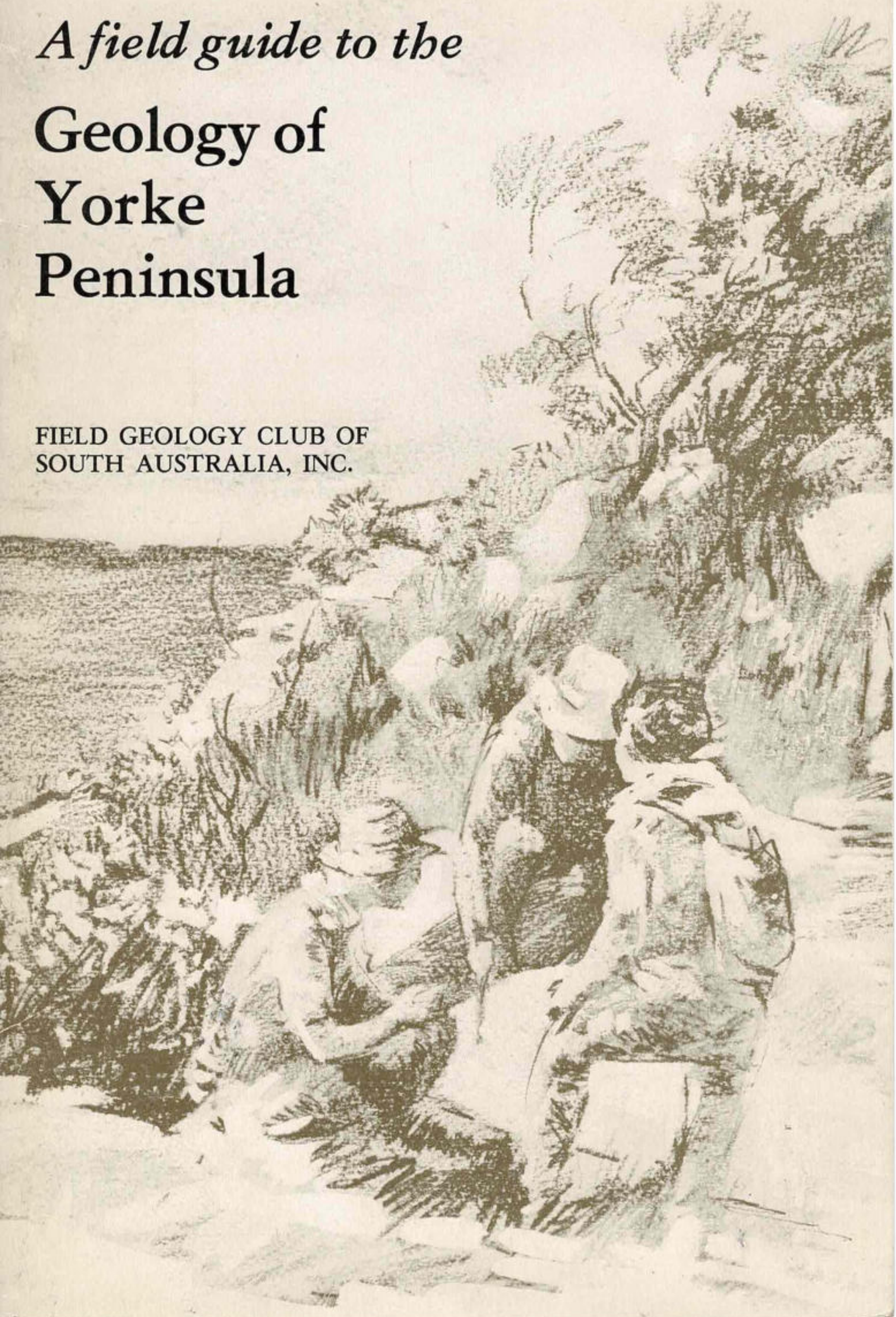
A field guide to the

Geology of Yorke Peninsula

FIELD GEOLOGY CLUB OF
SOUTH AUSTRALIA, INC.



A FIELD GUIDE
TO THE
GEOLOGY OF YORKE PENINSULA

Field Geology Club of South Australia Inc.
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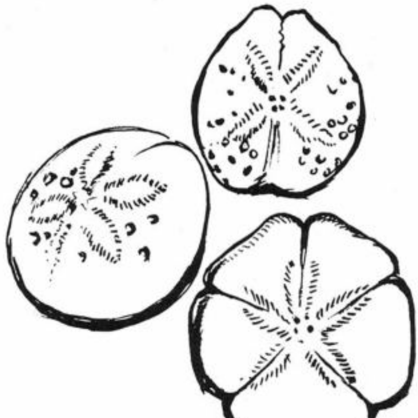

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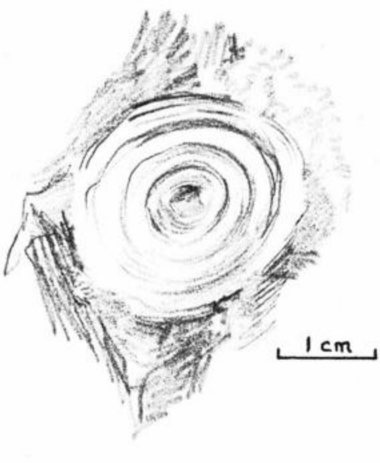

Marginopera (Pliocene)

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PREFACE

The Field Geology Club of S.A. is to be congratulated upon having produced this field guide for use by schools and the general public desirous of exploring the geology of Yorke Peninsula. It is principally the work of amateurs for amateurs. There has been valuable direction by Dr David Corbett in editing, and by him and Dr A. R. Milnes in field inspections, and much research into, and reliance upon, all relevant publications, most importantly, those issued by the Geological Survey of South Australia.

It is appropriate that amateurs should attempt to advance an interest in this area where the geological features were first described in print by the local teacher and natural historian, Mr J. G. O. Tepper, almost a century ago. It was in 1879 that Tepper wrote an "Introduction to the Cliffs and Rocks at Ardrossan" in the Transactions of the Philosophical Society which became the Transactions of the Royal Society of S.A. and the repository of further scientific papers on this region.

The members of the Field Geology Club believe that a deeper understanding of the geology will assist in the protection of geological features in their natural environment. A code for conduct in the field is included to emphasise the need for responsibility in this regard.

The Club acknowledges with gratitude the grant from the Commonwealth Government under the National Estate Programme which financed this publication. Any comments from users of this booklet will be received with interest and will assist in knowing whether it has achieved the aims of those who produced it.

E. M. McBriar.
Senior Tutor in Geology,
University of Adelaide.

ACKNOWLEDGEMENTS

The Field Geology Club wishes to thank the Federal Department of Environment, Housing and Community Development for the financial assistance awarded under the National Estate Programme without which this book could not have been produced. The substantial efforts of Mr Dean Gillett, the Club Secretary, in negotiating with the Department as the book progressed have been much appreciated.

Many individuals have assised during the course of the project, contributing in various ways to the production of the Guide and their help is here gratefully acknowledged.

The index map and locality maps were prepared in the cartographic office of the Royal Automobile Association and thanks are due to the R.A.A. executive and Mr Roy Taylor, Chief cartographer, for their valuable assistance. Professor C. C. von der Borch of Flinders University provided information relating to the stromatolites at Lake Marion and gave permission to publish photographs here reproduced as Plates 12-14; Mr E. P. Hughes of Waratah Gypsum Pty. Ltd. allowed access to the south west section of Lake Marion and Mr H. Harrison of Stenhouse Bay also provided assistance in this area. Mr Jack Nobbs and Mrs Margaret Nobbs undertook a special expedition to produce the photographs reproduced as Plates 3, 6, 7, 10. Mr Frank Hilton of the South Australian Museum identified the Recent shells from Pondalowie Bay, and Dr Colin Branch of the South Australian Department of Mines gave advice on matters relating to the geology of the peninsula.

Typing of the manuscript was undertaken by Mrs W. D. Hardy, Mrs T. Lynne, Mrs M. Priede and Mrs P. Mackowski. Mr Laurie Cahalan and Mr Roger Sheridan of Kerton Bros. Pty. Ltd. provided helpful advice regarding production of the book.

Finally, thanks are due to Mr B. P. Webb, Director of Mines for South Australia for his interest in the project.

Editor

INTRODUCTION

For the purposes of the guide Yorke Peninsula was divided into four regions of approximately equal size as shown on the key map.
Each is the subject of a self-contained itinerary, but in order to examine all aspects of the geological history of the peninsula it will be necessary to complete more than one of these.

More emphasis has been given to areas 3 and 4 for it is in the southern peninsula that the sequence is most complete and best documented. The area maps included are intended as a guide only and excursion leaders are advised to provide themselves with the 1:250 000 topographical maps, Maitland and Investigator.

Although this guide is for the most part written by amateurs for amateurs, a certain amount of basic knowledge is assumed. For those just beginning geology and who are unfamiliar with many of the terms and concepts of the science, reference to a dictionary of geological terms and to some of the many good introductory text books will be necessary. A short list of some of these is given in the reading list on page 65.

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Ern Carmichael
David Corbett (Chairman)
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Ern Carmichael	— southern area
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Editor
David Corbett

A Code for Geological Field Work

Introduction

The Geologists' Association in Britain, a large group comprising both amateur and professional geologists, recently published a code of conduct which has been supported by many other geologists and conservation bodies in Britain. The principles it embodies are equally relevant here in Australia and an amended version of the code is given below:

A geological 'Code of Conduct' has become essential if opportunities for field work in the future are to be preserved. The rapid increase in field studies in recent years has tended to concentrate attention upon a limited number of localities, so that sheer collecting pressure is destroying the scientific value of irreplaceable sites. At the same time the volume of field work is causing concern to many site owners. Geologists must be seen to use the countryside with responsibility; *to achieve this, the following general points should be observed.*

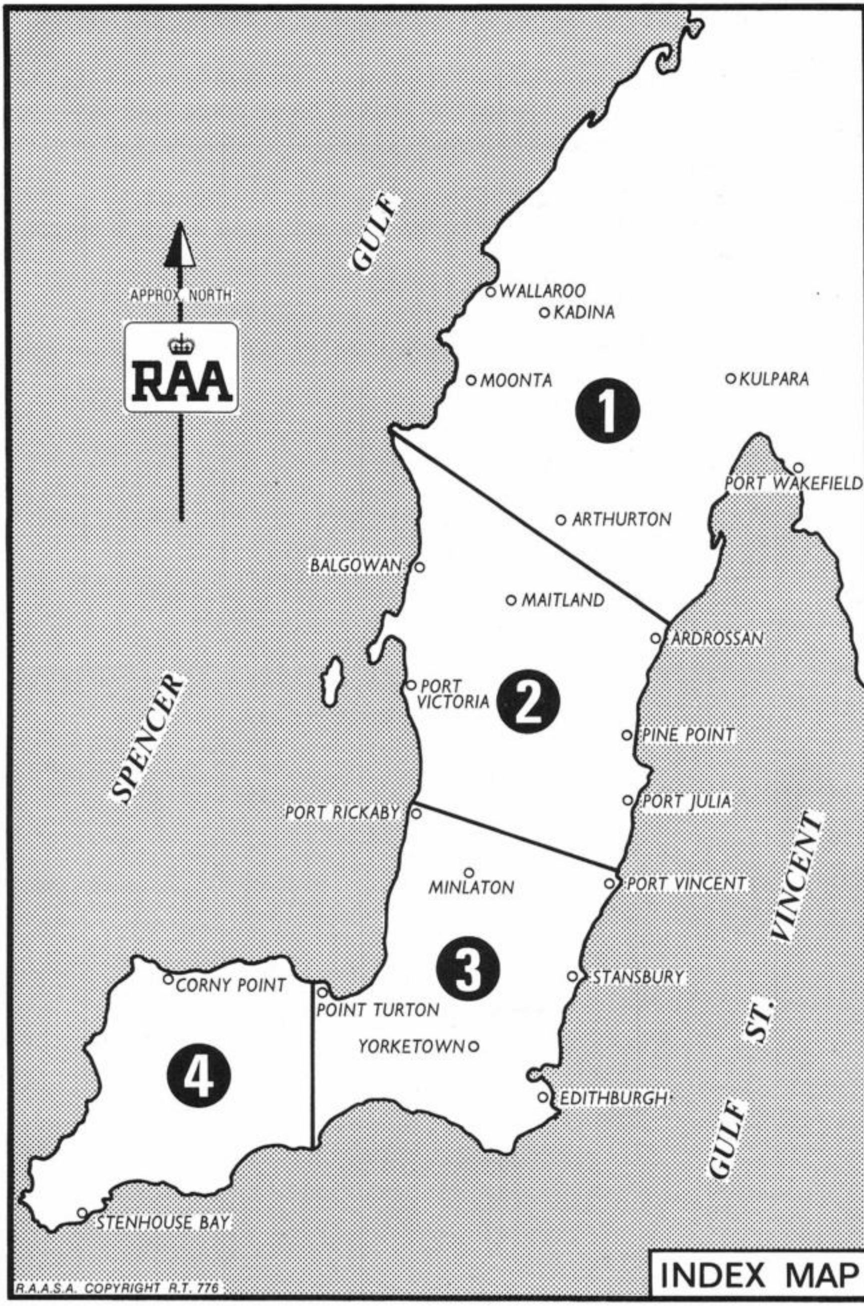
1. Remember to shut gates and leave no litter.
2. Always seek prior permission before entering private land.
3. Don't interfere with machinery.
4. Don't litter fields or roads with rock fragments which might cause injury to livestock, or be a hazard to pedestrians or vehicles.
5. Avoid undue disturbance to wildlife. Plants and animals may inadvertently be displaced or destroyed by careless actions.
6. On coastal sections, be sure you know the local tide conditions.
7. Don't take risks on insecure cliffs or rock faces. Take care not to dislodge rock, since other people may be below.
8. Be considerate. By your actions in collecting, do not render an exposure untidy or dangerous for those who follow you.

Collecting and Field Parties

1. Students should be encouraged to observe and record but not to hammer indiscriminately.
2. *Keep collecting to a minimum.* Avoid removing in situ fossils, rocks or minerals unless they are genuinely needed for serious study.
3. For teaching, the use of replicas is commended. The collecting of actual specimens should be restricted to those localities where there is a plentiful supply, or to scree, fallen blocks and waste tips.
4. Never collect from walls of buildings. Take care not to undermine fences, walls, bridges or other structures.
5. The leader of a field party is asked to ensure that the spirit of this Code is fulfilled, and to remind his party of the need for care and consideration at all times. He should remember that his supervisory role is of prime importance. He must be supported by adequate assistance in the field. This is particularly important on coastal sections, or over difficult terrain, where there might be a tendency for parties to become dispersed.

Visiting Quarries

1. An individual, or the leader of a party, should have obtained *prior* permission to visit.
2. The leader of a party should have made himself familiar with the *current state* of the quarry. He should have consulted with the Manager as to where visitors may go, and what local hazards should be avoided.
3. On each visit, both arrival and departure must be reported.
4. In the quarry, the wearing of safety hats and stout boots is recommended.
5. Keep clear of vehicles and machinery.
6. Be sure that blast warning procedures are understood.
7. *Beware of rock falls.* Quarry faces may be highly dangerous and liable to collapse without warning.
8. Beware of sludge lagoons.


GULF
SPENCER
ST. VINCENT
GULF
APPROX. NORTH
RAA
WALLAROO
KADINA
MOONTA
KULPARA
1
PORT WAKEFIELD
ARTHURTON
BALGOWAN
MAITLAND
ARDROSSAN
PORT VICTORIA
2
PINE POINT
PORT JULIA
PORT RICKABY
MINLATON
PORT VINCENT
3
STANSBURY
CORNY POINT
POINT TURTON
YORKETOWN
4
EDITHBURGH
STENHOUSE BAY
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INDEX MAP

Chapter 1

HISTORY

Yorke Peninsula and its neighbouring waters, Spencer and St Vincent Gulfs, were the last major features of the Australian coastline to be discovered. Early in 1802 Captain Matthew Flinders, commissioned by the British Admiralty to fill in the blanks along the Australian coastline, reached Denial Bay (Ceduna). This had been charted by the Dutch in the *Gulden Seepaart* in 1627. From that point Flinders was in unknown waters. He reached the south eastern tip of Eyre Peninsula in March 1802 and turned northwards, exploring the western side of Spencer Gulf. He returned down the western side of Yorke Peninsula charting Investigator Strait, sailing northwards along the eastern shores of St Vincent Gulf, landing on the Peninsula in the vicinity of Port Arthur, and returning down the western side of the gulf to complete the exploration of the Peninsula at Troubridge Point. His report of the Peninsula was good, "The shore was sandy, but soon rose, in an undulating manner, to hills covered with grass, and the several clumps of trees scattered over them gave the land a pleasing appearance from the waterside."

The Early Years

Pastoral development began on Yorke Peninsula in the middle of 1846 after the good grazing lands of the Northern Areas had been occupied. Charles Parrington selected the first Peninsula run for Alfred Weaver who was granted an Occupation Licence for sixty square miles "at the Oyster Fishery" (Stansbury).

The natives, the Naranga tribe, were peaceful at first but early in 1849 they began killing and driving off sheep. By mid-year the natives had killed a couple of shepherds and a native had been shot. A police station was set up at Moorowie; two whites and two natives were brought to trial but none were convicted. The presence of the police had a salutory effect and only isolated cases occurred after that. Dr Moorhouse, the Protector of aborigines, estimated in 1849 that there were about 150 natives on the Peninsula. Later William Fowler quoted local opinion that the tribe had been about 500 strong when settlement began but was reduced to half when he arrived in 1856. By 1880 there were less than a hundred left. Epidemics of measles and scarlet fever had taken their toll.

The first Pastoral Leases in 1851 brought a better deal to the squatters, who were given more security with a term of fourteen years. Runs were surveyed and the rental for Peninsula runs was assessed at ten shillings a square mile. Captain Walter Hughes bought the Wallaroo run in 1857.

Copper

That was a shrewd move. Hughes suspected copper for he had applied for a mineral section there in 1851, without success. He set his shepherds on the trail, asking them to collect any green stones which they might find for him. In December 1859 James Boor found several pebbles of green carbonate outside the burrow of a marsupial rat and told Duncan, the station manager who dug through the kunkar crust and found the lode. The story of this and of Paddy Ryan's find at Moonta twelve months or so later can best be read in Oswald Pryor's *Little Cornwall* which tells the story of the mining towns. Costeening at Moonta revealed a fabulous lode, with rich deposits of grey sulphide, green carbonate and red oxide less than twenty feet below the surface; while black oxide and sulphide was found at sixty feet and copper pyrites, yellow chalcopyrite and purple bornite were found at 120 feet, continuing to a considerable depth. In the first twenty months the Moonta Mining Company produced 8,000 tons of ore averaging nearly 25 per cent copper and paid £64,000 in dividends. It was the first mining company in Australia to pay a million pounds in dividends. Paddy Ryan drank himself to death before the first dividend was paid. The company continued to pay his widow £6 a week.

The Wallaroo Mining and Smelting Company was not so fortunate. Development costs ran up to £80,000 before the company began to pay its way. That company operated the smelters at Wallaroo for both mines till the two companies were amalgamated in 1889. Wallaroo and Kadina were laid out in 1861 and Moonta two years later. The population of the Moonta district was 10,000 with 6,000 living on the mines in 1870, and several years later the total reached 12,000 making Moonta the largest town outside of Adelaide in the colony. The mining district contained 30,000 in all.

The mines had a life of more than sixty years. Taylor's Shaft at Wallaroo reached a depth of 980 metres while Young's shaft was not much shorter at 900 metres. There were nearly 160 kilometres of levels, crosscuts and drives and about 3½ million tons of ore were produced, averaging 9% copper. The Moonta lodes produced about 2¾ million tons of 14% ore. Copper prices were high during the Great War of 1914-18 and there was a world-wide increase in mining activity but a fall in demand brought prices tumbling from £124 a ton to £64. The Wallaroo and Moonta mines had exhausted all the high grade ore and working low grade ore became uneconomical. The company lost a quarter of a million pounds and used up the entire cash reserves in the five years following the war. It was suggested that the mines could be kept going if the miners would accept a reduction in wages to £3.15.0 a week but they declined, and so, in November 1923, the shareholders voted for voluntary liquidation. The mines had produced a total output of 330,000 tons of fine copper worth over £20 million. The mining population drifted away to other mining fields. Everything saleable was salvaged and sold, but the towns still remained, supported by an established and prosperous farming community.

Agriculture

Agricultural development on Yorke Peninsula really began with the passing of the Strangways Act early in 1869 with provision for the sale of farm lands only on credit in specified areas. The whole of the Hundred of Melville, with the exception of the township area of Edithburgh, was designated the Troubridge Agricultural Area and was offered for sale before the end of the year and a few blocks were sold. A little over three hundred acres of crop was reaped in 1870 and the returns were good, averaging a little over ten bushels to the acre. That started a rush of farmers from the older wheat-sick districts of the Adelaide Plains, the Barossa Valley and the southern districts. The surveyors were kept busy; more Hundreds and two more Agricultural Areas were proclaimed early in 1872 and offered for sale. By the time land in Maitland and Kilkerran was ready for sale in the spring, all farm lands were open to purchase on credit with better terms. The success of agricultural settlement can best be judged by the acreages of wheat reaped in County Fergusson which rose from 552 acres in 1870 to reach a peak of 180,000 acres in 1884.

Most significant to Australian agriculture was the fact that in that time Yorke Peninsula farmers learnt to subdue the despised mallee lands. Charles Mullens at Wasleys had already proved that by knocking down and burning the top growth of the mallee scrub, it was possible to grow crops of wheat. Another big step was taken when R. B. Smith and his apprentice brother, Clarence, produced the first stump-jump ploughs at Arthurton in 1876. In a few years all blacksmiths from Snowtown to Edithburgh were making stump-jump ploughs. Scrub rollers were also improved. William Fowler introduced the diagonal beam across the front with a bobbin wheel on the side, allowing the team to travel over the scrub which had already been rolled.

A new Scrub Lands Act was passed in 1877, which gave the lessee better terms. It was an immediate success. In the first two and a half years, a quarter of a million acres were leased on its terms and at a special sale of leases in September 1881 even more land was taken up. This brought the last and scrubbiest areas of the Peninsula into development.

Towns, Ports and Railways

With settlement came the growth of townships. The earliest were ports to connect the Peninsula with Port Adelaide. Edithburgh, Wool Bay, Stansbury, Ardrossan and Port Victoria were laid out with business centres, parklands and outer suburban areas. Maitland (1872), Minlaton (1876), Arthurton (1877) and Curramulka (1878) were the only inland government towns which became established. Yorketown (1872) and Warooka (1876), on the other hand, grew from private subdivisions as did Port Vincent where the waterfront had been sold as farmland in 1855. Jetties for shipping the harvest had a higher priority than towns in those years of the wheat boom, and Price, Pine Point and Wool Bay on the east, Port Moorowie on the south, Point Turton, Minlacowie, Port Rickaby and Balgowan on Spencer Gulf all got jetties as well as the larger towns. Port Julia (1913), Coobowie (1925) and Marion Bay (1890) came later. The east coast ports, Ardrossan, Port Vincent, Stansbury and Edithburgh, were used firstly by ketches and schooners, then came the steamers and later, road transport. The shipping service continued till the steamers and ketches were commandeered for use in the islands around New Guinea during World War II. They never came back to the Gulf.

The situation was entirely different in Spencer Gulf. There the ports were mainly concerned with the grain trade. Grain ships came to Hardwicke Bay and anchored there, loading by lighter and ketch from Turton, Minlacowie and Rickaby, but no villages developed at these ports. Port Victoria, with its anchorage under the lee of Wardang Island, was the only town south of Wallaroo to grow on Spencer Gulf. It was the only town laid out on the west coast of the peninsula by the Government in the days of agricultural settlement. It received some support from the lime-sand development from Wardang Island, but its real boost came in the 1930's when Spencer Gulf became the last roadstead of the wheat clippers, a fleet of windjammers assembled under the flag of Captain Erikson. Eight or nine of these tall-masted vessels would lie at the anchorage while the ketches would drop their top masts to slide under the bottom yards of the tall-masters, with grain from both sides of the gulf. Unsuited for convoy work, the fleet was scattered during the Second World War.

The Lean Years

The drought began in the north in 1881 and 1882, and although there were some years of reasonable rainfall, the seasonal vagaries of the climate seemed to be adverse to the farmers. The general trend of yields was downwards with an occasional better harvest which never reached earlier levels. In addition, wheat prices followed the same downward trend, to reach a low level of about 2/- in the mid-nineties, when yields were also at their lowest ebb. Farmers were hard pushed to make ends meet; many of them failed to do so. Salt was the salvation of many of them.

Agricultural recovery

A few farmers believed that loss of fertility was the main cause of poor yields and after experiments with superphosphate, Professor Lowrie at Roseworthy College was convinced in 1890 that superphosphate was the answer. In 1892 Joe Parsons of Curramulka imported two English drills and sowed seed and super together, with good results. Other farmers soon followed suit and in 1896 when the Peninsula averaged two bushels, the Hundred of Minlacowie averaged 4.5 bushels and the Hundred of Ramsay, five bushels. That was the turning point. Never again (except 1914) were the yields below ten bushels.

About 1901 or 1902, the introduction of Prior barley, a superior type of malting barley, at Edithburgh, started a movement which was to make Yorke Peninsula world famous as a producer of malting barley and gave the district a fallow, wheat and barley rotation which materially added to the Peninsula's prosperity.

The demand for superphosphate led to the establishment of the Wallaroo Phosphate Company in 1899. The factory was able to use sulphuric acid from the smelters. Production was about 10,000 tons a year till 1908, when it rose sharply to 30,000 tons in 1913, when the company amalgamated with the Birkenhead operations of Mt Lyell as the Wallaroo-Mt Lyell Fertilizers Ltd. Production reached 135,000 tons in 1962. In the 1920's another fertilizer factory, Cresco, was built at Wallaroo and continued till about the end of the 1950's. A few years later W. M. L. amalgamated with Adelaide Chemical and operates as Adelaide and Wallaroo Fertilisers Ltd. Production continues at Wallaroo.

Salt

The return to prosperous conditions in agriculture brought an uplift in industry generally and to salt, lime and gypsum production on southern Yorke Peninsula. Salt production was first recorded on the Peninsula in 1874 when Thomas Wood took out a lease of 600 acres on Lake Fowler and shipped butchers salt to Adelaide. A Frenchman, Augustus Tocchi, set up a factory with concentrating pans and steam boilers for the final evaporation on Tubbs Lake, a mile east of Yorketown in 1876, producing about two tons a day. Pink Lake and Bookamurray Lagoon were leased in the early 1880's and William Telford commenced production on Ramsay Lake, six miles east of Port Vincent about the same time. The Castle Salt company was formed in 1889, and Henry Berry and Company set up at Edithburgh in 1891. From that time salt production began increasing. From 1891 to 1894 production stood at about 7,000 tons a year but then it jumped to an export industry of 30,000 tons by 1898. That year Henry Berry and Co. reconstructed the Castle Salt Co. as the Castle Salt Co-operative Company, with about two hundred independent Lake Fowler leaseholders and farmers with their own lakes on their register. A refinery was built at Edithburgh and opened the next year, followed by the Commonwealth Salt Refining Co. in 1905, and the Standard Salt Co. in 1912. Salt scraping and carting enabled many farmers in the district to survive through the agricultural crisis of the nineties. Southern Yorke Peninsula than became the mecca of the itinerant workers, shearers, canecutters, spendthrifts and alcoholics. Yorketown and Edithburgh took on the nature of frontier towns during the salt season each autumn. Production reached a peak of 57,000 tons in 1918, and the industry continued successfully till the Depression when the market declined. Exports dropped from 24,000 tons in 1927 to a little more than 9,000 in 1930, and the three companies were in difficulties. That year they were amalgamated with the Australian Salt Company which was operating at Lochiel. Production at Edithburgh continued at about 10,000 tons, with most of it going to New Zealand, until that country commenced its own production about 1950. The demolition of the Edithburgh factory by Australian Salt in 1970 signified the final closing down of the Company's operations there.

Lawrence Grayson commenced salt production by solar evaporation of sea water at Price in 1918, trading as Gulf Salt Ltd. till 1925, when the works were taken over by Ocean Salt Ltd. which closed its Port Augusta plant in 1929, and concentrated on production at Price.

Output there is now more than sixty thousand tons. Small scale production of salt from the brines pumped out of the gypsum leases and evaporated on Snow's Lake at Stenhouse Bay produced about ten thousand tons for some years, but has now been discontinued.

Several small producers also operated with the brines under the Peesey Swamp. Two of them are still operating. A feasibility study of large scale operation using these brines was undertaken recently but failed to reach the quantities demanded by the instigator.

Gypsum

Gypsum is another mineral closely associated with the salt lakes. Small deposits of seed and flour gypsum are found in the form of lunettes on the south-eastern side of some of the lakes around Yorketown. Augustus Tocchi formed a company at the end of 1873, and manufactured the first plaster of paris from Tubbs Lake (east of Yorketown) but the venture does not seem to have been a financial success. The largest lunette, seventy feet high and a mile long, adjoined Lake Fowler and has been worked intermittently for many years, much of it going to New Zealand. The leases are now held by Adelaide Brighton Cement who use it as a retarding agent in the manufacture of cement.

By far the greatest production has been from the Stenhouse Bay deposits. William Innes took up the first leases on Marion Lake in 1899, in the name of the Australian Gypsum and Whiting Co. which built the Marion Bay jetty and a tramline to the lake. The leases were taken over by A. H. Hassell in 1898 and worked by him for nearly twenty years. In 1913 the Innes family took out a lease on the western lake, established a factory and a village there called Inneston and built the Stenhouse Bay jetty, named after one of their financial partners. Soon after, Australian Gypsum Ltd of Sydney took out leases on the western end of Marion Lake and in 1925, Victor Electric Plaster Mills Pty Ltd bought Hassell's leases, lengthened the Marion Bay jetty and made improvements to suit bulk loading. The three companies amalgamated in 1930 as Waratah Gypsum Ltd, handed the Marion Bay jetty to the Harbors Board, closed the Inneston factory and abandoned the workings there, preferring Marion Lake, and concentrated the manufacture of plaster in Melbourne. A revival of trade after the Second World War brought increased activity and production more than doubled, reaching about a quarter of a million tons a year. Stenhouse Bay had been the chief source of gypsum for the plaster industry both in Australia and New Zealand until the mid 1960's when increased demand led the company to develop the Lake

MacDonnell deposits. With the major part of Marion Lake worked over, production ceased there at the end of 1972. The scenic coastal area from Cable Bay in the south to the south end of Constance Bay, over 6,000 hectares, was proclaimed as the Innes National Park in 1970, and the village of Stenhouse Bay was bought by the Government as a tourist town in 1975.

Lime

The ubiquitous kunkar has been used since the earliest days of settlement as the local source of building lime. A number of properties had their own hole in the ground to supply their own needs and local builders had their own kilns. The stone brought up by cultivation posed a disposal problem. Around Edithburgh farmers used the stone as dry walls instead of fences. Many of them still remain. George Hart is recorded as supplying lime ash from his kiln for the footpaths of Edithburgh in 1889, and he was possibly supplying lime to Adelaide. Farmers at Port Vincent and Ardrossan burnt lime for shipment in the lean times. After trade revived, Albert Pitt established kilns at Stansbury in 1898, and David Miller (Millers Lime) set up Charles Dry with kilns there a year or so later. The re-purchase and subdivision of Penton Vale Station about the same time did much to centre lime burning around Stansbury and Wool Bay and the district became the main supplier of lime for Adelaide's buildings. The old type intermittent flare kiln continued to be used till the late 1950's. The introduction of hydrated lime then brought about the establishment of the continuous process vertical kiln by Wool Bay Lime Ltd, south of Port Vincent. Laurie Dry at Stansbury is the only remaining limeburner operating intermittent kilns.

Flux

Following the establishment of the smelters at Port Pirie in 1889, the marine limestones of Yorke Peninsula were developed as a source of flux. Quarries at Port Hughes and north of Wallaroo towards Point Riley had supplied flux for the Wallaroo smelters. By 1896 contractors were prospecting on the east coast of the peninsula at Edithburgh, Hickey's Point north of Coobowie and at Stansbury. The Warden of Mines restricted leases close to Edithburgh jetty but thirty to forty tons a day were being quarried at Hickey's Point and three or four boatloads a week were sent from Stansbury. A new jetty was built there in 1905. However, a quarry was also opened at Point Turton in 1898 and in 1906 the B.H.P. decided to do all their quarrying there. Operations continued until the early 1920's when they were abandoned in favour of the Rapid Bay deposits. In 1910 Broken Hill Associated Smelters Pty Ltd began developing Wardang Island as a source of flux and found that the calcareous sand there was suitable and more easily procured than limestone. The works were continued until the mid 1960's when operations were transferred to Coffin Bay on Eyre Peninsula.

Cement

In 1913 Albert Pitt formed the Adelaide Cement Company to manufacture cement from the Tertiary limestone of the Stansbury cliffs. At first the old flux quarry at the end of the new jetty was used and the rock shipped to Birkenhead for manufacture. In 1919 the company built their own jetty at Klein Point and have continued to operate from that quarry. The plant has continually been upgraded and the company now has its own bulk-carrier the *Accolade*. The quarry face is about thirty metres high and stops a little above sea level. Productive capacity is now about 500 tons of crushed rock an hour.

Dolomite

The extension of bitumen roadways on the peninsula in the 1930's led to the opening of the Curramulka quarry in Cambrian limestone to provide a more durable surface than the kunkar which is still used for road formation. The quarry at Curramulka is only used intermittently for local supplies when required. The Cambrian dolomitic limestone, or dolomite, at Ardrossan was developed by the B.H.P. in 1948, as a source of refractories for the steel furnaces at Newcastle and Port Kembla. They built their own bulk-loading jetty and production is over 200,000 tons a year. The heaps of overburden are becoming quite a landmark on the coast road.

Bulkloading of grain

As a direct consequence of the installation of the dolomite jetty, bulk-handling of grain was introduced into South Australia. The Government wrote provision for the shipment of grain and salt into the initial agreement with the B.H.P. The Australian Wheat Board erected a silo there in 1952 and twelve million bushels were shipped over it in twelve months. S.A. Co-operative Bulk Handling Ltd was formed in 1955 as a grower's co-operative. The Ardrossan silo was bought and silos were built alongside the railway lines at Paskeville and Bute for the next harvest. A terminal silo was completed at Wallaroo in 1956, followed by a state wide extension of the system. S.A. Co-operative Bulk Handling finally assumed control of barley receivals in 1964.

This left the southern Yorke Peninsula farmers as the most disadvantaged in the State, fifty to eighty miles from the nearest silo. Edithburgh hoped to obtain a silo, but Harbors Board investigations found that the cost of blasting an entrance through the off-shore reef would be prohibitive and chose a new site at Point Giles, a few miles further north. The first silo was ready for receivals from the 1968 harvest but the six hundred metre jetty was not opened till nearly two years later. With a conveyor belt capable of loading at a rate of eight hundred tons an hour, Port Giles is the deepest port in South Australia and plays an important role in its grain shipping, topping up the largest cargoes ever to leave the State.

Twentieth century Agriculture

Since the turn of the century, agriculture has been the stable industry of Yorke Peninsula. The general trend has been one of increased production and higher yields with only minor setbacks due to seasonal vagaries and market fluctuations. The diversity of its products, the reliability of its rainfall and the efficiency of its farmers have made it one of the most productive areas of the Commonwealth.

"The Bottom end"

More powerful tractors and heavier machinery developed for scrub clearing, combined with profits from farming in the fifties, brought rough land in the Muloowurtie and Ramsay scrub areas into production. More extensive was the development in the western end of the peninsula, where sand spreads from the most recent exposure of the sea floor have not yet matured to complete soils. The area has always been regarded as "coasty", where sheep, especially young ones, do not thrive. Investigations elsewhere have proved that this is due to a lack of copper and cobalt in the pastures. Copper deficiency can be cured by the addition of copper sulphate to the superphosphate used in this country. Cobalt, on the other hand, must be supplied directly to the sheep in the form of a bullet which, when forced down the throat, lodges in the stomach and releases minute quantities there. In the 1920's the Department of Agriculture conducted investigations into the cause of poor barley and oat crops at Corny Point and pinpointed the trouble as a deficiency of manganese which was cured by the addition of manganese sulphate to the superphosphate. When clearing began in the lighter soils of the south western area after the Second World War, it became apparent after several crops that fade-out and frosting-off were markedly reducing the returns, a sign of manganese deficiency, even though crops had been sown with manganese. Experiments in 1963 proved that, by spraying the crop twice with manganese during the growing period, the trouble could be overcome. Gains were so outstanding that the practice immediately became general. Sub-division of the area, some of it under the Soldier Settlement Act, and a new sealed highway from Warooka to Stenhouse Bay, have made more development possible in this previously neglected district. The rainfall here is as high as anywhere on the peninsula and, ultimately, this part could become highly productive.

Fishing

Fishing is the oldest industry connected with Yorke Peninsula. Even before the first squatters arrived, Oyster Bay, now Stansbury, was established as the source of oysters for Adelaide tables, and beds at Black Point were worked but they were both depleted before the end of the century. Fishing has mainly been an individual occupation around the peninsula and little has been recorded of it.

It has been recorded that, about 1880, the Chinese were sending smoked fish from Edithburgh to the Melbourne market and another group were smoking fish at Point Turton. Chinaman Wells near Balgowan suggests that they were operating there too. In the 1920's Moonta Bay was said to have the largest fishing industry in South Australia with 370 people engaged there. The Y.P. Fishermen's Co-operative Ltd are still processing fish. The east coast towns all had sizeable fishing fleets at that time and still do, though the numbers are slightly reduced. Schnapper, whiting and snook, with butterfish and salmon, make up the main catch.

The Tourist Trade

Fishing, too, is one of the main tourist attractions. The present expansion of the trade dates from the end of the Second World War when an influx of campers came to the peninsula. Progress Associations were formed in all the coastal towns to organise caravan parks and camping grounds and they are still very active. Shack sites were made available at the most popular sandy beaches. Water and power have been provided where possible and the District Councils are still developing access roads, boat ramps and scenic drives. The State Government has bought the Stenhouse Bay township to be developed into a holiday village serving the Innes National Park and has plans for Wardang Island. Private enterprise too, has not been idle. Motels have been and are still being built at the most popular towns. A mild climate, scenic attractions, safe sandy beaches for young children, good fishing, swimming and surfing, good sporting facilities and accommodation among friendly people, make Yorke Peninsula a pleasant and popular resort.

Chapter 2

THE GEOLOGICAL HISTORY OF YORKE PENINSULA

Geological history is much like any other history in that it depends on an orderly arrangement of facts. Geologists achieve this by constructing a stratigraphic column—a sequence of rock units placed in order of relative age.

One of the guiding principles of geology has been the theory of 'Uniformitarianism' first outlined by James Hutton (1726-97) and which can be stated more simply as 'the present is the key to the past'.

Hutton saw that the processes of erosion, sedimentation, consolidation and uplift, which we can observe today, together with metamorphism and volcanism, could be called upon to explain the geology of the past.

Just as the stratigraphic column has acquired greater detail and, during this century a more precise 'absolute' time scale, so the theory of 'Uniformitarianism' has acquired a depth of meaning beyond the vision of most early geologists.

The Concept of 'Plate Tectonics'.

The reasons for similarities and differences between rock sequences and fossils from different areas have long puzzled geologists.

Until recently, it was generally held that the continents had remained 'fixed' through time, and land bridges were postulated to explain fossil similarities in lands widely separated by ocean. The echo-sounders, the magnetometers and the very precise means of measuring distances and positions that have been developed in the last 25 years have led to an exciting expansion of Hutton's theory.

The mapping of a world-wide chain of mid-ocean mountain ranges and the measurement of movements of centimetres a year between continents, has confirmed what previously had been speculation. The continents are not 'fixed' but 'float' upon moving crustal plates. Geologists and geophysicists have mapped some ten such plates, most with continental masses upon them and which move apart as upwelling basalt moves outward from the mid-ocean ridges, which form the plate boundaries.

Where plate meets plate, one of two things usually happens. One plate may be subducted, dipping steeply beneath the other to a depth of 700 kilometres until it is absorbed in the mantle; or the two plates may slip past each other along a massive transform fault. The New Zealand-Kermadec Trench-Tonga Trench is such a subduction boundary, where the Pacific Plate dips under the Australian Plate, while to the north-west, the Australian Plate is being subducted in the Java Trench.

By applying Hutton's theory, that 'the present is the key to the past', we may glimpse the magnitude of the events that have built the Australia we know.

Rifting of the Australian land mass

Some 80-100 million years ago, parts of New Zealand were rifted off the coast of Eastern Australia leaving a broad band of sunken continental crust connecting the two countries.

The Norfolk Island Ridge and Lord Howe Rise are parts of this crust, while the northerly continuation of a former broad east-Australian continental shelf still stretches along the Queensland coast as the Great Barrier Reef for almost 2,000 kilometres and is as much as 300 kilometres wide.

The volcanoes of New Zealand and the islands to the east and north of Australia form a great series of island arcs and add the lighter silicates, melted from the descending Pacific plate, to the Australian plate.

To the north-west of Australia, shallow, oil-rich sediments of the North-West Shelf, some 650 kilometres across, are slowly approaching the Java Trench and the island arc of the Indonesian Archipelago. Here, in the making, is the same sort of collision that has thrust upward the

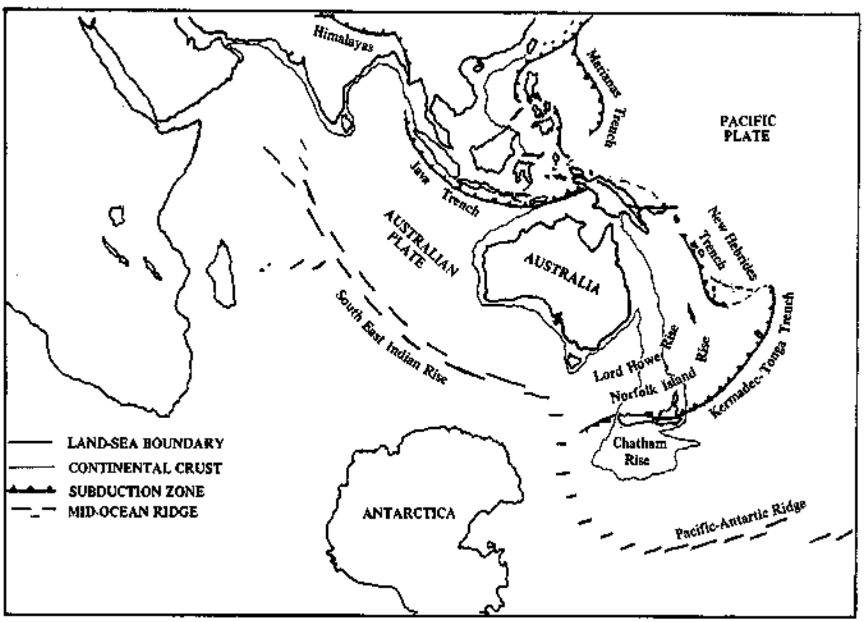


Figure 1: To the east of Australia, New Zealand is part of a great volcanic ocean-arc near the subduction zone. Submerged continental crust links the two countries. In early Precambrian time the subduction zone is thought to have been where central New South Wales is now situated. The Willyama province of Broken Hill lay between it and the mainland. Yorke Peninsula was part of a continental shelf which was colonized by 'coral-like' Archaeocyathids and scavenging Trilobites.

limestones and other sediments of part of the former Tethys Sea, to become the Himalayas as India collided with Asia.

The sediments now forming mountain ranges were originally deposited in structures called geosynclines. Uplifted and eroded former geosynclines, are normally found in couplets, with a miogeocline, or lesser geosyncline and a eugeocline, or true geosyncline. The miogeocline comprises the well sorted, shallow water sediments that cap the coastal plain and continental shelf to about 200 metres below sea level, that is, the edge of the shelf. The beds may reach a thickness of 15 kilometres as isostatic adjustments take place. The eugeocline is a thick and much less well sorted wedge of sediments spilled over the edge of the continental platform, often as turbidites derived from nearby volcanoes and with thin layers of limestone, ironstone and chert. Under compression, the eugeocline becomes intensely folded, metamorphosed and injected with granites.

Fifteen kilometres of sediments may be compressed into a mass more than 35 kilometres thick, throwing up a mountain range. The sediments of the miogeocline are thrown into less intense, ruglike folds because they rest upon the more rigid, crystalline, granitic basement of the continental craton.

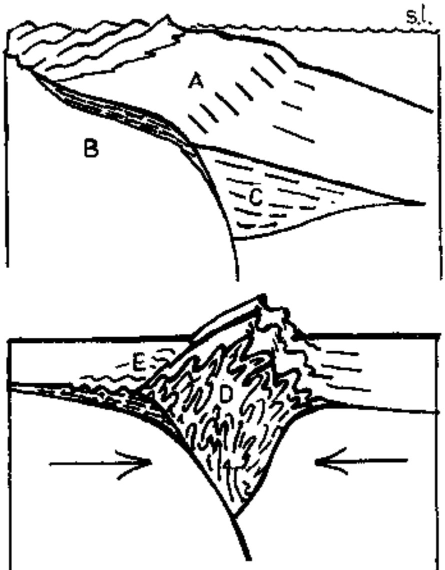


Figure 2a, b: Sediments from the land, form graded, well bedded, miogeoclinal deposits on the continental shelf (A). The beds lie on continental crust (B) and slope at about 1° to a depth of about 200 metres.

On the edge of the shelf the slope changes to about 5° and the sediments form a thicker eugeoclinal wedge, (C) as they spill to the deep ocean floor. Turbidity currents and mass slumping contort the beds.

Plate movements can compress this wedge to form a massive mountain range (D). The deeper sediments will be metamorphosed and injected by granites.

The miogeoclinal sediments (E), on the more rigid basement, will be folded less and may, in time, be partly buried by 'molasse' deposits eroded from the uplifted eugeoclinal wedge which will itself be eroded to form the basement for a new continental shelf.

Yorke Peninsula—the basement rocks

When the oldest rocks on Yorke Peninsula were being formed, the area was probably similar to the present Tasman Sea, with a major landmass to the west of the Gawler Platform and with islands and some continental crust, lying to what is now the east.

The vertically foliated gneisses, granites and other intrusive rocks of Yorke Peninsula are exposed over only about 10% of its almost 7,000 square kilometres, mainly around the coastline. The exact age of the most ancient of these basement rocks, roots of a mountain range formed under perhaps 20 kilometres of sediments, may never be known as subsequent metamorphism has reset the atomic 'clocks' that geologists use to date them.

Many features of the Yorke Peninsula basement gneisses suggest their origin as part of an ancient eugeocline complementary to the miogeocline of lower Proterozoic rocks (Cleve Metamorphic group) on Eyre Peninsula.

The Cleve Metamorphics comprise more than nine kilometres of metamorphosed sediments in the Cleve area and are prominent in the eastern highlands of Eyre Peninsula. They have an important marker band within them, the great iron formation which we see as a keel-like synclinal structure in the Middleback Ranges. Deposits of iron have not been found on Yorke Peninsula but some of the intrusive rocks are iron-rich and magnetic anomalies have been measured.

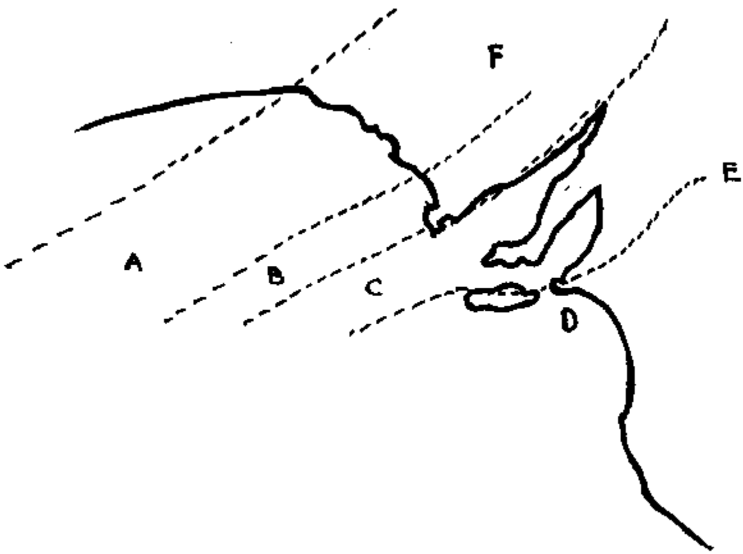


Figure 3: (*A*) Basement granites of the Gawler Block and remnants of the Cleve Metamorphics are thinly covered by Tertiary limestones. (*B*) More than nine kilometres thickness of the lower Proterozoic metamorphics form the Eastern Highlands of Eyre Peninsula. (*C*) Apparently related gneisses underlie the Adelaidean rocks of the Flinders and Mount Lofty Ranges and (*D*) granites and highly metamorphosed rocks of the Kanmantoo Group formed a similar eugeocline in Cambrian-Ordovician times. (*E*) The Broken Hill Province was an ancient island thrust westwards by orogeny. (*F*) The Gawler Range Volcanics have been remarkably stable for 1,500 m.y. Perhaps half of an estimated *two kilometres of their original thickness remains.*

Great beds of iron-rich silicates were deposited around the world in the period from 3,200 million years ago to 1,800 m.y. and the banded-irons that make up the immense iron ore deposits of Western Australia are of a similar age.

Some confirmation of the age of the apparent mio-eu-geosyncline couplet of the Cleve metamorphics and the basement rocks of Yorke Peninsula can be gained from the granites and gneisses of Eyre Peninsula. The ages of these vary but they indicate a major orogeny, when the rocks were folded and uplifted, from about 2,000 to 1,800 m.y. ago.

After this mountain building episode, Yorke Peninsula and adjacent areas were eroded, leaving a gap, or 'unconformity' in the historical record.

The gap can be partly filled by looking to Eyre Peninsula. Perhaps some of the rocks from Yorke Peninsula went to make up the early Carpentarian (1800-1400 m.y.) mineral banded quartzites and conglomerates of the Moonabie Formation, near Whyalla. This type of material is called 'molasse' and is normally deposited in intermontane basins in the final phase of an orogeny. A thick sequence of volcanic rocks, the Gawler Range Volcanics, had poured out over hundreds of square kilometres from about 1,535 m.y. with the focus of activity slowly moving to what is now the north-east.

It was not until nearly the end of the 400 million year interval of Carpentarian time, at about 1480 m.y. ago that dykes near Corunna on Eyre Peninsula and the related Moonta Porphyry on Yorke Peninsula were intruded. This marked the end of volcanism in the region.

Sedimentation begins again

The whole of the Adelaidean basement including Yorke Peninsula had been peneplaned, and sedimentation began again about 1,400 m.y. ago, but there is little evidence of this phase present on the Peninsula.

This was because Yorke Peninsula had become a relatively stable hinge zone near the edge of the continent with most of the sediments being transported to the east to provide the materials for the future Mount Lofty and Flinders Range.

A small area of Sturtian tillite, (an ice-transported boulder deposit) is the only evidence on the Peninsula of the passage of the Australian land mass through polar zones some 800 m.y. ago.

The delicate balance between subsidence and sedimentation on the Adelaidean shelf, from about 1,400 m.y. to 600 m.y. ago is unique in world geology because of the vast time span involved. As much as 24 kilometres of sediments accumulated as the continental shelf gently warped downwards and the Gawler Platform landmass rose.

Evidence of Early Life

In those treeless, grassless times, sediments accumulated at an average rate of 30 cms. in 10,000 years, about twice the measured Tertiary Period accumulation rate in St. Vincent's Gulf. Although worm casts and other fossil evidence in the Upper Precambrian rocks indicates that life was evolving, it was not until Cambrian times that organisms learned the trick of taking calcium from the sea to make themselves protective shells.

In the warm Cambrian seas, evidence derived from a study of the magnetic particles in the sediments (palaeomagnetic evidence) indicates that the equator ran from Victoria through central Australia to the Kimberley District. Lying directly on the crystalline basement in basins from below Minlaton almost to Moonta is an arkose, a felspar-rich sandstone, containing fossils of sponges, gastropods and the thin

Figure 4: Probable maximum extent of the sea (shaded area) during Precambrian-Cambrian times in South Australia.

conical shells of hyolithids. The arkose is interbedded with thick limestones and dolomites.

This unit is overlain by the Kulpara Limestone with algal limestones, an unfossiliferous zone and, near the top, a profusion of fossils.

The archaeocyathids, the most useful of Cambrian fossils because of their limited time range, superficially look like corals but are not related to them. They grew in large numbers forming reef-like structures.

The limestones also contain the remains of brachiopods, gastropods, hyolithids and fragments of trilobites, the scavengers of the shelf.

The Parara Limestone, dark grey, massive and rubbly, with egg-shaped carbonate nodules, overlies the Kulpara Limestone on Yorke Peninsula but inter-fingers with its equivalents elsewhere, indicating changing conditions within an increasingly mobile deposition zone. Next, Yorke Peninsula was uplifted, allowing the partial erosion of the Kulpara and Parara Limestones.

Eroded material from here and the surrounding land areas went to fill the rapidly subsiding Kanmantoo Trough, 80 kms to the east, where as much as 18 kilometres of eugeoclinal rocks can now be seen in a great arc around the eastern side of the Mount Lofty Ranges and on Kangaroo Island. Evidence for past rifting of the Australian land mass can be seen in the discovery of the same Cambrian Kanmantoo rocks near Bega in N.S.W., among geologically very much younger rocks.

On this erosional disconformity, the Minlaton Conglomerate was laid, apparently from deep gully erosion of nearby more elevated areas. Red beds, stained with iron, are followed by more limestones, rich in trilobites, brachiopods, sponges, hyolithids and the shallow water alga, Girvanella.

The study of bore-hole samples shows continued, if not always continuous, deposition of red felspathic sandstone, silt and mud, derived from the erosion of uplifted blocks on the site of the present day St. Vincent's Gulf and Investigator Strait.

Orogeny

The Delamerian Orogeny, the plate movement which ended the 800 m.y. of deposition in the Adelaide geosyncline, apparently began in Upper Cambrian times and extended into the Lower Ordovician. It did not involve massive volcanism in South Australia, like the previous outflow of the Gawler Ranges, but some basic rocks were intruded, with more rarely acid porphyry, as at Burra. The orogeny slightly folded the Cambrian limestones of Yorke Peninsula and caused some overthrusting near the Hummocks.

The fossil record for the Ordovician, Silurian, Devonian and Carboniferous periods is missing on the Peninsula, indicating that the region was a land area throughout this lengthy time period.

Glaciation

Permian glacial till and erratics mark the passage of Australia, or rather Gondwanaland (the supercontinent made of Australia, Antarctica, India, Africa and South America), through southern polar regions about 270 m.y. ago. Widespread evidence from these countries indicates that much of the supercontinent was below sea level, held there by the weight of the ice, as is happening in Antarctica now.

Erosion from the rising land, freed of its burden of ice, left another unconformity on the Peninsula.

Rifting and the Tertiary

The break between Australia and Antarctica, about 100 m.y. ago, caused a weakening and sagging of the crust over large areas of Australia, producing the depositional areas of the Nullarbor (Eucla Basin), the Murray Basin and the St. Vincent Basin of the gulf region.

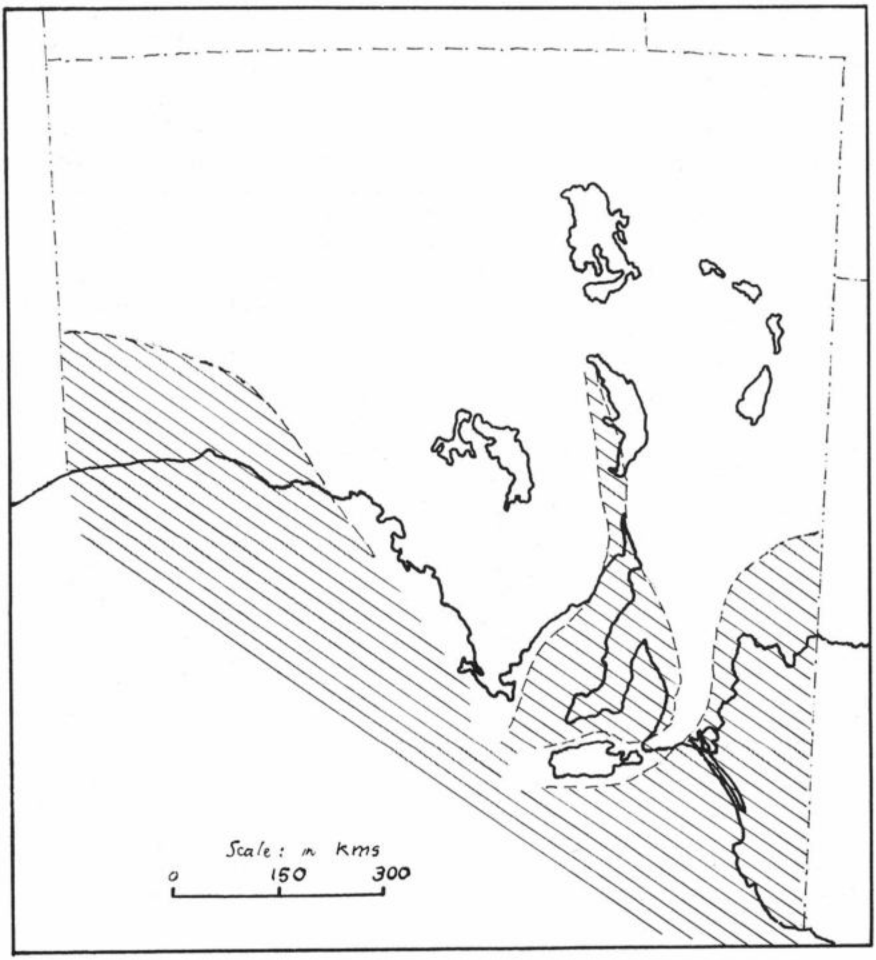


Figure 5: Probable maximum extent of the sea (shaded area) during Tertiary times in South Australia.

On the Peninsula, the Clinton Lignite and Muloowurtie Clay are equivalents of the freshwater North Maslin Sands, the South Maslin Sands and the Tortachilla Limestone of the eastern side of the St. Vincent Basin. The Blanche Point Marls are found on both sides of the basin and equivalents of the Port Willunga Beds extend to middle Miocene times when sedimentation ceased.

Present Day Land and Sea Movements

The resultant unconformity in the St. Vincent Basin was caused by the Kosciusckan orogeny of Eastern Australia which is still continuing. The seas returned late during the Pliocene Epoch about 2 m.y. ago, leaving thin beds of oyster shells, equivalent to the Hallett Cove Sandstone, at Point Giles and other localities.

The Quaternary, the latest geological Period, has been a time of major sea-level changes related to the waxing and waning of ice caps in the northern and southern hemispheres. There has been, overall, a fall in sea-level, as water has been locked up in the ice caps during the glacial periods. The vast aeolianite dunes, formed of consolidated shell fragments, seen on Yorke Peninsula and other parts of the South Australian coast were formed at this time.

In the last 10,000 years, sea-level has risen around the world by as much as 90 metres. Evidence of this may be seen as wave action erodes fossil-rich limestones to form new bays and islands on the coast of the Peninsula.

Further Reading

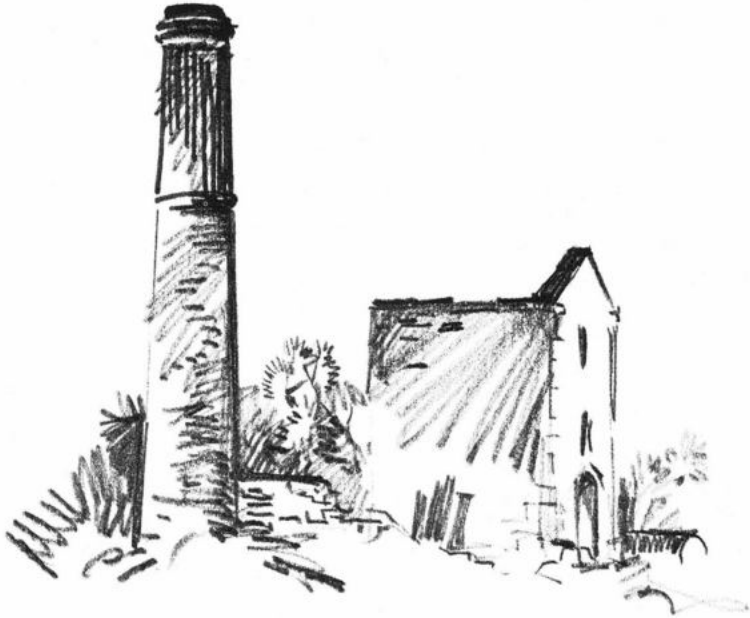
This chapter has done no more than sketch the geological history of Yorke Peninsula and some of the ideas of plate tectonics. For more detail the reader must turn elsewhere.

Earth science articles in the 'Scientific American' provide a good review of the very new science of plate tectonics. In particular, 'Plate Tectonics' by John F. Dewey, (May 1972) and 'Geosynclines, Mountains and Continent-building' by Robert S. Dietz (March 1972), are useful, but there are many others.

Other general references are given in the reading list on p 65.

YORKE PENINSULA SEQUENCE

Time Scale (Figures give commencing date for Period)	
Quaternary *The last 2 million years*	Block faulting of the Flinders and Mount Lofty Ranges is continuing and most present day geomorphological features have developed in this period. Additionally there have been changes in true sea level of more than a hundred metres due to glaciation and melting of the polar icecaps.
Tertiary 65 m.y.	Block faulting began in this period, extensive basin sediments were laid down in South Australia. Good exposures of Tertiary rocks can be seen on the eastern coast of Yorke Peninsula.
Cretaceous 135 m.y.	Unconformity. A long period of erosion when the glacial deposits were removed from higher areas.
Jurassic 190 m.y.	
Triassic 235 m.y.	
Permian 270 m.y.	Glaciation of Gondwanaland. Glacial deposits similar to those on Yorke Peninsula have been found in other countries. It is believed that they were joined to form a large polar continent.
Carboniferous 360 m.y.	
Devonian 395 m.y.	
Silurian 440 m.y.	
Ordovician 500 m.y.	The rocks of the continental shelf—the Adelaide Geosyncline were folded. Evidence of overthrusting from the compression can be found on the Peninsula.
Cambrian 570 m.y.	The stable platform rocks of the Peninsula sank to receive a variety of Cambrian sediments, arkoses, dolomites and fossiliferous limestones and red beds. There was a break in deposition when some of the sediments were eroded.
Adelaidean 1400 m.y.	Unconformity. A small area of Sturtian tillite and some quartz sands and conglomerates originally defined as 'Shield Proterozoic' were deposited in this period.
Carpentarian 1800 m.y.	Unconformity. It is likely that the basement gneisses were formed early in Carpentarian time. The Moonta Porphyry was intruded near the end of this period.
Lower Proterozoic 2250 m.y.	Stratigraphic and magnetic evidence makes it likely that the sediments from which the gneisses were formed were deposited from about 2000 m.y. ago.
Archaean Up to about 4500 m.y.	Geological maps and many references show the basement rocks of the Peninsula as Archaean. Accurate age dating has pushed this period back in the geological time scale and no Peninsula rocks may be as old as this.



Chapter 3

1. NORTHERN AREA

The traveller leaving Port Wakefield and heading north-west towards Yorke Peninsula will note the contrast between the rounded mass of the South Hummocks lying to the north and the low flat-topped plateau of the Peninsula stretching away to the south. (The Hummocks are formed of Precambrian sedimentary rocks related to those of the Flinders Ranges and lie outside the Peninsula as described in this guide).

Taking the Kulpara road, the visitor soon begins the sharp climb onto the plateau in a series of curves. The change in altitude between the salt flats at the head of the gulf and the town of Kulpara reflects the underlying geological structure and marks the surface expression of the *Kulpara fault,* a line of dislocation in the rocks which has raised the western (peninsula) country relative to that to the east. The topographic feature formed by the fault is known as the *Kulpara Fault Scarp.*

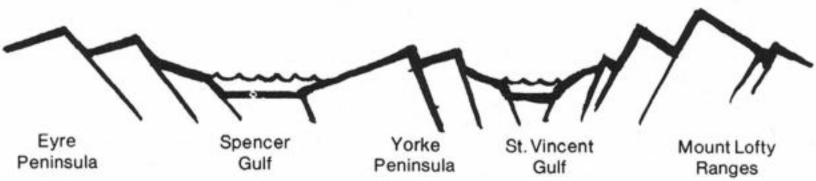
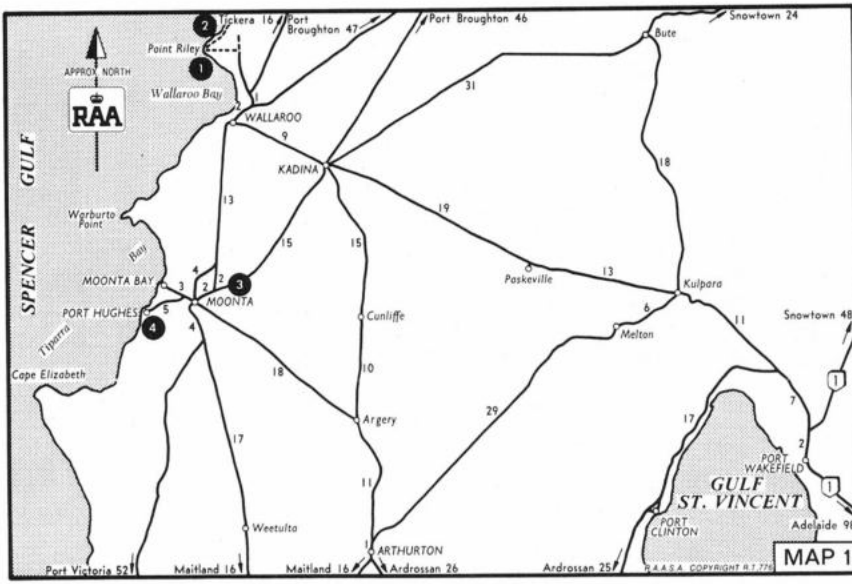


Figure 6: (after Twidale):

Yorke Peninsula is considerably affected by faulting initiated in late Tertiary times and which has broken the region into a number of fault-blocks the edges of which produce the characteristic low, but sharp, breaks in slope (the fault scarps) which are a noticeable feature of the topography of the area.



Locality 1. Point Riley

The first locality to be visited in the northern area is Point Riley. Proceed to Kadina and on to Wallaroo, taking the road north past North Beach and turning onto the dirt road, drive for 5 km to a cross-roads and turn left to Point Riley.

At the Point, and for several kilometres either side, there are good fore-shore outcrops of some of the oldest rocks exposed on the Peninsula. These are highly altered rocks, both metamorphic and igneous, which form the foundation or basement upon which all the other rocks on the Peninsula are found to rest. They are therefore commonly referred to as the *basement rocks.*

An examination of the Point Riley rocks shows a marked variation in grain size, from very coarse to quite fine, with the common feature that all are crystalline, that is, metamorphic or igneous in origin and not fragmental, that is, of sedimentary origin. The crystalline nature of the rocks is best seen in the prominent outcrops of brick-red 'granite' which are composed of large felspar crystals, reddish-brown in colour and which give the rock its overall colour, together with subsidiary amounts of clear to milky quartz. The felspars show the development of the well-marked cleavages characteristic of this mineral. The quartz exhibits no cleavage and fills in the 'spaces' between the larger felspar masses. These coarse felspar/quartz rocks are known as *pegmatites* and are igneous rocks intruded as mobile solutions during the later stages of consolidation of an igneous magma. Because of the fluidity of the parent material pegmatite minerals frequently grow to quite large size and often show good development of crystal faces.

Narrow veins of quartz, a few centimetres wide, are also conspicuous at the Point, again showing well-formed crystals, and there are also large blocks of vein quartz which have been derived from the weathering of larger quartz veins in the vicinity or offshore.

The commonest rock at Point Riley and to the north and south, is a fine-grained grey rock which is composed of the same minerals—quartz and felspar—as seen in the pegmatite, but which is known as *gneiss*. Gneisses are produced by deep-seated alteration of pre-existing rocks by heat and pressure. They are referred to as high-grade metamorphic rocks and they clearly indicate intense modification of what may have been an igneous or sedimentary parent rock.

The basement rocks of Yorke Peninsula are predominantly gneisses and their presence indicates the long and complex history of the region during Precambrian times. The intrusion of the pegmatites and quartz veins took place at a later stage, but still within Precambrian times, so that all the rock types so far described are classed as basement.

Similar rocks as well as types not seen at Point Riley will be described in the itineraries for the Central and South Western areas.

Locality 2. 1½ km North of Point Riley.

Take the vehicle track along the cliff-top for a distance of 1½ km north of the Point, and descend to the beach. The cliff at this locality is formed of limestone rich in fossil remains, which rests on the Precambrian basement described above. The actual contact is not visible at this point. The fossils occurring in the limestone are of marine animals similar to forms living in seas at the present time. They include the spines and broken skeletons of echinoids (sea-urchins), casts and molds of molluscs and also the large disc-shaped foraminiferan, *Marginopora*. Most abundant of all are the broken remains of 'lace-corals' or 'moss-animals' which are in fact bryozoans—an important group of marine animals living in colonies (see also p. 43). Some limestones are so rich in the remains of bryozoa that they are termed bryozoal limestones. The rocks at locality 2 are of this type.

From a study of the fossil content of this particular limestone, geologists have assigned it to the Miocene epoch of the Tertiary period. Rocks of this age will be met with again in areas 2 and 3. On the north-west coast of the Peninsula, Tertiary rocks crop out as far as Tickera to the north and also south to Wallaroo.

The Tertiary rocks of Yorke Peninsula are comparable in age to those forming the cliffs of Port Willunga and Aldinga, south of Adelaide on the opposite side of the gulf.

A distinctive feature at Locality 2 is the prevalence of solution-cavities in the upper layers of the limestone. These are frequently filled with large nodules of crystalline gypsum. Examples of these can be seen weathered from the cliff on the path down to the beach.

Return via Point Riley to Wallaroo and take the main road south to Moonta. Do not proceed directly to the town but continue on for 2 km to the junction known as 'Cross Roads' (keeping the railway on your left). At the junction, turn left over the railway line and immediately right onto a dirt track. The old ore dumps of the Yelta Mine are clearly visible a few hundred metres along on the left hand side of the track.

Locality 3. Yelta Mine Dumps.

The discarded pile of mined ore-rocks covers an extensive area and will prove a fruitful hunting ground for the mineral collector for many years. The Yelta Mine was one of many operative in the Moonta area between 1862 and 1923 when the mines closed. The rich copper mineralisation is associated with deep-seated Precambrian igneous rocks which are part of the basement described above, but which do not crop out at the surface in the mines area. At Moonta the host rock for the copper ores is the *Moonta Porphyry,* a fine grained greyish rock containing conspicuous red-brown felspar crystals. Specimens can be picked up in the dumps that have been derived from the workings. The list of minerals that have been recorded from the Wallaroo-Moonta lodes is extensive, each area, indeed each mine, often having its own distinctive suite of minerals.

Plate 1: Just memories left from the days when copper was king.

Ore rocks in a mining area contain the ore minerals (those of economic importance) and the gangue minerals (those associated with the ore minerals but of no economic importance). Among the ore minerals chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) were the most important. Some chalcopyrite can be picked up at Yelta but more abundant is the somewhat similar, brassy iron sulphide pyrite (FeS_2), one of the gangue minerals.

Other minerals likely to be found at Yelta include the iron oxide, hematite (Fe_2O_3) and a variety of hematite called martite (a pseudomorph, or replacement, of another iron oxide—magnetite). Martite retains the crystal form of magnetite but has changed chemically to hematite.

Tourmaline, a hard black complex silicate mineral and the somewhat similar dark mineral, horneblende, are also to be found, together with biotite (black) mica, felspar, and the distinctive green mineral, epidote.

Although the colourful oxidised copper minerals, malachite (green) and azurite (blue) are not found here, some of the rock surfaces are covered with a greenish-blue colourisation, which has formed from copper-charged waters depositing a secondary mineral—in this case *chalcanthite* (copper sulphate).

From Yelta, an interesting yet brief tour can be made of the mining area by following the strategically located signs. Of particular interest are Ryan's Shaft (site of the original discovery), Hughes Pump House and the National Trust Museum housed in the old schoolhouse, and the Miner's Cottage Museum.

Plate 2: The early settlers found building stone close at hand. In the foreground, kunkar boulders and at the rear a house built from the limestone.

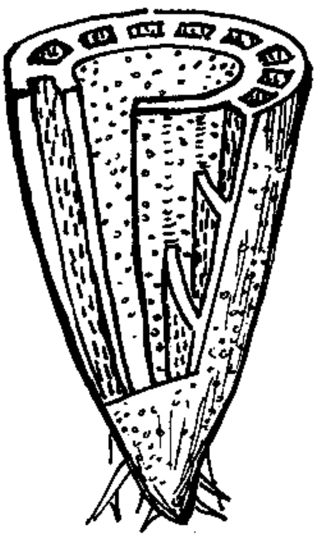
Locality 4. Port Hughes.

Returning through the town of Moonta, take the road to Port Hughes (not to be confused with Point Hughes on the coast south of Wallaroo). Here on the foreshore and south of the jetty,are extensive exposures of a flat-lying coarse pebbly sedimentary rock (conglomerate). This is the oldest sedimentary rock exposed on the Peninsula and rests uncon-

Plate 3: Above—Basal Conglomerates on the beach at Port Hughes. *Below*—A closer picture shows the large, well worn, quartz pebbles in the rock. Such pebbles may have been re-worked many times by the sea, as indeed, they are now being re-worked.

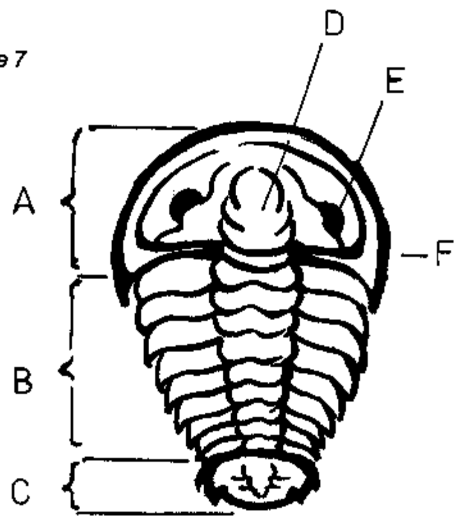
formably (i.e. with discontinuity) on the underlying basement rocks. These are poorly exposed but may be seen near the jetty.

The conglomerates have previously been described as Precambrian (Shield Proterozoic), but they may be of Lower Cambrian age. Whatever their age they indicate the initial incursion of the sea over an eroded Precambrian landscape. Conglomerates are very useful rocks to the field geologist, for they provide evidence of former shoreline environments, frequently, as here, marking the onset of a cycle of marine deposition. A close look at the conglomerate shows that the contained pebbles are well-rounded and chiefly of quartzite. Because of the coarse nature of the rock, no fossils are found in the conglomerates. Somewhat younger sedimentary rocks, predominantly limestones, which occur in other parts of the Peninsula near Kulpara and Ardrossan and at Curramulka do contain fossils which are of undoubted Cambrian age and the Port Hughes conglomerates are taken to mark the initiation of this phase of marine deposition. By inference, the highly altered rocks of the basement which lie beneath these Cambrian sediments are of Precambrian age.

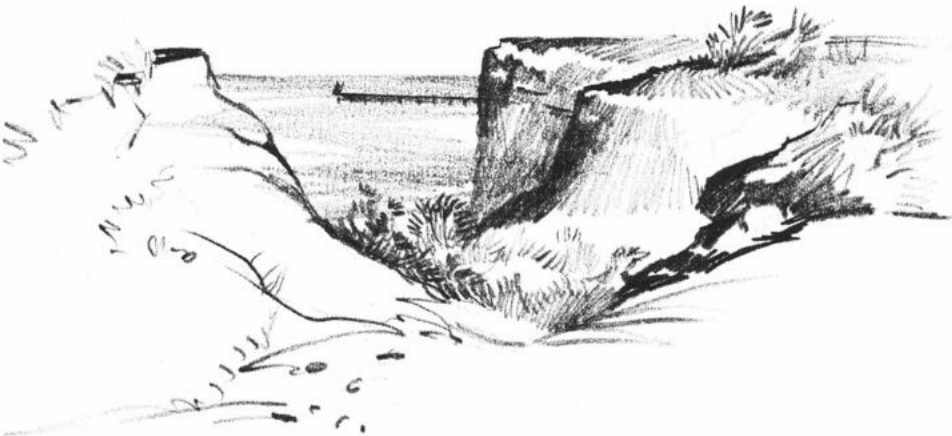


The Archaeocyathae lived in great numbers in the warm Cambrian seas. *Left,* the drawing shows a fossil cut away to show porous double cones joined by radial walls.

Figure 7



Trilobites scavenged the shallow sea bed. There were many species varying from a few centimetres to a metre long. Presumably many soft-bodied creatures served as their food supply but we have little or no knowledge of them. *Right,* a typical Trilobite with (A) Cephalon, (B) Thorax, (C) Pygidium, (D) Glabella, (E) Eye and (F) Genal Spine.



Chapter 4

CENTRAL AREA

Note: This excursion begins at Ardrossan. Localities 1-4 along the east coast can be treated as a separate excursion and linked to the itinerary for Area 3 (Southern area). To adequately cover Localities 1-4 will take about three quarters of a day.

The cliffs at Ardrossan and Pine Point can only be examined with safety at low tide. The localities described are approached from the shore platform by walking along the beach from the nearest access road. It is necessary to obtain permission from the B.H.P. Company, by contacting their office in Adelaide, before visiting the quarry.

Locality 1. Ardrossan Town Jetty

The approach to the Ardrossan Town Jetty makes use of a deep gully, which gave the town its original name of Clay Gully. The cliffs, approximately 18 m. high in this locality, are comprised of mottled red and green coloured clays overlain by red coloured sandy clays with gravel bands and lenses (Pl. 4a). These are of Pleistocene age, and are capped by surface limestone. The thin white bands that occur in the red clay of the cliffs in some places are of alunite (a hydrous sulphate of aluminium and potassium). Fossils do not occur in these cliffs although pebbles of older rocks containing fossils are common on the wave-cut platform beneath them—presumably these have been carried by currents from localities further south where they crop out.

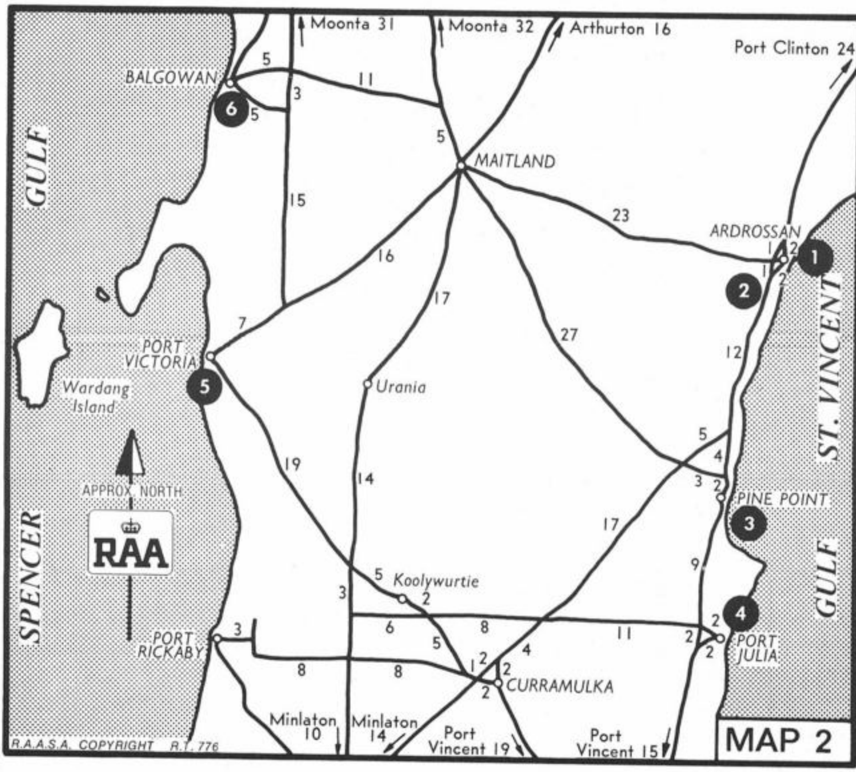
Cambrian fossils can be found in the water-washed pebbles at the base of the cliffs approximately 300 yards north of the jetty at low tide. The colour of the host rock varies from greyish-white, to buff, pink, and dark greyish-blue. The fossils are *Archaeocyathae* ('ancient cups') which were sponge-like animals which lived in fixed positions on the sea-floor, as do the present-day sponges (see Fig. 7).

Trilobite remains can also be found here. These generally occur as fragments, and at first may be difficult to locate. As noted above in the itinerary for Area 1, Cambrian rocks crop out south of Ardrossan in the Horse Gully area. Water-worn boulders of greenish coloured clay-rich rocks, containing numerous screw-like shells may also be found along the beach at the base of the cliffs (Pl. 4b). These are the remains of the gastropod Turritella, and the material in which they occur is a sandstone of Eocene (Tertiary) age, containing the mineral glauconite. Tertiary sediments, containing a large assortment of fossils, including molluscs and bryozoa, form a major portion of the cliffs south of this location (see p. 30).

Also to be found here are patches of black sand, which consist entirely of grains of ilmenite, a heavy, black, metallic mineral (an oxide of iron and titanium).

Locality 2. B.H.P. Dolomite Quarry

Proceed south out of the town towards Pine Point. The B.H.P. Quarry is just out of the town on the right hand side of the main road. The quarry, in which limestone and dolomite of Cambrian age are worked, was opened in about 1946. The buff coloured dolomite (a



ARDROSSAN TOWN JETTY LOCALITY.

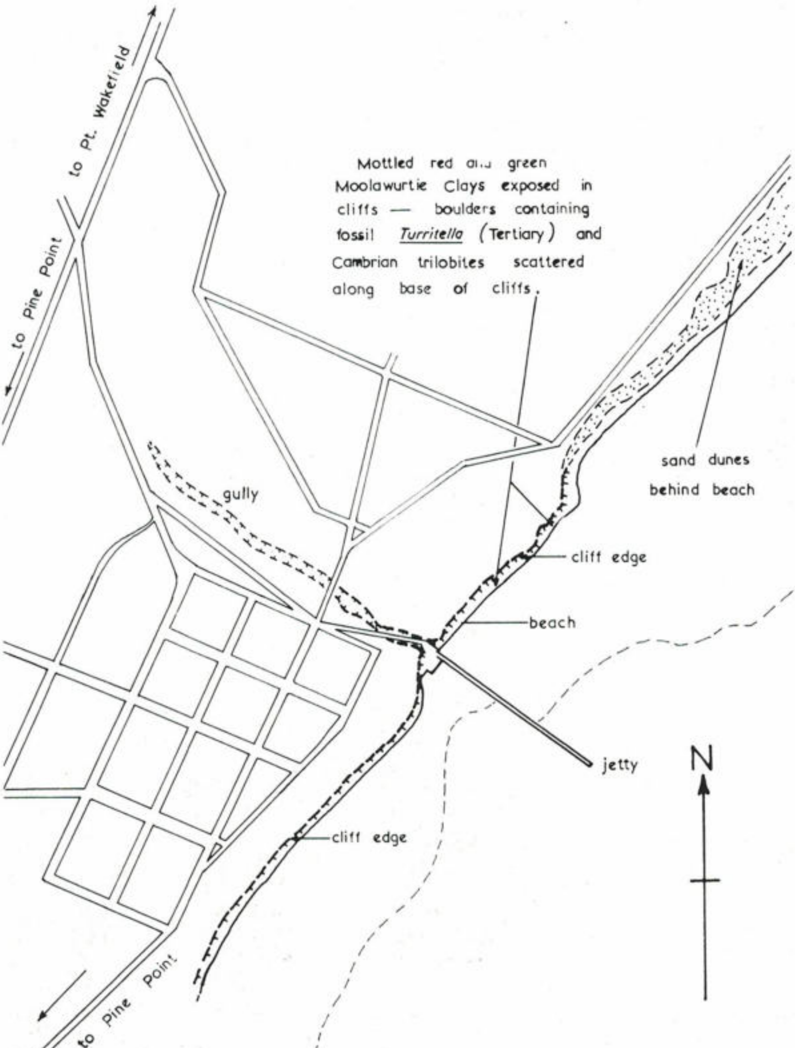


Figure 8:

calcium-magnesium carbonate) occurs as westerly dipping beds (Pl. 5a). Along joint planes and fractures in the dolomite there are abundant dendritic (fern-like patterned) growths of black manganese dioxide, precipitated from ground-water solutions.

Channels and potholes, eroded in the upper surfaces of the dolomite outcrop during Tertiary times, have been filled with sand and gravel composed almost entirely of well-rounded quartz grains and pebbles. In

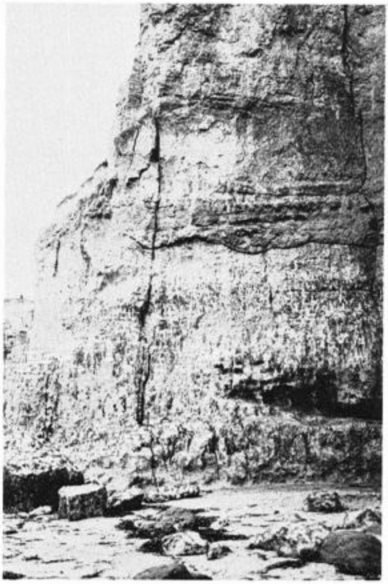


Plate 4a: Cliff section north of Ardrossan Jetty

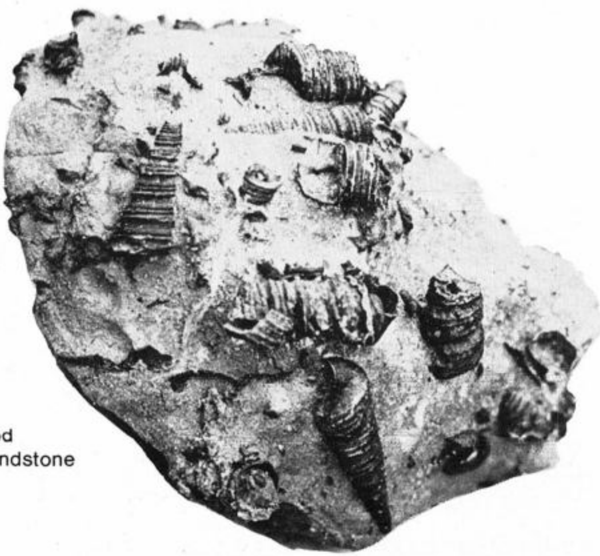


Plate 4b: Fossil gastropod Turritella in sandstone

some layers, the grains and pebbles have been coated with brownish iron oxide. The boundary between the Cambrian dolomite and the Tertiary pebbly sandstone is a good example of an unconformity; in this case representing a break in the geological record from Cambrian to Tertiary times, a period of some 500 million years.

There are no fossils to be found in the limestone and dolomite beds in the quarry.

Continue south along the coast road to Pine Point.

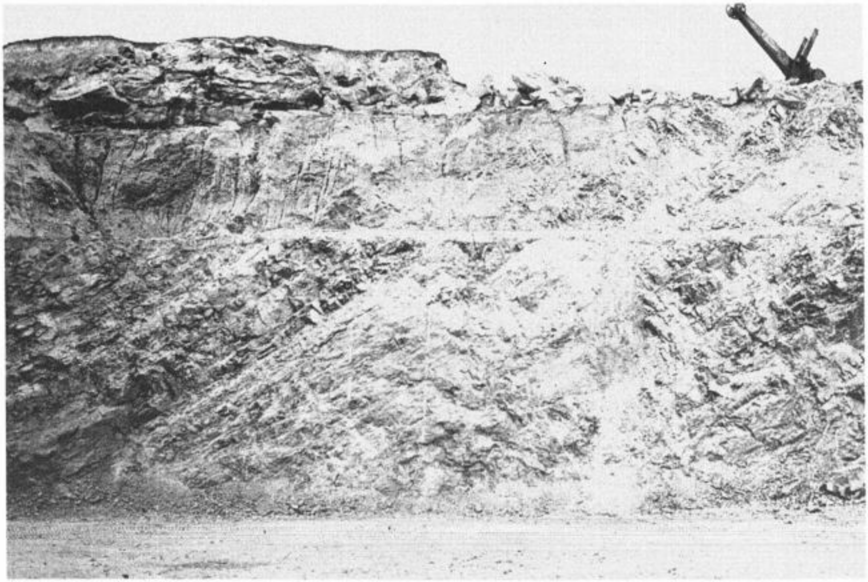


Plate 5a: The cliff face, B.H.P. Quarry, Ardrossan.

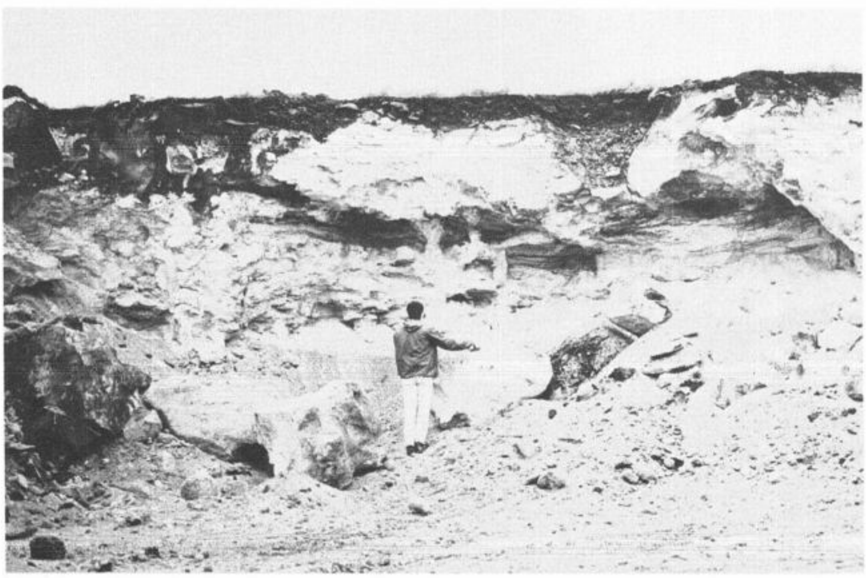


Plate 5b: Tertiary sands, B.H.P. Quarry, Ardrossan.

PINE POINT LOCALITY.

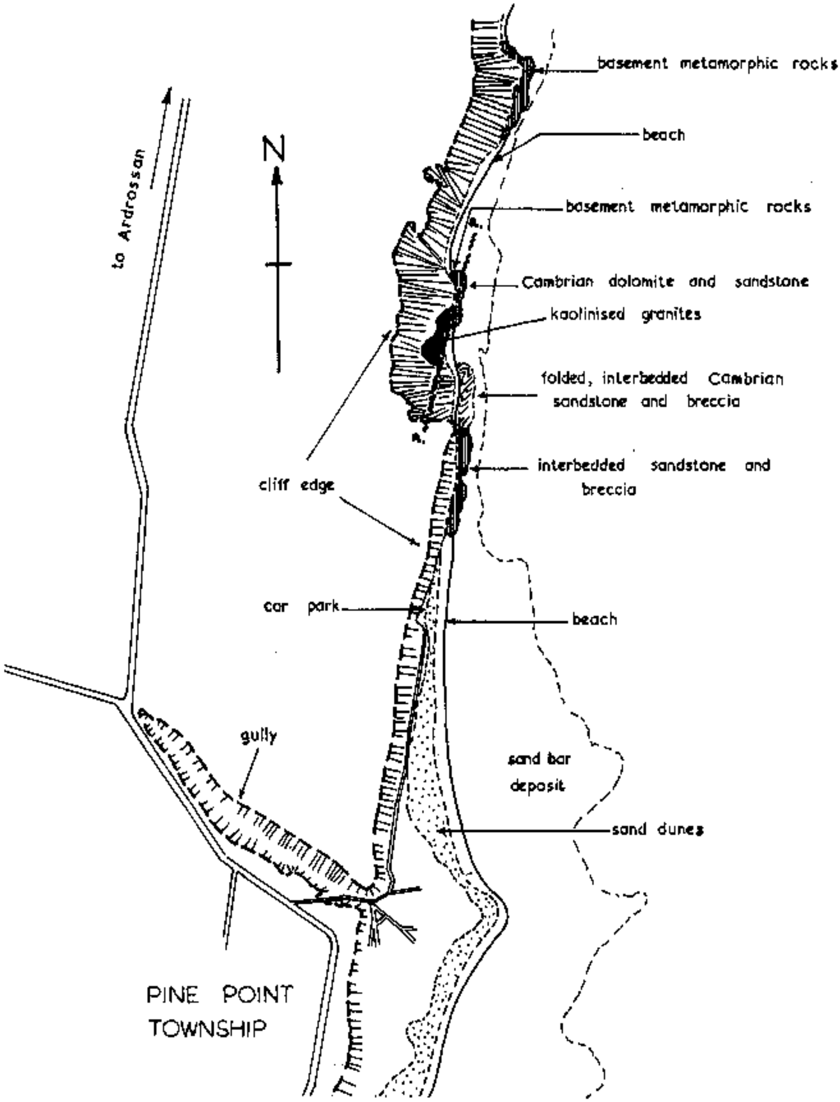


Figure 9:

Locality 3. Pine Point

On the beach about 275 m. north of the Pine Point Jetty, there are masses of red coloured *breccia* comprising bands and lenses of angular fragments of granitic and metamorphic rocks, inter-layered with bands of red sandstone. These sediments are of Cambrian age. The research work carried out on the Cambrian rocks of Yorke Peninsula by Dr B. Daily of the Geology Department at the University of Adelaide, has shown this sandstone and breccia to be stratigraphically younger than the Cambrian limestones, but at this locality they appear to be faulted against the basement rocks. This fault contact is evidence for the existence of the Ardrossan Fault, which finds its topographic expression in the well-marked fault scarp along the eastern edge of the Yarraroo Hills inland from Ardrossan and along the coastal cliff near Pine Point. The fault was initiated in Cambrian times, but was re-activated in late Tertiary times.

Further north along the beach, basement rocks crop out in the cliffs. They include kaolinised aplites (fine grained granitic rocks), and granites, together with serpentinised calc-silicate rocks. Good specimens of the minerals kaolinite (a white clay mineral), epidote (a pistachio-green mineral), serpentine (a fibrous, greenish mineral) and occasionally dark green to black amphibole can be found here. In some places, for example in White Clay Bay, extremely large granite masses have been completely altered to kaolinite which was mined in earlier times.

A little more than 3 km. north of Pine point, along the beach, Captain Hart, in 1847, opened the first copper mine on Yorke Peninsula. Captain Hart and Mr. A. Weaver bought two sections of land in this area, claiming they were going to establish a whaling station and sheep run. Instead however, they began mining copper, but were not successful.

Interesting specimens of malachite (a bright green copper carbonate) can still be found near the main shaft and in associated pits and diggings.

Near the Pine Point jetty, the beach is littered with limonite nodules, while in the cliffs behind the beach, there is abundant yellow chert and jasper.

Continue south from Pine Point to Port Julia. Tertiary rocks outcrop along considerable stretches of the eastern coast forming cliffs from Rogue Point south of Ardrossan to near Black Point. Here at the Point in geologically recent times, longshore drift of sand has created a seaward-jutting accumulation of sand known as a *cuspate foreland* producing the distinctive local coastal feature. The Tertiary rocks appear again at Port Julia.

Locality 4. Port Julia

Walking south from the jetty for 250 m. the cliffs are found to be reddish-brown sandy limestone. The reddish colouration is due to iron-staining. The rocks are sparsely fossiliferous but can be equated with the sequence of rocks of the eastern side of the gulf of the Maslin Bay-Port Willunga area.

The most interesting feature of this locality is the distinctive layer (stratum) of dark green sandstone known as the Port Julia Greensand which occurs at the base of the cliffs. It is about 0.5 m. thick and forms a useful geological marker horizon. The green colour is due to the presence of the mineral glauconite in the rock. Glauconite (a hydrated iron silicate related to the micas) is indicative of a shallow marine environment of deposition.

An anticlinal fold (upfold) can also be seen in the cliffs at this locality. *Note:* Hammers are not required. The greensand in particular is extremely soft and liable to erosion. The cliffs here are unstable and climbing is both unnecessary and dangerous.

Plate 6: Port Julia: Cliff section with green sand at base.

From Port Julia the excursion can be continued south to link with the itinerary for Area 3. To complete the excursion travel due west then turn north-west through Koolywurtie, and on to Port Victoria.

Locality 5. Port Victoria

The foreshore reveals extensive exposures of Precambrian basement rocks comparable with those seen at Point Riley (p. 22) and also at localities in the south-western area.

Many of the rocks are banded reddish-brown and grey gneisses. They are rich in felspar, and the overall colour of the rock is determined by the colour of the felspar. Muscovite (white mica) is abundant in some layers. Pegmatites also occur and indicate a later intrusion into the highly altered gneisses.

A distinctive rock type not seen further north but which becomes abundant in the south-western area is the dark-grey to black rock *amphibolite.* Amphibolites are composed of felspar and hornblende and vary in grain size from fine to coarse. They are rocks produced by the metamorphism of igneous intrusions—either concordant sheet-like bodies (*sills*); or less commonly from cross-cutting intrusions known as *dykes*.

Epidote is a common constituent of the amphibolites and also occurs in the gneisses.

Locality 6. Balgowan

In contrast to the crystalline basement of Port Victoria, about twenty kilometres to the north, the cliffs of Balgowan present perhaps the most complete section in Quaternary geological history of the peninsula, when the shore of Spencer Gulf lay further to the west. About a quarter of a kilometre north of the jetty, the early Pleistocene Ardrossan Clays and Sand Rock are exposed at the base of the cliff. Here the exposure of sandy clay is a brilliant orange-brown colour and extends northward for about one kilometre before disappearing below sea level. This is overlaid by a fine exposure of nearly three metres of the red sandy clay with alunite seams which comprise a major portion of the Ardrossan cliffs (see page 28) and can also be seen on other parts of the east coast.

On this red clay lie eight to ten metres of calcareous loess (fine wind-blown deposits) and the top of each added accumulation is marked by a duricrust of kunkar nodules. This is the south-west corner of a large area of seif dune formation which extends northward to Moonta and inland almost to Maitland and Arthurton. The dunes originated under desert conditions comparable to those of Central Australia today. Similar dunes are to be found north of Wallaroo, between Minlaton and Stansbury, and almost continuously, as a thin belt running from there northwards near the east coast. Inland they show, in roadside cuttings, a development of layers of pale brown sand above layers of kunkar which rise in conformity with the crests of the dunes. This suggests arid conditions alternating with more humid periods when the lime was leached to the subsoil. The dunes are palest in the west and south-west, becoming redder to the east and north-east.

At Balgowan the base of the dune complex is a soft, pale-orange calcareous rock containing soft nodules of lime and resting on the red clay. Crawford, in attempting to explain the lack of bedding, suggests the sudden accumulation of calcareous aeolian material in water, though he admits the truncation of the dunes by the present coast indicates that accumulation occurred at a time when sea-level was lower than at present. The absence of the massive pink kunkar layer which is present on so much of the peninsula can probably be explained by a difference in physical conditions. The flat sheets occur on the lower-lying wind swept areas where loessal deposits were thinner and lime charged water accumulated for short periods, permitting more deposition from solution.

There is therefore a coalescence of several separate deposits into the one flat sheet of rock, producing the nodule within nodule texture. Traces of black or dark organic matter on the outer skin of the nodules suggest that the climatic phase producing this deposit was more humid than the present day climate.

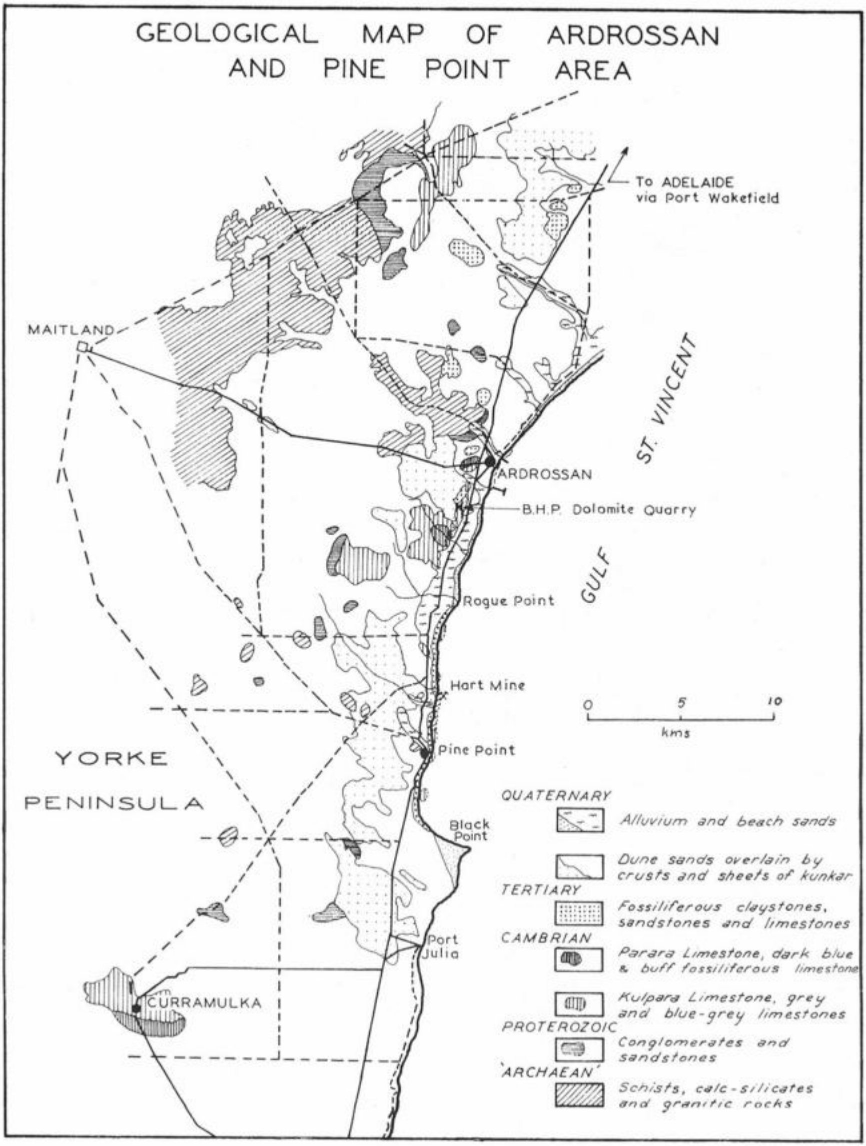

GEOLOGICAL MAP OF ARDROSSAN AND PINE POINT AREA
To ADELAIDE via Port Wakefield
MAITLAND
ST. VINCENT
ARDROSSAN
B.H.P. Dolomite Quarry
GULF
Rogue Point
Hart Mine
0 5 10
kms
Pine Point
YORKE
PENINSULA
QUATERNARY
Alluvium and beach sands
Black Point
Dune sands overlain by crusts and sheets of kunkar
TERTIARY
Fossiliferous claystones, sandstones and limestones
Port Julia
CAMBRIAN
Parara Limestone, dark blue & buff fossiliferous limestone
CURRAMULKA
Kulpara Limestone, grey and blue-grey limestones
PROTEROZOIC
Conglomerates and sandstones
'ARCHAEAN'
Schists, calc-silicates and granitic rocks

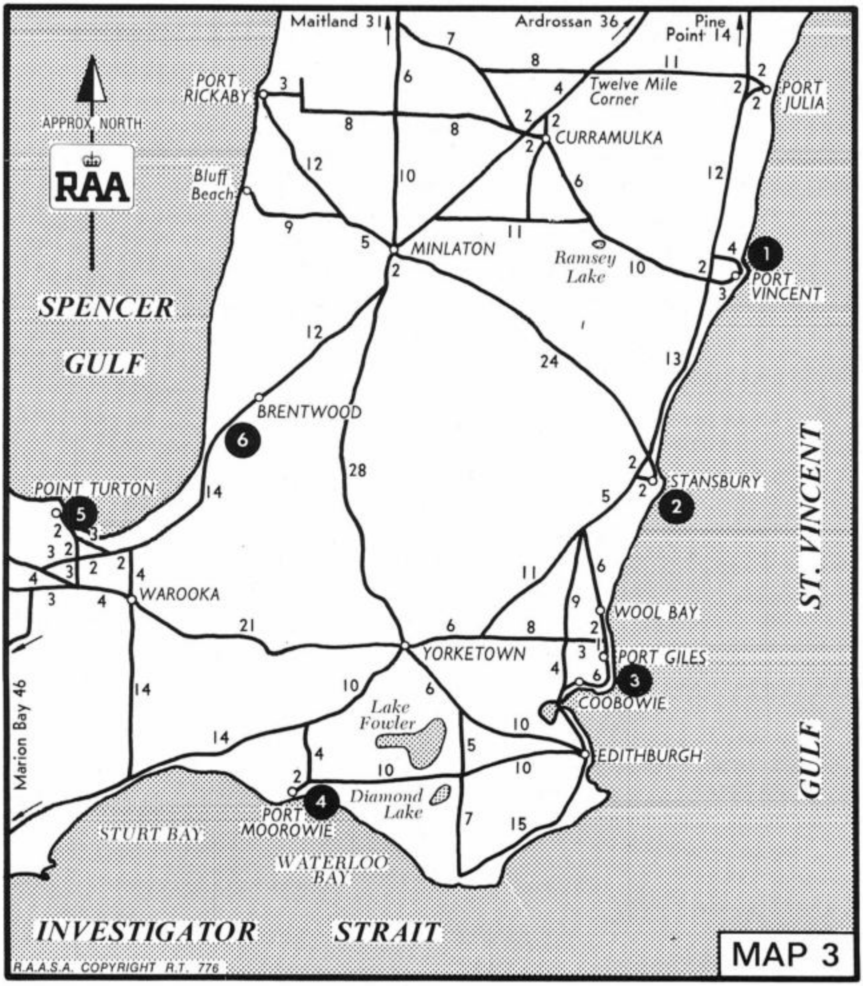
Figure 10:

Chapter 5

SOUTHERN AREA

The geology of the 'lower leg' of the peninsula contrasts sharply with the northern portion and the western 'foot'. The Precambrian basement is entirely hidden between Port Victoria and Point Souttar on the 'foot', while the Cambrian only crops out around Curramulka where it dips rather sharply into a trough filled with Permian glacial clay. Crawford (1965), has called this trough the Dalrymple Basin. Its formation probably began with slow sinking in Middle Cambrian times to form a trough in which the Ramsay Limestone, seen nowhere else on the peninsula, was laid down under the sea. During the period of faulting and uplift which followed, this trough remained as a basin in the crook of the elbow of the forerunner of the present Kangaroo Island and Mount Lofty Ranges. Then, much later, during the Permian glaciation, ice-sheets moved north-westwards across Fleurieu Peninsula from higher lands to the south-east, depositing the debris—soil and rocks gathered in their progress—over the landscape as they melted. Some of this debris has remained as glacial till in the Dalrymple Basin and dominates the topography of the lower Peninsula.

The dip of the Cambrian sediments can be detected in a short drive beginning at the Twelve Mile corner (where the road running westward from Port Julia meets the Ardrossan-Minlaton highway). At this corner we are on a rise of Precambrian sedimentary rocks about 130 metres above sea level. Red sandstone 'floaters' from the paddock can be seen in stone heaps by an old house half a kilometre north east of the corner. Travelling south-westward towards Minlaton we run down into the Curramulka Valley and, continuing past the Curramulka turn-off we see outcrops of the Cambrian limestone in random ridges. This is probably an *uvula* formation caused by sink holes in the underlying limestone. Turning towards Curramulka at the Mt. Rat cross-roads corner we travel along the floor of the valley. Pritchard (1892) considered this was an old glacial valley. Its direction lines up with the general direction of glacial movement but no evidence of till or erratics has been found here. The southern side of the valley is formed of Parara Limestone which lies stratigraphically above the Kulpara Limestone. Turning to the right as we enter Curramulka, we pass the town well which is a sink-hole cave on our left, and the quarry on our right, where the Parara Limestone has been quarried for road surfacing. As we reach the top of the hill Corra-Lynn



Cave is on our right. Its maze of passageways make it the longest cave in South Australia and the second longest in Australia. Entering the cave is not advisable except under the guidance of the Cave Exploration Society of S.A.

Continuing south until the Minlaton-Port Vincent road is reached, we turn left towards Port Vincent and another valley is seen on our right. This valley and the hill on its southern side are formed of Middle Cambrian Ramsay Limestone, which is still dipping towards the south. The Minlaton stratigraphic bore is another six kilometres further south and here the top of the Ramsay Limestone lies under 200 m. of surface marl and Permian clay. The Stansbury stratigraphic bore passed through 5 m. of Quaternary deposits, 41 m. of Tertiary limestone and 256 m. of Permian clay before bedrock was reached. The discovery of foraminifera in these bores in 1956 was the first evidence of a marine invasion of South Australia in Permian times. Travelling on to Port Vincent, we reach the top of a scarp just before we join the Curramulka-Port Vincent road which diagonally crosses the scarp. This scarp appears to be the southern-most extension of the block faulting prominent in the central portion of the peninsula. In this area the Cambrian rocks do not appear east of the scarp. The central ridge tapers away to the south. Much of the Ramsay seif dune area is about 100 m. above sea level dropping away to about 60 m. in the latitude of Stansbury and to 30 m. at Honiton. About three to four kilometres from the road junction, Ramsay Lake has a floor of Permian clay and the road crosses the East Coast Plateau to Port Vincent.

Locality 1. Port Vincent

The township of Port Vincent is built on a cuspate foreland, a tooth-shaped point of Recent raised beach sand with a spit or sand bar extending north-east and partly uncovered at low tide. This foreland, extending outwards from the coastal cliffs, has accumulated and is still growing as a result of the current and wave action moving sand gradually along the beach, a process known as longshore drift. A walk along the beach at low tide for about 1.5 km north of the wharf area can be most rewarding. It is possible to drive along the water front for a short distance past the cemetery. Then, walking along the beach, the intertidal flats, where not covered with sand, are seen to be a soft grey pebbly clay. This is the Permian glacial till. A string of well rounded granite boulders can also be seen. (See Pl. 7).

The granite boulders consist of an opalescent bluish quartz, large crystals (phenocrysts) of creamy-white microcline felspar, some greenish-white plagioclase felspar and a little biotite mica. It might also be possible to find xenoliths of Kanmantoo schist that were caught up in the granite when it was formed. These rocks are so similar to the granite at Victor Harbor that it is evident they must have been picked up as the glaciers passed over that area. There is also a lot of gritty iron-stained rock on the beach and, near the northern end of the erratics, a wall of this rock looks as though it had been built there. This deposit, extremely small in extent on the geological scale, only a few tens of metres long, a metre or so wide and less than a metre thick, has not been studied or positively identified, but, most probably, could be related to the Tertiary basal sands which are known to occur in the B.H.P. quarry at Ardrossan and in four or five places further north.

Plate 7: Large Granite erratics at Port Vincent

The cliffs behind the beach are composed of bryozoal Tertiary limestone which continues along the coast in a practically straight line, suggesting a line of fault, for about 48 km. from Port Julia to south of Wool Bay. The limestone, though not well exposed here, is capped by Quaternary clays in erosion hollows, lime rubble and solid kunkar. Here, at the only place where the glacial clay is exposed, the face of the cliff has slumped seaward and formed a secondary cliff seven or eight metres lower than the original. The kunkar topping is not so prominent on the secondary face, tending to fall back towards the face from which it came. This is a rotational slip (see Fig.11). Two features make it possible; the friable nature of the Tertiary sediments and the plastic and slippery nature of the Permian clay. The faulting is regarded as being deep-seated, a rejuvenation of older faulting, and the plastic clay, rather than moving as a block, tends to fold down like a carpet in a monoclinal fold. This would produce a sloping surface at the top of the strata and, when wet, would provide an ideal accelerator for any movement in the cliffs above. The upper layers of the bryozoal limestone in these cliffs have had most of the matrix removed by percolating water and so they tend to fissure and fracture easily. Very little undercutting or tidal action would be needed when the cliffs were saturated from winter rains to set the whole cliff face in motion.

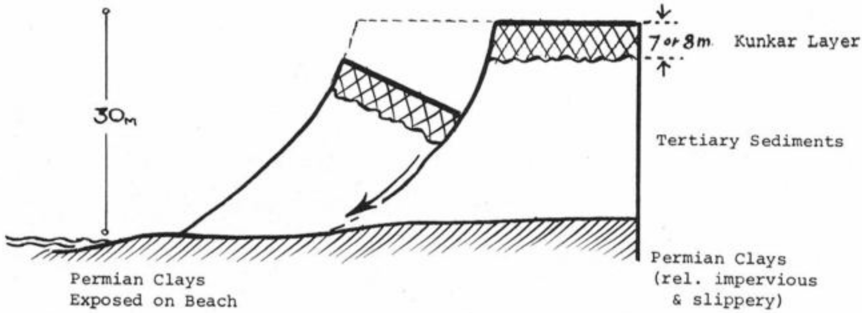


Figure 11: Rotational Slip in Cliff Face, Port Vincent

Locality 2. Stansbury

The Tertiary limestones of southern Yorke Peninsula can best be seen in the cliffs behind the Stansbury jetty where they were quarried first for flux for the smelters and later for cement manufacture till quarrying was moved a few kilometres further south to Klein Point. Travelling south from Port Vincent, the road traverses the East Coast Plateau which extends from Pine Point to Troubridge Hill on the south coast. This plateau is capped by hard dense kunkar limestone which is mostly very close to the surface and quite often exposed. Under this crust and scattered pockets of earlier Quaternary clay trapped in solution hollows, the Tertiary limestone of the cliffs extends westward for four to eight kilometres before it lenses out against the underlying Permian glacial clay. Nowhere can the Tertiary be seen on the surface though it has been found in wells and its probable boundary has been traced from aerial photos combined with field observations. About six kilometres from Port Vincent, in the vicinity of the vertical shaft limekiln, a wing of the Ramsay seif dune area runs through to the coast. In the cliffs opposite, much of the Tertiary has been eroded and replaced by Ardrossan clays and sandrock. During World War I alunite (alum stone) was mined from a band near the base of these clays.

At Stansbury quarrying has left a vertical face in the cliff behind the jetty, twenty metres or more high. The cliffs reach a height of about 30 m. at Klein Pt. The strata can be seen to be horizontal as they are throughout the length of the cliffs from Port Julia to south of Wool Bay. Numerous fossils identified from these beds leave no doubt that the cliffs are the same age as the Port Willunga beds on the eastern side of St Vincent Gulf. Thus they are regarded as Oligocene-Miocene in age. There is no stratigraphic break in deposition between the two epochs. At the top of the cliffs, under the kunkar, the surface is irregular, with erosion holes filled with a yellow-brown clay which is unlike the known Quaternary clays. The deposit ranges from uncemented bryozoal fragments, sands, sandy clays to sandy limestones, usually pale buff to yellow in colour grading downwards to the lower strata which are pink and similar to the Point Turton Limestone. Though this pink limestone has not been used as flux for at least seventy years, it is still known locally as red flux.

Plate 8: Tertiary Cliffs, Stansbury.

Bryozoans ('moss animals') are very small animals which live in colonies. Each animal has a hard protective case, either calcareous or horny, into which it can completely withdraw, but which is attached to the cases of other members of the colony. The phylum of the animal kingdom to which they belong is the Bryozoa. The colonies are usually attached to rocks, shells or seaweeds. Some form flat encrusting growths which are often referred to as seamats, while others take shrublike shapes and are commonly called lace and branching corals, though true corals belong to a different phylum. The name bryozoal has been given to this limestone because by far the greater part consists of fragments of the skeletons of these animals. Brachiopods or lampshells (called cockies beaks locally because of their shape), echinoderms or sea urchins and sea eggs and a number of varieties of molluscs may also be found, though most molluscs except the scallop (Chlamys) can only be seen in the form of internal casts or external impressions. Fossils are not abundant though small specimens of two species of the heart urchin *Lovenia* may be picked up on the foreshore beach at Stansbury. If time is available, it is worthwhile to have a short look at the beach in front of the Parade. Stansbury is situated on a cuspate foreland very similar to Port Vincent. Here the beach was eroding badly till groins were erected north of the point.

Locality 3. Point Giles (Hickey's Point)

To continue on from Stansbury it is necessary to take the Yorketown main road as the old coast road has been closed to allow extensions of the Klein Point quarry. At the next junction turn left to Wool Bay. About two kilometres further on, a well developed uvula can be seen in the paddocks on the left. This is a flat-bottomed depression with irregular boundaries and several islands, caused by the extension and combination of a number of sink holes into one larger hollow. It reaches to about 60 m. from the coast but has no visible outlet there. From Wool Bay to Port Giles, though the plateau remains level, the Oligocene-Miocene beds have been much eroded and the hollows filled with mottled Ardrossan clays, becoming much more extensive as we go south. In the vicinity of Port Giles the Oligocene-Miocene rocks disappear beneath sea level and a thin younger Pliocene sedimentary unit is exposed. At Hickey's Point (local nomenclature), about two kilometres south of Port Giles as the road begins its sweep to Coobowie, the beach can be reached through a road side gravel pit. A quarter of a kilometre north, Pliocene rocks rich in fossil oyster shells about one metre thick can be seen at low tide. This fossil 'oyster bed' is equivalent in age to the Hallett Cove Sandstone which forms a distinctive horizon lying horizontal on slightly tilted Eocene-Miocene rocks on the eastern side of the Gulf and is overlain by about four metres of gravelly mottled clay. The large cockle, *Anodontia sphericula*, and the large gastropod, *Campanile triseriale*, have been found here. The Oligocene-Miocene deposits have been eroded to form Coobowie Bay and the Salt Creek inlet, but can be seen again in the cliffs close to Edithburgh. Several hundred metres south of the jetty a small outcrop of Pliocene rocks can be seen on top of the Oligocene-Miocene and under the kunkar at the old swimming pool.

Locality 4. Port Moorowie

The best outcrops of the Permian can be seen in the cliffs along the south coast. By taking the road from Coobowie to Seven Roads, crossing the bitumen there, taking the road towards Honiton and the right fork half a kilometre further on, Lake Fowler and the remnants of the gypsum dune can be seen on the right in passing.

Lake Fowler, covering about 1,000 hectares, is by far the largest salt lake in the district and lies on a bed of Permian clay. A mixed heap of quite large erratics, granite and greywacke, the largest 2.5 metres x 2 metres, lies on the western bank. The Honiton rise on the left, about 30 metres above sea-level, is the extremity of the central ridge of the peninsula and is presumably a Permian hill buried beneath a kunkar cover. The remnants of the gypsum dune, which was originally a lunette

25 metres high and over 1.5 km. long, is composed of dessicated flour gypsum which was blown from the lake floor in an earlier stage of its history.

Turn to the right at the next road junction, and continue westward for nearly nine kilometres to Port Moorowie. In the cliffs behind the site of the old jetty (stumps can be seen on the beach) a conspicuous band of pale, very coarsely mottled material with red blotches and bands of laterite can be seen. The best locality to inspect the cliff is about 200 metres east of the jetty where there is a semblance of a point. Here the small hand-sized boulders in the clay are more numerous in the lower portion and the laterite is not so pronounced. The most common erratics are rocks known as Kanmantoo greywacke, but granite can also be seen. This clay, regarded as the Permian glacial clay, extends to about five metres above sea level and is capped by another band of darker mottled clay, the Ardrossan Clay of the Pleistocene epoch. At this point the Ardrossan Clay is less than a metre thick and is capped by a crust of kunkar in which two hard layers can be readily distinguished. The laterization near the jetty suggests that here was an old soil surface with the iron moving downwards into the underlying clay.

Depending on the time available, a walk westward from the jetty is well worthwhile. Point Gilbert is about one kilometre from the jetty. The kunkar crust progressively becomes thicker with the greatest increase shown with the development of a third, or lower, pavement not well developed at Port Moorowie, with a nodule-in-nodule texture. The erosion pattern becomes more pronounced, with atmospheric and wave action on the clay and marl undercutting the harder kunkar crusts till they fall in large boulders which gradually form a barrier to further erosion. In the first shallow embayment, the Permian clay is apparent with its usual greenish colour, though here it is reduced in thickness. Here too is another example of a fossil soil; a downward leaching of lime can be seen in the upper portion of the clay. In the second shallow bay the pattern has again changed; near the surface of the clay, small laterite pebbles can be seen and traces of thin alunite seams are also found. Further on, the clay disappears and at Point Gilbert the back of the undercut caves is the soft kunkar marl. Random pebbles of the Pliocene (Hallett Cove Sandstone) may be found in water-worn rocksonthe beach but they are not readily distinguished.

The Salt Lake Story

It is now time to look at the salt lake district, which we previously crossed on our approach to Port Moorowie. Take the road directly north for five kilometres from the beach to Greenhill Road and turn right towards Yorketown. Two more kilometres brings us to the south-west end of Munkowurlie.

Most of our travelling from Port Vincent has been over the flatter coastal plains, where the kunkar crust has been hard and dense as we have seen in the cliffs. In the salt lake area the kunkar is still present but its nature has changed. The topography is more undulating and the kunkar is much more rubbly, without the development of continuous sheets.

Continuing on, the elongated shape of Munkowurlie can be noticed with its extended channel draining from the country from Yorketown to the northeast. The smaller lakes are circular with the steeper banks on the south-west, while the larger lakes tend to become elongated; Diamond Lake, Sunday and Weavers' all subscribe to this pattern. Lake Fowler, the largest, is probably the result of a coalescence of several smaller ones. The whole of the lake district slopes gently towards the southwest and an old pattern of drainage is evident. During the Pleistocene Ice Age when sea-level was periodically lowered, loessal drift of lime sands from the sea floor to the south-west blocked the drainage and the annual evaporation in summer led to the formation of lakes.

Jack (1921), estimated that there are between 120 and 130 lakes in an area of about 40,000 hectares, and they cover about 3,500 hectares of which 2,400 hectares had a crust ranging from 32 mm. to over 5 cm. of salt. Jack also expounded the now accepted cyclic theory that the salt is carried inland and precipitated by the light coastal showers which provide most of the rainfall. Much of the salt was held in the soil by vegetation and only released after clearing and cultivation began in 1870, allowing increased ground-water circulation. It took about twenty years to achieve a maximum flow and another forty years to exhaust economic production. Salt scraping was at its peak between 1890 and 1930, though some production was continued on Lake Fowler for another thirty years.

In the vicinity of the fingerpost point to Pink Lake Cemetery, we are near the easterly boundary of the marine invasion during the Pliocene. Lime-cemented sandstone of this age can be seen on the floor of Pink Lake, one kilometre further east. At this fingerpost, 3.5 km. could be saved by turning left to the main road to Warooka and, turning to the left at the bitumen another drainage channel is crossed. The WSW-ENE trend of ridges and channels is apparent. Five kilometres from the corner (8 km. from Yorketown) the road curves down from the Pliocene of the plateau to Big Flat. This is an easterly embayment of the Pleistocene strait which is now the Peesey Swamp.

This flat is actually a raised beach area and shells can be found in the kunkar. On the western side of the flat as we pass through the cutting, the exposed kunkar should be observed. On the top is a moderately hard layer with a hard white upper skin while below, it grades into crusted nodules and rubble. From the cutting we drop down into a wing of the Peesey Swamp which is the outlet of the old drainage channel from Weavers Lagoon, 16 kilometres away to the north-east. Over the next ridge we are on the Peesey Swamp proper and the Warooka Hill can be seen on the other side as a fault scarp, at much the same height (30 metres) above sea level, as the country surrounding Weavers Lagoon. A wild-cat oil well drilled on the Peesey in the early 1930's revealed 45 metres of Quaternary sediments before reaching the Permian clay and no mention was made of any Tertiary limestone.

The similarity and lineaments of the aeolianite cliffs of Cape Spencer with those of Wedge Island, Thistle Island and southern Eyre Peninsula, suggest the possibility that the Peesey Swamp was at sometime during the Pleistocene one of the main outlets for the waters of Spencer Gulf, but there is no other geological evidence for this. The floor of the Swamp is in kunkar about 30 cm. thick, similar to that at Port Moorowie and observed in the cutting on the east of the swamp but with seashells embedded in it; that is, the swamp is a raised beach area.

Underlying the crust is a shelly sand with plentiful *Ostrea sinuatea, Cardium rackerti,* small specimens of the foraminiferan *Marginopera vertebralis* (60 mm. across) and a wide selection of other molluscs which can be found in Hardwicke Bay at present, can be seen in a waterhole just east of the Warooka Rubbish Depot. The strait in Pleistocene time was about 8 kilometres wide, and, judging by the development of kunkar on the southern coast, the opening there from Point Gilbert to the head of Sturt Bay was the first to be closed off, beginning with the development of a cuspate foreland culminating in Green Hill while another formed at Point Davenport.

Plate 9: Tertiary bryozoal limestones, Point Turton.

Locality 5. Point Turton

After crossing the Peesey Swamp, we ascend the scarp to Warooka and Point Turton can be seen to the north-west. The best exposure of the Point Turton limestone can be seen in the camping area behind the jetty. This limestone lithologically resembles the 'red flux', the lower part of the limestone at Klein Point, and its fossils are similar to those of the Port Willunga beds. It is regarded as Oligocene-Miocene in age. Where there are breaks in the sedimentation some fine specimens of bryozoa have been found. The thickness of the limestone is about 18 metres and it rests on the Permian clay which can be seen exposed at low tide in the cliff on the western side of Magazine Bay several hundred metres further west. The Permian clay is the main geological formation underlying Warooka Hill.

About 0.5 km. or less to the west of Fish Point, the most westerly point of the Port Turton limestone, a raised beach can be seen in the low cliffs. The top white kunkar crust lies on a band of shelly sand about 30 cm. thick. Where the underlying band of kunkar is not obscured by talus, it is seen to be another hard band with pink-coated nodules in it. Better exposures of this raised beach can be seen at Brown Point (The Bluff) and Port Rickaby on the west coast of the peninsula north of Minlaton.

Locality 6. Pliocene and Kunkar, 2 km south of Brentwood

Before a general discussion on the deposits of kunkar, it would be well to look at the Pliocene exposure south of Brentwood. By following the coast road from Point Turton we pass over some of the older kunkarised dunes of the Peesey Strait area while partly kunkarised beach dune ridges, marking the final closure of the strait lie between the road and the sea. After reaching the bitumen at Flaherty's Corner, we pass over a shallow extension of unconsolidated modern beach sand to the swamp floor, while skirting the extensive development of these modern coastal dunes on our left. As we reach the Hardwicke Bay shack area, hidden by lower dunes, the farmland on our right shows a grey soil when cultivated, with plentiful kunkar and represents an older consolidated dune system. At the end of the shack area, the road swings north-east on a low rise, drops several metres and runs straight over a featureless plain to Brentwood. The stop should be made two kilometres from this bend where loose stone is present on the roadside.

A hammer will be needed. The Pliocene rocks, not abundant, are harder and denser than the kunkar and, on a freshly broken surface, reveal that it is a lime-cemented sandstone with casts of marine shells, though it is possible to find specimens in which the shells in the outer layer of the rock have not been dissolved. Fossils found in this formation include *Diastoma provisi*, large *Anodontia sphericula* and very large specimens of *Marginopera vertebralis* (2.5 cm across). The Pliocene deposits appear to be a beach strand stretching from Port Moorowie, around Pink Lake, across the Hundreds of Moorowie and Minlacowie to Port Minlacowie, and appearing again at Port Rickaby and Wardang Island. They do not appear anywhere on the peninsula above 20 metres above sea level and do not seem to be connected with the oyster beds of the same age at Point Giles. They contain occasional fragments of glacial erratics.

The various formations of kunkar on Yorke Peninsula have not been identified nor their stratigraphic relationships determined. It had previously been thought that all kunkar had been formed by the evaporation of groundwater charged with lime seeping up from the underlying limestones by capillary action, till Crocker (1946), demonstrated that it occurs on non-calcareous bedrock and laterite and Permian clays. His theory that it has been formed from loessal drift from the uncovered sea-beds during times of Pleistocene glaciation has now received general acceptance and Firman (1969), has established stratigraphic relations for kunkar elsewhere. Some of his formations can be recognised, although because it is close to the source material, the Peninsula kunkar is much more complex. By breaking some of this kunkar, a pink band of concentric layering, either on the surface or around incorporated nodules, is the most prominent feature. This can be equated to the calcrete in the Bakara soil, a wider marker horizon, which Firman regards as the top of the Middle Pleistocene and dates as more than 45,000 years Before the Present (B.P.).

Inside the rocks here, pale greenish to buff nodules can be found, sometimes with black traces of dendrites suggesting a lacustrine origin.

On the farm of E. Carmichael (Section 140, Hd. of Moorowie) about 8 kilometres west-south-west from here in the same formation, well sections show 30 to 60 cms. of red-brown Bakara soil with large boulders lying on a hard crust with accumulations of these greenish nodules in a matrix of off-white kunkar for a depth of 60 to 100 cms.

This crust is evidently the Ripon surface of Firman and the greenish nodules could be related to the Bungunnia Limestone. The formation grades into a reworked crumbly granular kunkar containing Pliocene sandstone while the Permian clay lies 3 to 4 metres below the surface. The Pliocene boulders occur at all depths from the surface down, thicker near the base, but would only amount to one metre or little more in total thickness. The downward movement of the kunkar has definitely wedged the Pliocene upwards. In one instance a Permian erratic is cemented in surface kunkar.

The Pleistocene Epoch was a time of arid periods with loessal drift alternating with more humid climates in which soil was formed. The farm surface appears to have been stripped in an arid interval when further loess was blown from the gulf and the Peesey Strait. To the west, as far as the Peesey Swamp, lie grey soils, consolidated and kunkarised dunes, and on the farm itself, small rises of the same age. The kunkar of these dunes is white with abundant sand grains and is much softer than the Bakara type, except the upper crust which is extremely hard and shows straw coloured concentric banding.

North and south of the farm the dunes extend right across the Pliocene plateau and cover the whole of the salt lake area except the lake beds. The source material was evidently the exposed floors of the Peesey

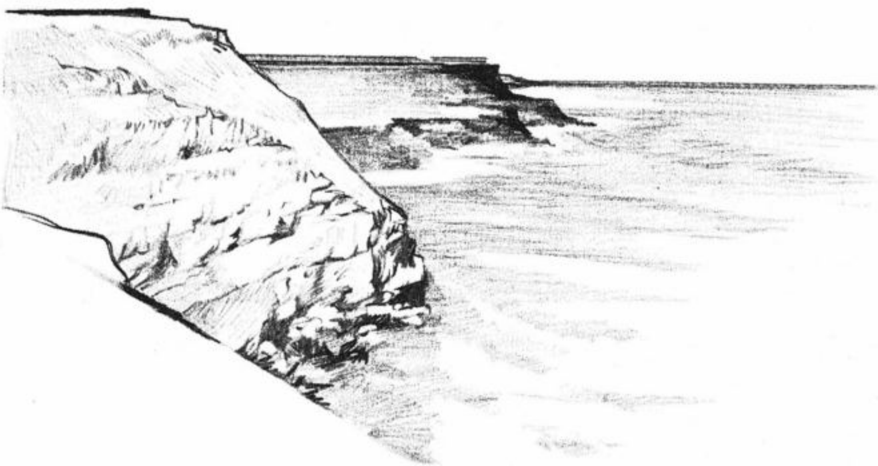
Strait, Investigator Strait and Spencer Gulf. Most of the exposures in the cliffs along the coast, both west and east, show a massive pink kunkar of 'nodule-nodule' texture, suggesting that the coastal plains received further loess as the cementing agent. Tentatively this could be placed as equivalent to the Pooraka Formation and the Loveday Soil Carbonates, that is, in the Upper Pleistocene.

The raised beaches exposed in the cliffs of Hardwicke Bay and Spencer Gulf all rest on this hard kunkar and are overlain by another crust of kunkar. This would be equivalent to the St Kilda Formation of the St Vincent Basin. Shells from that basin have been dated from 1,000 to 4,000 years B.P. In the higher and better drained areas of the salt lake district and further north where the loessal drift has formed dunes or followed the pre-existing contours, the hard pink kunkar is only present in valley floors such as the Koolywurtie-Minlaton Depression. In other areas the kunkar appears as a thin crust of boulders overlying rubble and marl and the dunes contain several disconnected bands of nodules at varying depths. Correlation becomes more difficult, though it is possible to recognize the Bakara band of nodules in some instances. South and west of Warooka the story is complicated still further by more recent unconsolidated dunes.

Summary

This excursion is planned as a one day trip commencing at Port Vincent and the round trip back to Port Vincent would involve about 160 kilometres with five other stops, at Stansbury, Giles Point, Port Moorowie, Point Turton and near Hardwicke Bay. The other items mentioned are provided for a running commentary.

If the western end is included in the itinerary, Point Turton is about 104 kilometres from Port Vincent and has a caravan park. In this case the last stop near Hardwicke Bay could be left till the return trip. If more time is available, Edithburgh and the Troubridge Scenic Drive are well worthwhile. Port Rickaby on the western coast could also be included. The Curramulka digression, if taken as a detour on the approach to Port Vincent, would involve about 30 kilometres, but could be reduced if included in the return trip directly to Adelaide.



Chapter 6

SOUTH WESTERN AREA

The itinerary for this tour begins at Hillocks Homestead and can be approached by following the southern cross-road from Yorketown, or, from Warooka by taking the road due south from the main Stenhouse Bay road, approximately 28 kilometres out of Warooka.
Note: Hillocks' is owned by W. M. & P. J. Butler.

A Permit must be obtained for each vehicle, and a key hired (for nominal deposit). This can easily be done at the homestead, or Koops' Garage, Clark's store at Warooka, Joe's at Marion Bay, or Butlers' Store at Stansbury. A map is supplied with the permit, which shows the position of Meteor Bay, the most easterly bay on the property.

The coast is very rugged and dangerous here, as it is exposed to the turbulent seas of Investigator Strait, and therefore swimming is not advisable. The track through the Butler property is well sited, as it has been laid out somewhat inland from the vegetated sand dunes which fringe the cliff top. This helps to protect both the coastline and the paddocks from erosion. Cars can be driven right to Meteor Bay, and parked on the cliff top.

Locality 1. Meteor Bay

Before descending to the beach from the kunkarised upper surface of the consolidated sand dune which forms the cliff at the back of the beach, note the different colours of the rocks in the bay itself. They are predominantly pink and grey, with outcrops of black rock in some areas, with lighter pink and whitish veins running through them all.

Climb down the sandy cliff to the beach, and walk eastwards to the first outcrop of black rock, which is an *amphibolite dyke* (refer p. 35). It intrudes the pink metamorphic gneisses which here show well-marked layering or foliation, and in some places, complicated small-scale folding (known as ptygmatic folding—Fig. 12). Note that there is an orange encrustation of lichen on the rocks above high water mark, not to be mistaken as a mineral constituent of the rock. The gneiss shows a very regular foliation, dipping south-west, and is well-jointed and fractured in several different directions. On many of the fracture planes in both the gneiss and the amphibolites, epidote crystals can be seen. Epidote is an alteration product of hornblende, a mineral which occurs abundantly in both the gneiss and the amphibolite.

A few metres further around the point is another black amphibolite dyke, typically weathered in pitted fashion, containing veins of quartz in which are found large crystals of hornblende. The hornblende probably recrystallised from the amphibolite, which contains a higher percentage of it, during the formation of the quartz vein.

Figure 12: An example of ptygmatic folding

Pinkish-white pegmatite dykes also intrude both the gneiss and the amphibolite, and in some places reach one or two metres in thickness. They are composed of very large crystals of potash feldspar, showing good cleavage faces, and with small clots of both biotite and muscovite mica. Most of these pegmatites also contain veins of white quartz, which may have been emplaced with the dykes, or, may post-date them.

Walking back around Meteor Bay to the western side, there are two interesting outcrops of gneiss, one pink and one greyish. The greyish outcrop is particularly spectacular as it contains a magnificent exposure of ptygmatic folding on its landward side. The actual intrusions which have been folded are of the pink gneiss, which is a more feldspar-rich rock, and hence has a pinker colour. The grey gneiss contains a higher percentage of basic minerals such as hornblende and biotite, which give it its grey colour. This rock could almost be termed a migmatite (a 'mixed' rock with both metamorphic and igneous components, resulting from deep-seated alteration). Here we have the pink (more granitic) veins, in the grey (more basic) gneiss. In some places in this bay, a "lit-par-lit" structure can be seen in the gneiss, thought to be caused by injection, or diffusion, of mobile material along bedding or cleavage planes.

The pink rocks appear very resistant to marine erosion and form a bar across that side of the bay. It is noticeable as being the most seaward rock at many of the prominent rocky headlands along this part of the coast.

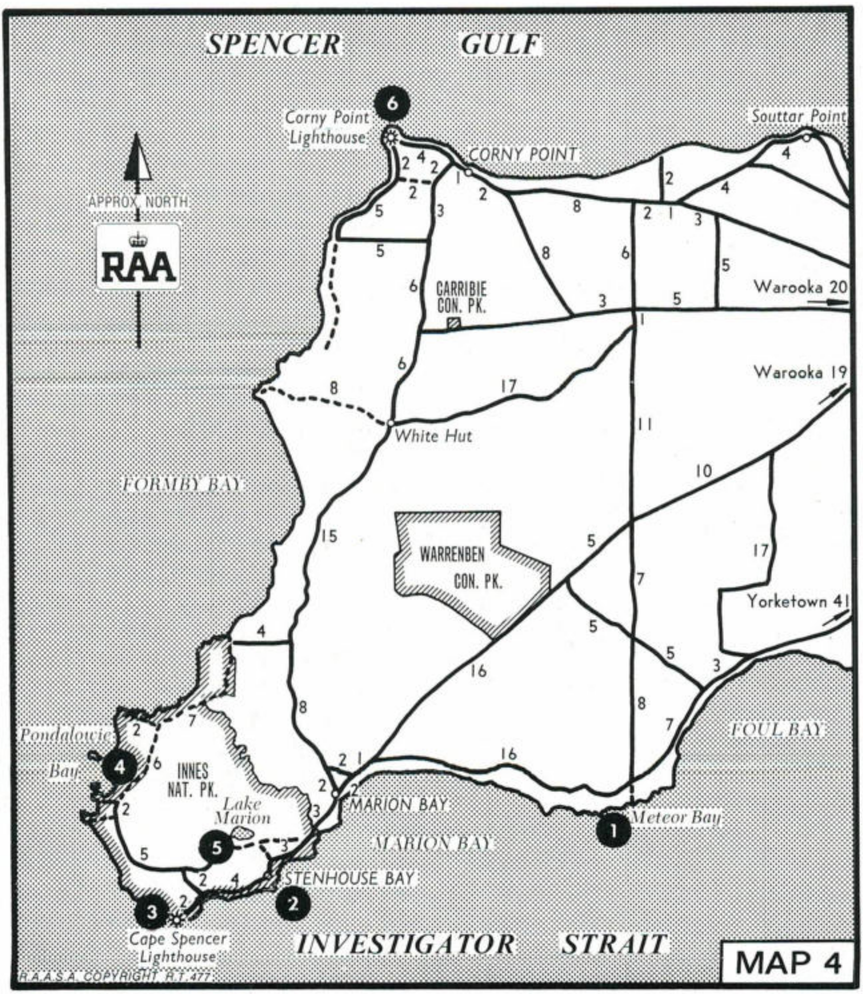
In some places a type of *graphic granite* texture, resulting from the intergrowth of quartz and feldspar, can be seen in the pink gneiss. The sand in the bay is very coarse, and is rich in calcareous shell fragments, as well as quartz and feldspar grains derived from the gneiss.

The geological history of this area and of the Yorke Peninsula basement rocks in general is extremely complex. The rocks are very old, and recent radiometric dating indicates an age of 1759 $\pm$ 66 m. yrs. for the pink gneiss, and 1638 $\pm$ 35 m. yrs. for the grey layered gneiss. Dating techniques only record the last phase of metamorphism of these rocks. There is no way of telling what the rocks were originally (i.e. whether they were sedimentary or igneous). There must have been several pulses of metamorphic activity which bought about the intrusion of the amphibolite dykes, and later, the light-coloured pegmatites with their large crystals, indicative of slow-cooling from hydrothermal solutions. Finally came the quartz veins;—quartz being normally the last mineral to crystallise out because it does so at a lower temperature than any of the above mentioned minerals.

It has been suggested (Crawford 1965) that the Precambrian basement rocks of Southern Yorke Peninsula (referred to as Archaean in that publication) may be related to very similar rocks on Southern Eyre Peninsula, and also to small outcrops of Fleurieu Peninsula. Subsequent faulting in Tertiary times, which produced Spencer and St. Vincent Gulfs, has dislocated the regional pattern, but Wedge and Thistle Islands trend in linear fashion between the two peninsulas, and they are also underlain by crystalline basement rocks.

During ascent of the sandy cliff, notice the level surfaces of the kunkarised upper layers, and the irregular modern sand dunes which overlie this, and which have been formed over the years by sand and shell fragments being blown up from the beach below, during the strong southerly gales frequent in this area.

Driving back towards the homestead, several more beaches are passed, notably Coffin Beach, which also displays similar pink gneiss and black amphibolite dykes.



Locality 2. Stenhouse Bay

After leaving Hillocks Drive (not forgetting to reclaim the key deposit!), drive westwards to Stenhouse Bay. Just south of the General Store, there is an exhibition of different types of gypsum, and other interesting features of the area, which are worth inspection. Then drive, or walk up the road to the cliff top above the jetty, where there is a look-out. Note that the road itself is made of crushed gypsum crystals, and some very beautiful examples can be found here at times, especially after rain. They show monoclinic crystal form and usually exhibit swallowtail twinning.

The lookout area commands a good view of Stenhouse Bay, which was once a very busy port, built for the gypsum trade. Looking to the east, the furthest point of the Bay is Rhino Head, and even from this distance two distinct land surfaces can be seen in the cliff, the upper, present-day level, and the lower, which is not many metres above sea-level. This lower level was probably caused by some of the many changes in sea-level which occurred during the Pleistocene Ice Age of the past two million years.

The cliffs here are being slowly eroded by the sea, and Rhino Head has an interesting rock 'stack' at its foot, which has been separated from the mainland by marine erosion. Inequalities in resistance of the aeolianite rocks of the cliff cause narrow zones to be more rapidly excavated, leading to the formation of crevices, caves and arches. If an arch collapses, a columnar rock stack is left, as we see here at Rhino Head. Many spectacular rock stacks (e.g. The Twelve Apostles near Port Campbell in Victoria) are found along the coast of southern Australia and were formed in a similar way. At the foot of the look-out cliff, are very large, smoothly-rounded granite boulders and 'whalebacks', forming a resistant basement which withstands the attack of the sea. Sheet-weathering can be seen on some of these granite surfaces. It is not advisable to try to examine these rocks at close range, but they have been classed as coarse-grained biotite gneiss.

Locality 3. Cape Spencer

The road continues west beyond Stenhouse Bay, and the first rise brings into view Cable Bay, Chinaman's Hat Island and Cape Spencer. This beautiful scenery is typical of the ruggest coastline which extends for several kilometres around the south-west extremity of the Peninsula. As mentioned above, the cliffs are composed of a resistant basement of Precambrian gneiss, which is overlain by up to 100 metres of aeolianite, which has a kunkarised upper layer and many interbedded reddish-brown 'fossil' soil layers.

Looking due south across Investigator Strait, Haystack Island, Seal Island and Althorpe Island can be seen, with Kangaroo Island in the far distance. Several families live on Althorpe Island to service the light-house and there is an air strip. These islands are formed in the same way as the coastal cliffs, Precambrian basement, a considerable thickness of sub-horizontally bedded aeolianite overlain by a thin layer of kunkar, wind-blown sand and a little vegetation.

The aeolianite is a calcareous rock which was formed about 500,000 years ago, when sea-level was much lower than it is at present, during one of the Pleistocene glacial episodes. Much of the continental shelf, consisting of a thick layer of calcareous material (the broken skeletons of marine organisms), was exposed, and surf and wind transported these shell fragments on to the land, forming very large dunes. As time went on the dunes became cemented by lime-rich solutions, still preserving the coarse cross-bedding, caused by the winds, which is easily seen on many cliff-faces. Sea-level fluctuated, and so did the land surfaces, soil profiles forming at some levels. These are often very noticeable, appearing as prominent pinkish sub-horizontal beds, in the pale brown cliffs.

Looking due west from here Wedge Island can be seen. Its typical wedge shape occured because it originally formed as a gigantic aeolianite dune in Pleistocene time. The southern cliffs of the Wedge, as it is known, are over 200 metres high.

Cars can be driven through the gate at the signpost proclaiming 'Innes National Park', and about 1 kilometre further on is the Cape Spencer carpark. It is a short walk to the lighthouse, from where a magnificent view may be had of the Southern Ocean rolling in and breaking upon the well-rounded massive outcrops of Precambrian basement at the base of the cliff. Looking back towards the land, there is a most spectacular small bay to the east of the Cape, cut into the high aeolianite cliffs, which drop sheer down to the sea. Note that the gneiss is much more widely jointed here than at Meteor Bay, which is why it is not easily eroded by the sea and so forms a promontory.

Plate 10: Aeolianite cliffs, Cape Spencer.

To the west, is a long, curving beach of white sand, backed by a high, vegetated, sand cliff, sloping at an angle of approximately 35°, (the angle of repose for sand). The beach is formed when the waves are diffracted around the prominent cape, which is undergoing continued attack by the ocean, and sediments are washed shorewards by the littoral currents on to the depositional beach area.

The path from the carpark to the lighthouse is once again paved with crushed gypsum crystals, and flanked by sand dunes which build up from sands which accumulate as a result of strong updrafts, caused by southerly gales blowing against the face of the cliffs.

Locality 4. Pondalowie Bay

Drive back to the Park gate and turn left, travelling north west. The road passes a salt lake to the east (Deep Lake) and also the tracks to the wreck of the 'Ethel' and to Reef Head, which branch off to the west. About 8 kilometres from the Park gate, Pondalowie Bay is reached. This bay is almost hemispherical in shape, and has been eroded by the sea, which broke through a gap in the aeolianite cliffs thousands of years ago. It is rimmed by undulating sandhills, which are vegetated in some places, but also contain several big 'blow-outs'.

There is a passable track on the south side of the bay, which leads out on to the point, near a small island. The surf is breaking through the gap

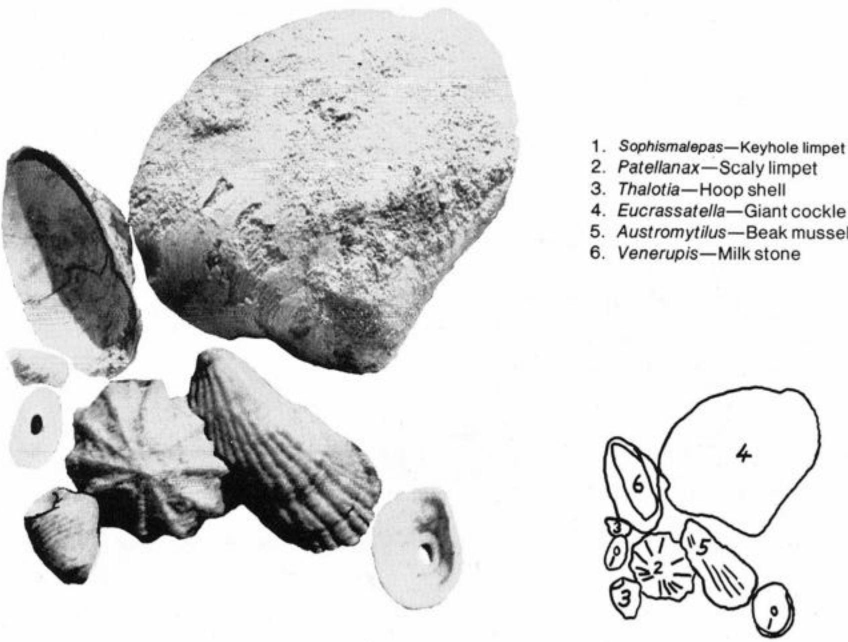


Plate 11: Shells from Pondalowie Bay

between the island and the mainland, and separating the two by its action. The water is very shallow here, which means that it is a high energy area and rapid erosion is taking place.

A 'raised beach' can be seen near the point to the south of the Bay. This is a shelly beach deposit, a metre or so above the present day level. The shell bed is more or less indurated, and capped by thin kunkar and wind-blown sand. It may have been active during the last high stand of the sea, about 120,000 years ago. (see Plate 11).

About 200 metres south of this area, is another bay, flanked by West Cape to the south, which also shows active marine erosion, and contains an incipient island; a small aeolianite-cliffed outcrop, connected by a very narrow isthmus to the beach within the bay. There are some well-developed, wave-cut platforms and notches at the base of the cliffs between Pondalowie Bay and West Cape. The swash of the storm waves thrusts rock fragments with great violence against the base of the cliff, carving out the notches, and forming an abrasion platform.

Locality 5. Lake Marion and the Gypsum Story

After leaving Pondalowie Bay, travel about 5 kilometres back on the same road, until the Inneston turn-off is reached on the eastern side of the road. At present there is no signpost here, but the tiny settlement can be seen on the hillside about half a kilometre from the road. It is possible to drive through the village, which consists of a few holiday cottages, and ruins, until an earth barrier across the track is reached. Cars should be left here, requiring a walk of about 3 kilometres to reach the gypsum and stromatolite site. The road past Lake Marion from just north of Stenhouse Bay is blocked by a gate, which is locked most of the time, so access is not possible from this direction.

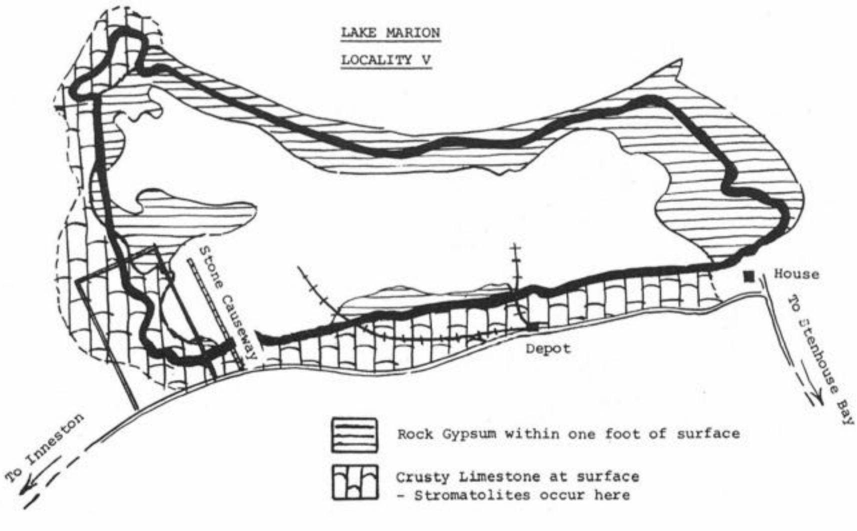


Figure 13: Lake Marion

Rock gypsum has been quarried extensively at Lake Marion for over 80 years. The gypsum, and algal stromatolites (see below), can be examined at the western shore of the lake, particularly at the locality shown on the map. It is not advisable to venture beyond this corner of the lake, as the tracks are not maintained at present, and can be dangerous.

The gypsum was blasted from the shallow lake deposits, washed and loaded into ships at Stenhouse Bay, before being sent to Adelaide for manufacture of plaster, and plaster products, as well as for other uses. The South Australian gypsum deposits are very important to the State, and much gypsum is mined for export also, but here in Southern Yorke Peninsula, the industry is phasing out, as it is no longer economically profitable.

Lake Marion is one of a number of saline lakes which are found in a narrow low-lying strip of land, from Royston Head to West Cape on the west coast, across to Stenhouse Bay and Marion Bay on the south coast. It is thought that this strip of swampy land formed a seaway between Cape Spencer, which was probably an island, and the rest of the 'foot' and that this seaway persisted until about 6,000 years ago. Thin marine calcareous sands were laid down with shells, etc., and sea-grass (Posidonia seaweed) banks.

As sedimentation built up high sand-dune barriers near Pondalowie

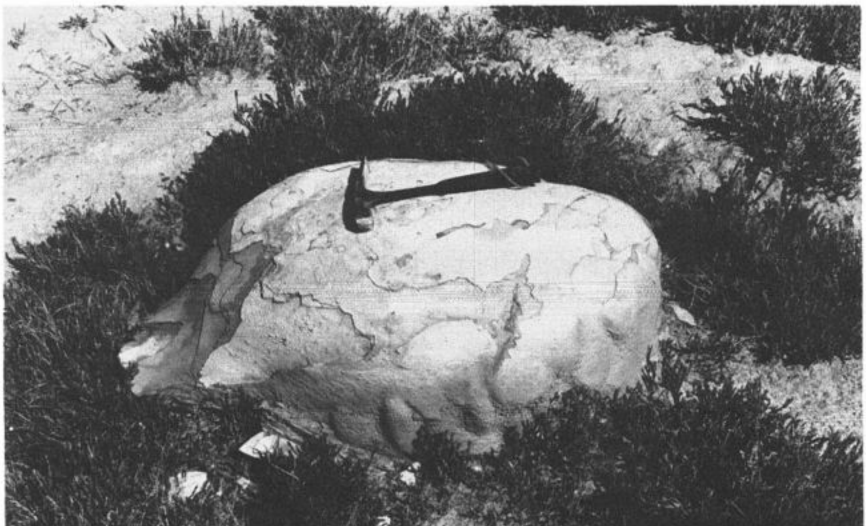


Plate 12: Example of a large stromatolite head from Marion Lake, excavated from sand-sized gypsum crystal sediment. The elongated nature of the head is related to the current direction acting when filamentous algae coating it were actively trapping fine-grained calcium carbonate mud.

and Browns Beach, this shallow depression was blocked off from the sea, and evaporative conditions prevailed, suitable for the crystallisation of the gypsum, salt and powdery calcium carbonate known as 'natural whiting'. Gypsum workings at Lake Marion have revealed that there is an uppermost layer, about 2 metres deep, of flour gypsum, then about the same thickness of rock gypsum, on top of black, sandy ooze with Posidonia weed fibres and gastropod shells, and a hard basement layer of calcreted fossiliferous sandy limestone of Pleistocene age.

Dickinson and King (1951) propose a theory for formation of the gypsum beds, which suggests chemical precipitation from concentrated brine during quite recent times, possible only 5000-7000 years ago. The deposits are very pure (about 95% gypsum), which probably indicates continuous, uniform conditions, with the fine banding of the prismatic gypsum crystals caused by seasonal changes in salinity (i.e. summer and winter conditions).

The most recent theory for the origin of the massive, crystalline gypsum, is that the flour gypsum (known as 'caso' by the miners), precipitates first, with minute carbonate partings, and diagenetically recrystallises to crystal gypsum.

Other lakes in this area, Snow, Deep and Spider Lakes, etc., all contain gypsum and salt deposits in varying amounts, although Lake Marion is the only one to have been extensively mined. For further details on the occurrence of gypsum in southern Yorke Peninsula refer to Dickinson and King (1951).

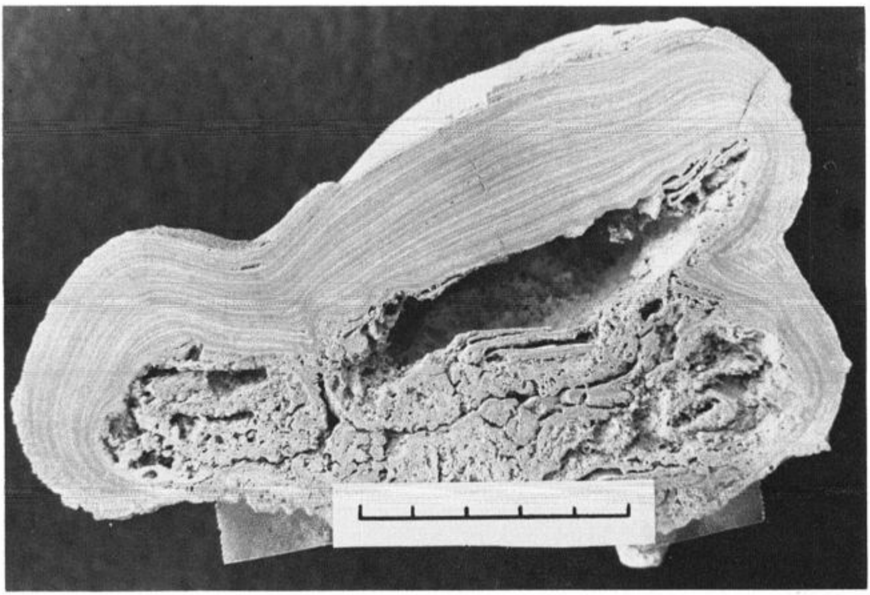
Plate 13: Stromatolites, Marion Lake. Scale in centimetres.

Another important feature of this area is the occurrence of *stromatolites*, which are rounded 'humps' of varying sizes (from a few centimetres to about 40 cms. in diameter), composed of thin, hard carbonate-rich laminations of sediments trapped by algal filaments. The unicellular algae are of the green or blue-green variety, and form mats which occur in very shallow water, as well as under moist on-shore conditions. Their gelatinous surfaces trap and bind the grains of sediment, and the algal filaments grow upward through these newly deposited layers, creating a dense dome of calcium carbonate. They are occasionally found with gypsum crystals growing between some of the central core layers.

The shape of these stromatolites is related to water movements, as they usually grow in the intertidal zone, and are often elongated by the movement of the water, i.e. elliptical, rather than round, with the major axis normal to the shoreline.

In this part of Lake Marion they are found in the calcium carbonate-rich margins of the lake, particularly on the western and southern sides, where heaps of them have been bulldozed off the surface of the gypsum to facilitate mining. They are not actively growing in this area, but have been in the very recent past. There are examples of active stromatolite growth in other lakes, such as Deep Lake.

Plate 14: Below—Cross-section of a typical Marion Lake stromatolite. The smoothly laminated outer limestone zone, now lithified, was once a flexible mat of blue-green filamentous algae, in which fine-grained calcium carbonate mud was trapped. The irregular core, also limestone, was once a mush of abundant algal filaments, gypsum crystals and carbonate mud. The large void once housed a gypsum crystal which has since dissolved. (Scale in centimetres.)



Stromatolites are particularly interesting as they have been found in some of the oldest sedimentary rocks known, and these ancient examples (which may be 3000 million years old) are practically identical with those found today. The algal tissue itself has not been preserved in the fossil examples, but the laminations are easily recognised. Fossil stromatolites are useful therefore in reconstructing ancient environments of deposition, as rocks containing them presumably were deposited in very shallow, intertidal conditions, assuming the concept of 'Uniformitarianism' (i.e. present conditions being indicative of those of the past). Nowdays they only grow in a few places in the world, including Shark Bay in Western Australia, and southern Yorke Peninsula, where they flourish in hypersaline conditions as at Lake Marion (about 6 times as salty as sea-water). The high salinity discourages other marine organisms such as crabs and gastropods that might graze on the algal mats and destroy the structures. During Precambrian times, stromatolites grew prolifically on most shallow continental margins, before the evolution of invertebrate animals which used the algae for food.

Locality 6. Corny Point

From Lake Marion, it is possible to by-pass Stenhouse Bay township, and reach the Corny Point road about 2 kilometres from the lake. Corny Point itself is about 45 kilometres north of here. Drive to the Lighthouse on the north-western point where there is a parking area and examine the rocky outcrop to the north of the lighthouse.

Here is found another extensive exposure of the Precambrian basement rocks, which have already been seen at Hillocks Drive, Stenhouse

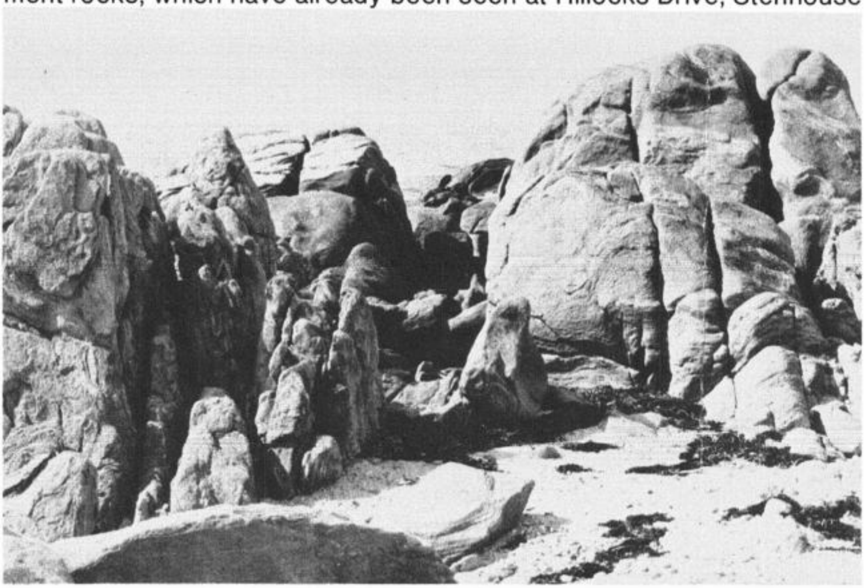


Plate 15: Vertically foliated gneisses, Corny Point.

Bay and Cape Spencer, and once again it is the tough resistant nature of these rocks which is responsible for the prominent, rocky headland on which the lighthouse is built. The gneiss is intruded by pegmatites, but gives an overall impression of a much greyer rock than that seen before, containing more basic minerals. Also, the felspar of the pegmatite is whitish, the quartz smoky, and in some places both muscovite and biotite micas are present. The gneiss is strongly foliated and contorted ptygmatic folding is common, and black amphibolite dykes are frequent.

Walking a few metres east towards the sandy beach, a thin bed (about 2 m. thick) of Tertiary limestone is seen, unconformably overlying the basement rock. The limestone is almost horizontally bedded and is very fossiliferous, but contains pebbles as well as fossil shells, indicating turbulent conditions of deposition, and possibly a near-shore environment. Some cross-bedding can also be seen, which supports the theory of near-shore deposition. The fossils include Pecten, echinoid spines, and bryozoans, and the limestone can be correlated with that at Point Turton (see p. 47) a few kilometres to the east. The unconformity between the gneiss and the limestone indicates a time gap of many millions of years, from about 1500 million years (the gneiss) to about 26 million years ago (the limestone). During this time interval the land could have been thrust up many times, and erosion removed any beds which may have been laid down during periods of submergence. Of the intervening sequence of events we have no evidence.

Plate 16: Fossil bryozoa.

Above the Tertiary deposit, is a calcrete horizon (kunkar), about 10 metres thick. There does not seem to be an aeolianite sequence in this area.

Continue on around the small bay to the northern side, where there is an outcrop of garnetiferous gneiss, containing reddish clots of the metamorphic mineral garnet. The sands of the beach are white and calcareous and much finer than those seen further south, indicating reworking of the dunes as well as the weathered gneiss.

Leaving the Lighthouse area, the road to Warooka passes through the little township of Corny Point, and just east of here, a small outcrop of rock can be seen in a paddock to the north. This is in private property, so cannot be examined at close range, but it is described by Crawford (1965), as low, rounded knots of dark-grey hornblende-gneiss. It was suggested by one of the very early geologists, Walter Howchin, that this may be a granite 'erratic' left by Permian glaciers. However, this is very doubtful, as it appears to be the upper part of a solid mass lying under the thin soil cover and related to the Corny Point gneiss.

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