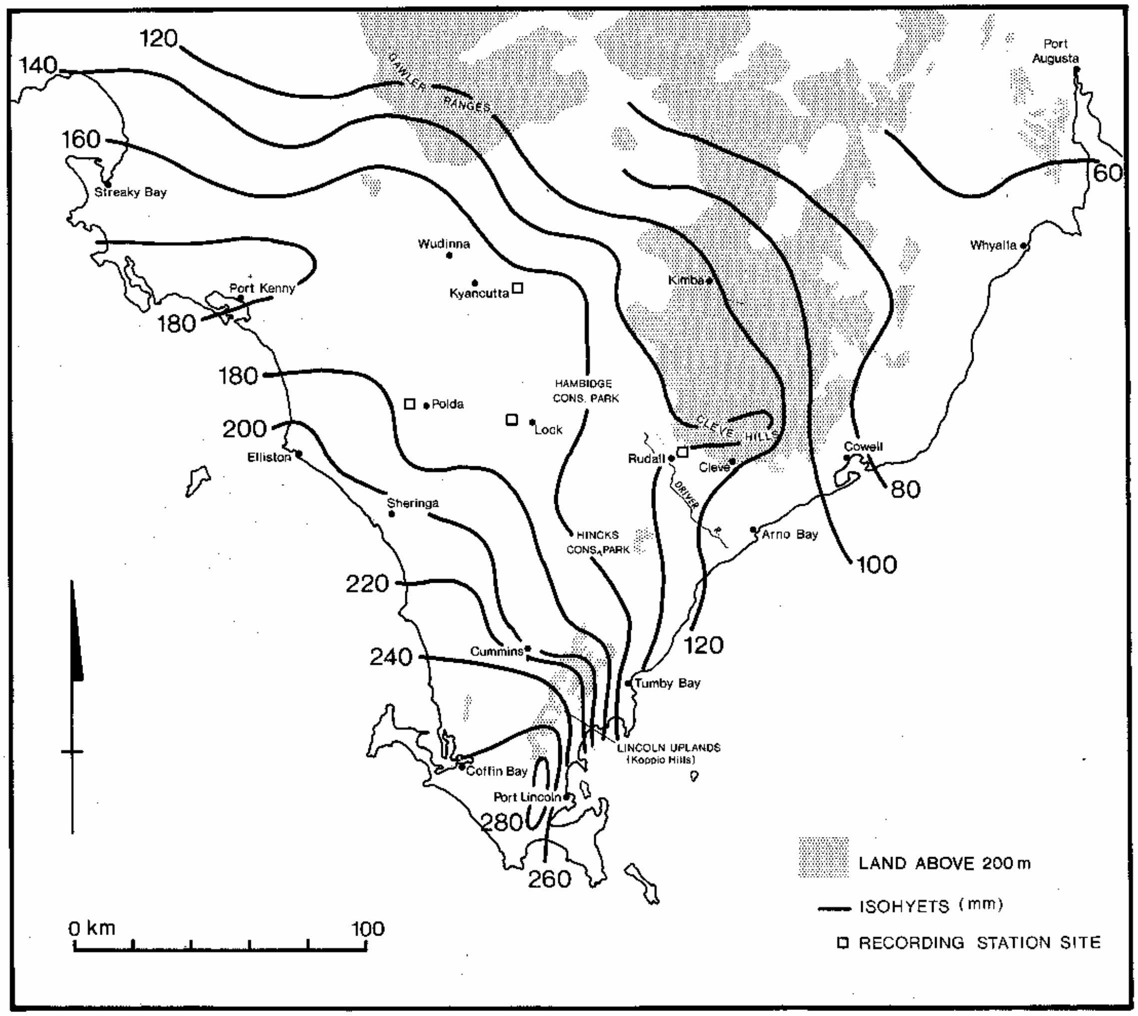


Fig. 2. Mean winter rainfall on Eyre Peninsula from Bureau of Meteorology data.

limits of 11.2±O.5%. The albedo measured over grassland or pasture at Rudall during the summer, was found to be 22.5±1.0%, decreasing to about 18% during autumn, while the mallee albedo remained essentially unchanged.

During the annual period of lowest solar irradiance, the albedo contrast between agricultural and wooded areas also decreases, because of welter, darker soils and the growth of new, green vegetation which is less reflective than dry pasture. These effects combine to minimise meso- and micro-climatic differences in winter, even though the effects of the wind regime remain to be considered. Nevertheless, it is to be expected that during summer the meteorological consequences of land clearance may best be observed. Fig. 6 shows typical diurnal regimes for the principal radiative fluxes for both grassland and mallee bushland during a clear, early February day near Rudall. Because the two sites were less than 2 km apart, the differences in the recorded values for the two sets of solar irradiance values, S_i, are almost certainly instrumental in origin, most probably in timing, since Table 1 reveals the daily totals at the sites to differ only by 1%. The graphical representation of Fig. 6 serves to emphasize the fact that although the albedo changes by almost exactly a factor of two from one location to the other, the net solar irradiance, S_i, is a far more important term in that it has a major influence on the net (all-wave) radiation, R_N. Both of these net radiative quantities vary far less dramatically between forest and farmland than the visual impact of their respective albedos. Nevertheless, the daily total net radiation over grassland-pasture

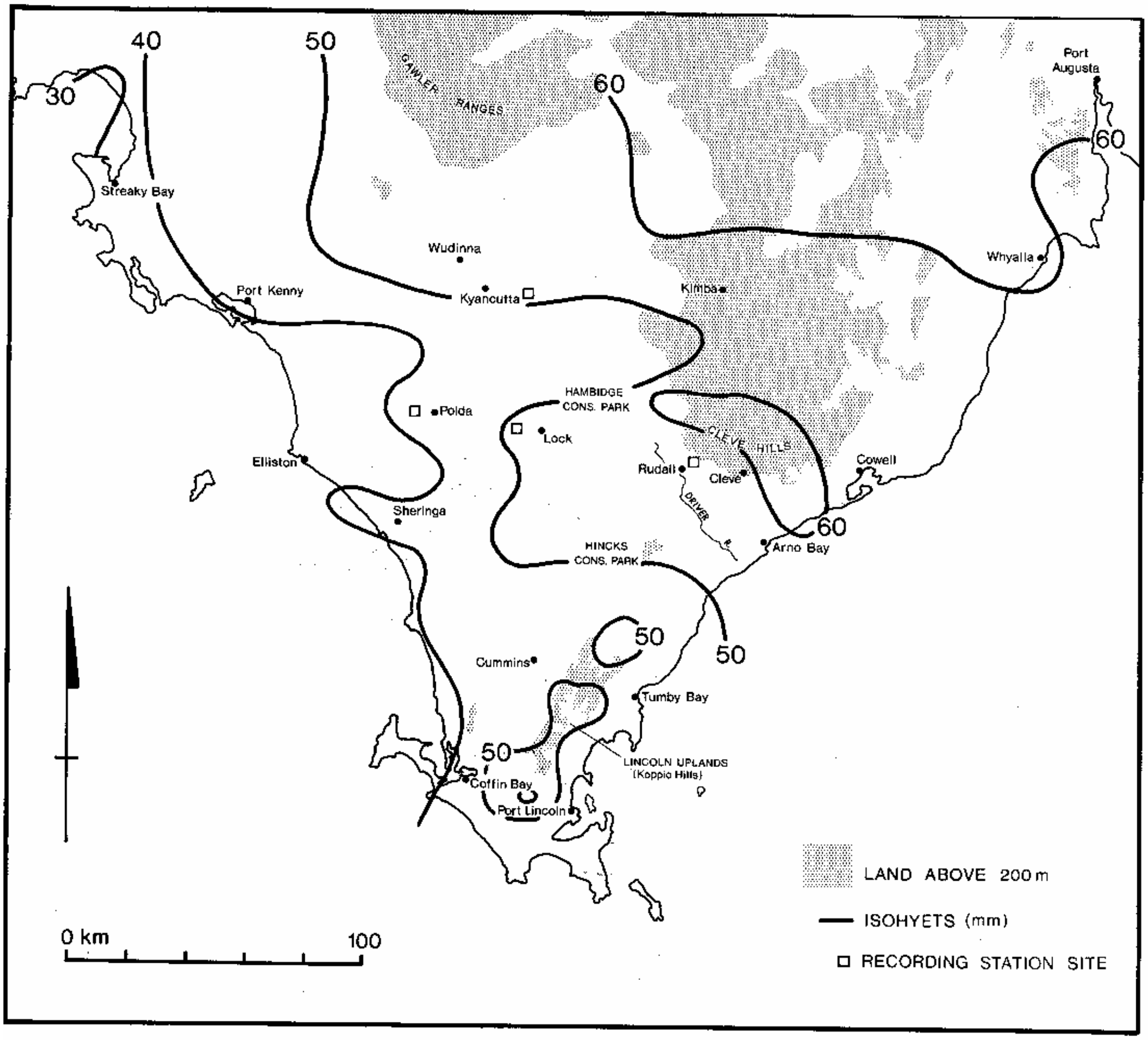


Fig. 3. Mean summer rainfall on Eyre Peninsula from Bureau of Meteorology data.

is only 82% of that over the mallee forest (Table 1). Again, the difference between the two locations is amplified during the period of greatest irradiance, and at midday during the summer the net radiation over short grass is barely 79% of that over the mallee canopy.

Micro-meteorologically, the deforested surface is thus significantly more energetic than cleared land. Comparative measurements have revealed that the deeper rooted mallee enables its leaves to continue to evaporate water long after the shallower root systems of grasses have been cut off from soil moisture during the dry seasons of the year. However, summer conditions tend to be so dry that, during this period of maximum net radiation, evaporative energy fluxes are always less than (and often small when compared to) sensible heating of the air, even above the mallee canopy. It is thus reasonable to expect convective activity to be measureably greater over bushland than agricultural areas.

TEMPERATURE

The typifying temperature regimes may be divided into those which are directly influenced by the sea, and those responding to the thermal properties of large areas of adjacent land. Although the presence and nature of the vegetation which may cover the latter control further differences, these are not normally as striking as the contrast between land and sea.

To illustrate the ameliorating effects of the sea, graphical diagrams have been constructed, from Bureau of Meteorology data. Fig. 7 provides a plot of Port Lincoln and Kyancutta mean monthly maximum as well as minimum temperatures. It clearly shows the contrast between maritime and

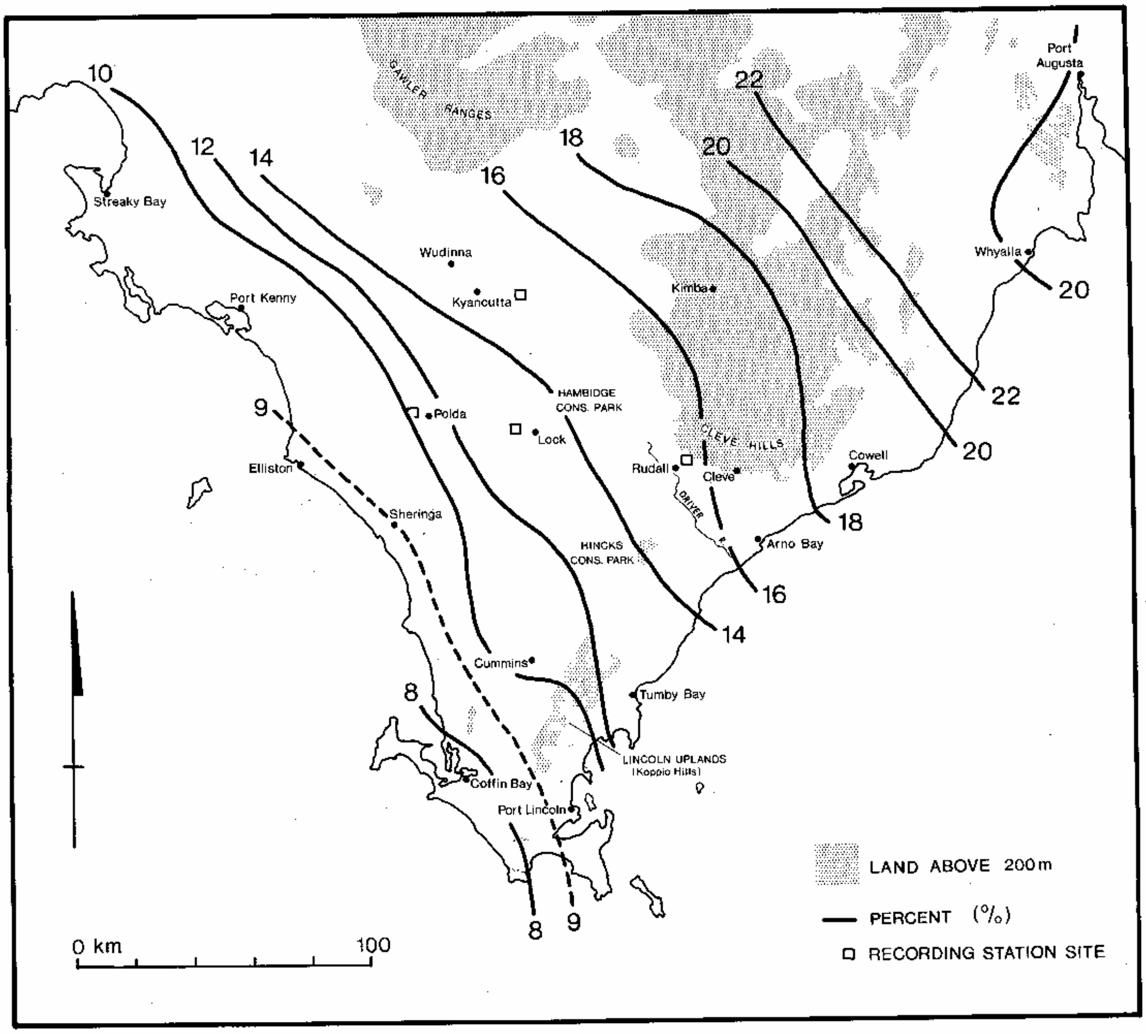


Fig. 4. Summer rainfall on Eyre Peninsula as a percentage of total annual rainfall: from Bureau of Meteorology data.

continental sites. The 1.5° of latitude separating the two stations does not mask the essential phenomenon. As might be expected, the maximum temperatures are greater at Kyancutta throughout the year, although the difference is only 1°C in mid-winter. By January, however, this difference steadily increases to almost 9^0C. Within one degree or less, this seasonal dependence of the difference between both maximum and minimum temperatures can be described by a linear relationship. The thermally inertial effect of the sea also ensures that minimum temperatures at Port Lincoln are higher than at Kyancutta, except marginally in January. Consequently amplitudes of mean monthly temperature excursions are far less at the maritime location. This effect is further illustrated by the fact that the seasonal variation of monthly means is 8.goC at Port Lincoln and 15.7°C at Kyancutta.

The degree of maritime influence over the prevailing temperature regime depends on winds at each site as well as proximity to the sea. By virtue of their geographical positions, stations such as Port Lincoln and Coffin Bay are exposed to almost island-like conditions except when subjected to northerly winds. The plot of Port Lincoln and Streaky Bay temperatures in Fig. 8 helps emphasize this point. The afternoon and evening sea breezes in summer and the westerlies in winter experienced at Streaky Bay, ensure that monthly mean minimum temperatures always are within one degree of each other at both locations. The annual mean minima are almost identical. The same is true of the mean monthly maxima during winter, when westerly winds from over the ocean generally prevail throughout the day. With the approach of summer months, this situation steadily changes, with Streaky Bay

Fig. 5. Aerial view over Hambridge Conservation Park and the adjacent agricultural lands toward Darke Peak. Sandridges, which have been subjected to varying stages of clearance are clearly evident.

being subjected to the heating effect of many more overland winds, particularly easterlies, than Port Lincoln, where the winds even from this direction, are cooled during their trajectory over Spencer Gulf.

The role of vegetation in determining various aspects of the thermal regime is a relatively complex one. For locations having soils of identical thermal admittance and exposed to equal insolation, local air temperatures and their vertical profiles may nevertheless vary greatly, as they are dependent on the height and density of the vegetational canopy as well as the magnitude of the evaporative latent heat flux. During summer, when higher levels of irradiance might be expected to amplify local differences, F. Chen (pers. comm.) has shown that latent heat fluxes are extremely low when compared to the other energy fluxes making up the surface energy balance for mallee bushland (Fig. 9). The consequence is a relatively high sensible heat flux. With lower levels of net radiation over grassland, the sensible heat flux will also be lower because the latent heat flux in both cases is so small.

The conclusion that the mallee surface is thermally more active than the grass, is supported by simultaneous measurements of air temperatures at about 1.7 m above ground level made by Shepherd (1985) and summarized in Table 2. Throughout the year at all times of the day, the wooded area is warmer as a result of both the lower albedo of the mallee canopy, and the fact

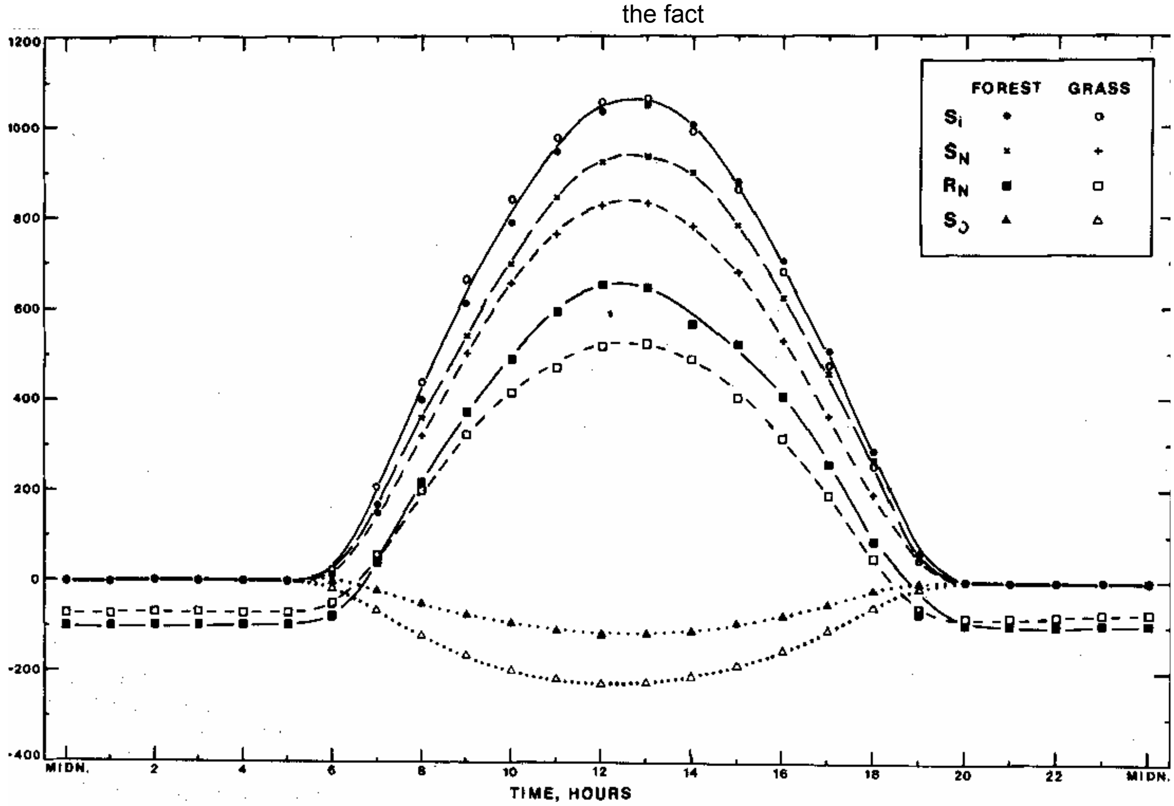


Fig. 6. The solar irradiance S_i, net solar radiant flux S_N and reflected radiant flux S_0, together with the net radiation (solar and infra-red) R_N are shown for adjacent mallee forest and grassland-pasture areas during mid-summer.

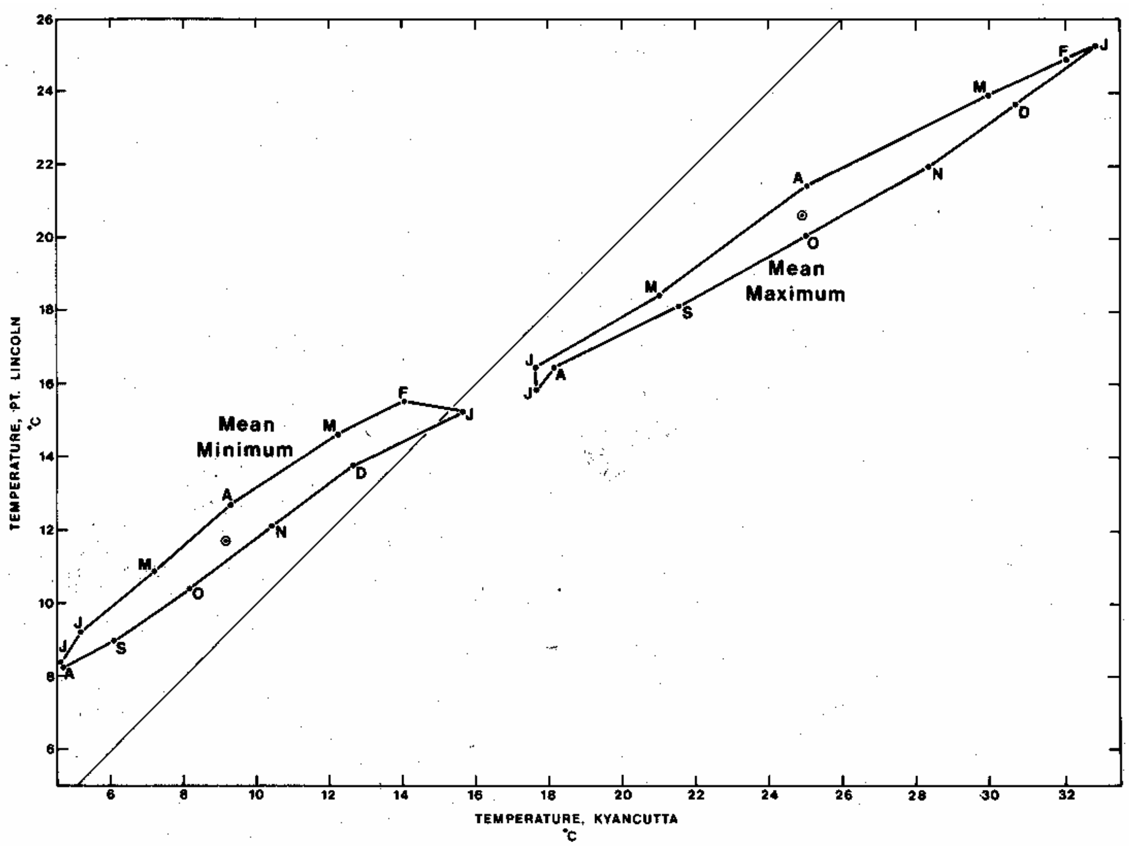


Fig. 7. Mean monthly maximum and minimum temperature relationships between Port Lincoln and Kyancutta.

Table 1. RADIATIVE CONTRASTS BETWEEN PASTURE AND MALLEE IN EARLY FEBRUARY.

Daily Total MJm^{-2}	S_i	S_o	$\beta = S_o/S_i$	$S_N = S_i - S_o$	R_N
Pasture Grassland	30.9	7.0	22.6%	23.9	11.2
Mallee Bushland	30.6	3.3	10.8%	27.3	13.7
Ratio Grass/Bush	101%	212%	210%	88%	82%

S_i: irradiance or incident short-wave radiation
S_o: reflected or outward short-wave radiation
β: short-wave albedo
S_N: net short-wave radiation
R_N: net radiation (short- and long-wave).

that the latter's open structure makes it a relatively efficient radiation trap.

High wind speeds result in smaller temperature differences between the two environments, because of the increased opportunities for thermal energy transfer; the mean values listed in Table 2 might be regarded as being typical for winds in the range 10-20 km h^{-1}. For winds of 0-10 km h -1 the maxima differ further by approximately 20%, while for stronger winds of 20-30 km h -1, the difference is diminished by about 40%. It can be concluded that the progressive deforestation of the Eyre Peninsula, in leading to generally windier conditions, results in the continual further erosion of the potential thermal activity of the remaining tree cover. While Bryson & Murray (1977) have inferred serious meteorological consequences of historically documented parallels of extensive vegetational denudation on the Indian sub-continent, other

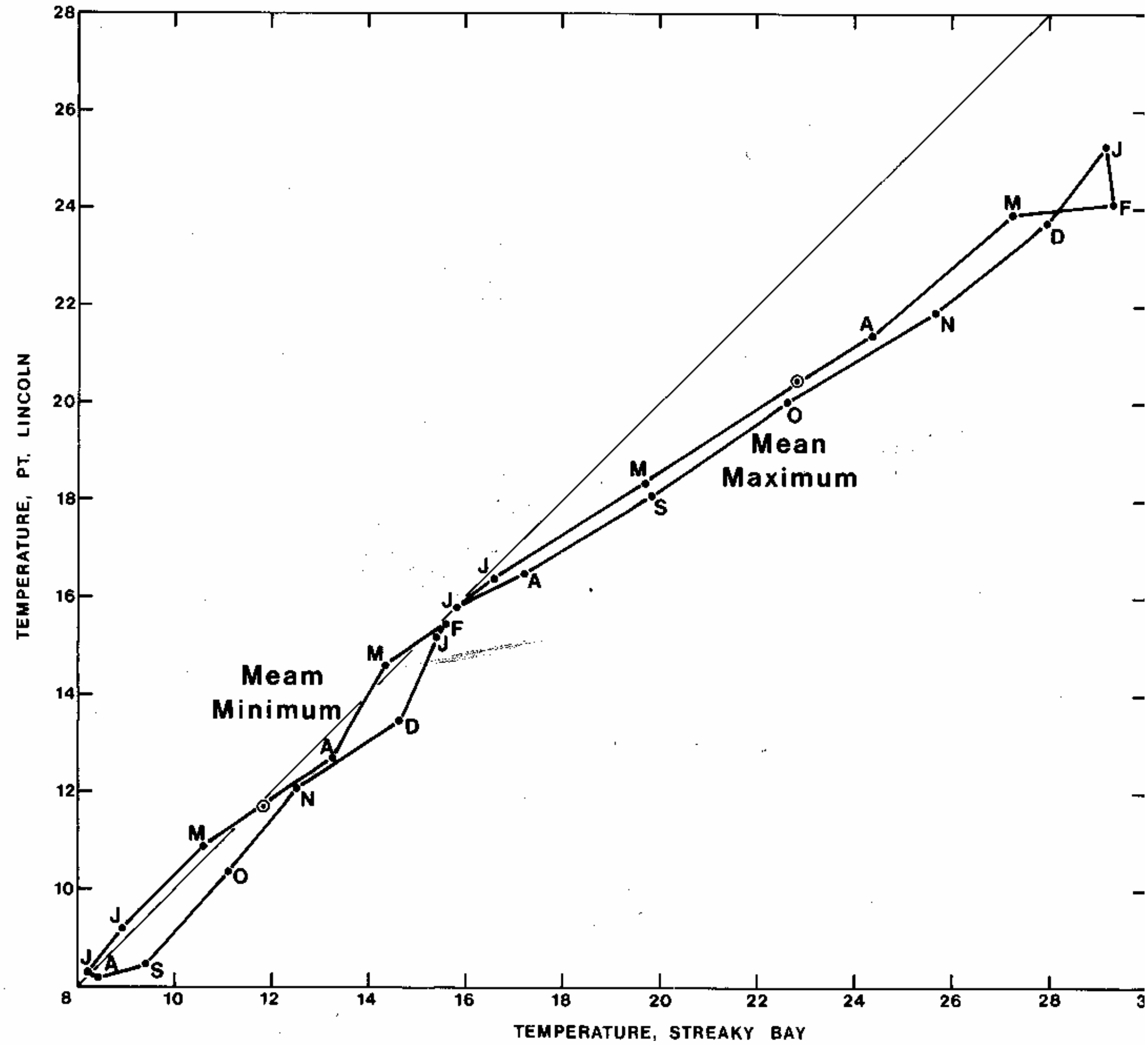


Fig. 8. Mean monthly maximum and minimum temperature relationships between Port Lincoln and Streaky Bay

Table 2. MEAN DIFFERENCES T°C, BETWEEN MAXIMUM (AND MINIMUM) MEAN TEMPERATURES O MALLEE AND GRASSLAND ENVIRONMENTS.

Period	Maximum Range of T	T	Minimum Range of T	T
Feb.-March	19-39°C	2.2°C	9-21°C	1.5°(
March-April	19-38	1.7	7-21	1.8
May-June	14-23	0.7	1-12	0.7
July-Aug.	9-22	0.5	2-9	0.7
Sept.-Oct.	15-35	1.1	1-15	0.4

authors including Wendler & Eaton (1983) and Melice & Wendler (1984) in their investigations concerning the desertification of the Sahel are more cautious. On the Eyre Peninsula, more micro-meteorological data are required over bare soils characteristic of drought conditions, to complement the work undertaken over grass and bushland.

WINDS

The gently rolling plains of the Eyre Peninsula, without substantial topographic relief and now largely deforested, are relatively unprotected from winds from all directions in all seasons. A major factor influencing the climatological regime of the region is the seasonal migration of the

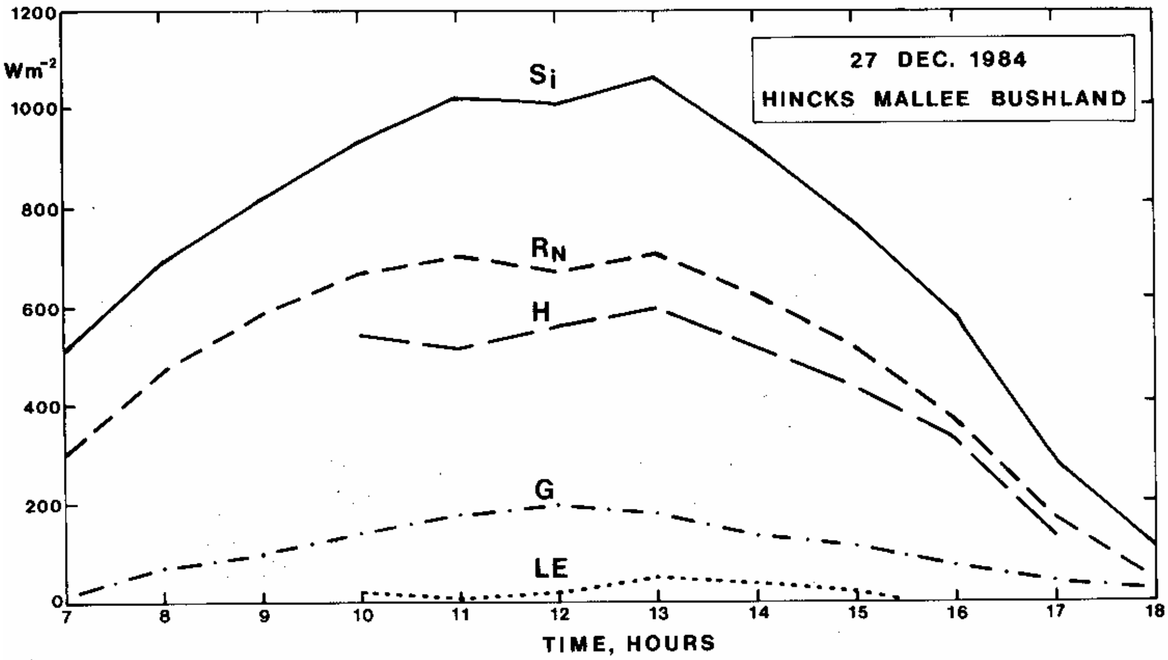


Fig. 9. Micro-meteorological energy fluxes over mallee bushland in Hincks Conservation Park in summer, as measured by Chen (1985) where the S_i is the solar irradiance, R_N the net radiation, H the sensible flux of heat into the atmosphere (convective and turbulent), G is the heat conducted into the ground and LE is latent heat flux associated with evapo-transpiration.

sub-tropical high pressure belt, whose cells constitute a broad subsidence zone varying front about 37°S in summer to 29°S in winter. Thermal contrasts between land and sea affect the longitudinal distribution of these cells and, from December to March, two of the 'preferred' locations are over the Great Australian Bight and the Tasman Sea. The anticyclones centred in these areas lead to southeasterly airstreams over Eyre Peninsula. During winter these anticyclones tend to be located over the central and eastern regions of the Australian continent, with a consequent dominant northwesterly air stream over the Peninsula which allows the mid-latitudinal cyclones to influence the hibernal climate of the southern coastal regions.

The distribution of gradient winds, with directions ascertained from sealevel isobaric charts and recorded speeds averaged over the early morning (approximately at 0900 h, before the possible onset of sea-breezes) at Lock, Kyancutta and Rudall, has been analysed by Shepherd (1985). The results for the two-year period November 1979-1981 are summarized in Fig. 10 and provide the synoptic background on which more localized phenomena caused by topography and land sea contrasts are superimposed.

Records obtained near Polda, Lock, Kyancutta and Rudall also enabled Shepherd (1985) to observe that deviations of 3 metre level winds from the directions of gradient winds are of similar magnitude at all four locations. Variations between the stations can be ascribed to the nature of the pressure gradient across the region, or to the effects of local topography.

Wind directions at the Rudall site are more influenced by topographic features than those at the other three stations, primarily because of the Driver River valley, which offers a wide northwesterly to southeasterly aligned gap through low ranges, thereby connecting the inner region of the Eyre Peninsula to the east coast. The Cleve Hills and southern Gawler Ranges were also found to influence some of the wind directions experienced at the Kyancutta station (about 15 km east of the township). The Polda basin station, sited in an extensive, shallow valley approximately 10 km west of the Polda wells, is shielded from the full force of the winds from all directions, which at the 3 metre level are found to have speeds of 60-70% of those recorded at the other stations. This latter observation emphasizes the importance of the exposure when considering the effect of the wind near the ground at any given location.

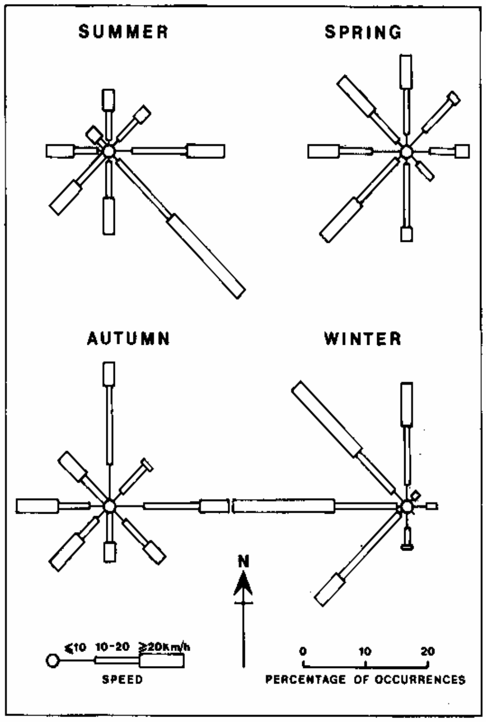


Fig. 10. Directional roses with classified speed groupings for gradient winds (whose main features are determined by the direction and density of isobars) shown for the central Eyre Peninsula as determined by Shepherd (1985).

Sea breezes reach most parts of the Eyre Peninsula on many days during summer, when their presence has a great ameliorating influence on air temperatures. These breezes are normally expected at coastal locations backed by extensive land areas, so that they are observed frequently as south-easterlies at Arno Bay, and as southwesterlies at Sheringa and Elliston. The inland penetration of these essentially separate systems 'is of considerable interest, and the passage of the southeasterly sea-breeze front through Cleve and Rudall is not unexpected, as is the arrival of the southwesterly front in Polda. More remarkable is the intersection and subsequent interaction of the two systems. Shepherd (1985) has recorded the times of arrival of the separate fronts at various locations (Fig. 11), showing the mean isochrones of sea-breeze fronts advancing across the central Peninsula from both coasts. Shepherd also found that at least one of the sea-breeze systems is observed on an average of about 14 days per month over a 6-month period extending from November to April and, furthermore, that on half of these occasions, both the southeasterly and southwesterly breezes blow, although not necessarily over their whole potential trajectory.

Southwesterly breezes are more likelY than southeasterlies on those days when only one of the two systems is observed. The development of sea breezes also is markedly dependent on the direction of the gradient wind, with more than 85% of the cases occurring on days with gradient winds blowing from a 180^0 sector centred on the east, with 65% being in the southeast to northeast range.

Observations of the wind directions over a transection of the Peninsula on a number of days during which both the southeasterly and southwesterly sea breezes were recorded have been reported by Shepherd (1985). Fig. 12 shows the results of such observations which were conducted sequentially. The supposition that wind directions were relatively stable during the period of measurement was checked from anemograph records obtained at the four fixed recording stations, including that near Kyancutta.

There have been other studies of coastal winds on the Eyre Peninsula for locations which include Whyalla (Schwerdtfeger & Williams 1975) and Port Augusta (Stark 1977). These reveal early morning local sea breezes at Whyalla being modified during the course of the day so that, by afternoon, their directions develop a strong southerly component and become almost identical to those prevailing at Port Augusta. This indicates that a larger scale oceanic-continental exchange develops during the course of the day. . This phenomenon also accounts for the direction of the sea breeze observed at Kyancutta, but it does not dominate the coastal wind regime in the south as it does in the more continental north.

A discussion of winds over the now substantially treeless expanses of the Eyre Peninsula would not be complete without reference to the influence of near surface aerodynamic roughness elements (or the lack of them) on the vertical profiles of horizontal winds near the ground. Because of the wide open expanses of the Peninsula, even low vegetation makes a significant contribution to the reduction of wind speeds near the ground. A useful estimate of this effect can be obtained by applying the logarithmic wind profile equation to the relatively simple cases of closely grazed pastures and 1 m high grassland or cereal paddocks. The result suggests that wind speeds at a height of 2 m may be up to 40% higher in the former case. Thus there can be no doubt that large scale land clearance has had an important influence on the 'living space' near the ground, and that injudicious clearance frequently will result in unacceptable stresses being suffered

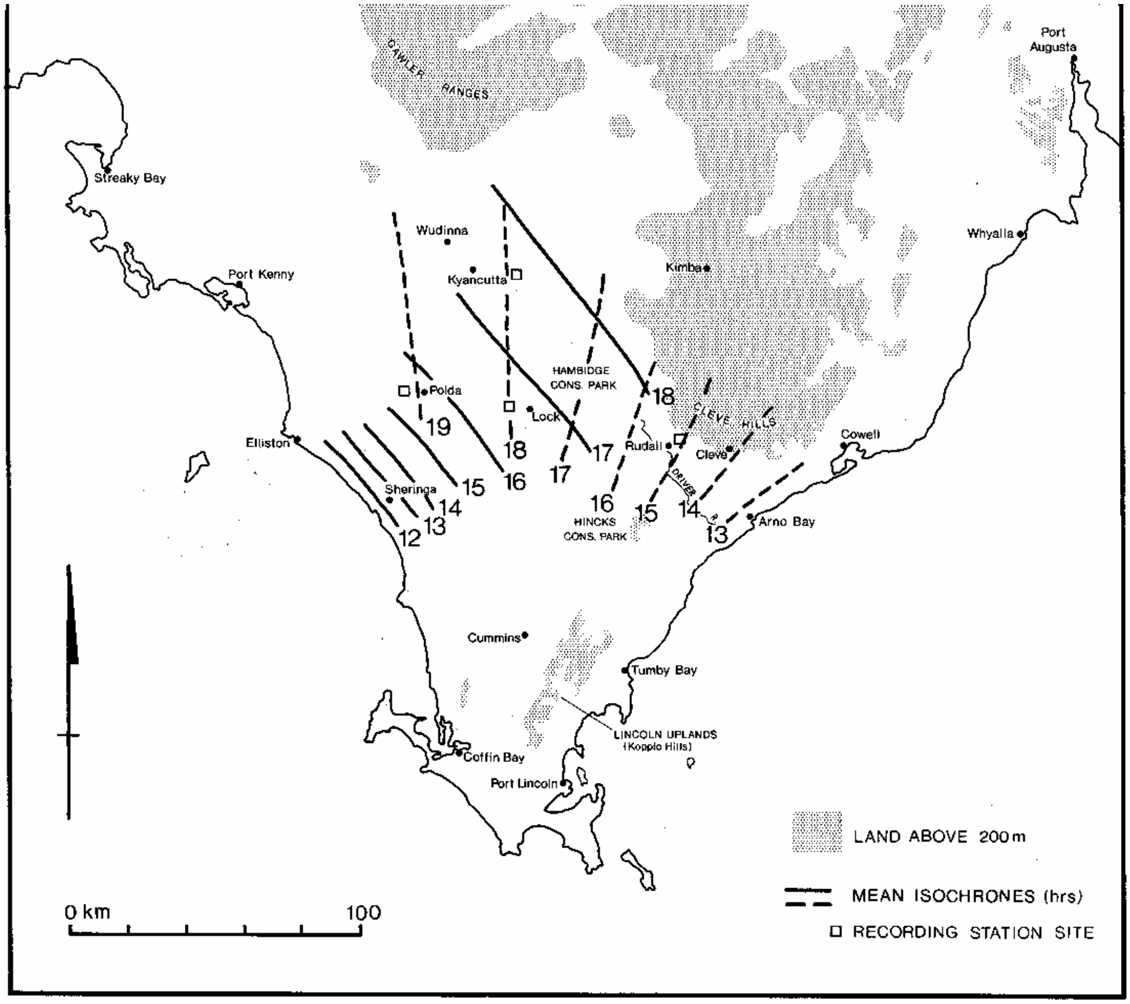


Fig. 11. **The mean arrival times (in C.D.S.T. hrs 24 hr clock) for the two sea-breeze systems which traverse the central Eyre Peninsula from the southwest and southeast respectively, as observed by Shepherd (1985).**

by the agricultural crops grown to replace the original bush. Peninsula as determined by Shepherd (1985). density of isobars) shown for the central Eyre

Every year, following harvesting and subsequent grazing by stock, the agricultural areas of the Peninsula become potentially vulnerable to erosive meteorological forces. Security of the agricultural terrain depends on an unreliable precipitation regime and the economic viability of those who farm the land. Assessment of the principal climatic parameters of the central and northern Eyre Peninsula leads to the conclusion that the country may reasonably be described as semi-arid. The current global experience is that this type of terrain deserves more care than has so far been demonstrated.

ACKNOWLEDGEMENTS

The task of describing a regional climate should not be undertaken lightly by a non resident. This contribution is based on repeated visits and observations which commenced in 1978 with a memorable flight over a drought-ravaged landscape with the late Capt. Nobby Buckley. Since then, some critics and many friends on the Eyre Peninsula have helped in the 'getting of local wisdom'. Without the practical assistance and interest shown by Mr and Mrs Sam Jericho of Rudall and the generosity of Mr Don Schultz of Adelaide, this project would have been impossible. Mrs Gail Jackson, Debbie Haggar and M. Foale kindly drew the diagrams

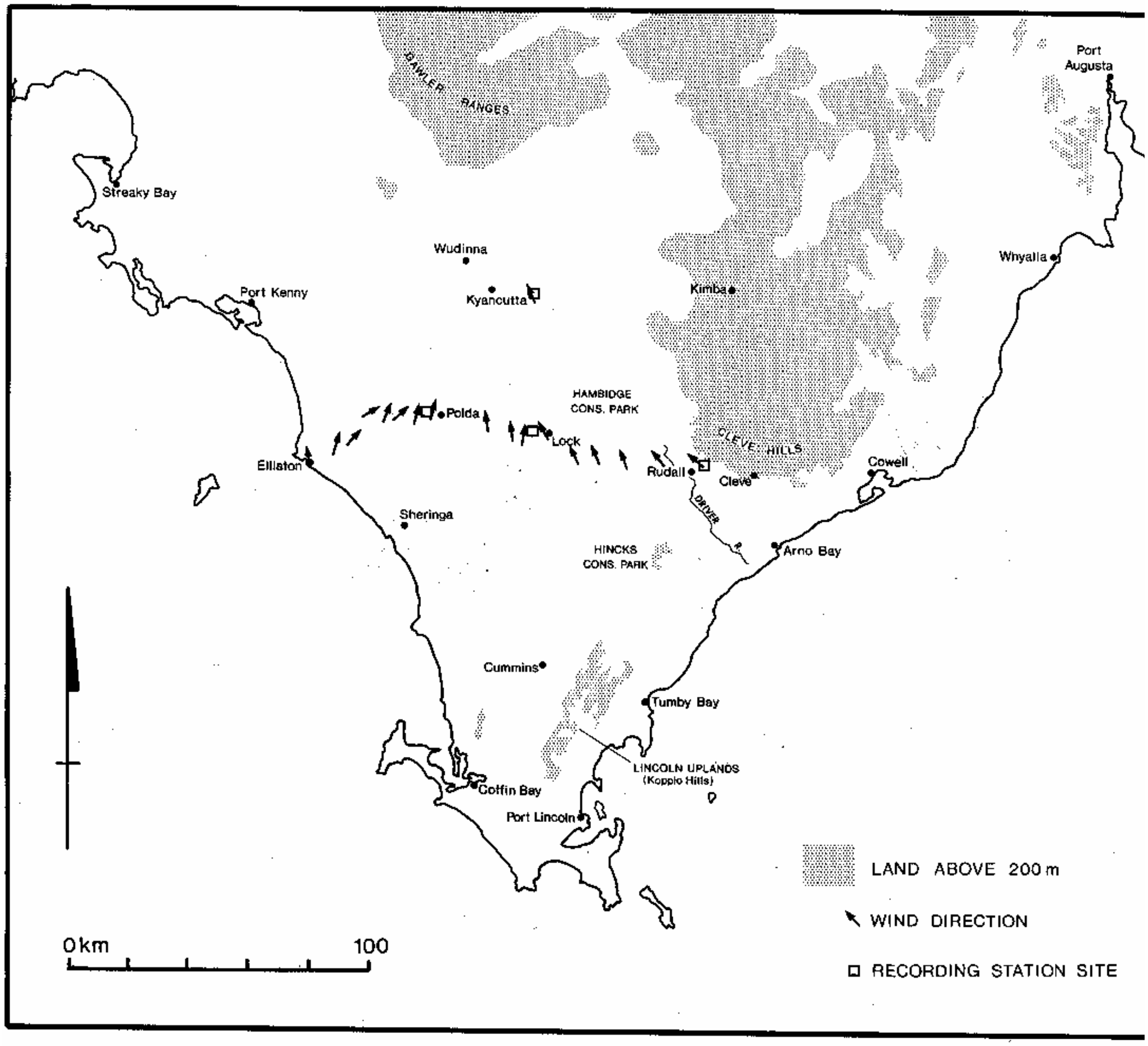


Fig. 12. Transection of stable sea-breeze directions obtained across the central Eyre Peninsula by Shepherd (1985)

REFERENCES

Bryson, R. A. & Murray, T. J. (1977). 'Climates of Hunger (Mankind and the World's changing weather)'. (University of Wisconsin Press, Wisconsin).

Bureau of Meteorology (1961). Climatological Survey, Region 11-Eyre, SA

Light, W. (1839). 'Brief Journal and Australian Diaries'. New edition (1984) with notes by David Elder (Wakefield Press, Adelaide).

Melice, J. L. & Wendler, G. (1984). Precipitation statistics in Southern Tunisia-a contribution to the desertification problem in the Sahel zone. *Arch. Met. Geoph. Bioclim.,* Ser. B. **33**, 331-348.

Schwerdtfeger, P. & Williams, S. (1975). Winds at Whyalla. *FIAM.S. Res. Rep.* No. 16.

Schwerdtfeger, P (1976). Climate *In* C. R. Twidale, M. J. Tyler and B. P Webb (Eds) 'Natural History of the Adelaide Region, (Royal Society of South Australia, Adelaide).

Shepherd, I. (1985). Flinders University M.Sc. thesis. Unpublished.

Stark, I. B. (1977). Winds at Port Augusta. *FIAM.S. Res. Rep.* No. 26.

Wendler, G. & Eaton, F. (1983). On the desertification of the Sahel zone. *Climatic Change* **5**, 365-380.

7: Hydrology

by R.G. SHEPHERD

INTRODUCTION

Following the first permanent white settlement on the peninsula at Port Lincoln in 1839, springs and streams were used for water supply. Later, particularly from 1880 to 1916, numerous dams were constructed by the Government as water conservation measures. The first larger scale system, which involved construction of three small reservoirs in the Cleve-Cowell area, was completed in 1912. The Tod River was discovered in March 1839 but work on a reservoir did not commence until 1918. In 1927 it was connected to Port Lincoln, and later to Ceduna and the earlier system near Cowell. However, by 1935 supply from the Tod Reservoir was causing concern, as intakes were below expectations.

Little use had been made of groundwater, except for stock and domestic purposes. Detailed investigations commenced in 1932 in the Robinson Basin near Streaky Bay (Fig. 1) and in the Uley Wanilla Basin, east of Coffin Bay, in 1935. Some investigations commenced in the Lincoln Basin in 1939 but a continuous program of drilling was delayed until 1956, and the basin was connected to the distribution system in 1962. In 1959 work commenced in the Uley South Basin, and pumping started in 1976.

In the Polda Basin between Lock and Elliston there were intermittent investigations from 1915, and particularly from 1928 to 1937 (Ward 1946). Investigations recommenced in 1962 and the basin was connected to the trunk main in that year. Groundwater now provides the greater part of the water supplies, rising in some years to 90%.

SURFACE WATER

The few streams are ephemeral, and most are saline or brackish during normal flow. The Tod River, near Port Lincoln, has a catchment area of 395 km^2 and is the largest; minor streams include Salt Creek and Driver River in the area north of Arno Bay.

Land clearing has increased salinity of surface water as shown by the Tod Reservoir. Natural vegetation now occupies only 20% of the catchment area and salinity of the reservoir has increased at an average annual rate of 13 milligrams/litre *(mg/L)* since 1930. Average salinity of the reservoir now exceeds 2000 *mg/L*. Valley salting is a problem in other catchments which have been cleared.

GROUNDWATER

Groundwater occurs in three geological environments which are of Precambrian, Tertiary and Quaternary ages (Shepherd 1978). The most important of these is Bridgewater Formation (Quaternary) which will be considered in greater detail than the others.

The Precambrian rocks include gneiss, amphibolite, schist, quartzite and dolomite in addition to granite and related igneous rocks, the latter occurring at intervals across the peninsula from north of Cowell to Ceduna. Groundwater occurring in the gneisses and other metamorphic rocks is generally of high salinity (Jack 1914). Water suitable for stock is known to occur mainly in favourable rock types in an area of higher rainfall near Port Lincoln. Within this area a few wells yield water suitable for pasture irrigation but quantities available are relatively small.

The granites and related rocks are not aquifers but, because they are almost impervious, run off occurs rapidly and may result in shallow, low salinity groundwater. Sediments of Mesozoic age occur in the Polda trough inland from Elliston, but apparently contain only salt water and are not considered in the groundwater resources. Tertiary sediments, mainly.sand, silt and clay, lignitic in part, are widespread. They occur mainly beneath the central plains north from Coffin Bay and within bedrock depressions in the northern part of the Peninsula (Johns 1961).

In addition these sediments occur commonly beneath younger formations near the south and west coast, particularly in the Lincoln, Uley South and Polda Basins. Salinity generally is high within the sand aquifers because of restricted recharge. Best known quality is 550 *mg/L* in a test well in

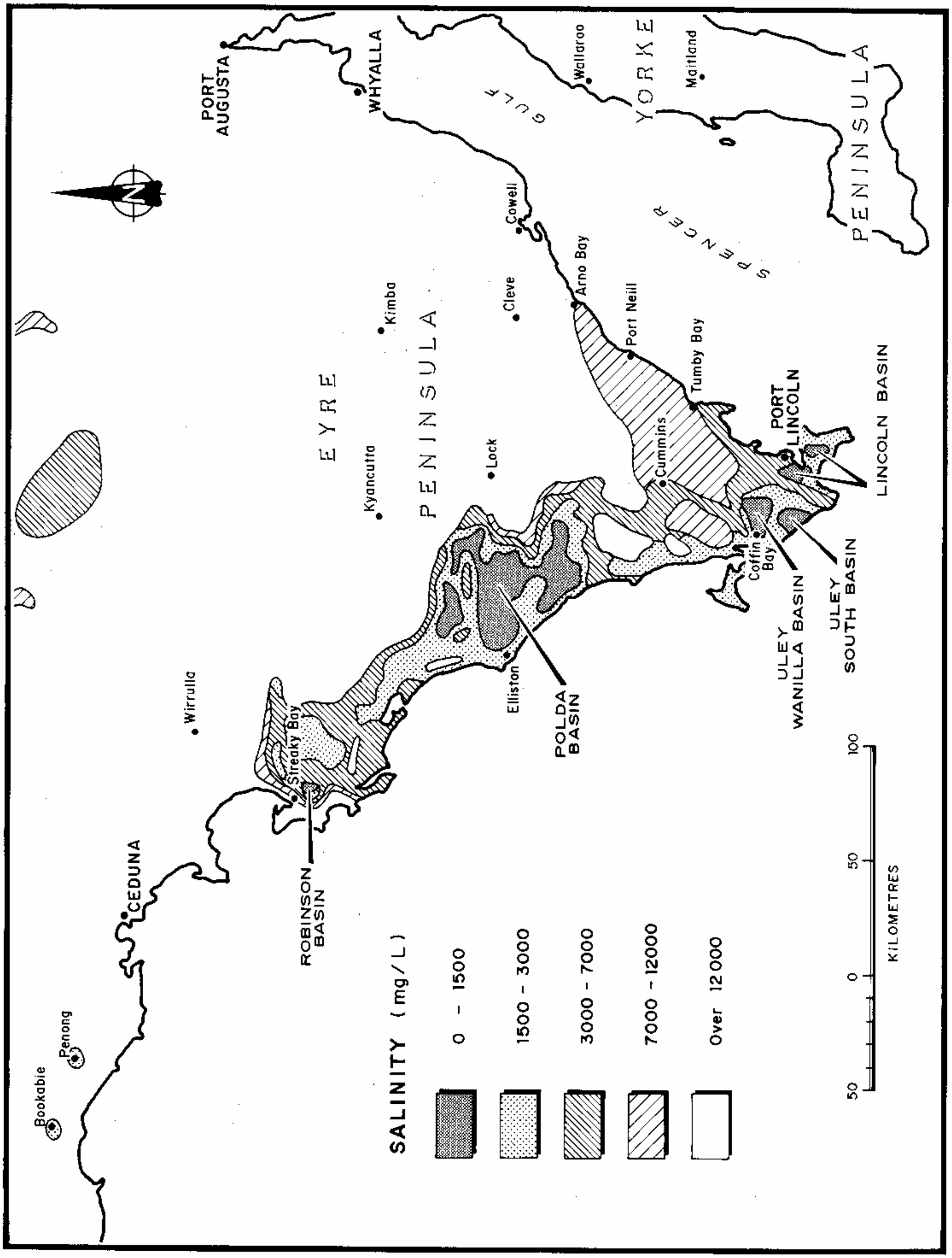


Fig. 1. Groundwater salinity.

Uley South Basin which also yielded 35 L/sec during a test. However, this yield was exceptional.

Quaternary sediments include alluvium and Bridgewater Formation. The former consist of gravel, sand, silt, and clay derived from the breakdown of the Precambrian rocks and redeposition of Tertiary sediments. The sands or gravels may contain useful supplies of stock water in those places where recharge can occur readily. The Bridgewater Formation consists of partly cemented calcareous sand usually calcreted at the surface. It extends from south of Port Lincoln along the west coast to beyond Streaky Bay and is an excellent aquifer. Generally salinity is less than 3000 mg/L and there are significant areas with salinity less than 1500 mg/L (Fig. 1).

A number of 'basins' have been distinguished on the basis of salinity less than 1500 mg/L. However, they are not basins in the geological sense. The southern basins-Lincoln, Uley South and Uley Wanilla are essentially similar hydrogeologically (Painter 1970). The Bridgewater Formation is relatively thick with a maximum of 130 m in the south, but saturated thickness is rarely more than 40 m. Recharge for all three basins is derived mainly from local rainfall with a component, probably minor, from underflow or surface flow. Groundwater flow is towards the sea and gradients are relatively flat, indicating sediments of high permeability.

For the Lincoln Basin salinities indicate that recharge from local rainfall is significantly greater than recharge resulting from overflow of Little Swamp at the northern end of the basin. High salinity groundwater occurs in a thick section of aquifer south of Proper Bay where standing water level is 1-2 m above sea level, but low salinity water may continue to 30 m below sea level, with salt water in the lower part of the aquifer. In other basins a salt/fresh interface has been detected at or near the coast in the Bridgewater Formation.

In the Polda Basin, the aquifer is much thinner (5-10 m) and rests on clay which is a confining bed above the underlying Tertiary aquifer, containing high salinity groundwater.

The Bridgewater Formation aquifer has a variable but generally high permeability as reflected in the pumping/drawdown relationship. In Uley South basin a well yielded 132 LIsee for a seven day test, the drawdown being only 2.5 metres. Salinity remained constant at 515 mg/L. Although this well was exceptional, some high yields, up to 55 Usee, were obtained elsewhere, particularly in the Polda Basin.

Various estimates of safe yield have been made for the main basins and some of these remain to be refined further. These estimates and

Basin	*Range of Estimated Safe Yields (Megalitres/Year)*	*Withdrawal 1982/83 (Megalitres)*
Uley-Wanilla	1 080- 4180	680
Uley South	3600-30000	6507
Lincoln	2230- 2400	354
Polda	14000-19000	967
Tod Reservoir	3 000 (including evaporation)	5115

withdrawal are included in Table 1.

Average evaporation of the Tod River Reservoir over a 21 year period has been estimated to be approximately 1300 ML/year. In the Lincoln Basin up to 2300 ML/year were pumped without significant lowering of water level. However, salinity increased by up coning, and in 1977 the pumping rate was reduced to 500 ML/year, and salinities have shown a slight decrease.

In the Robinson Basin the low salinity groundwater 'floats' on higher salinity water. The thickness of the low salinity zone is related to recharge and withdrawal. Special precautions, including concrete sumps placed beneath the pump intakes (Segnit & Dridan 1938) are necessary to prevent the rise of salt water during pumping.

North-west of Streaky Bay in the Penong-Bookabie area there are occasional small areas of low salinity groundwater, resulting from local recharge (Jack 1912). A good example is a large depression east of Penong where numerous wells tap good quality groundwater for use in the town. Salinity increases indicate that the safe yield may have been reached.

REFERENCES

Jack, R. L. (1912). The geology of portions of Counties Le Hunte, Robinson and Dufferin with special reference to underground water supplies (with maps). *Bull. geol. Surv.* S. *Aust.,* **1**.

Jack, R. L. (1914). The geology of the County of Jervois, and portions of the counties of Buxton and York, with special reference to underground water supplies (with maps). *Bull. geol. Surv.* S. *Aust.,* **3**.

Johns, R. K. (1961). Geology and mineral resources of Southern Eyre Peninsula (with maps). *Bull. geol. Surv.* S. *Aust.,* **38**.

Painter, J. A. C. (1970). Groundwater resources of Eyre Peninsula. *Mineral Resour. Rev.,* S. Aust. **129**, 123-127.

Segnit, R. W. & Dridan, J. R. (1938). Geology and development of groundwater in the Robinson Fresh

Water Basin, Eyre Peninsula (with map). *Bull. geo/. Surv.* S. *Aust., 17.*
Shepherd, R. G. (1978). Underground water resources of South Australia. *Bull. geo/. Surv.* S. *Aust.,* **48**.
Ward, L. K. (1946). The occurrence, composition, testing and utilization of underground water in South Australia, and the search for further supplies (with maps). *Bull. geol. Surv.* S. *Aust.,* **23**.

8: Native Vegetation

by R.T. LANGE and P.J. LANG

INTRODUCTION

The great botanical significance of the Eyre Peninsula region is obvious from the fact that 42% of the entire native flora of South Australia occurs there. Many fine examples of plant communities, particularly mallee which formerly clothed the now bare hinterlands, are in its conservation parks (see Chapter 17).

Knowledge of the flora and vegetation started to build up this century and there now is a substantial but scattered literature of maps, vegetation descriptions, floristic lists and pictures (reviewed at the end of this chapter). There are two other aspects of interest to botanically-minded visitors: the list of plants that are special there, and the diversity of vegetation types, and the transitions between them, that a passing motorist might detect.

SPECIAL EYRE PENINSULA PLANTS

Approximately l260 species of plants make up the native flora of the Eyre Peninsula region, as listed by Jessop (1983). Of that total 47 are noteworthy because either they occur nowhere else, or alternatively nowhere else in South Australia. Table 1 lists them accordingly; 29 are strictly endemic and the remainder are shared interstate, all 18 in Western Australia but only three in the eastern states. That reflects the considerable influence of Western Australian flora on that of Eyre Peninsula. There is space here to comment on a few examples of these special plants.

Haeckeria cassiniaeformis (Compositae) and *Commersonia tatei* (Sterculiaceae) are examples of shrubs unique to Eyre Peninsula but widely scattered and uncommon. The first resembles *Cassinia,* a common shrub of rocky outcrops, and the second is a small, slender shrub with crenate lobed leaves.

In contrast *Veronica parnkalliana* (Scrophulariaceae), a native speedwell also unique to Eyre Peninsula, was extremely restricted in its distribution there. It is known only from two collections made in 1909, namely the type collection near Port Lincoln and the other from nearby Warunda. It was a small herb with stems 20-40 cm long and small flowers of unrecorded colour, in racemes. It has probably been rendered extinct by extensive agricultural clearing (Leigh, Boden & Briggs 1984), which is a common fate of native plants in areas of better soils and rainfalls.

Another interesting endemic is the raspwort *Haloragis eyreana* (Haloragaceae), a perennial herb 10-30 cm tall from an underground rhizome and peculiar for flowering but reproducing only vegetatively. The flowers are sterile. This species is confined to a few square km between Cummins and Butler Tanks and recently still could be found on disturbed roadsides. Orchard (1980) suggests that it may have evolved from a more common *Haloragis* of the Mt Lofty Ranges.

Two Western Australian genera represented on Eyre Peninsula are *Darwinia* and *Verticordia* (Myrtaceae). *D. homoranthoides* is endemic to the southern peninsula, *V. wilhelmii* extends also to Yorke Peninsula and westwards. In the same family are *E. leucoxylon* ssp. *petiolaris* (SA bluegum) setting the western most extension of the species (Boland 1979) and *E. flocktoniae,* an eastern outlier of main distribution in southwestern Western Australia.

The bluegum subspecies has been isolated long enough to have evolved several distinctive features. The seedling and juvenile leaves are stalked, the fruits are large and bell-shaped and the flowers are more frequently coloured. The *E. flocktoniae* population isolated in southern Eyre Peninsula on lateritic soils is mallee-form although the West Australian specimens are usually single trunked. There are also northern distributions on Eyre Peninsula where the species tends to merge with *E. socialis,* from which it is distinguished by glossy green versus matt grey-green foliage and urn-shaped rather than globular fruits.

Another outlier from West Australian flora is *Anthocercis anisantha* spp. *anisantha* (Solonaceae), a spiny, intricate shrub on southern Eyre Peninsula with nearly leafless zigzag branch lets. The alternative subspecies *collina* is a South Australian endemic in the Gawler Ranges,

Table 1. PLANTS WITH DISTRIBUTIONS IN SOUTH AUSTRALIA CONFINED TO THE EYRE PENINSULA REGION

	WA	Gawler Ranges	Western Eyre Peninsula	Eastern Eyre Peninsula	Southern Eyre Peninsula	*Eastern Australia
Acacia gillii					+	
Acacia imbricata					+	
Acacia sp.nov. (aft. A. *rhigiophylla)*				+		
Acacia sp.nov. (aft A *steedmannil)*				+		
Adriana quadripartita	+	+				+
Anthocercis anisantha ssp. *nisantha*	+				+	
Brachycome breviscapis			+			
Brachycome xanthocarpa				+		
Commersonia tatei		+	+	+	+	
Cryptandra amara var. *floribunda*	+		+	+		+
Darwinia homoranthoides					+	
Davesia asperula ssp. *obliqua*				(+)	+	
Embadium uncinatum		+	+			
Eremophila interstans var. *interstans*	+	+				
Eremophila barbata				+		
Eucalytpus flocktoniae	+			(+)	+	
Eucalpytus lansdowneana ssp. *lansdowneana*		+				
Eucalyptus leucoxylon ssp. *petiolaris*				+	+	
Glossostigma sp.nov. (aft. G. *drummondii)*	+			+		
Grevillea biternata	+	+				
Grevillea parallelinervis		+				
Haeckeria cassinaeformis			+	+	+	
Hakea cycloptera		+	+	+	+	
Haloragis eyreana					+	
Helipterum oppositifolium	+	+				
Hibbertia paeninsularis					+	
Leptomeria preissiana	+	+				
Loxocarya fasciculata	+				+	
Melaleuca oxyphylla		+	+	+		
Melaleuca rhaphiophylla	+	+	+	+		
Microlepidium alatum			+			
Olearia adenolasia	+		+			
Pomaderris flabellaris					+	
Prostanthera calycina			+		+	
Prostanthera florifera		+		+		
Pultenaea trichophylla						+
Rulingia craurophylla	+	+	+			
Scaevola bursariifolia			+			
Senecio gawlerensis		+		+		
Spyridium leucopogon				+	+	
Spyridium sp.nov. (aft. S. *complicatum)*	+		+			
Stypandra glauca	+		+	+		+
Templetonia battii	+		+			
Thysanotus nudicaulis	+				+	
Thysanotus wangariensis				+	+	
Velleia cycnopotamica	+	+	+			
Veronica parnkalliana					+	

*Eastern Australia: Vic, N.S.W. or Qld
All Districts are defined in Fig 1

extending southwards to Carappee Hill and Caralue Bluff, with an outlier to the northwest at Mt Finke.Hills of these sorts, particularly granite inselbergs, are a distinctive feature of the Peninsula and tend to have characteristic floras. *Stypandra glauca,* nodding blue lily (Liliaceae) is typical of such flora and in South Australia is known only from a few isolated granite hills of central Eyre Peninsula, for example Wudinna, Corrobinnie and Carappee Hills. It has flaxlike leaves extending up the stem and bright blue flowers. It must earlier have been more abundant since Johns (1938) wrote that its leaves and stems were used by early settlers to thatch their shanties. This lily occurs widely in Australia and in New Caledonia.

Two recently-discovered endemics of eastern Eyre Peninsula are *Acacia* species not yet named. One which occurs on ironstone resembles

A. rhigiophylla and *A. colletioides,* differing from the first by having angular phyllodes and globular flower-heads and from the second by having prominent spiny stipules and single not twin inflorescences. The second endemic resembles A. *steedmannii* (D. Whibley, pers. com.) and is restricted to a small area in the Hundred of Glynn. It is of gaunt erect habit like *Nicotiana glauca.*

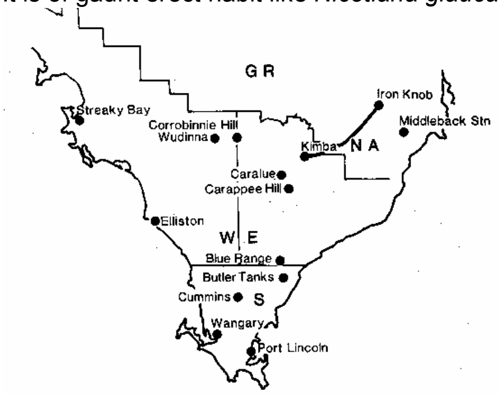


Fig. 1. Some places and divisions mentioned in the text. The described road between Iron Knob and Kimba is shown. NA = non agricultural zone, GR = Gawler ranges zone, W = western, E = eastern and S = southern zones.

The last examples for which there is space here

The last examples for which there is space here are also newly-discovered species, this time from restricted habitats in the south-east part of Hincks Conservation Park. One is *Eremophila barbata* (Myoporaceae), a small emu bush with lilac flowers akin to *E. crassifolia,* restricted to the upper reaches of Scour Creek valley and two smaller valleys incised into the Blue Range (Chinnock & Dutkiewicz 1985). The other is *Brachycome xanthocarpa* (Compositae), a small annual daisy (Cooke 1985).

This illustrates how important it is that conservation parks such as Hincks are large enough to embrace such special habitats, upon which special Eyre Peninsula plants may now depend absolutely. *Thysanotus wangariensis* would be another example, an endemic fringe lily known only from four collections: two near Wangary and two in Hincks (Brittan 1978).

OBSERVING THE VEGETATION

This next section is presented in the belief that with guidance, many passengers in vehicles travelling Eyre Peninsula roads would be interested to become better informed about the vegetation. So the following botanical travelogue from Iron Knob to Kimba on the Eyre Highway is tied to odometer readings which can be related to those in the reader's vehicle.

Distance (Km).

00.0 Turnoff to Iron Knob main street on left.

01.3 Low-lying drainage system (tributary of Salt Creek).
Eremophila longifolia (long-leaved emu bush) Tall Open Shrubland with *Cassia nemophila* (desert cassia)-see Fig. 2. A vegetation-type of restricted extent corresponding with these wetter alluvial soils. *E. longifolia* has pendulous grey-green leaves and spotted tubular flowers reddish coloured for bird pollination. It can make extensive clumps by suckering. Underneath are many salt-bush *(Atriplex vesicaria)* with its relatives *Maireana pyramidata* (black bluebush) and *Rhagodia spinescens* (a kind of berry saltbush). Also common is *Lycium australe* (native boxthorn), greyer and more succulent than the introduced African boxthorn.

02.3 Acacia papyrocarpa (western myall) Low Open Woodland-see Fig. 3. The main vegetation of the calcareous loam soils in this district. Western myall is very long-lived with an elegant spreading habit and graceful grey-green foliage which takes a silvery sheen at some angles. Observers will note rounded, shrubby young western myalls along the verges of the sealed highway but none in the paddocks (Fig. 4). This difference is due to water run-off effects and grazing effects and will lead to eventual loss of most of the woodland.

08.1 Pine Creek (Salt Creek). *Callitris preissii* (native pine) Low Woodland with an isolated patch of *Eucalyptus porosa* (mallee box) on the left. On creekline sands the native J pine (actually a cypress not a pine) forms a scattered woodland with western myall and slender hopbush *(Dodonaea angustissima).* The understorey is of saltbush and black bluebush which naturally prefers the low-lying situations (true bluebush *Maireana sedifolia* does not).

08.6 Western Myall Low Open Woodland. Scattered amongst the western myalls are groups of sugarwood or false sandalwood (Myoporum platycarpum) which are upright sparsely-foliated trees with shiny green leaves. Also present are small bullock bushes rather like olives (Heterodendrum oleaefolium) and Eremophila scoparia, silvery broom-like bushes with lilac insect pollinated flowers.

15.1 Casuarina cristata (blackoak) Low Woodland-see Fig. 5. The first of several such groves on this route. They spread by suckering and so form genetically uniform clusters.

Fig. 2. Tall Open Shrubland of long-leaved emubush with native boxthorn bushes left of centre. Staff = 2 m.

Fig. 3. Western myall Low Open Woodland over a grazed understorey of bluebush (*Maireana sedifolia*). Staff = 2 m.

26.5 Marker Sign: Kimba 60 km.

27.9 *Santalum acuminatum* (quandong/ native peach) trees on the left.

29.4 First mallee of *E. oleosa* (red mallee) and *E. gracilis* (yorrell), with associated under-shrubs, in pockets amongst the western myall woodland. These shrubs include *Geijera linearifolia* (sheep-bush), with dense waxy green foliage and clusters

Fig. 4. Roadside regeneration of western myall and mature trees to the left. Staff = 2 m.

Fig. 5. Blackoak Low Woodland over bluebush. Staff = 2 m.

of tiny white star-like citrus-family flowers, *Acacia colletioides* (spine-bush), *Exocarpos aphylla* (leafless, a partial root parasite), *Olearia calcarea* (daisy bush), *Rhagodia crassifolia* (fleshy saltbush) and *Cratystylis conocephala* (bluebush daisy). This last has to be inspected at close range to tell from a bluebush; it has wider, flatter leaves). Ground plants are *Zygophyllum* spp. (twin-leaf) and *Sclerolaena diacantha* (grey bassia).

30.3 Western Myall without Mallee.

32.9 Mixture of Mallee and Western Myall. For the next 10 km the two communities alternate: western myall tending to the lower land and mallee to the higher.

35.1 Mallee. Tall Open Shrubland of *E. oleosa*, *E. gracilis* and *E. brachycalyx*: see Fig. 6. The new sightings are *E. brachycalyx* (gilja), *Melaleuca pauperiflora* (boree) and *Myoporum desertii* (turkey bush).

41.5 Sign: Kimba 45 km.

42.4 Road crosses crest of sand-dune with *E. socialis* (red mallee) Open Scrub over *Triodia irritans* (spinifex) Hummock Grassland. See Fig. 7. Away from the crest a more typical community develops introducing *Acacia sclerophylla var. lissophylla* (hard-leaf wattle), *A. microcarpa* (manna wattle), *Melaleuca lanceolata* (dryland tea tree), *Rhagodia parabolica* (mealy saltbush), *Atriplex stipitata* (bitter saltbush) and *Halgania cyanea*, a small plant with vivid blue flowers.

From here on mallee of the *E. oleosa-E. gracilis*, *E. brachycalyx* associations predominates on the calcareous loams. The road verges through it have become dominated by various *Acacia* species which thrive on the run-off water.

46.5 Sign: Kimba 40 km.

47.0 Last patch of western myall.

51.0 Small low granite outcrop on left. *Melaleuca uncinata* (broombush)-*Beyeria leschenaultii* (turpentine)-*Eremophila alternifolia* (emu bush) Low Shrubland. This low vegetation marks the extent of influence of the outcrop. Other shrubs present include the hop-bushes *Dodonaea angustissima* and *D. lobulata* with colourful winged fruits.

51.5 Sign: Kimba 35 km.

53.2 Road intersects a larger granite outcrop and has a parking bay. *Melaleuca uncinata* (broom bush) *Beyeria leschenaultii* (turpentine) Low Shrubland. This vegetation contains *Triodia* and a wealth of heathy shrubs too numerous to list here, but very colourful in spring. *Calytrix*

Fig. 6. Mallee (*Eucalyptus oleosa* and *E. gracilis*) Tall Open Shrubland over bluebush daisy.

Fig. 7. Mallee (*Eucalyptus socialis*) Open Scrub over spinifex on crest of sand dune. Staff = 2 m.

involucrata, a fringe myrtle mainly confined to Eyre Peninsula, is of particular interest. This site is within Lake Gilles Conservation Park.

56.5 Sign: Kimba 30 km.

59.6 Road intersects major sand-dune system. *E. socialis-E. brachycalyx* Tall Shrubland with *Callitris verrucosa* (mallee cypress pine). Many species are encountered here for the first time in an excellent example of sand-dune flora of the peninsula. Examples include *Hakea francisiana* (a large shrub with strap-like leaves), *Leptospermum coriaceum* (a tea tree), *Olearia lepidophylla* (club moss daisy) which has minute scale-like leaves Clothing the stems and rutaceous species such as *Phebalium bullatum*, *Microcybe multiflorus* and *Boronia coerulescens.* An unusual shrub is *Grammosolen dixonii* (Solonaceae), with tomentose rounded leaves and star-shaped white flowers. It grows mainly on the disturbed sands of road cuttings.

69.1 End of Lake Gilles Conservation Park, beginning of agricultural zone.

71.5 Sign: Kimba 15 km.

72.0 Degraded remnant of *E. dumosa* (white mallee) Tall Shrubland. This is the first of several white mallee patches, a species of the heavier more fertile soils recognizable by its dull, dense foliage. The rough-barked *E. porosa* (mallee-box) is also present.

72.1 *Casuarina cristata* (blackoak) Low Woodland on right.

74.7 *Myoporum platycarpum* (sugarwood), *Callitris preissii* (native pine) Low Woodland. The change into this vegetation is correlated with localized quartzitic rocks. Prominent shrubs are slender hop bush and *Acacia hakeoides* (hakea wattle) and A. *ligulata* (umbrella bush).

79.5 *Eucalyptus incrassata* (ridge-fruited mallee). This mallee is seen as the road intercepts a somewhat indistinct dune area. E. socialis, E. brachycalyx and E. dumosa are also present.

86.4 Turn-off into Kimba on the right.

ACCOUNTS OF EYRE PENINSULA VEGETATION

This review outlines the main papers describing Eyre Peninsula's native vegetation. Plant names have been changed to accord with modern usage. Misuse of botanical terms like 'Association' and 'Formation' by some authors leaves it hard to tell what they meant by them, but most of them seem to have meant a particular type of vegetation named according to one or a few of its predominant species, and structural types such as grassland, scrub, woodland and so on, respectively.

In 1906 the German botanist Diels published a very small map of Australia's vegetation depicting Eyre Peninsula as 'mallee' with 'mulga' inland (Fig. 8).

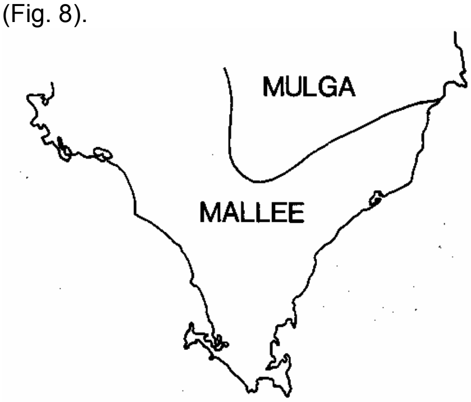
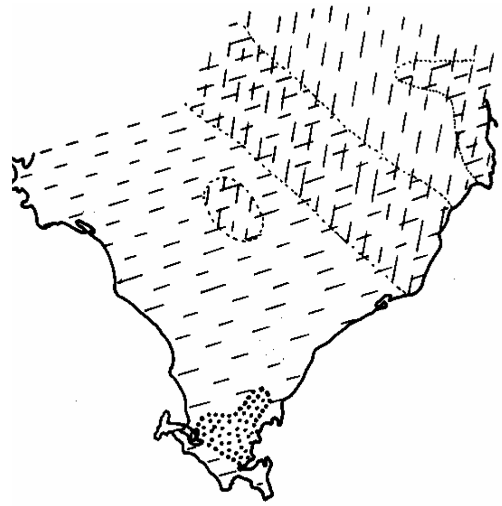


Fig. 8. Eyre Peninsula vegetation after Diels (1906).

Allowing *western myall woodland* to pass as *mulga,* then Diels' depiction was an appropriate start except his boundary-line between the two types (which Griffith Taylor reproduced in his *'Australian Environmenf* map of 1918) curved too far south into central Eyre Peninsula. That boundary was set nearer its correct position and further features were mapped when Prescott and Wood published in 1929 and 1930. In the interim, Osborn (1914) published an excellent annotated photograph of *mallee* vegetation at Port Lincoln. Prescott (then Professor of Agricultural Chemistry at the Waite Institute) had persuaded the Lands Department to prepare a map of pre-settlement vegetation from the botanical notes of the original land surveyors. The only version to be printed, much simplified, was pUblished in 1929 by Prescott himself. So far as Eyre Peninsula went it showed overlap of the *mallee* with *saltbush* and *bluebush* (Fig. 9) and it marked south-westerly limits of *cottonbush (Maireana aphylla).*

Wood (another chemist but who had been appointed lecturer in charge of botany at Adelaide University) had studied the floristics of *mallee* vegetation and also the flora of Kangaroo Island and adjacent peninsulas. He singled out and mapped *Eucalyptus diversifolia-E. cladocalyx* forest from the southernmost of the Eyre Peninsula *mallee* (Fig. 9).

Both authors represented *mallee* between Whyalla, Iron Knob and Port Augusta as of much greater extent than actual. Their maps show it



ːig. 9. Eyre Peninsula vegetation after Prescott (1929) and Wood (1929/1930). Diagonal hatching = mallee; vertical = saltbush and bluebush; stipple = *E. diversifolia–E. cladocalyx* forest.

continuous from Point Lowly to Port Augusta then westwards to Corunna. Actually this region was occupied by *western myall woodland* and *chenopod shrubland* as shown in Murray's map (1931).

In 1937 Wood published *'The Vegetation of South Australia'* with two vegetation maps. The first, a small sketch map, showed southernmost Eyre Peninsula as *'sclerophyll forest and macchia',* the central vegetation as *'mallee'* and the adjoining inland vegetation as *'mulga and saltbush'.* The second map, a coloured fold-out, divided Eyre Peninsula vegetation into the Associations showing in Fig. 10.

Wood's treatment was not very satisfactory and even changed the earlier mapping for the worse. Thus *mallee* dominance was re-extended far northeast of its correct boundary, *western myall woodland* was pushed almost clear off the peninsula and the Tregalana-Cultana-Lincoln Gap area was reclassified as *Atriplex-Halosarcia.* Wood (1946) published yet another sketchmap of Eyre Peninsula vegetation with further variations. The next main author, Crocker (1946), evidently disregarded Wood's treatments because he wrote that Eyre Peninsula vegetation had been ' ... so *little studied* as *to be almost unknown'.*

The approach to vegetation by Crocker (a soil scientist in the C.S.I.R.O.) was greatly influenced by his ability to relate vegetation to the soil

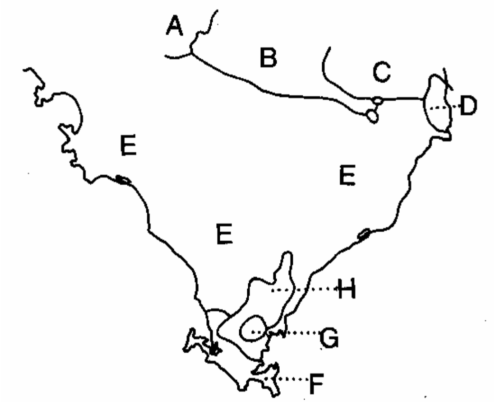


Fig. 10. Eyre Peninsula vegetation after Wood (1937). Association dominants: A = *Acacia aneura*; B = *Atriplex-Maireana*; C = *Acacia papyrocarpa*; D = *Atriplex-Salicornia*; E = *Eucalyptus oleosa–E. dumosa*; F = *E. incrassata*; G = *E. diversifolia*; H = *E. odorata*.

landscapes which he was surveying. He looked specifically at Eyre Peninsula's vegetation and was the last with opportunity to view it more or less whole, before agricultural clearing became excessive. He introduced Wood's terms *edaphic and climatic complex* to Eyre Peninsula vegetation description.

An *edaphic complex* in Crocker's usage meant the vegetation clothing one of his broad soil landscape categories (without necessarily sorting it into its constituent Associations). If a soil landscape extended through different climatic zones then according to Crocker it involved a *'climatic complex'.* Critics might say with some justification that Crocker's vegetation maps were his soils maps with different legends. Whatever the case, Crocker used these units to map Eyre Peninsula vegetation, starting in the arid northern part and working south.

Solonized brown soil landscapes on Eyre Peninsula extend from agricultural regions with about 400 mm of average annual rainfall to northern pastoral-zone localities with about 200 mm. That sets up the situation of the *climatic complex.*

Northern vegetation of this climatic complex consisted, according to Crocker, of the *Acacia papyrocarpa* (western *myall)-Casuarina cristata* (blackoak) edaphic complex (Fig. 11), involving four Associations, namely the *Acacia papyrocarpa-Myoporum platycarpum,* the *Casuarina cristata-Maireana sedifolia,* the *Atriplex vesicaria-Maireana sedifolia* and the *Maireana sedifolia.* More scientific papers have been written about these Associations than about any others on Eyre Peninsula, due to their ongoing pastoral importance (Jackson 1958, Lay 1979, Barker 1979, Noble 1979).

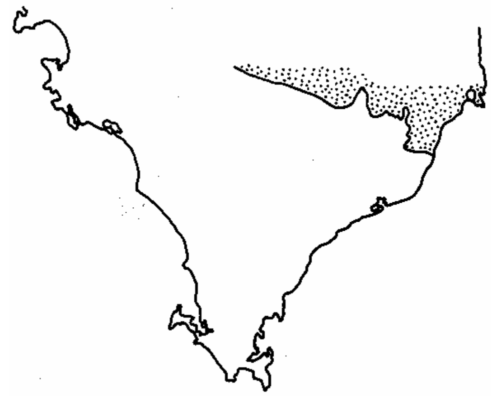


Fig. 11. Distribution of the *Acacia papyrocarpa–Casuarina cristata* edaphic complex after Crocker (1946).

Southern vegetation of this climatic complex on solonized brown soils consisted according to Crocker of the *Eucalyptus oleosa-E. gracilis-E. dumosa* edaphic complex (Fig. 12) involving six associations, namely the *E. dumosa-E. incrassata,* the *E. oleosa-E. brachycalyx,* the *E. oleosa-E. gracilis,* the *Casuarina cristata,* the *Callitris preissii* and a *Stipa-Danthonia* Association.

Next Crocker referred to the solonized wind piled siliceous sand landscape. The previously mentioned *E. dumosa-E. incrassata* Association extended to this as did northerly extensions of

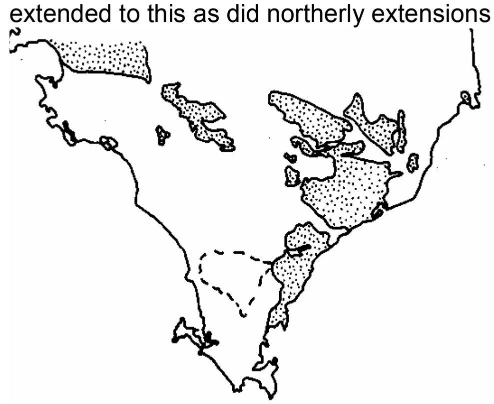
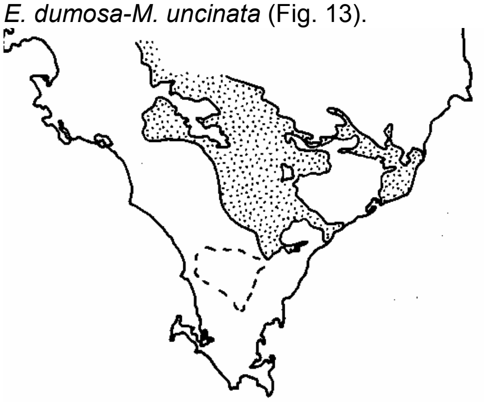


Fig. 12. Distribution of the *Eucalyptus oleosa–E. gracilis–E. dumosa* edaphic complex after Crocker (1946). The region within the broken line was shared with the next edaphic complex. (See Fig. 13).

vegetation types of the residual podsols further south. But in the main its vegetation was *E. incrassata-E. foecunda-E. flocktoniae* edaphic complex involving three Associations namely the *E. incrassata-E. foecunda-Melaleuca uncinata,* the *E. oleosa-M. uncinata* and the *E. flocktoniae-E. dumosa-M. uncinata* (Fig. 13).



ig. 13. Distribution of the *Eucalyptus incrassata-E. foecunda-E. flocktoniae* edaphic complex (After Crocker 1946).

Extending down the west side of the peninsula Crocker found exposed aeolianite travertine with Terra Rossa and Rendzina soils, and he termed the corresponding vegetation the *E. diversifolia-Allocasuarina verticillata-Melaleuca lanceolata* edaphic complex (Fig. 14). He left the northern part unsorted but mapped the southern part as two Associations, namely the *E. diversifolia* and the *Allocasuarina verticillata.* The other

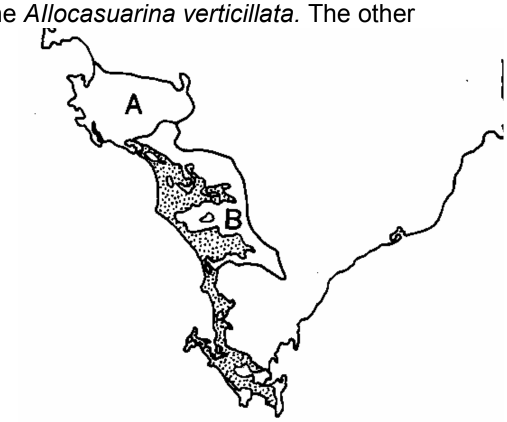


Fig. 14. Distribution of the *Eucalyptus diversifolia-Acacia verticillata-E. porosa* edaphic complex. A = unsorted complex, B = *E. diversifolia* Association, Stipple = *A. verticillata* Association, after Crocker (1946).

Associations making up the complex were the *E. porosa* and the *A. verticillata-M. lanceolata.*

The remaining small area about Wanilla with greatest rainfalls and most complicated soils involved pod sols, residual podsols and a narrow band with red-brown earths and brown soils. Crocker described the vegetation as *E. cladocalyx-Xanthorrhoea tateana-A. muelleriana* edaphic complex, *E. cladocalyx-A. verticillata-E. oleosa-M. uncinata* edaphic and climatic complex, and an *E. odorata-A. verticillata* edaphic complex.

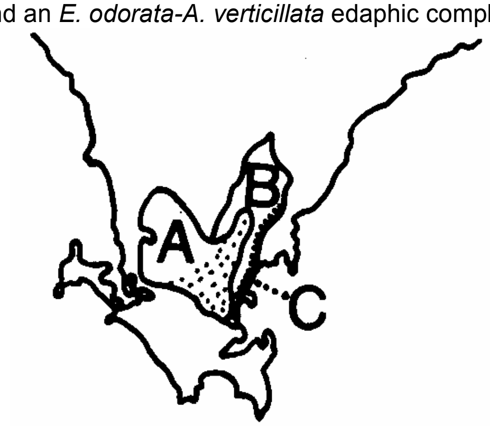


Fig. 15. Distribution of the Eucalyptus cladocalyx-Xanthorrhea tateana-Allocasuarina muelleriana edaphic complex = A, the *E. cladocalyx-Acacia verticillata-E. oleosa-Melaleuca uncinata* edaphic and climatic complex = B and the *E. odorata-A. verticillata* edaphic complex = C, after Crocker (1946). The stippled area is transitional between A and B.

Photographs and discussion in Crocker (1946) provide some detailed information about the foregoing types and the paper still stands as the landmark study which all should read.

In 1947 a collaborative essay by Crocker & Wood made numerous references to Eyre Peninsula vegetation including sketch maps of some species distribution, supposed plant refuges and migratory routes connected with prehistory and even a map claiming to show spread of the *E. diversifolia* Association since original land surveys in 1877. Preece (1983) independently referred to claims of *E. diversifolia* spreading on Eyre Peninsula.

A completely independent treatment of the Peninsula's vegetation appeared in 1957, from the forester's viewpoint (Bednall1957). Included was a map at the Formation level *(savannah* *woodland, mallee, mallee heath* and *arid woodland)* which gave a contrast to Crocker's views.

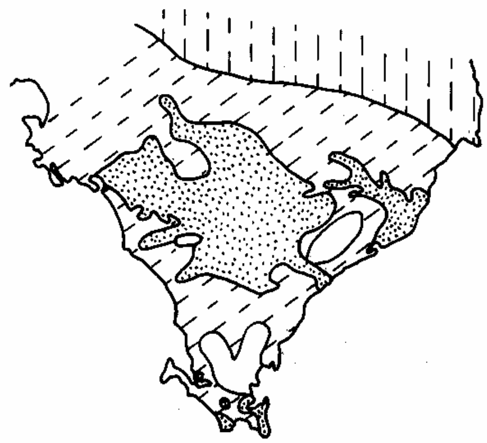


Fig. 16. Eyre Peninsula vegetation after Bednall (1957). Blank = Savannah woodland, diagonal hatching = mallee, vertical hatching = arid woodland, stipple = mallee-heath.

In 1958 a series of very informative articles were published by French which, although dealing with soils, included many comments about associated flora. French's papers included landform-soils diagrams scored for associated vegetation, and photographs.

The next substantial contribution was by Smith (1963) with detailed observations on the vegetational remnants of lower Eyre Peninsula. Smith discussed the field relationships of 21 eucalypt and 3 other species and then outlined the plant communities in three ways, first in a table, second in an itemized discussion and third in a map. These do not correspond with each other precisely but involve 12 communities as follows.

Five Associations were distinguished in the Mallee Formation, namely the *E. oleosa-E. gracilis, E. incrassata-E. foecunda, E. f1ocktoniae-E. dumosa-M. uncinata, E. diversifolia* and *E. conglobata.* Their field relationships were illustrated on a diagrammatic soil-landscapes section. The Savannah Woodland Formation was represented by the *E. camaldulensis,* A. *verticillata-M. lanceolata, E. odorata-E. leucoxylon, E. odorata-A. verticillata, E. odorata-E. behriana* and *E. odorata* Associations. These too were discussed with the aid of diagrammatic sections of landscape. The Sclerophyll Scrub Formation was represented by *E. ciadocalyx* Association and illustrated by photographs.

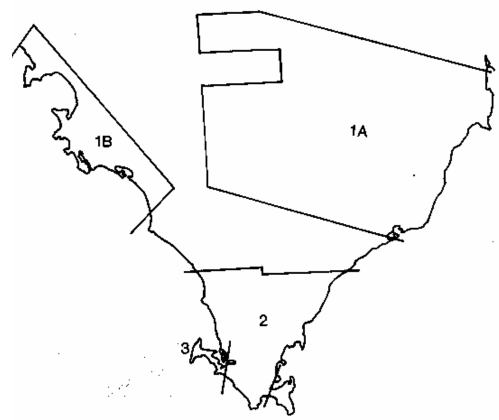


Fig. 17. The parts of Eyre Peninsula covered by Douglas (1981) = 1A, 1B, Smith (1962) = 2 and Hartshorne & Meyers (1983) = 3.

During the 1960's the new large tracts on the peninsula that had been set aside as wildlife reserves faced strong threats to clear them for agriculture. The Nature Conservation Society of South Australia, determined to resist clearing, saw the necessity of strengthening its case by bolstering knowledge of the reserves' natural values (Bonython & Preiss 1967, Lothian 1969, Preiss & Thomas 1970). Three surveys resulted covering Hambidge in 1966 then Bascombe Well in 1967 and Hincks in 1968. Hambidge and Hincks fall within Crocker's *E. incrassata-E. foecunda-E. flocktoniae* edaphic complex; Bascombe Well falls in his *E. diversifolia* Association. The reports include valuable plant lists, descriptions and photographs. Hincks contained 209 vascular species that Hambidge did not, for example, despite their incorporation in just one of Crocker's units.

In 1972 a rewritten second edition of • *The Vegetation of South Australia'* appeared (by Specht, formerly of Adelaide University's Botany Department), containing floristic checklists of Eyre Peninsula's *E. diversifolia, E. incrassata-M. uncinata, E. socialis-E. brachycalyx* and *E. socialis-E. gracilis* Associations, plus much else. The vegetation map was given another interpretation, this time in small format at the Formation level. It was not without questionable features, for instance the designation of *Ixiolaena leptolepsis* as an Association dominant.

In 1976 the South Australian Department for the Environment produced the first edition of a document entitled: *'Vegetation Clearance. Agricultural Regions of South Australia'* with a large map which exposed graphically the widespread obliteration of native vegetation, heightening the attention of nature conservationists to this issue. A survey describing the remaining natural vegetation on Eyre Peninsula was published under the auspices of the Nature Conservation Society of South Australia (Mowling 1979). The report made descriptive statements about remnant vegetation in each of 33 parts of Eyre Peninsula and made three successive presentations of them, with variations each time.

In 1980 Boomsma & Lewis published their book: *'The Native Forest and Woodland Vegetation of South Australia'* which, like Specht's book, contains much of relevance to Eyre Peninsula studies and which should be consulted directly. It includes a large vegetation map and numerous small species distribution maps as well as much discussion.

The early 1980's saw the first of the LANDSAT assisted examinations of South Australian vegetation including that of Eyre Peninsula, with two of the test-sites of Douglas (1981) from the South Australian Department of Environment and Planning (Fig. 17). Test-site 1A was mapped as 9 vegetation types for example. Two other relevant documents of recent date are' *The Vegetation of Coffin Bay Peninsula'* by the Wildlife Park Management section of the S.A. College of Advanced Education at Salisbury, and a National Parks and Wildlife Service document by Preece (1983) which also deals with Coffin Bay peninsula. The first involved a detailed map showing *'stabilized dune heath, sheoak open woodland, tea tree open scrub, heath land, coastal cliff heath, mallee scrub, samphire flats* and *salt paperbark thicket* (Fig. 17=3). The second involved descriptions of vegetation and an extensive plant list.

We end with reference to the large report by Davies (1982) concerning the conservation of major plant communities in South Australia. Davies assembled much literature and recognized 65 'association categories' of Eyre Peninsula vegetation, of which 37% were regarded by him as not conserved or poorly conserved.

In conclusion, it should be remembered that numerous plant-taxonomic works contain species distribution maps, illustrations and comments that bear on Eyre Peninsula vegetation. Those by Whibley (1980), Boomsma (1972), Carrick & Chorney (1979) and Wilson (1980) are examples.

REFERENCES

Barker, S. (1979). Shrub population dynamics under grazing-within paddock studies. pp. 83-106. *In* R. Graetz & K. Howes, (Eds.) 'Studies of the Australian Arid Zone. IV. Chenopod Shrublands'. (C.S.I.R.O. (Ausl.)., Div. Land. Res. Manag., Canberra).

Bednall, B. H. (1957). Forestry Handbook, South Australia. *Woods and Forests Dept.,* S. *Aust. Bull.* No.6.

Boland, D. J. (1979). A taxonomic revision of *Eucalyptus leucoxylon.* F. Muell. *Aust. For. Res.* **9**, 65-72.

Bonython, C. W & Preiss, K. E. (Eds.) (1967). Hambidge Wild Life Reserve: A survey by the Nature Conservation Society of South Australia. S. *Aust. Nat.* **42**, 35-63.

Boomsma, C. D. (1972). Native trees of South Australia. *Woods and Forests Dept.,* S. *Aust. Bull.* No. 19.

Boomsma, C. D. & Lewis, N. B. (1980). The native forest and woodland vegetation of South Australia. *Woods and Forests Dept.,* S. *Aust. Bull.* No. 25.

Brittan, N. H. (1978). A new species of *Thysanotus* R.Br. (Liliaceae) from Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **102**, 55-7.

Carrick, J. & Chorney, K. (1979). A review of *Melaleuca* L. (Myrtaceae) in South Australia. *J. Adelaide Bot. Gard.* **15**, 281-319.

Chinnock, R. J. & Dutkiewicz, D. L. (1985). Plant portraits: 19 *Eremophila barbata* Chinnock, sp. novo (Myoporaceae). *J. Adelaide Bot. Gard.* **7**, 307-13.

Cooke, D. A. (1985). Studies in the tribes Asterae and Inulae (Compositae). *J. Adelaide Bot. Gard.* **7***,* 273-87.

Crocker, R. L. (1946). An introduction to the soils and vegetation of Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **70**, 83-107.

Crocker, R. L. & Wood, J. G. (1947). Some historical influences on the development of the South Australian vegetation communities and their bearing on concepts and classification in ecology. *Trans. R. Soc.* S. *Aust.* **71**, 91-136.

Davies, R. J. (1982). 'The conservation of major plant associations in South Australia'. (Conservation Council of S. Aust, Adelaide).

Diels, L. (1906). 'Die Pflanzenwelt von West-Australien sudlich des Wenderkreises'. (W Engelmann, Leipzig).

Douglas, J. S. (1981). 'The feasibility study for an ecological survey of South Australia'. (Dept of Env. & Planning, S. Ausl.) Unpubl.

French, R. J. (1958). Soils of Eyre Peninsula. Parts 1III. *J. Agric. (S. Aust.)* **82**,512-29,578-94; **83**, 33-47.

Hartshorne, S. & Meyers, J. (1983). 'The vegetation of Coffin Bay Peninsula. Baseline Field Studies of the Coffin Bay Peninsula, Vol. III'. (S. Ausl. College. Adv. Ed., Salisbury, S. Aust).

Johns, C. W (1938). Flora of the Wudinna district, Eyre Peninsula. S. *Aust. Nat.* **19**, 13-4. J

Jackson, E. A. (1958). A study of the soils and some aspects of the hydrology at Yudnapinna Station, South Australia. *C.S.I.R.O. Div. Soils. Soils* & *Land Use Series* No. **24**.

Jessop, J. P. (ed.) (1983). 'A list of the vascular plants of South Australia'. *(Ad. Bot. Gard.* & *State Herb, Dept. Env. and Planning, South Australia)*.

Lay, B. (1979). Shrub population dynamics under grazing-a long term study. pp. 107-24. *In* (R. Graetz and K. Howes, (Eds.) 'Studies of the Australian Arid Zone. IV. Chenopod Shrublands'. (C.S.I.R.O. (Aust.) Div. Land Res. Manag., Canberra).

Leigh, J., Boden, R. & Briggs, J. (1984). 'Extinct and endangered plants of Australia.' (MacMillan, Melbourne).

Lothian, T. R. N. (Ed.) (1969). The Hundred of Blesing: A survey of its natural values carried out by the Nature Conservation Society of South Australia. S. *Aust. Nat.* **43**, 52-98.

Mowling, F. A. (1979). 'The natural vegetation of Eyre Peninsula, 1979'. (Nat. Conserv. Soc. S. Aust. Inc., Adelaide).

Murray, B. J. (1931). A study of the vegetation of the Lake Torrens Plateau, South Australia. *Trans. R. Soc.* S. *Aust.* **55**, 91-112.

Noble, I. R. (1979). Computer simulation models of extensive chenopod shrubland grazing systems. pp. *125-43 In* R. Graetz & K. Howes, (Eds.) 'Studies of the Australian Arid Zone.' IV. Chenopod Shrublands. (C.S.I.R.O. (Aust.) Div. Land Res. Manag., Canberra).

Orchard, A. E. (1980). An anomalous South Australian *Haloragis* (Haloragaceae). J. *Adelaide Bot. Gard.* **2**, 253-7.

Osborn, T. G. B. (1914). Botany, 27 pp. *In* 'Handbook of South Australia.' (Govt. Printer, Adelaide).

Preece, K. (1983). The biology of Coffin Bay National Park, Kellidie Bay Conservation Park and associated islands. Internal report. Dept. Env. & Planning, Adelaide.

Preiss, K. A. & Thomas, P. M. (Eds.) (1970). Hincks National Park: A survey of its natural values carried out by the Nature Conservation Society of South Australia. S. *Aust. Nat.* **45**, 29-78.

Prescott, J. A. (1929). The vegetation map of South Australia. *Trans. R. Soc.* S. *Aust.* **53**, 7-9.

Smith, D. F. (1963). The plant ecology of lower Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **87**,93-120.

South Australian Department for the Environment (1976). 'Vegetation Clearance in South Australia. Report of the Interdepartmental Committee on Vegetation Clearance.' (S. Aust. Dept. Env., Adelaide).

Specht, R. L. (1972). 'The Vegetation of South Australia.' (Govt. Printer, Adelaide).

Taylor, G. (1918). The Australian Environment. Advisory Council *Sci. Ind. (Aust.) Bull.* NO.1.

Whibley, D. J. E. (1980). 'Acacias of South Australia.' (Govt. Printer, Adelaide).

Wilson, P. G. (1980). A revision of the Australian species of Salicornieae (Chenopodiaceae). *Nuytsia* **3**, 1-154.

Wood, J. G. (1929). Floristics and ecology of the mallee. *Trans. R. Soc.* S. *Aust.* **53**, 359-80.

Wood, J. G. (1930). An analysis of the vegetation of Kangaroo Island and the adjacent peninsulas. *Trans. R. Soc.* S. *Aust.* **54**, 105-39.

Wood, J. G. (1937). 'The Vegetation of South Australia.' (Govt. Printer, Adelaide).

Wood, J. G. (1946). 'Distribution of the vegetation of South Australia.' (Govt. Printer, Adelaide).

9: Salt Lakes

by W.D. WILLIAMS

INTRODUCTION

Until recently, there had been little investigation of the inland waters of the Eyre Peninsula. The reasons are not difficult to discern: reflecting the general aridity of the region (see Chapter 6), water-bodies are sparse, for the most part ephemeral, and somewhat distant from centres of population. Despite this lack of attention, the waters of the Peninsula provide a range of habitat types (albeit limited), and have considerable scientific interest. The purpose of this chapter is to draw attention to this interest, and to document available information on the salt lakes as particularly interesting habitats. It draws primarily upon a recent limnological reconnaissance of the region (Williams 1984). The major emphasis is upon the biological features of interest in the lakes, though some comments are made upon hydrogeological and chemical feature.

LOCATION AND HYDROGEOLOGICAL BACKGROUND

The location of the major salt lakes is shown in Fig. 1, and Fig. 2 provides an indication of their general appearance.

The salt lakes fall into three broad categories: (1) more or less permanent; (2) ephemeral and mostly unpredictably filled; and (3) ephemeral and predictably filled. There are few permanent salt lakes and all are located near the coast. The largest is Lake Newlands which is fed by freshwater and marine seepages and by occasional direct marine incursion. The ephemeral but predictably filled salt lakes are also, for the most part, located near the coast. Inland, in northern areas where rainfall is both less predictable and less voluminous, the salt lakes are ephemeral and, as a general rule, contain water for less predictable and shorter periods. Following Warren (1982a), the coastally located waters are referred to as coastal salinas, and those inland as continental playas. Thus, coastal salinas are salt lakes adjacent to the present coast in which the salina water level is always near or above the undisturbed salina sediment surface. With few exceptions, they are athalassic in the sense of Bayly (1967), and do not have a direct surface connection to the open sea. Continental playas are continental salt lakes in which the present playa water table is often to be found several metres below the undisturbed playa sediment surface.

Essentially, the coastal salinas are lakes located between junes which comprise part of an extensive Quaternary beach-dune system (Warren 1982a, b). The lakes arose wherever the interdune elevation was below present sea-level, and thus represent surface exposures of the mainly marine groundwaters. Most appear to have formed 5-6000 years ago. At first, they were probably permanent and highly saline lakes up to 10 metres deep. Subsequently, sedimentation has filled them with a laminated gypsum sequence, so that the progression has been from a deep, permanent, meromictic (chemically stratified) lake with a more or less stable salinity in the lower layers to a shallow, ephemeral lake with a highly variable salinity throughout (Fig. 3). In most of the coastal salinas, therefore, Holocene (last 6000 years) evaporitic sediments overlie the Pleistocene calcarenite dune material. The deposits are generally arranged as an outer marginal fringe of carbonate material surrounding a central area of gypsum deposition. When the lake is dry, surficial sediments may be blown by the wind into marginal lunettes (crescentically shaped dunes) up to 10 metres high.

The large continental playas are much older than the coastal salinas; most of them appear to be older than 16 000 years, for they contain continental gypsum, and, according to Bowler (1978), the last phases of widespread gypsum deposition occurred before that time. All the playas are the termini of endorheic (closed) drainage basins, and thus represent local depressions in the surrounding landscape. As in the coastal salinas, deflation (wind-induced movement) of bed material, mainly clay and gypsum, often resulted in characteristic lunettes forming downwind of the prevailing wind direction.

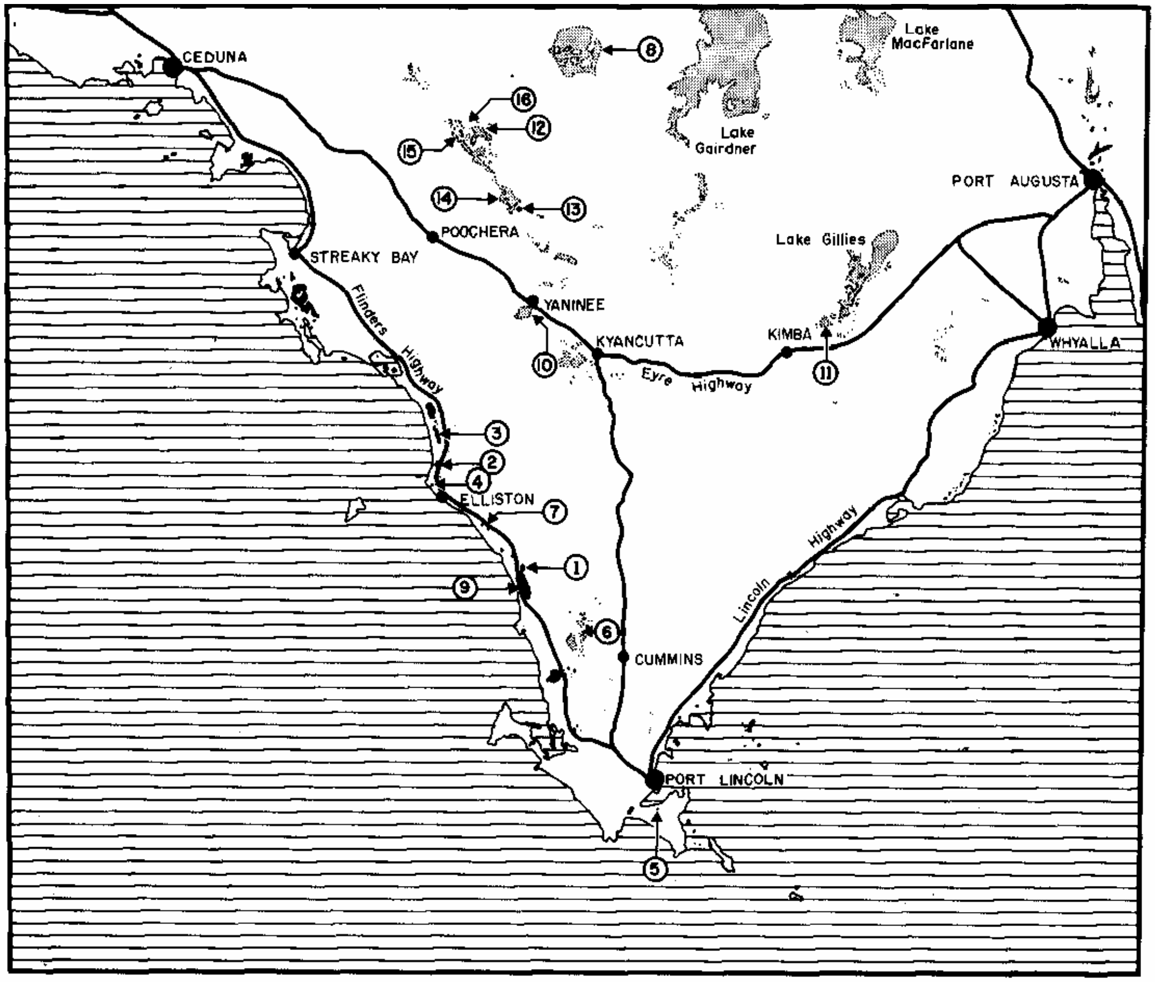


Fig. 1. Location of major salt lakes on the Eyre Peninsula. Coastal salinas shown black, continental playas stippled. Localities for which chemical and biological data are given in Tables 1 and 2 are indicated by an index number.

During the dry summer, the surface water of both coastal and continental lakes becomes increasingly saline and reduced in volume and area until, in most cases, the lakes become dry. At this time, the hydrology of the coastal salinas is greatly affected by their close proximity to the sea, for sea-water, penetrating the permeable coastal dunes, seeps into their sediments. The continental playas are not so affected and the extent to which their waters fluctuate in salinity and volume is a function of the extent and nature of any connection with the underlying continental groundwaters. Both coastal salinas and continental playas fill up with water following the accession to them of winter rainfall. Fig. 4 is a conceptual schema of seasonal hydrogeological events in the two sorts of lake based on Warren (1982a, b).

MAJOR CHEMICAL FEATURES

As a result of the marked seasonal shifts in the balance between precipitation and evaporation, salinity in most of the salt lakes on the Eyre Peninsula frequently may pass from values of less than that of seawater (<35‰) to values approaching the saturation point of sodium chloride (>350‰). Additionally, at anyone time there may be a range of salinities across a number of localities, even though there is a general temporal concordance in the pattern of salinity fluctuation in all the lakes. This is illustrated in Table 1 which documents the analytical results obtained from a series of samples collected in September 1981.

Table 1 also illustrates the relative homogeneity in the chemical composition of both coastal

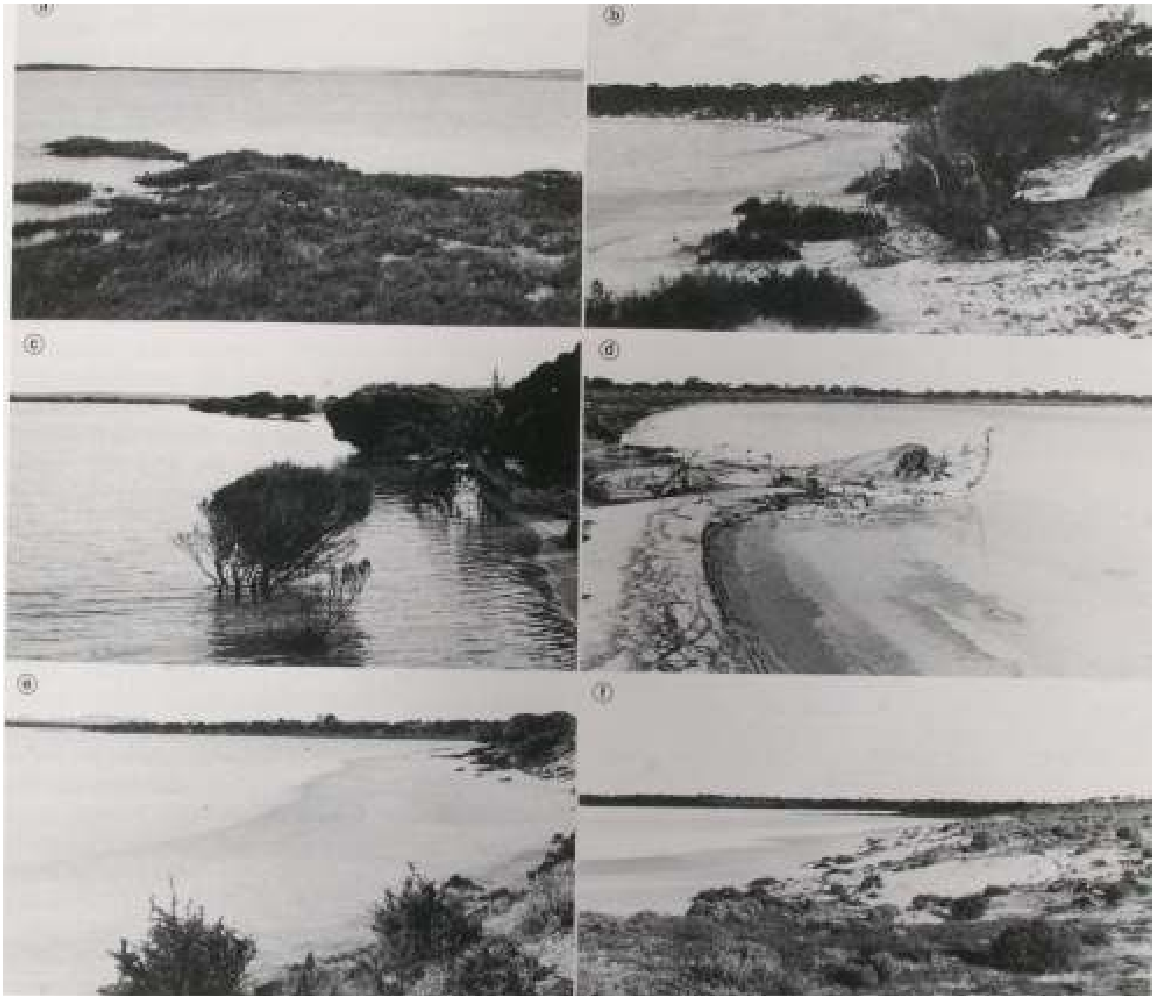


Fig. 2. General views of some salt lakes in the Eyre Peninsula. (a), Lake Hamilton; (b), Lakes Gillies; (c) Round Lake; (d), lake near Hiltaba; (e), another small lake near Hiltaba; (f), lake near Minnipa.

Table 1. MAJOR CHEMICAL FEATURES OF SOME SALT LAKES ON THE EYRE PENINSULA. Except for Pillie lake (sample collected November, 1979), samples collected 2-5 September 1981. Data for major ions as per cent equiv. cations. Rearranged from De Dekker, Bauld & Burne (1982) and Williams (1984). See Fig 1 for locations

Locality (Index No.)'	*Salinity (‰)*	*pH (field)*	*Na*	*K*	Ca	Mg	*$HC0_3$*	*Cl*	*SO.*
Round lake (1)	4.9	8.2	67.1	1.0	13.7	18.5	7.3	82.1	10.0
Middle lake (2)	26.7	8.0	74.3	1.2	6.5	18.0	1.2	87.2	11.7
Lake Newlands (3)	31.0	7.9	70.1	1.1	8.3	20.6	0.7	85.8	13.4
Lake N of Elliston (4)	31.2	7.9	69.4	1.2	9.5	20.0	0.6	83.0	16.3
Pillie lake (5)	36.2	8.5	82.0	1.0	1.0	16.0	1.0	82.0	13.0
Lake Malata (6)	37.0	8.2	76.0	1.0	11.1	11.8	0.3	87.8	12.1
Lake Tungketta (7)	39.0	8.0	81.2	1.1	4.4	13.4	0.9	92.4	7.0
Pool nr Kangaroo Well (8)	66.5	5.3	69.5	0.4	10.1	20.0	0.3	90.0	9.7
Lake Hamilton (9)	73.6		72.7	1.1	4.9	21.2	0.3	91.0	9.0
Lake Yaninee (10)	156.8	5.8	86.6	0.7	2.9	9.8	0.0	97.3	2.8
Lake Gillies (11)	192.8	3.0	82.7	0.5	1.8	14.9	0.0	98.2	1.6
Lake nr Hiltaba (12)	195.3	7.2	78.6	1.1	1.6	18.8	0.1	98.4	1.5
Lake nr Minnipa (13)	221.0	6.8	88.5	1.0	1.2	9.4	0.1	98.6	1.3
Lake nr Minnipa (14)	309.5		93.4	1.2	1.0	4.4	0.0	99.0	0.9
Lake nr Yantanabie (15)	311.6	5.5	94.6	1.2	1.3	2.9	0.0	99.0	0.9
Lake nr Hiltaba (16)	311.7	4.75	95.6	0.3	1.2	2.9	0.0	98.5	1.3

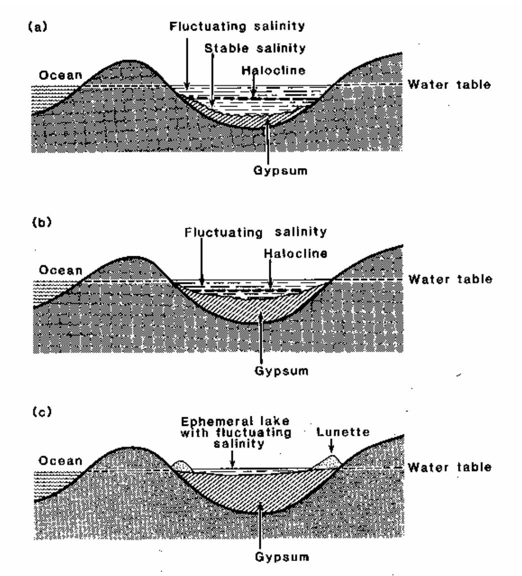


Fig. 3. Schematic evolution of coastal salinas, according to Warren (1982a). (a), early stage: a deep brine pond, chemically stratified, with a stable salinity in the lower layer; (b), a later stage: brine pond permanent, but less deep, and with a more variable salinity; (c), final stage (present): lake ephemeral, shallow, and highly variable in salinity. Redrawn and slightly modified after Warren (1982a).

salinas and continental playas. In all cases, the major chemical elements present are sodium and chloride, with the pattern of ionic dominance almost invariably: Na> Mg > Ca > K and Cl>$S0_4$>$HC0_3$. In this respect, the patterns of ionic dominance accord well with the pattern to be seen in present-day seawater, as, indeed, do the relative amounts of the ions present. The chemical similarity with seawater is not surprising in the coastal salinas; in the continental playas, it has been explained as due to marine salt accession via aerosols, rainfall and catchment flushing. This is certainly the most likely source of the salts in these water-bodies for there are no extensive beds of pre-Quaternary salts near them and from which salts could have been derived (Warren 1982a, b).

BIOLOGICAL FEATURES

The fauna recorded from the salt lakes is listed in Table 2. Note that this table is based-with one exception-on collections from a single sampling expedition only. Nevertheless, because salt lakes have low biological diversities, it is probable that, whilst certainly all species to be found in these lakes were not collected, the most important and common were. Most of the samples were collected in Spring (September), the season considered most propitious for collecting from this sort of lake. The sample from Pillie Lake was collected in November. To aid recognition, Fig. 5 provides simple line drawings (to various scales) of the commonest species.

Several general points can be made about the fauna. Firstly, it is quite clearly depauperate, in that far fewer species occur than occur in freshwater lakes. Secondly, the species assemblage as a whole is not a mixture of tolerant freshwater and marine species but, rather, a distinctive assemblage of species restricted to salt lakes. And, thirdly, though the relationship is far from obvious, in general the moderately saline lakes contain the most species and the highly saline lakes the least. No macrofauna occur in lakes with salinities above *200‰.*

These three general points reflect the situation which prevails worldwide in inland salt lakes. There are, however, many differences between the fauna of salt lakes on the Eyre Peninsula and on continents other than Australia. In particular, several animals characteristic of salt lakes outside Australia are absent: amongst these, special mention may be made of *Artemia salina* (the brine shrimp), *Ephydra* (the brine fly), and corixids. On the other hand, most of the inhabitants characteristic of Australian salt lakes are present: notable amongst these are species of *Parartemia, Daphniopsis, Calamoecia, Diacypris, AustraJocypris, Haloniscus* and *Coxiella.*

In overall features, then, the fauna of salt lakes on the Eyre Peninsula is like that of other Australian salt lakes, with an abundance of endemic forms and an obvious lack of cosmopolites. Additionally, there are a few species so far confined to the Eyre Peninsula (Table 2). These unique species indicate a degree of local distinctiveness within the Australian context. On the basis of a mathematical analysis which utilized "similarity coefficients", Williams (1984) suggested that the area with the closest faunal similarity was south-eastern South Australia, where there is also a large number of inland salt lakes (lakes near the Coorong).

One of the most notable, and certainly the least known, components of the fauna is a spider of the family Agelenidae. Until its discovery on the Eyre Peninsula, no truly aquatic spiders were known from Australia, in the sense that none was known which lived beneath the water surface as does *Argyroneta,* the widespread water-spider of the Northern Hemisphere. The spider is presently being described by Dr Barbara Main of the University of Western Australia. Nothing is known

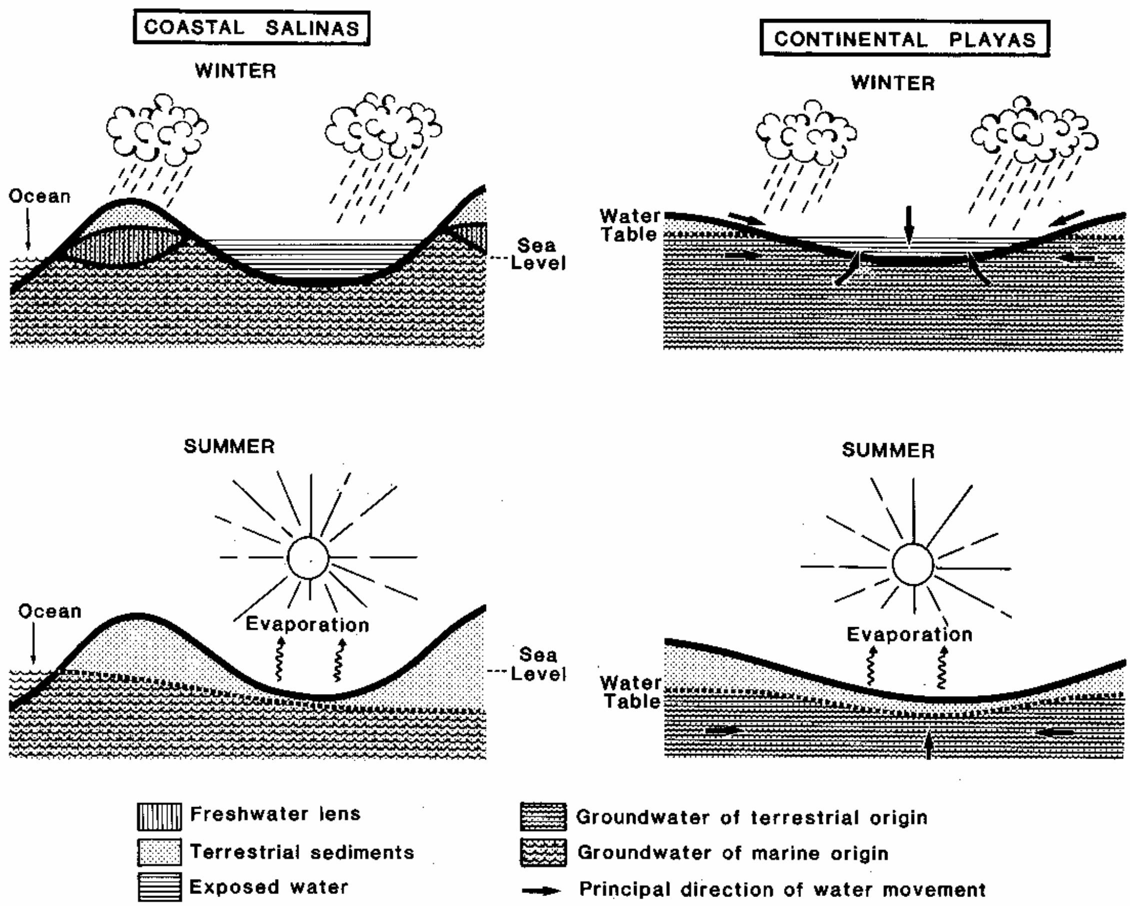


Fig. 4. Seasonal hydrogeological events in coastal salinas and continental playas of the Eyre Peninsula.

of its biology except that, during the time that water is present in the lakes where it has been found, it lives beneath marl plates or on vegetation lying completely submerged at depths of up to 25 cm and some 10 metres from the lake edge. It does so within an air bubble. Whether this air bubble serves the same function as that of *Argyroneta* is uncertain, but it is clear that the adaptations to life in highly saline ephemeral lakes possessed by this species must be many and varied. The species certainly merits further investigation.

Parartemia, the brine shrimp, is much better known. As the table indicates, two species have been recorded. One of them, P. *zietziana* (Fig. Sa), is widely distributed in salt lakes throughout southeastern Australia; the other, P. *cylindifera,* is known from elsewhere in South Australia and from Western Australia. Most is known about the biology of P. *zietziana* (Geddes 1980, 1981), but all species of the genus seem confined to salty environments. For P. *zietziana,* the salinity range recorded in the field throughout Australia is extremely broad, *27-300‰,* indicating powers of osmoregulation quite the equal of *Artemia* (to which genus, incidentally, it is not closely related). On the Eyre Peninsula, the recorded range of salinity is only slightly narrower, *27-195‰.* It is of interest to record that all species of *Parartemia,* like most of the fauna of Australian salt lakes, are endemic to Australia. There are eight species known so far, six confined to the west, one found on both sides of the continent, and one found only in the east. Unlike *Artemia, Parartemia* does not appear to use haemoglobin to transport oxygen, though it does have the ability to manufacture this pigment. Also, unlike *Artemia,* where parthenogenesis may occur frequently, *Parartemia* appears to reproduce only sexually. It produces two sorts of egg: a resistant one and a non-resistant one. Production of the former seems to be associated with rising salinities

Table 2. FAUNA OF SALT LAKES ON EYRE PENINSULA. Data from De Deckker *et al.* (1982) [1 locality] and Williams (1984) [10 localities].

Taxon	Salinity (‰)										
	4.9	26.7	31.0	31.2	36.2	37.0	39.0	66.5	73.6	156.8	195.3
Foraminifera											
Elphidium sp. *(sensu* Cann & De Deckker)			+	+		+					
Trochaminna inflata (Montagu)			+								
Anostraca:											
Parartemia cylindrifera Linder				+		+					
P. *zietziana* Sayce		+							+	+	+
Parartemia sp. (indet.)							+				
Cladocera:											
Daphniopsis pusilla Serventy		+		+	+	+	+				
D. sp. nov.						+					
Copepoda:											
Calamoecia salina Bayly		+		+		+	+				
Microcyclops dengizicus (Lepeschkin)								+			
M. sp. nov		+				+	+				
Mesochra baylyi Hamond					+						
Ostracoda:											
Diacypris fodiens (Herbst)		+		+		+			+		
D. *compacta*		+		+			+				
D. *dictyote* De Deckker		+		+							
D. *whitei* (Herbst)						+					
D. spinosa De Deckker					+						
Australocypris robusta De Deckker							+				
A. *dispar* De Deckker		+									
A. sp. novo						+			+		
Australocypris sp. (indet.)				+							
Reticypris clava De Deckker		+									
R. sp. novo								+			
Reticypris sp. (indet.)				+							
Platycypris baueri Herbst						+					
Mytilocypris praenuncia Chapman					+						
Isopoda:											
Haloniscus searlei Chilton		+	+	+			+				
Amphipoda:											
Afrochiltonia australis (Sayee)	+		+		+	+					
Insecta:											
Chironomidae								+			
Ceratopogonidae								+	+		
Tabanidae								+			
Stratiomyidae						+	+	+			
Tipulidae							+				
Anisoptera		+									
Zygoptera		+									
Coleoptera		+									
Arachnida:											
Agelenidae novo gen., novo sp				+							
Mollusca:											
Coxiella striata(Reeve)		+				+	+				
C. *glauerti* Macpherson		+				+	+			+	

Daphniopsis species (Fig. 5b), water-fleas, are not nearly as tolerant to high salinities as is *Parartemia zietziana,* and the highest salinity at which the genus has been recorded is 70‰ (but it does not normally occur above 60‰). Neverheless, the genus is widespread and common in salt lakes in Australia (Sergeev & Williams 1983). Unfavourably high salinities are overcome as resistant eggs within characteristic sacs, ephippia. Ephippial eggs result from sexual reproduction apparently induced, as in *Parartemia,* at least in part by rising salinities. For most of the time, however, it is parthenogenetic females which comprise the bulk of, or the total

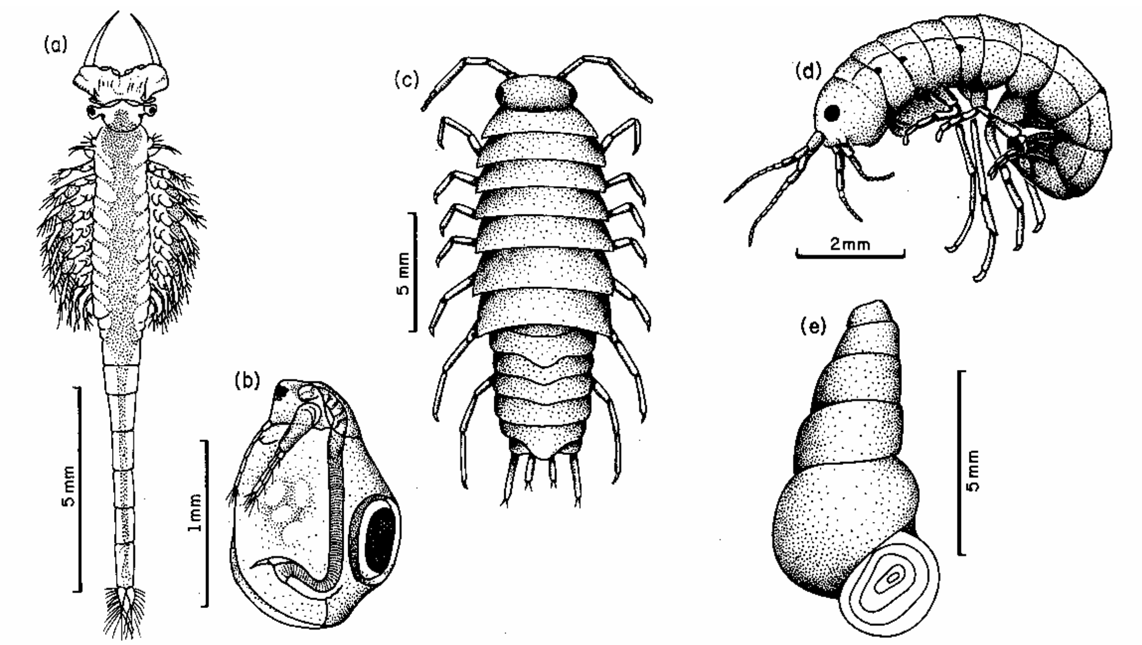


Fig. 5. Some common animals of salt lakes on the Eyre Peninsula. (a), *Parartemia zietziana*; (b), *Daphniopsis pusilla;* (c), *Haloniscus searlei;* (d), *Afrochiltonia australis;* (e), *Coxiella striata.*

population. Ephippia are small <1 mm), brownish to black oval bodies which may often be found in large numbers in the sediments of salt lakes during the dry season. The genus is closely related to *Daphnia,* the best known of all cladocerans. *Daphniopsis* is not endemic to Australia, but is found elsewhere only in a small part of Asia and on some Antarctic islands (there is also an unpublished record of its presence in South America). The most frequent Australian species appears to be *D. pusilla,* a species found in both halves of the Australian continent.

Haloniscus searlei (Fig. 5c), the salt lake slater, is perhaps the most interesting of all salt lake animals. It can tolerate salinities between ~4 and *192‰,* is a powerful osmoregulator, and can descend to depths of 14 metres in deep salt lakes. Its origins, however, are clearly terrestrial, its relationships being with the oniscoid isopods, the wood slaters. Moreover, since it is a peracaridan crustacean, its eggs are produced in a marsupium under the female thorax and are not resistant to desiccation. Resistance to desiccation during the summer in those ephemeral lakes where the species occurs is confined to the adult. Detailed observations of these resistant adults have not been made, but it appears that they survive in the damp microclimate beneath stones, under mats of vegetation (e.g. of *Ruppia),* and in similar situations. *Haloniscus* is found only in Australia and, with the possible exception of another genus in Turkmenia (for which exact information is lacking), is the only isopod to be found in highly saline inland waters. Its ecology has recently been reviewed (Williams 1983).

Finally, brief mention should be accorded *Coxiella* (Fig. 5e), the salt lake snail. Although two species are listed in Table 2, readers should be cautioned against placing too much reliance upon the identifications given. The facts are that despite the widespread distribution of species of this genus, their interesting ecology, and the endemicity of the family, the taxonomy is in urgent need of revision. The genus seems to be confined to saline lakes, but at least C. *striata* does not have good powers of osmoregulation: rather, it weakly osmoregulates at low salinities, osmoconforms at moderate salinities, and at high salinities isolates itself by closing its "lid" or operculum tightly (Mellor 1979). Individuals survive the dry season as adults with tightly sealed shells.

The flora has been so little studied that not much of a substantial nature can be said about it. It may be noted, however, that aquatic macrophytes are absent from the continental playas and scarce in the coastal salinas. We know most about Lake Pillie, due to the observations of De Deckker, Bauld & Burne (1982). In Lake Pillie, they recorded the charophyte *Lamprothamnium papulosum,* and the angiosperm *Ruppia.* Tentatively recorded from the microbial mat on the bottom of the lake were the algae *Phormidium hendersonii, Chroococcus turgidus* and, possibly, *Nostoc.* Photosynthetic sulphur bacteria were found in the bottom waters of sediment fissures.

The presence of microbial mats in salt lakes is always of interest because such mats and associated lithified sedimentary materials provide some of the oldest known fossil forms of life on earth. Of particular interest in this connection are stromatolites-laminated sediments accumulated on and between microbial filaments as an actively growing structure. However, whilst stromatolites are found in South Australia (in Marion Lake on the Yorke Peninsula and in some lakes near the Coorong; Walter & Preiss 1973, Warren 1892b) none has so far been found in lakes of the Eure Peninsula. Algal boundstone, i.e. sediments bound by algae, were noted by warren (1982b) in Sleaford Meer near Pt Lincoln.

ACKNOWLEDGEMENTS

The Australian Water Resources Council provided financial support for my investigations of saline waters on the Eyre Peninsula. This support is acknowledged. Dr J. K. Warren, University of Texas, Austin, is thanked for critical comments and useful discussion of a draft manuscript

REFERENCES

Bayly, I. A. E. (1967). The general biological classification of aquatic environments with special reference to those of Australia. *In* Weatherley, A. H. (Ed.). Australian Inland Waters and Their Fauna: Eleven Studies. (A.N.U. Press, Canberra).

Bowler, J. M. (1978). Glacial age aeolian events at high and low latitudes: a Southern Hemisphere perspective. *In* Van Zinderman Bakker, E. M. (Ed.). 'Antarctic Glacial History and World Palaeoenvironments. Proceedings of a SCAR symposium.' (Balkema, Rotterdam).

De Deckker, P, Bauld, J. & Burne, R. V. (1982). Pillie Lake, Eyre Peninsula, South Australia: modern' environment and biota, dolomite sedimentation and Holocene history. *Trans. R. Soc.* S. *Aust.* **106***(*4*),* 169-81.

Geddes, M. C. (1980). The brine shrimp *Artemia* and *Parartemia* in Australia. *In* Persoone, G., Sorgeloos, P, Roels, O. & Jaspers, E. (Eds). 'The Brine Shrimp: *Artemia.'* (Universa Press, Wetteren, Belgium).

Geddes, M. C. (1981). The brine shrimps *Artemia* and *Parartemia.* Comparative physiology and distribution in Australia. *In* Williams, W. D. (Ed.). 'Salt Lakes. Developments in Hydrobiology.' (Junk, The Hague).

Mellor, M. W. (1979). A Study of the Salt Lake Snail *Coxiella* (Smith) 1894, *sensu lato.* B.Sc. (Hons) Thesis, Department of Zoology, University of Adelaide (unpublished).

1982b) none has so far been found in lakes of the Eyre Peninsula. Algal boundstones, i.e. sediments bound by algae, were noted by Warren (1982b) in Sleaford Mere near Port Lincoln.

Sergeev, V. & Williams, W. D. (1983). *Daphniopsis pusilla* Serventy (Cladocera: Daphniidae), an important element in the fauna of Australian salt lakes. *Hydrobiologia* **100**, 293-300.

Walter, M. R., Golubic, S. & Preiss, W. V. (1973). Recent stromatolites from hydromagnesite and aragonite depositing lakes near the Coorong Lagoon, South Australia. *J. Sedim. Petrol.* **43**, 1021-30.

Warren, J. K. (1982a). The hydrological setting, occurrence and significance of gypsum in late Quaternary salt lakes in South Australia. *Sedimentology* **29**(5), 609-37.

Warren, J. K. (1982b). The hydrological significance of Holocene tepees, stromatolites, and boxwork limestones in coastal salinas in South Australia. J. *Sedim. Petrol.* **52**(4), 1171-1201.

Williams, W. D. (1983). On the ecology of *Haloniscus searlei* (Isopoda, Oniscoidea), an inhabitant of Australian salt lakes. *In* Hammer, U. T. (Ed.). 'Saline Lakes. Developments in Hydrobiology.' (Junk, The Hague).

Williams, W. D. (1984). Chemical and biological features of salt lakes on the Eyre Peninsula, South Australia, and an explanation of regional differences in the fauna of Australian salt lakes. *Verh. Int. Ver. Limnol.* **22**, 1208-1215.

10: Traditional Aborigines

by RONALD M. BERNDT

INTRODUCTION

Most of the information about the traditional culture of the people who originally occupied the Eyre Peninsula has disappeared entirely. Some people of Aboriginal descent still living identify themselves as belonging to at least two of the groups to which I shall refer-Gugada (Kukata), and Banggala (Pang kala). However, to learn something about the earlier socio-cultural life of the Eyre Peninsula people it is necessary to seek early sources. The most useful of these are the works of C. W. Schürmann, who first published on the Port Lincoln people in 1844, and of G. F. Angas (1847), who relied heavily on Schürmann The information is sparse; it is not based on systematic anthropological enquiry, and is often misleading. In the circumstances, it has to be interpreted in the light of more recent research in other parts of Aboriginal Australia. Fortunately, the historical accounts contain enough clues to make reasonably satisfactory 'interpretations possible.

The area demonstrates graphically the movement of members of various language units as 'cultural 'carriers'. The evidence points to a situation of territorial flexibility, especially apparent in regard to the Gugada, as contrasted with Tindale's (1974) insistence that there were normally clear-cut 'tribal' boundaries. This flexibility was certainly encouraged through early European settlement, which succeeded in dispersing local groups, but also provoked the movement of others who were not at that time so directly affected. It would seem, too, that speakers of Western Desert languages were entering this area well before European settlement.

My own interest in this region stems from having worked in 1939, 1940 and 1942 with Ngadjuri and Dieri men who had some knowledge of Banggala culture. In 1941 I obtained information on the Wirangu, and met some Gugada men, during field research at Ooldea.

THE LANGUAGE GROUP

Morehouse (in Taplin 1879) estimated the Aboriginal population of Port Lincoln at 400 in 1852; Taplin, however, questioned that figure, believing it to be higher; so did Eyre (1845). Poonindie mission station was established, and when the Adelaide Aboriginal school closed down in 1852 some of the children there, as well as young men and women, were transferred to the peninsula. By 1853 three 'grown-up' girls had 'married' local Aborigines, and the remaining boys and girls had 'fled to their bush relatives' (Hitchen 1859, Berndt & Berndt 1951). During this period, many Aborigines were still following a semi-nomadic life-style. On the basis of what we know of Aborigines in other areas during initial contact, it seems that the overall Aboriginal population of Eyre Peninsula did not exceed 2,000 persons.

Schürmann concentrated on the Banggala (Parnkalla); so did Wilhelmi (1861). According to Tindale (1974), Banggala country extended as far south as Franklin Harbour, then to Tumby Bay and into Port Lincoln with the establishment of European settlement; he mentions two divisions of this group. On their south he identified the Nauo as a separate group, but claimed that Banggala pressures had caused the Nauo to contract to the southwest. Schurmann (1879) seems to suggest that the Nauo were closely linked linguistically to the Banggala: for instance, that 'the Parnkalla dialect' resembled 'the Nauo language' although many words differed. One is reminded of the dialectal variations in northeastern Arnhem Land, or the 'language' entities that traditionally made up the so-called 'Narrinyeri' constellation of the lower River Murray. Information on cultural differences between Nauo and Banggala is, unfortunately, lacking, except that according to Angas (1847) the Nauo land of the dead was on islands in Spencer Gulf, while the Banggala located theirs on islands to the west, probably out from Coffin Bay Peninsula. But just what particular islands is not clear. If that information is correct, it could imply considerable movement and displacement of local groups prior to European contact. Howitt (1904) wrote of the Nauo or Willuro 'tribe'. This last word probably indicates direction *(wilurara,* a Western Desert word, or *wilyura* meaning west). Tindale (1974) says *wiljaru* is a Banggala word meaning 'westerners'. On the other hand, whether or not the Nauo originally occupied the western area of the Peninsula or were forced in that direction by the Banggala, the word *wilyura* or *willuro* could well have referred to the *wilyaru* ritual (see hereunder), which was central to Banggala and presumably to Nauo religious life. Interestingly, Bryant (1879) noted that the 'tribe' inhabiting the Gawler Ranges was called 'Wi lieu roo' and its ritual as *'willieroo'.*

On the northwestern side of the Peninsula were the Wirangu, on the coast south of the transcontinental railroad, roughly south of Ooldea and eastward to a little south of Streaky Bay (see Tindale 1974). They had experienced pressures from Western Desert people moving southward. Howitt (1904) had placed them wrongly, and used the names Tidni and Hilleri in the area where they had traditionally been located. Richards (1879) said the Tidni were at Fowlers Bay; but Tindale (1974) points out that both of these are Banggala and Gwiani (Kuyani) names for the Wirangu.

The Gugada (Kokata, Kukatha; *guga,* or *kuka,* variously spelt, means 'meat') were called Kukata by Schurmann (1879), who said they came from the north-west of the Peninsula and had a reputation for ferocity and for using sorcery. People at Ooldea in 1941 (Berndt & Berndt 1942) spoke of them as cannibals, whose white (grey) hair was a result of having intercourse with menstruating women. Provis (1879) reported similarly about the Gugada: the 'prevailing opinion' when he wrote was that they were cannibals before European settlement-but he had the grace to say that he doubted whether they actually engaged in this practice. However, he reported that menstruating women were segregated, and that if they were to remain in the same hut as a man, or men, the men would become grey-headed. Prior to 1878 (Provis 1879), Gugada were occupying country between Venus Bay and Point Brown, along the coast and inland to the Gawler Ranges; but he also said they were not restricted to that area and frequently came into Port Lincoln and Fowlers Bay. Tindale (1974), for example, writes of the Gugada (Kokata in his spelling) as occupying the Gawler Ranges, and claims that the term Ngannityiddi (Nganidjidi) mentioned by Schurmann (1879) was used by Nauo and Banggala speakers to indicate the Gugada propensity for sorcery.

According to the available information, then, while the Gugada traditionally came as far south as the north-western end of the Gawler Ranges and to at least part of Lake Gairdner, they were also spreading from the north-west into Eyre Peninsula prior to 1850 (Fig. 1). The evidence dealt with in this paper suggests that culturally, if not socially, they virtually overwhelmed, especially, the Wirangu, and were certainly making inroads into both Banggala and Nauo territories. On the northeastern side of the Peninsula, the Banggala were being forced southward to take over Nauo land. The Wirangu, essentially not a Western Desert population, had been forced southward by expanding Desert groups. While the Nauo were obviously influenced by (if not culturally akin to) the Banggala, it is tempting to speculate that the Wirangu and Nauo were protohistorically the original inhabitants of a large part of the Peninsula. The Banggala belonged culturally to the lakes Eyre and Torrens groups (that is, middle north and northeast Lakes people of South Australia). They traditionally occupied the northeastern sector of the Peninsula. Information on, and from, the Wirangu and Nauo is very sparse indeed. That in itself is not a criterion of importance, of course: for a non literate people in a colonial situation, the chances of having anything of their culture 'preserved' in writing were mixed, and quite variable. Nevertheless, on the face of the evidence available to us today, we must conclude that at the time of early European settlement on the Eyre Peninsula the two dominant Aboriginal socio-cultural systems were Banggala and Gugada.

SOCIAL RELATIONS

Surviving members of the once spatially extensive Wirangu language group, some of whom I met at Ooldea in 1941, were far too heavily jnfluenced by Western Desert culture to be able to separate out their basic social categories and kinship terms. They did, however, make it clear that they regarded themselves as being different from the Western Desert people. Howitt (1904) is of no help to us in this direction. Daisy Bates (1918) supplied a Wirangu (Wirongu) vocabulary which includes a number of Western Desert words, although there are just as many that I am unable to identify, even allowing for dialectal variation. Her kin term listing conforms closely with Elkin's (1939) for the Gugada, while his comparative table (1940) demonstrates a number of differences which, again, are not of Western Desert derivation. According to Elkin (1939), the Wirangu (who in 1930 were said by him to number about 40) had alternate generation, Desert-type categories named *kudarataga* (covering persons of one's own generation level, and those of one's grandparents and grandchildren) and *tarbuda* (covering

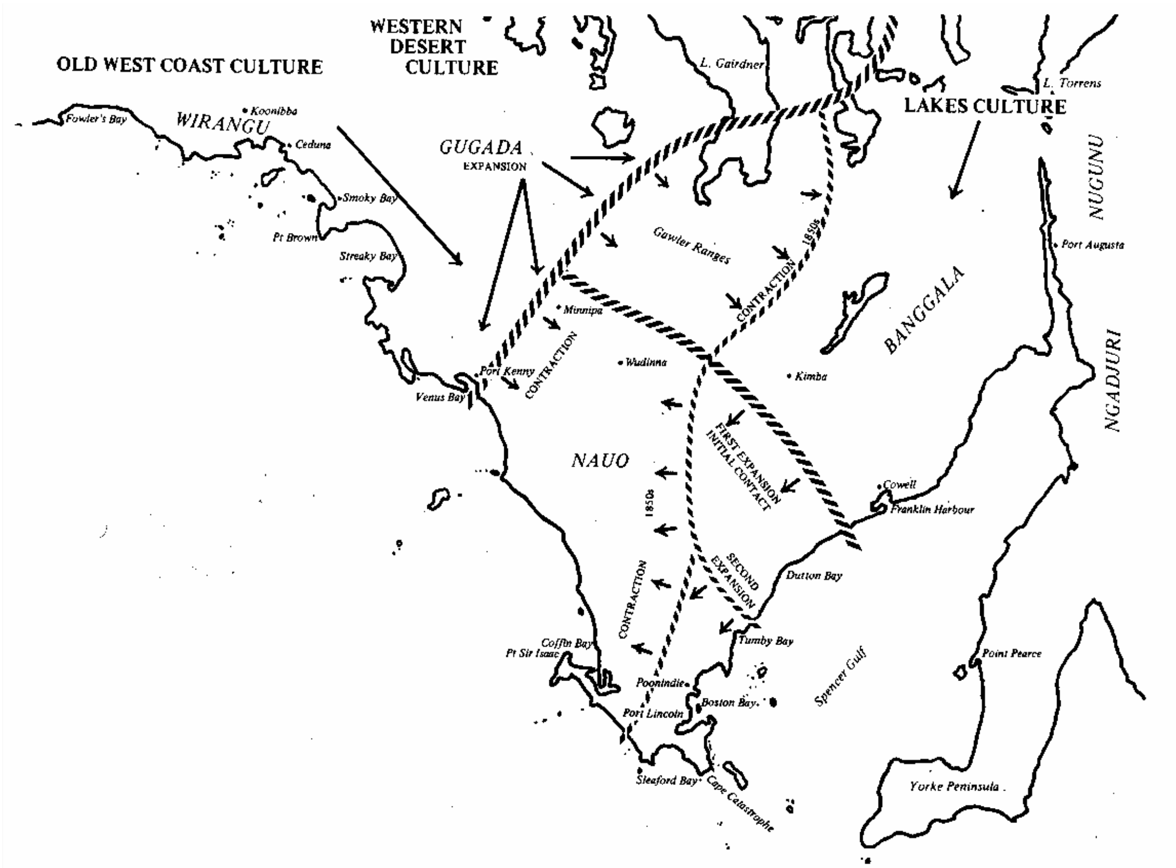


Fig. 1. Expansion and contraction of Aboriginal groups on Eyre Peninsula at the time of early European settlement.

persons of one's parents, great-grandparents, and children's generation levels); each category was endogamous; that is, the rule was marriage within categories, not between people in different categories. The kinship system was also of Desert type (Elkin 1939). So are the Gugada alternate generation levels and kinship system, discussed by Elkin (1939). At the time he wrote, the Gugada (Kukata) had been considerably depleted and numbered about 40 adults. However, from the perspective of Ooldea in 1941 that figure was much higher. The system was similar to that of the Andingari (Antakarinya) at Ooldea (Berndt & Berndt 1981), with only some slight terminological variations. Provis (1879) provided a short list of kin terms. While this bears some resemblance to Elkin's and the Berndts' material, there are major differences, which could perhaps indicate misunderstandings on Provis's part.

Essentially, the Gugada system utilizes a minimal number of terms to classify consanguineal and affinal kin; two in the grandparents and grandchildren's generation levels; and two in the parents' and children's generation levels, expanded to four where an avoidance relationship is implied. Ideally, a man was expected to marry a daughter of one of his mother's cross-cousins (her mother's brother's sons) and/or a daughter of one of his father's cross-cousins (his mother's brother's daughters); he would call such a prospective spouse *guri* (at Ooldea) or *waia.* From a female's perspective, she married a man who was ideally a son of one of her father's cross-cousins (his father's sister's daughters) and/or a son of one of her mother's cross-cousins (her father's sister's sons). A man or woman's cross-cousins, respectively, were regarded as being equivalent to siblings (Elkin 1939).

In the Banggala pattern, two exogamous ('marrying out') matrilineal moieties, *materi* and *gararu,* were important in all social contexts. Schurmann (1879) called them *mattiri* and *karraru;* Bryant (1879), *mathery* and *cariero,* regarding them as 'clans'; while Howitt (1904) called them *matthurie* and *kirarawa.* We can assume that each moiety was associated with several matrilineal 'totemic clans'. For instance, the

Ngadjuri (north of Adelaide), to the east of the Banggala, traditionally had matrilineal social groups, each associated with a natural species.

The Banggala system of kin terminology resembled that of the Wailpi (east of Lake Torrens), with some variations in local usage. According to Elkin (1938a), matri- and/or patri-cross-cousin marriage was traditionally the norm. It is obvious that the Banggala belonged to mainstream middle-northern social organizational patterning. While undoubtedly they were under direct pressure from Gugada intrusion, there is little evidence of this in their structural alignments. The case was very different, as we have seen, in regard to the Wirangu, where a process of incorporation had taken place.

The historical material provides little or no information about the territorial organization of the large-scale language units. Traditionally, the Gugada conformed more or less to the Western Desert pattern, which focused on small patrilineal local territorial descent groups having mythic associations with particular sites. On the other hand, the Banggala were solidly of 'Lake Eyre Basin' type: 'social' clans were matrilineal and 'ritual' clans were patrilineal, and the latter were directly linked to territory. It is not my intention here to go into any detail in regard to social organization. Nevertheless, according to my information, while a distinction was drawn between 'social' and 'ritual' clans, both were in fact social and both were ritual: the demarcation that has been made in the literature seems to have been based on a matter of emphasis. Two different terms were used (for example, as among the Dieri: see Berndt 1953): a man or woman possessed 'cult' (or ritual) mythic-natural species ('totemic') designations from father *and* mother; and that from a father was patrilineally inherited, but that from a person's mother was not passed on to his or her children. It would be more correct to speak of the former as social and the latter as personal. A man shared in the ritual manifestations of his mother's 'clan', but his primary religious commitment was to his father's 'clan'-and it was predominantly through this that the linkage with land was established.

ECONOMIC ADAPTATION

Except perhaps for the Gugada, the people of the region wore cloaks of kangaroo, possum and/or wallaby skin, especially in cold weather, turned fur-side outward during rain. Such cloaks were smaller than those worn originally by the Adelaide people, and the best of them were used by women in order to protect their small children (Schurmann 1879). Head- and waist-bands were commonly worn by men, who often placed a dingo's tail around the forehead or attached the tip of an animal's tail to their beards. In hot weather, men and women smeared their bodies with fat and ochres, or with soot from burnt grass-trees.

Weapons differed from those commonly used by Western Desert Aborigines. Hooked spears were for hunting land animals, short ones for fishing, and women had multi-purpose digging sticks. Various hunting and food-collecting techniques are mentioned in the early literature. For instance, men would surround shoals of fish in shallow waters and go spear-fishing by torchlight; they also used long thin boomerangs *(wadna),* which were not carried around but left at particular fishing places and used only for that purpose. Mountford (1939) described stone fish traps at Dutton Bay.

Men and women carried about with them what Schurmann (1879) called a *nurti* (or 'knapsack'), the larger ones belonging to women. They were made of skin or of net when they were lined with dry grass. Men carried theirs under the left arm with cords slung across the shoulder; women suspended theirs at their backs, secured by a band across the breasts. Schurmann provides a catalogue of what a man's *nurti* usually contained. Apart from weapons, there were a shell drinking vessel, a wooden scoop (for roasting roots), a round stone (for breaking animal bones), quartz knives with handles, ochres, sinew, bone needles, sharpened bones (for peeling roots), tufts of feathers (for decoration), beard tips, string fibre, spear-barbs, and so forth, along with food.

Food was divided into two categories: *mai* (vegetables and plants) and *baru* (all other foods, including meat). Not all varieties of fish were eaten, and not oysters, shell-fish or mushrooms. The only roots not cooked were those of the grass-tree. These, as well as pig's-face *(karkalla)* in season, were collected in large quantities . Termite-mound grubs were scooped up in handfuls and the 'rubbish' mixed up with them winnowed through a rounded bark receptacle (called *yuta,* and described by Schurmann, 1879). One vegetable, the *nondo* bean, which grew prolifically on the sandhills, was highly prized by people living at Coffin and Sleaford Bays. Large numbers of them would assemble in early summer to collect and eat *nondo.* Gugada people were reported to have threatened to burn or otherwise destroy this resource 'to aggravate their adversaries'. This statement is revealing, because it means that Gugada not only came down to the farthest part of the Peninsula but were regarded as intruders. Moreover, the threat suggests that they themselves were not attracted to this particular food resource.

Generally, a fairly wide range of *mai* and *baru* was available, too many to discuss in detail. The local Aborigines seem to have been reasonably well adapted to their environment, and were selective in their choice of foods. The relatively harsh winter period was offset by their constructing more substantial living quarters and protecting themselves from the cold and wet through the plentiful use of furs. Moreover, what they carried round in the *nurti* gave them ready access to essential equipment for everyday purposes.

Associated with food resources and their use-apart from questions as to when and where they were collected, by whom and how they were prepared, and the particular regulations and obligations which prevailed-there were what Schürmann (1879) called charms or 'imprecations'. These were used to 'remove the game from common use'--bringing it into a ritual context, or making it sacred. Moreover, there were age and sex-linked restrictions on the eating of particular foods. For instance, bandicoots should not be eaten by young men and women, on the grounds that doing so would discolour the beards of youths, or induce premature menstruation for girls. On the other hand, goanna and lizard meat was said to accelerate maturity, while snake meat would ensure that females were-fertile.

MARRIAGE AND THE FAMILY

I have already mentioned the dominant ideal marriage types which probably applied in this area. However, with Gugada intrusion on one hand and the expansion of alien settlement on the other, together with the introduction of non local Aborigines at Poonindie, adherence to a distinctive traditional custom would have become increasingly difficult. Nevertheless, it should have been possible to maintain the rules of marriage within one's own generation level (as with the Gugada and the Western Desert people) and moiety exogamy (as with the Banggala), long after actual contact with Europeans.

Schürmann's material, as noted, mainly referred to the Banggala. Both he and Provis mentioned polygyny (three wives being usual, rarely more), and pre-puberty betrothal for girls. It was usual, too, for a first wife to resist her husband's acquisition of a second or a third. Schürmann (1879) also mentioned 'wife-lending'. A distinction was drawn between 'own' wife or wives *(yungara,* Banggala: *yunga* Elkin 1938) and *karteti,* this last term referring to women over whom a man had a 'secondary claim, by right of brotherhood'. Provis, however, spelt *karteti* as *kurdet-thi* and said it meant a 'future wife'--that is, one who actually was or would be betrothed. Howitt (1904) took up this point and (quoting Schürmann) identified this marital arrangement as a manifestation of the Dieri *pirrauru (pirauru),* which he saw as a form of 'group marriage'. I do not intend to expand on this aspect here, since it has been the subject of much discussion and controversy over the years, especially during the early period of Anthropology. Elkin (1938b) referred to this custom as being relevant to the Wirangu. However, looking at the available information on the Wirangu, it does not seem to me that this identification can be made. That aside, the Banggala example conforms with the Lake Eyre Basin language groups-but, in this case, *not* as 'group marriage'. Rather, this is a straightforward case of institutionalized wife husband exchange, on a temporary basis, between 'brothers' who are categorized as such in actual or classificatory terms.

There is little detailed information on relations between husbands and wives. Husbands were said to be jealous when their wives engaged in extra-marital affairs without first seeking their approval. Most quarrels were said to have arisen from 'women not conducting themselves as they should do, or are often unreasonably required to do' (Schürmann 1879); from children quarrelling or hurting each other, which could cause conflict between their respective parents; and when food had not been equitably distributed according to kin obligations.

The number of children reared by a woman would not have exceeded four; and it was essential that their births be adequately spaced to ensure that no more than one child was suckled at the same time. This was taken (by Schürmann and others) to mean that some' children were killed at birth, but the frequency and range of this practice were not discussed. Children were named according to whether they were first or second born, and so on, a custom that was common among the Ngadjuri and other groups in the vicinity of Spencer Gulf and northward. Provis, however (1879), said they were also named after the place at which they were born. Since he is referring to the Gugada, this implies a child's association with a particular site (within a specific stretch of country) with mythic and ritual implications. On the other hand, the Banggala, apart from naming a child according to birth-order, had a personal naming procedure which took place during the initiation period (see below). Generally, at birth, a necklet consisting of a long tassel of possum fur twine was fastened round a child's neck and not removed until he or she could walk. This had its parallel in the Western Desert, where a similar ornament contained a child's umbilical cord.

RELIGIOUS ORIENTATION

Surprisingly, although the early literature is deficient in so many respects, in the sphere of religion it is quite detailed and, what is' more, conforms with information from later field research. For convenience, I refer to two aspects: mythology and initiation.

Mythology:

The Marrlye, called by Schürmann (1879) a 'fiendish monster', was manifested in bird form and was responsible for eating the hearts of people at night or doing them some serious injury. No mark was left on its victim to show what had been done, and the suggestion was that this was really sorcery performed by Gugada. On the other hand, Howitt (1904), referring to the Yerkla-mining (that is, the Mirning of Tindale), said that a great bird devoured all the people excepting three men and one woman, and that this was apparently a myth connected with circumcision. He also noted that the 'tribe at Fowlers Bay adjoins the Mirning, and at certain times of the year the two tribes have a ceremonial meeting'. This would probably refer to the Wirangu, and during such a meeting initiation rituals would be held. Under these circumstances, it is likely that the story of the Marrlye could be transmitted to groups farther south. But the Ngadjuri, too, told of a huge mythic spirit-creature which they called *mirlgi.* In this case, its bird-like qualities were not emphasized.

Another such being said to be found in great numbers was Purkabidni, a giant who killed human beings with his club.

The myths were of a different order. Schürmann recorded five of them (1879), and two of these (3 and 4) were also mentioned by Angas (1847). I summarize these in my own words.

1. Pulyallana named many localities in the southern and western parts of the Peninsula. His two wives left him, taking their children. In a rage he followed them, and eventually found them at Cape Catastrophe (on the southern point of what is now the Lincoln National Park), and killed them. Their bodies were metamorphosed there as rocks and islands: their breathing and groaning can still be heard, in a cave into which the sea rushes underground. Pulyallana himself went into the sky at or near Puyundu (Cape Sir Isaac) at Coffin Bay, where he became Lightning and Thunder man because of his anger. From the sky, he throws his clubs earthward, causing lightning strikes. When he first did this, he always struck down circumcision novices. But the ancestors persuaded him instead to hit sheoak trees. The lightning results from Pulyallana jerking open his legs in his spasms of anger.

2. Kupirri, a large red kangaroo (such kangaroos not being found in the Port Lincoln district at that time), was so large that no one could catch him. Instead, Kupirri ate all the persons who attempted to spear him. Eventually two renowned hunters, Pilla and Indya, found his tracks on the range stretching to the north, near Port Lincoln. They followed these and came upon him asleep at Mt Nilarro. They threw one spear after another, hitting Kupirri until their spears were blunt; but he remained alive. In frustration, the two men quarrelled and fought. Pilla hit his companion all over his body with the blunted spears, while Indya hit the other's nose with his spearthrower. Eventually, resolving their argument, they turned their attention again to Kupirri and this time killed him dead. When they cut him open, they found within him all the people he had swallowed. The two men revived them, cut up the kangaroo, cooked it and feasted on its flesh. Then they went in search of their wives and relatives, who were mourning their death. Later the two men turned into possum and native cat, each bearing the marks that were inflicted on them during their fight.

3. A large fire emerged from the western ocean and spread along the coast between Coffin and Sleaford Bays. The fire was so severe that it threatened to extend inland across the country. Two men, Marnpi and Tatta, decided that the only way to extinguish it was to 'bury it'. They set to work and covered the fire with a long line of white sandhills (which Flinders mistakenly identified as white cliffs) between the two bays.

4. A great fighter named Curlew (Welu) sought Nauo women by trickery. However, he was foiled in this, and in revenge he speared all Nauo men except for two young men, Karatantya and Yangkunu (two different kinds of hawk; but probably the latter is *junguna,* or *yunguna,* a white cockatoo: see Bates 1918). In fear, these two men climbed up into the higher branches of a tree. When Welu came after them and stood on a bough, stretching out to reach them, the two men broke it so that Curlew fell to the ground injured. A camp dog found and killed him, whereupon he 'turned into' a curlew bird. The other two remained in the tree where they became birds.

5. Two mythic lizards, Ibirri a male and Waka a female, were credited with demarcating

between the sexes in physical terms. In a traditional, non-mythic context, Aboriginal men killed *waka* lizards, and women killed *ibirri* lizards. Schürmann saw this as representing a symbolic expression of antagonism between men and women.

These myths provide an example of local mythology which purports to explain particular natural phenomena and why things are as they appear to be, but the sample is too small to go further than this. They seem to be distinctively Banggala and/or Nauo. In the second and fourth, parallels could be drawn with Western Desert mythology; but, except perhaps for the first, there is no indication of any linkage with substantiating ritual; nor, as far as I can see, are there any references to, for example, cave paintings (as described by Mountford 1957, at Cowell).

Ritual:

The most detailed aspect of Schürmann's account (1879) has to do with three ritual 'levels' through which a male novice had to pass; there is no comparable reference to female initiation.

The first, the *warrara* (a term which was used to indicate the novice at this stage), focused on the shedding of blood. Schürmann reported that he did not witness this ritual, but was told that men 'were very jealous of strangers being present, from fear that through them the women and children might become acquainted with the mysteries'. Provis (1879) made the same point: he was told what he recorded by a man named Shangilti. The second sequence, *pardnapa* (also indicating the novice), related to circumcision. Schürmann held that subincision took place during this second period or as an adjunct to it. The third stage was regarded by him as the most important: this was the *wilyaru,* which involved cicatrization, and the young men going through this ritual were called *wi/ya/kinyi.* Schürmann had seen this twice. Provis, however, placed the initiatory sequences differently: cicatrization, he said, came first, followed by circumcision and then subincision. Provis's information, it will be recalled, related to the Gugada, and his sequence of events correlates more or less with Western Desert procedure. Schürmann's sequence was more directly Banggala. Both accounts are, therefore, reasonably correct. The Wirangu (see Berndt & Berndt 1943), too, considered cicatrization to be paramount, as did several language groups within mainstream 'Lakes culture'. Interestingly, in recent (1983) claims made by Gugada-identifying Aborigines for protection of particular traditional sites in the Roxby Downs dam area, the *wilyaru* was also emphasized. In passing, it can be mentioned that western cultural pressures toward the east in relation to subincision did not proceed beyond the top of the eastern shores of Spencer Gulf, and included the Banggala as well as their neighbours, the Nugunu. Howitt (1904) gave a description of the Dieri *wilyaru,* and outlined the Yuri-ulu myth of the Urabunna (Arabana) and Kuyani (Gwiani) which spread southward toward (and into?) Banggala territory. A fragmentary version of that myth was also told to me in 1940. Incidentally, Howitt (1904) reproduced Schürmann's description of the three rituals. For our purpose here, a summarized outline only will be given of each of these rituals.

The three (actually four, if we regard subincision as ritually separate) initiation sequences vary structurally, although some of the dancing or ritual posturing is, or appears to be, similar. On the basis of what we know of such rituals in contiguous areas, they were organized according to restrictions on the bases of age and sex, and emphasized the acquisition of religious knowledge. They concerned the gradual revelation of such information and its meaning over a period of several years, each grade being punctuated by physical actions, not only *vis-a-vis* the novices but also (in regard to blood-letting) on the part of postulants. Novices were secluded once they were taken from the main camp (from the influence of women), and their faces and shoulders painted with black 'ochre'; they had to observe particular tabus and not speak loudly, only in whispers. On the conclusion of each stage, some outward manifestation indicated the ritual status they had attained. Such signs had to do with the way their hair was worn (for instance, drawn up into a bun, the hair being piled up on an emu feather pad coagulated with various substances, and surmounted with a net cap).

There was no ritual tooth-evulsion in the Spencer Gulf area, although Provis reported that it was common among people living north of the Gawler Ranges: that is, among Gugada. The outward marks of ritual status, as far as youths were concerned, also included their being given (at final initiation, the *wilyaru)* a girdle or waistband, arm bands, and a necklet of possum fur string, a length of which hung down behind a youth's back to be fastened to the waistband. The breaking of this string did not take place until the final seclusion period had been completed and the youths anointed with blood. They were then regarded as social *adults-junior* adults. The actions of participants, in the rituals that were held on such occasions, indicate that these had mythological significance: but no early reference considers this point. One feature which is mentioned on several occasions by Schürmann, and which took place in ritual procedure as well as in ordinary fighting, was of participants biting their beards in order to simulate anger. (This was also a characteristic of northern coastal Arnhem Land people.)

In the *warrara,* apart from anointing a novice's body with blood, a rite which also involved him sipping some, a 'whip' bullroarer was used. This secret-sacred object (a *pullakali)* had attached to it a length of cord, which, in turn, was fastened to one end of a stick. The stick would be held by the other end, the cord twisted around it, and then released like a whip. In contrast, during the *wilyaru,* ordinary bull roarers *(witarna;* Ngadjuri, *wetana)* were swung, and one of these was placed by its cord round the neck of each postulant on the conclusion of this sequence. In both the *warrara* (preliminary) and the *pardnapa* (circumcision) rituals, one implication was that women played an important part during the proceedings. For instance, men returning to the main camp with *warrara* novices carried live coals on pads of grass, and on arrival threw these into a heap before the women. Also, one of the women rubbed the partly congealed blood from the back of a youth with her cloak before he ran between a double line of men. With reference to blood, Schürmann (1879) claimed that women must not see a man bleeding, even in ordinary circumstances, and were themselves 'not allowed' to bleed ritually. Blood was apparently considered to be a life-essence; when releasing blood to relieve a severe headache, a man should not let it fall to the ground but should ensure that it ran over the body of another male person.

In the *pardnapa,* during the commencement of events leading up to the main ritual, men would follow certain women for some distance before they went their separate ways to hunt and collect food, to come together later in the initiation camp, from which they would subsequently withdraw. These women were of the same moiety as the novices, and before leaving the camp they would touch the shoulders and necks of men of their own moiety. On the initiation ground, men formed a human 'table' at the base of a tree where one of their number was perched in a forked branch. Novices were placed on the 'table', held down and, one by one, circumcised. The Ngadjuri *vadnaba* (that is, *pardnapa)* differed somewhat from Schürmann's description.

In the *wilyaru,* a youth knelt on his hands and knees and in that position was anointed with arm blood which, when partially congealed, was used as a guide to mark out where the cicatrizes would be cut: the design was followed in cutting with quartz flakes. One important feature of the *wilyaru* was what Schürmann called the 'inventing' of personal names by which initiates would be known on completion of these rites. According to Provis, during the actual cicatrization a further incision was made at the back of the neck and a leaf inserted within it: this signified, he said, that the new name had been placed within the youth. The Ngadjuri man with whom I worked in 1939-42 also told me that this 'name-giving' was an essential feature, not of the *wilyaru* but of the *vadnaba.* He was Barney Waria *(waria* meaning 'two'; that is, 'second born'). His ritual, 'given name' was Ngadlibuna.

TOWARD DEATH AND TRANSITION

Under this heading I bring together five aspects-medical attention, fighting, sorcery, death and the 'afterlife'--not only because the available information is slight, but because they belong to facets which concern the opposite side of ordinary everyday living, although an essential part of it. For instance, while quarrels-due to a range of circumstances-were common, serious fighting presumably led to injury and possible death, or at least required medical attention. On the other hand, while Schürmann made the point that not all deaths involved accusations of supposed sorcery, many would seem to have done so. Death, from the evidence available, suggested some form of transition, having to do with the deceased's soul.

Schürmann and Provis referred to various forms of treatment by Aboriginal doctors. Schürmann called them *mintapa.* Provis, however, used the word *mundabi* to refer to an 'evil spirit' believed to inflict illness-a word also used for the 'evil spirit' of a deceased person; this resembles the Western Desert concept of *mamu.* Whether or not *mintapa* or *mundabi* also meant a doctor is open to question, although Schurmann explained that *mintapa* were rare at Port Lincoln during his period there but were common among the Gugada. However, the Ngadjuri used the term *mindabu* or *mindaba* to refer to a 'spirit man', that is, an Aboriginal doctor.

In the matter of fighting, because of its serious nature, arrangements were made between the respective parties 'a long time' before the actual event took place. The main causes were said to be abduction of females, murder, physical injury and sorcery accusations. Examples supplied by Schürmann consist of confrontation, when members of both parties and their adherents exchanged abuse and, biting their beards or spears in anger, attacked each other by hurling spears. Severe injury or death from such fighting was rare. In fact, Schürmann emphasized that there was no urge to shed blood. Gugada were mostly blamed and feared for their sorcery and their belligerence, but SchOrmann noted that their reputation rested on sorcery rather than on fighting prowess. However, information on sorcery is meagre. One supposedly effective procedure was poking one's fingers (through a 'peculiar manipulation') into the side of an intended victim while simultaneously making an accusation. In one 'sorcery' example reported by Schürmann, the victim was a woman who had been bitten by a black snake. Her companion, another woman who was present at her death, insisted that she had revealed, just before she died, the name of her 'murderer'.

At Port Lincoln, burials were said to be accompanied by ceremonies. However, none of these were recorded, and Schürmann remarked (1879) that in the cases he witnessed they were 'dispensed with'. In one (presumably of Banggala type) the corpse, with legs flexed, was wrapped in a kangaroo skin and placed within a pit, its face toward the east in order to facilitate the soul's departure to the land of the dead. The pit was then covered with logs placed lengthwise over the aperture, with a mound of earth covering it. In another case (Provis 1879) probably of Gugada type, the hips of the corpse were broken and tied up in a sitting posture. It was then placed in a pit so that it, too, faced east. On this occasion all the deceased's possessions were buried with him, covered with grass and boughs and finally filled in. A semi-circular mound of earth with stones on top was assembled at the back of a swept area and extended over the grave, on which a large fire was kindled and kept burning for two or three nights in order 'to destroy the *mundabi* (spirit) which would otherwise injure living people'. While this varied from traditional Western Desert procedure, the two may be at least partly identified. For instance, in Western Desert explanations a fire at the grave was usually said to keep the deceased's spirit warm until it actually left its human vehicle; and the mound, in its conical form, symbolized the mythic Moon man who was killed by the Two Men (the Wadi Gudjara) in the creative era of the Dreaming. (See Berndt & Johnston, 1942 for examples, including a Wirangu burial). Moreover, the Gugada description suggests the possibility of later exhumation in order to divine, ritually, the person or persons responsible (through sorcery) for the death. However, the placing of the dead person's possessions in the pit suggests a Wirangu rather than a Desert traditional custom.

Schürmann's example of a burial, although said to be Banggala, could well have been Nauo, since the corpse was arranged in the pit facing east. The Banggala land of the dead was said to have been located in the west (see above). However, not too much attention should be paid to that point, since Western Desert corpses were, from all accounts, usually arranged in their graves to face east. Schürmann emphasized that there was 'more than one receptacle for departed souls'. On its journey to the land of the dead, the spirit was said to have been accompanied by a species of red-bill (apparently a sea bird); but Schürmann also suggested that the land of the dead was a temporary abode where the spirits awaited their eventual rebirth-that is, their return to the living. Both Schürmann and Angas gave examples where ancestors of local Aborigines were said to have returned in the guise of Europeans. For instance, several Europeans at Boston Bay (Port Lincoln) were believed by Aborigines to be spirits of their deceased relatives, and called by the personal names of these 'previously dead' kin. In another case, an Aboriginal named Ngarbi of Port Lincoln, who was 'executed' in Adelaide, said before he died that he would return as 'a white man'. Schürmann suggested that this belief was 'modern', not traditional. There are, however, plenty of such examples from other parts of Aboriginal Australia. They may perhaps be interpreted as devices to account for the presence of strangers, underlining their ambivalent attitude toward Europeans: afraid of them as spirits, dangerous, powerful and strange, but attempting to bring them within the range of human familiarity as 'relatives'.

CONCLUSION

As I have shown, there is enough material available to enable us to obtain a glimpse of the traditional Aboriginal scene on the Peninsula in the early part of the nineteenth century. Two primary cultural orientations are evident, one of which (Gugada) was intrusive prior to European settlement. While identification of one culture (Gugada) in contrast to the other (Banggala, either separately or in conjunction with Nauo) cannot always be made, it is reasonably clear in so far as social organization, initiation ritual and burial customs are concerned. Myths (or, rather, those few that have been recorded) appear to be distinctively of Eyre Peninsula origin, except for one; but the number available is far too small to be at all definite. However, there were actually *three* and not only two cultural streams: the Banggala, linking up with the northeastern Lakes constellation; the Western Desert, represented by the Gugada; and the Wirangu, which belonged to the 'old' West coast culture. The Bates material (1918) could repay more consideration from. a linguistic viewpoint (in relation to Wirangu), while space does not permit detailed treatment of Wirangu myths which I obtained at Ooldea in 1941.

What has been presented here is a reconstruction of some features of the traditional life of the Eyre Peninsula people, without much consideration of the tremendous changes that were taking place in all aspects of their living. In fact, the period when Schürmann and others were observing, and writing, there, marked the beginning of rapid disintegration and dispersement of the full-Aboriginal population and, gradually, the disappearance of the greater part of their culture.

In 1860, excluding Poonindie, there were three ration depots: at Port Lincoln (643 persons); Franklin Harbour (118) and Venus Bay (510). These were police depots, and the number of persons noted refers only to those who received rations. In the South Australian Aborigines' Department Return for 1866, similar depots are mentioned for Fowlers Bay, Streaky Bay and Poonindie, but without population figures. The disastrous history of the Poonindie mission is to be found in the South Australian Parliamentary papers for 1857-60. One of these (1859) states that the report it contained presented 'to the world ... the only successful experiment of civilizing and Christianizing the Aborigines of Australia ... It is a happy and well-conducted moral and religious community'. At that time there were 60 'inmates', and a number of people living in the bush were also said to be supported by the mission.

For the other side of that story and of the general conditions of Aborigines within the Port Lincoln and adjacent areas, we must turn to the Aborigines Select Committee's report for 1860. Poonindie was partially 'colonized' by children and young people from Adelaide and adjacent areas. That mission, as I have said, was short lived; many of its 'inmates' returned to their home territories, and some eventually made their 'home' at Point Pearce, which was established in 1868 (known earlier as the Yorke Peninsula mission; Point Pearce is also spelt 'Pierce'). See, for example, the Protector of Aborigines report for 1907 where a photograph depicts 'three generations of Pt Pierce Aborigines'. The two men shown in this are Tom Power and Phil Welch, who originally came from Poonindie. This particular photograph was the subject of an enquiry made by Doreen Kartinyeri (1983), who identifies the man standing on the left as Robert Wanganeen; Barney Waria, however, in 1939, identified him immediately as Tom Power, but did not know the names of the two women and child, although there is common agreement on the name of the other man. The photograph to which I refer was entitled 'three generations....'; Mrs Kartinyeri, however, refers to 'five generations...' (For further references to Point Pearce (or Pierce), see Gale (1972).)

By the 1860-70s, most of the local Eyre Peninsula Aborigines who remained in this area were established in fringe camps and/or working for European settlers. Just when the Gugada visitors ceased coming southward is not clear. Certainly, the South Australian government reports from the turn of the century do not specifically note by name, as far as I can see, ration depots within the main area of the peninsula. However, the reports and returns for 1899-1900 (with reference to Aborigines in settled districts of South Australia, 1900) mention that 250 Aborigines arrived at Fowlers Bay from Wilgena (near Tarcoola) and the Gawler Ranges: these people were most likely Gugada, but there are no references to their having gone southward. No doubt, a number of Aborigines (either of local origin, or having come in from elsewhere) remained in the district.

By 1946 (according to a report of the South Australian Aborigines' Protection Board) rations continued to be distributed in the 'western division', 'to old and infirm Aborigines as and when required', while 'a considerable number of men' were employed at Port Lincoln (Product Department) and at Wudinna on the Eyre Highway (Engineering and Water Supply Department). A map produced by the Division of National Mapping (1982) continues to designate Poonindie as Aboriginal leasehold land. There are also three other similarly held properties at Streaky Bay and Ceduna (Duckponds and Poverty Flat). The Aboriginal population at Port Lincoln is given as not being under 80, but not exceeding 300 persons. On the northeast of the Peninsula are the Aboriginal settlements at Port Augusta and Bungala; on the north-west at Koonibba and Yalata.

Probably the best overall compilation of ethnographic resource materials (but not specifically concerning the Eyre Peninsula region) is the anthropological baseline studies literature review (Sutton Partners 1981), which was prepared in relation to the Olympic Dam project, north of Woomera (see also Berndt 1983). While it is not possible to be categorical regarding the traditional southern boundary of the Gugada, it would seem reasonable, on the basis of early accounts, to suggest that it was on the northern reaches of the Gawler Ranges, which indent the north-western boundary of the Banggala (see Tindale 1974, who notes that the Kokada or Gugada were 'the so-called Gawler Range tribe').

The material in this paper, apart from surveying, redigesting and interpreting historical information in the light of anthropological understanding of Aboriginal traditional life, offers a brief glimpse of what the Aboriginal scene was like in the early days of European settlement in that area. There are undoubtedly, and unavoidably, considerable gaps. However, for Aborigines of today who may claim descent from the people who originally occupied this region, I hope that it will prove a contribution to their own heritage. In a sense, what we have here is a statement about the destruction of a people and their culture-people who, under happier and more enlightened conditions, could have coped quite well with the changes which came upon them, but who did not have any real opportunity to do so.

POSTCRIPT

I wish to thank Dr Louise Hercus of the Faculty of Asian Studies, Australian National University, for her kindness in reading through and commenting on the manuscript of this Chapter. Dr Hercus has carried out research for a considerable period on the languages of the Lake Eyre Basin; and she agrees with me that a great deal more work is needed in so far as the 'Lakes area' is concerned, and that includes Banggala. She informs me that Mrs Phyllis Croft (of Iron Knob) has knowledge of Banggala stories and traditional sites; her husband Harry, now deceased, was a Banggala speaker. Information of this nature is disappearing very rapidly indeed and needs to be recorded. Ms Rosemary Buchan of the Heritage Unit, Department of Environment and Planning, has expressed interest in doing this and should be encouraged. Dr Hercus notes that Myth 2, concerning Possum and Native Cat is widespread and was known also to Arabana people; and that in Myth 3, Marnpi is the name of the bronze-winged pigeon, known by that name throughout the Lake Eyre Basin. (Murnpeowie, for instance, gets its name from this bird, meaning pigeon/water; *murnpie* in Gason, in Woods ed. 1879, and *mernpe* in Wyatt, in Woods 1879).

Dr Hercus also referred to the subdivision of Banggala that was noted by Tindale (1974). He said that two such divisions were recognized: one, the Wartabanggala, originally occupied country north of Port Augusta and extending to Ogden Hill and almost to Quorn and Beltana; the other, the Malkaripangala, was located along the western side of Spencer Gulf. The existence of such a division, says Dr Hercus, was confirmed by one of the last knowledgeable Banggala men, Moonie Davis. I should explain that I did not include this information in my Chapter for a couple of reasons. I was not clear whether these two terms, each with its language name prefixed, constituted a territorial positioning or a language/dialect division. In other words, their social connotation was obscure and will probably not be elucidated until we know the meaning of each prefix.

Although my contribution does not discuss, to any extent, relations between Eyre Peninsula Aborigines and European settlers, I should add one reference to this. J. W. Bull (in his volume, *Early Experiences of Life in South Australia and an extended colonial history,* Wigg, Adelaide 1884, Book III, Chapters IV and V: 289-303, 307-10) outlines the history of hostilities between Port Lincoln and other Aborigines and settlers prior to 1843, which included military expeditions being sent from Adelaide. Such actions on the part of both peoples set the pattern for the rapid disintegration of Eyre Peninsula Aboriginal society and culture.

REFERENCES

Aborigines' Department (1866). 'Return'. (South Australian House of Assembly, Adelaide.)

Aborigines Office (1900). 'Reports and returns for 1898-1900 with reference to the Aborigines in the settled districts of South Australia'. (Government Printer, Adelaide.)

Aborigines' Protection Board (1946). 'Report', No. 20. (South Australian House of Assembly, Adelaide.)

Aborigines Select Committee (1860). 'Report of the Select Committee of the Legislative Council upon "The Aborigines"; together with minutes of evidence and appendix'. (Government Printer, Adelaide.)

Angas, G. F. (1847). 'Savage life and scenes in Australia and New Zealand'. (Smith, Elder, London; Johnson Reprint, 1967.).

Bates, D. M. (1918). Aborigines of the west coast of South Australia. Vocabularies and ethnographical notes. *Trans. and Proc. R. Soc.* S. *Aust.* **42**, 152-67.

Berndt, R. M. (1953). A day in the life of a Dieri man before alien contact. *Anthropos.* **48**, 171-201.

Berndt, R. M. (1983). Report on the Olympic Dam mining project in relation to Aboriginal interests. (For the South Australian Heritage Conservation, Department of Environment and Planning and the Kokatha People's Committee.) Unpublished.

Berndt, R. M. & Berndt, C. H. (1942). A preliminary report on field work in the Ooldea region, western South Australia. *Oceania.* **12**(4), 305-30.

Berndt, R. M. & Berndt, C. H. (1943). A preliminary report on field work in the Ooldea region, western South Australia. *Oceania.* **13**(3), 243-80.

Berndt, R. M. & Berndt, C. H. (1951). 'From black to white in South Australia'. (Cheshire, Melbourne.)

Berndt, R. M. & Berndt, C. H. (1981). 'The world of the First Australians'. (Lansdowne Press, Sydney; first ed. Ure Smith, Sydney, 1964; revised ed. Rigby, Adelaide, 1985.)

Berndt, R. M. & Johnston, 1. H. (1942). Death, burial, and associated ritual at Ooldea, South Australia. *Oceania.* **12**(3), 189-208.

Bryant, J. (1879). 'Gawler Ranges'. *In:* Taplin, G. (Ed.) 'The folklore, manners, customs, and languages of the South Australian Aborigines: gathered from inquiries made by authority of South Australian government'. (Spiller, Govt Printer, Adelaide; Johnson Reprint, 1967), 103.

Division of National Mapping (1982). 'Aboriginal land and population'. (Commonwealth of Australia, Map 12, Canberra.)

Elkin, A. P *(1938a).* Kinship in South Australia. *Oceania.* **8**(4), 419-52.

Elkin, A. P *(1938b).* Kinship in South Australia. *Oceania.* **9**(1), 41-78.

Elkin, A. P. (1939). Kinship in South Australia. *Oceania.* **10**(2), 196-234.

Elkin, A. P (1940). Kinship in South Australia. *Oceania.* **10**(3), 295-349.

Eyre, E. J. (1845). 'Journals of expeditions of discovery in Central Australia and overland from Adelaide to King George's Sound, in the years 1840-41'. (London.)

Gale, F. (1972). 'Urban Aborigines'. (Australian National University Press, Canberra, for the Academy of the Social Sciences in Australia.)

Hitchen, E. W. (1859). 'Report on Poonindie mission'. (Parliamentary Paper No. 30, Adelaide.)

Howitt, A. W. (1904). 'The native tribes of south-east Australia'. (Macmillan, London.)

Kartinyeri, D. (1983). Recording our history (as told to M. Gale) pp. 136-57. *In:* Gale, F. (Ed.) 'We are bosses ourselves: the status and role of Aboriginal women today'. (Australian Institute of Aboriginal Studies, Canberra.)

Mountford, C. P (1939). Aboriginal methods of fishing and cooking. *Mankind* **11**(7), 196-200.

Mountford, C. P (1957). Cave paintings in South Australia. *Rec.* S. *Aust. Mus.* **13**(1), 101-15.

Parliamentary papers (1857-1860). 'Report on Poonindie Mission'. (No. 136 of 1857; Nos. 150 and 177 of 1858; No. 30 of 1859; No. 96 of 1860, South Australian House of Assembly, Adelaide.)

Protector of Aborigines (1907). 'Report for 1906'. (Government Printer, Adelaide.)

Provis, C. (1879). 'The tribes of the western district' pp. *93-101. In:* Taplin, G. (Ed.), 'The folklore, manners, customs, and languages of the South Australian Aborigines: gathered from inquiries made by authority of South Australian government'. (Spiller, Govt Printer, Adelaide; Johnson Reprint, 1967.)

Richards, P-1. (1879). 'Fowlers Bay', p. 103. *In:* Taplin, G. (ed.), The folklore, manners, customs, and languages of the South Australian Aborigines: gathered from inquiries made by authority of South Australian government.' (Spiller, Govt Printer, Adelaide; Johnson Reprint, 1967.)

Schurmann, C. W. (1844). 'A vocabulary of the Parnkalla language as spoken by the Ilatives of Spencer's Gulf'. (Adelaide.)

Schurmann, C. W. (1846). 'The Aboriginal tribes of Port Lincoln'. (Adelaide.)

Schurmann, C. W. (1879). 'The Aboriginal tribes of Pt. Lincoln in South Australia. Their mode of life, manners, customs, etc.', pp. 209-51. *In:* Woods, J. D. (Ed.), 'The Native Tribes of South Australia" (Wigg, Adelaide).

Sutton Partners (1981). 'Anthropological baseline studies literature review'. (Olympic Dam Project Environmental Studies, Kinhill-Stearns Roger Joint Venture, Adelaide.)

Taplin, G. (Ed.) (1879). 'The folklore, manners, customs, and languages of the South Australian Aborigines: gathered from inquiries made by authority of South Australian government'. (Spiller, Government Printer, Adelaide; Johnson Reprint, 1967.)

Tindale, N. B. (1974). 'Aboriginal tribes of Australia. Their terrain, environmental controls, distribution, limits and proper names'. (Australian National University Press, Canberra.)

Wilhelmi, C. (1861). Manners and customs of the Australian natives, in particular of the Pt. Lincoln district. *Trans. R. Soc. Vict.* **5**, 164-203.

Woods, J. D. (Ed.) (1879). 'The native tribes of South Australia'. (Wigg, Adelaide.)

11: MARINE AND TERRESTRIAL ANIMALS

by C.H.S. WATTS and J.K. LING

INTRODUCTION

Europeans probably saw mammals in the seas off Eyre Peninsula long before they observed them on the land. Dutch navigators had penetrated as far east as Nuyts Archipelago off Ceduna by 1627, and in the course of their voyages would have seen seals (Pinnipedia) and whales and dolphins (Cetacea). By 1802 Matthew Flinders and Nicolas Baudin also would have seen both marine and terrestrial mammals in the region-the former possibly in great abundance.

In contrast, it was not until 1841 when Edward John Eyre penetrated inland that Europeans would have seen much of the terrestrial mammals. Unfortunately they recorded few of their observations. Tragically, within 50 years some 30-40% of the species of terrestrial mammals living when Eyre first crossed the Peninsula had vanished from the region. There is scant hope that populations of these species will ever again be seen there. In the seas the story is different and today huge southern right whales, dolphins and seals are seen fairly commonly around the Peninsula's coast, and there are many less common species of cetaceans and occasional seal stragglers.

MARINE MAMMALS

The earliest industries of the area, even before settlement, were whaling, sealing and fishing, and the remains of early sealers' huts and whaling stations may still be seen on some of the beaches and offshore islands. The South Australian Company, in addition to its operations at Encounter Bay on Fleurieu Peninsula, established whaling stations on Thistle Island at the foot of Spencer Gulf and at Sleaford Bay on the tip of Eyre Peninsula (Colwell 1969). Today the skeletal remains of whales and the occasional artefact found in the vicinity of these old whaling sites are reminders of earlier maritime enterprises.

All marine mammals are now protected in Australia under Commonwealth and State law, and the emphasis has shifted from exploitation to conservation.

In addition to seals, whales and dolphins seen alive in the waters and on land around the coast, many animals, particularly cetaceans, have been found dead and stranded on the sea-shore. The species of marine mammals recorded from Eyre Peninsula as either specimens collected and now held in the South Australian Museum or reliable sightings are listed in Table 1. This list probably is incomplete and more species of whales probably occur in the waters around Eyre Peninsula. Active 'whale watch' programmes should increase the number of recorded species.

BIOLOGY OF WHALES

Little or no research has been carried out on the cetaceans of the region, but as most species are cosmopolitan, something of the life histories of at least a few is known from other parts of the world.

The southern right whale *(Eubalaena glacialis)* was hunted intensively in the early nineteenth century from the various whaling stations around the coast and became a very rare sight indeed by the 1850s-so much so that it was believed to be almost extinct. In recent years, and particularly since 1983, there have been many reported sightings around Eyre Peninsula and the rest of the South Australian coast (Fig. 1), accounting for 200 or more animals. Cows of up to approximately 18 metres length accompanied by their 5- to 7-metre calves have been seen very close to shore in many shallow, sheltered bays, where they give the appearance of being in danger of stranding. However, this is a characteristic behaviour of nursing right whales which visit southern Australian shores during the winter and spring months. In summer they migrate to latitudes 45° to 50^{0}S, i.e. they are not true Antarctic or even Subantarctic forms. Their migration routes to, from and within Australia are not clearly understood, particularly whether there is a movement between the east and west coasts of the continent. Although individual whales may be identified by distinctive white patterns caused

Table 1 MARINE MAMMALS RECORDED FROM EYRE PENINSULA

Order and Family	*Genus and species*	*Common name*	*Remarks*
Cetacea	*Eubalaena glacialis*	Southern right whale	Becoming common
Balaenidae (Right Whales)	*Caperea marginata*	Pygmy right whale	Occasional strandings
Balaenopteridae	*Balaenoptera*	Minke whale	Occasional strandings
(Rorquals)	*Balaenoptera musculus*	Blue whale	Rare
Physeteridae	*Physeter macrocephalus*	Sperm whale	Occasional strandings
(Sperm Whales)	*Kogia breviceps*	Pygmy sperm whale	Occasional strandings
Ziphiidae	*Mesoplodon grayi*	Scamperdown whale	Occasional strandings
(Beaked Whales)	*Mesoplodon layardi*	Strap-toothed whale	Occasional strandings
Delphinidae	*Delphinis delphis*	Common dolphin	Common offshore
(Ocean Dolphins)	*Tursiops truncatus*	Bottlenose dolphin	Common inshore, occasionally
	Globicephala melaena	Long-finned pilot whale	Common at sea, occasionally
Carnivora	*Neophoca cinerea*	Australian sea lion	Locally common, but a threatened
Otariidae (Eared Seals)	*Arctocephalus torsteri*	New Zealand fur seal	Local small populations
Phocidae (Earless seals)	*Lobodon carcinophagus*	Crabeater seal	Rare visitor

Fig. 1. Southern right whale sighted at Merdayerrah, a few kilometres east of the SA/WA border.

by whale-lice covering the rough, thickened area (callosity) on the head, no intensive photographic surveys have been carried out around our coast to enable particular whales to be tracked successfully. Groups of as many as five right whales have been seen from the air near Fowlers Bay and pairs or singletons are now fairly common sights as they move almost from bay to bay around the Peninsula. They probably mate, give birth and suckle inshore. Studies in South America suggest a two- or three-year breeding cycle (Gilmore 1978). Right whales are surface-feeders on microzooplankton (cope pods) as well as larger euphausiids (krill), so their baleen plates are longer and the fibres finer and denser to trap their small prey.

Other whales mentioned in Table 1 include the abundant and friendly offshore common dolphin *(Delphinus delphis)* and inshore bottlenose dolphin *(Tursiops truncatus)* which feed on fish and squid and breed each summer. Forty-seven bottlenose dolphins stranded at Memory Cove in 1977, of which more than 20 were returned to the sea by human rescuers and the remainder were collected by museum personnel.

As well as these, several other species of small toothed and baleen whales have stranded on different parts of the Peninsula. The former include three species of beaked whales which are peculiar for their one or two pairs of variously shaped teeth on the lower jaw only, and the lack of a median notch on the trailing edge of the flukes. We know little of the life history of these most elusive forms: much of our information has been gained from studying stranded animals around the world in various stages of decay. So even their soft anatomy, reproductive biology and food habits have received little study and are not well understood.

BIOLOGY OF SEALS

South Australia's largest colonies of its two species of resident seals: the New Zealand fur seal *(Arctocephalus torsteri)* and the rare Australian sea lion *(Neophoca cinerea)* occur on islands off Eyre Peninsula. Moreover, the State's only mainland colony of sea lions is located at Point Labatt near Streaky Bay. The two species extend from Kangaroo Island to southern Western

Australia. There have been very few censuses of seal populations around the Peninsula. The last '"{as in 1983 and each species is now believed to number about 3000-5000 individuals-so they are not large populations.

Table 2. NEW ZEALAND FUR SEAL COUNTS AT SOUTH NEPTUNE ISLANDS 1969 AND 1970 (From Stirling 1971)

	JUNE 1969		*APRIL 1970*	
Category	*Actual*	*Adjusted*	*Actual*	*Adjusted*
Males	34	34	89	89
Females	340	596'	492	734'
Pups	536	536	661	661
?	51	51	2	2
TOTAL	961	1217	1244	1486

'Pup count x *100/90* (see text)

South Neptune Islands and Dangerous Reef in Spencer Gulf are important breeding sites; though the latter has suffered serious disturbance in recent years, probably from visiting boating parties, particularly those involved in filming sharks which prey on sea lions. Other islands of the Sir Joseph Banks Group and Nuyts Archipelago have smaller but nevertheless important colonies of fur seals and sea lions, and breeding also takes place at some of these sites. Thus fur seals and sea lions may be seen almost anywhere around the Eyre Peninsula coast. This and the fact that numbers fluctuate markedly at different places suggest that there is considerable mobility between haul-out sites. The extent of this mobility and the fidelity of seals to particular sites in the long term can only be determined by extensive marking and intensive resighting programmes, but it remains one of the most important factors to be considered in managing the populations. Moreover, because of this mobility and the wide scatter of the many haul-out sites, it is very difficult to determine total population sizes at anyone time.

Tables 2 and 3 provide some census figures for fur seals at the South Neptunes in 1969 and 1970 (the most recent counts) and sea lions around Eyre Peninsula in 1982-83. The figures for female fur seals have been adjusted on the assumption that 90% of cows produce a pup each year. Thus the hypothetical totals for 1969 and 1971 are 1217 and 1486 respectively. Numbers of sea lions at the Point Labatt colony have varied from 14 to 82 between 1966 and 1983, and for the whole of the Eyre Peninsula Spencer Gulf region, 1568-1754.

As elsewhere, the fur seals breed annually, a single pup being born about December, with a long-furred, black coat that is replaced with a shorter adult-type fur at about two to three months of age. Fur seals favour rocky ledges and headlands on which they are very agile, slipping quickly into the water when disturbed. They tend to be more excitable than sea lions, particularly when the latter haul out on sand. A dramatic change in behaviour seems to occur when sea lions are on a rocky substrate: which is their usual breeding habitat. On a small beach at Hopkins Island, however, there is usually a group of sea lions which are very excitable and flee quickly into the water when approached by boat or overland.

The sea lion's reproductive cycle is not completely understood, but Marlow (1968, 1975) thinks it is annual in individuals, although the season is somewhat protracted for the species

Table 3. AUSTRALIAN SEA LION COUNTS AT VARIOUS SITES AROUND EYRE PENINSULA IN 1982

Spencer Gulf	*No.*	*West Coast*	*No.* March	*No.* April
Curta Rocks	16	Reef off Point Bell		1
Williams I.	3	Point Labatt	42	45
North Neptune Is	22	Sinclair I.	14	5
South Neptune Is	60	Lounds I.	8	
Thistle I.	3	Smooth I.		6
Albatross I.	86	Purdie I.	106	188
Hopkins I.	68	Dog I.		10
Smith I.	15	Freeling I.		2
Lewis I.	47	Fenelon I.	27	69
Little Islet	44	West I.	5	17
English Islet	91	Masillon I.		8
Buffalo Reef	135	Lacy I.		7
Langton & Smith Rock	9	Evans I.		2
Dangerous Reef		Franklin I.	37	110
East Rock	170	Olive I.	198	155
Main Reef	190			
West Reef	170			
TOTALS	1129		439	625

There is some evidence from colonies further west, e.g. Purdie Islets, that pupping occurs at approximately 18-month intervals as has been suggested at Kangaroo Island (Ling & Walker 1978, 1979).

There is much difficult and tedious work to be done at the many scattered, rocky sites where seals haul out around the Peninsula's coast before a full understanding of fur seal and sea lion biology is possible. In the meantime, minimising disturbance is essential if breeding is to continue and ensure the survival of these not very numerous but important species in this region.

TERRESTRIAL MAMMALS

The land mammals reflect the arid or semi-arid nature of Eyre Peninsula. They are part of an assemblage of species found across semi-arid southern Australia from the south-west of Western Australia to the Riverina area of New South Wales (see Strahan 1983). A few typically desert-adapted species occur in the extreme north of the Peninsula; in the extreme south a few species typical of wetter areas survive precariously as remnant populations from a wetter past.

By far the commonest mammals are the introduced house mouse *(Mus domesticus)* and rabbit *(Oryctolagus cuniculus).* Of the native mammals, only a small proportion of a once rich fauna has survived the arrival of Europeans.

The most widespread and conspicuous of the remaining native mammals is the well-known western grey kangaroo *(Macropus fuliginosus)* which occurs throughout the Peninsula wherever areas of natural scrub remain. It is particularly common in the more northerly Acacia-saltbush regions, sheltering during the heat of the day under trees and browsing in the evening and at night. A close relative is the common wallaroo *(Macropus robustus)* with a much more restricted distribution and found predominantly in rocky areas to the north, although it is also present in sandy mallee areas in Hambidge National Park. Recent studies have shown that the common wallaroo does not need to drink to survive in arid country. In contrast, both the western grey kangaroo and the red kangaroo *(Macropus rufus)* need occasional access to water to survive periods of drought. At such times these species are known to travel long distances in search of green food and water. In particular, tagging studies of the red kangaroo have shown that individual animals can move up to 100 km to reach a patch of feed produced by an isolated shower. Animals of the inland plains, red kangaroos are only found on Eyre Peninsula in the pastoral lands in the north, coming as far south as Fowlers Bay on the West Coast and Whyalla or occasionally the sandhills behind Cowell on the east coast.

Two species of rock wallabies occur on the Peninsula but both have a very limited distribution. The black-footed rock-wallaby *(Petrogale lateralis)* is a widespread species found in many scattered localities in western and central Australia, but on the Peninsula is found only on Pearson Island off the coast. This population is different from the other mainland populations in several characteristics, presumably acquired since its isolation when sea levels rose about 8000-10000 years ago. A small population of the yellow-footed rock-wallaby *(Petrogale xanthopus)* occurs in the Gawler Ranges. This species also exists in good numbers in the Flinders Ranges and as small populations in parts of western New South Wales and south-western Queensland. Like all rock wallabies these two species are restricted to rocky cliffs and gorges where they shelter during the day, emerging at night to graze on herbs and grasses.

The brush-tailed bettong *(Bettongia penicil/ata)* was relatively common on the Peninsula but is now presumed to be extinct there. In 1982 the South Australian National Parks and Wildlife Service released some on islands in Venus Bay, and in 1983 on St Francis Island in the Nuyts Archipelago. These animals came from a captive colony bred from a few animals obtained from the South-West of Western Australia where the species is still found in low numbers in a few localities. The introductions appear to have been successful and this species has been returned to the list of living mammals of South Australia, albeit on rather isolated islands. Free from the predation of cats, foxes and dogs and left alone by man, there seems little reason why these colonies should not thrive.

One of the few large mammals other than the kangaroos that has survived, and possibly even prospered on the Peninsula, is the southern hairynosed wombat *(Lasiorhinus latifrons)* which appears to be extending its range in the eastern Gawler Ranges (Aitken 1971). This species constructs burrows which tend to be grouped together in warrens. Each warren may house up to 10 wombats. It is nocturnal but is known sometimes to bask at the burrow entrance in the weak winter sun.

Around Port Lincoln, the brush-tailed possum *(Trichosurus vulpecula)* survives in small numbers, most notably in the forest remnants in the south but also in other scattered localities such as Flinders Island and Iron Knob. Its tiny relative, the western pygmy-possum *(Cercartetus concinnus)*, no larger than a mouse, are found in reasonable numbers in areas of mallee scrub. They are occasionally discovered on farms rolled up in a tiny ball in hanging wheat bags or sleeping in hollow logs or grass-trees. The western pygmy-possums can enter a state of torpor for a few days during the colder months, curling up in a tight ball and letting their body temperatures drop to as low as 15°C. Pygmy possums are solitary animals that live on nectar, pollen and insects. Breeding takes place in the spring and summer when they can have two or three litters, each of up to six young. These leave the pouch but stay in a nest when about 24 days old. They become independent when about two months old.

Distinguished from the possums by their long fox-like faces, are a group of small ground dwelling, insect-eating marsupials, the dunnarts. Over much of the area the fat-tailed dunnart *(Sminthopsis crassicaudata)* is relatively common and is often disturbed from its nests in stumps and logs during scrub clearing. Unlike the kangaroos and possums the female dunnart has only a rudimentary pouch which provides protection for the 8-10 minute newborn young for only a few weeks. After this period they protrude from the pouch, hanging from the teats like a bunch of grapes. As they mature they eventually get too large to be dragged around by the mother and are left in a nest in a small burrow or hollow log whilst the mother forages for food. Occasionally, even quite large, fully formed young are seen riding piggyback on the mother. Up to 10 young at a time can be accommodated in the pouch, but the mortality rate appears to be high and usually only a few young from any litter survive until weaning. In good times this species stores fat in its tail, which becomes noticeably swollen. Its tail is shorter than its head and body. On the drier saltbush plains around Whyalla a close relative, the stripe-headed dunnart *(S. macroura)* occurs. This species also has a swollen tail but it is larger than its head and body. It is distinguished from its relatives by a dark stripe down the middle of its head.

Another close relative, the southern white bellied dunnart *(S. dolichura)*, which is occasionally found in the more northerly parts, has a much longer slender tail which does not become swollen, and has no dark stripe on its face.

Two of the State's most unusual small carnivorous marsupials are found on Eyre Peninsula. The kultarr *(Antechinomys laniget)* has the appearance of the much more common hopping-mouse. Like the hopping-mouse it has long hind legs and a long, counterbalancing tail tipped with a tuft of hair. Although the two forms are unrelated (one a marsupial the other a rodent), the gross structural similarities are indeed striking. This is an oft-quoted example of convergent evolution where unrelated forms have come to resemble each other through the action of natural selection. The kultarr is very rare in the region and has only been found on the open plains of the north-east around Kyancutta.

The other notable small carnivorous marsupial is the sandhill dunnart *(S. psammophila)* one of Australia's rarest animals, which is known from only six specimens and from only two localities. In 1894 a specimen was collected from near Lake Amadeus in the Northern Territory. For 75 years no more was heard of it until 1969, when further specimens were collected near Mamblin and Boonerdo on northern Eyre Peninsula. Since then the sandhills and mallee remaining in the area and in nearby Hambidge Conservation Park have been searched by mammalogists repeatedly without success. It is the largest of the dunnarts, 10 cm long in head and body, solidly built and with a slight tuft of hair on the end of the tail.

Perhaps just as intriguing is the solitary record from Eyre Peninsula of a brush-tailed phascogale *(Phascogale tapoatafa)* a rat-sized, arboreal carnivorous marsupial with a distinctive black bushed tail. Relatively common in some forested areas of the eastern states, the single specimen, found undamaged beside a road between Wangary and Wan ilia in 1979 remains an enigma until additional specimens are sighted. It could have been an escaped pet or part of a previously unknown population that has survived from pre European times.

Very recently another and even smaller carnivorous marsupial (Yvonne's ningaui, *Ningaui yvonneae)* was discovered in the mallee in Lake Gilles Conservation Park. The size and general shape of a small, brown house mouse but with a sharply pointed face and numerous small, sharp peg-like teeth, this species is thought to be reasonably common across southern Australia in arid and semi-arid mallee and mallee-broombush shrubland growing on sandy soils.

Besides the marsupials Eyre Peninsula is home to a variety of native rodents and bats. Only one native rodent is at all common. This is Mitchell's hopping-mouse *(Notomys mitche/lii)*. An inhabitant of heathland and mallee scrub, Mitchell's hopping-mouse constructs burrows up to 1.5 m deep in sandy soil where it lives communally with up to six other individuals of either sex. When times are good it lives on seed and some green plants, venturing out at night into cereal crops if these are alongside a scrubby sandhill. When times are bad it scrounges a living from a diet of roots and an occasional insect or seed. Up to five young are born in a grass-lined nest deep underground. They learn to walk and run in extensive underground tunnels before venturing onto the surface when about five wet;ks old. Although small, Mitchell's hopping-mice are long lived and have survived for over five years in captivity.

A larger rodent, the southern bush rat *(Rattus fuscipes greyi)* is found in dense populations on many offshore islands such as Pearson, Reevesby and Eyre and as a small isolated population in Hincks Conservation Park and in Lincoln National Park. These populations are remnants of a more widespread one that once stretched all along the South Australian coast 8000-15000 years ago. On Franklin Island, the world's last remaining stick-nest rats *(Leporillus conditor)-a* mere 700 or so-shelter precariously from the cats, rabbits, foxes and pastoralism that have driven them from the mainland. Here these lovely, docile animals build small nests of sticks interwoven with each other and a supporting bush and try to avoid being eaten by the barn owls and tiger snakes with which they share the island.

Little is known of the bats of Eyre Peninsula, but they appear common and widespread, having survived the coming of Europeans much better than ground-dwelling rodents and marsupials. Five genera and eight species have been recorded (Table 4). Bats are nocturnal, although some early risers can be seen soon after sunset hunting for insects over dams and around trees. During the day they roost, usually in small colonies, in caves, hollow trees and occasionally house roofs. Although not often encountered, bats are probably the most common native mammals in the area.

In addition to the marsupials, rodents, bats and seals, Eyre Peninsula has scattered populations of spiny anteaters or echidnas *(Tachyglossus aculeatus).* Together with the platypus *(Ornithorynchus)*, echidnas are among the last remaining examples of an early radiation of the mammals (the monotremes) and have retained some ancient characteristics, notably the method of reproduction. Instead of giving birth to live young the echidna and its relatives lay soft shelled eggs which, after somehow getting into the mother's pouch, hatch after a few days' incubation. The young remain in the pouch, for another three months obtaining their food by licking milk which is secreted onto an area of the mother's belly skin from underlying mammary glands.

The mammals most often seen in the area are introduced species. The most successful are undoubtedly the house mouse *(Mus domesticus),* rabbit *(Oryctolagus cuniculus),* cat *(Felis catus)* and fox *(Vulpes vulpes)*, which are widespread and ubiquitous. In addition there is the black rat *(Rattus rattus)* in coastal and agricultural areas, the goat *(Capra hircus)* in the Gawler Ranges, and the European hare *(Lepus europaeus)* south of the 200-250 mm isohyet.

There is little evidence that the introduced rodents-the house mouse and black rat-have had much effect on the native fauna. Rather they have tended to occupy areas degraded by man. But the combination of the fox, cat and rabbit and agricultural clearing has been devastating to the native terrestrial mammal fauna.

The extent of this devastation can be gauged from Tables 4 and 5 which list the species of mammals known to have lived on the Peninsula in the recent past. In both cases the subfossil material represents the regurgitated remains of prey species caught by owls probably only 100-300 years ago. It is a biased sample of the mammals present, as it includes only those species small enough to be captured and eaten by owls. Even the numbers of similarly-sized animals may not reflect their relative commonness since on Franklin Island, where bandicoots outnumber stick-nest rats 10:1, most of the remains found in owl roosts are those of the rarer stick-nest rats. Despite these limitations it is obvious that in the quite recent past Eyre Peninsula had many more species and many more individuals of small mammals than now. In a gross sense 13 of the 33 species (40%) of terrestrial mammals other than bats have become extinct (Table 4), and another three species are now reduced to precarious colonies on one or two offshore islands. It is highly probable that most of the species that remain are also greatly reduced in range and numbers. The cause of this massive extinction is unknown except that it is clearly correlated with European settlement in Australia, and is part of a pattern of mammalian extinction across the whole of arid and semi-arid temperate Australia.

The mammal fauna of Eyre Peninsula has been decimated. In some groups such as the bandicoots, small wallabies and the native rodents extinction is almost complete. If they persist today, it is in one or two tiny pockets within their former ranges. These refuges are often offshore islands. Eyre Peninsula is blessed with

Table 4. LAND MAMMALS OF EYRE PENINSULA BEFORE AND AFTER EUROPEAN SETTLEMENT

Common Name	*Scientific Name*	*Modern Records*	*Records >50 yrs old*	*Subfossil (bones)*	*Status in area*
Echidna	*Tachyglossus aculeatus*	+	+		Rare
Fat-tailed dunnart	*Sminthopsis crassicaudata*	+	+	+	Common
Dunnart	*Sminthopsis dolichura*	+		+	Rare
Sandhill dunnart	*Sminthopsis psammophila*	+		+	Rare
Kultarr	*Antechinomys laniger*	+		+	Rare
Dibbler	*Antechinus apicalis*			+	Extinct
Brush-tailed phascogale	*Phascogale tapoatafa*	+		+	Rare
Mulgara	*Dasycercus cristicauda*			+	Extinct
Western quail	*Dasyurus geoffroii*		+	+	Extinct
Narrow-nosed planigale	*Planigale tenuirostris*			+	?Extinct
Southern brown bandicoot	*Isoodon obesulus*			+	Extinct (on Is. of Nuyts Arch.)
Western barred bandicoot	*Perameles bougainville*			+	Extinct
Greater bilby	*Macrotis lagotis*		+		Extinct
Hairy-nosed wombat	*Lasiorhinus latifrons*	+	+		Common in places
Western pygmy-possum	*Cercartetus concinnus*	+	+	+	Common
Brush-tailed possum	*Trichosurus vulpecula*	+	+		Rare
Brush-tailed bettong	*Bettongia penicillata*		+	+	Extinct
Broad-faced potoroo	*Potorous platyops*			+	Extinct
Black-flanked rock-wallaby	*Petrogale lateralis*	+	+		Rare
Yellow-footed rock-wallaby	*Petrogale xanthopus*	+	+		Rare
Tammar Wallaby	*Macropus eugenii*		+		Extinct
Common wallaroo	*Macropus robustus*	+	+		Uncommon
Western grey kangaroo	*Macropus fuliginosus*	+	+		Common
Red Kangaroo	*Macropus rufus*	+	+		Common
Gould's mouse	*Pseudomys gouldii*			+	Extinct
Sandy inland mouse	*Pseudomys*			+	Rare
Plains rat	*Pseudomys australis*			+	Extinct
Heath rat	*Pseudomys shortridgei*			+	Extinct
Western mouse	*Pseudomys ocqidentalis*			+	Extinct
Greater stick-nest rat	*Leporillus conditor*	+			Rare (only on Franklin Is.)
Lesser stick-nest rat	*Leporillus apicalis*			+	Extinct
Mitchell's hopping-mouse	*Notomys mitchellii*	+	+	+	Common
Southern bush rat	*Rattus fuscipes*	+	+	+	Rare
Pale field rat	*Rattus tunneyi*		?+		Extinct
White-striped free-tail bat	*Tadarida australis*	+			Common
Little free-tail bat	*Mormopterus planiceps*	+			Uncommon
Gould's wattled bat	*Chalinolobus gouldi*	+			Abundant
Chocolate bat	*Chalinolobus morio*	+			Uncommon
Little brown bat	*Eptesicus pumilis*	+			Uncommon
Small forest eptesicus	*Eptesicus vulturnus*	+			Common
Greater long-eared bat	*Nyctophilus major*	+			Rare
Lesser long-eared bat	*Nyctophilus geoffroyi*	+			Abundant
INTRODUCED SPECIES					
Dog/Dingo	*Canis familiaris*	+			Rare
Fox	*Vulpes vulpes*	+			Abundant
Cat	*Felis catus*	+			Common
Rabbit	*Oryctolagus cuniculus*	+			Abundant
Hare	*Lepus europaeus*	+			Rare
Goat	*Capra hircus*	+			Rare
Black rat	*Rattus rattus*	+			Common
House mouse	*Mus domesticus*	+			Abundant

Table 5. SPECIES OF SMALL MAMMALS REPRESENTED BY BONE MATERIAL IN TWO OWL PELLET DEPOSITS ON EYRE PENINSULA

		DARKE PEAK		*BLOCK RANGE*	
Common Name	*Scientific Name*	*Min. No. Individuals*	*% of total*	*Min. No. Individuals*	*% of total*
Kultarr	*Antechinomys laniger*	3	2	-	-
Fat-tailed dunnart	*Sminthopsis crassicaudata*	2	1	-	-
Dunnart sp.	*Sminthopsis* sp. *murina* group	5	3	23	7
Sandhill dunnart	*Sminthopsis psammophila*	10	6	-	-
Narrow-nosed planigale	*Planigale tenuirastris*	2	1	-	-
Dibbler	*Antechinus apicalis*	-	-	2	-
Mulgara	*Dasycercus cristicauda*	1	1	2	1
Western quoll	*Dasyurus geoffrayi*	-	-	1	1
Western pygmy-possum	*Cercartetus concinnus*	2	1	-	-
Bandicoot	*Isoodon obesulus*	-	-	2	1
Western barred bandicoot	*Perameles bougainville*	24	14	-	-
Brush-tailed bettong	*Bettongia penicillata*	1	1	-	-
Broad-faced potoroo	*Potoraus platyops*	2	1	1	1
Plains rat	*Pseudomys australis*	13	8	87	28
Gould's mouse	*Pseudomys gouldi*	9	5	-	-
Field's mouse	*Pseudomys fieldi*	2	1	-	-
Sandy inland mouse	*Pseudomys hermannsburgensis*	4	2	-	-
Western mouse	*Pseudomys occidentalis*	13	8	2	1
Heath rat	*Pseudomys shortridgei*	3	2	6	2
Mitchell's hopping-mouse	*Notomys mitchellii*	18	11	1	1
Lesser stick-nest rat	*Leporillus apicalis*	1	1	-	-
Southern bush rat	*Rattus fuscipes*	21	12	172	55
Pale field-rat	*Rattus tunneyi*	-	-	2	1
House mouse	*Mus domesticus*	29	17	-	-
		170		310	

Darke Peak material collected and determined by G. C. Medlin.
Block Range material collected Jan 1984 by A. J. Watts. Determined G. C. Medlin, M. J. Smith & A. Baynes.
Block Range material deposited in South Australian Museum.

four such populations. On Pearson Island a race of the rare black-flanked rock-wallaby is found and on Franklin Island the stick-nest rat and the Nuyts Island bandicoot survive. The area around Mamblin in the north could well support the world's last populations of the sandhill dunnart.

It is both encouraging and a cause of great concern that populations of one of the world's largest and rarest mammals, the southern right whale, are recovering around Eyre Peninsula today, while the extinction or only precarious survival of some of our smallest mammals is occurring at the same time. There is a need for much greater protection of mammal habitat if this diverse and interesting fauna is to survive beyond the twentieth century

ACKNOWLEDGEMENTS

The authors are grateful to Dr Tony Robinson (South Australian National Parks & Wildlife Service) for access to the seal census data quoted here, to Mr Steven J. Doyle for permission to use his photograph of the southern right whale and to Dr A. Baynes (Western Australian Museum), Mr G. Medlin (Mawson High School) and Dr M. J. Smith (South Australian Museum) for help in identifying the bones found in owl pellets. Mr A. J. Watts is thanked for drawing our attention to the owl pellet deposit on Block Range. Mr Medlin very kindly allowed us to use his data on the animals he has identified in an owl pellet deposit on Darke Peak. Ms H. Aslin and Dr C. Kemper read and commented upon the manuscript which was typed by Mrs J. Murphy and Mrs P Kidd

REFERENCES

Aitken, P. F. (1971). The distribution of the hairy-nosed wombat, *Lasiorhinus latifrons* (Owen). S. *Aust. Nat.* **45,** 93-103.

Colwell, M. (1969). 'Whaling Around Australia'. (Angus and Robertson, Sydney).

Gilmore, R. M. (1978). Right whale. *In:* Haley, D. (Ed.) 'Marine Mammals of Eastern North Pacific and Arctic Waters'. (Pacific Search Press, Seattle).

Ling, J. K. & Walker, G. E. (1978). An 18-month breeding cycle in the Australian sea lion? *Search* **19**, 464-5.

Ling, J. K. & Walker, G. E. (1979). Seal studies in South Australia. Progress report for the period April 1977 to July 1979. S. *Aust. Nat.* **52**, 68-78.

Marlow, B. J. (1968). The sea lions of Dangerous Reef. *Aust. Nat. Hist.* **16**, 39-44.

Marlow, B. J. (1975). The comparative behaviour of the Australasian sea lions *Neophoca cinerea* and *Phocarctos hookeri* (Pinnipedia: Otariidae). *Mammalia* **39**, 159-230.

Stirling, I. (1971). Studies on the behaviour of the South Australian fur seal, *Arctocephalus forsteri* (Lesson). 1. Annual cycle, postures and calls, and adult males during the breeding season. *Aust. J. Zool.* **19***,* 243-266.

Strahan, R. (Ed.) (1983), 243-266. 'The Complete Book of Australian Mammals'. (Angus & Robertson, Sydney).

12. BIRDS

by H. J. ECKERT, S. A. PARKER and J. R. W. REID

INTRODUCTION

Given Eyre Peninsula's relatively close settlement and its proximity to Adelaide, one might expect its avifauna to be relatively well known. In the case of the offshore islands this is true; they have attracted a good de~1 of attention and have been surveyed recently by the National Parks and Wildlife Service (Robinson *et al.* in prep.). But for most mainland districts the formal record is sketchy, consisting largely of random observations biased towards spring and summer, and with only a few reference specimens to substantiate records. In fact, the southernmost part of the Peninsula is one of the least documented areas in the State, in this respect trailing behind more remote areas such as the Everard Ranges, the Simpson Desert and the Cooper's Creek system.

In Table 1 we list the 267 species so far acceptably recorded from Eyre Peninsula, and in Table 2 a further 17 species reports of which remain to be substantiated. In addition, we discuss briefly the avifauna of six major habitats of the region. No notations of habitat-preference are given in Table 1; instead, selected published bird-lists for each habitat are cited in the text.

MAJOR AVIAN HABITATS

Low Woodland (semi-arid)

Much of the north-eastern part of Eyre Peninsula consists of an open semi-arid woodland of scattered Western Myall, Sandalwood and Bullockbush with an understorey of bluebush and saltbush. Papers on the ornithology of this area include Sutton (1924, 1926), Bryant (1937) and Cox (1974). Characteristic birds include the Bluebonnet, Red-capped Robin, White-winged Wren, Thick-billed Grasswren, Slender-billed Thornbill, Chestnut-tailed Thornbill, Redthroat, Western Fieldwren, Spiny-cheeked Honeyeater, Black-faced Woodswallow and Australian Raven.

Open Scrub

In this category we include most of the mallee and mallee-heath of the central and southern districts, and the southern coastal dune-scrub. Most of this habitat is now cleared for agriculture, though significant areas are conserved *(e.g.* in Hincks, Hambidge, Bascombe Well and Pinkawillinie Conservation Parks, and Lincoln and Coffin Bay National Parks). Relevant articles include Weidenbach (1924), Sutton (1924, 1926), Storr (1947), Bonython & Preiss (1967), Preiss (1969), Preiss & Thomas (1970a, b) and Leiblich (1971). Characteristic species include the Malleefowl, Major Mitchell, Ring-necked Parrot, Southern Scrub-robin, Western Yellow Robin Jacky Winter, Western Whipbird, Blue-breasted Wren, Southern Emu-wren, Shy Heathwren, Rufous Treecreeper, Purple-gaped Honeyeater, Yellow-rumped Pardalote and Little Raven. The Southern Emu-wren is of particular interest, having been first recorded as late as 1946, and described as a distinct subspecies in 1981 (Storr 1947, Schodde & Weatherley 1981, Morgan 1982). The local population of the Western Whipbird is also noteworthy; it was first formally reported in 1966. (Parker & Reid 1978 and references therein).

Within the mallee, on heavier soils and around the inselbergs, there occur pockets of a taller, more open woodland of Black Oak, native pine, *Eucalyptus porosa* and others. Little is known about the birdlife of these pockets, though there is evidence that at least some of the local Yellowtailed Black Cockatoos visit the inselbergs in the non-breeding season.

Open Forest to Woodland

This consists mainly of larger gums such as Sugar Gum, Blue Gum and River Red Gum, and taller stands of such mallees as *E. diversifolia* and *E. lansdowneana.* Jt occurs principally in the areas of higher rainfall in the south of the Peninsula. Relevant articles on the birdlife include Hall (1910), White (1912), Cleland (1925), and Storr (1947) (see also Reid 1978). Characteristic species include Yellow-tailed Black Cockatoo Rainbow Lorikeet, Laughing Kookaburra, Scarlet Robin, Restless Flycatcher, Grey Fantail, Western Warbler and Diamond Firetail. In the 1970's, and perhaps earlier, Square-tailed Kites bred in this habitat in the Wanilla district, but have not been

Table 1. SPECIES OF BIRDS RECORDED FROM EYRE PENINSULA AND ITS OFFSHORE ISLANDS. For the purpose of the basic faunal analysis in the text, the breeding land birds are categorized by their distributions and hypothesized regional origins.

Data for table 1 have been compiled from those sources cited in the text and from Chapman (1966); Cleland (1926); Close (1981); Condon (1969); Cox (1978a, b, 1984); Finch (1975); Finlayson (1946); Ford (1971a, b, c, 1979); Garrett (1980); Gill (1978); Hermes & Bennett (1974); Jones *et al.* (1938); Keast (1958); Leiblich (1974); Matheson (1974); Parker (1977); Parker & Eckert (1983); Parker *et al.* (1985); Parker & May (1982); Pedler (1978); Reid (1975, 1983); Reid *et al.* (1984); Reid *et al.* (1977); Rix (1947); Shaw (1958); Smith (1972); Sullivan (1928).

Status

O Occasional, accidental
V More or less regular visitor
B Breeding reported
N No breeding reported
R More or less resident (breeding implicit)
* Introduced

Biogeographic origins/affinities

W Western (West Bassian or Eyrean)
E Eastern (East Bassian/Torresian)
S Widespread in southern Australia with little or no differentiation.
A Widespread in Australia

In cases where the identity of the local subspecies of a resident landbird is relevant to the faunal analysis, the name of the subspecies is given in parentheses.

Family CASUARIIDAE
Emu *Dromaius novaehollandiae* R (W)
Family PODICIPEDIDAE
Great Crested Grebe *Podiceps cristatus* V, B
Hoary-headed Grebe *Poliocephalus poliocephalus* V, N
Black-throated (Australasian) Grebe *Tachybaptus novaehollandiae* V, N
Family SPHENISCIDAE
Rockhopper Penguin *Eudyptes chrysocome* 0, N
Little Penguin *Eudyptula minor* R
Family DIOMEDEIDAE
Wandering Albatross *Diomedea exulans* 0, N
Black-browed Albatross *D. melanophrys* V, N
Grey-headed Albatross D. chrysostoma 0, N
Yellow-nosed Albatross *D. chlororhynchos* V, N
Shy Albatross *D. cauta* V, N
Family PROCELLARIIDAE
Southern Giant Petrel *Macronectes giganteus* V, N
Northern Giant Petrel M. *halli* V, N
Cape Petrel *Daption capense* V, N
White-headed Petrel *Pterodroma lessonii* 0, N
Kerguelen Petrel *P brevirostris* 0, N
Thin-billed Prion *Pachyptila belcheri* 0, N
Antarctic Prion *P vittata desolata* 0, N
Grey Petrel *Procellaria cinerea* 0, N
Fleshy-footed Shearwater *Puffinus carneipes* V, B
Short-tailed Shearwater *P tenuirostris* V, B
Manx Shearwater *P puffinus puffinus* 0, N
Fluttering Shearwater *P puffin* us *gavia* V, N
Family OCEANITIDAE
Wilson's Storm-Petrel *Oceanites oceanicus* V, N
White-faced Storm-Petrel *Pelagodroma marina* V, B
Family PELECANIDAE
Australian Pelican *Pelecanus conspicillatus* R
Family SULIDAE
Australasian Gannet *Sula serrator* V, N
Family ANHINGIDAE
Darter *Anhinga melanogaster* 0, N
Family PHALACROCORACIDAE
Black-faced Shag *Leucocarbo fuscescens* R
Great Black Cormorant *Phalacrocorax carbo* V, N
Pied Cormorant *P varius* R
Little Black Cormorant *P sulcirostris* V, N
Little Pied Cormorant *P. melanoleucos* R
Family PHAETHONTIDAE
Red-tailed Tropicbird *Phaethon rubricauda* 0, N
Family ARDEIDAE
Pacific Heron *Ardea pacifica* V, N
White-faced Heron A. *novaehollandiae* R, B
Great White Egret A. *alba* V, N
Little Egret A. *garzetta* 0, N
Eastern Reef Egret A. *sacra* R
Cattle Egret *Bubulcus ibis* 0, N
Nankeen Night Heron *Nycticorax caledonicus* 0, B
Little Bittern *Ixobrychus minutus* 0, N
Brown Bittern *Botaurus poiciloptilus* 0, N
Family THRESKIORNITHIDAE
Glossy Ibis *Plegadis falcinellus* 0, N
Sacred Ibis *Threskiornis aethiopicus* 0, N
Straw-necked Ibis *T. spinicollis* 0, N
Yellow-billed Spoonbill *Platalea flavipes* 0, N
Family ANATIDAE
Black Swan *Cygnus atratus* V, B
Freckled Duck *Stictonetta naevosa* 0, N
Cape Barren Goose *Cereopsis novaehollandiae* R
Mountain Duck *Tadorna tadornoides* ?V, ?B
Pacific Black Duck *Anas superciliosa* ?V, B
Australasian Grey Teal A. *gracilis* ?V, B
Chestnut Teal A. *castanea* R
Blue-winged Shoveler A. *rhynchotis* V, N
Pink-eared Duck *Malacorhynchus membranaceus* V, B
Hardhead *Aythya australis* V, N
Wood Duck *Chenonetta jubata* ?V, N
Blue-billed Duck *Oxyura australis* V, N
Musk Duck *Biziura lobata* V, N
Family ACCIPITRIDAE
Black-shouldered Kite *Elanus caeruleus* V, B
Letter-winged Kite *E. scriptus* 0, N
Black Kite *Milyus migrans* 0, B
Square-tailed Kite *Lophoictinia isura* V, B
Whistling Eagle *Haliastur sphenurus* R (A)
Brown Goshawk *Accipiter fasciatus* R (A)
Collared Sparrowhawk A. *cirrhocephalus* R (A)
Little Eagle *Hieraaetus morphnoides* R (A)
Wedge-tailed Eagle *Aquila audax* R (A)
White-breasted Sea-eagle *Haliaeetus leucogaster* R (A)
Spotted Harrier *Circus assimilis* 0, N

Swamp Harrier C. *approximans* R (A)
Family PANDIONIDAE
Osprey *Pandion haliaetus* R (A) Family
Family FALCONIDAE
Black Falcon *Falco subniger* 0, N
Brown Hawk *F. berigora* R (A)
Little Falcon *F. longipennis* R (A)
Peregrine Falcon *F. peregrinus* R (A)
Nankeen Kestrel *F. cenchroides* R (A)
Family MEGAPODIIDAE
Malleefowl *Leipoa ocellata* R (W) Family
Family PHASIANIDAE
Stubble Quail *Coturnix novaezelandiae* V, B
Family TURNICIDAE·
Painted Button-quail *Turnix varia* R (S)
Little Button-quail *T. velox* V, N
Family RALLIDAE
Lewin's Rail *Rallus pectoralis* 0, N
Banded Landrail *Gallirallus philippensis* V + ?R
Spotted Crake *Porzana fluminea* V, N
Baillon's Crake *P pusilla* 0, N
Spotless Crake *P tabuensis* 0, N
Black-tailed Native-hen *GaJlinula ventralis* V, N
Purple Swamphen *Porphyrio porphyrio* ?V, N Coot
Fulica atra V, B
Family OTIDIDAE
Australian Bustard *Ardeotis australis* V, N
Family PEDIONOMIDAE
Plains Wanderer *Pedionomus torquatus* 0, N
Family HAEMATOPODIDAE
Pied Oystercatcher *Haematopus ostralegus* R + ?V
Sooty Oystercatcher *H. fuliginosus* R
Family RECURVIROSTRIDAE
White-headed Stilt *Himantopus leucocephalus* V, N
Red-necked Avocet *Recurvirostra novaehollandiae* V, B
Banded Stilt *Cladorhynchus leucocephalus* V, N
Family BURHINIDAE
Southern Stonecurlew *Burhinus grallarius* ?R, B (A)
Family GLAREOLIDAE
Australian Pratincole *Stiltia isabella* 0, N
Family CHARADRIIDAE
Banded Plover *Vanellus tricolor* R (W)
Spur-winged Plover V. *miles* R
Lesser Golden Plover *Pluvialis dominica* V, N
Grey Plover *P squatarola* V, N
Red-capped Dotterel *Charadrius ruficapillus* ?R
Double-banded Dotterel C. *bicinctus* V, N
Mongolian Plover C. *mongolus* V, N
Large Sand-plover C. *leschenaultii* V, N
Oriental Plover C. *veredus* V, N
Hooded Dotterel C. *rubricollis* ?R
Black-fronted Dotterel *Eiseyornis melanops* V, N
Red-kneed Dotterel *Erythrogonys cinctus* V, N
Inland Dotterel *Peltohyas australis* V, N
Family SCOLOPACIDAE
Black-tailed Godwit *Limosa limosa* 0, N
Bar-tailed Godwit *L. lapponica* V, N
Whimbrel *Numenius phaeopus* 0, N
Eastern Curlew *N. madagascariensis* V, N
Marsh Sandpiper *Tringa stagnatilis* V, N
Greenshank *T. nebularia* V, N
Wood Sandpiper *T. glareola* V, N
Terek Sandpiper *Xenus cinereus* 0, N
Common Sandpiper *Actitis hypoleucos* V, N
Grey-tailed Tattler *Heteroscelus brevipes* V, N
Ruddy Turnstone *Arenaria interpres* V, N
Red-necked Phalarope *Phalaropus lobatus* 0, N
Latham's Snipe *GaJlinago hardwickii* V, N
Knot *Calidris canutus* V, N
Great Knot C. *tenuirostris* 0, N
Sanderling C. *alba* V, N
Red-necked Stint C. *ruficollis* V, N
Long-toed Stint C. *subminuta* 0, N
Sharp-tailed Sandpiper C. *acuminata* V, N
Curlew Sandpiper C. *ferruginea* V, N
Ruff *Philomachus pugnax* 0, N
Family STERCORARIIDAE
Brown (Subantarctic) Skua *Catharacta antarctica* 0, N
Arctic Jaeger *Stercorarius parasiticus* V, N
Family LARIDAE
Kelp Gull *Larus dominicanus* 0, N
Pacific Gull *L. pacificus* R
Silver Gull *L. novaehollandiae* R
Whiskered Tern *Chlidonias hybridus* 0, N
Gull-billed Tern *Gelochelidon nilotica* 0, N
Caspian Tern *Hydroprogne caspia* R
Crested Tern *Thalasseus bergii* R
Fairy Tern *Sterna nereis* R
Sooty Tern S. *fuscata* 0, N
Family COLUMBIDAE
Diamond Dove G. *cuneata* 0, N
Common Bronzewing *Phaps chalcoptera* R (W)
Brush Bronzewing *P elegans* R (S)
Crested Pigeon *Ocyphaps lophotes* R (W)
*Feral Pigeon (Rock Dove) *Columba Jivia* R
*Spotted Turtle-Dove *StreptopeJia chinensis* ?R
Family PSITTACIDAE
Yellow-tailed Black Cockatoo *Calyptorhynchus funereus (xanthanotus)* R (E)
Major Mitchell *Cacatua leadbeateri (mollis)* R (W)
Galah C. *roseicapilla* (?subsp.) R (W)
Little Corella C. *sanguinea* ?R (A)
Rainbow Lorikeet *Trichoglossus haematodus* ?R, B (E)
Musk Lorikeet *Glossopsitta concinna* ?R (E)
Purple-crowned Lorikeet G. *porphyrocephala* ?R, B (S)
Cockatiel *Nymphicus hollandicus* V, B
Ring-necked Parrot *Barnardius zonarius (zonarius)* R(W)
Mulga Parrot *Psephotus varius* R (W)
Bluebonnet *Northiella haematogaster* R (W)
Blue-winged Parrot *Neophema chrysostoma* V, N
Elegant Parrot *N. elegans* V, N
Rock Parrot *N. petrophila* R (W)
Scarlet-chested Parrot *N. splendida* 0, N
Budgerigah *Melopsittacus undulatus* V, N
Family CUCULIDAE
Pallid Cuckoo *Cuculus pallidus* V, B
Fan-tailed Cuckoo *Cacomantis flabelliformis* V, B
Black-eared Cuckoo *Chrysococcyx osculans* V, B
Horsfield's Bronze Cuckoo C. *basalis* V, B
Family TYTONIDAE
Barn Owl *Tyto alba* V + R (A)
Family STRIGIDAE
Boobook Owl *Ninox novaeseelandiae (ocellata)* R (W)
Family PODARGIDAE
Tawny Frogmouth *Podargus strigoides (brachypterus)* R (W)
Family AEGOTHELIDAE
Owlet-Night jar *Aegotheles cristatus* R (A)
Family CAPRIMULGIDAE
Spotted Night jar *Eurostopodus argus* R (W)
Family APODIDAE
Fork-tailed Swift *Apus pacificus* V, N
Family ALCEDINIDAE
Laughing Kookaburra *Oacelo novaeguineae* R (E)
Red-backed Kingfisher *Halcyon pyrrhopygia* V, N

Sacred Kingfisher *H. sancta* V, B
Family MEROPIDAE
Rainbow Bird *Merops ornatus* V, B
Family ALAUDIDAE
Singing Bushlark *Mirafra javanica* R (E)
Family HIRUNDINIDAE
White-backed Swallow *Cheramoeca leucosterna* V, B
Welcome Swallow *Hirundo neoxena* R (A)
Tree Martin *H. nigricans* V, B
Fairy Martin *H. ariel* V, B
Family MOTACILLIDAE
Richard's Pipit *Anthus novaeseelandiae* R (A)
Family CAMPEPHAGIDAE
Black-faced Cuckoo-shrike *Coracina novaehollandiae* V + R (A)
Ground Cuckoo-shrike *Pteropodocys maxima* V, N
White-winged Triller *Lalage sueurii* V, B
Family TURDIDAE
*Blackbird *Turdus merula* R
Family EOPSALTRIIDAE
Rose Robin *Petroica rosea* 0, N
Scarlet Robin P. *multicolor (boodang)* R (E)
Red-capped Robin P. *goodenovii* R (W)
Hooded Robin *Melanodryas cucullata* R (W)
Western Yellow Robin *Eopsaltria griseogularis* R (W)
Southern Scrub-robin *Drymodes brunneopygia* R (W)
Jacky Winter *Microecalleucophaea (assimilis)* R (W)
Family NEOSITTIDAE
Varied Sitella *Daphoenositta chrysoptera (pileata)* R (W)
Family PACHYCEPHALIDAE
Gilbert's Whistler *Pachycephala inornata (gilberti)* R (W)
Golden Whistler P. *pectoralis (fuliginosa)* R (W)
Rufous Whistler P. *rufiventris* R (A)
Grey Shrike-thrush *Colluricincla harmonica (rufiventris)* R (W)
Crested Bellbird *Oreoica gutturalis* R (W)
Family MONARCHIDAE
Restless Flycatcher *Myiagra inquieta* R (S)
Magpie-lark *Grallina cyanoleuca* R (A)
Grey Fantail *Rhipidura fuliginosa (alisteri)* R (E)
Willie Wagtail *R. leucophrys* R (A)
Family ORTHONYCHIDAE
Western Whipbird *Psophodes nigrogularis* R (W)
Chestnut Quailthrush *Cinclosoma castanotum* R (W)
White-browed Babbler *Pomatostomus superciliosus* R (W)
Family SYLVIIDAE
Clamorous Reedwarbler *Acrocephalus stentoreus* V, B
Little Grassbird *Megalurus gramineus (goulburni)* R (E)
Rufous Song lark *Cincloramphus mathewsi* V, B
Brown Songlark C. *cruralis* V, B
Family MALURIDAE
Superb Blue Wren *Malurus cyaneus* R (E)
Turquoise Wren M. *splendens (calla in us)* R (W)
Variegated Wren M. *lamberti (assimilis)* R (W)
Blue-breasted Wren M. *pulcherrimus* R (W)
White-winged Wren M. *leucopterus* R (W)
Southern Emu-wren *Stipiturus malachurus* R (S)
Striated Grasswren *Amytornis striatus* R (W) T
hick-billed Grasswren A. *textilis* R (W)
Family ACANTHIZIDAE
White-browed (Spotted) Scrubwren *Sericornis frontalis (osculans)* R (W)
Shy Heathwren *Hylacola cauta* R (W)
Redthroat *Pyrrholaemus brunneus* R (W)
Western Fieldwren *Calamanthus campestris (ethelae)* R (W)
Weebill *Smicrornis brevirostris (brevirostris)* R (S)
Western Warbler *Gerygone fusca (fusca)* R (S)
Inland Thornbill *Acanthiza apicalis* R (W)
Chestnut-tailed Thornbill A. *uropygialis* R (W)
Slender-billed Thornbill A. *iredalei* R (W)
Yellow-tailed Thornbill A. *chrysorrhoa* R (S)
Common (Southern) Whiteface *Aphelocephala leucopsis* R (W)
Family CLIMACTERIDAE
Rufous Treecreeper *Climacteris rufa* R (W)
Family MELIPHAGIDAE
Red Wattlebird *Anthochaera carunculata* R (S)
Spiny-cheeked Honeyeater *Acanthogenys rufogularis* R (W)
Yellow-throated Miner *Manorina flavigula* R (W)
Singing Honeyeater *Meliphaga virescens* R (W)
White-eared Honeyeater M. *leucotis (novaenorciae)* R(W)
Purple-gaped Honeyeater M. *cratita* R (W)
Yellow-plumed Honeyeater M. *ornata* R (W) .
Brown-headed Honeyeater *Melithreptus brevirostris (leucogenys)* R (W)
New Holland Honeyeater *Phylidonyris novaehollandiae (novaehollandiae)* R (E)
White-fronted Honeyeater P. *albifrons* V, B
Tawny-crowned Honeyeater P. *melanops* R (S)
Crimson Chat *Ephthianura tricolor* V, B
Orange Chat *E. aurifrons* V, B
White-fronted Chat *E. albifrons* R (S)
Family DICAEIDAE
Mistletoebird *Dicaeum hirundinaceum* ?R (A)
Family PARDALOTIDAE
Yellow-rumped Pardalote *Pardalotus xanthopygus* R (W)
Striated Pardalote *Pardalotus striatus (substriatus)* R (W)
Family ZOSTEROPIDAE
Silvereye *Zosterops latera lis (halmaturina)* R (E)
Family FRINGILLIDAE
*Goldfinch *Carduelis carduelis* ?R
Family PASSERIDAE
*House Sparrow *Passer domesticus* R
Family ESTRILDIDAE
Diamond Firetail *Emblema guttatum* R (E)
Zebra Finch *Poephila guttata* V, B
Family STURNIDAE
*Starling *Sturnus vulgaris* R
Family CORCORACIDAE
White-winged Chough *Corcorax melanorhamphos* R (E)
Family ARTAMIDAE
Masked Woodswallow *Artamus personatus* V, B
White-browed Woodswallow A. *superciliosus* V, B
Black-faced Woodswallow A. *cinereus (cinereus)* R (W)
Dusky Woodswallow A. *cyanopterus* R (S)
Family CRACTICIDAE
Grey Butcherbird *Cracticus torquatus* R (S)
White-backed Magpie *Gymnorhina tibicen leuconota)* R (E)
Grey Currawong *Strepera versicolor* R (S)
Family CORVIDAE
Australian Raven *Corvus coronoides (coronoides)* R (E)
Little Raven C. *mellori* R (E)
Little Crow *C bennetti* ?R, B (W)

Table 2. SPECIES AND SUBSPECIES REPORTED FROM EYRE PENINSULA BUT WHOSE OCCURRENCE THERE REQUIRES SUBSTANTIATION.

Common Diving-petrel Pelecanoides urinatrix	Dusky Moorhen Gallinula tenebrosa
Peaceful Dove *Geopelia placida*	Sulphur-crested Cockatoo *Cacatua galerita*
Red-rumped Parrot *Psephotus haematonotus*	Spine-tailed Swift *Hirundapus caudacutus* ?
House Swift *Apus affinis*	Shining Bronze Cockatoo *Chrysococcyx lucidus plagosus*
'Skylark *Alauda arvensis*	Western Silvereye *Zosterops lateralis gouldi*
Black Honeyeater *Sugomel niger*	Pied Honeyeater *Certhionyx variegatus*
Grey-fronted Honeyeater *Meliphaga plumula*	White-plumed Honeyeater M. *penicillata*
Blue-faced Honeyeater *Entomyzon cyanotis*	Little Wattlebird *Anthochaera chrysoptera*
White-browed Treecreeper *Climacteris affinis*	

reported since 1976 (Cox in Reid 1980). The area also contains the only known breeding grounds of the Eyre Peninsula population of the Yellow tailed Black Cockatoo, now reduced to about 30 birds, breeding in *E. cladocalyx* in the Koppio district.

The main southern concentration of this woodland is now largely cleared for farming, and clearing of the remaining stands, including the Sugar Gum woodland in which the Yellow-tailed Black Cockatoo breeds, is continuing. This is unfortunate, for although the avifauna of this habitat was the first on the Peninsula to be sampled (by George Masters in 1865-66), little collecting has been undertaken in it since, and it remains ornithologically one of the least known areas in South Australia

Fresh and Brackish Waters

The few fresh and brackish lakes and swamps of Eyre Peninsula occur chiefly in the South, *e.g.* Big Swamp, Little Swamp, Lake Wangary and Sleaford Mere. Also in the south is Tod Reservoir, on the Tod River. (References include Storr 1947, Eckert 1972, 1973.) These waters are notable for the seasonal occurrences of the Great Crested Grebe', Darter, Yellow-billed Spoonbill, Black Swan', Black Duck', Grey Teal*, Blue-winged Shoveler, Pink-eared Duck*, Hardhead, Bluebilled Duck, Musk Duck, Purple Swamphen, Coot' and White-headed Stilt, and the migratory waders Black-tailed Godwit, Marsh Sandpiper, Wood Sandpiper, Red-necked Stint, Curlew Sandpiper, Long-toed Stint, Sharp-tailed Sandpiper and Japanese Snipe. Only six (*) of the 14 common local waterbirds listed have been recorded breeding (and these only once or twice), which suggests either that their local breeding is of a very low frequency, or that more fieldwork is necessary. That the latter is the case is indicated by the almost total absence of published observations from Sleaford Mere, the largest body of water on the Peninsula (and incidentally the locality of the region's sole authentic record of Lewin's Rail, *vide* Parker, 1985).

Coasts and Islands

An excellent summary and bibliography of the birds of the offshore islands up to 1977-78 appears in AERF (1978); see also Parker & Cox (1978), Parker *et al.* (1979) and Hornsby (1978). In addition, the South Australian National Parks and Wildlife Service recently has completed a survey of the islands (Robinson *et al.,* in prep.).

Of particular interest are the species that, in South Australia at least, breed wholly or largely on offshore islands: Little Penguin, Short-tailed Shearwater (Fig. 1), White-faced Storm-Petrel, Black-faced Shag, Eastern Reef Egret, Cape Barren Goose, White-bellied Sea-eagle, Sooty Oystercatcher, Pacific Gull, Fairy Tern, Crested Tern and Rock Parrot. To this list has recently been added the Fleshy-footed Shearwater, long known as common off the Peninsula but not found breeding, on Smith I., until 1982 (Robinson *et al.* 1985). In addition, in the Eyre Peninsula region the Australian Raven is known to breed only on the myall-bluebush plains and on islands off the western coast.

Not all the islands are offshore. Some, like Goat I. near Coffin Bay township, and the ABC Islets in Venus Bay, lie in sheltered inlets. Goat I. is of particular note in being one of the most accessible South Australian breeding grounds of the Rock Parrot (Barrett 1910, Sutton 1924). The ABC Islets also carry breeding populations of this species (Jenkin & Waterman 1965), and together with Jones I. and Little Eyre I. are of further significance for their breeding colonies of the Australian Pelican. Another local breeding bird of sheltered islands is the Eastern Reef Egret (Gill 1980).

Not all the species recorded on the islands are characteristically marine or littoral. Many are landbirds, some apparently resident like the Nankeen Kestrel, Richard's Pipit, Red-capped Robin, Golden Whistler and Australian Raven, others probably stragglers like the Budgerigah, New Holland Honeyeater and Singing Honeyeater. Still others, such as the Barn Owl and Banded Landrail, once thought to be visitors, are

Fig. 1. Entrance to nesting-burrow of Short-tailed Shearwater on Perforated Island.

now regarded as of uncertain status and are being further studied.

Also deserving mention are the Cape Barren Goose, with large and important local breeding colonies off the west and south coasts and on the Sir Joseph Banks Group (Robinson *et al. 1982),* and the Southern Stonecurlew, now largely extinct as a breeding bird on the South Australian mainland but with breeding populations persisting on some offshore islands including Thistle I. and Boston I.

Of no less interest than the islands are the coasts, with their extensive sandy beaches, massive cliffs and numerous sheltered bays and inlets, the last frequently containing mangroves. How much work remains to be done along the beaches is evidenced by the fact that there are no unequivocal published breeding records from the mainland coast of Pied Oystercatcher, Red capped Dotterel or Hooded Dotterel, though almost certainly all three breed there extensively. Better worked are the bays and inlets, known to be havens for certain migratory waders such as the Grey Plover, Lesser Golden Plover, Mongolian Plover, Large Sand-Plover, Bar-tailed Godwit, Greenshank, Grey-tailed Tattler, Knot and Great Knot (Eckert 1974, J. Needle pers. comm.).

Cleared Land

As noted previously most of the mal lee and tall woodland of the Peninsula has been cleared for farming, and clearing of the remaining unconserved stands continues. While this is detrimental to many of the local species, it has allowed some birds of more open country to increase their populations *e.g.* Nankeen Kestrel, Galah, Richard's Pipit and Australian Magpie (Storr 1947). In addition, clearing for cereal crops may have been responsible for the presence on the Peninsula of the Singing Bushlark.

ORNITHOGEOGRAPHICAL AFFINITIES

Of the 105 species of land birds categorized as resident in Table 1, 53 are represented by species or subspecies of Western or Eyrean distribution (Ford 1974, Schodde 1982, Blakers *et al.* 1984, see also Hall 1910); these include the Malleefowl, Ring-necked Parrot, Southern Scrub-robin, Western Yellow Robin, Blue-breasted Wren and Rufous Treecreeper. Of the remainder, 16 are of eastern (East BassianfTorresian) affinities, 14 are widespread in southern Australia with little or no variation, and 22 are widespread throughout the continent.

The impression that Eyre Peninsula's resident land avifauna is dominated by western and Eyrean forms is heightened by the absence west of Spencer's Gulf of a large number of eastern species and subspecies. These include the Crimson Rosella *Platycercus elegans,* the Mountain Thrush *Zoothera lunulata,* the Spotted Quailthrush *Cinclosoma punctatum,* the Buff-rumped Thornbill *Acanthiza reguloides,* the White-throated Treecreeper *Cormobates leucophaea,* the Black-chinned Honeyeater *Melithreptus gularis* and the Red-browed Finch *Aegintha temporalis,* all of which have their westernmost populations in the Mount Lofty Ranges or on Kangaroo Island. Whether these species ever had western populations now extinct is an open question. The possibility cannot be ruled out, for some 17 species and superspecies currently occur as breeding birds east and west of Eyre Peninsula but not on the Peninsula itself, suggesting local extinction there; these include the Red-tailed Black Cockatoo *Calyptorhynchus magnificus,* the Regent Parrot *Polytelis anthopeplus,* the Elegant Parrot *Neophema elegans,* the Crested Shriketit *Falcunculus frontatus,* the Rufous Bristlebird *Dasyornis broadbenti* and the Little Wattlebird *Anthochaera chrysoptera.*

Of the 53 western and Eyrean resident landbirds on Eyre Peninsula, only three species (Blue-breasted Wren, Western Yellow Robin and Rufous Treecreeper) occur no further east. A few others have subspecies that occur no further east. All 53, however, have representatives of some kind further east, either consubspecific, conspecific or allospecific, with eastern limits ranging from the eastern side of Gulf St Vincent to the western side of the Great Dividing Range.

Most, if not all, of the 53 western and Eyrean forms on Eyre Peninsula are moderately to strongly sedentary birds whose ranges presumably expanded westward slowly with climatic change. The much smaller eastern element, on the other hand, consists mainly of migratory or highly dispersive species that may equally well have colonized or recolonized the Peninsula across the Eyrean Barrier, *e.g.* the highflying water-crossing Yellow-tailed Black Cocktaoo, the partly migratory Little Grassbird, Western Warbler and Restless Flycatcher, and the dispersive, water-crossing Silvereye and Little Raven. The presence of the dispersive and partly migratory Singing Bushlark may in fact be relatively very recent, and a consequence of the provision of suitable open habitat by clearing for crops.

ACKNOWLEDGEMENT

For information, discussions and much other generous assistance during our work on the birds of Eyre Peninsula we are indebted to many friends and colleagues: to local residents D. Barnes (deceased), B. Casanova, C. L. Gill, J. Jolly, D. Morgan, P. & J. Needle, J. Ramsey, L. and E. Warneke, J. Whillas; to fellow-visitors, J. B. Cox, J. McNamara, L. P. Pedler, G. B. Ragless and N. C. H. Reid; and to National Parks and Wildlife Service officers L. Higgins, A. C. Robinson, A. Spiers and F. Vickery. R. L. Zusi and S. L. Olson of the Smithsonian Institution kindly sent us information and specimens from the collection of birds made by C. Hoy on southern Eyre Peninsula in 1920.

REFERENCES

AERF (1978). Migratory Birds and their Habitats in Australia. Pt. 2, Offshore Islands and External Territories. Vol. 5, The Offshore Islands of South Australia (Australian Environmental Research Foundation Pty Ltd, Brisbane).

Barrett, C. (1910). Notes on the Rock-Parrakeet *(Neophema petrophila). Emu* **9**, 133-5.

Blakers, M., Davies, S. J. J. F. & Reilly, P N. (1984). 'The Atlas of Australian Birds'. (Melbourne University Press, Melbourne).

Bony1hon, C. W, & Preiss, K. A. (1967). Hambidge Wild Life Reserve. S. *Aust. Nat.* **42**, 35-63.

Bryant, C. E. (1937). Narrative of the Eyre Peninsula Camp-out. *Emu* **36**, 229-42.

Chapman, F. R. H. (1966). The Burmese Spotted Dove on Eyre Peninsula. S. *Aust.* Orn. **24**, 111.

Cleland, J. B. (1925). Notes on the birds of the Port Lincoln district. S. *Aust.* Orn. **8**, 46-50.

Cleland, J. B. (1926). Notes on the birds of Eyre Peninsula. S. *Aust.* Orn. **8**, 140-4.

Close, D. H. (1981). The Kelp Gull in South Australia. S. *Aust. Orn*. 28, 155-6.

Condon, H. 1. (1969). 'A Handlist of the Birds of South Australia, 3rd ed. (revised)'. (S. Aust. Orn. Assoc., Adelaide).

Cox, J. B. (1974). Some birds of north-eastern Eyre Peninsula. S. *Aust.* Orn. **26**, 142-4.

Cox, J. B. (1978a). The distribution and seasonal occurrence of gannets off the South Australian coast. S. *Aust. Orn.* **28**, 19-20.

Cox, 1. (1978b). Little Egret at Arno Bay. S. *Aust. Orn.* **27**,288.

Cox, 1. (1984). A probable record of a Plains Wanderer near Rudall, Eyre Peninsula. S. *Aust.* Orn. 29, 99.

Eckert, H. J. (1972). Notes on Eyre Peninsula birds. S. *Aust. Orn.* **26**, 42-7.

Eckert, H. J. (1973). Further notes on Eyre Peninsula birds. S. *Aust. Orn.* **26**, 119-20.

Eckert, H. J. (1974). Birds of Streaky Bay. S. *Aust. Orn.* **26**, 138-41.

Finch, B. W. (1975). Sight-record of a species of swift new for Australia. *Emu* **75**, 44.

Finlayson, H. H. (1946). Notes on a few birds seen on Eyre Peninsula and its islands. S. *Aust. Orn.* **18**, 22-3.

Ford, J. R. (1971a). Distribution and taxonomy of southern birds in the Great Victoria Desert. *Emu* **71***,* 27-36.

Ford, J. R. (1971b). Distribution, ecology and taxonomy of some Western Australian passerine birds. *Emu* **71**, 103-20.

Ford, J. R. (1971c). Subspeciation in the Gilbert Whistler. *Emu* **71**. 141-2.

Ford, J. R. (1974). Speciation in Australian birds adapted to arid habitats. *Emu* **74**, 161-8.

Ford, J. R. (1979). Speciation or subspeciation in the Yellow Robins? *Emu* **79**, 103-6.

Garrett, C. (1980). Ruff sighted on Eyre Peninsula. S. *Aust. Orn*. **28**, 112.

Gill, C. L. (1978). Grey Petrel from southern Eyre Peninsula. S. *Aust. Orn*. **28**, 28.

Gill, C. L. (1980). Observations on the Eastern Reef Egret in the Eyre Peninsula region. S. *Aust. Orn*. **28**, 107.

Hall, R. (1910). The birds of Eyre Peninsula, SA *Emu* **9**, 123-33.

Hermes, N. & Bennett, S. (1974). Birds of the Eyre Peninsula. *Canberra Bd Notes* **2**, 12.

Hornsby, P E. (1978). Notes on the birds of Pearson Island. S. *Aust. Orn*. **27**, 280-4.

Jenkin, C. R. & Waterman, M. (1965). An expedition to Eyre Peninsula and offshore islands. S. *Aust. Orn*. **24**, 45-8.

Jones, F W., Condon, H. 1., Mack, G., Rutter, J. F, & Tubb, J. A (1938). Aves, *In:* Reports of the McCoy Society for Field Investigation and Research, 2. Sir Joseph Banks Group, Pt 1. *Proc. R. Soc. Vic.***50**(2), 399-413.

Keast, A. (1958). Variation and speciation in the Australian Flycatchers. *Rec. Aust. Mus.* **24**, 73-108.

Leiblich, G. (1971). The Cortlinye Water Reserve. S. *Aust.* Om. **25**, 234-5.

Leiblich, G. (1974). Birds *In:* 'Carappee Hill Conservation Park Survey Report'. (Nature Conserv. Soc. S. Aust., Adelaide).

Matheson, W. E. (1974). The irruption of Native Hens in South Australia in 1972-73. S. *Aust. Orn*. **26**, 151-6.

McEvey, A. R., & Middleton, W. G. (1968). Birds and vegetation between Perth and Adelaide. *Emu* **68***,* 161-212.

Morgan,T D. (1982). Further sightings of the Southern Emu-wren from Eyre Peninsula. S. *Aust. Orn.* **29**, 22.

Parker, S. A (1977). The distribution and occurrence in South Australia of owls of the genus *Tyto.* S. *Aust. Orn*. **27**, 207-15.

Parker, S. A. (1985). The occurrence of Lewin's Rail on Eyre Peninsula, South Australia. S. *Aust. Orn*. **29**, 188.

Parker, S. A. & Cox, J. B. (1978). Notes on the birds of Pearson, Dorothee and Greenly islands, South Australia. *Trans. R. Soc.* S. *Aust.* **102**, 191-202.

Parker, S. A., & Eckert, H. J. (1983). Remarks on the taxonomy of the genus *Calamanthus* (fieldwrens). S. *Aust. Orn*. **29**, 65-71.

Parker, S. A., Eckert, H. J., Ragless, G. B., Cox, J. B., & Reid, N. C. H. (1979). 'An Annotated Checklist of the Birds of South Australia, Pt 1, Emus to spoonbills'. (S. Aust. Orn. Assoc., Adelaide).

Parker, S. A, Eckert, H. J., & Ragless, G. B. (1985). 'An Annotated Checklist of the Birds of South Australia, Pt 2A, Waterfowl. (S. Aust. Orn. Assoc., Adelaide).

Parker, S. A., & May, I. A. (1982). Additional notes on seabirds recorded in South Australia. S. *Aust. Orn*. **28**, 213-6.

Parker, S. A. & Reid, N. C. H. (1978). Birds *In:* M. J. Tyler (Ed.), 'The Status of Endangered Australian Wildlife' 109-115. (Royal Zoological Society, Adelaide).

Pedler, L. P *(1978j.* Some birds of eastern Eyre Peninsula. S. *Aust. Orn.* **27**, 287.

Preiss, K. A. (1969). The Hundred of Blesing. S. *Aust. Nat.* **43**, 51-98.

Preiss, K. A., & Thomas, P M. (1970a). Hincks National Park. S. *Aust. Nat.* **45**, 29-78.

Preiss, K. A., & Thomas, P M. (1970b). Hambidge, Hincks and Blesing. S. *Aust. Orn.* **45**, 79-84.

Reid, J. R. W. (1980). Bird Report, 1976. S. *Aust. Orn.* ***28,*** 127-37.

Reid, N. C. H. (1975). The Western Warbler on Eyre Peninsula. S. *Aust. Orn*. **27**, 6-8.

Reid, N. C. H. (1978). Yellow-plumed and Tawny-crowned Honeyeater in River Red Gums. S. *Aust. Orn.* **28***,* 24-5.

Reid, N. C. H. (1983). Review: R. Schodde, 1982, The Fairy-Wrens, a Monograph of the Maluridae. S. *Aust. Orn*. **29**, 77-80.

Reid, N. C. H., Lindsey, 1., Carpenter, G., Harper, D., & Kernot, R. (1984). New records of Rose Robins in South Australia with comments on plumage and previous reports of Rose and Pink Robins. S. *Aust. Orn.* **29**, 100-5.

Reid, N. C. H., Paton, J. B., & Paton, D. C. (1977). Critical range limits of the turquoise and Black-backed Wrens in S.A. S. *Aust. Orn.* **27**, 216-21.

Rix, C. E. (1947). The Blue-breasted Wren in South Australia. S. *Aust. Orn*. **18**, 52-3.

Robinson, A C., Canty, P D., Mooney, P A., & Ruddock, P (in prep.). South Australia's offshore islands. Dept Env. Plan. S. Aust. Spec. Pubis.

Robinson, A. C., Delroy, L. B., & Jenkins, R. B. (1982). The conservation and management of the Cape Barren Goose *Cereopsis novaeholJandiae* Latham in South Australia. S. Aust. Nat. Pks & Wildlife Service Spec. Publ. 1.

Robinson, A C., Spiers, A., & Parker, S. A. (1985). First breeding record of the Fleshy-footed Shearwater in South Australia. S. *Aust. Orn.* **29** (in press).

Schodde, R. (1982). Origin, adaptation and evolution of birds in arid Australia, *In:* W. R. Barker & P oJ. M. Greenslade (Eds), 'Evolution of the Flora and Fauna of Arid Australia' 191-224. (Peacock, Adelaide).

Schodde, R., & Weatherley, R. G. 1981. A new subspecies of the southern Emu-wren *Stipiturus malachurus* from South Australia with notes on its affinities. S. *Aust. Orn*. **28**, 169-70.

Shaw, E. L. (1958). Birds of the lower Eyre Peninsula. S. *Aust. Nat.* **32**, 46-52.

Smith, O. (1972). Yellow-tailed Black Cockatoos at 'Ucontitchie Rock'. S. *Aust. Nat.* **47**, 46.

Storr, G. M. (1947). Some birds observed on southern Eyre Peninsula. S. *Aust. Orn.* **18**, 31-7, 54, 70.

Sullivan, C. (1928). Bird notes from the West Coast. S. *Aust. Orn*. **9**, 164-9.

Sutton, J. (1924). An ornithological trip around Eyre Peninsula. S. *Aust. Orn.* **7**, 118-59.

Sutton, J. (1926). North-east Eyre Peninsula. S. *Aust.* Om. **8**, 171-219.

Weidenbach, W. W. (1924). Birds noted on a trip to Cowell and the Hundred of Mangalo. S. *Aust. Orn.* **7**, 193-6.

White, S. A. (1912). Field ornithology in South Australia. *Emu* **12**, 1-8.

13: Reptiles and Amphibians

by T.D. SCHWANER, B. MILLER and M.J. TYLER

INTRODUCTION

The presence of numerous habitat types on Eyre Peninsula is reflected by a rich diversity of reptiles, but the aridity results in the occurrence of relatively few amphibians. A total of 97 species (almost one half of the known herpetofauna of the State) has been recorded there (Table 1). Discoveries during recent surveys in conservation parks, offshore islands and the adjacent Nullarbor Plain (see Schwaner & Miller 1984a, b) indicate that many significant distributional records, and even new species, will be found there.

Despite the large number of reptiles and amphibians recorded from the Eyre Peninsula, many species are represented in the South Australian Museum by a single specimen; most are known from specimens from only one or two localities, and knowledge of distributions of most species is incomplete. This lack of understanding of individual variation among known populations has frustrated efforts to formally recognize new forms. The deficiency is unfortunate because knowledge of the distributions of unique forms has become critical to support or refute arguments for conservation of some of the remnants of mallee and other components of the native vegetation.

REPTILES

Turtles

Marine turtles are sighted frequently in waters off southern and west coast areas of the Eyre Peninsula (see Houston 1979). Three species: the leather-backed turtle *(Dermochelys coriacea),* family Dermochelyidae, the loggerhead turtle *(Caretta caretta)* and the green sea turtle *(Chelonia mydas),* family Cheloniidae, have been recorded from photographs only. Sightings in southern coastal waters represent individuals that have strayed from breeding grounds and nesting beaches along the northern coasts of Australia and elsewhere. One recent report of *D. coriacea* from Louth Bay noted the coincidental occurrence of a 'large amount of jellyfish' in the area (T. A. Simmonds, *in litt.,* 29.vi.1984). Leather-backed turtles have numerous long spines in their throats to 'shred' jellyfish as they pass into the turtle's stomach during feeding.

Snakes

Typhlopidae

Three families of snakes are represented on the Eyre Peninsula. The blind snakes (Family Typhlopidae) are harmless, nocturnal, secretive, worm-like forms that burrow in sand and leaf litter, or seek refuge in stumps, logs and termite mounds. There they feed on termites, small worms and insects and their eggs. They comprise three species: *Rhamphotyphlops australis, R. bituberculatus* and *R. endoterus* (Fig. 1).

Fig. 1. *Rhamphotyphlops endoterus.*

Little new information on the natural history of blind snakes has been published since Waite (1929). The late F. J. Mitchell, Curator of Reptiles at the South Australian Museum (1955-1970), annotated his copy of Waite (1929), describing the abundance of *R. biturberculatus* in 'casuarina country' and its habit of 'moving about on [the) surface on hot sultry nights. 11.viii.59'. Mitchell also noted that *R. australis* 'emits an audible squeak when handled roughly-repeatedly heard during attempts to photograph a specimen in daylight. 9.v.58'.

Table 1. REPTILES and AMPHIBIANS OF THE EYRE PENINSULA. Species marked with an asterisk have not been collected, but are likely to occur there.

TURTLES	DERMOCHELYIDAE
	Dermochelys coriacea
	CHELONIDAE
	Caretta caretta
	Chelonia mydas
SNAKES	TYPHLOPIDAE
	Rhamphotyphlops australis
	R. bituberculata
	R. endoterus
	BOIDAE
	Liasis childreni
	Morelia spilota
	ELAPIDAE
	Acanthophis antarcticus
	Demansia psammophis
	Drysdalia mastersi
	Echiopsis curta
	*Furina diadema**
	*Neelaps bimaculata**
	Notechis ater
	Pseudechis australis
	Pseudonaja affinis
	P. modesta'
	P. nuchalis
	P. textilis inframacula
	Simoselaps bertholdi
	S. fasciolatus
	S. semifasciatus
	Suta suta
	Unechis flagellum
	U. nigriceps
	U. spectabilis
	Vermicella annulata
LIZARDS	*PYGOPODIDAE*
	Aprasia inaurita
	A. striolata
	Delma australis
	D. fraserii
	D. nasuta
	Lialis burtoni
	Pygopus lepidopodus
	*P. nigriceps**
	VARANIDAE
	*Varanus gilleni**
	V. rosenbergii
	GEKKONIDAE
	Diplodactylus elderi
	D. granariensis
	D. intermedius
	D. tesselatus
	D. vittatus
	Gehyra variegata
	Heternotia binoei
	Lucasium dameum
	*Nephrurus levis**
	N. stellatus
	Phyllodactylus marmoratus
	Rhynchoedura ornata
	Underwoodisaurus milii
	AGAMIDAE
	Ctenophorus cristatus
	C. fionni
	C. fordi
	C. pictus
	Diporiphora linga
	Gemmatophora norrisi
	Moloch horridus
	Pogona barbatus
	P. minor
	P. vitticeps
	Tympanocryptis adelaidensis
	T. lineata
	*T. tetraporophora**
	SCINCIDAE
	Cryptoblepharis plagiocephalus
	C. *virgatus*
	Ctenotus atlas
	C. brooksi
	C. *pantherinus*
	*C. regius**
	C. robustus
	C. schomburgkii
	C. uber
	Egernia carinata
	E. inornata
	E. multiscutata
	E. stokesii
	E. striolata
	Eremiascincus richardsoni
	Hemiergis initialis
	H. millewae
	Lampropholis delicat
	Leiolopisma entrecasteauxii
	Lerista bougainvillii
	L. distinguenda
	L. frost
	*L. labialis**
	L. microtis
	L. muelleri
	L. picturata
	L. terdigitata
	Menetia greyi
	Morethia adelaidensis
	M. *boulengeri*
	M. *butleri*
	M. *obscura*
	Tiliqua melanops
	T. occipitalis
	T. scincoides
	Trachydosaurus rugosus
	LEPTODACTYLIDAE
	Limnodynastes tasmaniensis
FROGS	*Neobatrachus centralis*
	N. pictus
	Neobatrachus sp
	Ranidella signifera

Boidae

The family Boidae is represented by the large carpet python, *Morelia spilota,* up to 3 m long, and the smaller (to 1 m) Children's python, *Liasis childreni* (Fig. 2). These are non-venomous snakes that capture and subdue vertebrate prey by constriction, a method that kills by suffocation (not crushing). Both species are known to inhabit rocky areas, particularly hillsides, cliff faces and scree slopes, but are never locally abundant. Residents of Whyalla state that carpet and Children's pythons are common in the nearby Middleback Ranges, but little is known of the status of boid populations elsewhere in South Australia and the general feeling is that these species are rare. A carpet python from the area of Fowlers Bay, examined recently by T.D.S. and released, is the first recorded specimen from that area since 1917.

Fig. 2. *Liasis childreni.*

A population of carpet snakes on St Francis Island in the Nuyts Archipelago near Ceduna thrives on lizards and mutton birds. These highly protected snakes are intermediate in colour and scale patterns between carpet pythons in southwestern Western Australia and more easterly populations on the Eyre Peninsula and in the Murray River valley. Their presence supports the claim that a connection between southwestern and southeastern Australia across the southern continental shelf existed prior to flooding of the shelf by rising sea levels during the last 10-20 000 years.

Elapidae

Most snakes on the Eyre Peninsula belong to the venomous family of front fixed-fanged species, the Elapidae. They include the large and dangerous death adder, tiger snake, mulga or king brown snake, and the brown snakes, as well as a number of smaller, less harmful species.

Eighteen species are recorded from the region and three others are likely to occur there.

The distinct, viper-like appearance of the death adder *(Acanthophis antarcticus)* and its curious spiny tail which wriggles to attract prey, are features unique to this elapid snake (Fig. 3). Although restricted to patchy, dwindling habitats of undisturbed coastal dunes, and mallee with abundant leaf litter, death adders are easily bred in captivity (Mirtschin 1984) and may survive in protected areas by carefully monitored management programmes.

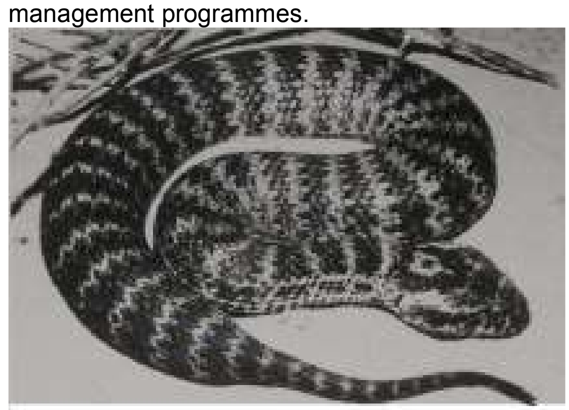


Fig. 3 *Acanthophis antarcticus.*

The black tiger snake *(Notechis ater')* is seen rarely in southern coastal mainland areas from Port Lincoln to Ceduna, but is locally abundant on many offshore islands. These magnificent, jet black snakes are the subject of an intensive study of variation and evolution (Schwaner 1985). Island populations differ markedly in maximum attainable length and weight. These differences are explained almost entirely by differences in the kinds of prey available to them since their isolation from each other 6-10 000 years ago. Research into the patterns of growth, and life history traits of tiger snakes, and comparisons of their population ecology, morphology and genetics, may reveal processes that determine the origin of new species.

The mulga or king brown snake *(Pseudechis australis)* occurs in" many habitats on the Eyre Peninsula but is nowhere locally abundant. Although primarily a diurnal species, mulga snakes have been seen on very warm nights. Mulga snakes reputedly have the largest quantity of venom per body size of any Australian elapid (Mirtschin & Davis 1983). They are voracious feeders, biting and chewing venom into their prey. Food consists of small mammals, lizards and snakes.

Brown snakes *(Pseudonaja* spp.) are represented by three species on the Eyre Peninsula, but a fourth species, the ringed brown snake *(P modesta,* Fig. 4), may be found in the extreme northwest of the region. The western brown snake, *P nuchalis,* is the most abundant and widespread snake on the Peninsula. Juveniles are light brown with a black band on the head and neck, separated by an orange ring. Adults exhibit such a bewildering variety of colours, patterns and sizes that the species is believed to comprise several distinct forms. This has been partially confirmed by chromosomal and biochemical studies (Mengden 1985, M. Adams & P Baverstock, pers. comm.).

The peninsula brown snake, *P textilis infra macula,* is restricted to southern Yorke Peninsula and the coastal areas of the Eyre Peninsula from Whyalla to the far West Coast (Fig. 4). Although believed to be isolated, melanistic forms of the widespread eastern brown snake *(P t. textilis),* peninsula brown snakes

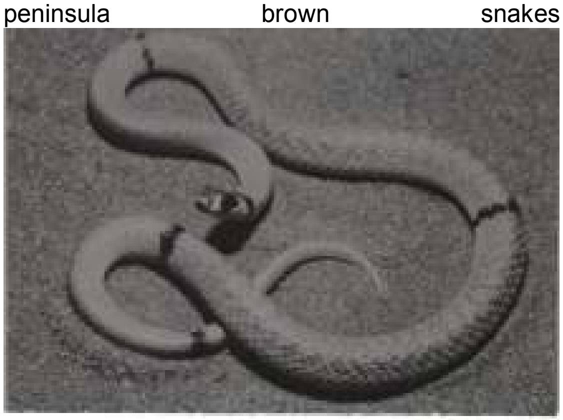


Fig. 4 *Pseudonaja modesta.*

sometimes exhibit colour patterns that are similar to the dugite, *P affinis,* which extends eastward from Western Australia along the Nullarbor and west coast of the Eyre Peninsula. Mengden (1985) has shown the western brown snake and dugite of southern Eyre Peninsula both have a diploid chromosome number of 34, whilst the eastern brown snake has 38. One specimen of the peninsula brown snake from Coffin Bay had an intermediate chromosomal number of 36 (Mengden pers. comm.).

Brown snakes usually try to escape when approached but can be aggressive and dangerous when cornered. Their venom, although small in quantity, is extremely toxic. Brown snakes eat small mammals, lizards and other snakes. Their ranges and numbers seem to be increasing in many areas in concert with the house mouse. They will take small to medium sized sleepy lizards and blue-tongued lizards, and are among a number of Australian elapid snakes that subdue their prey by constriction as well as by envenomation (Shine & Schwaner 1985).

The status of these highly variable, and medically important, snakes is under intensive study. Fortunately, a single antiserum seems to be effective in treating humans bitten by brown snakes, although some variation in response to treatment for bites from different areas has been noted (J. White, pers. comm.). Obviously their identification is a taxonomist's nightmare for which a good solution does not yet exist.

The majority of snakes on the Eyre Peninsula are small, inoffensive, relatively harmless species. The slender, yellow-faced whip snake *(Demansia psammophis)* is a swift moving, diurnal, lizardeating species, widespread in mallee and low scrub and easily recognized by a white or yellowish vertical bar in front of the eye. Master's snake *(Drysdalia mastersi)* is a small, dark coloured, diurnal but cryptic snake, infrequently found in coastal areas under rock, logs and leaf litter. An isolated population of Master's snakes also exists on St Francis Island. The bardick *(Echiopsis curta)* is a brown, unpatterned, secretive, nocturnally active, lizard-eating snake (Shine 1982), typically found in mallee and porcupine grass habitats (Fig. 5). One juvenile specimen from 'sandy coastal dunes' near Streaky Bay was mistakenly identified as a newborn death adder (T. Dennis 3.x.1982, *in litt.).* Three species of banded sand snakes *(Simoselaps* spp.) are widespread in the region. All are brightly coloured with red, black and white bands or rings, found in sand or leaf litter, and differ markedly in diet (Shine 1984). *S. bertholdi,* the most common species, feeds almost exclusively on sand-swimming skinks, genus *Lerista. S. semifasciata* eats only lizard eggs, and S. *fasciolatus* (Fig. 6), here reported from the Eyre Peninsula for the first time, feeds on both lizards and their eggs. The curl snake or myall snake, *Suta suta,* is a pale brown species distributed along the northern edge of the region in drier areas of saltbush/bluebush scrub. Although normally a small snake, it can be aggressive and nervous when provoked, and may strike repeatedly from flattened, S-shaped coils. Large individuals should be considered dangerous. Three species of little whip snakes, *Unechis flagellum, U. nigriceps* and *U. spectabilis* (Fig. 7), all resemble juvenile brown snakes in size and colour pattern, but differ in having undivided

Fig. 5 *Echiopsis curta.*

Fig. 6 *Simoselaps fasciolatus.*

Fig. 7 *Unechis spectabilis.*

scales under the tail and a smooth, shiny, opalescent appearance. All three forms are lizard eaters. *U. nigriceps* favours rocky hillsides and dry creek beds in the Middleback Ranges, the coastal hills of southeastern Eyre Peninsula and the Marble Ranges. *U. spectabilis* is a lowland form, commonly found in saltbush/bluebush and mallee habitats. *U. flagellum* is restricted to St Francis Island, as a relic isolated some 8-10 000 years ago from populations further east on Kangaroo Island and the adjacent mainland. Finally, the black and white ringed bandy-bandy *(Vermicella annulata)* is a widespread but secretive snake, usually found near termite nests where it feeds almost exclusively on blind snakes. Like the curl snake, the bandy-bandy throws its body into S-shaped curves and strikes repeatedly when threatened, but is not considered dangerous. The red-naped snake, *Furina diadema,* is a small, secretive species that may be found under rocks, logs or litter in the far northwest of the Eyre Peninsula. Likewise, the western black-naped snake, *Neelaps bimaculata,* is a burrowing species whose range may extend from the Great Victorian Desert into the far northwest of the region (Cogger 1983).

LIZARDS

Pygopodidae

Five families of lizards are represented on the Eyre Peninsula. The snake and worm-like lizards, family Pygopodidae, are unique to the Australian region (Kluge 1974). They lack forelimbs and hindlimbs are reduced to small, scaly flaps just above the vent. Unlike legless lizards in other parts of the world, pygopodids lack eyelids and ear openings may be present or absent. In most species the tail is much longer than the body and is easily broken.

Two earless species of worm-like pygopodids, *Aprasia inaurita,* on the mainland, and *A. striolata,* known from a single specimen from St Francis Island, are insect feeders that burrow in sandy soils or leaf litter.

Among the snake-like, insectivorous pygopodids, *Delma australis, D. nasuta* and *D. fraseri* occupy mallee and porcupine grass from coastal to central arid areas of the Eyre Peninsula. Burton's snake lizard, *Lialis burtonis,* is a sharpsnouted, lizard-eating pygopodid, highly variable in colour and pattern, and common and widespread in undisturbed habitats of mallee and porcupine grass. One population of *L. burtonis* is isolated on St Francis Island. The common scaly-foot, *Pygopus lepidopodus* (Fig. 8), and the hooded scaly-foot, *P. nigriceps,* appear to occupy separate, or marginally overlapping ranges on the Eyre Peninsula. *P. lepidopodus* forages diurnally in coastal heath and mallee. *P. nigriceps* whose colour pattern mimics that of a juvenile brown snake (Bustard 1970), is a nocturnal or crepuscular forager, primarily in red sand hills of the arid and semiarid interior (Fig. 8).

Fig. 8 *Pygopus lepidopodus.*

Pygopodids may be highly derived forms of the family Gekkonidae (Kluge 1974), with which they share many features such as eyes without lids and a broad, flat fleshy tongue used to keep the eyes clean. Unlike pygopodids, however, geckos have well developed, pentadactyl limbs, more typical lizard-like bodies and nocturnal habits.

Gekkonidae

The genus *Diplodactylus* is represented by at least five species on the Eyre Peninsula. The jewelled gecko, *D. elderi,* a velvety grey or black lizard with small, scattered white spots, is entirely confined to porcupine grass. The widespread wood gecko *(D. vittatus)* complex contains several chromosomal races (King 1977) in southern Australia. In rocky areas on the Eyre Peninsula, the complex is represented by the grounddwelling species, *D. granariensis. D. vittatus* presumably is restricted to areas east and south of Pt Augusta (Cogger 1983) but specimens from Whyalla resemble *D. vittatus* in colour pattern and their status may be linked to an old form, *D. furcosus* (Storr 1979). The eastern spiny-tailed gecko, *D. intermedius,* a slender, pale grey or brown species with spindly limbs, commonly is found climbing in saltbush or bluebush shrubs, or in dead trees in arid or semiarid areas. The tessellated gecko, *D. tessellatus,* here reported for the first time from the Eyre Peninsula, is a ground dwelling species known from a single specimen collected under debris at Lincoln Gap in the northeast of the region (Fig. 9).

Two of the most common geckos in Australia are the tree dtella, *Gehyra variegata,* found under tree bark and exfoliating rocks, and Bynoe's gecko, *Heternotia binoei,* a ground dwelling species found hiding by day under any form of ground litter or debris. Both species are highly variable in colour and pattern, and exhibit several distinct chromosomal races, some of which consist only of females (Moritz 1983).

Swales between dunes support two geckos with markedly different diets. The beaded gecko, *Lucasium damaeum,* hides in shallow burrows by day and forages widely at night, feeding on a variety of ground dwelling insects. The beaked gecko, *Rhynchoedura ornata,* occupies the same habitat but feeds almost entirely on ants.

The knob-tailed geckos, *Nephrurus levis* and *N. stellatus,* are characterized by broad heads and short, fat fails with a distinct knob at the end. Only *N. stellatus* is known from the Eyre Peninsula but *N. levis* may be found in the far northeast corner of the region in dry, sandy areas.

The thick-tailed gecko, *Underwoodisaurus milii,* is similar in size and shape to *Nephrurus,* but lacks the tail knob and favours coastal areas, particularly those with broken limestone rocks. Individuals on offshore islands have been observed to hide in mutton bird burrows by day, emerging at night to forage where they are preyed upon by tiger snakes.

Fig. 9 *Diplodactylus tessellatus.*

On islands of the Sir Joseph Banks Group and the Nuyts Archipelago, marbled geckos, *Phyllodactylus marmoratus,* occur in large numbers. Dozens can be uncovered in a short time by turning limestone rocks and debris above the high tide mark along coastal margins.

Agamidae

Dragon lizards, family Agamidae, are represented by 13 species on Eyre Peninsula. The genus *Amphibolurus* no longer is recognized by Storr (1982) who now places the known species into several genera to better reflect their relationships. The widespread genus *Ctenophorus* contains the moderately large, long-tailed and swift moving crested dragon, C. *cristatus* (Fig. 10), the colourful and diverse rock dragon, C. *fionni,* the small mallee dragon, C. *fordi,* and the widespread painted dragon, C. *pictus.* Specimens of the arboreal jacky lizard, *Gemmatophora muricata* from eucalyptus

Fig. 10 *Ctenophorus cristatus.*

woodlands in southern, central and western Eyre Peninsula have been redescribed as a new species G. *norrisi Witten* & Coventry (1984). The large, widespread bearded dragons, *Pogona barbatus,* P. *vitticeps,* and P. *minor,* are frequently seen crossing roads or basking on rocks and fence posts during the summer. Males typically display an extensible gular frill or 'beard' when disturbed. In the extreme northwest of the region the small, slender dragon, *Diporiphora linga,* is common among porcupine grass in arid sandridge country. The earless dragons, genus *Tympanocryptis,* now include *T. adelaidensis* (which in fact has exposed ear openings and inhabits coastal heath), *T. lineata,* an earless form with a brown and a rufescent colour morph in northern and southern Eyre Peninsula, respectively, and *T. tetraporophora,* a possible inhabitant of stony hills, table lands and plains in the far northeast of the region. Finally, the thorny or mountain devil, *Moloch horridus* (Fig. 11), with large, sharp, spiny scales covering the entire dorsum, is the most bizarre dragon.

Fig. 11 *Moloch horridus.*

In spite of the frightening appearance it is a harmless, slow moving species whose diet consists entirely of small black ants (genus *Iridomyrmex).*

For a more detailed discussion of dragons on Eyre Peninsula refer to Houston (1978).

Varanidae

Goannas or monitor lizards, family Varanidae, are represented by *Varanus rosenbergi* (Fig. 11) along the southeastern coast and some offshore islands of the peninsula, its close relative, *V. gouldii* (Fig. 12), in arid, sandy areas of the northeast, and perhaps the pygmy monitor, *V. gilleni,* an arboreal species found in tree hollows and under bark along the extreme northern border of the region. *V. rosenbergi* may have been introduced to Reevesby Island (Mirtschin 1982). As top predators capable of feeding on a wide range of vertebrate and invertebrate prey, these lizards could determine the survivability of other species through competition for food or habitat, or by direct predation. However, arguments for their eradication are questioned by Schwaner (1985) and further debated by Robinson *et al.* (1985).

Fig. 12 *Varanus gouldii.*

Scincidae

Skinks, family Scincidae, are the most numerous and diverse family of lizards on Eyre Peninsula. The family is characterized by the presence of boney plates called osteoderms embedded in each scale. Those of the dorsum are particularly thick in some species and are believed to offer protection from predation, whilst in other forms the osteoderms are smaller or thinner and may function to strengthen the body wall during burrowing. Skinks usually are diurnal and largely insectivorous or herbivorous.

Snake-eyed skinks, *Cryptoblepharus* spp., are the most widely distributed genus of lizards in the world. On Eyre Peninsula, C. *plagiocephalus* is an inland, arboreal species with a narrow, ragged edged, pale, longitudinal stripe bordered above bv black blotches. The closely related species

C. *virgatus,* inhabits rocky coasts of mainlands and offshore islands, and typically has a well defined pale dorsolateral stripe bordered above by a sharp-edged, continuous black stripe.

The striped skinks, genus *Ctenotus,* now include over sixty species in Australia (Cogger 1983), seven of which occur in a variety of habitats on the Eyre Peninsula. On rocky hilltops and scree slopes with porcupine grass, C. *pantherinus* and C. *robustus* coexist; populations of the latter species in the northeast and throughout the Middleback Ranges have an unusual colour pattern and may represent a new form (Fig. 13).

Fig. 13 *Ctenotus robustus.*

A similar species, C. *uber,* prefers coastal hills where it hides under flat rocks and among bluebush shrubs. A population of C. *uber* on Roxby Island shelters in dense leaf litter under *Myoporum* shrubs and is the primary prey of tiger snakes on this island. Two small, similarly patterned skinks, C. *brooksi* and C. *schomburgkii,* occur in coastal vegetated dunes along the west coast and in open scrubland near red sand dunes, respectively. C. *atlas* is a slender, many striped species found in mallee and porcupine grass. In the far northeast of the region, C. *regius* also may be found in mallee and porcupine grass, as well as in bluebush and timbered areas.

The genus *Egernia* contains the large, spiny, flat-tailed Stoke's skink, *E. stokesii,* that forms colonies in rocky hillsides. The desert skink, *E. inornata,* is a burrowing species with a cylindrical body and short legs. It occurs in drier, sandy habitats of the northern and eastern parts of the Peninsula. Another burrower, *E. multiscutata,* is abundant in coastal sand or limestone rock, and frequents mutton bird burrows on many offshore islands. A closely related species, *E. whitii,* is found in coastal limestone of extreme southeastern Eyre Peninsula. The fragmented ranges of these two species on islands, peninsulas, and restricted areas of the mainlClnd across southern Australia (Cogger 1983) suggest a former distribution along the now flooded continental shelf. The tree skink, *E. strio/ata,* is a moderately large skink favouring timbered, rocky hillsides in the Middleback Ranges. A similarly sized species, *E. carinata* also climbs in trees on the mainland, but prefers coastal rocks in the Ceduna area and on Flinders Island.

The broad-banded sand swimmer, *Eremiascincus richardsonii,* is restricted to red sand hills where it frequents rabbit warrens and shallow burrows under logs.

Hemiergis millewae and *H. initialis* favour mallee and porcupine grass, and *H. peronii* inhabits coastal limestone rocks, heath and shrubs with litter. *H. peronii* on offshore islands is a common prey item of juvenile tiger snakes.

Lampropholis delicata and *Leiolopisma entrecasteauxii* are southeastern species represented by relict populations on southern Eyre Peninsula, and on several offshore islands. Formerly both must have been more widely distributed along the now flooded continental shelf.

Eight species of sand-swimming skinks, genus *Lerista,* occur on the Eyre Peninsula, and four of these have been found on several offshore islands. All are fossorial and cryptic, except for *L. microtis* which may be observed foraging

Table 2. CHARACTER STATES SEPARATING SPECIES OF *LERISTA* KNOWN ON EYRE PENINSULA. Numbers below forelimbs and hindlimbs refer to numbers of digits *(L. labialis* lacks entire forelimb). M = Moveable; F = Fixed.

Species	*Forelimbs*	*Hindlimbs*	*Eyelid*	*Midbody Scale Rows*
Lerista bouganvillii	5	5	M	22-24
L. microtis	5	5	M	18-20
L. distinguenda	4	4	F	18-20
L. frosti	4	4	M	18-20
L. muelleri	3	3	F	18-22
L. terdigitata	3	3	M	18-22
L. picturata	1 or 2	1 or 2	M	18-22
L. labialis	0	2	M	18-20

among coastal shrubs. The genus is noted for the variety of limb reductions exhibited by its many species (Table 2).

One of the most widespread skinks in Australia, *Menetia greyii* is distinguished from most other skinks on the Eyre Peninsula by having five toes and four fingers. Little is known of the ecology and life history of this minute skink (only about 30 mm in body length) other than its diurnal habits and swift movement in leaf litter or grass. Populations occur on several offshore islands in the region.

Four species of the widespread genus *Morethia* (M. *adelaidensis,* M. *boulengeri,* M. *butleri* and M. *obscura)* may be found in the same or similar habitats. Although superficially very similar in colour, pattern and size, these skinks are easily identified and may avoid each other in nature by different behavioural patterns (P. R. Baverstock pers. comm.).

The blue-tongued lizards, genus *Tiliqua,* and their sister species (Hutchinson 1981), the sleepy lizard, *Trachydosaurus rugosus* are among the larger, more conspicuous lizards of South Australia, and are particularly noticeable on Eyre Peninsula. The slender, fossorial blue-tongues, *T. melanops,* live in porcupine grass and, occasionally, under debris. *T. branchiale* has been discovered on several offshore islands of the Nuyts Archipelago, and its presence, again, points up the possibility of a more widespread population 20 000 years ago, perhaps connecting with similar forms in southern and Western Australia. The western blue-tongued lizard, *T. occipitalis,* has fewer body bands than the common or eastern blue-tongued lizard, *T. scincoides.* Both species occupy areas with abundant shrubs and mallee but *T. scincoides* appears to be restricted on the Eyre Peninsula to the Corrunna Hills near Whyalla (Johnston (984). Finally, the large and harmless sleepy lizard *(Trachydosaurus rugosus)* is perhaps as symbolic of Australia as the koala or the kangaroo. Although thousands of these lizards are killed on the highways each spring, they seem to have adapted to man's presence and are frequent visitors in gardens and around human dwellings, as well as open fields and roadside patches of natural and weedy growth.

AMPHIBIANS

Frogs

Leptodactylidae

All of the frogs found on Eyre Peninsula are leptodactylids. This is surprising because the other family of frogs occurring in southern Australia (the Hylidae) is well represented in the south-west of WA., and the species occurring there have a close relationship with species in the south-east of the continent. Hence species such as *Litoria ewingi* and *L. raniformis* would be anticipated to inhabitat the area of highest rainfall at the southernmost tip of the peninsula. Surprisingly both species are absent.

The species with the most extensive geographic distribution on Eyre Peninsula is the marbled frog, *Limnodynastes tasmaniensis.* Elsewhere in SA it extends from Gidgealpa Waterhole north of Moomba to the lower southeast. On the Eyre Peninsula it is found commonly beneath litter surrounding dams, and is likely to be distributed by man amongst earth moving machinery and transportable homes (Martin & Tyler 1978). *Limnodynastes tasmaniensis* breeds in temporary pools and is the only species on the Eyre Peninsula to deposit eggs in a nest of foam floating on the surface of the water.

The globular form of the fossorial *Neobatrachus* species permits their generic identification on the Eyre Peninsula, but identification of species is much more difficult, and it is evident that there is an undescribed species (M. Mahony *in litt.).* Roberts (1978) demonstrated that *N. pictus* extends to the Eyre Peninsula and Tyler (1978) suggested that the other described northern species *(N. centralis)* is confined to the north-east of the State. The identity of the remaining populations on the peninsula remains uncertain.

The frog let *Ranidella signifera* is confined to the southern extremity of the peninsula and is therefore a relict population isolated by the current aridity. In contrast other isolates (as on Kangaroo Island and Tasmania) have been isolated by rising sea levels.

The toadlet *Pseudophryne bibroniwas* reported from Port Lincoln by Metcalf (1940) but this identification is suspect and requires confirmation.

ACKNOWLEDGEMENTS

Reptile surveys of the Sir Joseph Banks Islands were made possible by a grant to TDS from the South Australian Wildlife Conservation Fund. The following people generously provided information and assistance to help compile this summary: the late P. Aitken, G. Aldridge, P. Bird, K. Casperson, P. Cockerham, S. Delean, T. Dennis, S. Doyle, M. Francis, M. Gordon, K. Gowlett, S. Hanniford, C. Harvey, N. Holmes, G. Johnston, K. Jordan, N. Karagiannis, R. Longmore, P. Mann, P. Mirtschin, T. Morely, G. Nicholls, I. Olsen, A. C. Robinson,

S. Sarre, L. Schwaner, K. Scott, T. Sim, T. Simmonds, D. Smith, J. Smith, M. Thompson, S. Tremont, K. Turner and F. Vickery. T. P. Morely is thanked for figures 9 and 13. Special thanks go to Ken Scott and Dean Smith of Tumby Bay, and Nick Karagannis of Ceduna, for providing safe transport to offshore islands. We are particularly grateful to Adrienne Edwards for assistance in the curation of the voucher specimens and documentation upon which this paper is based.

REFERENCES

Bustard, R. (1970). 'Australian Lizards.' (Collins, Sydney). Cogger, H. G. (1983). 'Reptiles and Amphibians of Australia.' 3rd Edtn (Reed, Sydney).

Houston, T. F. (1978). Dragon Lizards and Goannas of South Australia, *Spec. Educ. Bull. Ser.* S. *Aust. Mus., Adelaide.*

Houston, T. F. (1979). Sea turtles in South Australia. S. *Aust. Nat.* **53**, 42-6.

Hutchinson, M. (1981). Systematic relationships of the genera *Egernia* and *Tiliqua* (Lacertilia: Scincidae). A review and immunological assessment. *In* Banks, C. B. & Martin, A. A. (Eds) 'Proceedings of the Melbourne Herpetological Symposium' (Zoological Board of Vie., Melbourne).

Johnston, G. R. (1982). The herpetofauna of the Middleback Range area, South Australia 1. An annotated checklist. *Herpetofauna* **14**(1), 52-60.

Kluge, A. G. (1974). A taxonomic revision of the lizard family Pygopodidae. *Misc. Publ. Mus. Zool., Univ. Michigan (147).*

King, M. (1977). Chromosomal and morphometric variation in the gekko *Diplodactylus vittatus* (Gray). *Aust. J. Zool.* **25**, 43-57.

Martin, A. A. & Tyler, M. J. (1978). The introduction into Western Australia of the frog *Limnodynastes tasmaniensis. Aust. Zool.* **19**, 320-44.

Mengden, G. A. (1985). A chromosomal and electrophoretic analysis of *Pseudonaja. In* Grigg, G., Shine, R. & Ehmann, H. (Eds.)., 'Biology of Australasian Frogs and Reptiles.' (Surrey Beatty, Sydney).

Metcalf, M. M. (1940). Further studies on the opalinid ciliate infusorians and their hosts. *Proc. U.S. Natl. Mus.* **87**(3077), 465-634.

Mirtschin, P. J. (1982). The Goulds goanna, an Australian native, alien to Reevesby Island. S. *Aust. Nat.* **57**(1), 18-9.

Mirtschin, P. J. (1984). The common death adder *Acanthophis antarcticus* in South Australia. Its status and conservation. S. *Aust. Nat.* **58**(2), 24-8.

Mirtschin, P. & Davis, R. (1983). 'Dangerous Snakes of Australia.' (Rigby, Adelaide).

Mortiz, C. (1983). Parthenogenesis in the endemic Australian lizard *Heteronotia binoei* (Gekkonidae). *Science* **220**, 735-7.

Roberts, J. D. (1978). Redefinition of the Australian leptodactylid frog *Neobatrachus pictus* Peters. *Trans. R. Soc.* S. *Aust.* **102**, 97-105.

Robinson, A. C., Mirtschin, P. J., Copley, P. B., Cantry, P. D. & Jenkins, R. B. (1985). The Reevesby Island goanna-a problem in conservation management. S. *Aust. Nat.* **59**(4), 56-62.

Schwaner, T. D. (1985). Population size and structure of black tiger snakes, *Notechis ater niger,* on offshore islands of South Australia. *In* Grigg, G., Shine, R. & Ehmann, H. (Eds.). 'Biology of Australian Frogs and Reptiles.' (Surrey Beatty, Sydney).

Schwaner, T. D. (1985). The eradication of a native animal from an island reserve-a critical assessment of the Reevesby Island goanna case history. S. *Aust. Nat.* **59**(4), 52-55.

Schwaner, T. D. & Miller, B. (1984a). Reptiles new to the fauna of South Australia. *Trans. R. Soc.* S. *Aust.* **108***,* 215-6.

Schwaner, T. D. & Miller, B. (1984b). Range extensions of reptiles in South Australia. *Trans. R. Soc.* S. *Aust.* **108,** 217-8.

Shine, R. (1982). Ecology of the Australian elapid snake, *Echiopsis curta, J. Herpetol.* **16,** 388-93.

Shine, R. (1984). Ecology of small fossorial Australian snakes of the genera *Neelaps* and *Simoselaps* (Serpentes, Elapidae). *In* R. A. Seigel, L. D. Hunt, J. L. Knight, L. Malaret & N. L. Zuschlag (Eds) 'Vertebrate Ecology and Systematics-a Tribute to Henry S. Fitch' pp. 173-183 (Mus. Nat. Hist. Univ. Kansas, Lawrence).

Shine, R. & Schwaner, T. (1985). Prey constriction in venomous snakes. *Copeia* (in press).

Storr, G. M. (1979). The *Diplodactylus vittatus* complex (Lacertilia, Gekkonidae) in Western Australia. *Rec. West. Aust. Mus.,* **7**(4), 391-402.

Storr, G. M. (1982). Revision of the bearded dragons (Lacertilia: Agamidae) of Western Australia with notes on the dismemberment of the genus *Amphibolurus. Rec. West. Aust. Mus.,* **10**(2), 199-214.

Tyler, M. J. (1978). Amphibians of South Australia. (Govt Printer, Adelaide).

Waite, E. R. (1929). 'The Reptiles and Amphibians of South Australia.' (Govt Printer, Adelaide).

Witten, G. J. & Coventry, J. (1984). A new lizard of the genus *Amphibolurus* (Agamidae) from southern Australia. *Proc. R. Soc. Vie.* **96**(3), 155-9.

14: Fish and Major Fisheries

by C.J. GLOVER and A.M. OLSEN

INTRODUCTION

The extensive coastal waters around Eyre Peninsula provide a wide variety of habitats for a prolific and diverse fish fauna, including species of considerable commercial and recreational importance. As at Kangaroo Island (Glover 1979) the marine fish fauna of the Peninsula is typical of southern Australian coastal waters.

The Peninsula's marine fish fauna has close affinities with the fish fauna off southern and south-western Western Australia and, to a lesser degree, with that off western Victoria and north west Tasmania.

Whereas the marine fishes of commercial importance have been studied extensively, much remains to be done to clarify the status and identity of many lesser known species, particularly those of the offshore deepwaters and smaller species of the shallow littoral zone.

Because of the semi-arid nature of much of the Peninsula, the freshwater fish fauna is depauperate.

MARINE ENVIRONMENT

Physical Features

The exposed western coast features high limestone cliffs, prominent headlands and a few shallow bays behind narrow high entrances. However, the modifying influence of offshore islands of the Nuyts Archipelago (St Francis Isles) allows the development of extensive sea grass communities on their protected shores, with the consequent attendant fish fauna. There is little or no freshwater runoff from the semi-arid interior.

On the other hand the more protected eastern shoreline of Eyre Peninsula in Spencer Gulf is flatter, with fewer cliffs and more sand beaches and mangrove flats between headlands. The fish fauna of these environments is similar to those of the protected seagrass communities of the west coast shallow bays.

These differing marine environments are the preferred habitats of specific groups of fishes. The species in these groups are similar to those documented by Glover (1979) for similar habitats around Kangaroo Island.

Salinity and temperature

The eastern region of the Great Australian Bight receives inputs from several different sources. For example the south-east Indian Ocean (salinity 35.4-36. 0 $^{0}/_{00}$, temperature 17-21°C) flows in from an easterly direction for most of the year; the Leeuwin Current of low salinity (35.0$^{0}/_{00}$) and high temperature flows eastwards, coastwise for varying periods each year, and sub-Antarctic intermediate water (35.0-35.6$^{0}/_{00}$, 9-14°C) is brought in by the West Wind Drift. The mixed waters of the surface-flowing Flinders Current (mean salinity 35.35^{0}/oo, mean temperature 14°C) come from the gyre south of South Australia (Bye 1972). Salinity distribution across, and within, shelf waters is controlled by advective processes, although additional mixing is brought about by the reversal in direction of a easterly-south-easterly flow in winter, to a westerly-north-westerly flow during November to March. The velocity of the surface flow averages about 5 cm sec^{-1}. The strength of the easterly movement of the mixed water mass varies from year to year depending on the mean latitude of the passage of the weather fronts across Southern Australia (Rochford 1975; Thompson & Veronis 1983).

An ephemeral temperature inversion within the shelf waters south of Eyre Peninsula occurs during October and November (Kitani 1977).

Spencer Gulf is a reverse estuary with waters of highest salinities and temperatures being present furthest from the open sea at the head of the gulf. Thus the marine environment of upper Spencer Gulf is basically a hypersaline-high water temperature ecosystem. Spencer Gulf receives on its western side water from eastern Bight sources as a northward flowing current. Values for salinity and temperature vary from year to year and seasonally between 35.7 and 37.3$^{0}/_{00}$ and 13.0° and 18.0°C respectively. Branches of this northward flowing current are deflected southward in the Tiparra Reef area to form a higher salinity counter current flowing southwards along the opposite shore. Thus across the entrance to Spencer Gulf there is an increase in salinity and temperature from west to east (Bullock 1975; Bye & Whitehead 1975).

By the time the northward moving current reaches Point Lowly at the entrance to the basin of upper Spencer Gulf, its salinity range has risen to 42.0-44.8^{0}/oo and temperature range widened to 11.0-24°C. In the Channel off Pt. Augusta a further 50 km north, the salinity range has risen further to *43.2-48.6^{0}/oo* and the maximum temperature limit raised by 2°C to 26.0°C (Johnson 1981). The salinity increase is due to evaporative and mixing processes.

HISTORY

The journals of the earliest European navigators to visit the coast of Eyre Peninsula (Thyssen in 1627, D'Entrecasteaux in 1793, Flinders in 1802, Baudin & Peron in 1802) made little comment about the fish fauna other than referring to catching fish to supplement diet.

One of the earliest scientific fish collections made in South Australia came from Port Lincoln and resulted in the description of the leafy seadragon *Phycodurus eques* (Gunther 1865). During the late 1860's and early 1870's F. G. Waterhouse of the South Australian Institute Museum (later the South Australian Museum) made collections off the east coast.

The earliest known fish collections from the Great Australian Bight date from 1888 but some specimens in the South Australian Museum collection are believed to antedate them. Since that period various expeditions and individuals collecting in waters off Eyre Peninsula have supplied material to the South Australian Museum and other institutions.

MARINE FISHES

Most marine species are described and illustrated in the handbook of South Australian fishes by Scott *et al.* (1974) and the handbook of south-western Australian fishes by Hutchins & Thompson (1983). Most of the marine species listed by Glover (1979) from waters around Kangaroo Island also occur off Eyre Peninsula (Kuiter 1983; Glover unpubl.). Hutchins & Thompson (1983) reported that of the 344 species they listed for south-western Western Australia, 210 (61%) extended eastwards to, at least, off South Australia, and therefore would be found off Eyre Peninsula.

The known marine fish fauna off Eyre Peninsula, down to the base of the continental slope, is about 300 species. This figure represents approximately 67% of the species recorded from South Australian marine waters (Glover 1982; unpubl.).

Whereas the majority of the Peninsula's mostly smaller inshore species maintain more or less permanent resident populations, there are regular migratory visitors (e.g. Australian salmon) and occasional oceanic vagrants (e.g. oceanic sunfish *Mola* sp., basking shark *Cetorhinus maximus,* black marlin *Makaira indica,* and the lizardfish *Saurida undosquamis)* whose presence in these waters is attributed to dispersion by the easterly flowing Leeuwin Current from the southeast Indian Ocean waters off Western Australia.

This estimate of about 300 species undoubtedly is incomplete, but it indicates a diverse fauna typical of the temperate waters of the Flindersian Province of southern Australia. Further collecting and taxonomic research should add to the known fish fauna, particularly from deeper water and shallow inshore areas.

INLAND FISHES

The Peninsula's depauperate freshwater fish fauna is at least partly attributable to the lack of extensive permanent natural bodies of freshwater.

Only four exclusively-freshwater fishes have been recorded on Eyre Peninsula: three exotic species (redfin perch *Perca fluviatilis,* goldfish *Carassius auratus* and rainbow trout *Salmo gairdneri)* which were introduced into certain dams (and perhaps reservoirs) but which appear not to have become established in any natural waters, and the native callop (yellow-belly) *Macquaria ambigua* introduced into certain dams with the aim of establishing a freshwater recreational fishery. Of these species, only redfin perch and goldfish would be expected to establish breeding populations in dams.

Two predominantly freshwater native species, which usually spend part of their life cycle at sea, are also present on the Peninsula.

The common galaxias *Galaxias maculatus* has been recorded in several waters connecting with the sea (notably the Tod River, North Shiels Creek, Lake Wangary and a tributary of Little Swamp), and probably occurs in other natural inland waters, especially those connecting with the sea. Normally it spends most of its life in freshwater and spawns in estuarine reaches. The larvae drift out to sea, returning to freshwater later to grow to maturity. In south-western Victoria some populations have been found to have adapted to reproducing in landlocked coastal lakes.

The black bream *Acanthopagrus butcheri* is found in the estuary and lower reaches of the Tod

River, and probably occurs in some other coastal waterways connecting with the sea. It normally inhabits estuarine and freshwaters, occasionally migrating into the open sea.

Another native species recorded on the Peninsula is the small-mouthed hardyhead *Atherinasoma microstoma.* It has been found in the permanent spring-fed saline waters of Lakes Hamilton and Newland, on the west coast south of Venus Bay. These two large lakes are isolated from the nearby sea. Elsewhere in Australia the small-mouthed hardyhead inhabits brackish to saline (but not fresh) waters of estuaries and coastal lagoons and lakes. It occurs elsewhere in similar situations on Eyre Peninsula.

A range of otherwise normally-marine fishes also have been recorded in inland waters connecting with the sea on the Peninsula. A notable example are those fishes which have been recorded in Lake Wangary whose permanent water varies from fresh in winter to brackish in summer, and which connects periodically with the sea via Minniribbie Creek. No less than 11 diverse marine species have been recorded at various times in Lake Wangary and/or connecting Minniribbie Creek, i.e. estuary catfish *Cnidoglanis macrocephalus,* white-spotted angler fish *Phyllophryne scortea,* small-mouthed hardyhead *Atherinasoma microstoma,* Port Phillip pipefish *Syngnathus phillipi,* cobbler *Gymnapistes marmoratus,* sea mullet *Mugil cephalus,* crested weedfish *Cristiceps australis,* snake blenny *Ophiclinus* sp., blue-spot goby *Pseudogobius olorum,* pigmy leatherjacket *Brachaluteres jacksonianus,* rough leather-jacket *Scobinichthys granulatus.*

Native marine species have been introduced into some of the Peninsula's natural brackish and saline lakes and impounded waters. These attempts to establish viable populations sometimes have not been successful due to adverse weather conditions, especially prolonged droughts.

The above and other marine or primarily marine species undoubtedly enter and frequent the estuaries and lower reaches of other coastal waterways e.g. the congolli *Pseudaphritis urvillii* a well known inhabitant of estuaries and lower river reaches, recorded in coastal waters though not in any inland waters. Most sea-connected waterways occur along the east coast.

Most of the inland fish records are in the southern half where the majority of permanent natural waters and waterways are located. However, introduced redfin perch and goldfish lave been recorded in several dams in the Gawler Ranges.

Descriptions and further information of the inland fishes are provided in the general texts by Scott *et al.* (1974), McDowall (1980), Cadwallader & Backhouse (1983) and Hutchins & Thompson (1983). More specialised information is included in other publications and theses listed in Glover & Ling (1976) and Glover (1979, 1983).

COMMERCIAL AND RECREATIONAL FISHERIES

Major Fisheries

The waters surrounding Eyre Peninsula, which includes all Spencer Gulf, are the most commercially productive in the State. The marine recreational fishery is renowned for the variety of species which provide abundant and excellent sport for line, spear and big-game fishermen, but there is no freshwater recreational fishery.

Over 400 licensed commercial fishermen operate in these waters and Port Lincoln is the base for most of the 30 large tuna, 31 prawn trawling and 33 of the 54 rock lobster vessels. The value of these and smaller line and net fishing vessels is approximately $40 million.

On the west coast 80% of the fishing effort of scale fishermen is expended in line fishing for spotted whiting and snapper, but in Spencer Gulf the fishing effort is divided about equally between line fishing and netting (hauling and meshing) methods.

Table 1 lists the 1983-84 total catches and their values of the State's nine most important fisheries; in seven the yields from Eyre Peninsula waters are the highest. The third column of the table shows the percentage of the State total catch taken from these waters; the two remaining columns list the percentage contribution to the region total taken from the two respective areas.

The most valuable fishery in the Eyre Peninsula region is the western king prawn, 91% of which comes from Spencer Gulf. In 1983-84 the regional catch was valued at over 17 million dollars.

Although the rock lobster fishery is the next most valuable for the State, only 15% comes from waters off the west coast of Eyre Peninsula; landings are worth $2.6 million.

The $8.2 million southern bluefin tuna fishery, using mainly large pole and live bait fishing vessels crewed by four or more men, is based on Port Lincoln. All of the catches are landed at either Port Lincoln or two or three other west coast ports.

Landings

The southern bluefin tuna catch of 10 619 tonnes is the highest yielding fishery, all of the

Table 1. LANDINGS FROM EYRE PENINSULA WATERS EXPRESSED AS PERCENTAGE OF STATE TOTAL CATCH-NINE MAJOR FISHERIES-1983/84

Species	*Total catch (state) (Tonnes)*	*Landed value (*$OOO's)*	*Regional percent. of total catch*	*Percentage of Eyre Peninsula catch*	
				West Coast	*Spencer Gulf*
Western king prawn	2791	17415	84	9	91
Southern bluefin tuna	10619	8177	100	100	
Southern rock lobster	2412	17029	15	100	
Whiting	837	3919	68	40	60
Abalone	1066	4121	82	100	
Shark Species	1497	2100	26	73	27
Garfish	436	1205	61	9	91
Snapper	395	1010	89	4	96
Australian salmon	422	308	73	25	75

regional catch being landed at Thevenard, Streaky Bay and Port Lincoln by about 35 vessels based at Port Lincoln. Visiting interstate tuna vessels also operate seasonally from Port Lincoln. There is international concern about the southern bluefin tuna stock being overfished and in 1984 a management strategy to conserve the stock was implementedIn terms of total weight landed, the western king prawn fishery is ranked as the second major fishery with 2791 tonnes. Thirty-one vessels authorised to trawl in Eyre Peninsula waters landed 84% of the State total catch. Most of the catch (91%) was taken in Spencer Gulf and much landed at Cowell or Port Lincoln. Cowell is closer to the trawling grounds and requires a shorter journey for the vessels.

Of the total State catch of southern rock lobster 15% is taken from waters off the west coast of Eyre Peninsula by vessels from ports between Port Lincoln and Thevenard-Ceduna.

1497 tonnes of shark carcases are landed at various ports around the coast. Several species are netted commercially, principally school, gummy and whiskery sharks. The proportions of each in individual catches vary according to the location of the fishing area and season. School sharks are taken only off the west coast. There is concern about overfishing of the stocks of sharks in south-eastern Australian waters.

Landings of Australian salmon have fluctuated widely in the five year period 1979/80-1983/84. During the first three years catches were 608-683 tonnes annually before a sudden rise to 1012 tonnes in 1982/83 then a fall to 422 tonnes the following year. Difficulties with suitable netting localities for netting of salmon cause much of the fluctuations in landings. In 1981-82 only 2.5 tonnes of Australian salmon were netted on the west coast, whereas in the two following years 605 and 49 tonnes respectively were caught.

Catches in the more protected waters of Spencer Gulf have been less variable, ranging between 407 tonnes in 1981/82,90 tonnes in 1982/83 and 288 tonnes in 1983/84.

In 1983/84, 73% of the annual total catch of Australian salmon was taken in Eyre Peninsula waters, three quarters of which was from Spencer Gulf. Because of concern about the stock of Australian salmon, and the effect of fishing pressures on it in South Australian waters, an upper catch limit of 1000 tonnes has been established pending the results of further research studies.

1066 tonnes of greenlip and blacklip abalone in the shell were landed by South Australian divers in 1983/84, 60% of which was greenlip abalone. The greenlip abalone is the major species (60%) in catches from Eyre Peninsula waters.

The sixth ranking fishery by weight landed is based on three species of whiting, of which the spotted or King George whiting is the most important, constituting 85% of the total of 837 tonnes in 1983/84. 68% of the State total whiting catch came from the Peninsula region, 40% of the regional catch came from the west coast and 60% from the calmer and protected waters of Spencer Gulf. It is the preferred species of both recreational and commercial fishermen.

Garfish (436 tonnes) and snapper (395 tonnes) are also much sought after and most come from Spencer Gulf waters. Only 9% of the garfish and 4% of the snapper catches of the region are from west coast areas.

Biological Data

Western King *Prawn-Penaeus latisulcatus*

This Indo-Pacific prawn (Fig. 1) extends across northern Australia from Cockburn Sound (W.A.) to Sussex Inlet (N.SW.) and in discrete populations in South Australia off the west coast of Eyre Peninsula, Spencer Gulf, Investigator Strait and Gulf St Vincent.

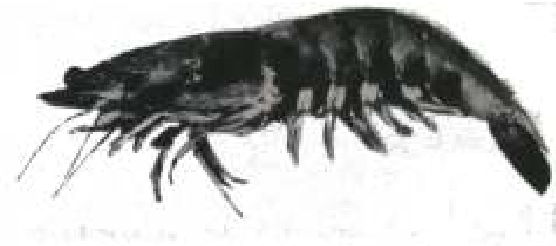


Fig. 1. Western king prawn *Penaeus latisulcatus*.

Mature prawns may begin spawning in early October with peak spawning in November-December in the shelf waters of the west coast, Spencer Gulf, Gulf St Vincent and Investigator Strait. The eggs are planktonic and when hatched the free-swimming larvae undergo a number of moults, so that by January the post larvae are settling in their sheltered, hypersaline, shallow water nursery grounds. The developing juveniles embed in the muddy bottom during the day and emerge at night to feed. By early November the sub-adults (26 mm carapace length (Cl)) begin their migration towards deeper water and are recruited into the fishery as maturing prawns (30-40 mm Cl) by January. Growth of these one year old prawns is rapid in summer (8 *mm/month)* and weight doubles in two to three months (King 1974).

Prawns may live at least three years and reach a carapace length of 70 mm; the females (145-190 mm total length) are larger than males (130-156 mm Tl). During daylight the mature prawns also embed their bodies in the muddy-sandy bottom.

Fishing for this species is carried out only during the dark phases of the moon and is suspended entirely for a few days before and after the full moon, because prawns do not emerge to feed as they do during the darker moon phases. The South Australian prawn fishery is considered to be maximally exploited (Carrick 1982).

Southern Bluefin Tuna- *Thunnus maccoyii*

The southern bluefin tuna (Fig. 2) spawns south of Java in the north-east Indian Ocean in a very restricted area between longitudes 100-125°E and latitudes 10-20^{0}S. The larvae drift southwards, develop and the juveniles enter the Albany (Western Australia) tuna fishery as one and half to three year recruits, 40-75 cm in length, and weighing 1-8 kg. However the Albany tuna fishery takes mostly the smaller fish under 60 cm.

Older (3-51/2 year) and larger (60-120 cm) fish weighing 5-30 kg are taken in South Australian waters. Most of the southern bluefin tuna caught in shelf waters off Eyre Peninsula by pole and live bait methods, are immature.

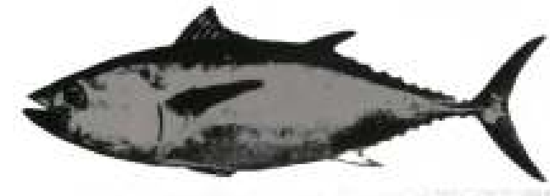


Fig. 2. Southern bluefin tuna *Thunnus maccoyii*.

After moving off the continental shelf waters of Australia the six-year old maturing fish seek open oceanic waters and 'have a circumpolar distribution between latitudes 30'l.500S, large mature tagged tuna, above 130 cm, released as juveniles in South and Western Australian waters, have been recovered by Japanese ocean-going long line vessels in the southwest and eastern Indian Ocean, South Atlantic Ocean and eastern Pacific off New Zealand (Murphy & Majkowski 1981).

The fully mature female southern bluefin tuna (140-160 cm) is relatively fecund, each releasing 14-15 million free-floating eggs (0.66-1.05 mm diam.) during two releases over a period of six months from October to March. About two-thirds of the eggs are spawned during the first release.

At a total length of about 222 cm the southern bluefin tuna weighs about 200 kg and is possibly 20 years old (Robins 1963; Murphy 1979).

In Australian coastal waters the southern bluefin tuna feed on a wide range of fish species, cephalopods, crustaceans and salps in that order of importance (Robins 1963).

Southern Rock lobster-*Jasus novaehollandiae*

This species of lobster (Fig. 4) is better adapted to the cooler temperate waters of south-eastern Australia than to the warmer marine environment of western Eyre Peninsula where high summer water temperatures (21-22CO), higher salinity and low nutrient waters predominate. The region supplies only 15% of the State's total catch of the southern rock lobster.

Tagged lobsters have shown movement and distribution patterns on continuous limestone rock strata in Anxious Bay resembling those found in the South East of the State (lewis pers. comm,; lewis 1983). However there is little or no movement of lobsters from the isolated rock outcrops which occur on the flat shelf sea floor. Rock lobsters have no defensive chelae to protect

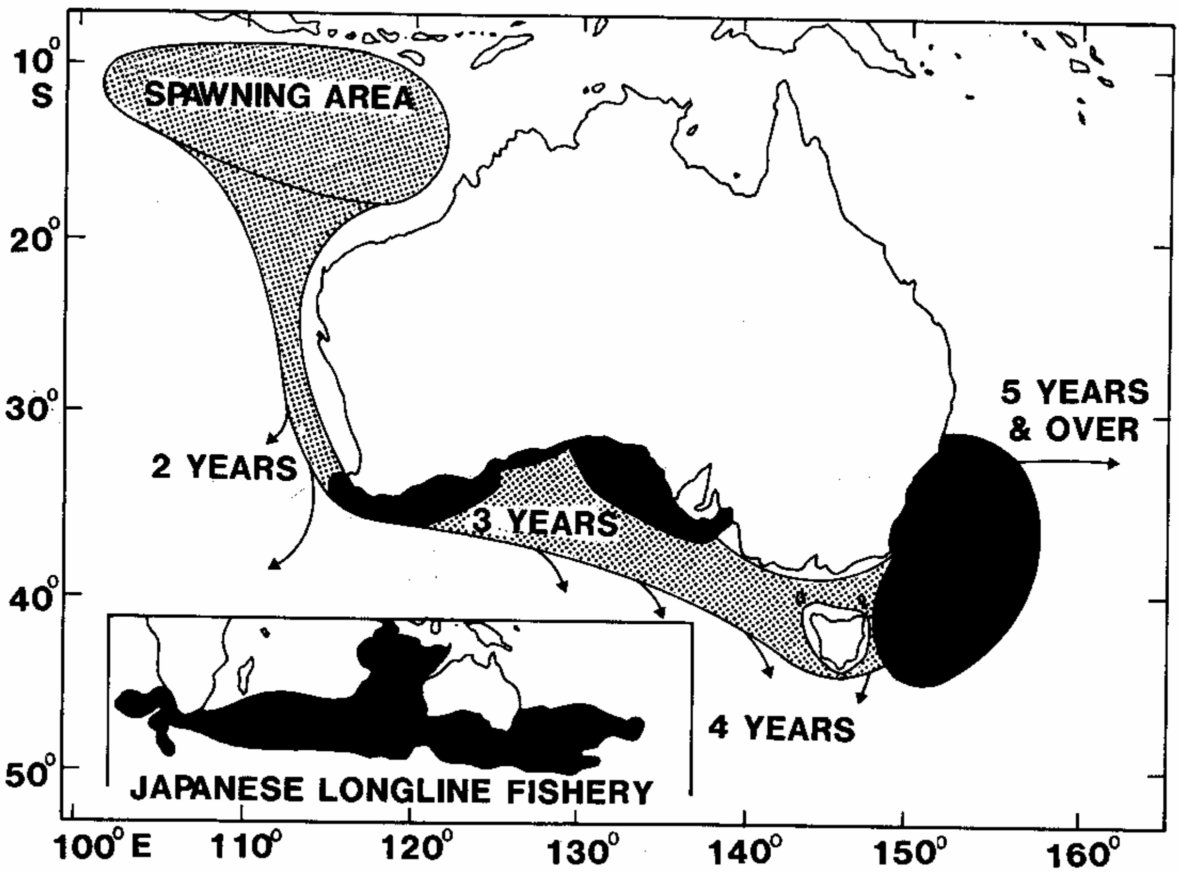


Fig. 3. Southern bluefin tuna spawning area and migration pattern off Australia. Operation areas of the Australian commercial fishery are shaded and the arrows indicate direction of fish escapement (after Murphy & Maikowski 1981).

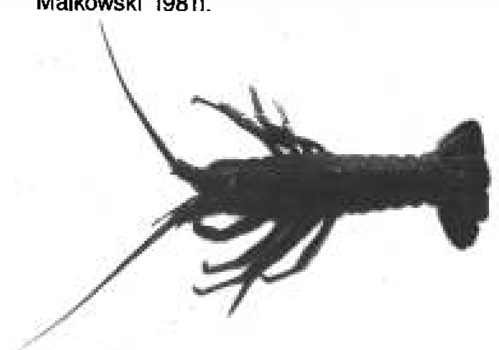


Fig. 4. Southern rock lobster *Jasus novaehollandiae*.

themselves, and so are vulnerable to predation if they leave their rock shelters in day time to cross exposed sea floor areas.

Colonisation of the isolated rock outcrops and reefs occurs when the planktonic larvae, released during the previous November, begin metamorphosing into the transparent puerulus (mean 10.3 mm total carapace length, TCl) and commence their benthic stages during August and September.

Fertilised eggs of rock lobsters produce free swimming larvae after 95-150 days of incubation and aeration under the tails of females. The warmer the sea temperature the quicker the development of the embryos. The newly hatched naupliosoma larvae are free swimming for only a few hours before metamorphosing into the carnivorous phyllosoma larvae. This second stage is negatively phototropic, i.e. it avoids light and feeds on plankton at night and disappears from the surface waters during the day. In Tasmanian waters these phyllosoma larvae descend to 17-18 m depth during the day and rise to the surface to feed after darkness. The second and third stage larvae may remain inshore for 12-13 weeks before disappearing (Olsen 1966).

Hatching of eggs in South Australian waters occurs in October and November, and coincides with the reversal of direction of flow of the water mass from an easterly south-easterly direction to a north-westerly-westerly direction. It is presumed that the larvae are carried into the open ocean waters during the three-four month westerly flow, and are returned inshore as metamorphosing puerulus larvae with the March reversal of direction (Vaux & Olsen 1961).

During their first year, juvenile rock lobsters may moult about 10 times and reach a mean TCl of 35.6 mm, but thereafter the number of moults (ecdyses) decreases with age to one or two per annum for sexually mature lobsters. At two years of age juveniles have a mean TCl of 54 mm; at three years a mean TCl of 66 mm, and at four years a mean TCl of 77 mm. At each moult juveniles, 50-70 mm TCl, may absorb as much as 20% of their weight of water to swell the body and gain an increase in length and volume before the new shell hardens in 7-9 days. With increase in length and age the number of ecdyses per annum decreases and water uptake falls to about 14%. Growth increments of 3.2-5.7 mm (8.3% mean increase) per ecdysis were found in 40-48 mm TCl experimental lobsters which decreased to 1.0-4.3 mm (2.6% mean increase) for 90-98 mm TCl lobsters (Fielder 1964). Growth increments for three tagged male rock lobsters, 91-97 mm TCl, in one year were 6.4%-7.4% and, after two years, the same three lobsters had 14.2-23.2% increments on their original TCL. In the same wild population, a mature female lobster 88 mm TCl increased only 2.8% in one year. Because of variable growth in lobsters it is not possible to age them after they reach sexual maturity at about four years; most females are mature between 75-80 mm TCl, and most males above 90 mm TCl. Overcrowding and poor food availability may stunt growth and reduce the mean sizes of the sexes at maturity.

Juvenile rock lobsters are gregarious but, as they grow older, they tend to seek individual shelter holes and crevices appropriate to their size. After sexual maturity females increase in size only about one-third the rate of males (Olsen, unpubl. data). Male lobsters grow bigger than females. A male rock lobster weighing 6.13 kg was caught in South Australian waters; a male 215 mm TCl weighed 5.22 kg, whereas three males (all 206 mm TCl) ranged 3.74-4.08 kg. The largest female, 184 mm TCl, weighed 2.86 kg. There are records of 6.8 and 7.7 kg males being caught, but they cannot be substantiated.

Underwater observations on the behaviour of rock lobsters around baited pots, and laboratory experiments on dominance order for shelter showed that largest rock lobsters dominate smaller lobsters (Olsen 1958; Fielder 1965).

Spotted Whiting-*Sillaginodes punctatus*

The spotted or King George whiting (Fig. 5) fishery of South Australia is unique in that the major component of the catch comes from the immature portion of the stock. The legal minimum length (IMl) of 28 cm is less than the length at maturity (36 cm for female and 32 cm for male spotted whiting).

Fig. 5. Spotted whiting *Sillaginodes punctatus*.

At first spawning a female whiting, 37 cm Tl and 2½ years old produces about 114 000 eggs. The figure rises to over 460 000 eggs for a female, 45 cm Tl at 3112-5 years (depending on the area). Males require proportionately less time and reach first maturity at 32 cm. In the Ceduna area female spotted whiting reach 28 cm and weight 160 g in 1112 years, whereas it takes at least two years in northern Spencer Gulf and Port Lincoln area and 2113 years in Coffin Bay. Thus, in the Ceduna area female whiting require only an additional nine months to reach sexual maturity after entering the fishery and 14-19 months in other areas (Jones 1979, 1980). Because fecundity of the species is high, present management strategies allow sufficient escapement of mature fish to spawn, thus maintaining adequate recruitment to the stock to sustain a stable fishery.

Tagging results show that there is virtually no interchange of juvenile populations between different west coast bays, and no movement between the different nursery grounds in seagrass-mangrove communities of upper Spencer Gulf. A spawning migration from these areas takes place later when the fish are more than 36 cm long and 360 g in weight and about three-four years old. Sub-adults from west coast bays move out into deeper water around the offshore islands and in upper Spencer Gulf sub adult fish begin moving southwards towards the entrance of Spencer Gulf during late summer to early autumn.

Sexually mature whiting are known to congregate in the autumn (May-June) around rocky areas on which the brown seaweed *Scaberia* sp. ('cork weed') grows. Eggs of spotted whiting are small and presumably planktonic and, after fertilization, either drift or are carried by currents and tides to inshore nursery grounds.

Development and growth is rapid in the warmer months (November-May) of the first two years, particularly in the Ceduna area where at 28 cm Tl most spotted whiting weigh around 160 g; at

36 cm about 320-360 g and at 40 cm about 600 g but less elsewhere in a comparable period. Spotted whiting may reach a maximum length of 70 cm and attain a maximum weight of 4.7 kg. Their maximum age is 10-12 years (Caton 1966; Jones 1979).

Abalone-*Haliotis* species

Abalone are large marine snails which feed on algae and hold their position on rocks by suction. The greenlip abalone *(H. laevigata)* (Fig. 6)'feeds on drift red algae and seagrasses whereas the blacklip *(H, rubra)* (Fig. 7) browses on algae at night and hides by day,

Fig. 6. Greenlip abalone *Haliotis laevigata*.

Fig. 7. Blacklip abalone *Haliotis rubra*.

The sexes are separate in both species and both reach sexual maturity when about three years old. Both species broadcast their ova and spermatozoa into the surrounding waters in short bursts at irregular intervals during a period of several months; fertilization of the ova is external. The greenlip abalone spawns between October and March whereas the blacklip has a major spawning between February and April, and a minor one between October and December

Both species are very fecund, each at their first spawning releasing about 100000 eggs, subsequently rising to 2-8 million at six years of age. The male gonads are cream whereas the fully ripe female gonads are green. However the ovary of the blacklip abalone may undergo developmental colour changes from grey, blue, and brown, finally becoming green at maturity.

After fertilisation the eggs pass through about four free-swimming stages, in about 2-4 days in the greenlip and up to 14 days in the blacklip, before secreting a shell and settling on the bottom to feed initially on diatoms, later on algae. The metamorphosis from a fertilized ovum to a 15-20 mm abalone takes three months in water temperatures of 13Q.20°C, At one year of age the mean length is 50 mm; at three years the mean length is 120 mm and at five years 140 mm (Shepherd & Hearn 1983). 80th species may live about 15 years and reach maximum diameters (length) of 20-22 cm. The legal minimum length of *H. laevigata* is 145 mm (140 g cleaned weight) and of *H. rubra* 130 mm (113 g cleaned weight). The maximum yield of cleaned meat produced from an abalone is about 560 g.

Sharks-Carcharhinidae species.

The present day commercial catch is composed mainly of the school *(Galeorhinus galeus),* the gummy *Mustelus antarcticus* and the whiskery *Furgaleus ventralis* sharks, but initially the landings were mostly school and gummy sharks. The whiskery shark became important in the catch after mesh nets replaced bottom longlines in the fishery. All three species are moderate in size, the school sharks and gummy sharks may grow to about 174 cm. All three species are ovoviviparous, the female school shark producing a maximum of 41 living young each about 30 cm total length during

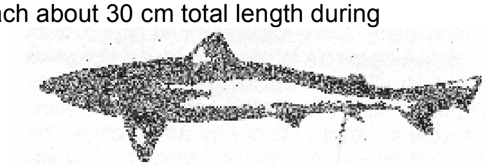


Fig. 8 School shark *Galeorhinus galeus*

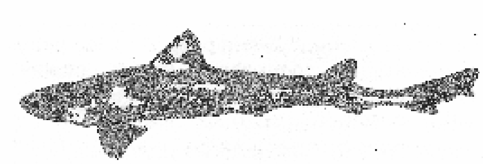


Fig. 9. Gummy shark *Mustelus antarcticus*.

December in inshore nursery areas in Victoria and Tasmania. Female gummy sharks 120 cm total length produce a mean number of 10 pups and maximum of 23 of similar total length per pregnancy. Studies on the young school sharks show that they remain in their nursery areas for one-three years before migrating to the deeper continental shelf waters (Olsen 1954, 1984). There is no such recognizable pattern with newly born gummy sharks.

During late autumn school sharks make a northward winter migration away from the cooling Tasmanian and Victorian waters to warmer waters. Their incidence decreases in the southern waters in about May and begins increasing in South Australian and New South Wales waters from late July or August. The schools appear in greater numbers in waters off Eyre Peninsula from August until about October when they begin their southerly migration back to the Tasmanian and Victorian areas (Fig. 10). Gummy and whiskery sharks do not show similar purposeful migrations.

Male school sharks mature at about 120 cm TL when more than eight years old, and the females at about 135 cm when more than 10 years old.

Mating is believed to occur in deep water along the edge of the continental shelf about June when the northward migration begins. The young develop throughout the mother's northward and return migration, and she releases them in a nursery after the return to Tasmanian and Victorian waters The gestation period is approx.. six months and only half the mature females carry yound each year. After birth growth is relativeky slow as the school shark are known from tagging studies to live at keast 53 years. They reach a maximum length of 174 cm in south-eastern Australian waters. Tagged scholl sharks have been recaptured aftyer 33 years and 9 months of freedom (Olsen 1984)

No tagged school sharks from south-eastern Australia have been recovered from either Western Australian or New Zealand waters but a gummy shark tagged at the western entrance to Bass Strait was caught again after eight years of freedom 65 km east of Esperance, Western Australia. This 153 cm female carried 14 yoiung 10 cm long when caught (Walker 1984).

Little is known about the biology of whiskery sharks.

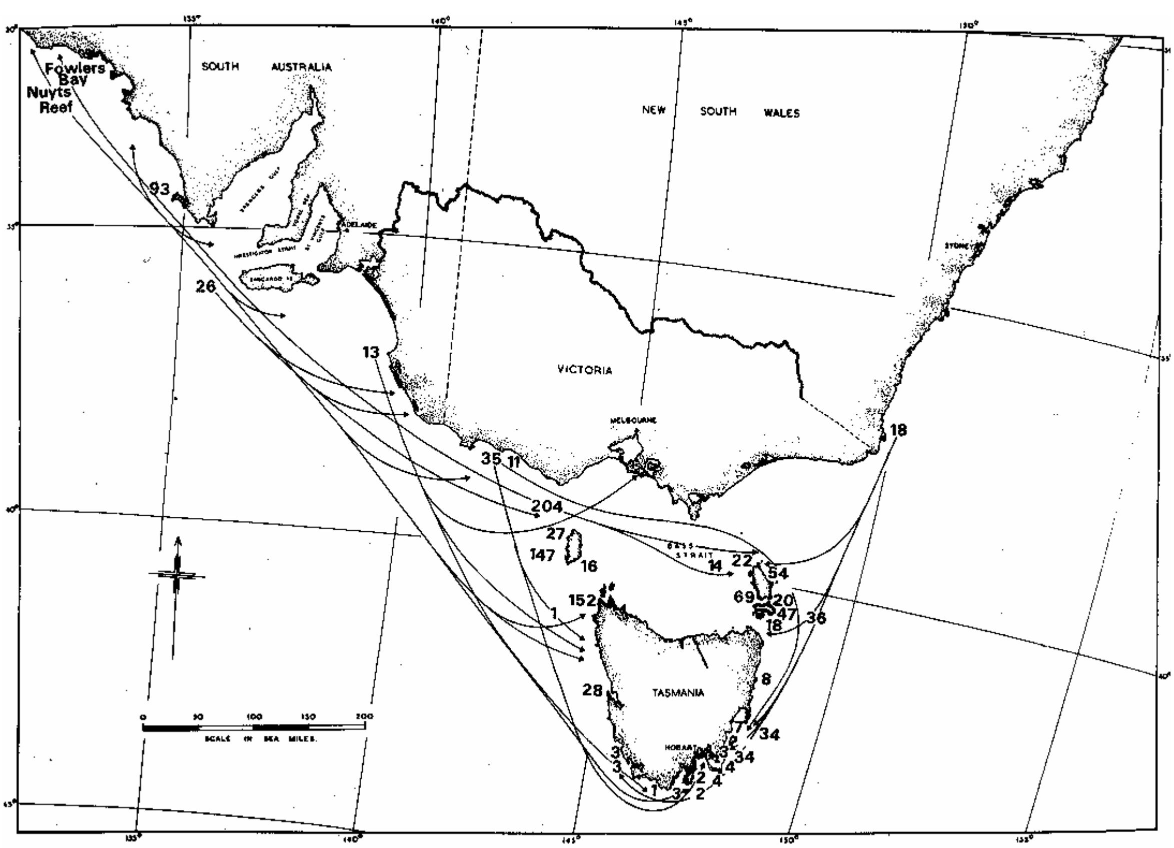


Fig. 10. Migration movements of school sharks tagged in South Australian, Victorian and New South Wales waters (numbers refer to releases at that location).

Garfish-*Hyporhamphus melanochir*

This species (Fig 11) prefers the shallow inshore waters of seagrass communities in which it feeds on small crustaceans and certain algae growing on the blades of the seagrasses.

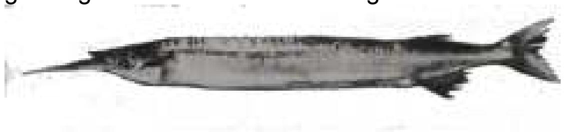


Fig. 11. Garfish *Hyporhamphus melanochir.*

Garfish reach maturity when over 2112 years old and about 28 cm TL. Spawning occurs from September to March, but the peak period is October to November. Garfish eggs are relatively large (3 mm diam.) and on release are attached by the female to the blades of seagrasses. About 9000-10000 eggs are produced by a fully mature female.

The legal minimum length (LML) for garfish is 21 cm, reached when they are 13-14 months old. Garfish in recreational anglers' catches range 23-30 cm TL (60-120 g) and only very occasionally is a 42 cm garfish weighing about 350 g hooked. A 44 cm fish weighing about 400 g is estimated to be seven years old (Ling 1958; Jones 1979).

Between 50-60% of the 1977/78 commercial catch of garfish at Port Lincoln and 60-80% in upper Spencer Gulf were immature fish. However, despite the large component of immature fish in the annual catch, the total yield of the fishery has risen slowly since 1951/52 to the 1983/84 level of 436 tonnes.

Snapper-*Chrysophrys auratus*

Snapper (Fig 12) are highly prized by both recreational and commercial fishermen. The legal minimum length for snapper is 28 cm TL (300 g) which is attained by most fish in two years, although some at that size may be three or four years old. The sex ratio in the commercial catch is 46 males : 54 females.

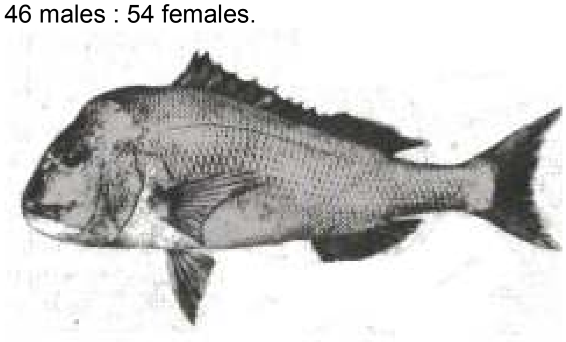


Fig. 12. Snapper *Chrysophrys auratus.*

First spawning in females is at 28 cm although most do not spawn until their third year when about 290 000 eggs each are released which are small and free floating. The number of eggs released increases with age (size), a six year old female 56 cm TL (2 kg) produces about six million eggs. Females spawn during October to February in both shallow and deep waters of gulfs and exposed bays.

At one year the snapper reach 22 cm TL; at two years 28 cm; at four years about 45 cm and 1 kg, and 56-57 cm and 2 kg by their sixth year. Two female snapper of 93 cm weighed 10.89 and 10.4 kg respectively whereas a larger male of 96 cm weighed 9.3 kg. A Victorian snapper 121 cm TL weighed 19.5 kg. There is no difference in the growth rates of males and females in South Australian waters.

Nearly 9000 snapper have been tagged and released and 274 recovered (Jones 1984). Results indicate a tendency for juvenile fish to move greater distances than adults. Older fish tend to remain around reefs throughout the year and remain in inshore and gulf waters. In the spring schools of mature snapper 60 cm and above make a spawning migration from offshore waters into the upper regions of both gulfs.

Scale and otolith readings show that snapper live to about 28 years. A two-year-old snapper released near Tickera, was recaptured nearly 18 years after release. The theoretical maximum length of snapper is 125 cm (Jones 1979).

Australian Salmon-*Arripis esper*

There are two species of Australian salmon, but only the western species (Fig 13) with a gillraker count range of 25-31 extends from Western Australia, across South Australia to Victoria and Tasmania. The eastern species, with a higher gill raker count of 33-40 is confined to Tasmania, Victoria, New South Wales and rarely southern Queensland (Malcolm 1960). Until recently the western form was considered to be a subspecies of the eastern *Arripis trutta;* their taxonomic status remains uncertain. The Australian Salmon is a misnomer as it does not belong to the family Salmonidae.

Fig. 13. Australian salmon *Arripis esper.*

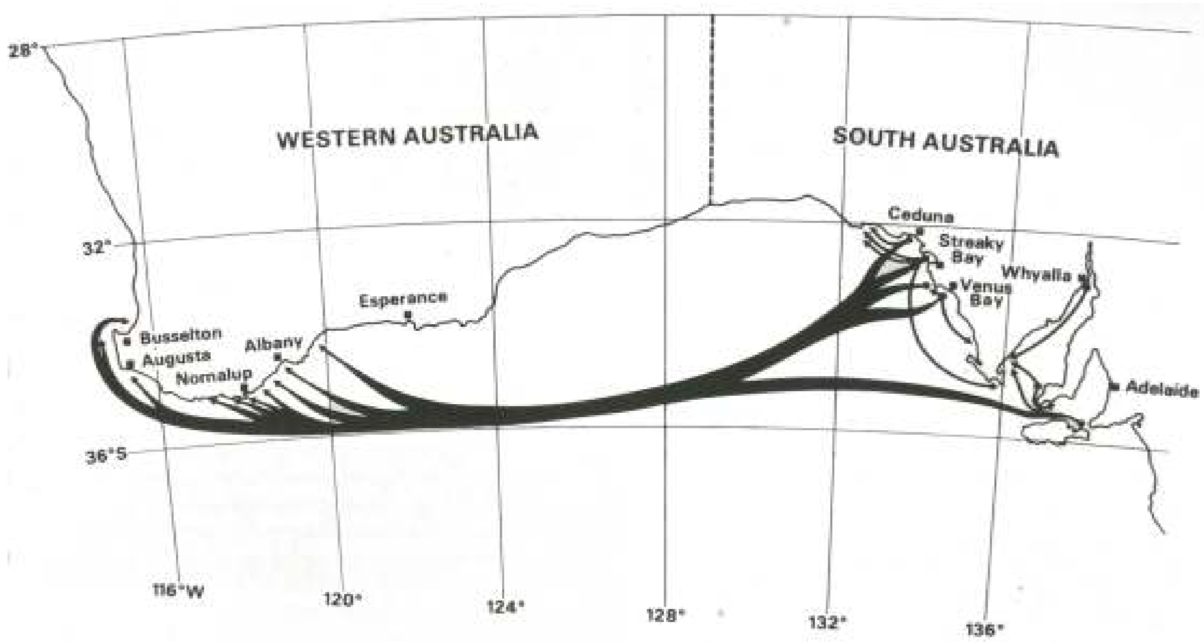


Fig. 14. Locations of recoveries of Australian salmon tagged in South Australian waters (after Stanley, 1979).

Australian salmon mature during their fifth to sixth year when above 54 cm TL and spawn off the lower west coast of Western Australia. If the fish spawn in high salinity, sub-tropical water, the larvae are carried eastwards across the Great Australian Bight to nurseries in South Australia, Victoria and Tasmania. However, if spawning occurs in low salinity tropical water, the larvae may die before reaching their eastern nurseries.

Tagging records show that growing juveniles from Tasmania and Victoria migrate westwards through South Australia. However they may remain in the latter waters for up to five years before continuing their migration. 70% of the commercial catch of salmon in Australia consists of mostly two-three year old fish averaging 46 cm TL.

More than 11 000 Australian salmon have been tagged in South Australian waters (over 2000 in 1952 and an additional 9000 between December 1974 and June 1976). Recoveries from these releases show that the movement is spread over four age groups, the fastest growing fish migrating at an age of three years and the slowest growing fish at six years (Stanley 1979).

The Western Australian beach seine fishery catches mostly five, six and seven year old fish averaging above 54 cm TL and only about half the migrants reach their spawning grounds. If the South Australian moiety of the stock is considerably reduced by fishing before migrating this local fishing effort can result in lowered salmon catches by Westarn Australian fishermen. Tag returns show that catches of Australian salmon by recreational fishermen in Western Australia may be equal to about 30% of the commercial catches of that state (Walker 1978, 1984; Jones 1983).

Growth rates of Australian salmon are faster off Western Australia than in South Australia (Stanley 1980). Only rarely nowadays are 12 year old Australian salmon caught which are almost 1 metre in length and weigh about 10 kg.

ACKNOWLEDGEMENTS

The assistance of Mr Kevin Branden (Dept of Fisheries) and Mr Roman Ruehle (South Australian Museum) in preparing the figures is gratefully acknowledged. Other Fisheries Department colleagues provided constructive criticism during the preparation of the manuscript, and fisheries officers on Eyre Peninsula provided advice and information. The photographs of the southern bluefin tune and the snapper are reproduced from 'The Marine and Freshwater Fishes of South Australia', by Scott *et al.* 1974) by courtesy of the Flora and Fauna of South Australia Handbooks Committee.

REFERENCES

Bullock, D. A. (1975). The general water circulation of Spencer Gulf, South Australia, in the period February to May. *Trans. R. Soc.* S. *Aust.* **99**(1), 43-53.

Bye, J. A. 1. (1972). Oceanic circulation south of Australia. Antarctic Oceanology II. The AustralianNew Zealand Sector. **19** *Antarctic Res. Series, 19. Amer. Geophys. Union.*

Bye, J. A. 1. & Whitehead, J. A. Jr. (1975). A theoretical model of the flow in the mouth of Spencer Gulf, South Australia. *Estuarine* & *Coastal Mar. ·Sci.* **3***,* 477-81.

Cadwallader, P. L. & Backhouse, G. N. (1983). 'A guide to the freshwater fish of Victoria.' (Victorian Govt. Printing Office, Melbourne).

Carrick, N. (1982). Spencer Gulf prawn fishery-surveys increase our knowledge. *SAFIC* 6(4), 3-32.

Caton, A. E. (1966). Preliminary synopsis of biological data on the Australian (spotted or King George) whiting *Sillaginodes punctatus* (Cuv. & VaL) 1829. Southern Pelagic Project Committee. Technical Session CSIRO. Agenda Item 5.

Fielder, D. R. (1964). The spiny lobster, *Jasus lalandei* (H. Milne-Edwards) in South Australia. 1. Growth of captive animals *Aust. J. Mar. Freshw. Res.* **15***(2),* 77-92.

Fielder, D. R. (1965). A dominance order for shelter in the spiny lobster *Jasus lalandei* (H. Milne-Edwards). *Behaviour* **24**(3-4), 236-45.

Glover, C. J. M. (1979). Fishes. Chapt. 12, 139-153. *In* M. J. Tyler, C. R. Twidale & J. K. Ling (Eds.). 'Natural history of Kangaroo Island'. (Royal Society of South Australia, Adelaide).

Glover, C. J. M. (1982). A provisional checklist of marine fishes (Amphioxi, Petromyzones, Myxini, Elasmobranchii, Holocephali, Teleostomi) recorded in South Australian coastal waters. S. *Aust. Mus. Inform. Leaflet,* **70**, 1-25.

Glover, C. J. M. (1983). Freshwater and marine fishes. Chapt. 15, 157-67. *In* M. J. Tyler, C. R. Twidale, J. K. Ling & J. W. Holmes (Eds.), 'Natural history of the South East'. (Royal Society of South Australia, Adelaide).

Glover, C. J. M. & Ling, J. K. (1976). Marine fishes and mammals. Chapt. 14, 187-9. *In* C. R. Twidale, M. J. Tyler & B. P. Webb (Eds.) Natural history of the Adelaide region. (Royal Society of South Australia, Adelaide).

Gunther, A. (1865). On the pipe-fishes belonging to the genus *Phyllopteryx. Proc. Zool. Soc.* (London) **2**, 327-8, pis. 14-15.

Hutchins, B. & Thompson, M. (1983). 'The marine and estuarine fishes of south-western Australia.' (Western Australian Museum, Perth).

Johnson, J. E. (1981). Hydrological data for Upper Spencer Gulf, 1975-1978. *Fish. Res. Pap. Dep. Fish. (S. Aust.).* No.3.

Jones, G. K. (1979). Biological investigations on the marine scale fishery in South Australia. S.A. *Dept. of Agri. and Fisheries. Report.* 72pp. (mimeo).

Jones, G. K., (1980). Research on the biology of spotted (King George) whiting in South Australian waters. *SAFIC* **4**(1), 3-7.

Jones, G. K., (1983). Species composition and catch rates by recreational and commercial fishermen in southern Eyre Peninsula waters. *SAFIC* **7**(4), 9-18.

Jones, G. K. (1984). A review of the commercial fishery for snapper *(Chrysophrys auratus)* in South Australian waters. Discussion paper. Dept. of Fisheries, South Australia, November 1984.

King, M. G. (1974). Trawl survey of prawns in Spencer Gulf, Investigator Strait and Gulf St. Vincent. *SAFIC* **1**, 8.

Kitani, Kozo (1977). Some observations on the temperature inversion off Kangaroo Island, Southern Australia. *Bull. Far. Seas. Fish. Res. Lab.* **15**, 1-11.

Kuiter, R. J. (1983). An annotated list of fishes of The Investigator Group, South Australia. *Fisheries Research Paper Number* 7. Dept. of Fisheries, South Australia.

Lewis, R. K. (1983). The Southern Rock Lobster. Chapt. 17, 177-81. *In* M. J. Tyler, C. R. Twidale, J. K. Ling & J. W. Holmes (Eds.), 'Natural History of the South East.' (Royal Society of South Australia, Adelaide).

Ling, J. K. (1958). The sea garfish. *Reporhamphus melanochir* (Cuvier and Valenciennes) (Hemirhampidae), in South Australia. Breeding, age determination, and growth rate. *Aust. J. Mar. Freshw. Res.* **9**(1), 60-110.

Malcolm, W. B. (1960). Synopsis for FAO species and stocks. Thesaurus of data on *Arripis trutta* (Bloch and Schneider). *In* 'Commonwealth-States Fisheries Conference, Southern Pelagic Project committee, Technical Session, Cronulla, 1966.' Vol. 3., SPP(T) 66/1/44. (CSIRO, Cronulla).

McDowall, R. M. (Ed.) (1980). Freshwater fishes of southeastern Australia. (Reed, Sydney).

Murphy, G. I. (1979). Southern Bluefin Tuna. Fishery Situation Report 1. CSIRO Cronulla. 10p. South Eastern Fisheries Committee of the Standing Committee on Fisheries.

Murphy, G. I. & Majkowski, J. (1981). State of southern bluefin tuna population: fully exploited. *Aust. Fish.* **40**(11), 20-9.

Olsen, A. M. (1954). The biology, migration, and growth rate of the school shark *Galeorhinus australis* (Macleay) (Concharhanidae) in south-eastern Australian waters. *Aust. J. Mar. Freshw. Res*. **5**(1*),* 353-410.

Olsen, A. M. (1958). Comment on feeding patterns of *J. lalandei* based on underwater observations. *Aust. Fish Newsl.* **17**(4), 9.

Olsen, A. M. (1966). An investigation into the effect that harvesting of *Macrocystis* might have on the stocks of spiny lobster or marine crayfish *(Jasus lalandei).* Interim Report. Alginates (Aust.) Pty. Ltd. and CSIRO Division of Fisheries & Oceanography.

Olsen, A. M. (1984). Synopsis of biological data on the school shark, *Galeorhinus australis* (Macieay 1881) *FAG Fish Synop.,* 139, 1-42.

Robins, J. P., (1963). Synopsis of biological data on bluefin tuna *Thunnus thynnus maccoyii* (Castlenau)

1872. U.N., FAO Fisheries Rep. **2**(6), 562-87.

Rochford, D. J., (1975). Oceanography and its role in the management of aquatic ecosystems. *In* H. A. Nix & M. A. Elliott (Eds), Managing Aquatic Ecosystems. *Proc. Ecol. Soc. Aust.* **8,** 67-83.

Scott, 1. D., Glover, C. J. M. & Southcott, R. V. (1974). 'The marine and freshwater fishes of South Australia' (2nd Edition). (Govt Printer, Adelaide).

Shepherd, S. A. & Hearn, W A. (1983). Studies on southern Australian abalone (Genus *Haliotis).* IV. Growth of *H. laevigata* and *H. rubra. Aust. J. Mar. Freshw. Res.* **34**, 461-75.

Stanley, C. A. (1979). Decline in WA. salmon catch. *Aust. Fish,* **38**(3), 14-5, 17.

Stanley, C. A. (1980). Australian salmon. *CSIRO Div. Fish. Oceanogr. Fish Sit. Rep.* No.5.

Thompson, R. O. R. Y. & Veronis, G. (1983). Poleward boundary current off Western Australia. *Aust. J. Mar. Freshw. Res.,* **34**, 173-85.

Vaux, D. & Olsen, A. M. (1961). Use of drift bottles in fisheries research. *Aust. Fish. Newsl.* **20**(1), 17-20.

Walker, M. H. (1978). Utilization of the Bunbury & Geographic Bay marine resource by professional and amateur fishermen. *Dept. Fish. Wild. West. Aust. Rep.* **36**, 1-64.

Walker, M. H. (1984). WA. salmon fishery stronger in *1984. Aust. Fish.* **43**(11), 14-6.

Walker, 1. I. (1984). Tagged shark recaptured. *FINS.* **17**(1),25.

15: Distribution patterns of some beetles (Tenebrionidae and Scarabaeidae)

by E. G. MATTHEWS

INTRODUCTION

The aim of the study that forms the basis of this chapter is to determine whether a portion of the beetle fauna of Eyre Peninsula reveals any consistent patterns with regard to distribution on the peninsula and the offshore islands, and relationships with the fauna of other parts of Australia.

The groups chosen were those with which I am relatively familiar. All the tenebrionids known from the peninsula are included in the survey except the introduced ones and the genus *Chalcopterus* Blessig, the species of which are difficult to recognize. Even so, no tenebrionid genera have been revised recently except *Brises* Pascoe (Matthews 1986), therefore the identification of the specimens surveyed must be considered unreliable. In the Scarabaeidae only those groups revised recently are included in this survey: the Dynastinae (Carne 1957a), Rutelinae (Carne 1956, 1957b, 1958), *Elephastomus* Macleay (Carne 1965), *Onthophagus* Latreille (Matthews *1972), Blackburnium* Boucomont (Howden 1979) and *Liparetrus* Guerin (Britton 1980). A few additional well-known lamellicorn species are included in this analysis on the basis of collection records only.

The scarab species mentioned in the present work, or some congeners, are illustrated in Matthews (1984). Most of the cited tenebrionid species are figured here (Figs 1-8).

The first conclusion that emerges from the present study is that the beetle fauna of Eyre Peninsula is inadequately sampled. The 70 species surveyed are each represented by an average of less than three locality records on the peninsula and islands. The maximum number of peninsula localities for one species is seven. With such data it is perhaps presumptuous to conclude anything at all, even tentatively, ahd so any statements made here have a tenu0US basis.

The Tenebrionidae are a particularly successful group in arid regions, being adapted to feed on dried vegetable matter under relatively high temperature conditions. In South Australia they are summer-active as adults, generally confining foraging activity to the night hours of the hottest months (Matthews 1985a). They are prominent in the fauna of the offshore islands.

The Scarabaeidae have higher moisture requirements and generally seek their food in the soil as larvae, often also as adults. Many of them feed on live plants. They tend to be winter active in southern Australia because that is when the soil is sufficiently moist to permit digging activity. They are notably unsuccessful in surviving on the islands.

ENDEMISM

In the groups surveyed, there are no higher categories and only six species which are restricted to Eyre Peninsula: four Tenebrionidae (two of these from the islands) and two Scarabaeidae. That is about 9% of the fauna and the actual figure is likely to be lower as more collecting turns up some of these species elsewhere. In the Coleoptera as a whole only one supra-specific taxon is apparently endemic to Eyre Peninsula: the eucnemid 'living fossil' genus *Echthrogaster* Blackburn (see Matthews 1985b). The development of endemism is possible only in a region of long-standing stability protected by effective barriers against new immigrants. Clearly these conditions do not prevail on the peninsula.

DISTRIBUTION PATTERNS ON EYRE PENINSULA

Because of the poor representation of material, it is impossible to extrapolate general distribution patterns from the actual data. The procedure is therefore reversed to start with the environmental regions established from other studies (Laut *et al.* 1977) to establish whether the beetle records tend to correspond with these regions.

A biogeographic region is real for a given taxon if a substantial proportion of the species found within it do not occur outside of it. In the case of Eyre Peninsula, where there is virtually no endemism, a region could be considered real if it shares more of its species with areas of equivalent climate outside the peninsula than with other areas of the peninsula itself. As for the boundaries of a biogeographic region, they can be considered real if there is a substantial difference in biotic composition immediately on either side of them. In the case of Eyre Peninsula, there are no sharp topographic or other natural features which can act as barriers, and virtually any line following an isohyet across almost anywhere on the peninsula can separate biotas which display a certain proportion of species differences, but the line itself has no validity as a boundary.

The line I have arbitrarily chosen to use is that which runs along the 400 mm annual isohyet and separates the combined Southern Highlands and Plains (4.1) and West Coast (4.2) environmental regions from the combined Central Mallee Plains and Dunes (4:3) and Northern Myall Plains (4.4), environmental regions (See Fig. 1, Chapter 17). The latter are in turn bounded to the north by the 250 mm isohyet, north of which is the Western Pastoral Province (7). In a previous attempt to divide South Australia into life zones relevant to the coleopterous fauna (Matthews 1980), I called the first region above the Dry Sclerophyll, the second the Mallee, and that north of the 250 mm isohyet, the Eremaean. I will revert to this terminology for brevity and consistency, treating the beach and island faunas separately (see below).

Considering the two environmental regions on the peninsula proper, in the Dry Sclerophyll there are 23 known species in the beetle groups in question, of which 10 are found to the north and 13 are not. Included in the 13 are three of the four non-insular endemic species of Eyre Peninsula: the tenebrionid *Dysarchus tuberculatus* Blackburn (Fig. 1) and the scarabs *Corynophyllus andersoni* Blackburn and *Liparetrus fimbriatus* Blackburn.

The Mallee region supports 29 of the species considered here, of which 19 do not occur to the south and 10 do. There is one apparent endemic species.

The broad overlap between the regions, with 10 species from each crossing the 'boundary', casts doubt on the relevance of the line chosen, as suspected, but conversely the fact that over half the species are confined to one side or the other shows that there is some kind of zonation across the peninsula following isohyets, with a steady replacement of species as we proceed from southwest to northeast. Far more numerous

1 cm

Fig. 1. *Dysarchus tuberculatus* Blackburn, length 15 mm.

collection data would be needed before we can say any more than that.

When the scarab genus *Onthophagus* Latreille was revised (Matthews 1972) I had no records of any species occurring on Eyre Peninsula. Since then I have seen specimens of the widespread *0. jubatus* Harold, from the Mallee region, and *O. pentacanthus* Harold, an eastern species now found on most of the peninsula. The former specimens undoubtedly represent a long standing occurrence which simply was overlooked before, as *0. jubatus* is small and rarely collected. *0. pentacanthus,* on the other hand, is conspicuous and often seen digging under cow dung. It is very unlikely that it was overlooked by the early collectors, such as Thomas Blackburn, who lived in Port Lincoln from 1882 to 1886. In fact, I have seen no records of *0. pentacanthus* from Eyre Peninsula dating from before 1965; thereafter it has turned up regularly and is now represented by 37 specimens from seven localities throughout the Mallee and Dry Sclerophyll regions of the peninsula. Probably it is a recent introduction from across the gulf.

RELATIONSHIPS WITH OTHER REGIONS

The next question to be addressed concerns the origins of the Eyre Peninsula fauna. If we take the two recognized regions separately, of 23 species that occur in the Dry Sclerophyll, three are endemic, 16 occur also to the east, and four occur both to the east and the west, from New South Wales to Western Australia. Of the endemic species mentioned here, two belong to generally distributed genera and one to an eastern genus: the fauna of the Dry Sclerophyll region is overwhelmingly of eastern affinity, arriving across the gulf or present before the gulf was as extensive as it is now. Three species are known outside Eyre Peninsula only from Yorke Peninsula and/or Kangaroo Island suggesting either that the latter places are likely jumping off points for propagules crossing the gulf, or that the three areas are remnants of a former natural region.

The only species which may be of direct northern origin is the endemic tenebrionid *Dysarchus tuberculatus* Blackburn (Fig. 1). It belongs to a small genus of broad distribution through the arid interior from Queensland to Western Australia, and is rarely encountered. I have seen no specimens collected within the last 50 years or so.

The 29 species occurring in the Mallee region include one possible endemic from the Ceduna area *(Helaeus orbicularis* Carter), 12 which also occur in eastern Australia, 10 which are of general southern distribution from east to west, five known elsewhere only from Western Australia, and one apparently of northern origin. These figures again suggest a predominantly eastern provenance or affinity for this fauna, but the five species shared only with Western Australia indicate that there is a significant component (at least 17%) of the Mallee region fauna which came across the Nullarbor, or which was once of general west-central distribution but is now confined to Eyre Peninsula and southwestern Australia. Only one of the five species *(Adelium occidentale* Blackburn) is known to occur now in the Nullarbor.

THE BEACHES

Six tenebrionids occur mainly on the beaches all along the shores of the peninsula. They cannot be assigned to any of the biogeographic regions because of their special adaptation to marine littoral conditions regardless of general climate. All extend westward as far as Geraldton or beyond, and eastward at least to Yorke Peninsula *(Celibe brunnipes* Boisduval, *Trachyscelis ciliaris* Champion, Fig. 2), usually to the East Coast and Tasmania. One littoral species *(Hyocis bakewelli* Pascoe, Fig. 3) also tends to extend inland in arid areas. All but one *(Scymena amphibia* Pascoe, Fig. 4) are recorded from at least one island, and all are wingless. No scarabs are known from the beaches.

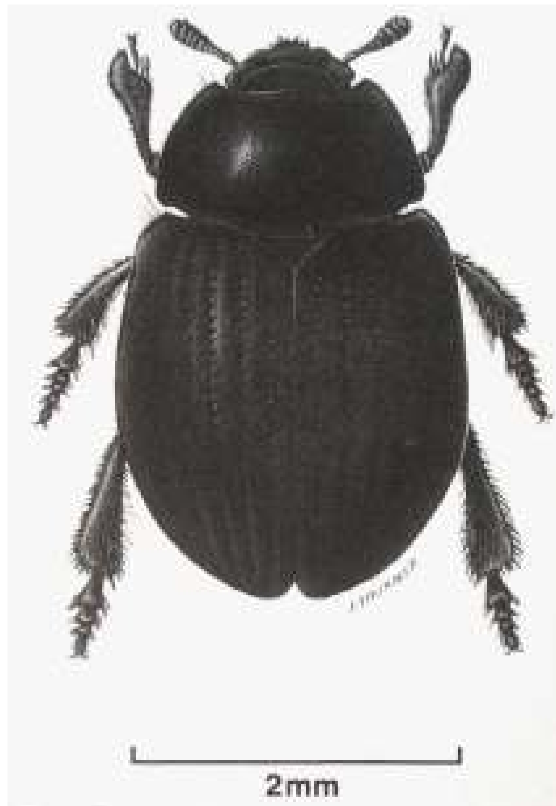


Fig. 2. *Trachyscelis ciliaris* Champion, length 2.5 mm.

THE ISLANDS

Seventeen tenebrionid and three scarab species have been collected from the islands off Eyre Peninsula. Two tenebrionids are apparently insular endemics: *Celibe oleatus* Carter from

Fig. 3. *Hyocis bakewelli* Pascoe, length 2 mm.

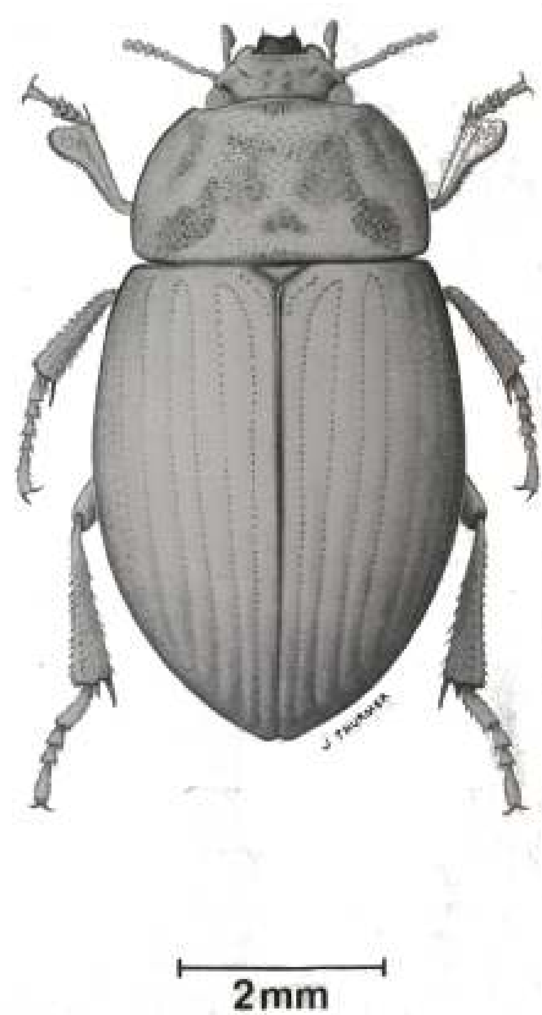


Fig. 4. *Scymena amphibia* Pascoe, length 6 mm.

Pearson and Greenly islands and *Celibe posidonius* Carter from South Neptune. These are the oldest islands of any size (10 500 years old or more) and therefore the ones we would expect to have produced endemic species, if speciation had occurred at all. There is also a dwarf piedish beetle (Fig. 6), either an undescribed species or an exceptionally small *Helaeus haagi* Dohrn, collected by S. Parker from Short-tailed Shearwater burrows on Perforated Island. This island was separated from the mainland about 9100 years ago.

The ancestors of the three species mentioned above were probably present originally when the islands were formed as a result of rising sea level. It is impossible to say whether the remaining 17 insular species, which cannot be distinguished at present from mainland populations, were present originally or arrived as immigrants after isolation of the islands.

Of the 17 insular tenebrionid species, 14 (82%) are flightless and were so at the time of isolation or colonisation, since they belong to wholly flightless genera. This contrasts with a 57% level of f1ightlessness among the tenebrionids of mainland Eyre Peninsula, about average for the family. All the scarab species, both on islands and on the mainland, are fully winged.

In the group surveyed here 44 species (63%) are'tenebrionids and 26 (37%) are scarabs on Eyre Peninsula as a whole, but on the islands 86% are tenebrionids and 14% scarabs. The conclusion is that the tenebrionid way of life is far more suitable for survival on, or colonisation

Fig. 5. *Celibe oleatus* (Carter), length 12 mm.

Fig. 6. *Helaeus haagi* Dohrn, length 7 mm.

of, islands. This is probably because of the tenebrionids' ability to withstand dry conditions and feed on a large variety of dry, dead foods, whereas the scarabs' dependence on specific living foods reduces their options when they are confined to a small area.

Moreover, the relatively high proportion of flightless species among the insular, as opposed to the mainland, tenebrionids shows that flightlessness is of positive advantage in island survival. This is already a well-known phenomenon among beetles (see, for instance, Darlington 1943), and can be explained by postulating an energy saving when useless wings do not have to be developed or supported. The 'flight-oogenesis syndrome' ensures that energy saved on reducing wing development is channelled towards increased reproductive potential.

As for the origin of the insular fauna, 16 of the 18 non-endemic species of both families are known from the mainland of Eyre Peninsula and it can be assumed that if any post-isolation colonisation occurred, these species came from the nearby shores. Five of these are marine littoral specialists and an additional three often occur in sand dunes behind beaches. These adaptations are the most likely to lead to island colonisation by way of flotsam. The two species not now known from mainland Eyre Peninsula, both tenebrionids like the endemic species, are *Exangeltus gracilior* Blackburn (winged) and *Ectyche nana* Pasco (wingless) The two are known also from eastern South Australia but are exceptionally rare species, seldom encountered anywhere, and I consider that both did at one time occur on Eyre Peninsula, if they are not there now. Like many rare species which are sensitive to environmental interference, they may survive today better, or only, on islands where the habitat is less disturbed. The islands where these species have been found (and their ages of separation from the mainland) are: Pearson

Fig. 7. *Exangeltus gracilior* Blackburn, length 9 mm.

Fig. 8. *Ectyche nana* Pascoe, length 3 mm.

(10 500), Reevesby (8 000), Franklin (7 700), and Masillon (7 700).

DISCUSSION

Eyre Peninsula cannot be sharply divided into faunal regions on the basis of the known distribution of the species considered, but there is some evidence of a gradual replacement of species from south to north. The marine littoral zone constitutes a sharply defined subregion on its own.

The peninsula has been populated mainly from the east, across Spencer Gulf which with very few exceptions does not constitute a barrier effective enough to permit endemic elements to evolve on the peninsula itself. Some Western Australian elements appear in the Mallee region only but there are very few species of northern origin, in spite of the apparent ease of access overland. In other words, climatic differences are more effective barriers to dispersal than are water gaps.

On the offshore islands the largely flightless tenebrionids are far more successful colonists, or (more probably) survivors from the original fauna, than are the winged scarabs. This is probably due mainly to the former's xerophily and non-specific food requirements, but there is also evidence that flightlessness is a positive advantage in island survival.

REFERENCES

Britton, E. B. (1980). A revision of the Australian chafers (Coleoptera: Scarabaeidae: Melonthinae). Vol. 3. Tribe Liparetrini: Genus *Liparetrus. Aust.* J. *Zool. Suppl. Ser.* **76**, 1-209.

Carne, P. B. (1956). A revision of *Saulostomus* Waterhouse and description of a new ruteline genus (Scarabaeidae, Coleoptera). *Proc. Linn. Soc. N.S.W* **81**, 62-70.

Carne, P. B. (1957a). 'Systematic revision of the Australian Dynastinae'. (C.S.I.R.O., Melbourne).

Carne, P. B. (1957b). A revision of the ruteline genus *Anoplognathus* Leach (Coleoptera: Scarabaeidae). *Aust.* J. *Zool.* **5**, 88-143.

Carne, P. B. (1958). A review of the Australian Rutelinae (Coleoptera: Scarabaeidae). *Aust. J. Zool.* **6***,* 162-240.

Carne, P. B. (1965). A revision of the genus *Elephastomus* Macleay (Coleoptera: Geotrupidae). J. *ent. Soc. Old.* **4**, 3-13.

Darlington, P. J., Jr. (1943). Carabidae of mountains and islands: data on the evolution of isolated faunas, and on atrophy of wings. *Ecol. monogr.* **13**, 46-61.

Howden, H. F. (1979). A revision of the Australian genus *Blackburnium* Boucomont (Coleoptera; Scarabaeidae: Geotrupinae). J. *Aust. ent. Soc.* **14***,* 439-41.

Laut, P., Heyligers, P. C., Keig, G., Loffler, E., Margules, C., and Scott, R. M. (1977). 'Environments of South Australia Handbook.' (Division of Land Use Research, CSIRO, Canberra).

Matthews, E. G. (1972). A revision of the scarabaeine dung beetles of Australia. I. Tribe Onthophagini. *Aust.* J. *Zool. Suppl. Ser.* **9**, 1-330.

Matthews, E. G. (1980). 'A guide to the genera of beetles of South Australia.' Part 1 (Special Educ. Bull. Ser., S. Aust. Museum, Adelaide).

Matthews, E. G. (1984). 'A guide to the genera of beetles of South Australia.' Part 3. (Special Educ. Bull. Ser., S. Aust. Museum, Adelaide).

Matthews, E. G. (1985a). Foraging activity of some tenebrionid beetles in a South Australian mallee area. *In:* Greenslade P. and Majer, J. D. (Eds) 'Soil and litter invertebrates in some Australian Mediterranean-type ecosystems.' Vol. 1 Western Australian Institute of Technology. BioI. Bull. No. 12, 63-64.

Matthews, E. G. (1985b). 'A guide to the genera of beetles of South Australia.' Part 4. (Special Educ. Bull. Ser., S. Aust. Museum, Adelaide) (in press).

Matthews, E. G. (1986). A revision of the troglophllic genus *Brises* Pascoe, with a discussion of the Cyphaleini (Coleoptera, Tenebrionidae). *Rec.* S. *Aust. Museum* (in press).

16: Moths and Butterflies

by P. B. McQUILLAN and R.H. FISHER

INTRODUCTION

The Order Lepidoptera includes all moths and butterflies and is one of the major orders of invertebrates represented in South Australia. More than 2000 species occur within the State, and of these about 97% are moths. At least 600 species probably occur on Eyre Peninsula.

As an environment for lepidopterans, Eyre Peninsula provides a diversity of habitats. A mallee flora is dominant, but outliers of wetter open forest occur in the south, and open Acacia woodland and low chenopod shrubland reach the northern Peninsula at their southern limit. The persistence or intrusion of each of these elements contributes a range of species which enriches the Peninsula fauna as a whole. The recent displacement of native vegetation by introduced pastures, crops and weeds, has been catastrophic for most species, but has created opportunities for a few to colonise these new resources.

The suborders Dacnonypha, Monotrysia and Ditrysia occur on Eyre Peninsula. The recently discovered *Lophocorona pediasia*, whose larval biology is unknown, occurs in low open woodland with a chenopod understorey and represents the primitive Dacnonypha.

Monotrysian moths include the hepialids *Fraus polyspila*, *Abantiades marcidus*, *Trictena argentata* and *Aenetus blackburni*. *Ae. ombraloma*, described from Port Lincoln probably does not occur in South Australia. Other monotrysians present are various Nepticulidae, Adelidae (e.g. *Nemotois* associated with *Bursaria spinosa*) and several Incurvariidae. The tiny adults of Heliozelidae visit rutaceous flowers in early spring.

The suborder Ditrysia encompasses the great majority of moths and all the butterflies. Collectively they exploit most plants and products derived from them. Families which have some larvae feeding as borers in living plant tissue include Cossidae (*Xyleutes*), Tortricidae (*Arotrophora*), Xyloryctidae (*Cryptophasa*) and Pyralidge. The larvae of Gracillariidae are tiny specialised miners which usually live and feed within leaves and stems, although the early instars of many Tortricidae, Gelechiidae and Oecophoridae adopt a similar habit. Young terminal shoots are commonly webbed together and fed upon by older larvae of these three latter families as well as some Epermeniidae, Xyloryctidae and Pyralidae. Consumers of whole leaves include larvae of the majority of larger ditrysians such as Limacodidae, Geometridae, Lasiocampidae, Anthelidae, Saturniidae, Sphingidae, Notodontidae, Arctiidae, Noctuidae and Agaristidae and all butterfly families. Some small groups are more specialised. Flowers are eaten by *Heliocosma* (Phaloniidae) on *Helichrysum*, *Pollanisus* (Zygaenidae) on *Hibbertia* and *Chloroclystis* (Larentiinae) on Fabacaeae. The larvae of many butterflies of the family Lycaenidae are also flower feeders. External root-feeders are *Synemon* (Castniidae) on *Lepidosperma* and *Xyleutes* on *Maireana*. Dead leaves and other detritus are exploited by many Tineidae, Oecophoridae and Pyralidae and a range of taleporine Psychidae feed on lichens. The larvae of some *Stathmopoda* (Stathmopodidae) and *Cyclotorna* (Cyclotornidae) are carnivorous on scale insects.

The history of an overwhelmingly phytophagous Order such as Lepidoptera is inexorably linked to that of the associated flora. The extensive semi-arid vegetation systems of Eyre Peninsula have recruited species which can tolerate firstly the stressful environment and, secondly, the nutritional constraints imposed by the physiological makeup of the available food plants. The poor nutrient status of much semi-arid adapted foliage, including *Eucalyptus*, reflects that of the soil, and probably has been as significant a hurdle as aridity for the moth fauna to overcome (I. F. B. Common pers. comm.). The adaptations to aridity of potential food plants, often manifest in anti herbivore modifications such as scleromorphy and antifeedants, have been an additional challenge to the lepidopterous fauna.

Adaptations to avoid heat stress are largely behavioural. Thus, many larvae are cryptic feeders either in plant tissue, within constructed cases, or in the soil. Such habits may be characteristic of whole families such as

Hepialidae, Cossidae, Castniidae and Psychidae, and like nocturnal activity in most larvae, are 'useful preadaptations' of long standing. However, for some other groups such as some oecophorids, they represent a novel response to aridity. Groups denied this option exhibit other heat-avoidance mechanisms. Many Geometridae and Noctuidae aestivate as pupae in the soil or litter over the hottest months. Eclosion in autumn is triggered by seasonal environmental factors such as a drop in temperature and the arrival of rainfall leading to elevated soil humidity. Such conditions also stimulate a flush of vegetative growth in the flora-asynchrony which provides these insects with an abundance of attractive food for their larvae. McFarland (1973) found that the first instar larvae of some autumn-flying Geometridae are capable of a short facultative diapause in the eggshell until stimulated to hatch by rainfall. Moths which must dig to the surface from buried pupae often exhibit modifications such as a corneous frontal process or tibial spines (e.g. *Eremochroa*, Fig. 1F).

Some species have overcome the chemical defences of their foodplants in unique ways; the larvae of *Myrascia* (Oecophoridae) sequester oils from *Leptospermum* in a foregut diverticulum where it is not only isolated but can be regurgitated as a deterrent to predators (Common & Bellas 1977).

Several species of wasp-mimicking moths occur on Eyre Peninsula, including *Sagalassa* spp. (Brachodidae), *Hestiochora rufiventris* (Zygaenidae) and *Syntomis* spp. (Ctenuchidae).

THE MOTH FAUNA

Moths and man

A range of moths and their immature stages were familiar to the aborigines of Eyre Peninsula, featuring in their folklore and songs. On the west coast larvae and adults of the large hepialid moth Abantiades marcidus were eaten and their seasonality and association with certain *Eucalyptus* roots was understood (Tindale 1932). The root feeding larvae of cossid moths featured in the diets of aborigines in western South Australia, including *Xyleutes leucomochla* on the roots of *Acacia ligulata*, X. *biarpiti* on the roots of *Zygophyllum*, *Cataxophylla cyananges* on the roots of *Acacia* and an undescribed species from

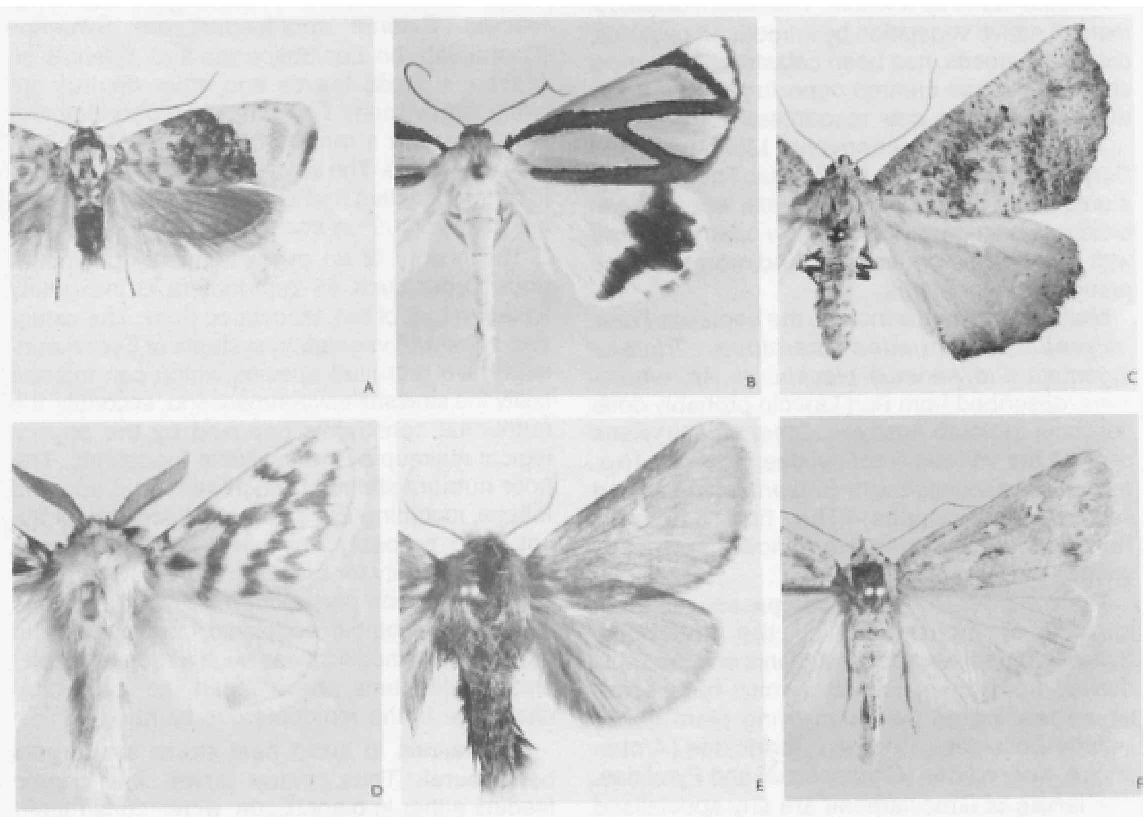


Fig. 1. Moths of Eyre Peninsula: A. *Piloprepes antidoxa*, male; B. *Thalaina angulosa*, male; C. *Mnesampela privata*, female; D. *Perna chlorophragma*, male; E. *Teara contraria*, male; F. *Eremochroa* sp., male.

Salsola kali (Tindale 1953). All these cossids are widespread in the shrublands of central Australia and extend into northern Eyre Peninsula.

Recorded European contact with the fauna begins with the lepidopterist Edward Meyrick who collected numerous species in the vicinity of Port Lincoln on a visit in the early 1880's. Over many years, descriptive references to these species were scattered through a series of publications dealing with the Australian moth fauna. Between 1882 and 1886 Thomas Blackburn, a parson and coleopterist, was stationed at Port Lincoln and forwarded moth specimens to the Broken Hill lepidopterist Oswald Lower. The attractive hepialid *Aenetus blackburni* and the xyloryctid *Cryptophasa blackburni*, both described in 1893, honour their collector. Little activity occurred over the next 60 years until Norman Tindale collected in southern Eyre Peninsula in the early 1950's. Since the late 1960's a small number of private and institutional collectors have added to our knowledge of the fauna.

A small number of species has been introduced accidentally by European man, and yet other native species have benefited from his presence.

OVERVIEW OF THE MOTH FAUNA

Moths of the Myall Woodland System

In northern Eyre Peninsula are low woodlands dominated by *Acacia*, especially *A. sowdenii*. An understory of chenopods and other shrubs is often present which in the absence of taller elements occasionally forms a low shrubland.

Conspicuous in this habitat is the thaumetopoeid *Teara contraria* (Fig. 1E), the gregarious larvae of which cluster in large silken bags suspended amongst *Acacia* or *Cassia* which they commonly defoliate. The hairy larvae are sometimes seen moving over the ground in a processionary manner. The bags contain large amounts of frass and urticating hairs attached to cast skins which probably aid in defence against predators. Matthews (1976) suggests that the bag may help maintain higher than ambient temperatures.

A host of Geometridae are supported by Acacia including *Thalaina* (Fig. 1B), *Loweria* and *Amelora* (*sensu lato*). *T. kimba* is abundant in this region (McQuillan 1981). Several species of *Anthela* rely on *Acacia* foliage as a food plant as does the plutellid *Homadaula* and various Cosmopterygidae with larvae webbing the shoots.

Chenopodiaceous plants are attacked by defoliating noctuids such as *Omphaletis*, *Rictonis* and *Agrotis*, a geometrid *Chlenias*, as well as larvae of the day-flying agaristid *Apina callisto* and ctenuchid *Syntomis*. *Xyleutes* larvae feed externally on the roots and various gelechiids web the terminal buds. Other moths commonly collected in this shrubland include the cosmopterygid *Mimodoxa*, the oecophorids *Eulechria habrodes*, *Pachybela* and *Nephogenes*, and unusual acronyctine noctuids of the genus *Eremochroa* (Fig. 1F).

Moths of the mallee system

This is the dominant vegetation complex on Eyre Peninsula and important food plant elements are Myrtaceae, Proteaceae, Fabaceae, Sapindaceae, Rhamnaceae and Asteraceae. This system probably is the richest in moths, and a bias towards myrtaceous-feeding species strongly reflects the dominance of this family in the flora, both in species diversity (23 species in seven genera) and biomass. The adaption to a dry environment that is a hallmark of much of the Australian Lepidoptera (Common 1970) is well illustrated by the cryptic larval biologies of many moths.

Eucalyptus hosts a large number of genera, including the geometrids *Chlenias*, *Fisera*, *Gastrinopa*, *Mnesampela*, *Stibaroma*, and *Crypsiphona*, the lasiocampids *Entometa*, *Perna* (Fig. 10), *Pinara* and *Porela*, and a host of small moths such as the oecophorids *Hippomacha*, *Eupselia* and *Hypertropha*. Many tortricids and oecophorids (e.g. *Zonopetala* and *Thema*) feed on dead eucalypt leaves. *Melaleuca* supports a range of Dichromodes species, *Syneora*, *Symmetroctena* and *Chlorocoma* (all Geometridae) as well as the nolid *Aquita*, the tortricid *Bathrotoma*, the zygaenid *Hestiochora rufiventris* and the oecophorid *Myrascia*. On *Leptospermum* are found the geometrids *Chlorocoma* and *Dichromodes*, the thaumetopoeid *Epicoma*, and the oecophorid *Thudaca* amongst others. On Proteaceae occur the notodontid *Danima banksiae*, the geometrids *Oenochroma vinaria* and *Dinophalus* and several species of Xyloryctidae which construct frass covered galleries amongst the foliage. *Dodonaea* (Sapindaceae) is the foodplant of the geometrids *Parosteodes* spp., *'Chlenias' melanoxysta* and *'Crypsiphona' eremnopis*, as well as the gelechiid *Protolechia lithina*. *Casbia* spp. (Geometridae) feed on several genera of Rhamnaceae and archipine tortricids are common on Asteraceae.

The flush of ephemeral forbs which often follows rainfall is usually exploited by noctuoids which are well adapted by polyphagy and a short larval period to respond to such opportunities.

Although Specht (1972) subdivided the mallee system into four associations, the composition of the lepidopteran fauna is not known in sufficient detail to check for a corresponding differentiation.

Moths of the open forests

Pockets of open forest persist in favoured wetter areas of southern Eyre Peninsula which preserve outliers of large *Eucalyptus* species such as *E. leucoxylon*, *E. viminalis* and associated flora. The lepidopteran fauna of this habitat is reminiscent of that of the Mount Lofty Ranges to the east. Characteristic species are the saturniid *Antheraea helena*, the geometrids *Mnesampela privata* (Fig. 1C) and Capusa *senilis*, the thaumetopoeid *Oenosanda boisduvalii*, and the oecophorid P*iloprepres antidoxa* (Fig. 1A) all of which feed on *Eucalyptus*. Several species of Glyphipterygidae fly in the vicinity of Juncaceae growing in damp areas.

Moths of the Coastal Dunes

The flora of the Eyre Peninsula dunes is similar to that of coastal dunes elsewhere in southern Australia (Specht 1972). McFarland (1979) found larvae of the agaristid *Comocrus behrii* feeding in April on *Amyema melaleucae* at Murninnie Beach; adults of this moth exhibit hill-topping behaviour. Males of the so-called whistling moth, *Hecatesia* sp., can be heard in many dune areas at dusk during summer. During flight, a modification of the forewing produces a loud whirring sound which possibly may aid the moths in defending their territory from rivals. Their larvae feed on *Cassytha*. The noctuid *Rictonis* (formerly *Nictocris*) has many species in southern Australia and several of these are restricted largely to coastal areas. Larvae remain hidden in the sand by day but emerge at night to feed on grasses. *R. callimera* larvae were recovered from dune sand near Elliston by McFarland (1979). Other coastal inhabitants include the geometrid *Euloxia meracula* on *Pimelea serpyllifolia*, the lymantriid *Acyphas leucomelas* and various Gracillariidae on *Acacia sophorae*, the pyralid *Hellula undalis* on *Cakile maritima*, and the oecophorids *Eulechria leucophanes* (from Port Lincoln sandhills, Meyrick 1883) and *Tortricopsis callichroa* (Sheringa, Meyrick 1902).

Moths of the Culture Steppe

In its broadest sense, the culture steppe is that part of the environment which has been modified by man's activities (Matthews 1976). Prominent examples on Eyre Peninsula are pastures and croplands, parks and gardens, and derelict land colonised by weeds.

The majority of introduced moths are dependant on such habitats and may be nearly cosmopolitan in their distribution. In the absence of their natural predators and parasites they sometimes acquire pest status. Familiar examples are *Plutella xylostella* on cabbages and other brassicaceous plants, *Phthorimaea operculella* on potatoes, and a range of phycitine pyralids such as *Plodia interpunctella* and *Ephestia* spp. on stored food products.

A number of native moths have been advantaged by the establishment of extensive ryegrass-clover pastures. The crambine pyralids *Hednota* and the oecophorid *Philobota productella* are abundant. Other natives, polyphagous on a wide range of dicotyledons, have flourished following the introduction of a myriad of weeds and garden plants. These include the tortricid Epip*hyas postvittana*, the geometrids *Scopula rubraria*, *Ectropis excursaria* and *Xanthorhoe vicissata*, and the noctuoids *Agrotis munda*, *Chrysodeixis argentifera*, *Apina callisto*, *Spilosoma glatignyi* and *Utetheisa pulchelloides*.

THE BUTTERFLY FAUNA

Of the 38 species recorded from Eyre Peninsula a few range widely throughout the various plant communities and vegetation types. However, most have fairly restricted distributions which follow very closely the distribution or abundance of their larval food plants. Two subspecies: the hesperiid *Hesperilla chrysotricha naua* and the lycaenid *Ogyris barnardi delphis*, virtually are confined to Eyre Peninsula, but as yet there is no other evidence amongst butterflies to suggest that the geographic isolation of the Peninsula from other parts of the continent has encouraged speciation. However, studies of two more species, the hesperiid *Hesperilla donnysa* and the satyrid *Geitoneura klugii* are incomplete and may in time enlighten this subject. The attention paid in the past by lepidopterists to butterflies in this area has been fairly limited, and more comprehensive field work in the future, especially in the west and north, may prove productive.

In the following account subspecific names have not been included unless they have a particular significance. More detailed descriptions of each species and its life history will be found in Fisher (1978).

HESPERIIDAE (skipper butterflies)

The rare *Trapezites sciron* (sciron skipper, Fig.' 2) is recorded only from Hincks National Park. Its early stages are associated with *Lomandra glauca* (Fisher 1984). *Trapezites luteus* (white-spot skipper) is also rare with one record

Fig. 2. *Trapezites sciron*, freshly emerged from pupa

Fig. 4. Egg of *Motasingha dirphia* on *Lepidosperma viscidum*, Mount Drummond.

of a specimen from near Port Lincoln in 1911. *Hesperilla donnysa* occurs widely in southern and central Eyre Peninsula. As in other parts of South Australia two subspecies are recognised, *H. d. liluta*, with larvae on *Gahnia ancistrophylla* and *G. deusta*, and the slightly larger and darker *H. d. delos*, whose larvae feed on the taller *G. trifida*, *G. filum* and *G. sieberiana*. The subspecies *Hesperilla chrysotricha naua* (chrysotricha skipper) occurs only on Eyre Peninsula, from near Port Lincoln to Lake Hamilton. Its larvae also feed on tall *Gahnia* and build twisted shelters from the eaves (Fig. 3). *Motasingha dirphia* (dirphia skipper) lays its eggs singly (Fig. 4) near the base of the leaves of *Lepidosperma viscidum* and

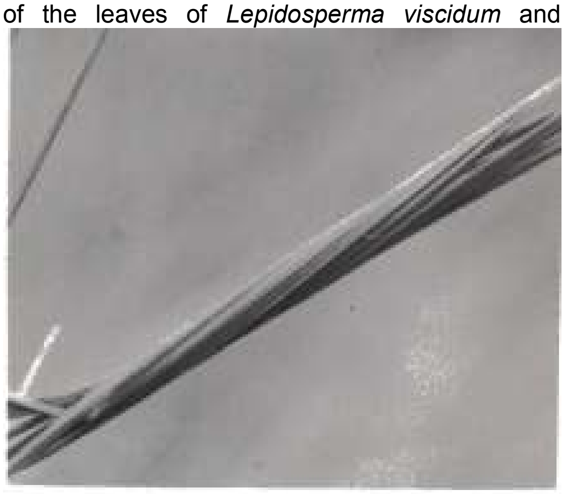


Fig. 3. Twisted larval shelter of *Hesperilla chrysotricha* on *Gahnia trifida*, Lake Hamilton.

probably *L. carphoides*, and is recorded from near Port Lincoln and Mount Drummond. *Antipodia atralba* (black and white skipper) occurs mainly in the south where its host plants are *Gahnia lanigera* and *G. ancistrophylla*. *Ocybadistes walkeri* (southern dart) is the only hesperiine skipper recorded from the Peninsula, with larvae feeding on couch and kikuyu grasses used commonly in domestic lawns.

PAPILIONIDAE (swallowtails)

Three species have been recorded near Whyalla: *Papilio anactus* (dingy swallowtail) and *P. aegeus* (orchard butterfly) have conspicous larvae which feed on cultivated Citrus trees, although *P. aegeus* is quite uncommon in South Australia. *P. demoleus* (chequered swallowtail), normally an inland butterfly, occurs frequently in southern areas. Its larvae feed on *Psoralea*.

PIERIDAE (whites and yellows)

The bright yellow *Eurema smilax* (small grass yellow) is often common during the summer in the more arid north of the Peninsula. Its larvae feed on *Cassia*, including *C. nemophila*. The colourful *Delias aganippe* (wood white) occurs occasionally throughout the Peninsula but is not common. Its larvae, gregarious when young, feed on mistletoes and *Santalum* and occasionally on *Exocarpos*. *Anaphaeis java* (caper white) is also widespread and sometimes common in early summer, reaching most of the Peninsula in the course of migratory flights from its breeding grounds in the Flinders Ranges and northern

New South Wales. The introduced *Pieris rapae* (cabbage white) is a pest of domestic and market gardens. There appear to be no records of its larvae feeding on native plants but the butterfly often appears far from settled areas.

NYMPHALIDAE (danaids, browns, nymphs)

The native *Danaus chrysippus* (lesser wanderer) and the introduced *D. plexippus* (wanderer, monarch) occur occasionally throughout Eyre Peninsula. The larvae of both species feed on several asclepiads, including the introduced *Stapelia variegata* found in the hills near Whyalla.

In the eucalypt forest near Port Lincoln *Heteronympha merope* (common brown) and *Geitoneura klugii* (Klug's xenica) appear commonly, and their distribution extends somewhat to the north and northeast. Throughout this range specimens of the latter are indistinguishable from the nominate subspecies *G. k. klugii*. However, to the northwest and near Ceduna specimens are substantially paler (Fig. 5) and they occur in more open scrub, often frequenting areas of dappled sunlight beneath mallee eucalypts. Further study of these pale specimens and their distribution is needed to establish their taxonomic status.

Three other nymphalids occur widely and are seen commonly in gardens on sunny days; *Vanessa kershawi* (painted lady) and *Junonia villida* (meadow argus), both with larvae feeding on a variety of native and introduced plants, and *Vanessa itea* (Australian admiral) whose larvae feed on nettles and whose adults sun themselves head-downwards (Fig. 6). The large and

Fig. 6. *Vanessa itea*, resting in a characteristic head-downwards position.

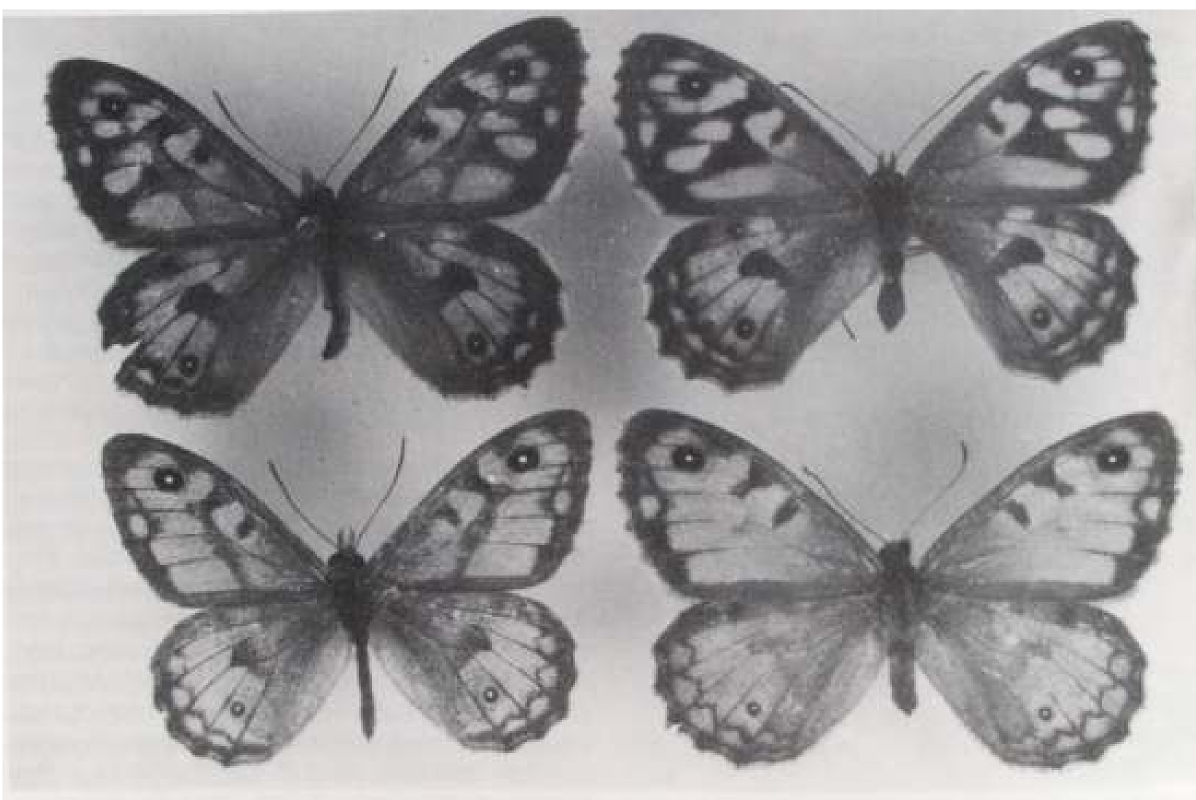


Fig. 5. Male and female *Geitoneura klugii* from Port Lincoln (above) and pale form from Ceduna (beneath).

spectacular *Polyura pyrrhus* (tailed emperor) has been recorded occasionally in Whyalla and probably has become established there on ornamental trees and shrubs such as *Brachychiton* and *Acacia*, and on *Robinia pseudacacia*.

LYCAENIDAE (blues)

This large family is represented by 16 species. Lower (1893) lists *Hypochrysops ignitus* (fiery Jewel) from Port Lincoln but it has not been collected there recently. Elsewhere, the larvae of this pretty butterfly shelter during the day in ant byres at the base of its host plants *Acacia pycnantha* and *Choretrum glomeratum*, emerging at night to feed on the stems and leaves. A single specimen of the rare *Ogyris idmo* (large brown azure), whose life history remains unknown, was collected near Ceduna in 1942. Lower (1893) recorded this species from near Port Lincoln. The type locality for the subspecies *Ogyris barnardi delphis* (Barnard's azure) is near Iron Knob. There it is quite abundant during spring, flying over western myall trees (*Acacia sowdenii*) which bear pendant masses of its mistletoe food plant, *Amyema quandang*. Sharing this habitat is *Ogyris amaryllis* (amaryllis azure), although this species is distributed more widely in the north of the Peninsula and its larvae feed on a variety of mistletoes.

South Australia's only endemic species, *Jalmenus lithochroa* (lithochroa blue, Fig. 7) is recorded from Port Augusta flying near its host plant, *Acacia victoriae*, Its eggs (Fig. 8) resemble a mass of tiny sea urchins and are laid near the base of the tree. Its larvae are attended by several kinds of ants. A similar species but

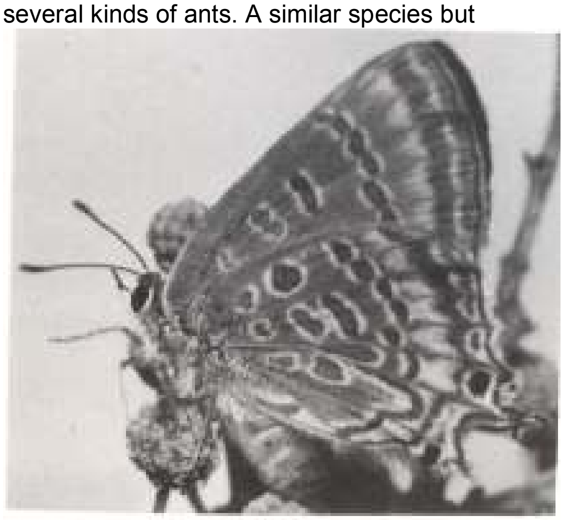


Fig. 7. *Jalmenus lithochroa* on flower buds of *Acacia victoriae*, Port Augusta.

Fig. 8. Eggs of *Jalmenus lithochroa*, Port Augusta.

without tails to the hindwings is *Jalmenus icilius* (icilius blue), whose larva (Fig. 9) feeds on *Cassia nemophila* near Whyalla and Minnipa. Three *Candalides* occur widely. The small *C. acastus* (blotched blue) has larvae which feed on the fine twining parasite, Cassytha glabella while larvae of C. hyacinthinus (western dusky blue) are associated with the coarser *Cassytha melantha*. The host plant of *C. heathi* (rayed blue) on Eyre Peninsula has not been determined although this species has been collected from the east coast to Ceduna.

An interesting feature of some lycaenid larvae, particularly those that feed on flowers, is the degree to which cryptic colouration or form is

Fig. 9. Mature larva of *Jalmenus icilius* on *Cassia nemophila*, Minnipa.

used as a defence against predation and probably parasitism. The larvae of a few species can even change colour, quite rapidly, to match different parts of the flowers which they are eating. On Eyre Peninsula these phenomena can be observed in several species. The larva (Fig. 10) of the tiny *Nacaduba biocellata* (double-spotted lineblue) curls around the flower buds of many Acacia. *Neolucia agricola* (fringed blue) appears in spring and summer and its larvae are found on the coloured flowers of *Dillwynia*, *Eutaxia* and *Pultenaea* which they resemble closely (Fig. 11). The larvae of *Theclinesthes albocincta* (Fig. 12) are pink or green and difficult to detect on the flowers and leaves of their food plant, *Adriana klotzschii*. The widespread *Theclinesthes serpentata* (chequered blue) has larvae which feed on various saltbushes (*Atriplex* etc.) and the texture of the larval cuticle resembles remarkably the surface of their leaves (Fig. 13). *Theclinesthes miskini* occurs in the north, with several *Acacia* as host plants. *Lampides boeticus* (pea blue) has been recorded near Whyaila and probably occurs quite widely as its larvae feed on various native and introduced leguminous plants, as do those of the common and widespread *Zizina labradus* (common grass blue).

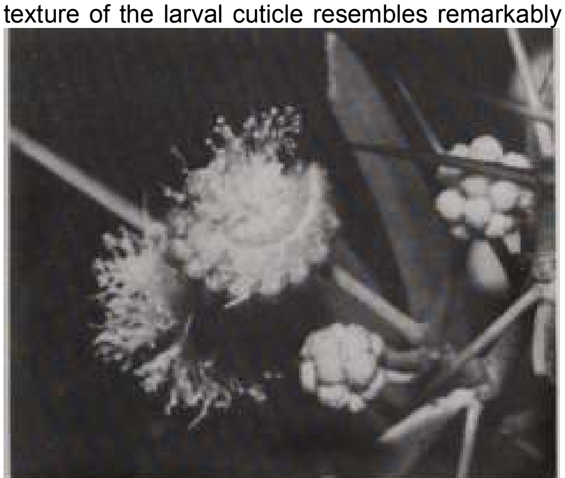


Fig. 10. Larva of *Nacaduba biocellata* on flowers of *Acacia victoriae*.

Fig. 11. Larva of *Neolucia agricola* with flowers of *Eutaxia* sp.

Fig. 12. Young larva of *Theclinesthes albocincta* on flower buds of *Adriana klotzschii*.

Fig. 13. Larva of *Theclinesthes serpentata* on leaves of *Rhagodia* sp.

ACKNOWLEDGEMENTS

We thank Mr M. Potgieter for preparing Figure 1. The Australian Biological Resources Survey provided financial assistance for a study and the

National Parks and Wildlife Service gave permission to collect and study the fauna of National Parks. Mr J. S. Womersley assisted botanical identifications and Mr P. Hudson provided valuable observations of butterfly species occurring near Whyalla.

REFERENCES

Common, I. F. B. (1970). Lepidoptera. In, CSIRO (Ed.) 'Insects of Australia'. (Melbourne University Press, Melbourne).

Common, I. F. B. & Bellas, 1. E. (1977). Regurgitation of host-plant oil from a foregut diverticulum in the larvae of Myrascia megalocentra and M. bracteatella. (Lepidoptera: Oecophoridae). J. Aust. ent. Soc. **16**, 141-7.

Fisher, R. H. (1978). 'Butterflies of South Australia'. (GoV!. Printer, Adelaide).

Fisher, R. H. (1984). Life history of the sciron skipper Trapezites sciron eremicola Burns (Lepidoptera: Hesperiidae). Trans. R. Soc. S. Aust. **108**, 131-2.

Lower, O. B. (1893). List of South Australian Rhopalocera. Trans. R. Soc. S. Aust. **17**, 1-12.

McFarland, N. (1973). Some observations on the eggs of moths and certain aspects of first instar larval behaviour. J. Res. Lepid. **12**, 199-208.

McFarland, N.(1979). Annotated list of larval food plant records for 280 species of Australian moths. J. lepid. Soc. **33**, Supplement, 72 pp.

McQuillan, P. B. (1981). A review of the Australian moth genus Thalaina (Lepidoptera: Geometridae: Ennominae). Trans. R. Soc. S. Aust. **105**, 1-23.

Matthews, E. G. (1976). 'Insect Ecology'. (University of Queensland Press, Brisbane).

Meyrick, E. (1883). Descriptions of Australian microlepidoptera. IX. Oecophoridae. Proc. Linn. Sac. N.S.w 7, 328-83.

Meyrick, E. (1902). Descriptions of new species of Lepidoptera (Oecophoridae). Trans. R. Soc. S. Aust. **26**, 133-74.

Specht, R. L. (1972). 'The Vegetation of South Australia'. 2nd Edtn. (Govt. Printer, Adelaide).

Tindale, N. B. (1932). Revision of the Australian ghost moths (Lepidoptera Homoneura, Family Hepialidae). Part 1. Rec. S. Aust. Mus. **4**, 497-536.

Tindale, N. B. (1953). On some Australian Cossidae including the moth of the witjuti (witchety) grub. Trans. R. Soc. S. Aust. **76**, 56-65.

17: NATIONAL PARKS

by A.C. ROBINSON and L.M.B. HEARD

INTRODUCTION

There are 48 parks managed by the South Australian National Parks and Wildlife Service on Eyre Peninsula south of a line between Penong and Port Augusta. Collectively they occupy an area of 278 501 hectares which is approximately 5% of the peninsula.

These parks are discussed in relation to the appropriate environmental associations recognised for the Eyre and Yorke Peninsula province of South Australia according to Laut *et at.* (1977). Four environmental regions are recognised and described by these authors (Fig. 1) and parks are designated in each of them.

General descriptions of each park are given below, beginning in the Southern Highland and Plains Environmental Region and moving northwards. The offshore island parks are assigned to the nearest Environmental Region, although they were not considered in the study of Laut *et al. (1977).*

The size and complexity of the parks varies considerably as does the amount of resource information available on each. In the following discussion an attempt has been made to summarise the information and to provide the visitor with a brief introduction to the individual parks. Park locations are set out in Table 1.

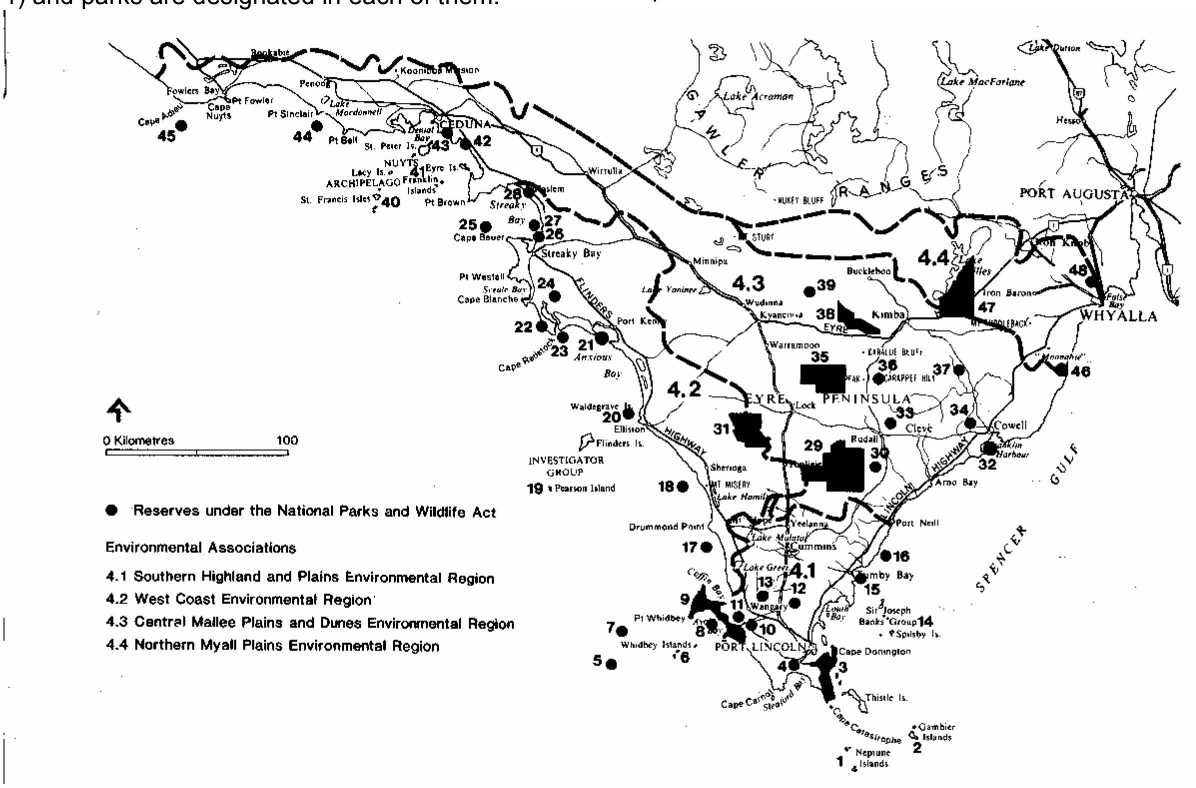


Fig. 1. Reserves and environmental associations of Eyre Peninsula.

Table 1. NATIONAL PARKS AND WILDLIFE SERVICE RESERVES ON THE EYRE PENINSULA

Park	*Location Map (1:50 000)*	*Year of Dedication*	*Contact Ranger* 14	*Kiosk* 13	*Water* 14	*Toilets*	*Facilities for Handicapped*	*Picnic Areas* 2,13	*Barbecue Facilities* 2,13	*Bush Camping* 1,2,13,14	*Camping* 1,2,13,14
Southern Highland and Plains Environmental Region											
3. Lincoln National Park	Jussieu 6028-II Pt 6128 and Pt 6027-II Thistle Pt 6128-III & 6127-IV Lincoln 6028-I & Pt 6128-IV	1941	1D		—	—			—	—	—
4. Sleaford Mere Conservation Park	Sleaford 6028-III & Pt 5928-II Jussieu 6028-II & Pt 6128-III & Pt 6027-I	1969	1D								
9. Coffin Bay National Park	Wanilla 6028-IV, Wangary 5928-I, Whidbey 5928-IV & Pt 5929-III	1982	1A		5 —					—	—
10. Kellidie Bay Conservation Park	Wanilla 6028-IV	1954	1A		5					—	—
12. Wanilla Conservation Park	Wanilla 6028-IV	1978	1D							—	—
13. Murrunatta Conservation Park	Wanilla 6028-IV	1984	1A								
West Coast Environmental Region											
21. Venus Bay Conservation Park	Venus 5831-IV	1976	1B							—	—
22. Point Labatt Conservation Park	Calca 5731-I	1973	1B								
24. Calpatanna Waterhole Conservation Park	Ripon 5732-II, Calca 5731-I	1974	1B							—	—
28. Caratoola Recreation Park	Carawa 5733-III, Haslam 5732-IV	1969	1B							—	

Camping ground	Caravan Access	Caravan Park	Fees Payable	Walking Trails	Bushwalking Trails	Fishing	Swimming	Boating	Birdwatching	Viewpoint	Ranger Office	Pamphlet	Off-road parking	Horseriding	Accommodation	Access
1,2,13,14		1,2,13,14	1		15,14	7		8,12							1,2,13	
—	3 —	21 —		15 —	15 —	—	22 —	23 —	—	—		—	—		24 —	25 km south of Port Lincoln. Take the main sealed road south to Tulka (Proper Bay Road). Turn east at Tulka. This unsealed road leads to the park's western boundary.
	4 —								—							15 km south-west of Port Lincoln. Take the main sealed road south from Port Lincoln to Tulka (Proper Bay Road). Continue south on this road to the first major T-junction. Take the Sleaford Bay Road (unsealed) to the right. This goes around the western side of the mere.
	3 —			15 —		—	22 —	6 —	—	—	—	—	—	19 —		2 km south-west of Coffin Bay township. Follow the bay around to a National Park signpost. Turn west and travel about 1 km to a Y-junction. Turn south and travel to the park.
						—	—	6	—	—				19 —		1.5 km east of Coffin Bay township. The main sealed Coffin Bay Road bisects the park.
	4 —								—							4 km east of Wanilla (town). Take the Wanilla-North Shields Road (unsealed) which bisects the park.
									—							35 km west of Port Lincoln, 19 km north-east of Coffin Bay township. Travel to the Coffin Bay turn-off intersection and take the unsealed road north. Continue north for 4.3 km ignoring the easterly turn-off to Wanilla.
						—	22 —	11	—							1 km west of Port Kenny. Please contact the Far West District Office for specific directions.
	3 —								—	—			—			40 km south of Streaky Bay. Take the Flinders Highway (sealed) south-east for 18 km to the Calca turn off to the south. Travel along this unsealed road to the Calca-Sceales Bay Road turn off to the west. Take this road west for 9 km to the Point Labatt turn off to the park 19 km to the south.
	4 —								—							28 km south-east of Streaky Bay. Take the Flinders Highway (sealed) south-east for 18 km to the Calca intersection, then take the unsealed road towards Calca for 10 km to the park boundary.
	4 —								—							42 km north of Streaky Bay, ½ km north of Haslam. Please contact the Far West District Office prior to visiting. From Streaky Bay take the Flinders Highway north for 41 km to the Haslam turn-off. Turn south onto the sealed road to Haslam. The park is on the north side of this road.

Table 1. (continued)

Park	Location Map (1:50 000)	Year of Dedication	Contact Ranger 14	Kiosk 13	Water 14	Toilets	Facilities for Handicapped	Picnic Areas 2,13	Barbecue Facilities 2,13	Bush Camping 1,2,13,14	Camping 1,2,13,14
Central Mallee Plains and Dunes Environmental Region											
29. Hincks Conservation Park	Kielpa 6130-IV, Hincks 6130-III, Nicholls 6030-II, Palkagee 6030-I	1941	1D							—	—
30. Verran Tanks Conservation Park	Hincks 6130-III	1983	1D							—	—
31. Bascombe Well Conservation Park	Pearce 5930-II, Kappawanta 5930-I, Tooligie 6030-III, Murdinga 6030-IV	1970	1A							—	—
32. Franklin Harbor Conservation Park	Gibbon 6230-II, Cowell 6230-I	1976	1D							—	—
33. Rudall Conservation Park	Rudall 6130-I	1973	1D							—	—
34. Middlecamp Hills Conservation Park	Mangalo 6230-IV Cowell 6230-I	1977	1D							—	—
35. Hambidge Conservation Park	Darke 6131-III, Hambidge 6031-II	1941	1D							—	—
36. Carappee Hill Conservation Park	Darke 6131-III, Carappee 6131-II	1973	1D					16	16 —	16 —	16 —
37. Sheoak Hill Conservation Park	Heggaton 6231-III, Glynn 6231-II	1978	1D							—	—
38. Pinkawillinie Conservation Park	Kimba 6131-I, Panitya 6131-IV	1970	1A							—	26 —
39. Corrobinnie Hill Conservation Park	Corrobinnie 6032-II	1983	1A							—	—

Camping ground	Caravan Access	Caravan Park	Fees Payable	Walking Trails	Bushwalking Trails	Fishing	Swimming	Boating	Birdwatching	Viewpoint	Ranger Office	Pamphlet	Off-road parking	Horseriding	Accommodation	Access
1,2,13,14		1,2,13,14	1		15,14	7		8,12							1,2,13	
									—	— [10]						85 km north of Port Lincoln, 8 km east of Tooligie. From Tooligie take the Tooligie-Rudall Road (unsealed) for 25 km, then turn south at Tooligie Hill onto the Nicholls Track (unsealed) which leads into the north-western corner of the park. Please check with the Port Lincoln District Office about specific access directions.
									—	—						15 km west of Verran (township). Please contact the Port Lincoln District Office for specific access directions.
									—							20 km west of Lock, 8 km west of Murdinga. From Murdinga travel west along the Murdinga-Elliston Road (unsealed) and continue through the first main intersection to the park.
						—	— [22]	11	—							5 km south of Cowell. Take 'The Knob' Road (unsealed) south of Cowell for 15 km then turn east and travel along this unsealed road to the park.
	— [4]								—							60 km west of Cowell, 15 km north-east of Rudall. Please contact the Port Lincoln District Office for specific directions to this park.
									—							23 km east of Cleve, 15 km west of Cowell. Please contact the Port Lincoln District Office for directions.
									—	— [20]						The south-west corner of the park is 25 km north-east of Lock. Access from Darke Peak brings you to the north-east corner of the park. Please contact the Port Lincoln District Office for specific directions.
	— [4]								—				—			6 km north-east of Darke Peak. Take the unsealed road north-east from Darke Peak toward the Cowell-Kimba Road. This road runs along the southern boundary of the park.
	— [4]								—							35 km north of Cowell. Take the Cowell-Kimba Road (unsealed) for 35 km. The park boundary is on the western side of the road.
	— [4]								—							65 km north-west of Kimba. Travel west along the Eyre Highway (sealed) from Kimba for about 50 km to the Buckleboo signpost. Turn north onto the Koongawa-Buckleboo Road (unsealed) and travel for 15 km. This road goes through the north-western tip of the park.
									—							20 km north-east of Kyancutta. Take the Buckleboo Stock Route Road (unsealed) past Peella Rock to the park's southern boundary.

Table 1. (continued)

Park	Location Map (1:50 000)	Year of Dedication	Contact Ranger 14	Kiosk 13	Water 14	Toilets	Facilities for Handicapped	Picnic Areas 2,13	Barbecue Facilities 2,13	Bush Camping 1,2,13,14	Camping 1,2,13,14
42. Laura Bay Conservation Park	Mallee 5633-I, Wallonippie 5633-II	1973	1B							—	—
43. Wittelbee Conservation Park	Mallee 5633-I, Thevenard 5633-IV	1969	1B							—	—
Northern Myall Plains Environmental Region											
46. Munyaroo Conservation Park	McGregor 6331-II, Charleston 6331-III	1977	1C		25					—	—
47. Lake Gilles Conservation Park	Barna 6231-IV, Nilginee 6231-I, (Note: part of the area is out of hundreds).	1971	1C		9					—	—
48. Whyalla Conservation Park	Cultana 6432-III	1971	1C								—
Offshore Island Conservation Parks (involving numbers 1, 2, 5, 6, 7, 8, 11, 14, 15, 16, 17, 18, 19, 20, 23, 25, 26, 27, 40, 41, 44 & 45.)			27		17			28	28	28, 27	

NOTES:
Northern Regional Office
National Parks and Wildlife Service
9 Mackay Street
P.O. Box 483
Port Augusta, S.A. 5700
Telephone: (086) 42 3800.

1. Permits and fees are required for camping. They are available from:

A): Coffin Bay District Office, National Parks and Wildlife Service, Coffin Bay National Park. Postal: P.O. Coffin Bay 5607. Telephone: (086) 85 4047.

B): Far West District Office, National Parks and Wildlife Service, 15 Bay Road, Streaky Bay. Postal: P.O. Box 219, Streaky Bay 5680. Telephone: (086) 76 1098.

C): Port Augusta District Office, National Parks and Wildlife Service, 9 Mackay Street, Port Augusta. Postal: P.O. Box 483, Port Augusta 5700. Telephone: (086) 42 3800.

D): Port Lincoln District Office, National Parks and Wildlife Service, 90 Tasman Terrace, Port Lincoln. Postal: P.O. Box 866, Port Lincoln 5606. Telephone: (086) 82 3936.

2. Seasonal fire bans apply in all of the Eyre Peninsula districts. For specific dates of bans please contact the Northern Regional Office or the appropriate District Office. No wood fires are allowed within the parks during a seasonal fire ban period. Gas barbecues are allowed in some parks in cleared or designated areas except on days of Total Fire Ban.

3. Caravans can go into some areas of the park depending on the conditions of the road surface. Check with the appropriate District Office.

4. Caravans can go only to the park boundary.

Camping ground	Caravan Access	Caravan Park	Fees Payable	Walking Trails	Bushwalking Trails	Fishing	Swimming	Boating	Birdwatching	Viewpoint	Ranger Office	Pamphlet	Off-road parking	Horseriding	Accommodation	Access
1,2,13,14		1,2,13,14	1		15,14	7		8,12							1,2,13	
	3 —					—	—		—	—			—			15 km south-east of Ceduna. Take the Flinders Highway (sealed) south east from Ceduna for 15 km. Turn west at the Laura Bay intersection and travel for 2 km along the unsealed road to the park entrance.
	3 —					—	—		—				—			10 km south-east of Ceduna. Take the Decres Bay Road (unsealed) south-east from Ceduna for 10 km. The park boundary is on the southern side of the road.
						—	22 —		—							45 km south of Whyalla. For directions please contact the Port Augusta District Office as access is through private property.
	4 —								—							50 km south-west of Iron Knob. Eyre Highway (sealed) passes through the park.
									—	—						10 km north of Whyalla. The Lincoln Highway (sealed) runs along the park's eastern boundary.
				27, 18	27, 18	7	22	12, 8, 17								Contact the National Parks and Wildlife Service Northern Regional Office or the appropriate District Office (addresses in notes below) prior to visiting the park for specific directions.

5. Rainwater is available at the Coffin Bay District Office. Non-drinkable water is available at Yangie Bay, Coffin Bay National Park.

6. Boat ramp facilities are found at Coffin Bay township and at Point Avoid in Coffin Bay National Park where a beach ramp is available with access to 4WD vehicles only.

7. A Department of Fisheries booklet sets guidelines for recreation fishing. This includes licensing, registration of fishing gear and areas prohibited to recreational fishing. This is to protect fish breeding grounds and to ensure that fish stocks do not become depleted.

8. A pamphlet on safety, general rules of boating and the licensing for motor boat operators and recreational boating charts are available from the Department of Marine and Harbours. Information on tides is also available there. A booklet on boat ramps in South Australia is available from the Department of Environment and Planning.

9. Non-drinkable water supplies are sometimes available at two dams north of the Eyre Highway on the eastern boundary of the park.

10. Views over the eastern side of the park from Verran Hill on the Nicholls track. Please contact the Port Lincoln District Office for specific directions.

11. Boat launching facilities are available at Cowell, Elliston and Venus Bay.

12. The coastline has many exposed and submerged rocks and reefs. Care must be taken at all times when boating in these open seas as conditions may change rapidly.

13. For travel information, location of nearest town facilities, accommodation, caravan and camping parks, please enquire from your tourist agent or the South Australian Government Tourist Centre, 18 King William Street, Adelaide 5001. Telephone: (08) 212 1644.

14. A number of parks are in remote areas, requiring 4WD vehicles and the appropriate 1:50 000 scale topographic maps. Visitors must be prepared for emergencies and carry supplies of water, food and fuel to ensure a safe return journey.

15. Please contact the appropriate National Parks and Wildlife Service District Office for information on walking trails and bushwalking.
16. Private gas barbecues are allowed only in the camping area except on days of Total Fire Ban.
17.As island parks are very remote visitors must be prepared for emergencies and carry supplies of food, fuel and water to ensure a safe return journey.
18. Some islands support large populations of venomous snakes. Adequate protective footwear and leg coverings must be worn.
19. Please check with Coffin Bay District Office for information on horseriding in the park.
20.Views over the park can be gained from the Prominent Hill Track-foot access only. Please contact the Port Lincoln District Office for specific details as this area is very isolated.
21. There are no powered sites available.
22.Please take care when swimming in the open seas as conditions may change rapidly. Sharks also are common in tnese waters.
23. Boat ramp facilities are available at Port Lincoln and Taylors Landing in Lincoln National Park.
24.Cape Donington Cottage is available for school and community groups. Bookings must be made at the Port Lincoln District Office well before visiting.
25. Non-drinkable water is sometimes available in the dam along the northern boundary.
26. Camping with vehicle access can only occur in the old gravel pits along the Koongawa-Buckleboo roadside.
27.Please contact the National Parks and Wildlife Service Northern Regional Office or the appropriate District Office prior to visiting for information on access, bushwalking and bushcamping. Most islands are unsuitable for overnight visits. 28. Islands have little wood and plant material in which the fauna can make homes and forage. Please do not collect, remove or use it in fires of any form. Please contact the appropriate District Office regarding fire bans on the islands' parKs and the use ot gas appliances.

SOUTHERN HIGHLAND AND PLAINS ENVIRONMENTAL REGION

This region encompasses the southern uplands along the east coast of the tip of Eyre Peninsula and the undulating to low hilly plains to the west.

The many offshore islands are the high remnants of a much more extensive region which has been inundated by rising sea levels since the last glacial period.

1. Neptune Islands Conservation Park (442 ha) The park consists of all the islands in the North and South Neptunes with the exception of the southern-most island which is one of South Australia's last few manned Lighthouse Reserves. The Neptunes are rounded islands supporting an open heath land dominated by *Olea ria ramulosa* but with quite large areas of Coastal tussock grass *(Poa poiformis)* grassland. These grassland patches support 2-4 breeding pairs of Cape Barren Geese *(Cereopsis novaehollandiae)* annually in the winter months (Robinson *et al.* 1982) while the whole island supports dense populations of the Southern Bush Rat *(Rattus fuscipes).* The islands are mainly known for their large populations of New Zealand Fur Seals *(Arctocephalus forsten).* The fur seal population on the southern island of the North Neptunes is one of the largest in South Australia (Stirling 1971a, b).

All of the islands of Neptune Islands Conservation Park are extremely remote and landing by boat can be very dangerous. There have been a number of shipwrecks on these islands. An airstrip and helipad are maintained on the lighthouse island while heavy equipment is landed from the lighthouse servicing vessel at a jetty. Only the most skilled boat operators should consider visiting this island Conservation Park.

2. Gambier Islands Conservation Park (64 ha). The park comprises three islands and islets of the Gambier Group, North Island, SW. Rocks and Peaked Rocks. Wedge Island, the main island of the Gambier Group is held in freehold title and is run as a tourist resort. It is doubtful if anyone has landed on SW. or Peaked Rocks but North Island is relatively well known. It consists of an igneous basement covered with the sandstones and calcretes of the Bridgewater formation which have been eroded into steep coastal cliffs and an extensive dune system covering nearly half of the island. Almost half of this dune system supports no vegetation and is severely eroded. Finlayson (1951) speculates that this erosion has been caused by a fire deliberately lit in 1916 in the grassy sheoak woodland that covered this part of the island. Sand drift began almost immediately and by 1949 there was only one living sheoak present; today there is none. Goats were introduced by sealers in the 1820s and although there were about 20 in 1949 they now appear to be extinct. Rabbits were introduced for possible fur production in the 1950s and unfortunately there are still rabbits (grey furred Chinchilla variety) there. As a result of the introduction of these animals the remaining Coast

Daisy Bush *(Olearia axillaris)* tall shrubland has virtually no understorey except ephemeral herbs and a few grasses. Despite this extremely open habitat the island supports an extremely large population of Southern Bush Rats and these formed part of a recent genetic analysis of island populations of this species (Schmitt 1978; Schmitt & White 1979). North Island has a number of relatively sheltered landing sites for boats and is no doubt visited occasionally from Wedge Island.

3. Lincoln National Park (17 227 ha). The park includes most of the Jussieu Peninsula, to the south east of the city of Port Lincoln, together with the following offshore islands: Rabbit, Bickers, Owen, Little, Lewis, Hopkins, Smith, Albatross, Curta Rocks and Liguanea. The park is particularly significant in the history of South Australian exploration through its association with the voyage of Matthew Flinders in 1802. A memorial on Stamford Hill in the park commemorates Flinders' visit to the area while the Cape Catastrophe, Memory Cove area was the scene of the most tragic incident of Flinders' circumnavigation of Australia. On February 22, 1802, Flinders' ship *Investigator* was anchored off Cape Catastrophe and he sent eight of his crew in the ship's cutter to the shore to search for water. Although the cutter was siqhted returning it never reached the *Investigator* and later was recovered floating bottom upwards; no trace of the crew was found. The names given by Flinders to the islands in this area commemorate the names of his officers and crewmen drowned in this incident.

Although the area that is now Lincoln National Park was dedicated as a Flora and Fauna Reserve in 1941 surprisingly little is known of the biology of the area. Since the work of Robert Brown, the botanist on the *Investigator* there have been several general descriptions of the vegetation of southern Eyre Peninsula including the area of Lincoln National Park (Wood 1930; Crocker 1946; Smith 1963; Specht 1972). Two short visits to the park in 1963 resulted in a short published account of the area's biology (Reeves & Wilson 1964) and a plant list derived from this study was published by Specht (1963). The discovery of the Western Whipbird *(Psophodes nigrogularis)* in the park in 1966 produced a brief burst of interest (McNamara 1966) and a detailed study of sedimentation in Pillie Lake has been conducted (De Deckker *et al.* 1982). More detailed surveys were carried out by staff of the National Parks and Wildlife Service in March 1982 and January 1983 and these have been incorporated in a draft management plan currently in preparation for the park. This work resulted in the production of (1:50000) vegetation map in which 21 separate vegetation associations were recognised.

Beginning with the offshore islands and moving inland, the following brief description highlights some of the more interesting aspects of the park's biology. On wind-swept Albatross Island off the southern tip of Thistle Island there is a small breeding colony of Australian Sea Lions *(Neophoca cinerea).* This island only supports a low herbland of *Atriplex muelleri* but the other larger islands all have chenopodioid shublands with either Marsh saltbush *(Atriplex paludosa)* or Grey Saltbush *(Atriplex cinerea)* as the dominant plants. All support very large breeding populations of Short-tailed Shearwaters *(Puffinus tenuirostris)* but on Smith Island, the first South Australian breeding colony of the Flesh-footed Shearwater *(Puffinus carneipes)* was discovered in 1982 (Robinson *et al.* in prep). On Curta Rocks there are large breeding colonies of the delicate little White-faced Storm Petrel *(Pelagadroma marina)* while both the islands and the mainland coast support significant breeding populations of White-bellied Sea Eagles *(Haliaeetus leucogastery* and Ospreys *(Pandion haliaetus).* In areas with steep cliffs facing south and west a low open scrub of Cushion Bush *(Calocephalus brownil)* develops and this gradually merges into a low open scrub of Sea Box *(Alyxia buxifolia)* with Dryland Teatree *(Melaleuca lanceolata), Acrotriche patula,* velvet bush *(Lasiopetalum discolory* and a variety of other shrubs forming quite dense vegetation patches. These denser heaths are the home of Southern Bush Rats, Southern Emu Wrens *(Stipiturus malachurus),* Spotted Scrub Wrens *(Sericornis frontalis)* and Field Wrens *(Calamanthus fuliginosus).* The dune systems support a closed heath of Currant Bush *(Leucopogon parviflorus)* and this is the stronghold of the Western Whipbird, and species such as the White-browed Babbler *(Pomatostomus superciliosus)* and the Brush Bronzewing *(Phaps elegans).* The majority of the park is covered with mallee of two basic types, one nearer the coast dominated by the Coastal White Mallee *(Eucalyptus diversifolia)* with a diverse heathland understorey and further inland an association dominated by Yorrell *(Eucalyptus gracilis)* with deep leaf litter and a much more open understory. Port Lincoln Parrots *(Barnardius zonarius)* and Southern Scrub Robins *(Dyrmodes brunneopygia)* are common mallee birds while the Sand goanna *(Varanus rosenbergil)* and the Peninsula Brown Snake *(Pseudonaja textilis inframacula)* are frequently seen.

Lincoln National Park is a popular bush camping area with approximately 20 000 visitors annually. Although much of this visitor use is on a day trip basis from Port Lincoln, the presence of mallee right to the water's edge on the sheltered northern parts of the park facing Proper Bay means that the camping areas at Stamford Beach and Spalding Cove also are quite popular. Further details of the facilities provided in the park can be obtained from the park pamphlet (National Parks and Wildlife Service 1984).

4. Sleaford Mere Conservation Park (688 ha). The park consists of a shallow coastal brackish lake which contains some small islands. Leading away from the water's edge are unusual grey black mud-like mounds which vary in size from a few centimetres to one metre. These stromatolites only occur in this saline environment where they are formed by the accumulation of sand and silt on growing mats of algae. The Mere is bounded by steep sided sand dunes to the south and east, and by a gently undulating calcarenite landscape to the west. Immediately surrounding the lake is a closed sedgeland of *Gahnia triffida* with a variety of aquatic and swamp plants beneath. In some areas there is a closed scrub of Salt Water Teatree *(Melaleuca halmaturorum).* Very little is known of the fauna of the area. Southern Bush Rats are found in the dense sedgeland areas while Chestnut Teal *(Anas castanea)* are known to breed on the small islets. Perhaps the most interesting aspect of this park however is the presence in the lake of a land locked population of skates: fish normally found in shallow inlets and bays with a direct connection to the sea.

5. Rocky Island (south) Conservation Park (20 ha). A remote and isolated dome shaped granite island which has probably been visited only by helicopter (Robinson *et al.* in prep). It supports a small area of Grey Saltbush shrubland, but there are large areas of bare rocks. Among the tumbled boulders near the water's edge is a large breeding population of New Zealand Fur Seals while higher on the island among the saltbush is a small population of Australian Sea Lions.

6. Whidbey Isles Conservation Park (271 ha). A group of spectacular and virtually untouched islands including, from the Coffin Bay Peninsula, Golden, Price, Perforated, North and Central Four Hummocks Islands. The southern-most of the Four Hummocks is a lighthouse Reserve with a small automatic lighthouse on its lofty summit which is now serviced by helicopter but was formerly serviced from the sea in a hazardous operation using a flying fox up the steep sides of the island. The outermost islands are granite domes with little of their former Tertiary limestone capping remaining. They support a heath land vegetation in small soil pockets and Red Correa *(Correa reflexa)* and *Olea ria ramulosa* are among the characteristic plants. Small numbers of Cape Barren Geese breed on these islands while the pockets of deeper soil support small breeding populations of Short-tailed Shearwaters. The spectacular Perforated Island, named by Matthew Flinders for the large hole eroded through the middle of the island, has aeoleonite cliffs rising sheer from a water level platform of granite. On its flat top dense tussocks of Coastal Tussock Grass are entangled with a variety of other shrubs, and it is possible to walk over this vegetation mat without touching the ground. Beneath this vegetation is an extremely dense population of Southern Bush Rats and, during the summer breeding season, large numbers of Short-tailed Shearwaters. Price and Golden Islands also retain much of their limestone capping but lack sheer cliffs and so are fairly easily accessible from the sea in calm weather.

7. Greenly Island Conservation Park (190 ha). Perhaps one of the most scenically spectacular of South Australia's offshore islands. This enormous granite dome with steep sides plunging straight into deep water is split by two large crevasses which effectively break the island up into three blocks. The top of the island is capped with a Drooping Sheoak *(Allocasuarina verticillata)* and Dryland Teatree woodland while the lower slopes, where soil still clings to the rocky dome, have either a Coastal Tussock grassland or a Marsh Saltbush shrubland. A scientific expedition to Greenly Island in 1938 resulted in the naming of a number of the features and the description of a new species of lizard, *Egernia multiscutata,* abundant there and now known to be common on many offshore islands. An expedition in 1978 (Parker & Cox 1978; Fatchen 1982; Robinson 1980) produced additional information but, perhaps more interestingly, demonstrated the significant impact of the island wallaby population. Tammar Wallabies *(Macropus eugenil)* were introduced to Greenly Island (most probably from Kangaroo Island) in 1907 as a potential food source for shipwrecked mariners. Prior to this Greenly Island had been isolated for 10 500 years with its only herbivores being Bush Rat and Cape Barren Geese populations. The wallabies thrived on the main island and on the south west section but were unable to cross the narrow sea gap of the crevasse to reach the north east section. An examination of the vegetation on the ungrazed section of the island clearly

demonstrates that the wallabies have significantly simplified the island's vegetation both structurally and in terms of number of plant species (Fatchen 1982). The extensive Coastal tussock grasslands appear to be a product of wallaby grazing, and there is a strong case for an attempt at eradication of these animals from this otherwise very little disturbed piece of wild Australia.

8. Avoid Bay Island Conservation Park (16 ha). Only Black Rocks have been surveyed by the National Parks and Wildlife Service. Its limestone capping is steeply sloping and eroded into crevices and caves in many places. The chenopioid shrubland, which grows on the area of shallow soil, is riddled with thousands of seabird burrows, the larger ones belonging to Little Penguins and probably Short-tailed Shearwaters, but the majority appeared to have been made by White-faced Storm Petrels. A pair of White-bellied Sea Eagles nest regularly on one of the stacks; Rock Parrots *(Neophema petrophila)* are also very common and probably breed here.

9. Coffin Bay National Park (30 000 ha). Although the area was purchased in 1975 it was not dedicated until 1982. Biological investigation of the park took place in the 1970s with members of the South Australian Ornithological Association, the Mammal Club of the Field Naturalists Society of South Australia, several herpetologists and National Parks and Wildlife Service Rangers collecting information on the fauna of the area while the wilderness value of the park was assessed by Lesslie & Taylor (1983). In 1983 detailed investigation of the vegetation was undertaken by students of the South Australian College of Advanced Education (Salisbury). Windswept bare sand ridges and lower scrub-covered dunes dominate the landscape of the park while older calcrete ridges and low lying rocky pavements and swampy areas are more characteristic of the Point Whidbey to Point Sir Isaac area. The southern coastline has striking sandstone cliffs, sandy beaches and excellent views of the nearby offshore islands, while the northern coastline has tranquil bays and the swamps of Port Douglas. This range of environments support 148 species of birds, 26 species of reptiles and two or three species of terrestrial mammals although at least eight more species are known to have inhabited the area at the time of European settlement.

Over 40% of Coffin Bay National Park is covered with a sand dune heath dominated by Currant Bush and Coast Daisy Bush. It supports a similar fauna to that described for Lincoln National Park. Cliffs and beaches are another of the park's characteristic habitats. Cliffs generally support a low wind-pruned shrubland of species such as the Cushion Bush, *Frankenia pauciflora, Samolus repens* and *Eutaxia microphylla.* Rock Parrots are abundant in this habitat, while on inaccessible stacks and cliff ledges the large nests of White-bellied Sea Eagles and Ospreys are found. The sandy beaches of the park are favoured breeding sites for the Red-capped Plover *(Charadrius ruficapillus),* the Pied Oystercatcher *(Haematopus longirostris)* and the Hooded Plover *(Charadrius rubricollis).*

Until earlier this century large parts of the undulating calcrete plateau at the western end of Coffin Bay Peninsula supported an extensive low woodland of Drooping Sheoaks. This habitat is now seriously disturbed and, in some areas completely destroyed from the combined impact of horse, cattle, rabbit and, perhaps, kangaroo grazing. A relic of the original vegetation type can be seen on a small island in Vangie Bay. Up until the late 1960s there was a population of Glossy Black Cockatoos *(Calyptorhynchus magnificus)* on Coffin Bay Peninsula, a species which seems to have a very close relationship with the Drooping Sheoak. This species is no longer present.

Swamps are the other major habitat on Coffin Bay National Park and areas such as Lake Damascus are surrounded by Saltwater Teatree with a Thatching Grass *(Gahnia filum)* tussock sedgeland in areas where water remains in the summer. In areas regularly inundated by the sea samphire *(Sarcocornia blackiana)* swamps are found. These areas attract large numbers of migratory waders in spring and summer from their breeding areas in the northern hemisphere. In spite of the degradation of some areas of Coffin Bay National Park it is regarded as one of the few areas of substantial wilderness quality remaining in the settled more temperate areas of South Australia (Lesslie & Taylor 1983). This wilderness is accessible from a number of vehicle tracks within the park such as those to Vangie Bay and Point Avoid. Bush camping and walking are the major and most appropriate uses in this park and it is hoped that with wise management many of the areas will begin to recover from the severe overgrazing of the last 100 years.

10. Kellidie Bay Conservation Park (1780 ha). Similar in many ways to Coffin Bay National Park it contains a much larger area of undulating calcrete which supports a low woodland of Dryland Teatree with a heath understorey. It also contains larger areas of mallee open scrub with the main species being Coastal White Mallee with some Kingscote Mallee *(Eucalyptus rugosa).* The major habitat in which Kellidie Bay differs from

Coffin Bay is the large swamps developed along Merintha Creek in the northern quarter of the park. A rare composite *Pleuropappus phyllocalymmeus* occurs here while the dense thickets of *Melaleuca neglecta* which line much of the swamp's margin is an increasingly rare vegetation type on Eyre Peninsula. The fresher of these swamp types attract several uncommon birds such as the Wood Sandpiper *(Tringa glareola)* Latham's Snipe *(Galinago hardwickii)* and the Buff-banded Rail *(Rallus phipippensis).* The Marsh Harrier *(Circus aeruginosus)* is also a common sight over these swampy areas. There are a number of tracks through the park and bushwalking, bushcamping and horse riding are popular activities.

11. Mt Dutton Bay Islands Conservation Park (20 ha). Seven small islands are included in this park of which only the Brothers, Rabbit and Goat Islands have official names. All consist of outcrops of limestone weathered into jagged shapes around the coastal margins. All originally would have supported a low shrubland of Nitre Bush *(Nitraria billardien)* but they have now been invaded by a wide variety of introduced plants, the most obvious of which is African Boxthorn *(Lycium ferocissimum).* In spite of the degree of disturbance they are still of biological significance. Eastern Reef Egrets *(Ardea sacra)* breed on Goat Island (Gill 1980) while Buff banded Rails breed on Rabbit Island. The largest of the Brothers is a major breeding site for Crested Terns *(Sterna bergii),* Caspian Terns *(Hydroprogne caspia)* and Rock Parrots. Of some interest was the presence through the 1970s of a single Sooty Tern *(Sterna fuscata)* in this breeding colony (Gill 1973). This species normally breeds only on islands off the Western Australian, Northern Territory and Queensland coasts. Early this century, as part of a guano mining operation some fossil bones were collected from a limestone sinkhole on this island. Six species were identified including an extinct kangaroo, a giant flightless bird and a fur seal skull fragment, one of the very few seal fossils found in Australia. All these islands are easily accessible by boat in calm weather and visitors should take care not to disturb the breeding seabirds.

12. Wanilla Conservation Park (278 ha). This park situated in hilly terrain conserves a large remnant stand of the Sugar Gum *(Eucalyptus cladocalyx)* low open forest which was formerly quite widespread on southern Eyre Peninsula. Sugar Gums are an endemic South Australian species occurring elsewhere on Kangaroo Island and the southern Flinders Ranges. They were widely cultivated around the turn of the century for planting as windbreaks on farms throughout the agricultural areas of South Australia and these neat rows of sugar gums are a characteristic feature of much of the agricultural landscape of South Australia.

13. Murrunatta Conservation Park (99 ha). This park dedicated in 1984 is on a west-facing slope with lateritic soil supporting an open scrub of Coastal White Mallee and Ridge-fruited Mallee *(Eucalyptus incrassata).* It has a varied understorey with, in some places yackas *(Xanthorhoea tateana)* on stems up to 2 m tall and, in other areas, patches of Porcupine Grass *(Triodia irritans)* and groves of the spectacular red bottle-brush *Callistemon macropunctatus.*

14. Sir Joseph Banks Group Conservation Park (777 ha). All the islands of the Sir Joseph Banks Group, with the exception of Spilsby Island, fall within the park and this readily accessible archipelago of low islands (Nixon 1967) covered with Marsh saltbush shrubland provide yachtsmen and power boat owners with a wide variety of sheltered anchorages. Reevesby Island, the largest within the park was the centre of agricultural pursuits carried out in the Sir Joseph Banks Group prior to their acquisition as Conservation Parks.

The farm buildings remain on Reevesby island and there are many other legacies of this long period of sheep grazing and cropping there and on the other outlying islands which were also used for winter sheep grazing. The natural beauty of these islands is one of their attractions but their associated wildlife is also of great interest. The park was originally acquired to protect the Cape Barren Goose which breeds in winter on many of the islands of the group; this is the most important breeding area in South Australia (Robinson *et al.* 1982). From about November White-faced Storm Petrels arrive to breed in their burrows on many of the islands but, as they spend the day feeding at sea and only return to their nests after dark, a torchlight ramble is needed to catch a glimpse of them. There are Australian Sea Lion colonies on English and Langton Islands, large breeding colonies of Black faced Shags *(Leucocarbo fuscescens)* on Winceby and English Islands and Black Tiger Snakes *(Notechis ater)* on Hareby, Roxby and Reevesby Islands. In short the Sir Joseph Banks Group is a naturalist's paradise and, with proper respect from visitors, it will remain so for many years to come.

15. Tumby Island Conservation Park (30 ha). Tumby Island is close to the shore in Tumby Bay. The central section of the island supports an open scrub of Ridge-fruited Mallee with an open

understory of Mallee Broombush *(Melaleuca uncinata).* A sand dune system supports a typical shrubland of Coast Daisy Bush, while round the more exposed edges of the island is a low shrubland of Marsh saltbush. This vegetation type was heavily infested with both boxthorn and rabbits but intensive control programmes in recent years have brought both of these pests under control.

16. Lipson Island Conservation Park (1 ha). This 'island' can be reached from the mainland at low tide but it is still sufficiently isolated to support a large breeding colony of Crested Terns: probably one of the most easily accessible in South Australia. Take care when visiting this colony as the resident Silver Gulls are ever ready to steal a tern egg or chick left unguarded as a result of human disturbance of their rookery.

WEST COAST ENVIRONMENTAL REGION

This region consists predominantly of undulating to hilly calcarenite plains with occasional steep sided hills of quartzite. Inselbergs, salt lakes and bare coastal dunes are prominent local features, while along much of the coastline there are low cliffs. Much of this region has been cleared for agriculture.

17. Rocky Island (north) Conservation Park (16 ha). This is a small rocky islet which has no vegetation and in rough weather would at times be completely covered by waves. It supports variable numbers of Australian Sea Lions but they only appear to use it as a hauling out and basking site and do not breed there.

18. Cap Island Conservation Park (8 ha). A small island which still retains a portion of its calcrete capping on the underlying igneous rock base. Only salt resistant vegetation such as the samphire *Halosarcia halocnemoides* finds a foothold here, and its fauna is typically oceanic with a small breeding colony of White-faced Storm Petrels and a resident pair of Sooty Oystercatchers. Of special interest was the collection in 1980 of the body of the White-fronted Tern *(Sterna striata)* representing the westernmost record for this species in South Australia.

19. Investigator Group Conservation Park (117 ha). This park excludes the two largest islands in the Investigator Group, Flinders and Pearson Islands. Flinders Island is held as a pastoral lease while Pearson Island is a Lighthouse Reserve managed by the Commonwealth Government. The islands of the Investigator Group scenically are some of the most spectacular of all South Australia's offshore islands, and also perhaps the best known biologically. Most of this work however has been carried out on Pearson Island. Research dates back to an expedition in 1923 and, as the Island has never been grazed or farmed, it is probably the most scientifically important of the State's offshore islands. Most visitors to the Investigator Group camp on Pearson Island which has two safe anchorages. It is possible also to land with care on Dorothee Island. The other islands in the park, the Veterans, Ward and Topgallant are of dubious access from the sea, and have only been visited by helicopter. For a more detailed account of these islands together with a bibliography of all previously published work, see Robinson *et al.* (in prep).

20. Waldegrave Islands Conservation Park (324 ha). Waldegrave Island was farmed and grazed until its dedication as a Conservation Park in 1967. There remains extensive areas of cleared land which support a pasture of introduced grasses and some quite large infestations of African Boxthorn. However a large proportion of the island is covered with native vegetation little modified by past grazing. This, together with the spectacular coastline of cliffs and sandy beaches, makes Waldegrave Island an attractive place to visit. It is quite easily accessible by boat from Elliston and landings can be made on a number of sheltered beaches. During the winter months the island supports at least 20 breeding pairs of Cape Barren Geese and large numbers of nonbreeding flock birds, making it (after the islands of the Sir Joseph Banks Group) the second most important breeding area for this species in South Australia. Banding studies (Robinson *et al. 1982)* have shown that Cape Barren Geese breeding on Waldegrave Island stay in the Elliston area for the summer, feeding in swamps around the margins of Lake Newland and on grain in wheat paddocks. They roost on the beach or fly back to the island for the night. It is therefore important for the overall conservation of this species in South Australia that the apparently separate population on the west coast of Eyre Peninsula, whose main breeding area is Waldegrave Island, be disturbed as little as possible.

21. Venus Bay Conservation Park (1460 ha). The park consists of the Venus Bay Peninsula (Cape Weyland), Germein Island and five other small islands in Venus Bay (Garden, Tank, A, B and C). The mainland section of the park supports an open mallee scrub of Kingscote Mallee and/or Yorrell over a shrub layer of Candle Bush *(Geijera linearifolia)* and Dryland Teatree. The spectacular cliffs on the ocean side of the park support a variety of low open shrubland formations depending on the degree of exposure, while along

the sheltered Venus Bay coast there are areas of samphire swamps and Mangrove woodlands together with sandy beaches. Access to the peninsula is by a single narrow track which can be rough in places and care should be taken. A wide range of very attractive bush campsites can be found in this park. Germein Island is a large Mangrove and samphire swamp built by the tidal currents in Venus Bay and it also has an area of tall densely vegetated sand dunes. It is surrounded by shallows and sandbars but is easily accessible by boat at high tide. The winding tidal channels through the mangroves and the still pools in the samphire swamps are fascinating places to explore. The other islands in the bay are all small limestone outcrops with a thin soil covering, and they originally supported a low shrubland of Sand Wattle *(Acacia ligulata)* or Marsh Saltbush. Several of them have been quite heavily grazed in the past by sheep and rabbits but are gradually recovering. Small populations of Pelicans *(Pelicanus conspicillatus)* breed regularly, while one island has been used as a sort of 'halfway house' in the National Parks and Wildlife Service project to reintroduce captive bred Brush-tailed Bettongs *Bettongia penicillata* to St Francis .Island.

22. Point Labatt Conservation Park (31 ha). This small coastal park features rugged limestone cliffs above granite slabs which extend out to sea protecting a small sandy beach.

It conserves the only mainland breeding colony of the Australian Sea Lion in South Australia. The Park is well signposted, accessible along dirt roads from Streaky Bay and one of the important tourist attractions in this area. The Sea Lions can be viewed from a fenced platform on the cliff and an explanatory sign gives information on aspects of sea lion biology. Regular counts of the sea lions at Pt Labatt have been made since 1966 (Robinson *et al.* in prep). During that period numbers have fluctuated between 15 and 60.

23. Baird Bay Islands Conservation Park (24 ha). Jones Island at the mouth of Baird Bay and another unnamed island at the head of the bay comprise this park. Both islands are well vegetated with a Sand Wattle shrubland, but Jones Island on its seaward slopes has a small colony of Australian Sea Lions who occupy an area of Round-leaved Pigface *(Disphyma crassifolium)* and Ice Plant *(Mesembryanthemum crystallinum)* herbland. Pelicans breed in a grassy area in the centre of Jones Island.

Both islands are readily accessible from the nearby mainland and can be landed upon without difficulty.

24. Calpatanna Waterhole Conservation Park (3603 ha). The eastern part of the park is characterised by gently rolling low calcarenite ridges and occasional old fixed dunes. Small swamps fill many of the depressions but there are no well defined surface drainage channels or water courses. This part of the park supports an open scrub of White Mallee *(Eucalyptus dumosa)* Yorrell and Yalata Mallee *(E. yalatensis)* over Dryland Teatree with some patches of Grey Cypress Pine *(Callitris canescens)*. The western part of the park consists of a series of irregularly shaped lakes occupying depressed areas at about sea level which are seasonally filled by groundwater but are usually dry through summer. On the east and north easterly margins of these lakes loose sediment from the surface has blown into low banks and, in some places dunes up to 4 metres high. The lakes are surrounded by a low open woodland of Saltwater Teatree and this gradually merges into a mixed vegetation with species such as joined native cherry *(Exocarpus aphyllus)*, Porcupine Grass and scattered trees of Drooping Sheoak. More than 40 species of birds have been recorded from the park and Western Grey Kangaroos are often encountered.

25. Olive Island Conservation Park (12 ha). A small flat-topped islet and a cluster of reefs off Cape Bauer make up this park. Only the main islet still has a remnant of a calcarenite capping, while the surrounding reefs consist simply of the resistant granite basement. A small sandy beach on the islet provides a relatively easy boat landing site. The island supports a low shrubland of Marsh Saltbush with scattered plants of Nitre Bush and is home to a breeding colony of more than 150 Australian Sea Lions.

26. Pigface Island Conservation Park (6 ha). A rocky remnant of limestone lying close to the shore of the southern curve of Streaky Bay it has a patchy low shrubland vegetation with a number of introduced Rock Doves *(Columba livia)* roosting in its broken limestone edges. The remains of a cormorant breeding colony were found on the seaward face of the island, the species using this area is possibly the Little Black Cormorant *(Phalacrocorax sulcirostris)* as they were seen roosting round the island coast.

27. Eba Island Conservation Park (121 ha). This island was farmed prior to its dedication as a reserve in 1966 and the ruins of the old farmhouse and a variety of agricultural implements remain. Some paddocks that were cleared and cultivated are now being invaded by the native vegetation but the majority of the island is a sand dune field and quite densely vegetated. Eba Island is connected to the mainland by a sandbar which

virtually dries at low tide; this has allowed foxes to move onto the island. It is easily accessible by boat and landings can be made on the beach facing the mainland.

28. Caratoola Recreation Park (55 ha). This park is a small remnant of the extensive Summer Red Mallee *(Eucalyptus socialis)* open scrub which occurred formerly in' the Streaky Bay District. Although degraded though grazing, there is virtually no other natural vegetation remaining in the surrounding district with the exception of the road reserve on either side of the Flinders Highway. The park is fenced and is available for walking, it is not accessible for vehicles. In spite of its relatively disturbed nature, 28 species of birds have been recorded.

CENTRAL MALLEE PLAINS AND DUNES ENVIRONMENTAL REGION

This is the largest Environmental Region on Eyre Peninsula and extends across the peninsula from its western extremity to Spencer Gulf. It consists of an undulating plain with an extensive cover of dunes and sand sheets and supported a variety of mallee formations until much of the area was cleared for agriculture. In the east there is a region of hilly uplands on meta sediments, while isolated quartzite ranges and granite outcrops form prominent and biologically significant inselbergs throughout the region,

29. Hincks Conservation Park (66 285 ha). The majority of the park consists of a system of sand dunes and in the northern two-thirds of the park they are generally parallel, aligned north-west south-east. South west of a fairly sharp dividing line is another sand system of irregular dunes derived from a great area of alkaline calcareous sands stretching from the shores of the Great Australian Bight. The Blue Range on the eastern boundary of the park rises to some 250 m while Verran Hill at 172 m is the only other elevated point in the park.

The northern parallel dunes are covered with a mallee-broombush open scrub with Ridgefruited Mallee and Slender-leafed Red Mallee *(Eucalyptus foecunda)* being the major Mallee species with Mallee Broombush *(Melaleuca uncinata),* Green Teatree *(Leptospermum coriaceum)*, Dwarf Oak *(Allocasuarina muellerina)* and Fringed Myrtle *(Calythrix tetragonal* being common understorey species. The irregular dunes again support Ridge-fruited Mallee open scrub but other mallee species include Summer Red Mallee, Murraylands Mallee *(Eucalyptus cyanophylla)* and Coastal White Mallee while there is much less Mallee Broombush in the understorey, The creeklines of the Blue Range support dense thickets of *Bursaria spinosa* and the showy blue hibiscus *Alyogyne huegelii.* A survey of the park in 1968 by the Nature Conservation Society (Preiss & Thomas 1970a, b) recorded 60 species of birds, 29 species of reptiles and six species of native mammals. One of the interesting records was the discovery of a population of Southern Bush Rats in the dense vegetation of the Blue Range. This is the most north-westerly population of the species on the South Australian mainland.

Hincks Conservation Park has been subjected in recent years to a series of wildfires and the park gives a vivid impression of overlapping fire scars and a variety of vegetation at different stages of recovery. The single access track across the park is narrow and sandy and suitable only for four wheel drive vehicles, but the vast majority of the park provides an important area of trackless wilderness: a reminder of what much of central Eyre Peninsula was like before European settlement.

30. Verran Tanks Conservation Park (118 ha). The park includes a hill 180 m high supporting a Mallee Broombush shrubland with scattered emergent mallee trees, Geologically it is similar to the Blue Range in nearby Hincks Conservation Park. On top of the hill there are outcropping sheets of Blue Range granite with Drooping Sheoaks and a ground cover of Pigface *(Carpobrotus rossil),* On the lower edge of these granite sheets is a stone wall built round the contour to lead water runoff into a stone lined drain, and then into a large roofed underground tank. There is a track leading to the old tank site.

31. Bascombe Well Conservation Park (32 200 ha). The landscape is characterised by low, gently sloping ridges and intervening depressions. The kunkar pavement is normally exposed and the surface strewn with numerous limestone boulders; this makes travel on the few tracks in the park a slow and sometimes painful business. Most of the park supports a mallee-broombush open scrub or tall shrubland of Coastal White Mallee and occasionally Summer Red Mallee amd White Mallee *(Eucalyptus dumosa)* with Mallee Broombush and a variety of understorey shrubs throughout the area, In the north-western corner particularly, are regular depressions generally oval in shape 3-5 km long, These obviously have accumulated more soil than the surrounding stony ridges and support groves of Black Cypress Pine *(Callitris preissil)* and some Drooping Sheoaks. In the most favoured areas there are magnificent stands of

River Red Gums *(Eucalyptus camadulensis)* over an understorey of grasses and ephemerals.

This rough country was held under a series of grazing leases from 1856 and there are a number of houses and stockyard ruins with good examples of dry limestone walls and native pine post and rail fences in some of the park's 'glades'. It is a good area for bird watching with 72 species recorded (Preiss 1969). Twenty-three species of reptiles and two species of native mammal have been recorded there and, with care on the rough tracks, some pleasant bush camping sites in the wooded glades can be reached but they are only for the more intrepid and self-sufficient camper.

32. Franklin Harbor Conservation Park (1334 ha). A long narrow sandy peninsula, protecting the mouth of Franklin Harbor, and four inner bay islands make up this park. The islands and the sheltered waters on the harbor side of the Peninsula have a low woodland of Mangroves *(Avicennia marina)* and a tidal saltmarsh. This area is accessible by vehicles along the edge of the saltmarsh for a distance around the peninsula. White-faced Herons and large flocks of Grey Teal feed in the tidal shallows. The dunes of the narrow peninsula support a low open woodland of Black Cypress Pine with occasional trees of Dryland Teatree and shrubs such as Sand Wattle and Candle bush.

A pleasant sandy beach facing into Spencer Gulf runs the length of the Peninsula. The park is accessible with care along the track around the saltmarsh for several kilometres but care should be taken in following it too far towards the harbor entrance where it becomes rather boggy. The best way to explore the entrance islands and their associated mangrove channels is by boat from Cowell. There is a report of a small population of Euros *(Macropus robustus)* which became isolated in this park as the country inland towards the hills was cleared. This requires confirmation.

33. Rudall Conservation Park (348 ha). This remnant of natural vegetation lies on a gentle footslope with sandy soils in the east and loamy soils to the west. A small former Railway Reservoir is in the the west of the park. This former Railway Reserve was extensively cut over for timber but the few remaining trees in this area are very large specimens of Red Mallee *(Eucalyptus oleosa).* The cleared areas support a number of introduced grasses and herbs but the vegetation is mostly a dense tall shrubland of Mallee Broombush with a variety of emergent eucalypts including White Mallee, Summer Red Mallee, Ridge-fruited Mallee and Slender-leafed Red Mallee with some patches of the Grey Cypress Pine. Little is known of the flora and fauna of this park.

34. Middlecamp Hills Conservation Park (857 ha). An area of rugged low stony hills which supports a variety of vegetation types including a Drooping Sheoak low woodland, a Peppermint Box *(Eucalyptus odorata)* and Mallee Box open scrub with a heath understorey, a tall open shrubland of Wallowa *(Acacia calamifolia)* and a Mallee Broombush low shrubland with areas of Porcupine Grass. The park contains trees of the distinct Eyre Peninsula form of Blue Gum *(E. leucoxylon petiolaris)* and there is a possibility that it may support a population of Tammar Wallabies. No systematic biological survey has been carried out.

35. Hambidge Conservation Park (37 992 ha). This large park consists of a low sand dune system forming roughly parallel ridges running north-west south-east. Unlike Hincks Conservation Park to the south, however, Hambidge has some extensive areas of red loamy soils and was the subject of a long and somewhat bitter conservation battle between 1952 and 1962 when a large area in the south-west corner was resumed and ultimately cleared for agriculture (Harris 1974). As part of the conservation movement's response to this pressure a biological survey of the park was carried out in 1966 (Bonython & Preiss 1967). The park was part of a study by McLaren (1979) which examined the role of habitat islands in the conservation of birds where its large area of continuous natural vegetation was used as the baseline 'mainland' area against which the bird faunas of a variety of different sized patches of natural vegetation remaining in the surrounding agricultural land were compared.

Hambidge Conservation Park, like the four other large parks on central Eyre Peninsula, is becoming more critically important for the conservation of the large suite of plants and animals with specialised habitat requirements within the vegetation formations conserved. A single example, the plight of the large Desert Sminthopsis *(Sminthopsis psammophila)* vividly illustrates the dilemma. This species was described in 1894 from a sinple specimen captured by members of the Horn Scientific Expedition between Kurtitina Well and Ayers Rock in the Northern Territory. It was not seen or collected again until 1969 when a single specimen caught escaping from a burning Porcupine Grass tussock was brought into the South Australian Museum from a block being cleared for agriculture 80 km northeast of Hambidge Conservation Park (Aitken 1971). An additional six specimens were found in subsequent clearing operations within 100 m of the park boundary and at the time it was suggested that there were large areas of similar habitat within the park. Further surveys of the park in 1979 and 1984 failed to find any trace of this enigmatic animal.

36. Carappee Hill Conservation Park (782 ha). Rising to 485 m Carappee Hill is the highest and most extensive granite inselberg on Eyre Peninsula (Davies 1975). In general it is dome shaped but is dissected deeply by valleys, particularly on its eastern side. This bulk of rock in the path of the prevailing winds has created some interesting jumbled patterns of sand dune fields on the lee side of the rock mass. The vegetation of the surrounding plains and dunes was originally mallee open scrub but most of this has now been cleared and only a small remnant remains which includes a clump of the Eyre Peninsula Bluegum within the park boundaries. On the rock itself there is a complex vegetation mosaic depending on aspect and soil depth with *Melaleuca raphiophylla* low open forest with patches of Mallee Box and an understorey of plants such as Baeckea Broombush *(Baeckea behril)*, *Grevillea aspera* and Sticky Hopbush *(Dodonaea viscosa).* In other areas Baeckea Broombush form virtual single species low shrublands. Over 200 species of plants have been recorded including species such as *Stypandra glauca* and *Grevillea aspera* which appear to be confined to areas of granite outcropping in South Australia.

A biological survey of the park was carried out in 1974 (NCSSA 1974). A population of Euros occurs on the park quite possibly now isolated from the other areas of suitable habitat on Darke Range and Caralue Bluff by the extensive clearance of the natural vegetation on the sand plains between these rock outcrops. In 1964 a single animal thought to be a Yellow-footed Rock Wallaby *(Petrogale xanthopus)* was sighted on Carappee Hill (Jericho 1969). The hill has been searched for rock wallabies on a number of occasions subsequently and no trace has been found. They are now assumed to be extinct in the area (Copley 1983). Carappee Hill is a fascinating place for bushwalking and bush camping and the extensive view from the top over the surrounding country is well worth the reasonably difficult climb through the dense vegetation on its lower slopes.

37. Sheoak Hill Conservation Park (759 ha). The park is an area of relatively undisturbed vegetation dominated by a north-south trending quartzite ridge which culminates in the 355 m high Sheoak Hill. A main road passes along the eastern boundary of the park but access within the park is on foot only. The ridges and valleys of the park support a dense mallee tall shrubland over Mallee Broombush and a variety of understorey shrubs, while there are some areas of pure Mallee Broombush open heath. The understorey shrubs provide a brilliant wildflower display in spring, the best time to walk in this park.

38. Pinkawillinie Conservation Park (17 718 ha). The Buckleboo-Koongawa road runs through the park but apart from this it is a trackless wilderness area with an even larger area of presently vacant Crown Land extending to the north west of the existing park boundary. It consists of a jumbled mass of sand dunes with some of the larger ridges running in a northwest to southeast direction. On the dune crests Slender leaved Mallee and Ridge fruited Mallee occur as a tall shrubland with Green Teatree, Grey Cypress Pine and the spectacular Grass-leaved Hakea *(Hakea francisiana)* among the associated plants. In the interdunes a tall shrubland of Yorrell and White Mallee are found over a shrub understorey of Nealie *(Acacia rignens)* and Porcupine Grass. The adjoining Crown Land area was the subject of a biological survey by the Nature Conservation Society in 1981; the results have not been published.

39. Corrobinnie Hill Conservation Park (211 ha). A former Water Reserve the park includes a granite inselberg recorded as a Geological Monument of South Australia, and an area of the surrounding vegetated parallel dune systems. The rock itself supports large stands of *Melaleuca raphiophylla* and Barren Range Wattle *(Acacia becklen)* which are confined to the shallow granite soils of these Eyre Peninsula inselbergs. At the base of the rock is a narrow band of Mallee Box open scrub which grades into a mallee community dominated by Yorrell, Red Mallee and Gilja *(Eucalyptus brachycalyx)* with an understorey of Mallee Broombush as the sand dune systems become the dominating environmental influence. Corrobinnie Hill has long been a popular picnic spot for local people but prospective visitors should note that access along the Buckleboo Stock Route Road can only be accomplished safely in a four-wheel drive vehicle.

40. Isles of St Francis Conservation Park (1320 ha). The park comprises St Francis, Dog, Smooth, Egg, West, Masillon, Fenelon and Hart Islands. As with most of the major offshore island groups pastoral leases were held since the late 1800s and the main island of St Francis has been altered significantly by nearly a century of farming and sheep grazing before its acquisition for

conservation in 1967. It is recovering gradually and the farmhouse and sheep yard ruins are being overtaken by saltbush and, unfortunately, the Boxthorn introduced as a hedge plant on the remote island where transport of posts and wires for fencing from the mainland was an expensive undertaking. The island is still home to an enormous breeding population of Short-tailed Shearwaters, a population of Island Bandicoots *(Isoodon obesulus)* and a variety of interesting reptiles. An animal that didn't survive the agricultural exploitation of St Francis Island was the Brush-tailed Bettong which, according to Wood Jones (1923-25), swarmed on the island when it was first occupied. The bettongs apparently had a taste for the garden produce and cats were introduced to exterminate them. Although Wood Jones did not know which species of bettongs occupied St Francis Island, bones collected in 1971 from a sandhill blowout allowed them to be identified as *Bettongia penicillata* (Robinson & Smyth 1976). The National Parks and Wildlife Service is currently engaged in the early stages of a project to reintroduce Brush-tailed Bettongs with releases in 1980 and 1984 of animals from a breeding programme, beginning with animals collected from the southwest of Western Australia.

The other islands of the St Francis Group are much less disturbed than the main island and are biologically interesting in their own right (Robinson *et al.* in prep). Visitors intending to land on these remote islands should be experienced in boat handling. A safe anchorage can be found in Petrel Bay on St Francis Island and landing is relatively easy on the sandy beach. Landings on the other islands should only be attempted in calm weather.

41. Nuyts Archipelago Conservation Park (1981 ha). This park includes all remaining offshore islands between Rocky Point and Point Brown, with the exception of St Peters Island which is held under a Pastoral Lease, and Evans island which is a lighthouse Reserve managed by the Commonwealth Government. They include a wide variety of limestone capped islands on massive granite bases, generally supporting a low shrubland of Marsh Saltbush. Most of the islands have large Short-tailed Shearwater breeding colonies in the summer months and Purdie, Lounds and the islets off Franklin Island support breeding colonies of Australian Sea Lions. Goat and Franklin islands have dense populations of very large Black Tiger Snakes but the most significant thing about this island group is the presence on the Franklin Islands of the last known population of Greater Stick-nest Rats *(Leporillus conditor).* These animals were distributed widely on the Australian mainland at the time of European settlement but were last definitely recorded on the northeastern part of the Nullarbor Plain in the 1930s. Wood Jones discovered the Franklin Island population in 1920 and it, together with the island's tiger snakes, are now the subject of detailed ecological studies being conducted by the National Parks and Wildlife Service and the South Australian Museum.

Because of its importance to conservation Franklin Island has been proclaimed a Prohibited Area; permission to visit is required from the Director, National Parks and Wildlife Service. Some of the other islands in Nuyts Archipelago such as Eyre Island are readily accessible by boat from the mainland, but most are wild and remote places best left to the seabirds and seals that make their homes here.

42. Laura Bay Conservation Park (251 ha). The undulating plain that makes up most of this park supports an open scrub of Yorrell and Red Mallee over an understorey of Bladder Saltbush *(Atriplex vesicaria).* Patches of Dryland Teatree with little other than moss and ephemeral plants are common and the whole area of the park provides a multitude of pleasant bush campsites. Fox Creek, a small tidal creek, lined with mangroves and saltmarsh, flows from the park into the sheltered waters of Laura Bay while there is an extensive sand dune system above small sandy coves on the ocean shore of the park. Several rocky headlands support a low wind-pruned heathland while the dunes, where vegetated, support a shrubland of Coast Daisy Bush and *Acacia anceps.*

In 1911 a landing site was established in Laura Bay to loading ketches with bagged grain hauled from the surrounding farms on horse drawn drays. An elaborate underground water tank was constructed in 1914 in what is now the park and it remains very largely intact beside the track leading to the beach. The National Parks and Wildlife Service has carried out some reclamation work on the areas of bare drifting sand using a series of brush fences; visitors to the park should keep their vehicles to the designated tracks to aid revegetation.

43. Wittelbee Conservation Park (148 ha). This small coastal park has a fine sandy beach, a low rocky headland and a series of dunes behind the beach grading into a small area of mall.ee open scrub and saltmarsh in a low-lying area. The rocky headland supports a heathland of Red Templetonia *(Templetonia retusa),* Dryland Teatree and Jointed Native Cherry while the mallee, swamps and dune systems support

vegetation types similar to those described for Laura Bay Conservation Park. There is good road access to the beach and bushcamping and bird watching are appropriate activities.

44. Sinclair Island Conservation Park (2 ha). A single granite dome arching above the surf in calm weather but completely covered by storm waves, Sinclair Island provides a resting place for Australian Sea Lions and Crested Terns. To our knowledge it has not been landed on. It was named on 31 January 1802 by Matthew Flinders after his midshipman) Kennet Sinclair.

45. Nuyts Reef Conservation Park (5 ha). Named by Flinders after Pieter Nuyts who in 1627 sailed along the shores of the Great Australian Bight as far as the island group now known as Nuyts Archipelago. Nuyts Reef consists of three main clusters of rocks which form a roughly triangular pattern. The westernmost group is dominated by a 13 m high islet. No-one is known to have landed on this islet. An aerial survey in 1977 counted 120 sea lions on this remotest part of South Australia.

NORTHERN MYALL PLAINS
ENVIRONMENTAL REGION

This region is geomorphologically similar to the Central Mallee Plains and Dunes Environmental Region, but has been separated from it because of a distinct change in vegetation from mallee to myall, and in land use from wheat growing to extensive pastoralism. It has undulating plains with calcrete development and reddish calcareous earths with local development of sand dunes, sand sheets and salt lakes. It also includes the extensive hog back ridges of the Middleback Ranges.

46. Munyaroo Conservation Park (12 385 ha). This park straddles the transition zone between the mallee open scrub dominated by Gilja, Red Mallee and Yorrell over a mixed understorey of *Olea ria muelleri,* and Dryland Teatree down a pronounced escarpment to the gently undulating plains in the northern part of the park which support a Myall *(Acacia papyrocarpa)* and Sandlewood *(Myoporum platycarpum)* low open woodland over a shrubland of Bluebush *(Maireana sedifolia)* and Bladder Saltbush. In the western part of the park on the ironstone ridges of the Moonabie Range is an area of Native Peach *(Santalum acuminatum)*, Grey Cypress Pine and Weeping Pittosporum *(Pittosporum phylliraeoides).* The park was dedicated in 1977 but very little is known of its biology. Scrub clearing contractors who have worked in the general area have reported 'rat kangaroos' so there is a chance that this large trackless area may still support a remnant South Australian population of Brush-tailed Bettongs. The park runs to the western shores of Spencer Gulf where there is a beach and coastal dune system backed by samphire flats and claypans. Access to the park is via a track running along the coast but the National Parks and Wildlife Service office in Port Augusta should be contacted for directions regarding access roads.

47. Lake Gilles Conservation Park (45114 ha). A large, semi-arid park incorporating several small salt lakes and bounded to the northwest by the more extensive Lake Gilles. Samphire swamps border the salt lakes while the associated gypsum dunes support an open woodland of Black Cypress Pine and Bullock Bush *(Heterodendron oleifolium).* Most of the park consists of gently undulating terrain supporting a Myall woodland over Bladder Saltbush and Stipa grasses, and this grades towards the south into an area of parallel sand dunes clothed in a 'whipstick' mallee open scrub of Red Mallee and Ridge-fruited Mallee, with patches of Mallee Broombush but very little other understorey. On the larger dune swales the calcareous loam supports an open scrub to open woodland of mallees such as Summer Red mallee, Gilja and Broad-leafed Box *(Eucalyptus behriana)* over a Bladder Saltbush understorey. The majority of the park south east of the lake however supports a tall open scrub of Yorrell and Gilja over an understorey of False Blue bush *(Cratystylis conocephala)* or Bluebush. In the southeastern area of the park an outcropping of ancient crystalline basement rock, the Cleve Metamorphics is found; it supports a shrubland of Mallee Broombush and various Hop bushes and *Eremophila* species with patches of Porcupine Grass. The only published survey of the park is that of Wood (1975) but in 1980 the rangers of the National Parks and Wildlife Service Northern Region conducted a biological survey recording four species of native mammals, 54 species of birds and 27 species of reptiles. The Eyre Highway runs through the centre of the park and tracks into the southern part of the park are accessible for conventional vehicles and provide access to a variety of pleasant bush camping sites. Access to the park north of the Highway is by four wheel drive only.

48. Whyalla Conservation Park (1011 ha). The park is roughly divisible into two regions; an easterly, relatively flat, low lying plain supporting a low Myall woodland over Bladder Saltbush and bluebush shrubland, and a western portion dissected by a series of low-lying hills rising to

100 m with isolated sandstone cliffs. The lower ridges support a shrubland of *Sida virgata* associated with shrubs such as *Rhagodia spinescens,* Ruby Saltbush *(Enchylaena tomentosa)* and *Plagianthus microphyllus.* On more exposed slopes a shrubland dominated by Hopbush *(Dodonaea lobulata)* is found, while the tops of the hills support a low shrubland of *Plagianthus microphyllus* and *Sida intricata.* Wild Dog Hill, a sandstone outcrop rising abruptly from the plain in the north west corner of the park, supports a number of characteristic cliff dwelling plants not found elsewhere in the park including *Isotoma petraea,* Daisybush *(Cassinia laevis)* and the Rock Fern *(Cheilanthes sp.).* Lewis (1974) has studied the park in relation to the impact of visitor use from Whyalla on the management of the area and her thesis contains a more detailed discussion of the geology, soils and vegetation. The park is popular for bushwalking and bush camping, and there is a picnic area accessible to conventional vehicles at the base of Wild Dog Hill. A walking trail leads to the top of the hill where good views of the surrounding plains can be obtained.

DISCUSSION

The National Parks and Wildlife Reserves on Eyre Peninsula contain a wide variety of scenically attractive and scientifically important natural areas. Some of the undisturbed offshore islands and the large mallee parks of the central peninsula are of national significance. Together they provide both tourists and local residents with a glimpse of a wide cross section of Eyre Peninsula more or less as it was before the arrival of Europeans.

In the chapter on National Parks in the South East of South Australia Robinson & Rowberry (1983) attempted an analysis of just how representative the present park system is. This analysis has been repeated for Eyre Peninsula.

Knowledge of the vegetation in the State conservation reserve system has increased substantially in recent years, particularly with the work of Davies (1982), whose data have been substituted for those of Specht *et al.* (1974): the basis for the analysis of the southeastern parks. Unfortunately there has not been an equivalent upgrading in broad scale vegetation mapping of the State or in the quantitative assessment of the areas of natural vegetation remaining following land clearance. We have therefore continued to use the State vegetation maps of Boomsma & Lewis (1980), and the vegetation clearance data of Harris (1976). The continued use of Boomsma & Lewis' map allows more direct comparison of the Eyre Peninsula figures with those for the South East, but it has unfortunately necessitated a considerable simplification of the park vegetation types recognised by Davies (1982). Hence only the simple comparison of the major structural vegetation types can be made. There has been a considerable but unknown amount of clearance of natural vegetation of Eyre Peninsula since the work of Harris (1976) (based on aerial photography from 1967 to 1974). The figures used in Table 4 for the amount of natural vegetation remaining on Eyre Peninsula therefore will be higher than those remaining today.

The proportions of each of the four Environmental Regions (Laut *et al. 1977)* recognised for Eyre Peninsula conserved in the State's conservation reserve system is shown in Table 2. An Environmental Region is defined as 'aggregations of land systems with some unifying theme' and they are based mainly on geomorphological criteria (Laut *et al.* 1977). It is clear that the West Coast Environmental Region is poorly represented in conservation areas, while the remaining three regions (5-9% of their area

Table 2. PARKS OF EYRE PENINSULA IN RELATION TO ENVIRONMENTAL REGIONS (after Laut *et al. 1977)*

Environmental Region	*Total Area (ha) of Environmental Region*	*No. of parks in each zone*	*Total area (ha) of parks in each zone*	*% of area reserved*
Southern Highlands and Plains	584811	16	51 903	8.88
West Coast	1070102	12	5777	0.54
Central Mallee Plains and Dunes	3123000	17	161 484	5.17
Northern Myall Plains	772000	3	59521	7.71
TOTAL	5549913	48	279512	5.03

Table 3. MAINLAND PARKS OF EYRE PENINSULA IN RELATION TO STRUCTURAL VEGETATION TYPE (after Boomsma & Lewis 1980).

Vegetation type	*Total Area (ha) originally covered by each vegetation type (a)*	*Area of vegetation type in parks (b)*	*No of parks with vegetation type represented*	*% of reserve now in each vegetation type; (b/271723x100)*	*% of each original vegetation type now reserved; (b/ax100)*
Forest	104715	208	1	.1	.2
Woodland	366503	8439	6	3.1	2.3
Open scrub	3926825	221502	21	81.5	5.6
Shrubland	942440	14680	6	5.4	1.6
Coastal Succerssion	209430	26894	8	9.9	12.8
TOTAL	5549913	271723	25	100	4.9

Note some parks contain more than one vegetation type and so total area is greater than the no of parks analysed.

managed for conservation) are better represented. A consideration of the reserve system in relation to the five major structural vegetation types recognised as originally occurring on Eyre Peninsula by Boomsma & Lewis (1980) is shown in Table 3. The three most poorly conserved vegetation types on Eyre Peninsula.are forest, shrubland and woodland. Forest was always restricted to a very small area of southern Eyre Peninsula and has been extensively cut for fence posts and firewood and to open up grazing land. At present this remnant sugar gum forest is only conserved in Wan ilia Conservation Park and the few remaining larger remnant patches are in urgent need of conservation. Shrubland (in terms of Boomsma & Lewis' vegetation map) is confined to the northern part of the peninsula where the open scrub vegetation gives way to an open Myall woodland with an understorey of various species of chenopod shrubs. The only parks containing significant shrubland areas on Eyre Peninsula are Lake Gilles, Munyaroo and Whyalla Conservation Parks. Although 2% of the original woodland vegetation is now conserved this is composed largely of the heavily degraded Sheoak and Dryland Teatree woodlands of Lincoln and Coffin Bay National Parks and Kellidie Bay Conservation Park on the southern tip of the peninsula. The once extensive woodlands of the west coast have been largely cleared and only a small area is conserved in Bascombe Well Conservation Park (Table 4). Additional small areas of woodland of a different type are in Carappee Hill and Middlecamp Hills Conservation Parks. The remaining two vegetation types (which are clearly of much lower agricultural value), open scrub and coastal succession, are relatively well conserved, and there are additional areas of coastal succession vegetation on the offshore island conservation parks which were not included in this analysis.

ACKNOWLEDGEMENTS

The assistance of the National Parks and Wildlife Service field staff in the Northern Region in the preparation of this chapter is gratefully acknowledged.

Table 4. AREAS OF UNCLEARED LAND REMAINING ON EYRE PENINSULA (after Harris 1976)

County	*Total area*	*Area uncleared (1976)*	*% of county uncleared*	*Area of parks* (1984)	*% of county dedicated* as *parks*	*Park* as *% of uncleared land*
Flinders	482387	177 499	36.8	50072	10.4	28.2
Musgrave	629412	278056	44.2	32200	5.1	11.6
Robinson	699951	232035	33.2	5548	0.8	2.4
Jervois	994515	294490	29.6	120860	12.2	41.0
Le Hunte	462216	139583	30.2	211	0.05	0.02
Pl. Buxton	416669	179524	43.1	62832	15.1	35.0
TOTALS	3685180	1301 187	35.3	271 723	7.4	20.9

REFERENCES

Aitken, P F. (1971). Rediscovery of the large desert sminthopsis *(Sminthopsis psammophilus* Spencer) on Eyre Peninsula, South Australia. *Viet. Nat.* **88***,* 103-11.

Bonython, C. W. & Preiss. K. A. (1967). (Eds). Hambidge Wildlife Reserve, A survey by the Nature Conservation Society of South Australia S. *Aust. Nat.* **42**,35-63.

Boomsma, C. D. & Lewis, N. B. (1980). The native forest and woodland vegetation of South Australia. Bulletin 25 Woods and Forests Department, South Australia.

Copley, P B. (1983). Studies of the Yellow-footed Rock Wallaby, *Petrogale xanthopus* Gray (Marsupialia: Macropodidae) 1. Distribution in South Australia. *Aust. Wildl. Res.* **10**, 47-61.

Crocker, R. L. (1946). An Introduction to the soils and vegetation of Eyre Peninsula, South Australia. *Trans. R. Soc.* S. *Aust.* **70**, 83-107.

Davies, R. J. (1982). 'The conservation of major plant associations in South Australia.' (Conservation Council of South Australia, Adelaide).

Davies, W. J. (1975). 'A land description of Carappee Conservation Park.' (Soil Conservation Branch, SA Dept of Agriculture, Adelaide).

De Deckker, P, Bauld, J. & Brune, R. V. (1982). Pillie Lake, Eyre Peninsula, South Australia: Modern environment and biota, dolomite sedimentation and holocene history. *Trans. R. Soc.* S. *Aust.* **106**(4*),* 169-81.

Fatchen, 1. J. (1982). Vegetation distribution and change of offshore islands of the Investigator Group and Whidbey Isles, Great Australian Bight. *Trans. R. Soc.* S. *Aust.* **106**, 39-60.

Finlayson, H. H. (1951). Further .notes of some birds seen upon islands off the Eyre Peninsula coasts, South Australia, with remarks on the soil erosion of North Gambier Island. S. *Aust. Ornith.* **18**, 22-3.

Gill, C. L. (1973). Sooty Tern in Coffin Bay. S. *Aust. Ornith.* **26**, 133.

Gill, C. L. (1980). Observations on the Eastern Reef Egret in the Eyre Peninsula Region. S. *Aust. Ornith.* **28**(4), 107.

Harris, C. R. (1974). *The National Parks and Reserves of South Australia,* MA Thesis, Geography Department, University of Adelaide. Unpublished.

Harris, C. R. (1976). (Ed). Vegetation clearance in South Australia: Report of the inderdepartmental committee on vegetation clearance (Govt. Printer, Adelaide).

Jericho, S. G. (1969). *Petrogale xanthopus,* S. *Aust. Nat.* **44**,20.

Laut, P, Heyligers, PC., Keig, G., Loffler, E., Margules, C., Scott, R. M. & Sullivan, M. E. (1977). 'Environments of South Australia, Province 1, South East.' (Division of Land Use Research, CSIRO, Canberra).

Lesslie, R. G., & Taylor, S. G. (1983). Wilderness in South Australia: an inventory of the State's relatively high quality wilderness areas. University of Adelaide, Centre for Environmental Studies, Occasional Paper NO.1.

Lewis, M. M. (1974). Ecological studies towards management of Whyalla Conservation Park, South Australia, B.Sc. (Hons) Thesis, Department of Botany, University of Adelaide. Unpublished.

McLaren, N. E. (1979). The role of habitat islands in the conservation of birds in the mallee of Central Eyre Peninsula, M.Env.Stud. Thesis, Centre for Environmental Studies, University of Adelaide. Unpublished.

McNamara, D. (1966). The Western Whipbird on Eyre Peninsula. S. *Aust. Ornith.* **24**, 93.

National Parks and Wildlife Service (1984). Lincoln National Park pamphlet. (Government Printer, Adelaide).

Nature Conservation Society of South Australia (Eyre Peninsula Group) (1974). Carappee Hill Conservation Park, Survey Report, September 1974. (N.C.S.SA, Adelaide).

Nixon, L. G. B. (1967). The Sir Joseph Banks Islands, Spencer Gulf: reconnaissance. (SA) *Mining Review,* No. 121, 60-9.

Parker, S. A. & Cox, J. B. (1978). Notes on the birds of Pearson, Dorothee and Greenly Islands, South Australia. *Trans. R. Soc.* S. *Aust.* **102**, 191-202.

Preiss, K. (1969). ed. The Hundred of Blesing: A survey of its natural value carried out by The Nature Conservation Society of South Australia 30 September-9 October, 1967. S. *Aust. Nat.* **43**, 52-98.

Preiss, K. A. & Thomas, P M. (1970). (Eds). Hincks National Park. A survey of the natural values carried out by The Nature Conservation Societ} of South Australia, 5-13 October 1968, S. *Aust. Nat.* **45**, 29-78.

Preiss, K. A. & Thomas, P M. (1970). Hambidge, Hincks and Blesing: An assessment of three areas on Eyre Peninsula. S. *Aust. Nat.* **45**, 79-84.

Reeves, P R. & Wilson, P (1964). Report to the Nature Conservation Society by the project group studying the reserve in the Hundred of Flinders. (N.C.S.S.A., Adelaide).

Robinson, A. C. (1980). Notes on the mammals and reptiles of Pearson, Dorothee and Greenly islands, South Australia. *Trans. R. Soc.* S. *Aust.* **104**, 93-100.

Robinson, A. C. & Smyth, M. E. B. (1976). The vertebrate fauna of Nuyts Archipelago, South Australia. *Trans. R. Soc.* S. *Aust.* **100**, 171-6.

Robinson, A. C., Delroy, L. B. &. Jenkins, R. B. (1982).

The conservation and management of the Cape Barren Goose *(Cereopsis novaehollandiae* Latham) in South Australia. *Dept Env. Plan.* S. *Aust, Special Publication* **1**, 1-50.

Robinson, A. C. & Rowberry, G. M. (1983). National Parks. pp. 223-37. *In* M. J. Tyler, C. R. Twidale, J. K. Ling & J. W. Holmes (Eds), 'Natural History of the South East.' (Royal Society of South Australia, Adelaide.

Robinson, A. C., Canty, P D., Mooney, P A. & Rudduck, P. M. (in prep.). South Australia's Offshore Islands. *Dept Env. Plan.* S. *Aust, Special Publication* **4***.*

Robinson, A. C., Spiers, A. & Parker, S. A. (in press). First breeding record of the Fleshy-footed Shearwater in South Australia. S. *Aust. Ornith.*

Schmitt, L. H. (1978). Genetic variation in isolated populations of the Australian Bush Rat *Rattus tuscipes. Evolution* **32**, 1-14.

Schmitt, L. H. & White, R. J. (1979). A comparison of metric and protein variations in the Australian Bush Rat *Rattus tuscipes greyi. Aust. J. Zool.* **27**, 547-59.

Smith, D. F. (1963). The plant ecology of lower Eyre Peninsula. *Trans. R. Soc.* S. *Aust.* **87**, 93-110.

Specht, R. L. (1963). Flora conservation in South Australia PI. II. The preservation of species recorded in South Australia. *Trans. R. Soc.* S. *Aust.,* **87**, 63-92.

Specht, R. L., (1972). 'The Vegetation of South Australia.' (Government Printer, Adelaide).

Specht, R. L., Roe, E. M. & Broughton, V. H. (1974). Conservation of major plant communities in Australia and Papua New Guinea. *Aust. J. Bot. Suppl. Ser.* **7**, 236-318.

Stirling, I. (1971a). Studies on the behaviour of the South Australian fur seal, *Arctocephalus torsteri* (Lesson). 1. Annual Cycle, postures and calls, and adult males during the breeding season. *Aust. J. Zool. 19,* 248-66.

Stirling, I. (1971b). Studies on the behaviour of the South Australian fur seal, *Arctocaphalus torsteri* (Lesson) II Adult females and pups. *Aust. J. Zool,* **19**, 267-73.

Wood, J. G. (1930). An analysis of the vegetation of Kangaroo Island and the adjacent peninsulas. *Trans. R. Soc.* S. *Aust,* **54**, 105-39.

Wood, R. M. (1975). 'A land description of Lake Gilles National Park.' (Land Conservation Branch, SA Dept. of Agriculture, Adelaide).

Wood Jones, F. (1923-25). The Mammals of South Australia.' (Government Printer, South Australia).

18: Biogeography

by M.J. TYLER

INTRODUCTION

The current distribution of animals and plants upon any landmass is attributable to a variety of factors that assist or constrain them. These factors include the physical history of that landmass, the environments that exist now and existed in the past, and the differing abilities of organisms to colonise and disperse by land, sea and air. Biogeography explores distribution and causative factors.

BIOGEOGRAPHIC UNITS

The first a.ttempt to divide the Australian continent into a series of units (Provinces) that are meaningful in a biogeographic sense was that of Spencer (1896). Spencer recognised three provinces: a northern and northeastern province (Torresian), with a southeastern (Bassi an) mainly located east of the Great Dividing Range, and a vast, central, arid area termed the Eyrean (Fig. 1).

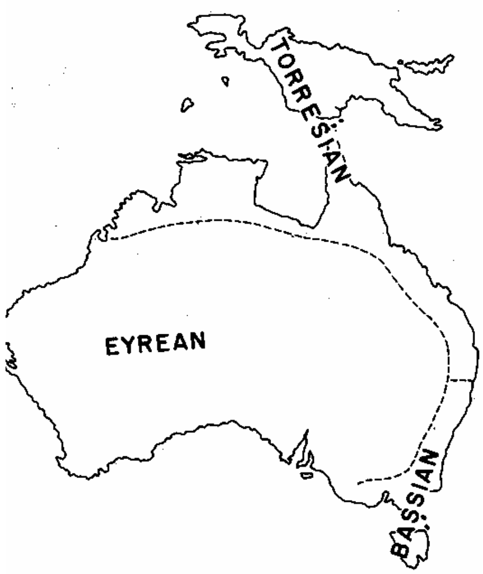


Fig. 1. Biogeographic Provinces of Australia. (After Spencer 1896).

Spencer's scheme has persisted with only slight modification (principally recognition that the southwest of W.A. has affinities with the Bassian province). By virtue of its position and biota the Eyre Peninsula remains an area that is extremely difficult to classify within a single province. It has been considered entirely Eyrean (Horton 1973), partly Eyrean and partly Bassian (Common & Waterhouse 1972), or entirely Bassian (Johnson & Briggs 1975). The differing provincial boundaries involving Eyre Peninsula described by these authors are shown in Fig. 2.

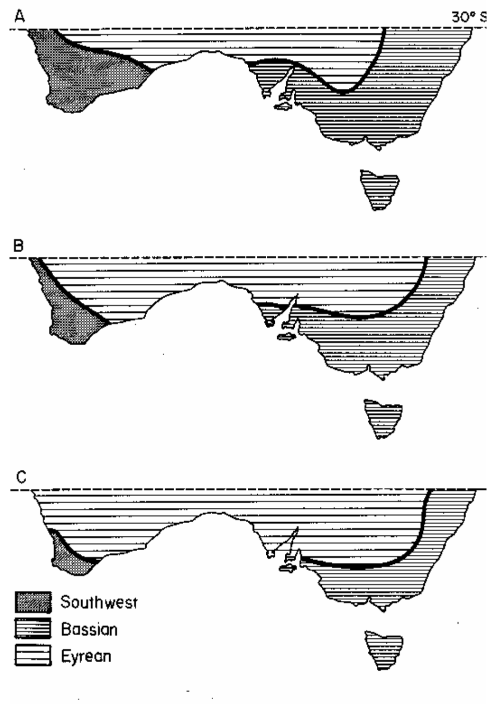


Fig. 2. Differing concepts of the relationships of Eyre Peninsula to biogeographic provinces of southern Australia. A. After Johnson & Briggs (1975); B. After Common & Waterhouse (1972); C. After Horton (1973).

Laut *et at.* (1977) used Landsat imagery to provide a subdivision of South Australia into a series of units that they termed 'environments'. These units represent a system that does not equate with provinces. The system is meaningful within a South Australian perspective but is not wholly compatible with the perspective adopted here of examining Eyre Peninsula as a component of southern Australia.

The significance of Eyre Peninsula reflects its geographic position between the (Bassian) southeast of the continent, and the southwestern portion of Western Australia: areas with substantial biogeographic affinities to one another. Fluctuating Climates in the Pleistocene and, particularly, periods of lower sea-level during glacial periods, created a corridor up to 200 km wide located south of the existing southern coastline. It is accepted widely that this corridor (Fig. 3) was used by organisms dispersing between the southeast and the southwest of the continent (Galloway & Kemp 1981).

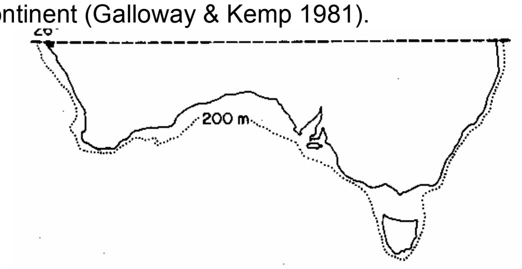


Fig. 3. Corridor of continental shelf exposed when sea-level fell by 200 m.

STATE OF FLORAL AND FAUNAL STUDIES

Biogeographic interpretations can only be as good as the data on which they are based. It is therefore worth reviewing the current state of knowledge of the flora and fauna of the peninsula.

During the planning stages of this volume several potential contributors declined the invitation to prepare chapters, because they stated that insufficient was known of their particular speciality to permit anything comprehensive to be written.

Of those contributors who have prepared chapters the inadequacy of observations is emphasised repeatedly. Williams (Chapter 9) points out that his survey of the salt lakes and their fauna is the only one that has been undertaken. Schwaner *et at.* (Chapter 13) indicate that additional species of reptiles and quite possibly new species can be anticipated.

Matthews (Chapter 15) selected two particular groups of beetles because these were the only members of their families that were sufficiently well known taxonomically, but noted that the best documented species on Eyre Peninsula was known from only seven localities there.

The absence of many organisms on Eyre Peninsula is surely more apparent than real. For example Jamieson (1974) drew attention to the absence of earthworms in museum collections: no one had searched for them.

In comparing Eyre Peninsula with other components of southern Australia a further problem lies in the inadequacy of knowledge of the area to the west. Results of a recent major survey of the Nullarbor Plain have yet to be published. It follows that the current review is necessarily brief and its conclusions tentative.

ENVIRONMENTAL PARAMETERS

The relatively monotonous physical nature of Eyre Peninsula (in comparison with other areas) is not conducive to the creation of much diversity of habitats. Consequently there are few notable differences in the fauna of anyone part of Eyre Peninsula from another. The major exception to this very broad generalisation involves the southern tip of the peninsula, which receives substantially higher rainfall (Schwerdtfeger, Chapter 6).

The southern tip of the peninsula therefore is potentially significant as an area in which relict populations from the periods of higher rainfall are likely to be found.

ENDEMISM

As Matthews (Chapter 15, p. 183) observes, 'development of endemism is possible only in a region of long standing stability protected by effective barriers against new immigrants.' On these grounds Eyre Peninsula is not an area in which a high degree of endemism would be anticipated. Nevertheless a number of species and sub-species apparently are confined to the area.

Of the flora Lange & Lang (Chapter 8) note that of the 1260 species recorded from Eyre Peninsula by Jessop (1983), 29 are unique to the peninsula. Lange & Lang note that at least one of these (the native speedwell *Veronica parnkalliana* is known only from collections in 1909 near Port Lincoln and may have become extinct. Other plant species such as the raspwort *Hatoragis eyreana* are extremely restricted in their distribution.

Isolation of the blue gum on the Eyre Peninsula has been of sufficient time for it to evolve distinctive features leading to its recognition as a subspecies: *Eucalyptus leucoxylon petiolaris.*

Eyre Peninsula has its own species of funnel web spider: *Atrax eyrei* which is found at the southern extremity (Gray 1984). Its closest relatives are A. *flindersi* of the southern Flinders Ranges and Mt Remarkable, and A. *adelaidensis* which extends from Clare to Hahndorf and includes a portion of the Adelaide Metropolitan area.

Main (1981) reported the existence of a further species of spider (an *Aganippa* species) awaiting description.

Amongst the marine fauna is included a viviparous asteroid named *Patiriella parvivipara* by Keough & Dartnell (1977). It is known from five localities on the west coast and its closest relatives are species occurring on coastlines further to the east and southeast.

Included in the vertebrates is an undescribed species of frog of the genus *Neobatrachus* (M. Mahony, in litt.).

RELICS

Fluctuating climates in Australia since the Miocene have resulted in the expansion of the geographic range of species followed by their constrictions. From time to time the fragmentation of species into two or more allopatric populations is an event that may lead to speciation.

Because of its position as a stepping stone between major centres of speciation in the southeast and the southwest of the continent, the populations on Eyre Peninsula exhibit varying degrees of divergence from those occurring in the other two areas. At the maximum extreme of divergence the Eyre Peninsula populations have formed endemic species or sub-species whose closest relatives exist in the southwest or southeast (examples are provided above). In a number of other instances species appear to be effectively isolated there, but are not considered to have diverged in any respect from allopatric populations elsewhere. Such populations are said to be disjunct and they constitute relics of species that once occupied a much more extensive geographic area.

One such relic is the spider *Stanwellia occidentalis* which has been found on Eyre Peninsula, 'in the moss capping of shaded cliffs', and at Albany in Western Australia (Main 1981). The Eyre Peninsula population represents the eastern extremity of the range of the species. In contrast the small leptodactylid frog *Ranidella signifera* is found only to the east, becoming widespread in the southeast of the continent (Fig. 4).

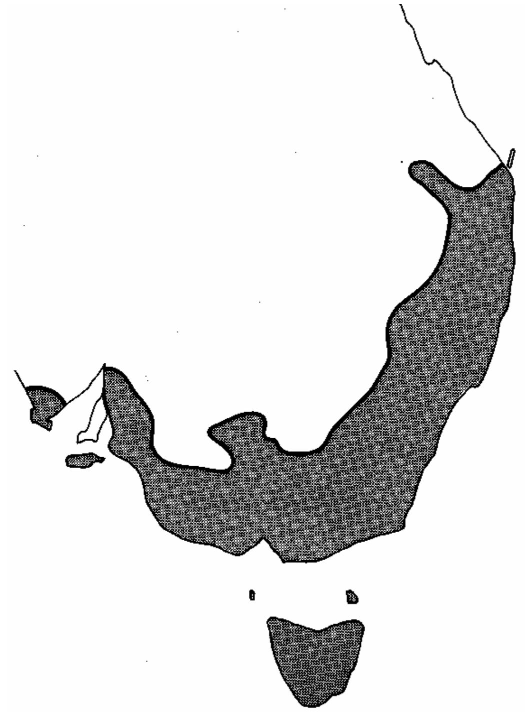


Fig. 4. Distribution of the frog *Ranidella signifera* in southeastern Australia (After Brook 1983).

A possible parallel is a second species of small frog, *Pseudophryne bibroni.* Metcalf (1923) described the protozoan parasite *Protoopalina bibroniifrom* a single frog from Port Lincoln. There are no subsequent records in the literature, and the presence of the host at Port Lincoln or elsewhere on Eyre Peninsula requires confirmation.

The islands off the southern coast of Eyre Peninsula have provided a refuge for a number of species. Notable amongst the large animals is the black-footed rock-wallaby *(Petrogale lateralis)* known from scattered localities in western and central Australia (Watts & Ling, Chapter 11). This disjunction may have been brought about, at least in part, by land clearance on the mainland.

Koch (1977) considered southern Eyre Peninsula, and particularly the offshore islands, one of a number of significant refuges for several species of scorpions.

Research being undertaken by T. D. Schwaner on the black tiger snake *Notechis ater,* explores abundance and inter-island divergence of a species scarce upon the mainland. The current inference is that the snake is sufficiently flexible in an adaptive sense to evolve rapidly. Schwaner's studies are a potential benchmark in evolutionary studies.

Whereas the isolation of *N. ater upon* offshore islands is an event physically finalised on the last occasion in the Holocene, other events have taken on a totally different time scale. Such is the case with beetles of the genus *Eucanthus* which are confined to Eyre Peninsula and a .narrow coastal strip of Western Australia to as far north as Shark Bay. Apparently the same genus occurs in North and South America (Howden 1981).

By far the most significant of the relics upon Eyre Peninsula is the small (10 mm) ant *Nothomyrmecia macrops.* Widely considered to be the most archaic of all living ants, it was described in 1934 from two specimens collected at an unspecified locality south of Balladonia in W.A. Despite numerous searches it was not rediscovered until 1977 when several colonies were found by a CSIRO party southeast of Ceduna (Taylor 1978). The species has yet to be rediscovered in Western Australia.

In its behaviour Taylor (1978) notes that *N. macrops* resembles the better known 'bulldog' ants of the genus *Myrmecia.*

HISTORICAL ASPECTS

During glacial periods in which substantially more of the world's available moisture was converted to ice, sea levels dropped by up to 200 metres below their present levels. Sea level falls of far less magnitude produced drastic effects upon the coastline of South Australia, and particularly the area adjacent to Eyre Peninsula. Nelson (1981) points out that a fall of only 25 m would have exposed most of Spencer Gulf and Gulf St Vincent, and would have linked Kangaroo Island with Fleurieu Peninsula. It may also have united the offshore islands with the southern tip of Eyre Peninsula. In fact they and Kangaroo Island would have been hills upon an undulating plain. The impact of these physical changes upon the terrestrial fauna of Eyre Peninsula would have been profound, providing at various times direct land links with the eastern part of the continent. It is likely that at such times the frog *Ranidella signifera* reached Port Lincoln. Whether the period was accompanied by climatic amelioration on the northern portion of Eyre Peninsula (a northerly shift of existing isohyets), or whether migration was across the exposed land of the gulfs is uncertain. Exposed land would, in the short term, have been both sandy and salty and unsuitable for creatures such as frogs.

For the presumed migration route along the southern corridor to Western Australia, the question of the suitability of the soil is rarely considered, but Galloway and Kemp (1981) query whether the soil was sandy. Alas, there is no direct evidence. It is likely that any moister conditions upon the corridor would have been accompanied by less arid conditions upon the Nullarbor Plain and Eyre Peninsula. Williams (1980) listed the Pleistocene vertebrate fossils from three sites upon Eyre Peninsula: Calca (southeast of Streaky Bay), Brothers Islands in Coffin Bay, and Kyancutta. Although Williams specifically cautions against biogeographic interpretation of the deposits, because of inadequate understanding of the ages of the deposits, one fact can be deduced. Namely that there are no species represented that require substantially moister conditions than exist at the sites today.

It may be concluded that knowledge of the fauna and flora of Eyre Peninsula is inadequate to permit broad conclusions about its past and present biogeography. Nevertheless existing data are sufficient to demonstrate that an understanding of Eyre Peninsula is vital to studies of the entire southern portion of the continent. Because of its intimate floral and faunal links with the southeast and southwest of the Peninsula, the southern portion at least may be considered a part of the Bassian Province.

ACKNOWLEDGEMENTS

I am indebted to Ruth Evans for the provision of the figures, and to Heather Kimber for typing the manuscript.

REFERENCES

Common, I. F. B. & Waterhouse, D. F. (1972). 'Butterflies of Australia.' (Angus & Robertson, Sydney).

Galloway, R. W & Kemp, E. M. (1981). Late Caenozoic environments in Australia. Chap. 4, pp. 53-80. *In* A. Keast (Ed.) 'Ecological Biogeography of Australia.' (W Junk, The Hague). Mygalomorphae) with notes on burrowing behaviour. *Rec.* S. *Aust. Mus.* **18**(19), 441-452.

Gray, M. R. (1984). The taxonomy of the *Atrax adelaidensis* species group (Macrothelinae: Mygalomorphae) with notes on burrowing behaviour. Rec. S. Aust. Mus. **18**(19), 441-452.

Horton, D. R. (1973). The concept of zoogeographic *subregions.Syst. Zool.* **22**(2), 191-195.

Howden, H. F. (1981). Zoogeography of some Australian Coleoptera as exemplified by the Scarabaeoidea. Chap. 35, pp. 1007-1035. *In* A. Keast (Ed.) 'Ecological Biogeography of Australia.' (W Junk, The Hague).

Jamieson, B. G. M. (1974). Earthworms (Oligochaeta: Megascolecidae) from South Australia. *Trans. R. Soc.* S. *Aust.* **98**, 79-112.

Jessop, J. P (Ed.) (1983). A list of the vascular plants of South Australia. (Adelaide Botanic Gardens & State Herbarium, Dept of Environment & Planning, Adelaide).

Johnson, L. A. S. & Briggs, B. G. (1975). On the Proteaceae-the evolution and classification of a southern family. *Bot.* J. *Linn. Soc.* **70**(2), 83-182.

Keough, M. J. & Dartnell, A. J. (1977). A new species of viviparous asterinid asteroid from Eyre Peninsula, South Australia. *Rec.* S. *Aust. Mus.* **17**(28), 407-416.

Koch, L. E. (1977). The taxonomy, geographic distribution and evolutionary radiation of Australo-Papuan scorpions. *Rec. W Ausf. Mus.* **5**(2), 81-367.

Laut, P, Heylingers, PC., Keig, G., LOffler, E., Margules, C. & Scott, R. M. (1977). 'Environments of South Australia Handbook.' (Divn Land Use Res., C.S.I.R.Q., Canberra).

Main, B. Y. (1981). Australian spiders: diversity, distribution and ecology. Chap. 28, pp. 807-853. *In* A. Keast (Ed.) 'Ecological Biogeography of Australia.' (w. Junk, The Hague).

Metcalf, M. A. (1923). The opalinid ciliate infusorians. *Bull. U.S. National Mus.* **120,** 1-484.

Nelson, E. C. (1981). Phytogeography of southern Australia. Chap. 25, pp.733-759. *In* A. Keast (Ed.) 'Ecological biogeography of Australia.' (W. Junk, The Hague).

Brook, A. J. (1983). Atlas of Australian Anura. Dept Zoology, University of Melbourne. Publ. (7).

Spencer, B. (1896). 'Report on the work of the Horn Scientific Expedition to Central Australia.' Part 1 (Dulau, London).

Taylor, R. W. (1978). *Nothomyrmecia macrops:* a livingfossil ant rediscovered. *Science* **201,** 979-985.

Williams, D. L. G. (1980). Catalogue of Pleistocene vertebrate fossils and sites in South Australia. *Trans. R. Soc.* S. *Aust.* **104***(5),101-115.*