

29 Faults

SOUTH



AUSTRALIA

Department of Mines

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

Bulletin No. 39

The Geology of Yorke Peninsula

By A. R. CRAWFORD, M.Sc., Assistant Senior Geologist

Issued under the authority of

THE HONOURABLE SIR A. LYELL McEWIN, K.B.E., M.L.C.
MINISTER OF MINES

SOUTH



AUSTRALIA

Department of Mines

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

Bulletin No. 39

The Geology of Yorke Peninsula

By A. R. CRAWFORD, M.Sc., Assistant Senior Geologist

Issued under the authority of
THE HONOURABLE SIR A. LYELL McEWIN, K.B.E., M.L.C.
MINISTER OF MINES

PRICE 10s.

*Geological Survey Office,
Department of Mines,
Adelaide.*

9th February, 1965.

*To the Hon. Sir A. Lyell McEwin, K.B.E., M.L.C.,
Minister of Mines.*

I submit a report by Assistant Senior Geologist A. R. Crawford, describing the geology of Yorke Peninsula.

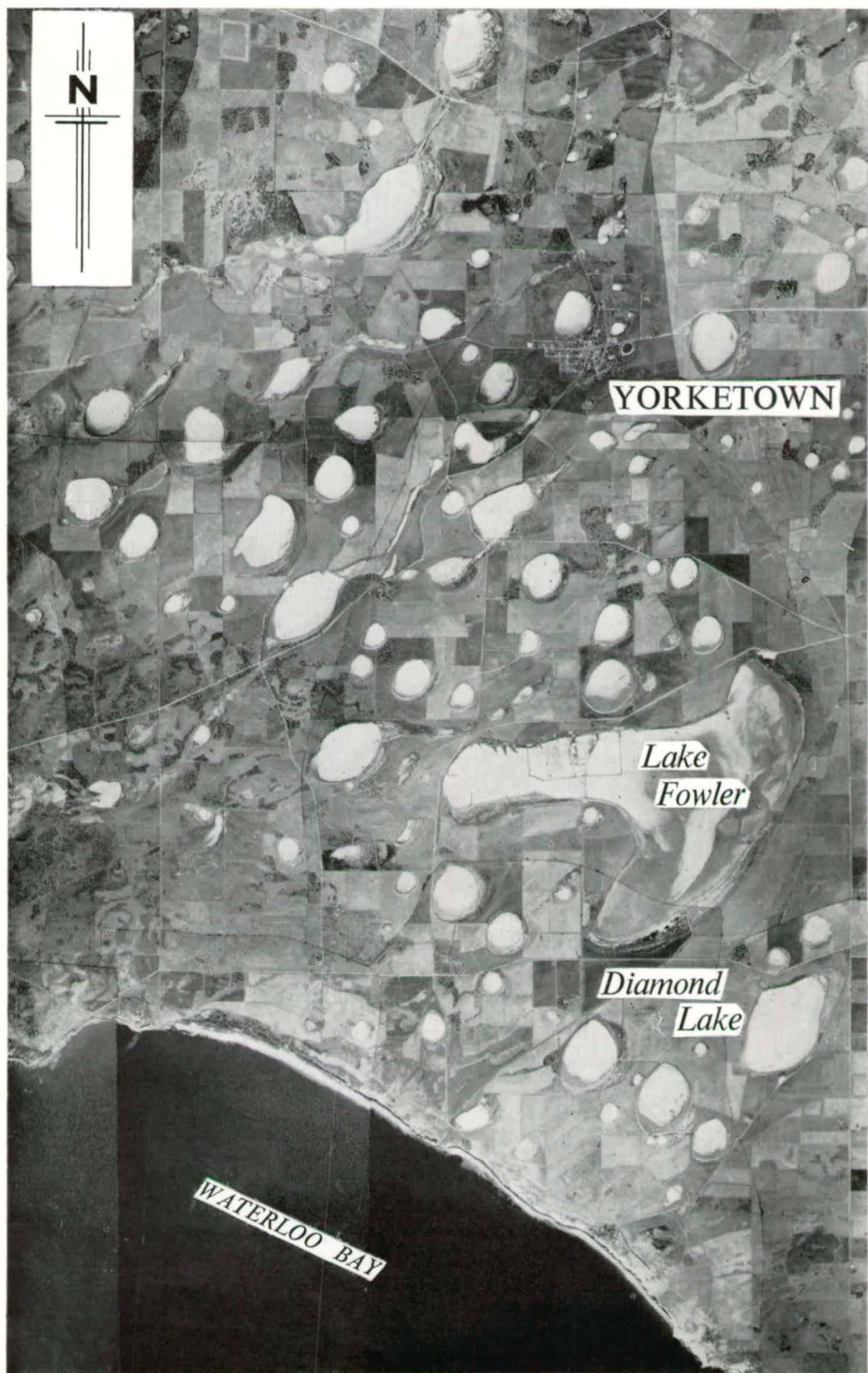
This report is based on two years of field investigations and geological mapping, and is the first publication dealing with the peninsula as a whole. It is an important contribution to the knowledge of the geology of the State, while the section dealing with mineral resources will be a useful reference for further work in the area.

The report is submitted for approval to print as a Bulletin of the Geological Survey of South Australia.

T. A. BARNES, Government Geologist.

Approved,

A. LYELL McEWIN, Minister of Mines.



Vertical air photo of the salt lake district—Lower Yorke Peninsula

Frontispiece]

CONTENTS

	PAGE
CHAPTER 1	
GENERAL INFORMATION	7
Introduction	7
Climate	8
Discovery, Exploration and Settlement	9
Previous Geological Work	10
Fieldwork and Acknowledgements	11
Notes on Difficulties in Mapping and Presentation	12
CHAPTER 2	
STRATIGRAPHY	13
Archaean (Including Rocks Intrusive into Archaean)	13
General	13
Archaean metasediments and associated rock-types	13
Structure of the Archaean basement	14
Metamorphism and metasomatism	15
The Moonta Porphyry	16
Local details of Archaean outcrops	19
Proterozoic	23
Shield Proterozoic	23
Geosynclinal Proterozoic	24
Cambrian	24
General	24
Kulpara Limestone	26
Parara Limestone	26
Red bed clastics, conglomerates, and shales	27
Sedimentary breccias of Pine Point and limestone conglomerate of Rocky Point	27
Ramsay Limestone	28
Possible higher beds	28
Permian	28
General	28
Local details of Permian rocks	28
Tertiary	31
General	31
Eocene	32
Oligo-Miocene	34
Lower Miocene—Melton Limestone	36
Pliocene	36
Structure	37
Quaternary	38
Older Pleistocene (possibly in part Pliocene)	39
Younger Pleistocene and Recent	41
Kunkar	41
Fixed desert seif dunes and associated sand spreads	44
Aeolianite and aeolianite kunkar	45
Older alluvial clays	46
Raised beaches and related features	46
Beach dune ridges	48
Downwash, high-angle slope deposits, and fault scarp debris	49
Recent dunes and sand spreads	49
Saline swamps, salt flats, and salt lakes	50
Recent alluvium	56
CHAPTER 3	
STRUCTURE AND TECTONICS	57
General	57
Post-Cambrian Folds	57
Age of the Post-Cambrian Folding	58
Faulting	58
Off-Shore Faults	60
Age of the Faulting	60
Wider Implications of the Subsurface Structure of the Moonta-Wallaroo Area	61
The Pine Point Thrust	61
Note on the Earthquake of 1902	62
CHAPTER 4	
GEOLOGICAL HISTORY	63
CHAPTER 5	
COMMENTS ON MINERALIZATION	68
Magnetite Mineralization and Aeromagnetic Anomalies	68
Mineralization at Moonta-Wallaroo and the Moonta Porphyry	68
Mineralization in the Cambrian	69
Mineralization in the Cainozoic	70

CHAPTER 6	PAGE
THE MINERAL INDUSTRY OF YORKE PENINSULA	71
Copper and Associated Metalliferous Minerals	72
Dolomite and Limestone	72
Dolomite for the steel industry	72
Limestone for cement manufacture	73
Limestone for road metal	73
Limestone for flux	73
Limestone for lime	73
Limestone for building	74
Lime Sand	74
Gypsum	74
Salt	75
Phosphate	75
Kaolin Clay	76
Montmorillonite Clay	76
Alunite	76
Lignite	76
Natural Whiting	77
Concrete Sand	77

CHAPTER 7	PAGE
BIBLIOGRAPHY	78

APPENDIX

MINLATON AND STANSBURY STRATIGRAPHIC BORES	83
Subsurface Stratigraphy and Micropalaentology	83
Abstract	83
Introduction	83
Port Willunga Beds—Miocene	84
Lower Permian glacigenes	84
Cambrian	84
? Marinoan Series—Upper Proterozoic	86
Minlaton Bore—Lithological Log	86
Stansbury Bore—Lithological Log	91
References	95

PLANS AND ILLUSTRATIONS

Plates

Vertical air photo of the Salt Lake District—Lower Yorke Peninsula	Frontispiece
PLATE I.—View towards Tickera from 6 miles northeast of Point Riley. Shore platform of Archaean gneiss, striking northeast, cut by quartz-jasper veins on left foreground	} Between pp. 64 and 65
PLATE II.—Cliffs of Quaternary aeolian and gypsiferous lacustrine beds overlying and infilling solution holes in Tertiary limestones, with Archaean shore platform, $\frac{1}{2}$ mile north of Point Riley	
PLATE III.—White Clay Bay, 2 miles north of Pine Point. Cliffs of white kaolinized aplite overlain by Tertiary and Quaternary	
PLATE IV.—Possible palimpsest of false bedding, Archaean paragneiss, 1 mile southeast of Point Souttar	
PLATE V.—Corny Point, looking west-southwest. Kunkar and aeolianite on Archaean	
PLATE VI.—Corny Point. Banded and pygmatically folded hornblende gneisses of slightly "raised" shore platform	
PLATE VII.—Port Hughes. Quartz-pebble conglomerate and quartzitic sandstone (shield Proterozoic) forming beach outcrop	
PLATE VIII.—Current-bedded quartzitic sandstone (shield Proterozoic), Dinham's quarry, 2 miles northwest of Ardrossan	
PLATE IX.—Quarry, Section 62, Hundred of Ninnes (between Kulpara and Bute) showing 25 feet of tillite under kunkar	
PLATE X.—Close-up of tillite in quarry, Section 62, Hundred of Ninnes	
PLATE XI.—Lower Cambrian Kulpara Limestone, Wallaroo harbour railway cutting, showing predominantly angular fragments of quartzite in matrix of dolomitic limestone	
PLATE XII.—Lower Cambrian Parara Limestone, Curramulka roadstone quarry	
PLATE XIII.—Sedimentary breccia (? upper Lower Cambrian), 1 mile north of Pine Point	
PLATE XIV.—Sedimentary breccia (? upper Lower Cambrian), 1 mile north of Pine Point. Close-up showing angular debris of Archaean	
PLATE XV.—Sedimentary breccia (? upper Lower Cambrian), 300 yards north of Pine Point jetty	
PLATE XVI.—Close-up of sedimentary breccia (? upper Lower Cambrian), 300 yards north of Pine Point jetty	
PLATE XVII.—Permian till with boulders of Cambrian Kamantoo greywacke overlain by current-bedded Tertiary calcarenite (Point Turton Limestone), Point Turton	
PLATE XVIII.—Close-up of Permian till, on beach 1 mile north of Port Vincent	
PLATE XIX.—Erratic of even-grained Port Elliot-type granite, 1 mile southwest of Urania	
PLATE XX.—Strongly current-bedded coarse quartz sands (Eocene), Crowell's sand pit, 3 miles west of Price	
PLATE XXI.—View from middle bench of Ardrossan dolomite quarry (The Broken Hill Pty. Co. Ltd.), showing eroded surface of Lower Cambrian Kulpara Limestone plastered over with pale-grey kaolinic clay and overlain by current-bedded coarse quartz sands, in part cemented	
PLATE XXII.—Correll's sand pit, section 99, hundred of Kulpara, showing 40ft. of coarse, slightly gravelly, current-bedded quartz sand, strongly iron-stained along the laminae in the lower part. Thin kunkar cover	
PLATE XXIII.—North end of Wool Bay (Klein Point) limestone quarry, showing large irregular solution cavities in Oligo-Miocene Port Willunga Beds, filled with clay. Upper quarter of face is in Pleistocene red clays overlain by kunkar	
PLATE XXIV.—Deeply eroded surface of Port Willunga Beds in road cut, south entrance to Wool Bay jetty, showing clay pockets	
PLATE XXV.—View south-southeast from $\frac{1}{2}$ mile north of Wool Bay, showing flat-topped cliffs of kunkar overlying red Quaternary clays resting on deeply eroded surface of Tertiary Port Willunga Beds	
PLATE XXVI.—Large sink-hole in Melton Limestone, 2 miles north of Melton	
PLATE XXVII.—Dense pink recrystallized bryozoal Melton Limestone overlain by yellow nodular algal Pliocene limestone and Quaternary, Point Hughes	
PLATE XXVIII.—Ardrossan Clays and Sandrock, 100 yards south of town jetty, Ardrossan	
PLATE XXIX.—Red clay with alunite seams overlying mottled Ardrossan Clays and Sandrock and overlain by kunkar, Moonta Bay	
PLATE XXX.—Alunite seams in clayey sand occupying erosion channel cut in Tertiary Port Willunga Beds, 5 miles south of Port Vincent	
PLATE XXXI.—Duricrust at Moonta Bay, overlain by pisolitic laterite	
PLATE XXXII.—A typical section in kunkar, $\frac{1}{4}$ mile north of Port Julia jetty	
PLATE XXXIII.—Kunkar, lacking any marked middle horizon, capping cliffs at Ardrossan	
PLATE XXXIV.—Kunkar showing festoon structure, 2 miles west of Ardrossan (Section 42, Hundred of Cunningham)	
PLATE XXXV.—Alternation of hard kunkar layers and soft aeolianite, Cape Elizabeth	

PLATE XXXVI.—Cliffs in Quaternary, Balgowan. Thick aeolian suite overlying red clay with alunite seams	} Between pp. 64 and 65
PLATE XXXVII.—Cross-section of kunkarised seif dune, 5 miles south of Moonta	
PLATE XXXVIII.—Kunkarised branches in soft aeolianite, overlying greyish-orange kunkar with numerous black nodules—1 mile south of Royston Head	
PLATE XXXIX.—Repetition of kunkar nodule horizons in upper part of sequence—Balgowan	
PLATE XL.—Upper surface of Proterozoic quartzitic sandstone overlain by kunkar, northern Brealey stone quarry, Wallaroo	
PLATE XLI.—Decalcified red sand overlying kunkar nodules formed in a pre-existing soil. Wiltunga Church, 20 miles northeast of Kadina	
PLATE XLII.—Piled aeolianite and kunkar, Cape Spencer	
PLATE XLIII.—Calcareous loess on bedded aeolianite—10 miles northeast of Stenhouse Bay	
PLATE XLIV.—Aeolianite on kunkarised aeolianite, 2 miles south of Point Annie	
PLATE XLV.—Coastal cliff at Troubridge Hill, 2 miles west of Troubridge Point, showing massive flat-lying kunkar overlain by dune with kunkar cap	
PLATE XLVI.—Emerged ("raised") beach overlying (?) Pleistocene mottled clays and overlain by kunkar marl. Exposed in gully 1 mile southeast of Point Riley	
PLATE XLVII.—View of southeast shore of Lake Fowler, with large gypsum dune	
PLATE XLVIII.—Surface of massive crystalline gypsum from northeast corner of Marion Lake	
PLATE XLIX.—Typical crystalline gypsum from massive bed—Marion Lake	
PLATE L.—Small reverse faults in Eocene sand—Correll's sand pit, section 99, Hundred of Kulpara	
PLATE LI.—View southwest from ruins of Moonta Mines, showing level surface of Moonta plain	
PLATE LII.—Peeseey Swamp from its eastern edge, with the Warooka plateau beyond ..	
PLATE LIII.—The Salt Lake District. View south from 7 miles west of Stansbury	
PLATE LIV.—Typical view in the southeast of the peninsula, with piles of kunkar nodules collected from the paddocks	

Text Figures

FIG. 1.—Plan showing location of Yorke Peninsula, with administrative divisions and geological sheet boundaries	} In pocket at back of <i>Bulletin</i>
FIG. 2.—Rainfall, monthly averages and isohyets of annual averages	
FIG. 3.—Faults and associated lineaments	page 59
FIG. 4.—Aeromagnetic anomalies	} In pocket at back of <i>Bulletin</i>
FIG. 5.—Geomorphic sketch	
FIG. 6.—Geomorphic units	
Maitland sheet—4-mile Geological Series (4 miles to 1 inch)	} In pocket at back of <i>Bulletin</i>
Investigator sheet—Geological Atlas Special Series (4 miles to 1 inch)	
Yorke Peninsula—Generalized geological map of Pre-Quaternary rocks (8 miles to 1 inch)	

APPENDIX

Columnar sections—Minlaton and Stansbury Stratigraphic Bores	} In pocket at back of <i>Bulletin</i>
--	--

The Geology of Yorke Peninsula

Chapter 1

GENERAL INFORMATION

INTRODUCTION

Yorke Peninsula lies between Spencer Gulf and Gulf St. Vincent, on the South Australian coast between Long. 136° 49' and 138° 7' E. As its discoverer—Matthew Flinders—wrote: "it is singular in its form, bearing some resemblance to a very ill-shaped leg and foot", with Cape Spencer as the toe of the foot at Lat. 35° 20' S.; the Althorpe Islands lie four miles farther south. The northern boundary of the peninsula is easily defined on the east coast by the head of Gulf St. Vincent, but on the west coast the boundary is indefinite; in a geographical sense it perhaps lies between Wallaroo and Port Broughton. Structurally the unit includes all the country up to the Hummocks Range and its continuation northward almost to Port Pirie. This *Bulletin* deals with an area having an arbitrary boundary along the northern edge of the Wallaroo one-mile sheet (Lat. 33° 45' S.), only passing reference being made to the area to the north, most of which is masked by sand dunes. Reference is necessarily made to the northeastern area on part of the Blyth and Wakefield one-mile sheets. The latter sheet, mapped by R. C. Horwitz, is described in separately published explanatory notes by that author*. A very small area on the Dublin one-mile sheet, near Price, is dealt with here.

The peninsula extends about 150 miles from north to south and varies in breadth from 30 miles at Arthurton to 20 miles at Stansbury, but the foot is 50 miles long. In this area of approximately 2,650 sq. miles there is not one permanent river or stream, and even in winter water-courses have very rarely been seen to flow. The peninsula forms an area of gentle, indeed for the most part extremely smooth relief both on the large and small scale. Its maximum elevation is just over 800ft. near Arthurton in the central spine of high land. The foot nowhere reaches 350ft. and is joined to the main part by a belt of salt swamps only a little above sea-level. This division is important, for it has profoundly affected the human geography in controlling land settlement; the remoter foot being still largely uncleared and unoccupied while the main part is wheat, barley, and grazing country which has long been settled and is now evenly and fairly well populated.

The northwestern part of the peninsula was for many years an important copper-mining area. Here were the famous Wallaroo and Moonta copper mines; discovered in 1860 and finally abandoned in 1923. The towns of Moonta and Kadina grew around these mines and Wallaroo developed as a port with smelters. They remain today the largest settlements, though no underground mining of any kind now takes place here nor anywhere on the peninsula, and the smelters are long since demolished. Quarrying goes on; dolomite is quarried at Ardrossan, for shipment to the steelworks of New South Wales; limestone near Wool Bay, for cement-making at Port Adelaide; and road metal from limestone at Curramulka and from innumerable wayside pits in the superficial limy crusts (kunkar). Shelly sand is taken from Wardang Island for the Port Pirie smelters, and both gypsum and salt are won from the lakes, dunes, and swamps of the southern end of the peninsula. There are semi-artificial salt pans at Price.

* Horwitz, R. C., "The Geology of the Wakefield military sheet," *Geol. Surv. S. Aust. Rep. Invest.* 18, 1961.

Natural water-supplies of good quality are scarce, in spite of a moderate and fairly reliable annual rainfall, and an abnormally low run-off. Nearly all the settled area now has a close network of piped water brought from the east. Only in a small area, northeast of Ramsay Trig, is drinkable underground water found in any quantity.

CLIMATE

The area covered by this *Bulletin* is slightly larger than the "Yorke Peninsula" of the Bureau of Meteorology. The latter area is bounded by a line drawn from the head of Gulf St. Vincent to Tickera, so that the northeastern half of the Wallaroo sheet lies in the meteorological district known as the "Lower North". No sharp meteorological distinction exists.

Temperature

Reduced normals are available for Kadina, Maitland, and Warooka, and the summer and winter monthly average maxima and minima are tabulated below:

	January		July	
	Max. °F.	Min. °F.	Max. °F.	Min. °F.
Kadina	88.0	58.5	61.0	42.0
Maitland	84.5	58.0	58.5	43.5
Warooka	82.5	59.0	58.5	44.0

These show slightly higher summer maxima and lower winter minima in the north, with a milder more maritime climate in the southern part of the peninsula.

Rainfall

Average annual rainfall exceeds 20in. on the highest parts of the peninsula to the northeast and east of Maitland, and over the highest sections of the southwest. Averages decrease towards the coastlines—more rapidly on the eastern side than on the western—and to the north except for the region of the Hummocks. In the northwest and around Ardrossan, the average falls below 14in. Monthly averages are illustrated in fig. 2.

Variation in annual rainfall is shown by the following records:

	Average annual in.	Lowest in.	Highest in.
Moonta (1872-1950)	14.83	6.77 (1876)	26.78 (1889)
Maitland (1879-1950)	19.84	11.46 (1914)	32.63 (1889)
Corny Point (1888-1950)	17.62	10.91 (1950)	30.41 (1917)

There is a considerable range in the extremes—approximately 70 per cent of years in the drier regions receive rainfall within 25 per cent of the average, while in the wetter portions between 80 and 90 per cent of years are within these limits.

The monthly averages show a marked winter maximum—more than 75 per cent of the annual total falling during the period April-October, with almost two-thirds of the annual average in the period May-September.

Although occasional very heavy falls occur in association with thunderstorms, the daily registrations are mainly light, and chiefly result from shower activity during and following the passage of cold fronts of the southern depressions. The average number of wet days varies from 70 to 120 per annum over the region.

Winds

No anemometer records are available for the area. The general wind-pattern is similar to that of adjacent coastal regions, but modified by strong sea-breezes which, because of the narrowness of the peninsula, affect all of it to some degree.

In the rather bare open landscape, strong winds are rather common, and most detached homesteads are protected by substantial windbreaks. The strongest winds usually occur during the winter and early spring months; but strong winds are most frequent during the warmer months largely due to the sea-breeze effect.

From the foregoing, it will be apparent that the peninsula—although it has a fairly reliable moderate rainfall—has hot summers and mild winters which, together with persistent and often strong winds, result in a fairly high evaporation rate. The geological circumstances, together with the topography, lead to a shortage of good underground water, and a total lack of permanent streams. All the lakes on the peninsula are very saline and dry out in summer.

DISCOVERY, EXPLORATION, AND SETTLEMENT

Yorke Peninsula was discovered by Matthew Flinders in 1802 (Flinders, 1814). After the discovery of Eyre Peninsula Flinders sailed north in the *Investigator* to what is now Port Augusta and returned south along the coast, sighting and naming Point Riley on Monday, 15th March, 1802. In the next six days he named Point Pearce, Corny Point, Hardwicke Bay, Spencer Gulf, Cape Spencer and the Althorpe Islands. Then after visiting Kangaroo Island he returned to name Troubridge Hill and Investigator Strait on the 27th and the Hummocks on the 29th. On the 30th he named Gulf St. Vincent and Yorke Peninsula, the latter after the Earl of Hardwicke, First Lord of the Admiralty, who had previously been the Rt. Hon. Charles Philip Yorke, and who had accompanied Flinders on one of his voyages; he later authorized the publication of Flinders' Journal. Troubridge Shoal was named on 1st April.

Shortly after Flinders' visit, Baudin, the French explorer, visited the area in his ship *Le Géographe*, which Flinders had met in Encounter Bay. French names were later given to much of the country, the peninsula being named Presqu'île Cambacères. In contrast to the mainland and Kangaroo Island none of these have been retained on Yorke Peninsula.

Exploration and settlement of Yorke Peninsula was later than either the mainland or Eyre Peninsula. Whereas County Flinders (Eyre Peninsula) was proclaimed in 1842, *i.e.*, in the same year as eight mainland counties, County Daly was not proclaimed until 1862 and County Fergusson, 1869. No doubt the lack of a harbour as good as Port Lincoln contributed to this, but the main reason was a belief, well founded, that the country was all scrub and lacked water. The east coast of the peninsula was explored by Robert Cock and R. G. Jameson at the end of 1838, and the west coast separately by McLaren and Cock in 1839. In that year Cock and James Hughes explored the country between Port Vincent and Port Victoria. A special survey was made of Port Vincent and a road cut to Yorke Valley, where it was proposed to form a township. This never developed. Instead, the first real settlement was at Gum Flat, east of Minlaton, in 1847 by T. Giles on behalf of G. Anstey. This was the only known locality for native gums on the peninsula and had earlier been visited by Charles Parrington. It was stated that "no water existed between the Wakefield River and Gum Flat", except for the coastal springs at Tiddy Widdy.

Partly for lack of water, settlement remained slow until the impetus from the discovery of copper in the north in 1860; and though that resulted in the rapid growth of Moonta, Kadina, and Wallaroo, the remainder of the peninsula developed its towns only in the seventies and after. Yorketown dates from 1872, Curramulka from 1878, Maitland from 1883, and Minlaton from 1888; all developing as centres for the wheat and barley farmers, who had benefited from the invention of the stump-jump plough by Clarence Smith of Ardrossan. Water remained a problem, defeated only by reticulation from reservoirs in the northern Mount Lofty Range. The northern part was connected many years ago, but the south was connected, as far as Edithburgh, only in 1959.

Railways do not exist on Yorke Peninsula except for the single line from Port Wakefield to Kadina and Wallaroo with its extension to Moonta. The narrowness of the peninsula, together with its smooth relief and central spine, made it practicable to cart wheat and barley to the coast fairly easily, and as many as 20 jetties were once in use for loading, with Wallaroo, Edithburgh, Farquhar jetty (Klein Point) and Port Victoria shipping the biggest tonnages. The smaller jetties are now much less used, and greater use is made of an excellent road network covering all the main part of the peninsula. The western part of the foot now has a good road direct to Stenhouse Bay from near Warooka, as well as that to Corny Point, and further agricultural development of this part will presumably follow, though it presents soil problems.

The present-day mineral industry is described in a separate chapter, based on a review by C. M. Willington. The history of the former copper-mining and smelting industry of the north was described by R. Lockhart Jack (1917).

PREVIOUS GEOLOGICAL WORK

No geological work on the area as a whole has been published before.

The earliest recorded statement on the geology is by R. G. Jameson (1838), who explored the east coast with R. Cock, and in a letter to the *South Australian Gazette and Colonial Register* stated that the (east) coast "is generally 'bluff', and is composed of horizontal earthy strata, the upper beds of whitish marl-like appearance, having the usual covering of vegetable mould, mixed with a reddish ferruginous loam. In its geological formation it bears, therefore, a strong resemblance to the land on which Adelaide is built".

The Rev. J. E. Tenison Woods (1862) mentioned limestone cliffs on the coast, but the earliest detailed geological description is by Samuel Higgs, Superintendent of the Wallaroo mines, who in 1872 contributed notes on the mining district to the "Transactions of the Royal Geological Society of Cornwall". These gave a crude general picture of the regional geology of the northern part of the peninsula. Higgs noted the ubiquity of the calcareous crusts, their intimate relation with the Tertiary limestones, and the unconformity between the crusts and the "clay-slate". He also referred to gneiss north of Wallaroo.

Otto Tepper's discovery of fossils near Ardrossan in 1878 was the second record of fossiliferous pre-Mesozoic rocks in South Australia. Tepper, the local schoolteacher, exhibited trilobites and corals (actually, *archaeocyatha*) in limestones which Tate referred to the Lower Silurian. By 1890 these were realized to be of Cambrian age. The discovery was a distinct advance in South Australian geology and made possible the division of the older rocks of the State into Precambrian and Cambrian.

Tepper published a general account of the Ardrossan area in 1879, with two sections and a map. Tate and Rutt wrote short papers on the Port Wakefield railway bore (1882) and used sections to illustrate the geology of the head of Gulf St. Vincent. Further work by Tepper appeared in the same year. Fletcher found fossils in 1890 at Curramulka, and the area was described by Pritchard in 1892. Except for a valuable paper on the southern part of the peninsula by Howchin in 1901, notes on the same area by Greenway and Phillips in 1902, and various short palaeontological papers by Etheridge and Basedow, nothing significant was published from that time until R. Lockhart Jack's *Bulletin* No. 6 of 1917. This dealt with the Moonta-Wallaroo mining district and covered the hundreds of Wallaroo, Kadina and Tiparra. The geological maps and text, together with the information accumulated in Howchin's paper of 1918 on the Ardrossan-Maitland area, have been the basis of all subsequent work in the north of the peninsula, and of great assistance to the present author.

In 1925, Howchin summarized knowledge of the Cambrian rocks. A short note by Barnes and Kleeman on those of Kulpara appeared in 1934.

In 1942, Dickinson discussed structural controls of the Moonta and Wallaroo lodes. Subsequently a great deal of exploration by geophysical methods and some by geochemical methods has been done both by the Department of Mines and private enterprise. Some diamond-drilling, consequent upon this work, has been done, mostly around Kadina. This has had disappointing results. The total absence of outcrop will no doubt continue to discourage, but the area presents fascinating geochemical and structural problems with the prospect of high rewards.

Little further work has been done on the post-Archaeon formations. Daily (1956) has studied and defined the Cambrian sequence. Ludbrook, Glaessner, and Wade have done limited work on the Tertiary. A reconnaissance of the southern half of the foot of the peninsula was carried out by King in 1953 for the Kingscote 4-mile geological sheet, and the same author later produced a reconnaissance map (unpublished) extending from Arthurton to Minlaton. Detailed mapping of the Wakefield one-mile geological sheet by R. Horwitz (1959) revealed what appeared to be a major thrust from the east, extending north-south approximately along the Kulpara scarp. This was an important discovery.

The study of oil prospects and alleged seepages has been made by A. Wade and L. K. Ward. More recently, stratigraphic drilling as a preliminary in oil search has been carried out by the Department of Mines. Some associated geophysical work was done, and other geophysical work revealing high magnetic anomalies in the Archaeon was followed up by diamond drilling. Little boring is done for water except in the western part of the foot, in the vicinity of Curramulka, and along the southeast coast.

FIELDWORK AND ACKNOWLEDGMENTS

Field mapping of the Maitland 4-mile sheet started in July 1958, and continued, with interruptions, until June 1959. This included some mapping of the Wallaroo one-mile sheet and of the southern part of the peninsula (on the Kingscote 4-mile sheet). Systematic mapping of the Wallaroo one-mile sheet started in January 1960 and was completed in March 1960. In April and May 1960, mapping of the southern part of the peninsula was completed.

Mapping was carried out using 40-chain R.A.A.F. air photographs. Mosaics covering the one-mile sheet areas were used as working sheets, and the final colour-roughs were constructed on the 2-mile scale for the Maitland and Investigator sheets and on the 2in. to 1 mile scale for the Wallaroo sheet.

Special acknowledgment is due to Mr. E. F. Richards and the staff of the Cartographic office of the Survey and Drafting Section for their successful efforts in producing complicated detailed maps.

Acknowledgment for assistance in the field is due to local residents too numerous to name individually. Mr. E. J. Carmichael of Moorowie—who provided much information about the Pliocene—deserves especial mention.

Many useful discussions have been held with colleagues of the Geological Survey Branch of the Department. Palaeontological work was done by Dr. N. H. Ludbrook, with some by Mr. T. M. Steel. All petrological work was done at the Australian Mineral Development Laboratories (formerly Parkside Laboratories, Department of Mines) by Mr. H. W. Fander, with whom the author has had continual and valuable contact. In addition, the writer is indebted to members of the staff of the Department of Geology, University of Adelaide; of the Division of Soils, C.S.I.R.O.; and of the Commonwealth Bureau of Meteorology.

Photographs are by the author except for plate 49, the source of which is unknown.

NOTES ON DIFFICULTIES IN MAPPING AND PRESENTATION

The peninsula presents a difficult mapping problem. This was recognized by Howehin ("not a region that can easily be mapped in a geological sense"—1918, p. 185) and by R. Lockhart Jack (1917, p. 19). This is because of the ubiquitous Quaternary cover, much of which is a thick crust of surface limestone or kunkar. It should be noted that this kunkar is present to some degree over many areas beyond those in which it is mapped as a formation.

In the past this discouraged mapping. R. L. Jack—who is the only person to have published a map of any extent—decided to omit the kunkar. But he was working in an area where many shafts and prospecting pits existed and at a time when float was not removed by machines. Moreover this map was produced to illustrate a *Bulletin* concerned primarily with mining.

The present author felt that mapping of the Quaternary was essential for a Geological Survey sheet. Such a sheet is used by a variety of people with differing interests. Those, for instance, who are concerned with soils, or with any kind of boring or trenching, could scarcely be expected to find much value in a map which failed to show what is commonly a hard—sometimes intensely hard—limestone up to 10ft. thick, and in places 30ft. or even more. From the geochemical point of view the sequence of events in the Quaternary is exceedingly important. For these reasons, and to give a complete picture of the geology as we see it today, the Quaternary has been mapped and subdivided as much as the various scales permit.

But so extensive is the Quaternary cover that such a map would provide hardly any information about the relationship of the Precambrian, Palaeozoic, and Tertiary formations. Short of producing two separate maps for each sheet area—which was impracticable—a compromise was reached in which on the one-mile map and four-mile map lines have been drawn indicating the sub-Quaternary limits and boundaries of those older formations, where known; and the eight-mile map of the whole peninsula drawn omitting all masking Quaternary. It is hoped that this, together with fairly detailed tectonic sketches, several sections, and the plotting on the larger-scale maps of a selection of the reliable borehole data will provide an acceptable presentation of the geology in mapped form.

Chapter 2

STRATIGRAPHY

ARCHAEAN (INCLUDING ROCKS INTRUSIVE INTO ARCHAEAN)

General

Yorke Peninsula is essentially a broad ridge of Archaean* rocks generally thinly covered by younger deposits. There are two areas of thicker cover. In the southeast, a deep basin of Cambrian rocks occurs (the Dalrymple Basin); and in the same area, but extending northwestwards and westwards, Permian erosion has removed both the Cambrian and Precambrian rocks to well below present sea-level, and replaced them by glacial deposits.

Outcrops of Archaean rocks are limited to about one-tenth of the total area of the peninsula. Exposures adequate for recording stratigraphic and structural observations are rare except in the limited cliff and beach outcrops, most of which extend along what appears to be bedding foliation and are thereby less valuable than they might be.

The known exposures show that the rocks are mostly metasediments—containing amphibolites—some of which may originally have been intruded into much of the outcropping rock; but the largest apparently intrusive body is the Moonta Porphyry. This is a rock type which is nowhere exposed and appears to be confined to the northwestern part of the peninsula. The age of the intrusive granitic rocks is difficult to determine as no observable contacts with younger beds are available; but the absence† of any intrusion or signs of metamorphism affecting the Proterozoic and Cambrian rocks suggests that the intrusions are older than the Proterozoic, although the precise age of the thin Proterozoic is problematical. It was recognized many years ago (Jack, 1917) that rocks now classed as Proterozoic lie unconformably upon the Moonta Porphyry. The porphyry could therefore be regarded either as Archaean (as has been done on the Maitland four-mile sheet) or as Proterozoic, but older than the thin arenaceous sediments which represent the Proterozoic on the peninsula (as has been done on the later “Generalized Geological Map of Pre-Quaternary Rocks”). The age relationship of the Moonta Porphyry and the granitic intrusive rocks is uncertain, but it may be that they are almost the same age, younger than the Precambrian metasediments and older than the Proterozoic sediments. Some of the basic intrusives may be similarly related.

For purposes of description here, all these rocks are included in the Archaean.

Archaean Metasediments and Associated Rock-Types

About 100 specimens from exposures, several museum specimens from abandoned mines, and selected parts of diamond-drill cores have been examined petrographically. As far as possible the surface specimens have been collected from representatively spaced localities.

* The term “Archaean” is used here in the sense of pre-Adelaide System, as is common practice in South Australia.

† A dyke of dark-green rock, intrusive into the Cambrian dolomitic limestone at the eastern end of the Wallaroo harbour railway-yard, was seen prior to 1957 by B. Campana, A. A. Gibson, and the author.

Widening of the railway has destroyed the section. No record of petrological examination can be traced, but the dyke was comparable with those of lower Palaeozoic age which intrude the Cambrian and older rocks of the Mount Lofty Range.

Most of them are paragneisses; a much smaller proportion are less-metamorphosed sediments. The commonest rock-types are felspathic gneiss, felspathic biotite gneiss, hornblende gneiss, and biotite-hornblende gneiss. Albite gneiss is known at Bird Island. Flaser gneiss occurs at Moonta Bay. At Wallaroo North Beach, tourmalinized migmatite occurs, and a similar rock occurs north of Pine Point.

A hornblende granulite, probably derived from gabbro, is found in the Balgowan drillhole cores. A hornblende-lamprophyre dyke occurs at Corny Point.

Amphibolite rocks are common in the southern coastal outcrops and near Port Victoria, forming a small proportion of the outcrop. They occur as concordant bodies of constant width (a few feet) suggesting an origin as sills. A few discordant dyke-like bodies also occur. In the north, beyond Point Riley, amphibolites are much less common. According to Jack (1917) basic rocks intrude the Precambrian metasediments at Moonta but were not recorded in the Moonta Porphyry.

The magnetite in the Weetulta and Balgowan drill cores is associated with amphibolite. Calc-silicate rocks are known from the Penang mine, near Winulta and southeast of Urania. A hornblende-epidote gneiss from Wallaroo North Beach is regarded as of amphibolite facies, and comparable rocks from the Wallaroo mines have been noticed.

Schists are apparently confined to the northern part of the peninsula. At the Parara mine, near Ardrossan, the country-rock is mica schist. Schists, including chlorite schists, are common in the Wallaroo Mines area, and biotite schists are recorded in the Weetulta and Balgowan diamond-drill holes and in the Maitland No. 1 Government bore. Schists occur—much contorted and pegmatized—at Wallaroo North Beach and at Moonta Bay. These are possibly related to the "igneous schists" recorded by Jack in the Moonta Porphyry.

Quartzites and felspathized quartzites occur, particularly in the north. Garnet granulite (metasedimentary) is characteristic of the Port Victoria area.

Granites, aplites, and pegmatites are widespread. The present author, whilst accepting that they are commonest at the surface in the area east of Arthurton, prefers not to regard that area as a granite batholith (Arthurton Granite of Jack, 1917). Metasediments are known from the same area, and comparably coarse pegmatites and graphitic granite occur everywhere from Tickera to Corny Point, forming usually only a small proportion of the coastal outcrops. Granite is also known southwest and southeast of Maitland; pegmatite at the Parara mine; and aplite near Pine Point and in the Wallaroo-Bird Island-Warburto Point area. Similar rocks are known in several drill cores, often intimately associated with schists and gneisses so that rapid alternations of the one and the other appear in the cores. It therefore seems preferable to regard the whole area as having been injected to varying degrees by granitic material. The Tickera Granite of Jack is a paragneiss similar to the paragneisses of the west and south coasts, both having been injected by pegmatites.

Structure of the Archaean Basement

The structure of the Archaean rocks is difficult to resolve for lack of outcrop. Inland outcrops are generally deeply weathered and are usually of no value in providing structural information. Coastal outcrops do not extend across the strike for any significant distance.

There is, however, a remarkable consistency in the strike of the gneissosity in any particular area, and petrographic examination of oriented specimens strongly suggests that this is bedding foliation. The plotting of the observed directions builds up to a picture (*see* "Tectonic Sketch", Maitland 4-mile sheet) which shows that in the north, the direction is northeasterly; in the centre, northerly;

and in the south, northwesterly; swinging to westerly in the extreme south in the coastal outcrops west of Point Yorke. These presumed bedding foliation directions are moreover commonly vertical or very steeply inclined. Cleavage is only rarely observed.

This apparent pattern is obviously sympathetic with the pattern in southern Eyre Peninsula (Johns 1961), the Precambrian of which is, on the large scale, undoubtedly arcuate in outcrop. So much so, that it is tempting to connect the rocks along strike at the mouth of Spencer Gulf.

There are several possible explanations. One is that the arc is the expression of a simple large-scale fold. With vertical or almost vertical bedding foliation this implies an immense thickness of metasediments, of the order of 500,000 feet.

Another explanation is that a much smaller thickness of metasediments has been isoclinally and repetitively folded and later bent into an arc. Lack of facing information from the scattered outcrops prevents proof.

A third explanation is that initial thicknesses have been exaggerated by intricate minor folding (rheid folding of Carey, 1954). This is not incompatible with the consistency in the strike of the gneissosity even if that is due to bedding foliation. In the author's opinion this is probably the correct explanation.

Metamorphism and Metasomatism

The metamorphism of the Archaean has been briefly studied. The following sequence of events is postulated:

- (a) Regional metamorphism of thick predominantly arkosic and partly calcareous sediments by heat and pressure, consequent upon deep burial and folding. Granitization of deeper material; some small-scale intrusion of granite in centre and north. Local metasomatism (especially tourmalinization). Widespread scattered gabbro intrusion.
- (b) (i) Intrusion of the Moonta Porphyry in the northwest, with contact metamorphism and mineralization by injection of the surrounding gneisses. Intrusion of complementary dykes in the Wallaroo Mines area, and sporadically elsewhere in the north. ?Some intrusion of basic material.
(ii) Widespread but variably intense granite-pegmatite-aplite intrusion with feldspathization. Associated metasomatism.
[The relationship of (i) and (ii) being uncertain but possibly close, with (ii) following shortly upon (i).]
(iii) Some dynamic metamorphism due especially to (ii) but partly to (i).

Events under (a) and (b) occurred before the deposition of the "shield Proterozoic". (See p. 23.)

- (c) Local dynamic metamorphism during post-Cambrian tectonism. Probably confined largely to a presumed lower Paleozoic orogeny and to post-Mesozoic block faulting and subsequent jostling of fault blocks.

This sequence is thought to be essentially correct, but is likely to be least accurate in the timing of the intrusion of granitic bodies, as it is very difficult on the available evidence to determine whether these are of more than one age (as suspected) or essentially of one period. Some pegmatites post-date the Moonta Porphyry (as Jack noted) and it seems probable that they and minor aplite and adamellite occurrences in the Wallaroo-Moonta area are all of the same age; possibly, as suggested above, only slightly younger than the porphyry itself. But the granites noted in diamond-drill hole core from Weetulta and Balgowan, and specimens from the Penang mine, are so intimately associated with paragneissic material that for them an earlier period of intrusion seems more likely, either predating or contemporaneous with the folding which led to their metamorphism. Some support is given by granitized sediments being known to occur in the cores. Indeed, the whole process is one in which "intrusion" is a word implying too clear-cut an entry and it can perhaps only be described as metasomatic-metamorphic.

Regional Metamorphism

Metamorphic facies appears to have no clear geographic pattern. There is a range of variation from low green-schist facies to granulite facies, with most specimens in the amphibolite facies. Most of the paragneisses are quartzofelspathic, but almandine-hornblende gneisses are common and diopside-bearing gneisses occur also. Rocks of granulite facies are known only from borehole core and the Point Pearce district (where sillimanite-biotite gneisses are more common) although rocks approaching granulite facies occur near the Parara copper mine.

Contact Metamorphism

Rocks of actinolite-epidote-hornfels facies occur, particularly north of Pine Point—where they may be associated with aplitic intrusion—and in the Wallaroo-Moonta-Kadina area (in numerous borehole cores).

Dynamic Metamorphism

Cataclastic structures are common in rocks of the Pine Point district where strong tectonic disturbance dates from (probably) lower Palaeozoic thrusting and Tertiary and subsequent faulting. This appears to be a dynamic metamorphism solely due to strong mechanical forces at low temperatures. Dynamic metamorphism affects many rocks collected from the northwest, being recorded in specimens from the northern limit of mapping near Tiekera southwards to the area west of Maitland. Dynamic metamorphism clearly of regional significance, and better described as regional metamorphism, affects most of the Archæan of the southwest, where cataclastic features in the narrower sense are absent.

The Moonta Porphyry

The Moonta Porphyry was first geologically described by Ward and Jack (1912) in discussing the general geology of the Yelta and Paramatta mines, north-northeast of Moonta. They distinguished a group of "older felsites and felspathic porphyries" which were variable in outward habit: "Both in the presence or absence of schistosity and in the proportion of phenocrysts to groundmass the members of this group vary rapidly from point to point; yet the several varieties are so closely associated in the field that the essential unity of the group is undoubted". They attributed the differences to (a) magmatic differentiation and (b) later selective crushing, and stated that there was "no definite evidence to show whether the intrusive or the effusive phase of igneous activity is represented by these rocks. No fragmental types were observed either in the underground workings or in the dumps around the shafts, and no vesicular types were recognized."

Jack (1917) mapped "intrusive felspar porphyry in places showing schistose structure" over an area of 17 sq. miles north and east of Moonta, with an almond-shaped outcrop. Jack's boundary was "approximately laid down on the evidence afforded by scattered workings and occasional field stones". A very much smaller area was mapped east of Thrington. He discussed the rock under the heading of "Felspar Porphyry", though he writes of the "injection" of a "large mass of felsite and felspar porphyry." His account of the rock types is not significantly different, though more detailed, from that of Ward and Jack, describing "normal massive material" as reddish-brown, with a very fine-grained groundmass, phenocrysts of pink felspar about $\frac{1}{8}$ in. in diameter, and a lesser number of bluish quartz crystals somewhat smaller in size. He adds that the proportion of phenocrysts to groundmass varies within wide limits. Jack stated that "in no instance is it possible to see the actual contact between the felspar porphyry and the surrounding sediments . . . The intrusive character . . . is indicated by the bifurcation in the vicinity of the Parrara mine*. Partly because of this

* This mine, 2 $\frac{1}{4}$ miles north of Moonta, is not to be confused with the Parara mine, 2 miles northwest of Ardrossan.

bifurcation, the discovery of feldspar porphyry east of Thrington and in the Wandilta mine dump and (doubtfully *in situ*) near the Duryea workings, but partly also because of a suspected difference between the strike of the nearest exposed Precambrian sediments and the alignment of the long axis of the outcrop, Jack regarded the rock as intrusive and not effusive. Much of his account is devoted to a comparison of the rock with the very much more extensive and more variable porphyry of the Gawler Range, which he regarded as effusive.

Dickinson (1942, p. 11) was the first to use the term "Moonta Porphyry". Dickinson attributed a "remarkable continuity" of fissuring in the Moonta mines to a "uniformity of the porphyry rock" (p. 12); and regarded the "apparent lenticular shape of the Moonta Porphyry mass" as not entirely original but caused at least in part by combined stresses.

As the Moonta Porphyry is nowhere exposed and most dump specimens are possibly, from the very fact of their original location, not typical, it is difficult to study the rock as a body. Some comments on a few specimens are made below. Comment on the possible sub-Quaternary outcrop is also made. Speculation on its habit and relationship to the rocks it apparently intrudes, and to other intrusive rocks, is made in chapter 5.

Specimen Descriptions

Analyses

A specimen (T.S. 4710) from prospect-pit dumps at Bald Hill (2 miles NE. of Moonta) was described by H. W. Fander (Australian Mineral Development Laboratories) as follows: "Glomeroporphyritic crystals of oligoclase are set in a fine-grained groundmass of sodic plagioclase, microcline, quartz and chlorite-laths. The grain size of the groundmass is on the borderline between microgranodiorite and dacite; the rock can therefore be termed a porphyritic granodiorite or dacite, though the latter term (porphyritic dacite) is perhaps preferable."

A macroscopically identical specimen from the same locality was analysed by H. W. Sears (Australian Mineral Development Laboratories) and is tabulated with an analysis by W. S. Chapman of "normal feldspar porphyry" of Moonta (Jack, 1917, p. 26) the exact location of which is not apparent.

	Bald Hill porphyry (Analyst— Sears, 1961)	Normal feldspar porphyry (Analyst— Chapman, 1914)
Silica, SiO ₂	71.2	73.02
Alumina, Al ₂ O ₃	12.1	13.39
Ferric oxide, Fe ₂ O ₃	2.56	1.87
Ferrous oxide, FeO	1.86	1.40
Magnesia, MgO	1.61	0.55
Lime, CaO	0.66	0.42
Soda, Na ₂ O	3.15	2.38
Potash, K ₂ O	4.60	4.89
Water at 100°, H ₂ O —	0.16	0.06
Water over 100°, H ₂ O +	0.12	0.70
Carbon dioxide, CO ₂	0.17	Nil
Titanium oxide, TiO ₂	0.58	0.52
Phosphorus pentoxide, P ₂ O ₅	0.10	0.07
Ferric disulphide, FeS ₂	—	0.20
Sulphate, SO ₃	Nil	—
Manganese oxide, MnO	0.13	0.02
Barium oxide, BaO	—	Nil
Chlorine, Cl	Nil	0.03
Cupric oxide, CuO	—	0.05
	—	99.57

It is important to add here that work by Fander on the material from Bald Hill, in an attempt to assess its age by the zircon method, shows that it contains detritally rounded fragments as well as euhedral crystals of tourmaline, suggesting incorporation and complete assimilation of material from the intruded originally sedimentary rocks. This is in accord with its position near the edge of the sub-Quaternary outcrop.

A museum specimen from the Yelta mine (T.S. 4508) is a red sodic rhyolite, faintly flow banded, with laths of chlorite forming green schlieren. Another specimen, from the Hamley mine area, is a rhyolite of extrusive type. Crushed gneissose porphyry, dynamically metamorphosed and recrystallized, is common in the mine dumps, and a variety showing boudinage was noted (T.S. 6378) in a museum specimen from 1,320ft. in Taylor shaft.

Jack recorded Moonta Porphyry in the dumps of the Wandilta mine. It was not noted in a re-examination, but a (originally) monomineralic rock, an oligoclaseite, was found (T.S. 6180) which may be a variant of the porphyry.

In the Department of Mines drilling of recent years, several holes were put down southwest of Kadina. In hole H.49, about $\frac{3}{4}$ mile west-southwest of the Duryea mine (and on section 128, hundred of Wallaroo) highly altered "granite" was the first rock met beneath the Quaternary, and the less-altered deeper material—porphyritic microgranite—is probably a variant of the porphyry (*e.g.*, T.S. 6446). More normal porphyry was entered below (*e.g.*, T.S. 6447). No recognizable Moonta Porphyry was noted in a rapid re-examination of the many cores from numerous holes farther north, in the area west of Kadina. But in a group of holes drilled north of Kadina in an investigation of magnetic anomalies, one hole (N.K.4, on section 912E, hundred of Wallaroo; almost exactly 10 miles NE. of Wallaroo post office) cut magnetite-rich felspathic gneiss at about 500ft., the dip of the hole being north at 50 deg. These gneisses appear to the writer to be possible metamorphosed variants of the porphyry. Their significance is discussed in chapter 5.

Sub-Quaternary Distribution of the Main Mass of Moonta Porphyry

To map the "outcrop" of the Moonta Porphyry is difficult because it is completely concealed under soil, hard kunkar and, in places, thin clays and gravels. Jack's boundaries were based almost entirely on mine information. On the present maps a sub-Quaternary distribution is shown and is slightly different from Jack's in the north and in the east. An extension to the north is based on known intersections in several recent Department of Mines exploratory drillholes. In the east it was noted that the porphyry formed high ground, and there the limit has been extended slightly, partly by mapping physiographic features.

To the south and southwest towards Maitland and Balgowan, it is important to realize that the extensive seif dune cover, with the almost certain existence of Quaternary clays beneath, makes knowledge of that area impossible to obtain without drilling. No basement rock appears in the Cape Elizabeth area, so that the coastal cliffs and beaches offer no help. The question of a southern extension of the porphyry is unresolved. At the time of mapping, the present author concurred with Jack in drawing a provisional boundary only a short distance beyond Moonta, where a prominent south-facing slope about 2 miles south of the town suggests a change to softer, more easily weathered rocks. However, it is possible that this is an erosional feature of different origin. It appears to be the right bank slope of an old valley, the contours of which are somewhat obscured by the seif dune cover. It is therefore possible that Moonta Porphyry

exists immediately under Quaternary, in an area east of Cape Elizabeth crossed by the Moonta-Balgowan road.*

Other Possible Sub-Quaternary Outcrops of Moonta Porphyry

In addition to the main mass of porphyry, Jack mapped a small area east of Thrington, with an approximately oval area with a long axis about half a mile long, extending NW.-SE., and a little more than a quarter of a mile across. From his map he appears to have regarded it as overlapped on its northwest side by what is now regarded as shield Proterozoic. From his text it is evident that the basis of this outcrop was only "the presence of numerous stones". The area is now arable land and the only rock seen in the recent mapping was a boulder dug out by one farmer, and apparently broken off from a larger mass, which is an amphibolite closely comparable with others almost certainly of sedimentary origin. It is possible that Jack's stones were float from an undetected soil-covered outcrop, but they may have been Permian erratics. Another possibility is mentioned in chapter 5.

Jack also noted felspar porphyry in the dump of the Wandilta main shaft (as mentioned above); "in the vicinity of the Duryea workings" (which he suspected of being carted there); and as narrow veins penetrating quartzite at the Copper Hill mine. Checking of the Copper Hill mine dump showed no rock which could be regarded as Moonta Porphyry.

Local Details of Archaean Outcrops

Tickera-Point Riley-Wallaroo North Beach (North End)

A continuous outcrop of Archaean rocks extends from about a mile north of Tickera southwards through Point Riley to the north end of Wallaroo North Beach, as shore outcrops in low cliffs (plate I). The predominant rock type is a red granitic gneiss probably of metasomatic origin. A consistent planar foliation in the more gneissic varieties is parallel to the coast alignment north of Point Riley; south of there the coast has been strongly influenced by joints. The foliation is vertical, or nearly so. Pegmatites occur, though not prominently. A discordant vein of quartz and jasper about half a mile south of Myponie Point, about 2ft. wide, is vertical and strikes 135 deg. This contains amethystine quartz.

At the southern end of this outcrop a hornblende-epidote gneiss occurs, associated with medium-grained granitic gneiss characteristic of the northern area.

Wallaroo Town

Except for a tiny weathered inlier of red gneiss (probably paragneiss) at the eastern end of the harbour railway yard, no outcrop of Archaean is to be seen at Wallaroo itself; but boring on the area west of the sulphuric acid works (on the old smelter site) showed granitic rock at about 40ft. below sea-level. This was deeply weathered, there being a gradual upward transition from hard fresh granite to a clay with angular granite fragments. Aplite was found in nearby foundation pits at the fertilizer works of Wallaroo-Mount Lyell Fertilisers Limited.

Warburto Point

Archaean albite gneiss occurs at Warburto Point and on Bird Island reef.

* It is also just possible that this feature is a continuation of one exactly in line with it on Eyre Peninsula, which extends from the coast near Gibbon Point at 285 deg., past Cleve towards the southern end of Darke Peak. This limits the Archaean outcrop of that district to the area to the north of the linement, that to the south being under shallow Quaternary cover. It may be a normal fault with small downthrow to the south. Similarly aligned straight faults of small southerly downthrow have been noted by the writer in northwestern Eyre Peninsula; one is 80 miles long.

Moonta Bay-Port Hughes

From about 200yds. south of Moonta Bay jetty to 400yds. south of Port Hughes jetty there extends a beach outcrop of Archaean and Proterozoic rocks broken only by patches of beach sand. The Archaean is generally gneissic and is in places very tightly folded with a general north-south trend to the foliation; being unconformably overlain by almost horizontal proterozoic rocks. A specimen from the northern part of the outcrop is a flaser gneiss, metamorphosed, metasomatized, and then crushed. A specimen from the very small outcrop of Archaean south of the Port Hughes jetty is a brecciated aplite. To the northeast of the jetty brecciated biotite gneiss occurs.

Thrington

Between Kadina and Kulpara two small outcrops of Archaean have been mapped. Neither have any exposure of fresh rock and even float is scarce, but the area north of the railway has provided blocks of dark hornblende gneiss.

This northeastern outcrop was mapped by R. L. Jack as Moonta Porphyry, but as stated above none has been seen by the present author.

Penang Mine (No Outcrop)

Dump material shows amphibolite, banded calc-silicate, and feldspathized sandstone.

Agerly (No Outcrop)

Drilling showed gneisses and schists under shallow Quaternary.

Arthurton-Winulta Area

At Arthurton quartzo-feldspathic gneiss occurs, and at the Arthurton tank of the Engineering and Water Supply Department (section 363, hundred of Tiparra) amphibolite occurs. To the east, pegmatite becomes very common and this is probably the area most affected by pegmatization. The rock can be seen in numerous dumps in the paddocks, very coarse float being abundant. Pink pegmatite, with some schorl, is the commonest rock-type.

Calc-silicates occur $1\frac{1}{2}$ miles west of Winulta, in Winulta Creek. Medium-grained leucocratic granite occurs 3 miles south of Winulta.

Maitland Area

Maitland is built on a ridge of Archaean rocks, and float can be picked up on the Winulta road. An old oil bore in the parklands entered gneiss immediately, as did a water bore in the showgrounds. A Government bore in the west parklands struck granite at 51ft., and another on section 72E, hundred of Maitland, struck pegmatite at 199 feet.

Two miles south of the town, on the Minlaton road, a shallow cutting reveals weathered feldspathic rock of adamellite composition, probably a feldspathized arenaceous sediment. Other exposures occur sporadically along the ridge extending south, parallel to and west of the road.

Maitland Mines

On section 371, hundred of Maitland, and in that vicinity, the commonest rock is a fine-grained biotite-hornblende gneiss. Similar rock occurs in patchy exposures to the southwest, with occasional pegmatite masses. Much of this area is very deeply weathered.

Ardrossan Area—Parara Mine

Biotite schist and muscovite quartzite (tourmalinized recrystallized arkose) are the country-rocks at Parara mine, but calc-silicates occur half a mile southeast, north of Dinham quarry. Pegmatites, with very large masses of black tourmaline, occur south of the mine; and knotted cordierite schists also occur.

Pine Point

From about half a mile north of Pine Point, Archaean rocks are exposed in the cliffs for 2 miles and show considerable mineralization. The main rock-type at the southern end is aplite, forming irregular masses which are everywhere almost completely kaolinized (plate III). These are associated with very strongly altered hornblende-rich rocks which are intensely sheared and brecciated, and others so changed as to be unrecognizable. Boulders from veins of hornblende are found on the beach. Northwards, coarser very felspathic rocks occur; alteration is much less severe, and in one locality felspathic gneiss with north-south foliation is seen. The whole area is affected by a tectonic brecciation, sediments of presumed upper Lower Cambrian age having been apparently thrust against the Archaean from the east.

Inland, scarcely any basement is exposed. In the south, pegmatite float is seen. A small road-metal quarry at the north end of Pine Point township shows biotite hornfels and a scapolitized felspathic igneous rock. The rock type westwards (*e.g.*, sections 45 and 76, hundred of Muloowurtie) appears to be quartzofelspathic gneiss.

Nearer Ardrossan, at the Hillside copper mine, marble was recorded in the shafts. The area almost certainly has been subjected to faulting, now concealed by the Quaternary rocks, and the marble may be of Cambrian age.

Port Victoria, Point Pearce, and Wardang Island

At Port Victoria, the main rock-type is a red felspathic gneiss, described by Fander as a calcic paragneiss. Grey gneiss and coarse-grained amphibolites rich in epidote occur.

Very similar rocks extend southward for a few miles; occur along the west coast of Wardang Island; form Rocky Island, Green Island, and Mungaree Island; and extend around the southern end of Point Pearce peninsula. A muscovite-biotite gneiss was recorded half a mile northeast of Point Pearce. Small pegmatite intrusions exist on Point Pearce peninsula.

Point Souttar

From opposite the property known as Brutus Castle, section 243, hundred of Para Wurlie, a low beach outcrop extends for 2 miles, almost to Point Souttar, and a shorter similar outcrop occurs 1 mile west of the point. These rocks are very consistent in type, being red felspathic paragneisses and hornblende gneisses, which are nearly always in regular banding about 1 in. wide, with a coarse texture, and a strike of 120-130 deg., and dipping 60° SW. The hornblende is an unusual type. One concordant amphibolite band was seen in the eastern outcrop. A possible palimpsest of false bedding was noted 1 mile southeast of Point Souttar (plate IV).

Corny Point

East of Corny Point township a small outcrop of Archaean is shown. This is the "Granite Rock" shown on the hundred of Carribie plan, regarded by Howchin (1900) as an erratic. In a paddock, on the side north of the main road, low rounded knobs of dark-grey hornblende gneiss can be seen, and these appear to be the upper part of a solid mass which lies under very thin soil around them. This looks more like a small bedrock tor than an erratic, especially as the rock

is not significantly different in type and lineation from those near Point Souttar and at Corny Point, and as the outcrop is almost at sea-level and lies immediately south of beach dune ridges.

At Corny Point proper, wide beach outcrops occur for half a mile on each side of the lighthouse (plate V). These are predominantly light- or dark-grey garnetiferous hornblende-gneisses with concordant amphibolites; but pegmatites are common, and there is much coarse graphic granite. The gneisses—although generally persistent in the direction of their prominent banding—are periodically strongly contorted, the contortions often starting and ending very abruptly. Ptygmatic folding occurs (plate VI). The general strike is 150 deg. in the east, 120-130 deg. in the west. Amphibolites are up to 10ft. thick, pegmatites usually thinner; but masses of pink graphic granite several feet across occur, especially west of the lighthouse. Farther west, vertical very regularly banded brown-weathering schistose gneiss outcrops, striking 130 deg. A prominent black amphibolite of possibly lamprophyric origin nearby is concordant with the gneisses.

West Coast of the Foot

From Berry Bay to Point Annie, massive whaleback beach outcrops extend continuously, being separated from those of Corny Point by a short stretch of open sandy bay. These outcrops are all very coarse augen gneiss, having a granitoid texture with big phenocrysts of perthite and orthoclase. Some finer-grained schistose bands occur which are rich in apatite.

Similar outcrops occur at Daly Head but are more broken in appearance. Amphibolite of gabbroic origin was recorded. At Royston Head, wide massive outcrops of dark-grey gneiss occur. Tate (1890) recorded wolfram in the Archaean north of the head, but examination was insufficiently detailed to confirm this.

On the west side of Cape Spencer, medium-grained feldspathic gneiss occurs. Glastonbury (1939) regarded the typical gneiss here as an orthogneiss but his descriptions could equally well refer to a paragneiss, and the rock resembles very much the paragneisses to the north. Hornblende schists also occur, and very minor pegmatites.

All these west-coast outcrops show a bedding foliation consistently aligned northwest-southeast.

South Coast of the Foot

The only outcrops east of Cape Spencer are at Stenhouse Bay and those extending almost continuously from Hillock Point to about $1\frac{1}{2}$ miles beyond Cape Yorke, on the west side of Foul Bay. One very small outcrop is known on the east side of Marion Bay, 3 miles west of Hillock Point.

At Stenhouse Bay, coarse-grained biotite gneiss occurs in massive outcrops at the foot of the cliffs $\frac{1}{4}$ mile west of the jetty, facing south. They extend only a short distance westward and are very consistent in appearance. Specimens of this rock, taken as an age-determination sample in 1958, were examined by H. W. Fander and found to contain detritally rounded zircon suggesting sedimentary origin.

In the Hillock Point-Point Yorke outcrops, pink biotite paragneiss is very common. Amphibolites also occur. The foliation is approximately east-west.

Althorpe Islands

Dark rocks presumed to be Archaean gneisses, and similar in type to those of Stenhouse Bay and Cape Spencer, occur at the base of the aeolianite cliffs of the Althorpe Islands and form reefs, especially on the west side. The author has had no opportunity to inspect them and has been unable to obtain specimens. No Departmental records of any specimens exist.

PROTEROZOIC

The Proterozoic rocks of the peninsula are of two distinct facies, both of which are separated from the Archaean basement by a strong angular unconformity.

- (a) A thin arenaceous "shelf" sequence, principally of quartzitic sandstones, quartzites, conglomerates, and arkosic sandstones; with beds rather more shaly near the top locally. This is the characteristic Proterozoic of the central and northern peninsula.
- (b) "Geosynclinal" Proterozoic typical of the Adelaide System, though rather less thick than is common in the Mount Lofty Range. This is present only in the Kulpara scarp zone (on the Wakefield one-mile sheet) and as a small overthrust remnant (klippe) in the southeast of the Wallaroo sheet area. Other concealed overthrust remnants may exist in the same area.

It will be evident from the maps that the Proterozoic of type (a)—which hereafter will be called the "shield Proterozoic"—formerly covered most of the Archaean outcrop, and at the present day only remnants remain in shallow basins and as outliers on hill-tops. It is probable that shield Proterozoic occupies the lower part of the Dalrymple Basin sequence. No Proterozoic is known in the western part of the foot of the peninsula.

Shield Proterozoic

Few good exposures exist. The best are at Port Hughes and in the Wallaroo district and near Winulta. The rocks are flat-lying or dip slightly.

At Port Hughes, for 300 yards south of the jetty, quartz-pebble conglomerates and quartzitic sandstones lie horizontally on a very poorly exposed gneissic basement (plate VII). The thickness of shield Proterozoic exposed here is about 10ft. To the north, in Moonta Bay, similar rock laps on to the basement and can be seen at low tide.

No shield Proterozoic is seen at Wallaroo on the coast, but it is exposed in the two "Brealey Stone" quarries where 5 to 8ft. of hard, rather brittle quartzitic sandstone can be seen. At Warburto Point—and on Bird Island and its reef—beds identical with those at Port Hughes can be seen with a total thickness of 5 feet.

A coarse pebble conglomerate caps the hills on either side of the valley which extends westwards from Winulta. Various good minor exposures exist; one, north-west of Winulta, shows a definite eastward dip. Good exposures of massive conglomerate can be seen in a road cutting 1 mile west of Winulta. Half a mile south of Winulta, reddish shaly sandstones occur which appear to be the higher-most beds in that district.

There are scarcely any other extensive exposures on the peninsula. Two good quarry exposures are known: Dinham (2 miles NW. of Ardrossan, section 77, hundred of Cunningham; plate VIII) and Wundersitz (1½ miles E. of Maitland, section 215, hundred of Maitland) which show 10ft. and 6ft. respectively of a cross-bedded quartzitic sandstone, sub-horizontal. At each locality the total thickness of shield Proterozoic is undoubtedly much greater than that exposed.

On the eastern side of Mount Rat, slabs of quartzitic sandstone containing occasional rounded boulders are poorly exposed over a small area. Conglomerate can be seen west of Port Julia and in other small exposures shown on the map (which have mostly had to be greatly exaggerated in size to show them at all). As with the basement-rock types, many areas have been mapped as outcrop on the evidence of abundant float.

The distribution of these scattered outcrops, together with scanty borehole records of similar rock-types, indicate the existence—prior to erosion—of a deposit essentially constant in type, and varying in thickness from approximately 200ft. in the east to a few feet in the west.

In the northeast, however, there appears a change of rock type. One mile southeast of Paskeville, quartzitic sandstone is seen. Two miles southeast, and in several places northeast, the Proterozoic is, at least in part, much redder and more micaceous and is essentially an arkose. Some shaly beds are known. This is probably in the lower part of the sequence.

North of Clinton Centre, soft white shaly sandstones have been seen in dam dumps. These are regarded as local areas of Cambrian transition beds.

More precise dating of the shield Proterozoic is not practicable. It may be of any age within the Adelaide System and may contain material which has been reworked at least once. The problem is complicated by the known presence of arenaceous sediments at the base of the Cambrian on the Wakefield sheet area.

Geosynclinal Proterozoic

In the Kulpara scarp zone there is a sequence of Adelaide System beds comparable in lithology with those of the Mount Lofty Range though reduced in thickness. It is unnecessary here to recapitulate the descriptions given in the explanatory notes to the Wakefield one-mile sheet by R. C. Horwitz*.

No examples of geosynclinal Proterozoic have been recorded on the Maitland or Investigator geological sheets, but on the Wallaroo one-mile sheet area an important exposure of a tillite was revealed when a roadstone quarry, in kunkar, on section 62, hundred of Ninnes, was deepened (plates IX and X). Lying under 8ft. of kunkar, 25ft. of Adelaide System tillite—probably, but not certainly, Sturt Tillite—has been exposed. This contains a great variety of erratics of which at least one type is almost certainly of Torrensian origin. It is significant that bulldozing of the area 100yds. west of the quarry revealed lateritized shield Proterozoic, which has also been seen as float 250yds. east, as well as 1 mile south.

Rocks from a well dump $\frac{1}{4}$ mile northeast (at the southwest corner of section 92) are of fluvioglacial type†.

The occurrence is interpreted as a small overthrust remnant or klippe. In normal circumstances it would never have been found, though it does occur approximately along the projection of the Yararoo thrust (Horwitz, 1959, 1961). It is, of course, possible that this material forms part of a small outlier of Sturtian rocks, possibly preserved by having been downfaulted, if the shield Proterozoic hereabouts is of earlier Sturtian or pre-Sturtian age. It could even be an inlier, if the shield Proterozoic is post Sturtian. It seems best at present to regard it as a klippe.

CAMBRIAN

General

Cambrian rocks are widespread in the north and centre of the peninsula and are present in the south in the Dalrymple Basin under Permian cover. They are absent in the Yorketown area and to the west, and the extension of the Dalrymple Basin southwards in the area east of Yorketown is uncertain.

Daily (1956) has studied the Cambrian of South Australia and established a faunal succession based on numerous well-exposed (but incomplete) sections, of which three are in Yorke Peninsula-Kulpara, Ardrossan (Horse Gully), and Curramulka. Additional work by Daily (Horwitz and Daily 1958 and still in progress) on the material provided by the Minlaton stratigraphic bore (on section 210, hundred of Ramsay, 6 miles east-southeast of Minlaton) showed that there is

* Horwitz, R. C., *Report of Investigations*, 18, 1961.

† This information was not available at the time of compilation of the Wallaroo one-mile sheet, on which the well is shown to be in shield Proterozoic on field identification.

here a Middle Cambrian limestone containing *Redlichia*. This outcrops 4 miles south of Curramulka and is indistinguishable from the upper limestone (Parara) of the Lower Cambrian. Work on this bore has made possible a division of the Cambrian of Yorke Peninsula into four stratigraphic units. It should be noted that the inclusion in the upper Lower Cambrian of the sedimentary breccias of Pine Point, and the closely related limestone conglomerate of Rocky Point is based only upon lithological comparison of several thin sections, and may be incorrect; but no better position for these rocks has yet been found. They are apparently thrust from the east and can be compared with the geosynclinal Proterozoic of the Wallaroo sheet area.

The stratigraphic relation of the Cambrian rocks to the shield Proterozoic is clear, though the contact is nowhere satisfactorily exposed. At Kulpara, the Proterozoic is not, strictly, shield Proterozoic, but Pound Sandstone. It was at first thought that the Minlaton stratigraphic bore penetrated into the Proterozoic—as is indicated on the map—but re-examination of the core showed that, in addition to the arenaceous material, some calcareous material persists almost to the bottom of the bore, and it is not certain that it has indeed passed out of the Cambrian succession.

There is little doubt, though, that the Cambrian transgression is more extensive than that of the shield Proterozoic. In two areas, the Cambrian lies directly on the Archaean basement—Wallaroo harbour railway-yard, and in the westerly of the two Balgowan diamond-drill holes. Over most of the peninsula, shield Proterozoic underlies Cambrian, and outcrops tend to follow sympathetically. The Cambrian, like the Proterozoic, is only very gently folded.

The sequence of Cambrian rocks recognized on the peninsula is as follows:

(Not distinguished on map)	<i>in situ</i> . Fragments of red sandstone, hundred of Ramsay.
(Lower) MIDDLE CAMBRIAN	RAMSAY LIMESTONE
Thickness: 107ft. in Minlaton stratigraphic bore, possibly reduced by Permian erosion.	Dark blue-grey crystalline nodular limestone; with buff dolomitic, rather shaly, interstitial matter, containing <i>Redlichia</i> .
LOWER CAMBRIAN	(unnamed) Red bed clastics and evaporites and conglomerates and shales of Minlaton stratigraphic bore. Not known to outcrop. Sedimentary breccias of Pine Point, and associated limestone conglomerate of Rocky Point.
Thickness: 453ft. in Minlaton stratigraphic bore.	
Thickness: 100ft. seen.	
	PARARA LIMESTONE
Thickness: 75-100ft. at Ardrossan; 400-450ft. at Kulpara; 946ft. in Minlaton stratigraphic bore.	Dark blue-grey crystalline nodular limestone; with buff dolomitic, rather shaly, interstitial matter and pyrite, containing <i>Yorkella</i> and <i>Pararaia</i> .
	KULPARA LIMESTONE
Thickness: 1,200ft. at Kulpara (Daily); 350ft. seen at Ardrossan; 30ft. at Wallaroo; 1,053ft. + in Minlaton stratigraphic bore.	Grey limestones and yellow dolomitic limestones (in upper half) siliceous limestones. Intraformationally brecciated limestone. With <i>Archaeocyatha</i> and brachiopods.

The outcropping Cambrian of the peninsula is nearly all Kulpara Limestone. Parara Limestone is confined to a relatively small area southwest of Ardrossan; another south of Curramulka; and a small exposure at Dowlingville (which has not yet been proved to be Parara rather than the lithologically indistinguishable Ramsay Limestone; on structural grounds the former is more likely). The Ramsay Limestone is confined to the hundred of that name.

Kulpara Limestone

Apart from the sections at Kulpara and Horse Gully previously mentioned, the Kulpara Limestone is well exposed only at Curramulka, at Ardrossan in the dolomite quarry of The Broken Hill Proprietary Co. Ltd., and in the Wallaroo-harbour railway-yard, where it contains abundant Archaean debris at the base and much angular quartzite gravel a little higher (plate XI). Elsewhere, the Kulpara Limestone is so effectively concealed by thick encrustations of kunkar that it can be recognized only when that cover is penetrated. A good deal of float and a distinct photogeologic pattern due to solution makes mapping possible.

In the northeast, a very few fragments of Kulpara Limestone, often almost completely changed to kunkar, have been seen on what is really a Proterozoic outcrop. The limestone has been almost completely eroded from this area.

In the shallow fold extending westerly from Clinton Centre to Cunliffe, there are no satisfactory exposures. This also applies to most of the outcrop near Ardrossan, except between Horse Gully and the town. The curious narrow syncline extending south from Yorke Valley is also unexposed north of Koolywurtie, but discontinuous poor exposures can be discerned towards the remarkable basin of Curramulka where bare rock slabs dot the paddocks. Here oolitic and chalcidonic varieties can be seen, and the lowest beds are exposed in the Town cave (D. J. Taylor, quoted by Daily, 1956).

A small outcrop of Kulpara Limestone, dipping east at 30 deg., occurs at Sliding Rock near Muloowurtie Point, where it is probably downfaulted from the Cambrian southwest of Ardrossan. Boulders of Kulpara Limestone were found at 100-107ft. in a bore at the silo $\frac{1}{2}$ mile south of Ardrossan, suggesting that the Cambrian might occur slightly below that depth.

In the northeast there are good exposures on the Kulpara scarp, west of Clinton, where phosphate has been worked as a fissure deposit. Phosphate has also been recorded west of Ardrossan.

Parara Limestone

The Parara Limestone, in its type-area at Horse Gully, occurs as an outcrop less than 1 mile in width conformably overlying Kulpara Limestone. It extends from a short distance south of the B.H.P. dolomite quarry on high ground to beyond Horse Gully on the upper slopes of which the massive beds are well exposed. These are dark blue-grey argillaceous limestones rich in trilobite fragments. Daily (1956) records *Yorkella australis* in the lower part and trilobites allied to *Pararaia* in the upper. The non-exposed softer bands are dolomitic. Seventy-five feet of Parara Limestone is recorded by Daily in this type-area.

A small outcrop of what is probably Parara Limestone occurs in the creek opposite the church at Dowlingville 5 miles north of Ardrossan, but no dating has been possible on the fragmentary fossils found so far. It is lithologically identical with the material exposed 1 mile south of Curramulka in a road-metal quarry (plate XII). There, 30ft. of mottled nodular limestone occurs, the nodules being of dense crystalline dark blue-grey limestone and up to 1 foot in size, in a matrix of softer shaly buff dolomitic rock. Pyrite, galena, and chalcopyrite occur sporadically throughout the rock, with small amounts of fluorite. The Parara Limestone is approximately 100ft. thick at Curramulka according to Daily, but this seems a very conservative estimate and the thickness may be little less than the 946ft. recorded in the Minlaton stratigraphic bore. This revealed almost identical rock remarkably consistent in lithology, except for a member in the upper part, 250ft. thick, which is a massive light-grey and light-pink limestone.

At Correl cave, 2 miles south of Curramulka, similar limestone occurs.

Red Bed Clastics, Conglomerates, and Shales

Nowhere have strata lying immediately above the Parara Limestone been found in outcrop. In the Minlaton stratigraphic bore, from 1,177ft. to 724ft., the following sequence was logged:

From		To		Thickness		
ft.	in.	ft.	in.	ft.	in.	
724	0	1,087	6	363	6	Red bed clastics and evaporites
1,087	6	1,117	0	29	6	Limestone conglomerate.
1,117	0	1,177	0	60	0	Chocolate to grey laminated shales
1,177	0	2,123	0			(Parara Limestone).

The thickest member of this formation, the red bed clastics and evaporites, is very calcareous from 724ft. to 770ft., and then grades into gypsiferous shales to 809ft. Below this are siltstones, limestone, and shales with intraformationally brecciated and slumped beds below 893 feet.

Daily (personal communication) records probable red bed clastics in sink holes on section 110N, hundred of Ramsay.

Sedimentary Breccias of Pine Point and Limestone Conglomerate of Rocky Point

At the southern end of the small raised beach at Pine Point, masses of red breccia are seen *in situ* on the beach, composed almost entirely of angular Archaean debris (plates XV and XVI). To the west, under the Tertiary sandy clays in the cliff, 3ft. of red fine-grained arkosic sandstones occur. Mapping one mile farther north showed that similar sandstones with lenses of sedimentary breccia outcrop on the beach from the northern end of the raised beach northwards for about three-quarters of a mile (plates XIII and XIV). A cliff gully outcrop can be seen $\frac{1}{4}$ mile north.

These beds dip seawards (plate XIII) at about 20 deg. for most of the outcrop, but $\frac{1}{4}$ mile north of the north end of the raised beach, extremely tight folds come in and a little farther north the beds are juxtaposed against outcrops of quartzitic Archaean, the cliffs behind being kaolinized aplite or strongly altered hornblende Archaean.

No further outcrops occur until the southern end of White Clay Bay is reached, where rotted sedimentary breccias and fine-grained arkosic sandstones occur at the foot of the cliffs. None have been seen in White Clay Bay where the Archaean occurs in very confused structures, but small outcrops occur 200yds. north. About 1 mile north, two extremely small outcrops of similar rock have been seen, one on the beach and another (discovered by B. Daily) in the cliffs.

At Rocky Point, there is a patch of limestone conglomerate on the outer part of the beach immediately north of the Eocene quartzitic sandstone outcrops which extend seawards from the base of the cliffs forming the point. Rounded boulders of light-grey dolomitic limestone occur in a reddish sandstone matrix. No fossils have been found in the boulders but they are lithologically identical with parts of the Kulpara Limestone.

Examination of the matrix material, both from the sedimentary breccias and the limestone conglomerate, shows similarities with material found in the Minlaton stratigraphic bore between 1,040ft. and 1,047ft. and at 1,087ft. Field evidence suggests that the limestone conglomerate and the sedimentary breccias are thrust from the east. Provisionally, they are both regarded as of upper Lower Cambrian age, equivalent to part at least of the red bed clastics and evaporites sequence of the Minlaton stratigraphic bore. Examination of material from the Stansbury stratigraphic bore (section 117, hundred of Dalrymple, 2 miles west of Stansbury) at 965ft., 1,037ft., and 1,361ft. shows marked similarities with the Minlaton stratigraphic bore material listed above, and for this reason the sub-Permian part of the Stansbury stratigraphic bore has been provisionally placed in the upper Lower Cambrian.

Ramsay Limestone

Kunkar-encrusted outcrops of limestone which is lithologically similar to Parara Limestone occur 5 miles south of Curramulka where they appear to form a shallow syncline plunging south-southwest. These are Middle Cambrian limestones containing *Redlichia* and *Archaeocyatha*. They have been given the name of Ramsay Limestone from their occurrence in the hundred of that name.

Core from the Minlaton stratigraphic bore, between 615ft. and 724ft., was found to contain similar fossils.

Possible Higher Beds

Fragments of red sandstone were found within the Ramsay Limestone syncline, but as they were clearly piled float their origin is uncertain. They may be float from red beds above the Ramsay Limestone.

PERMIAN

General

Permian rocks cover a large part of the peninsula and are predominantly of glaciogene type. Since erratics were recorded on the highest point of the peninsula northeast of Arthurton at approximately 800ft. above mean sea-level, it is assumed that the whole of the peninsula was at one time covered by Permian glaciers, or by Permian seas into which glacial debris was dropped.

The rocks include boulder till, siltstones, sandy siltstones, and loose sands. Their attitude, as far as it can be determined, is essentially horizontal.

No glaciated bedrock has been seen. Erratics in the till, or washed out from it, have been recorded north of Port Vincent, at Urania, Port Victoria, Port Moorowie, near Troubridge Hill, Point Turton, and Point Souttar. Transported blocks of local material occur, especially in the north, and have not all been shown on the map. Erratics have also been seen embedded in kunkar derived from Pliocene limestone, itself deposited on Permian material.

Of the erratics, the several near Port Vincent are of Murray Bridge or Encounter Bay type granite; another of Encounter Bay type granite was found at Urania. Numerous boulders of Kammantoo type greywacke have been recognized in the south of the peninsula and at Urania.

The maximum known thickness of the Permian is 776ft. in the Stansbury stratigraphic bore. Ludbrook (1957a) recorded arenaceous foraminifera (principally *Hyperammina acicula*, *Ammodiscus oonahensis*, *Ammovertella inclusa* and *Tolypammina undulata*) in both bores. She suggested that conditions of deposition were deltaic. Ludbrook (*see* Appendix herein) suggested that conditions, at least in part, were marine. The identification of these Lower Sakmarian foraminifera gave the first definite evidence of the age of any South Australian Upper Palaeozoic glaciogenes. Some of the sand in the upper 110ft. of the Minlaton bore may, however, have been reworked in Tertiary time and if so should, strictly, be regarded as Tertiary in age.

No stratigraphical sequence can so far be established, most of the deposits being ill-exposed, and the marine or quasi-marine Permian being certainly known only in two boreholes.

Local Details of Permian Rocks

Yorke town Area

The most extensive Permian outcrop is in the Yorketown district where it is, however, nearly everywhere kunkar-encrusted to a greater or lesser degree. Boulder till is seen in numerous cliff sections usually on the protected northwest sides of the larger salt lakes, and boulders of exotic granite can often be seen.

The Permian outcrop hereabouts can be distinguished from that of the Tertiary—even when both are kunkar-covered—by its gentle undulations and variety of landscape. Much of the outcrop to the north of Yorketown, towards Curramulka, is covered by sand dunes which are essentially seif dunes—part of the older Quaternary—but which have become modified in pattern and partly altered to transverse type dunes. Between these dunes patches of Permian clay occur.

To the south, kunkar increases in thickness and becomes a solid sheet towards the coast, completely masking the Permian till which can be seen only in the sea-cliffs between Port Moorowie and Troubridge Hill. It is often concealed by falls of the overhanging hard kunkar. In this till, which is rotted and mottled (suggestive of lateritization), Kanmantoo type greywacke can be found. No more than 15ft. of this till is normally visible, often much less; thin Pleistocene clays separate it from the kunkar, and at Troubridge Hill thin Tertiary also occurs.

Warooka-Point Turton-Point Souttar

Warooka lies on a faulted mass of Permian till capped by Tertiary limestone. Erratics were recorded on the eastern slopes of the hill. Permian is known in Peesey Swamp from 138ft. to 650ft. in the Peninsula Oil Syndicate Ltd. bore.

At Point Turton, about 4ft. of greyish boulder till is poorly exposed at the base of the cliffs $\frac{1}{4}$ mile west of the point, under Tertiary (plate XVII). Till can also be seen east of the jetty. At the former locality, Kanmantoo type faceted erratics were noted.

The westernmost known outcrop of Permian was that recorded by Greenway and Phillips (1902) at Point Souttar. This was not found by the present author, but he was fortunate in arriving nearby at a time when a shallow beach excavation revealed grey pebbly till.

Permian is known in several bores in the central part of the interior of the foot of the peninsula, west of Warooka, but its exact western limit is very uncertain. The "granite rock", shown on the official hundred map and regarded by Howchin as an erratic, is more probably a knob of basement *in situ*. It is a biotite gneiss with a bedding foliation direction not much different from the general direction at Corny Point. No Permian is known along the west coast of the foot, but thin clays met in bores northeast of Stenhouse Bay could be Permian, and Permian is known at Jim Brown well, 2 miles east of Royston Head. It seems probable that thin patches extend over much of the area, preserved in undulations of the basement under Quaternary cover.

Port Victoria-Urania-Minlaton

Permian siltstone, containing small exotic pebbles, occurs as a very small patch 50yds. north of the Port Victoria jetty. This is the only recorded outcrop on the coast hereabouts, but at Port Rickaby and in other localities nearby, a few inches of greenish clay with pebbles can occasionally be seen at about high-water mark where kunkar cliff-falls do not conceal it.

Several salt lakes exist on Permian clays southeast of Port Victoria, towards Minlaton. Borehole information shows that this whole area is underlain by thick Permian, which extends towards the area south of Curramulka.

At Urania, boulder till occupies two patches in the western part of the Urania Gap. The southern of these shows a 4ft. diameter erratic of Port Elliot type even-grained granite (plate XIX), and a 4ft. by 3ft. by 2ft. faceted boulder of Kanmantoo type greywacke was collected.

Curramulka-Port Vincent

Curramulka occupies a curious smooth basin in the Cambrian which has been regarded as glacially eroded (Pritchard 1892). It is of interest, and may be significant, that the only known Permian on the east coast lies east-southeast

of Curramulka, 1½ miles north of Port Vincent; that the southern extension of the Mount Rat ridge falls away under Permian cover west-northwest of Curramulka; and that, in general, the direction of Permian glacial erosion in Fleurieu Peninsula is from the southeast. This might suggest that the Curramulka Basin is in fact due, at least in part, to glacial erosion.

However, no glacial deposits are known in the basin, while the area to the south is thickly covered with them.

The Port Vincent outcrops can be seen only at low tide. Several large erratic boulders, now well-rounded, of Victor Harbour type granite occur.

Some soft grey pebbly till can be seen (plate XVIII). Much iron-stained hard gritty rock occurs, and in one place is so resistant along its vertical joints that it forms a small wall on the beach. This may not certainly be Permian and could be Tertiary, and is possibly the material mentioned by H. Y. L. Brown (1884) in his *Parliamentary Paper* on Yorke Peninsula as an occurrence of the "Silurian" rocks.

Maitland-Arthurton

Patches of Permian clay are known from boreholes southwest of Maitland, and their distribution is indicated approximately on the map as it appears to form a distinctive pattern on the air photos in spite of the Quaternary cover.

Permian till may occur as similar patches in Yorke Valley. The present author does not think that glacial erosion has shaped Yorke Valley, but considers it to be a complex fault-angle depression which has since been occupied—probably very temporarily—as a lake, and has certainly been affected by solution of the Cambrian limestone which underlies part of it. It is possible that the faulting which produced the depression existed in Permian times, and that the valley was a Permian lake dammed by ice at Urania, with an escape southeastwards later through the Urania Gap, and finally, drained subterraneously towards Curramulka. Alternatively, the valley might have been occupied by stagnant ice. Any glacial erosion which took place was probably on a small scale.

Northwest of Maitland, the existence of patches of Permian in hollows of the bedrock under Quaternary cover was suspected. It was confirmed by a re-examination of the Weetulta diamond-drill hole core, which revealed material lithologically identical with the Port Victoria Permian between 45ft. and 65ft. It is possible, also, that green montmorillonitic clay found under kunkar by A. A. Gibson in the Engineering and Water Supply Department tank-site investigations near North Kilkerran is of Permian age.

Permian has been mapped east of Agery on the basis of material seen below kunkar in a shallow pit on section 43, hundred of Tiparra. This, although white and not easily distinguished at first from the overlying soft kunkar, is a white silt with quartz grit, very similar to the Port Victoria material and identical with material from near Port Elliot, 50 miles south of Adelaide. The area to the west does not expose any material satisfactorily except near Agery, and the outcrop shown on the map is approximate only.

At Arthurton tank, very large faceted transported blocks occur. These are on what is now the highest point of the peninsula (approximately 800ft.). A similar block was seen near Weetulta, on a lower upland crest.

Careful search has revealed no Permian—nor any erratics or transported blocks—in the area farther northwest. In the northeast, material doubtfully like that of Port Victoria and Agery has been noted near Clinton Centre and also 5 miles northeast of Paskeville. In the latter case it is regarded as a variety of lateritic crust rather than Permian. A small outcrop of (doubtful) boulder till has been recorded by Horwitz on the Wakefield one-mile sheet northeast of

Kulpara. In the area immediately northwest of Bute, and partly covered by the eastern part of the Wallaroo sheet, scattered blocks of Cambrian dolomitic limestone lie on the Proterozoic outcrop and are regarded as glacial erratics.

TERTIARY

General

Tertiary rocks cover only a small proportion of the peninsula but are prominent in the cliffs along the east coast. Everywhere they rest unconformably on the older rocks and are essentially horizontal. They are all shallow-water marine, paralic or deltaic sediments, with a thickness nowhere known to be greater than 400ft., and mostly less than 200 feet. They extend in age from Eocene to Pliocene, and a division on the maps has been made into four as follows:

Pliocene: Hallett Cove Sandstone

Lower Miocene: Melton Limestone

Oligo-Miocene: Port Willunga Beds, with Port Julia Greensand. Limestone at Urania. Point Turton Limestone

Eocene: Blanche Point Marls. Quartzitic sandstone of Rocky Point. Muloo-wurtie Clays. Cross-bedded coarse lignitic sands of the northeast.

The Eocene and Oligo-Miocene beds form the western part of the St. Vincent Basin sediments, which are much thicker on the eastern side of Gulf St. Vincent and presumably extend beneath it. Their present distribution is controlled by north-south faulting which also still strongly influences topography. Only fragmentary remains occur now above 200 feet above mean sea-level, either as thin caps or as pocket deposits.

The lower Miocene Melton Limestone is the product of a later transgression and is restricted to the northernmost part of the peninsula, remnants occurring widely between Kulpara and the coast at Wallaroo, and best seen in the type area.

The Pliocene, distinct again, is restricted to low levels near or on the coasts in the south and west.

Clearly, apart from the limits of distribution due to structural control of sedimentation, the present extent of Tertiary rocks is much less than that of the original area of deposition. Apart from that under Quaternary cover, much material has been lost by erosion. But there is no evidence that Tertiary seas once covered the whole of the peninsula, as no relics have been found above 460ft. above mean sea-level.

A remarkable feature is that everywhere the upper layers of the calcareous Tertiary rocks—where not covered by younger clays—have been reconstituted to kunkar, almost always with the destruction of traces of fossils and original texture. Thin deposits are commonly completely reconstituted. It seems probable that much kunkar could originally have been Tertiary rock. However, the existence of kunkar does not necessarily imply the former existence of Tertiary rock because kunkar is known to form not only on and from limestones and lime-rich rocks of other ages, but from Quaternary calcareous loess of extra-peninsular origin, which is widespread. The common presence of such loess directly overlying Tertiary rocks makes assessment of the amount of material reconstituted very difficult.

This feature, together with the abnormally smooth relief offering scarcely any exposures inland, makes mapping of the Tertiary extremely difficult and tedious. Some boundaries are necessarily approximate. Others have been established by very careful scrutiny of float, well dumps, and dam dumps, and collation of borehole data. Most knowledge was derived from examination of coastal cliff sections.

Eocene

Basal Sands and Lignites

The oldest Eocene rocks, the basal sands, do not occur exposed in natural outcrop.

The basal coarse cross-bedded quartz sands are known at depth in the Price-Clinton* area. Bores were sunk in search of economic deposits of lignite near Clinton and the thickness of the sands is known to vary from less than 200 to over 400ft. A bore about 1 mile west of Price passed through 386ft. of lignitic sands under 14ft. of Quaternary.

These sands are clearly a thick sequence occupying an extensive area of deposition, as they resemble in every way sands of similar age near Balaklava and around Adelaide. They probably extend southwards, not necessarily continuously.

Sands identical in lithology, but thinner and very local in distribution, may be seen in several quarries extending from near Mona (on the eastern part of the Wallaroo sheet) to Ardrossan. The known locations of deposits are, from north to south—

- (a) A disused filled-in sandpit on section 222, hundred of Ninnes, 1½ miles west-northwest of Mona railway halt.
- (b) Correll's sandpit, section 99, hundred of Kulpara, 6 miles northeast of Paskeville.
- (c) Crowell's sandpit, section 165, hundred of Cunningham, 3 miles west of Price.
- (d) A disused sandpit, section 33, hundred of Cunningham, 1 mile southwest of Ardrossan and ¼ mile north of the dolomite quarry of The Broken Hill Proprietary Co. Ltd.
- (e) The dolomite quarry of The Broken Hill Proprietary Co. Ltd.

The deposit (a) is known to overlie Proterozoic sandstone, and is very shallow.

At Correll's pit, 40ft. of coarse, slightly gravelly cross-bedded quartz sands are exposed, strongly iron-stained along the bedding laminae in the lower part (plate XXII). These lie under a few feet of kunkar and the existence of the sand was revealed by rodents. Occasional fragments of lower miocene algal gritty limestone occur in the kunkar. The underlying rock is not known, but from mapping in the vicinity could be Cambrian limestone or Proterozoic arkose. The pit lies only about 80yds. west of a small fault scarp, a possible continuation of the Bute fault.

The other three deposits all lie immediately west of the Ardrossan-Kulpara fault scarp.

At Crowell's pit, sands similar to those at Correll's occur, but less iron-stained. These also underlie kunkar and are of restricted occurrence, almost certainly in a pocket—no doubt a solution hole—in the Cambrian limestone known to be the bedrock thereabouts. The sands have been proved to 50ft. (plate XX).

At the disused Ardrossan sandpit, the excavations are less than 12ft. deep. The material is similar, though cemented unevenly by secondary silicification, with consequent curious and unusual effects on the upper and lower surfaces of fallen blocks. These are the beds mentioned by Howchin (1918, pp. 206-7) which he regarded as high-level older Pleistocene alluvium. Similar masses of sedimentary quartzite showing "heavy mineral banding"—which may be iron staining of current bedding laminae—litter the slopes immediately to the south. These are partly rounded by weathering and it is of interest that two similar masses, buried flush with the ground, occur 200yds. east of Crowell's pit. These are all, no doubt, residual from deposits now eroded.

* Clinton lies in the southwest corner of the Wakefield one-mile sheet, 5 miles north of Price.

PLATE I



Shore platform of Archaean gneiss, striking northeast, cut by quartz-jasper veins in left foreground: typical low cliffs of Quaternary and Tertiary on Archaean in the distance—View towards Tickera from 6 miles NE. of Point Riley

PLATE II



Cliffs of Quaternary aeolian and gypsiferous lacustrine beds overlying and infilling solution holes in Tertiary limestone: with Archaean shore platform— $\frac{1}{2}$ mile N. of Point Riley



Cliffs of white kaolinized aplite overlain by Tertiary and Quaternary—
White Clay Bay, 2 miles N. of Pine Point



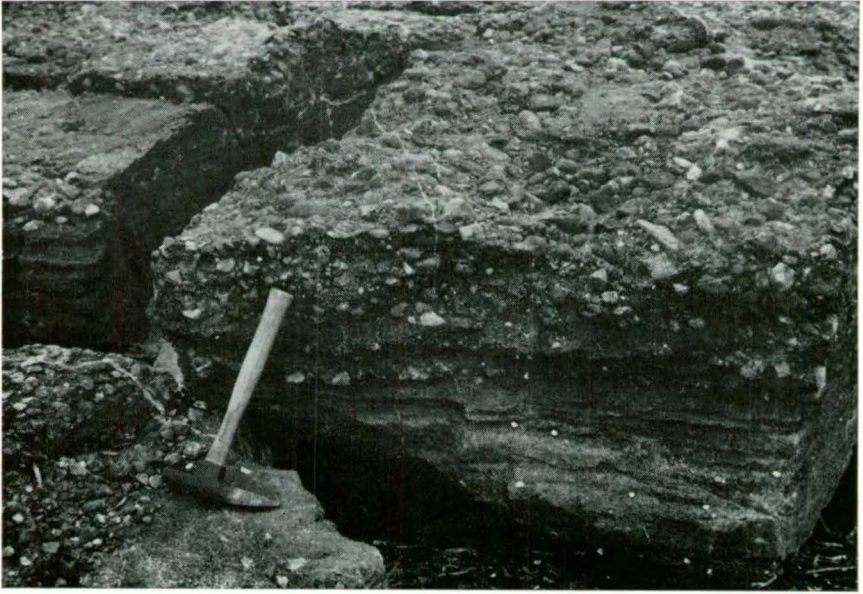
Possible palimpsest of false bedding; Archaean paragneiss—
1 mile SE. of Point Souttar



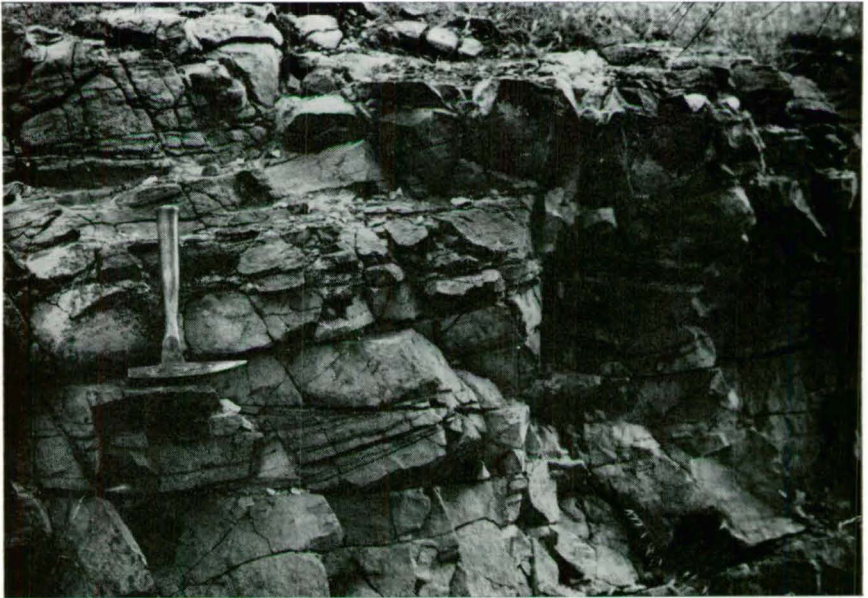
Kunkar and aeolianite on Archaean (in foreground and across bay)—
Corny Point; looking west-southwest



Banded and ptygmatically folded hornblende gneisses of slightly
"raised" shore platform—Corny Point



Quartz-pebble conglomerate and quartzitic sandstone (shield Proterozoic) forming beach outcrop—Port Hughes; south of Jetty



Current-bedded quartzitic sandstone (shield Proterozoic)—Dinham quarry, 2 miles NW. of Ardrossan. Direction of current is from west

PLATE IX



Quarry showing 25ft. of tillite under kunkar—Section 62, hundred of Ninnes (between Kulpara and Bute)

PLATE X



Close-up of tillite in quarry on section 62, hundred of Ninnes



Lower Cambrian Kulpara Limestone: showing predominantly angular fragments of quartzite in a matrix of dolomitic limestone—Wallaroo harbour railway cutting



Lower Cambrian Parara Limestone. Dip is south at about 10 deg.—Curramulka roadstone quarry



Sedimentary breccia (? upper Lower Cambrian)—1 mile N. of Pine Point



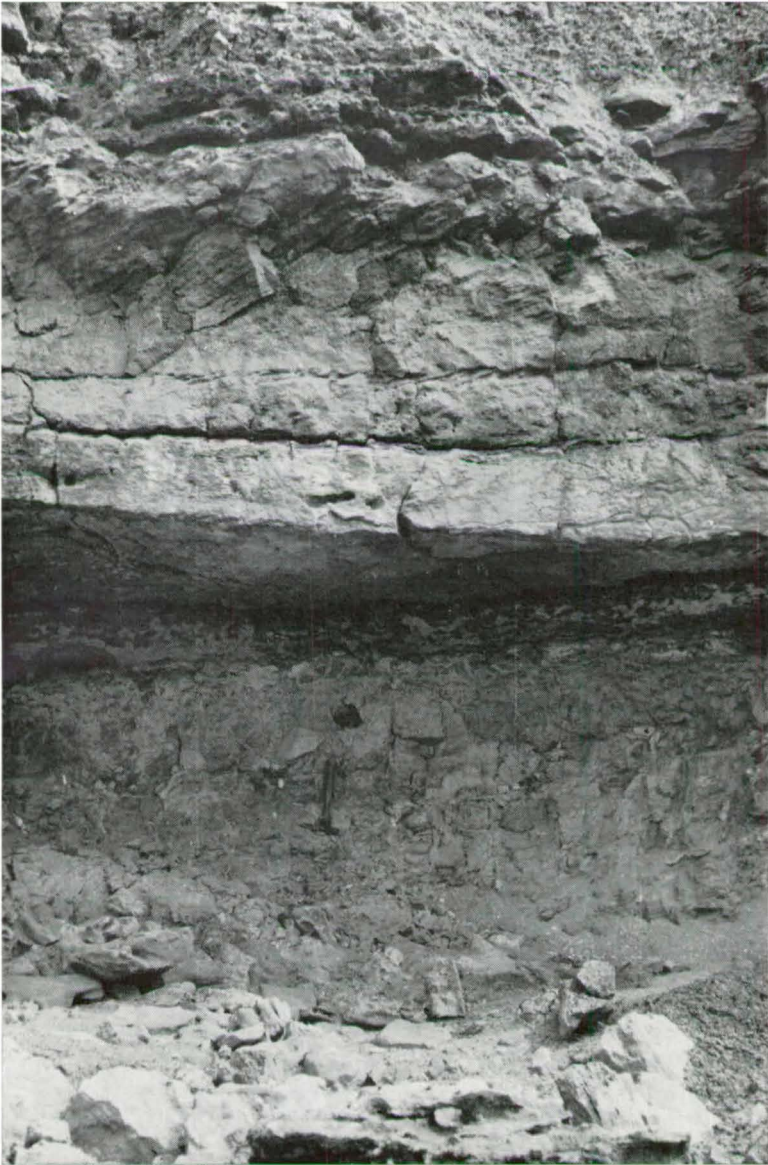
Sedimentary breccia (? upper Lower Cambrian): close-up showing angular debris of Archaean—1 mile N. of Pine Point



Sedimentary breccia (? upper Lower Cambrian)—300yds. N. of Pine Point jetty



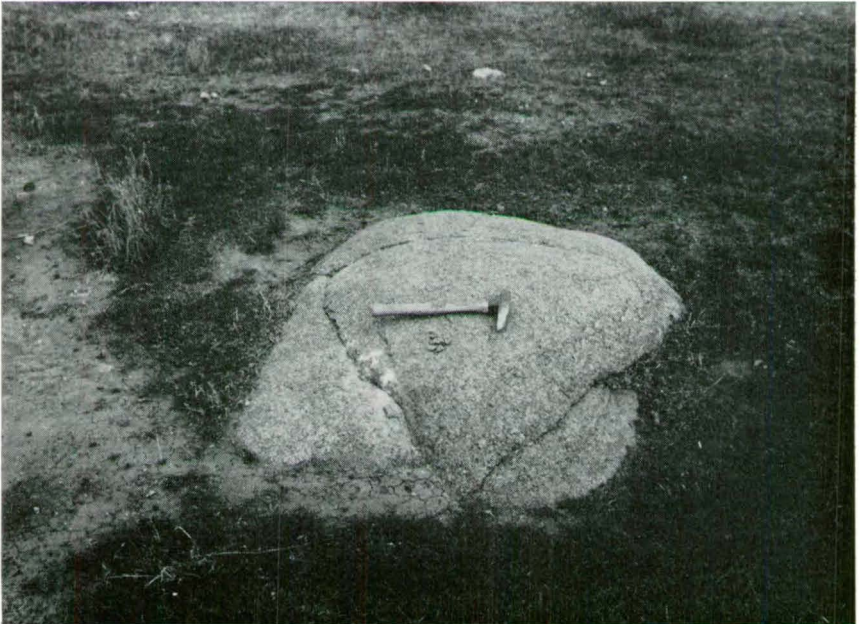
Close-up of sedimentary breccia (? upper Lower Cambrian)—300yds. N. of Pine Point jetty



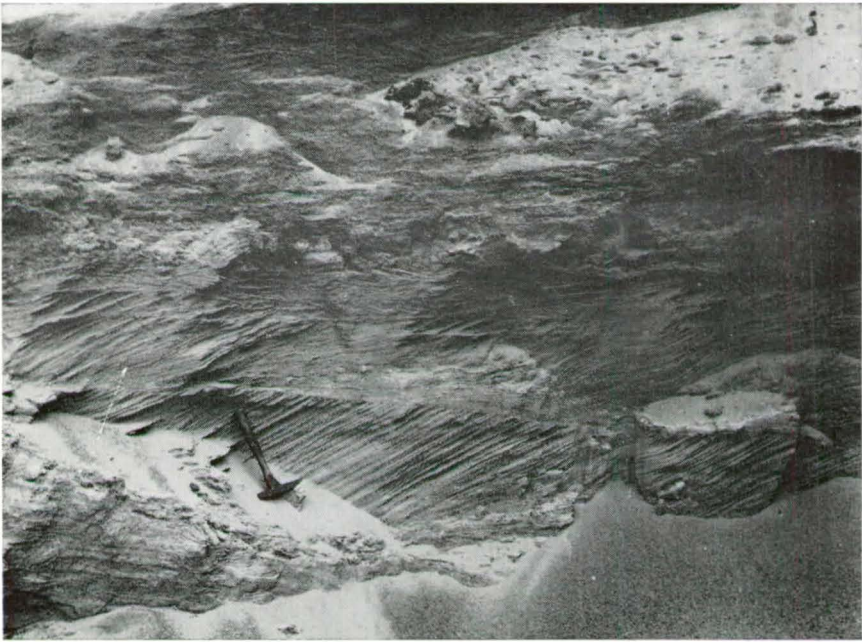
Permian till: with boulders of Cambrian Kanmantoo greywacke (near hammer)
overlain by current-bedded Tertiary calcarenite (Point Turton Limestone)—
Point Turton



Permian till: pencil points to small erratic of granite—On beach 1 mile N. of Port Vincent



Erratic of even-grained Port Elliot-type granite—1 mile SW. of Urania



Strongly current-bedded coarse quartz sands (Eocene)—Crowell's sand pit, 3 miles W. of Price and 10 miles NNE. of Ardrossan



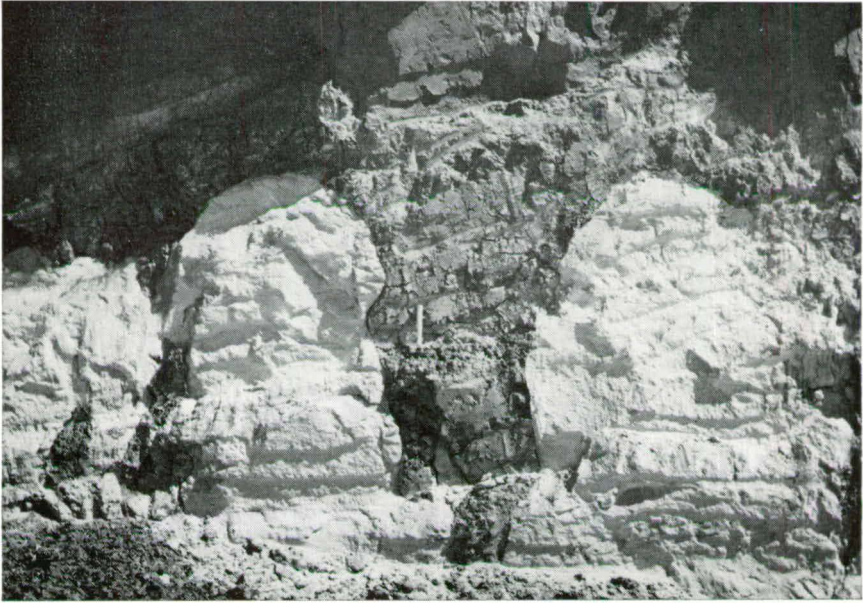
View from middle bench of dolomite quarry: showing eroded surface of Lower Cambrian Kulpara Limestone plastered over with pale-grey kaolinitic clay and overlain by current-bedded coarse quartz sands, in part cemented (overlying Quaternary stripped)—The Broken Hill Proprietary Co. Ltd., Ardrossan



Sand pit: showing 40ft. of coarse, slightly gravelly, current-bedded quartz sand; strongly iron-stained along the laminae in the lower part—Correll's sand pit, section 99, hundred of Kulpara



Limestone quarry: showing large irregular solution cavities in Oligo-Miocene Port Willunga Beds, filled with clay. Upper quarter of face is in Pleistocene red clays overlain by kunkar; boundaries obscured by wash—North end of Wool Bay (Klein Point)



Deeply eroded surface of Port Willunga Beds in road cut: showing clay pockets—South entrance to Wool Bay jetty



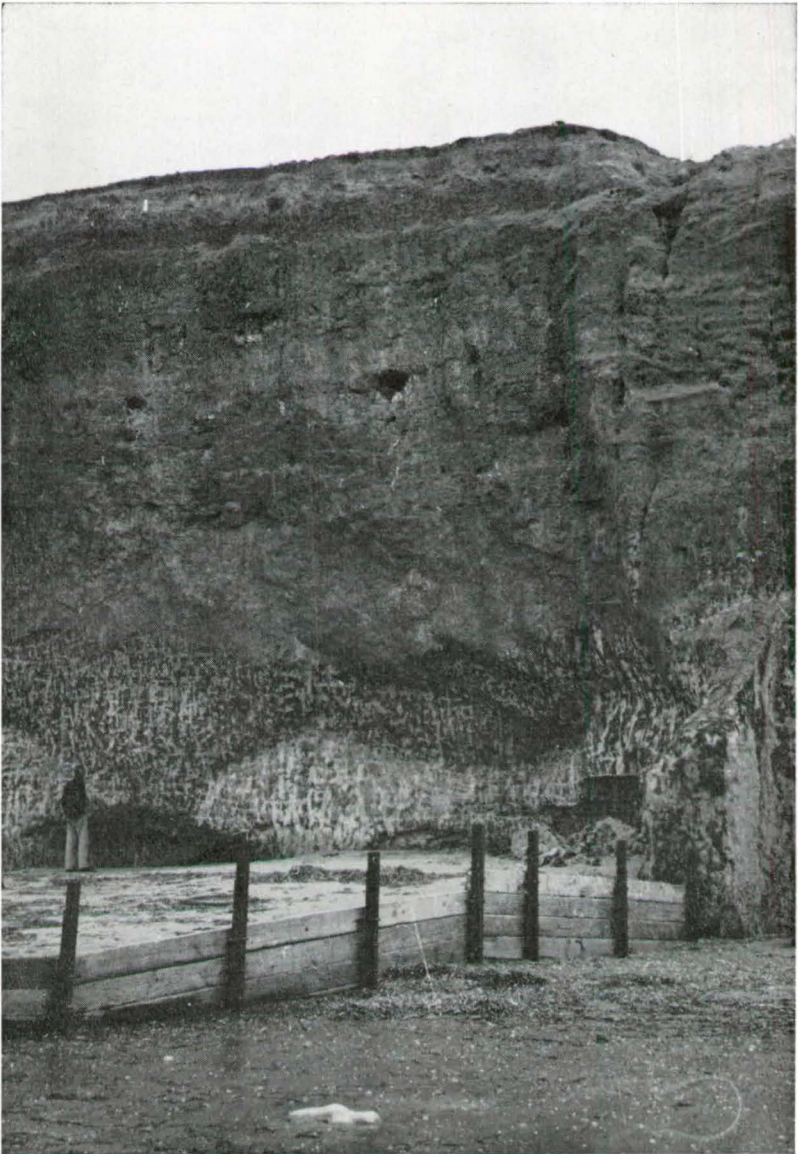
Flat-topped cliffs of kunkar overlying red Quaternary clays resting on a deeply eroded surface of Tertiary Port Willunga Beds; pockets of yellow-brown clay in the latter extend almost to sea-level—View south-southeast from $\frac{1}{2}$ mile N. of Wool Bay



Large sinkhole in Melton Limestone: 30ft. of conglomeratic bryozoal cross-bedded sandy limestone is exposed—2 miles N. of Melton



Dense pink recrystallized bryozoal Melton Limestone (foreground): overlain by yellow nodular algal Pliocene limestone and Quaternary—Point Hughes



Ardrossan Clays and Sandrock: note prominent mottling (concealed by down wash in middle of cliff) and pseudo-stratification. Upper part is gravelly and is overlain by thin red clays with alunite seams (concealed by wash) and kunkar—100yds. S. of Ardrossan town jetty



Red clay, with alunite seams, overlying mottled Ardrossan Clays and Sandrock and overlain by kunkar—Moonta Bay



Alunite seams in clayey sand occupying an erosion channel cut in Tertiary Port Willunga Beds: note sharp lower boundary of seams and gradual change of colour at upper boundary—5 miles S. of Port Vincent



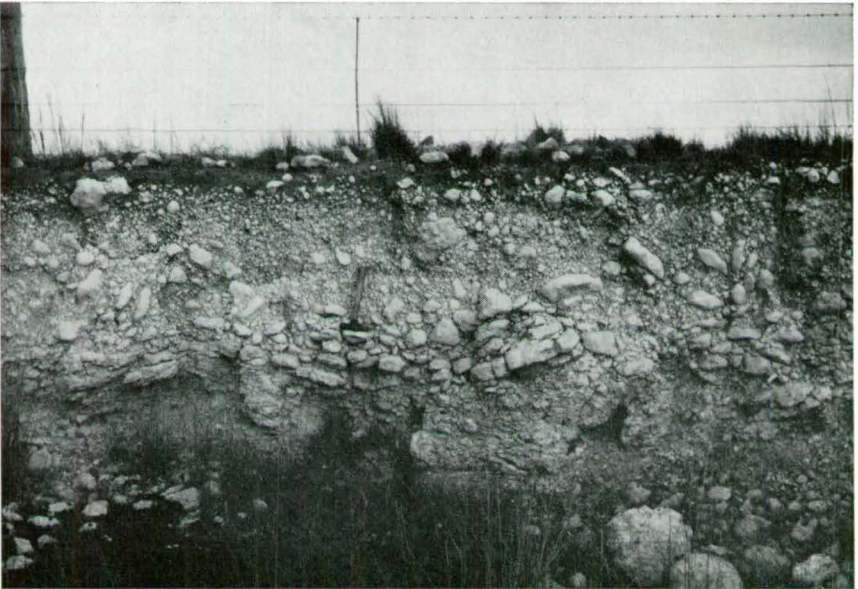
Duricrust overlain by pisolitic laterite—Moonta Bay



A typical section in kunkar: showing upper nodular bed, middle massive bed, and lower marl with nodules— $\frac{1}{4}$ mile N. of Port Julia jetty



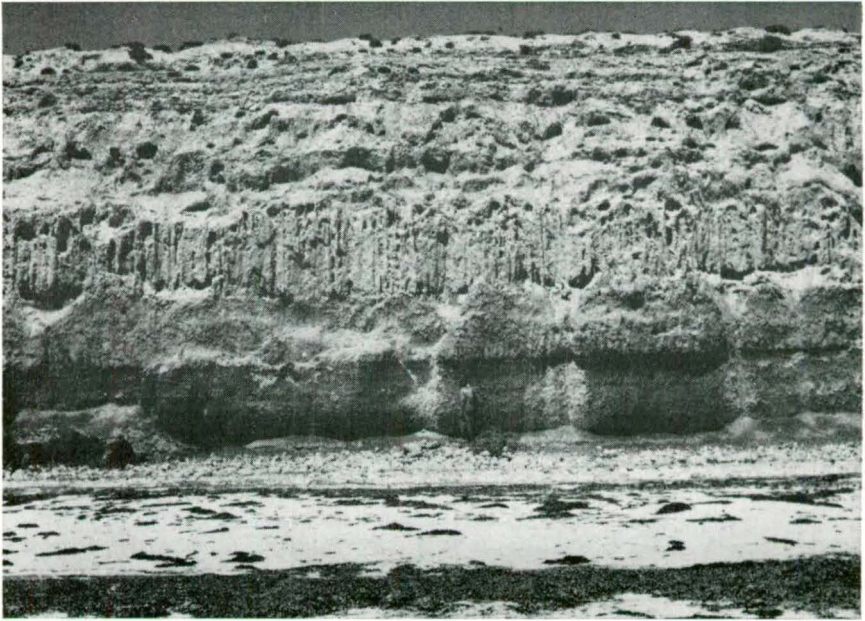
Kunkar, lacking any marked middle horizon, capping cliffs: hill in distance on right is Lower Cambrian Kulpara Limestone—Ardrossan



Kunkar, showing festoon structure—Section 42, hundred of Cunningham; 2 miles W. of Ardrossan



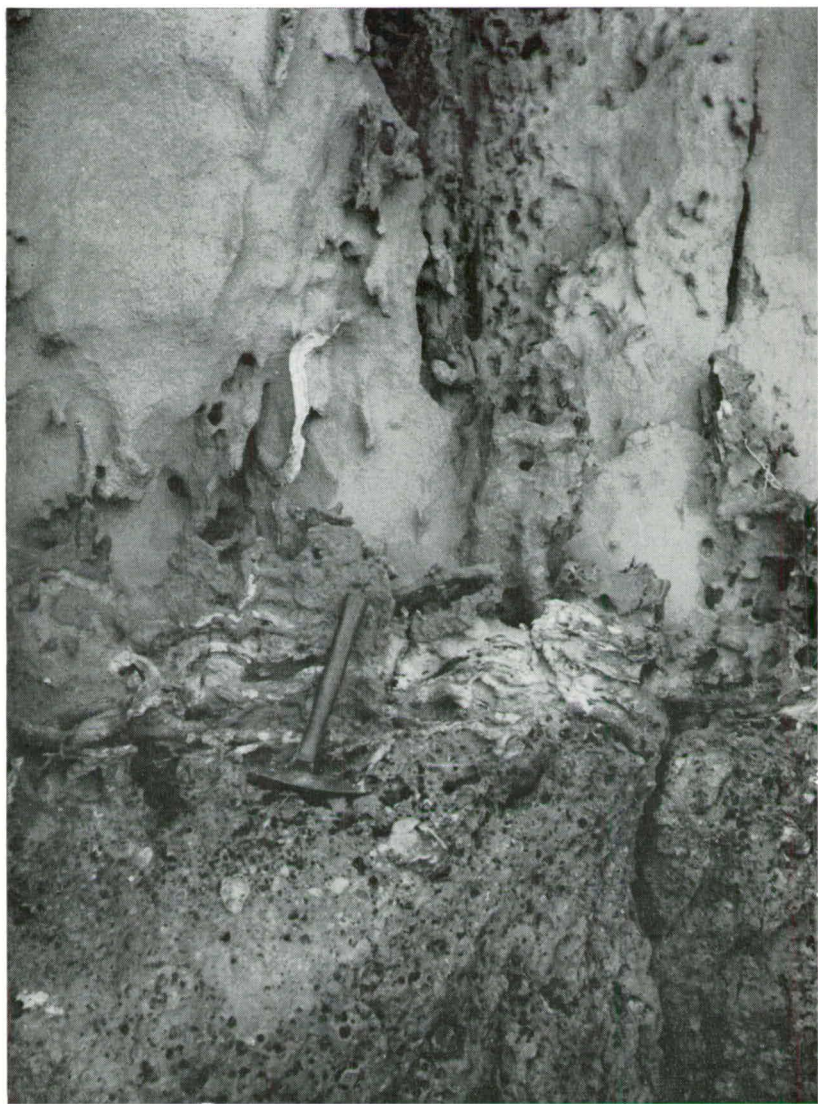
Alternation of hard kunkar layers and soft aeolianite—Cape Elizabeth



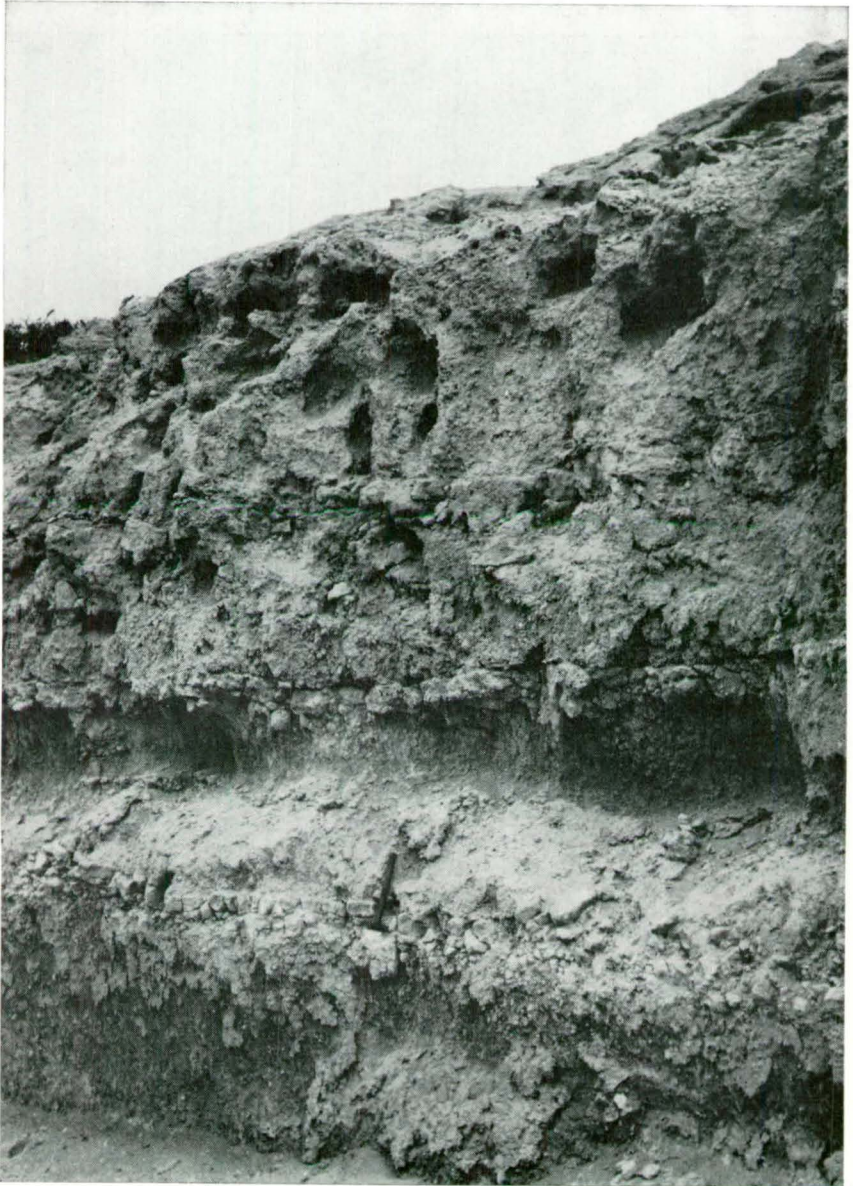
Cliffs in Quaternary: thick aeolian suite (25ft.) overlying red clay with alunite seams; seaweed conceals top of Ardrossan Clays and Sandrock—Balgowan



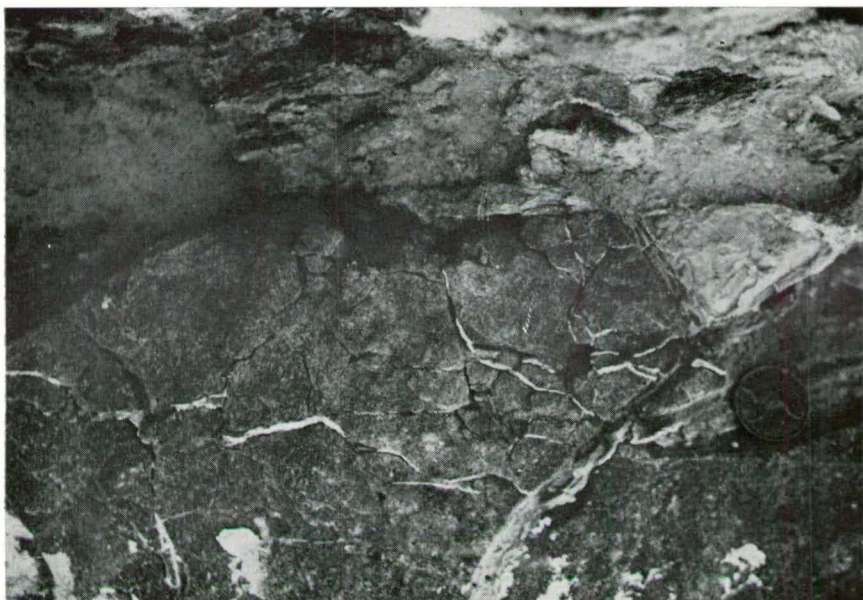
Cross-section of kunkarized seif dune—5 miles S. of Moonta



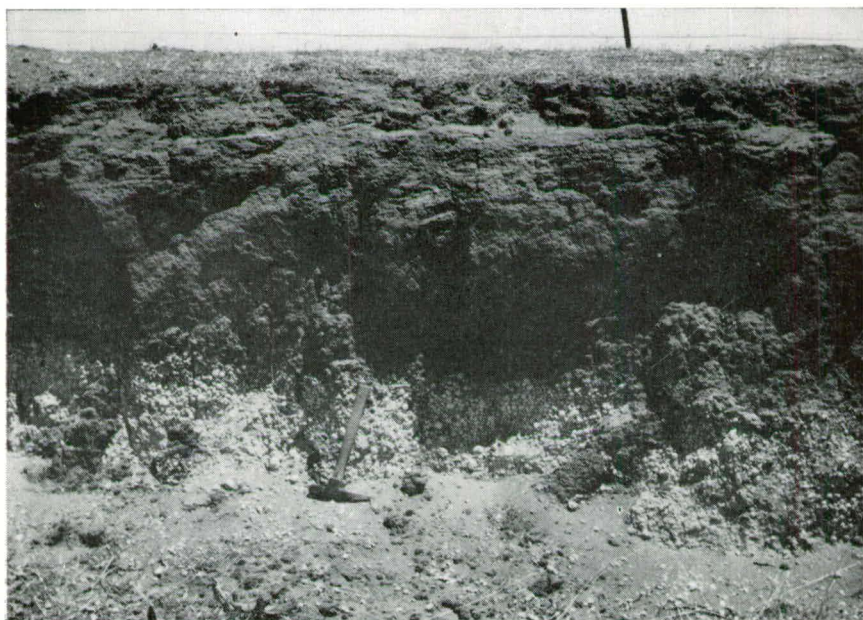
Kunkarized branches in soft aeolianite, overlying greyish-orange kunkar with numerous black nodules—1 mile S. of Royston Head



Repetition of kunkar nodule horizons in upper part of sequence—Balgowan

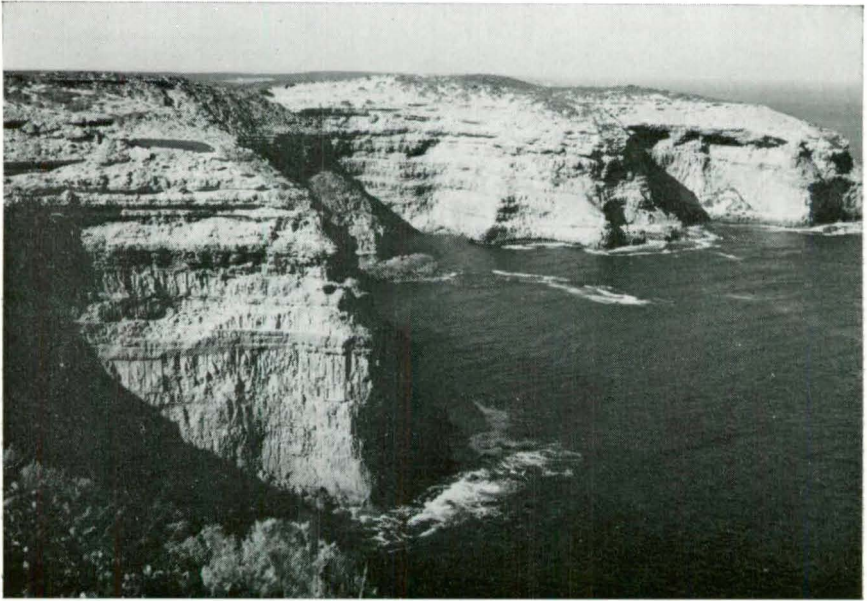


Upper surface of Proterozoic quartzitic sandstone, overlain by kunkar: showing penetration by veins of lime which have wedged up fragments of sandstone into the kunkar—Northern Brealey stone quarry, Wallaroo



Decalcified red sand overlying kunkar nodules formed in a pre-existing soil—Wiltunga Church, 20 miles NE. of Kadina

PLATE XLII



Piled aeolianite and kunkar: height of cliff face about 250ft.—Cape Spencer

PLATE XLIII



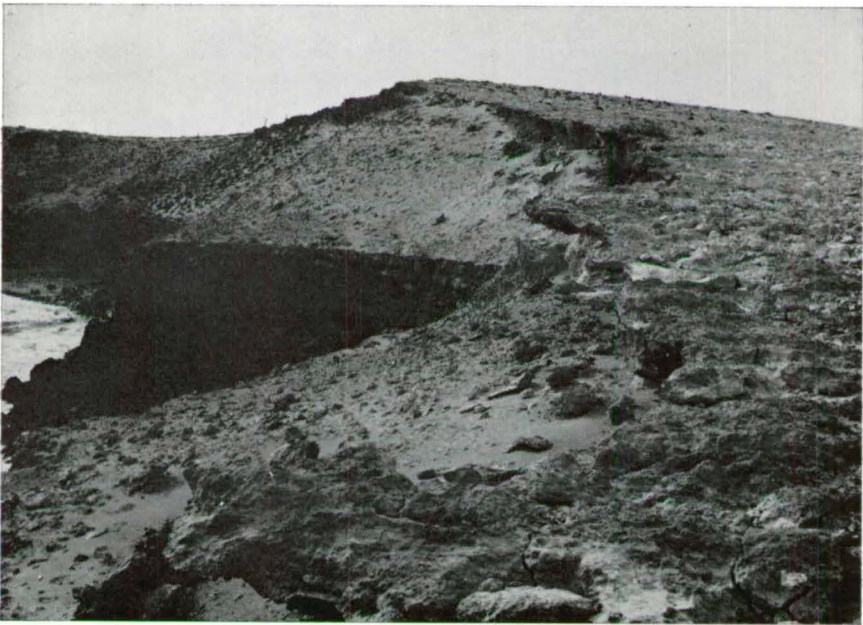
Calcareous loess on bedded aeolianite—10 miles NE. of Stenhouse Bay

PLATE XLIV

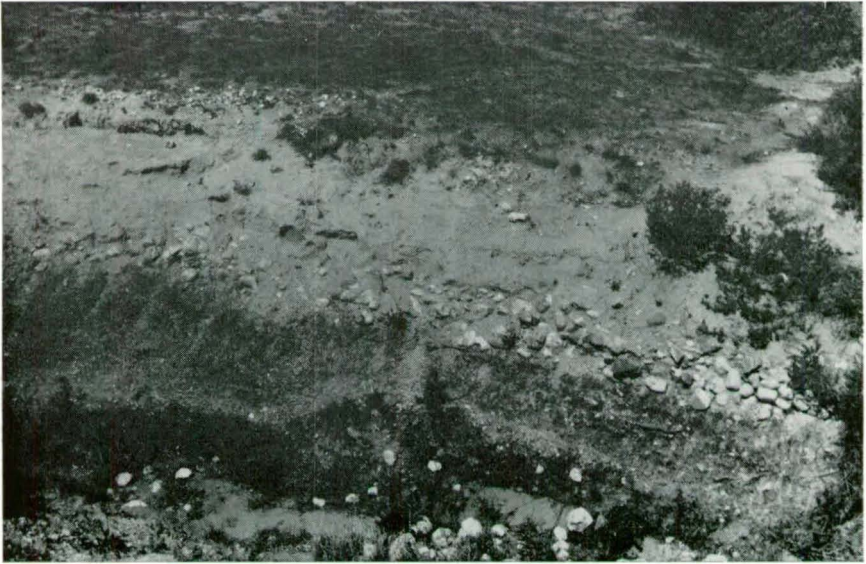


Aeolianite on kunkarized aeolianite (hammer resting on latter)—2 miles S.
of Point Annie

PLATE XLV



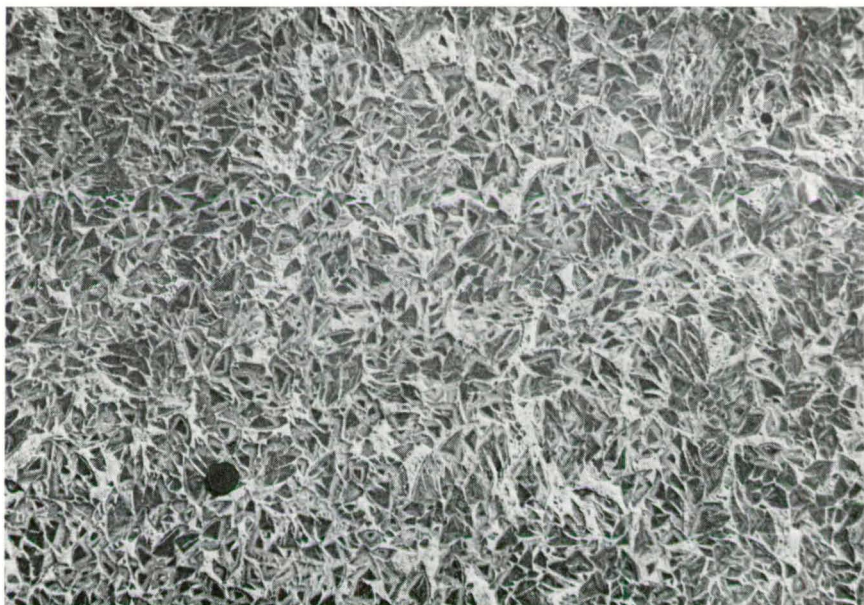
Coastal cliff: showing massive flat-lying kunkar overlain by dune with
kunkar cap—Troubridge Hill, 2 miles W. of Troubridge Point



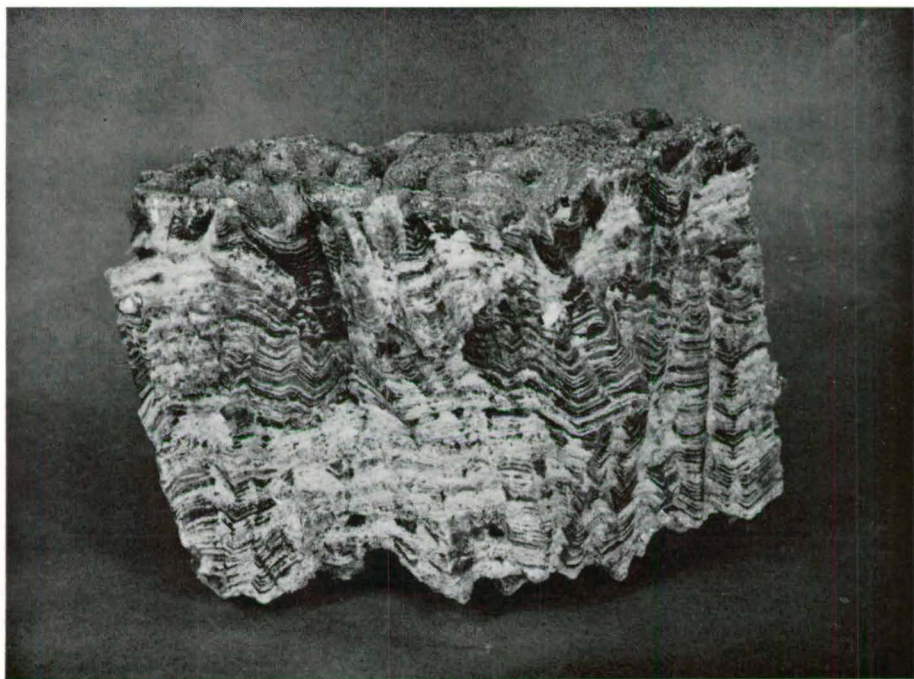
Emerged ("raised") beach overlying (?) Pleistocene mottled clay, and overlain by kunkar marl—Exposed in a gully about 1 mile SE. of Point Riley. The beach slopes towards the sea



Large gypsum dune, 80ft. high—Southeast shore of Lake Fowler



Surface of massive crystalline gypsum—Northeast corner of Marion Lake



Typical crystalline gypsum from massive bed—Marion Lake



Small reverse faults in Eocene sand—Correll's sand pit, section 99,
hundred of Kulpara



View showing level surface of Moonta plain—Southwest from ruins of Moonta mines



Peesey Swamp, from its eastern edge—with the Warooka plateau beyond



The salt lake district—view south from 7 miles W. of Stansbury. The irregular large lake in near distance is Weaver Lagoon. Lake Fowler is the large lake towards the south coast



Typical view in the southeast of the peninsula—with piles of kunkar nodules collected from the paddocks

In 1959-1960, clearing of overburden from the upper bench of the B.H.P. dolomite quarry revealed similar deposits as infillings in an extremely uneven surface of Cambrian dolomite, clearly eroded under karst-like conditions (plate XXI). The sands were everywhere underlain by pale-grey or white clays plastered fairly evenly over the dolomite surface, but sometimes filling pockets completely. Local cementation of the sands has taken place by secondary silicification (commonly confined by horizontal upper and lower surfaces) so that intensely hard blocks had to be removed along with loose sand.

With the exception of the deposit (a), which possibly occupied an erosion hollow, all these deposits are here regarded as of identical origin. Their distribution and mode of occurrence suggest that in early Eocene time there existed scarps with scarred rugged edges comparable to those of typical karst areas of today (e.g., western Yugoslavia, NW. Yorkshire) which were submerged beneath shallow waters. Sand rapidly filled up numerous solution holes, fissures, enlarged joints, and valley exits. The presence in the B.H.P. quarry exposures of a lining of grey clay containing Archaean detritus suggests that heavy rainfall had sloughed material eastwards into these holes prior to submergence.

On this hypothesis, it is to be expected that similar deposits, as yet undiscovered, exist in the same scarp zones, concealed by kunkar.

Muloowurtie Clays and Blanche Point Marls Equivalents

The Muloowurtie Clays (Tepper 1879) occur in the cliffs south of Rogue (Roger) Point to Muloowurtie Point. At the latter point Tepper recorded "Ardrossan Marble", i.e., Kulpara Limestone, at the base of the cliff, and above it a yellow clay with oysters, "Pecten", echinoderms, and fish-teeth, succeeded by a white plastic sandy clay with *Fibularia gregata* Tate. Above this is a one-inch thick sandy limestone overlain by 9 to 20ft. of sandy yellow clay and sandrock with "*Terebratula*" and 6ft. 6in. (locally more) of unfossiliferous ochreous clays.

Overlying these beds are others which are the equivalent of the Blanche Point Marls of the eastern side of the gulf (Reynolds 1953). These (the "Turritella Grits" of Tepper) are shelly clays with discontinuous, nodular bands of dense fine-grained silicified sandstone rich in *Turritella*, passing up into grey and pink sandrock, though with much local variation. Alunite occurs in them in nodular masses in sub-parallel bands through a thickness of 2½ft. and over a stretch of 10ft. in a good exposure of the beds 200yds. north of Menie Hill—where the lower part of the cliff, possibly in Muloowurtie Clays, was obscured by a storm dune at the time of observation. They extend southwards with a strong development of the sandstone in the bay at the south end of which is the outcrop of Kulpara Limestone at the base of the cliff, known as Sliding Rock. This sandstone is underlain by glauconitic clayey sand, and the overlying ochreous clays become very glauconitic, southwards toward Muloowurtie Point.

Farther south, ochreous clays extend discontinuously as far as Rocky Point, resting directly on the Archaean at Hart mine and for 1 mile southward, on Cambrian sedimentary breccias at Pine Point, and on Cambrian conglomerate at Rocky Point. At Rocky Point, a white quartzitic sandstone is a prominent member and has provided plant remains. The sequence in the cliff at the point may extend up into the Oligo-Miocene*. It is described by Howchin (1918). Much limonitic and hematitic material, derived from the Tertiary, litters the beach south of Pine Point jetty.

An important but quite distinct suite of outcrops of the equivalents of the Blanche Point Marls occurs as isolated cappings—usually visible only as scattered float—on hill tops along the Ardrossan-Price scarp. These are the "high-level

* On the Maitland 4-mile sheet the beds from 1 mile north of Pine Point to Rocky Point have mistakenly been shown as only of Oligo-Miocene age.

outcrops" of Howchin (1918, p. 204), and are conchoidally weathering silicified sandstone, light and porous, usually pink or yellow and rich in *Turritella* moulds. Microscopic examination shows that a second silicification has affected this material; the remaining larger fossils of calcite still present in the nodules of the cliff exposures having been completely changed to silica, and laths of quartz developed also. This second silicification is due to sub-aerial weathering, during which the softer marly beds have later been totally removed by erosion.

Oligo-Miocene

General

The main occurrence of the Oligo-Miocene beds is along the east coast where, from Port Julia southward, there is an almost continuous exposure for about 30 miles of soft bryozoal limestones, sandy limestones, sands, and sandy clays which are usually ochreous, pale buff or yellow in colour, but contain pink iron-stained and green glauconitic beds. They form cliffs capped by white kunkar and usually, though not invariably, with Pleistocene clays between the kunkar and the Tertiary. The cliffs are generally between 20 and 60ft. high, but reach 100ft. locally. South of Wool Bay, near Giles Point, they decline in height, the Oligo-Miocene falling away below sea-level and thin Pliocene beds becoming intercalated between the Oligo-Miocene and the Quaternary. No exposures occur inland because of Quaternary cover, but the western limit of the beds has been determined from borehole and other evidence.

On the south coast, limestone is exposed under kunkar in the cliffs extending west from Troubridge Hill.

Large outliers concealed by kunkar form cappings around Warooka and in the Point Turton cliffs where a thickness of 50ft. is exposed below the kunkar (plate XVII). This is formally named the Point Turton Limestone. At Corny Point a fragment of limestone, probably of Oligo-Miocene age, is known, but elsewhere none has been seen though remnants may exist under the ubiquitous Quaternary.

Elsewhere on the peninsula, Oligo-Miocene limestones are conspicuously absent, the only certain occurrence being at Urania. Occurrences of limestone east of Urania, in southern Yorke Valley, are possibly of Oligo-Miocene age, as are those known in bores to the north and east of Minlaton. If these occurrences are all Oligo-Miocene, then that in southern Yorke Valley is the highest known, being approximately 250ft. above sea-level.

No detailed stratigraphic examination of these beds has yet been undertaken, but numerous palaeontological identifications show that the exposures along the east coast are equivalent to the Port Willunga Beds on the east side of Gulf St. Vincent, and there is a strong lithological resemblance. The Point Turton Limestone is palaeontologically similar to part of that sequence. The Urania limestone resembles that at Point Turton, but the limestones of southern Yorke Valley are less certainly correlated and lithologically more nearly resemble the lower Miocene of the north. No palaeontological examination of the concealed Tertiary of the Minlaton area has been made.

The Port Julia Greensand is a prominent, very glauconitic clayey sandstone occurring at the base of the cliffs $\frac{1}{4}$ mile S. of Port Julia jetty, and about 1ft. 6in. thick. This is a useful marker band.

The Warooka outlier beds are essentially horizontal, but may have a slight westerly regional dip. At Point Turton, Denholm (1957) noted slight arching in an east-west section. Greenway and Phillipps (1902) stated that the Point Turton Beds form an anticline rising from sea-level at either end to a height of 55ft. at the apex. There is little doubt that a fault cuts off this outlier on its eastern side, but no Tertiary was noted in the Peninsula Oil Synd. bore in Peesey Swamp. Since

completing mapping, the author has noted that R. W. Segnit recorded "Miocene" along the coast west of Fish Point as a thin bed under kunkar. This was not seen by the author, who was also unable to trace the Tertiary recorded by Howchin nearby at Brutus Castle.

Erosion and Loss by Solution

A very important feature of the exposed Oligo-Miocene is the evidence of erosion by solution. This is a clue to its absence over large areas of what was presumably once its outcrop, and in the author's opinion, supporting Howchin (1901), is locally a significant factor in explaining the origin of the salt lakes of the Yorketown area.

The Oligo-Miocene of the main "outcrop" increases in carbonate content southwards, as shown by analyses of samples taken from the cliffs (Nixon, 1961). Solution is not very evident in the cliffs near to Port Julia (where the silica content is abnormally high) but farther south they reveal numerous pockets or funnels now usually clay-filled. These are well displayed in the old quarry at Stansbury, and are a prominent feature of the Klein Point quarry where there are numerous but irregularly occurring clay-filled pockets in the face (plate XXIII), and are known at floor level (60ft. below the surface). Much of the bryozoal limestone has become rubbly by loss of matrix. The clay filling the pockets is yellow brown and unlike any known Quaternary clays.

Because of the complete Quaternary cover, sink holes are not normally seen inland. But on section 1, hundred of Dalrymple, on the property known as "Blairgowrie", 2 miles north of Wool Bay, the ground has become so affected by solution that a uvala has developed, *i.e.*, a flat-bottomed depression with very irregular boundaries and "islands" formed by the coalescence of numerous sink-holes. This was observed to be "very wet" in 1946, after continuous exceptionally heavy rain. It extends to within 200yds. of the top of the cliffs but has no surface outlet in that direction. The development of this uvala is an example of the second stage of solution in the sequence from small holes to large depressions—which in some cases were probably the precursors of those now occupied by salt lakes in the area to the west. A third stage is seen where the limit of the Tertiary is deeply indented eastward 5 miles west of Stansbury on the Roger Corner road; the indentation is considered to be a fully developed uvala with the western side removed, and Tertiary is absent from its floor.

Near Wool Bay the cliffs show very deep solution erosion of the Port Willunga Beds (plates XXIV and XXV) and the inlet of Salt Creek Bay may owe its origin to solution.

There are also extensive flat-bottomed depressions north of Minlaton, east of the Maitland road. These occur in areas where Tertiary limestones have been recorded in bores and are probably uvalas.

Eroded hollows were recorded in the Point Turton limestone cliffs by Howchin (1900a) in an area now quarried away.

It is evident from the sequence and disposition of the formations in the coastal cliffs that very considerable erosion, mostly by solution, occurred before deposition of the Quaternary, although of course it has gone on continuously since. Basedow (1901) noted an erosional surface within the Tertiary sequence north of Edithburgh. The Pliocene at Edithburgh rests on an eroded surface of Oligo-Miocene; and to the north the deep indentations in the Oligo-Miocene surface, filled in with clay, scarcely affect the horizontality of the Quaternary, there being only a slight undulation of the bedding planes.

Lower Miocene—Melton Limestone

The Melton Limestone outcrops in the hundred of Kulpara, north of Melton, where it is well exposed in a large sinkhole on section 388 (plate XXVI). This shows about 30ft. of conglomeratic sandy bryozoal cross-bedded limestone rich in *Lepidocyclina*. Outcrops around Kulpara (to the east, on the Wakefield one-mile sheet) contain *Austrotrillina howchini*. All these occurrences are regarded as of "Batesfordian" lower Miocene age (Ludbrook, 1963). The formation exists under kunkar over a wide area farther north—in places, completely kunkarized. Fragments are known for up to 10 miles south of Melton. To the west, remnants occur as float south of Paskeville and Thrington and near Cunliffe. In the depression between Cunliffe and Kadina the limestone occurs under kunkar. At the Boor's Plain quarry on section 68, hundred of Kadina, 5ft. of massive kunkar overlies 5ft. of cream-coloured massive algal limestone. Nearer Cunliffe, fragments occur containing Archaean debris. This sub-kunkar occurrence extends east and northeast of Kadina almost to Alford. Along the northwest coast, the southernmost known outcrop is $1\frac{1}{4}$ miles south of Point Hughes, but the distribution of sink-hole impressions on the air photographs, and scattered float and minor quarry sections, indicate its extension inland and over 2 miles farther south. North of Wallaroo, to beyond Tickera, the coastal cliffs show discontinuous outcrops of the Archaean. Nearer Wallaroo and at Point Hughes (plate XXVII) 5ft. of very hard recrystallized and pink bryozoal limestone occurs on the foreshore. This is overlain by 6ft. of nodular limestone of Pliocene age (containing *Anodontia* and *Diastoma provisi*) and 15 or more feet of Quaternary (Ludbrook, 1959). The nodular limestone contains powdery calcite in the voids. North of Wallaroo, 10ft. of similar nodular limestone (nodules approximately 1ft. in diameter) occurs at the southern end of section 924, hundred of Wallaroo (1 mile SE. of Point Riley). Farther north, up to 26ft. of limestone is seen, e.g., at Myponie Point, and there is a distinct difference between a lower bryozoal bed and an upper nodular bed, as at Point Hughes, and which is there undoubtedly of Pliocene age; but at Myponie Point a bryozoal limestone overlies 8ft. of algal nodular limestone (much affected by solution), itself overlying 15ft. of bryozoal limestone. As far as can at present be determined, this is all of Miocene age, and the existence of Pliocene beds north of this point is doubtful.

One mile north of Point Riley, the boundary between the nodular and the bryozoal beds has been subjected to much solution and the cavities are filled by clay and huge nodules of gypsum (plate II). The clay and gypsum are regarded as post-Tertiary, and related to the gypsum of the area north of Tickera on the Broughton one-mile sheet. The clay is exceptionally rich in montmorillonite.

Pliocene

The Pliocene is known over only relatively very small areas of the peninsula—all near to sea-level—the highest outcrops being east of Peesey Swamp at about 65ft. above sea-level. Apart from the extensive but very thin kunkar-covered (and very much kunkarized) outcrop in the area south of Port Minlacowie, all known occurrences are in coastal cliffs except for one west of Edithburgh. The occurrences are all shelly, hard, sandy limestones locally very rich in oyster shells.

The Pliocene of the peninsula resembles very closely that of the Adelaide region where it has been given the name Hallett Cove Sandstone by Crespin (1954). The formation name has been retained for this area, although the lithology is essentially calcareous, if commonly sandy.

At Port Minlacowie, sandy limestone with *Anodontia* occurs under kunkar, and similar material extends for 20 miles to the south coast at Port Moorowie where there is a comparable occurrence. Sandy and gritty limestone, generally very rich in pelecypods, has been found at numerous points in this area by Mr. E. J. Carmichael (a local resident) and with his assistance and using air photos,

it has been possible to determine an eastern boundary. The formation is extremely thin and often almost completely changed to kunkar. Much of it is conglomeratic and fragments of erratics derived from the Permian have been noted in it. To the west it is overlain by Quaternary kunkarized shell dune ridges associated with the former marine strait now known as Peesey Swamp. Its western limit is therefore unknown but it has nowhere been seen in the swamp and it was not recorded in the Peninsula Oil Synd. bore—though that does not necessarily imply its absence.

Comparable Pliocene deposits may occur on the edges of the Pondalowie Bay-Marion Bay former marine strait in the extreme south-west, but have not so far been recorded*.

On the east coast, Pliocene is known only at Giles Point and in the Edithburgh area. At Giles Point, 3ft. of oyster-rich sandy limestone occurs at the base of low cliffs of Pleistocene clays and kunkar. At Edithburgh similar material occurs under kunkar (Ludbrook, 1957c) and overlying Port Willunga Beds—which at Giles Point are probably just below sea-level. A similar limestone is recorded 1½ miles west of Edithburgh in a well-section.

On the west coast north of Port Minlacowie, Pliocene sandy limestone very rich in fossils occurs on the south coast of Wardang Island as a 2-ft. bed under kunkar and overlying Archaean. Farther north it is seen at Point Hughes (plate XXVII), and nearer to Wallaroo, but north of Wallaroo its existence is as yet uncertain (see under lower Miocene, above).

As pointed out by Ludbrook (1959), the Pliocene is markedly transgressive, but it seems probable that the Pliocene seas nowhere affected land now over 100ft. above sea-level.

Structure

Eocene

Apart from the gentle folding north of Sliding Rock, noted above, the Eocene beds appear to be horizontal, or to have a slight seaward dip, as at Pine Point. Both this and the folding may be related to the presumed existence of a north-south normal fault immediately west of and parallel to the coast, which was in existence in Eocene time and controlled sedimentation.

Oligo-Miocene

The beds are essentially horizontal. The restriction of all exposures along the east coast to an almost straight north-south coast-line means that any structural evidence is of limited value.

There is no satisfactory evidence of regional dip of the main east-coast occurrence. In so far as the Port Willunga Beds overlie Eocene in the north and underlie Pliocene in the south, there could be a regional dip southward but if so it would be negligible and could be original. The precise relationship with the Eocene has yet to be established. In the south, the Port Willunga Beds have no significant southerly dip in the cliffs between Stansbury to beyond Wool Bay. The falling away of the beds towards Giles Point appears to be erosional. Almost everywhere the Port Willunga Beds show some evidence of an eroded upper surface, and south of Wool Bay deep indentations are clearly seen in the cliffs. There may be an easterly dip, but this is difficult to establish because of lack of east-west exposures. On the section D-D' on the Maitland 4-mile sheet such a dip has been assumed. This is drawn using the known western limit of the Tertiary and the base of it as determined in the Stansbury stratigraphic bore.

* C. Bleys and T. M. Steel recorded reworked Pliocene material from a bore immediately north of Marion Bay in 1961.

Minor gentle folding of the beds of the main outcrop is occasionally seen, especially north of Port Vincent. Other dips are possibly non-tectonic. Faulting within the outcrop is uncommon and very minor. The following points are of interest:

- (a) Near Pine Point and southwards to Corrodgery trig the western limit of the Tertiary is apparently an almost straight line, associated with a sudden change of height of the underlying basement. This suggests a fault with an easterly downthrow extending close to and parallel with the coast to about 1 mile south of Pine Point and then swinging south-southwest towards Corrodgery trig. The inferred fault may well have been the western limit of deposition, or at least have had a strong influence on deposition.
- (b) South of Corrodgery trig, the western limit swings towards the coast, and then south of Ramsay trig it becomes very irregular due to retreat by solution. It seems possible that the Yacca fault scarp may have been the western limit of deposition in this area.
- (c) Concerning local structures, Glaessner (1953b, p. 43) refers to a large anticline at Port Julia with an axis pitching southeastward under Gulf St. Vincent. The author noted a southeasterly strike here with a northeast dip of 10 deg.; but no west limb is visible and the strike swings to south and then to south-southwest as it is followed farther south along the wave-cut platform. South of Sheoak Flat there is a small dome similarly revealed. Thus minor folding occurs along north-south axes with pitch variation producing elongated domes and basins. The Port Julia fold is rather stronger than most that have been seen and appears to persist northward as a monocline explaining the comparable but less sudden falling away below sea-level of the Tertiary south of Rocky Point.

Similar minor doming affects the Oligo-Miocene at the Stansbury and Klein Point quarries.

Such tectonic dips have nowhere been seen to exceed 10 deg. except in the entrance to the Klein Point quarry—where the tectonic origin is uncertain.

- (d) Between Stansbury and Port Vincent, and especially nearer the former town, there are persistent easterly dips of up to 15 deg. in the cliffs. In this stretch the profile of the cliff top near its edge is in sympathy with the dip, which remains easterly even at the heads of small bays. The writer suspects that these dips are not tectonic but due to gravitational cambering of the limestone on Permian clay just below sea-level, the clay having been squeezed out seawards.

Lower Miocene

The lower Miocene is poorly exposed but there is no doubt that it is essentially horizontal. No minor folding has been seen. However, the highest known Miocene deposits of the peninsula are those near Melton, which reach over 450ft. above sea-level. The relationship of these to those at sea-level in the west is explained by the relative uplift of the Cambrian-Precambrian basement in the east. Thus the Melton Limestone appears to have a slight westward regional dip, though it may well have been originally much thicker towards the west and then reduced by erosion.

The Pliocene beds are so restricted in area and thickness, and so poorly exposed, that no comment can be made under this heading, except to say that their very distribution was probably controlled by minor folding continuing along old-established axes. Such a movement probably explains the absence of marine Pliocene along the west coast between Point Pearce and Moonta, and from most of the east coast.

QUATERNARY

In terms of area of outcrop the Quaternary rocks are by far the most important on the peninsula. They conceal bedrock over more than 90 per cent of the peninsula, but their relative thickness in relation to the bedrock is insufficient—except very locally—to permit including them in the cross-sections on the Maitland sheet, in spite of the greatly exaggerated vertical scale used.

A great variety of deposits exists, which it is difficult to place in a time sequence. A distinction can be made between an older group of essentially argillaceous beds and a younger one which includes the calcareous crusts (kunkar), old desert dunes, coastal dunes and related deposits, and alluvial and lacustrine clays. The older group, shown in yellow on the four-mile sheets, consists of the Ardrossan Clays and Sandrock (possibly in part of Pliocene age) together with overlying alunite-bearing clays. The younger group has been divided into ten types of deposit and their placing in the geological reference column on the maps is not necessarily strictly chronological.

Older Pleistocene*

The oldest Quaternary deposit is the "Ardrossan Clays and Sandrock", named and described in its type area by Tepper (1879) and described again by Howchin (1918). It is best displayed in the cliffs north and south of the Ardrossan jetty (plate XXVIII), where it is overlain by the alunite-bearing red clays and kunkar. In the cliffs, about 35ft. of mottled argillaceous sandrock is exposed. The colours are dark red and pale olive-green. Small angular gravel is scattered through the rock—which is moderately hard—together with occasional derived fossils, including *Turritella*, from the Blanche Point Marls. A very small proportion of gypsum occurs throughout the rock as small crystal masses. Gravel bands occur especially in the upper part; the upper surface is eroded and disconformable with the overlying formation.

The mottling—which is a striking feature of the deposit—may be caused by lateritization, the upper indurated laterite zone being absent by erosion and the pallid zone concealed. This is supported by the discovery of pale material beneath the mottled in the Ardrossan silo foundation test-bore which showed mottled material from 21 to 44ft. and pale material from 44 to 62ft. However, the presence in the mottled material of very fresh felspar gravel is an argument against a lateritic origin, and the mottling may be due merely to alternate drying and wetting in an environment of low relief. The mottling appears to produce banding which simulates bedding, which, with a similar but less pronounced vertical fissuring, leads to the breaking away of cubic masses by marine erosion.

In the vicinity of Ardrossan, false-bedded gravels overlie the mottled beds and are included in the formation.

The formation is very poorly exposed inland from Ardrossan, whilst along the coast its exposure is limited by gradual diminution in the height of the coastal cliffs north and south of Ardrossan. Two miles south of Ardrossan, the cliffs lie behind a low raised-beach and are degraded, with the formation obscured by Recent downwash. The formation is again locally exposed at several localities farther south along the east coast, but occurrences are limited and too small to show on the map. Thus, in the cliffs south of Meninie Hill, patches occur overlying the Eocene, and south of Rocky Point less than 10ft. is present in the cliffs towards Black Point.

Between Black Point and Port Vincent, a thin representative is occasionally to be seen in the cliffs. South of Port Vincent this type of occurrence continues, but at the old alunite mines 6 miles north of Stansbury, the major part of the cliff is occupied by the Ardrossan Clays and Sandrock, which fill in a great erosion hollow in the Port Willunga Beds. A smaller occurrence of the same type occurs a little farther north. The alunite, which was mined during the first World War, occurs in the lowest part of the formation as parallel bands of nodular type, 1 to 6in. in thickness, continuing for the full length of the abnormally

* Possibly in part Pliocene.

thick development of the Ardrossan Clays and Sandrock. Shaft sinking showed that it extends inland for 600ft., with an average total thickness of about 18in. (plate XXX).

Southwards the formation thins out, there being only 3ft. at 1 mile farther south, and none at Stansbury or at the Klein Point quarry. At Wool Bay, a red ochreous sandrock overlying a current-bedded more yellowish soft sandstone (combined thickness 8ft.) is attributed to the formation. Farther south, the more characteristic mottled material overlies ochreous sandrock, together up to 17ft. thick. At Giles Point, 12ft. of slightly gravelly mottled clay overlies the Pliocene.

On the south coast, the formation has been seen only in the cliffs between Troubridge Hill and Port Moorowie, and its outcrop is discontinuous. It is very thin in this area, probably nowhere more than 4 feet.

On the west coast, the formation has been seen only from Balgowan northwards. At Balgowan it occurs at the base of the cliffs about a quarter of a mile north of the jetty, where it is a brilliant orange-brown colour. This outcrop extends about three quarters of a mile northward. The next occurrence—too small to show on the Maitland 4-mile sheet—is at Port Moonta (Moonta Bay). Here the jetty is built on flat outcrops of strongly ferruginized very gritty sandrock and in the low cliff immediately south of the car park, this is seen to be impregnated with silerete. It is overlain by pisolitic iron oxide.

This abnormal, ferruginized and silereted occurrence is almost identical with sections in the Cordillo Downs area of the Great Artesian Basin, where duricrust is overlain by pisolitic iron oxide (laterite) and was demonstrated to the author by H. Wopfner, who first suggested the comparison on seeing the Moonta section (plate XXXI).

About a quarter of a mile south it occurs at the base of 15-ft. cliffs as a bright red-brown bed of which only 2ft. is exposed (plate XXIX, lowest formation in cliff). It is probably about 5ft. thick as Archaean rocks outcrop a few yards lower down the beach. Another minor occurrence was noted north of Wallaroo.

Inland, large areas of mottled clays, sometimes with small gravel, in the area west of Maitland, have been placed in this formation. These are very poorly exposed but are known in bores.

In the Weetulta area, the clays are probably only a capping on a basement "high", thickening to the west (where they were recorded in the Weetulta diamond-drill hole) and south—and spread over remnant patches of Permian lying on the basement south of Bagnall Hill—they fill a shallow depression in the basement—possibly caused by faulting on the east side of the Proterozoic inliers. This depression is now bisected by the Government Bore Fault. It was evidently drained at one time by the meandering alluvium-filled channel which extends west towards Point Pearce Mission; but after the development of the fault, any drainage of the eastern half has been directed southward.

Another large area lies northwest of Urania. This is less clearly defined. Two old drainage channels can be traced from it, east of Victoria trig, but the easternmost part appears to have contributed material to Yorke Valley.

It is evident from the cliff exposures of the formation that it is essentially an arenaceous-argillaceous deposit which may have been subsequently lateritized and then eroded. Whether lateritized or not, it occupied bedrock depressions and valleys, or formed a thin skin on the gentle slopes of the Archaean surface, from which it is largely derived. The amount of transportation is however very variable. There is no doubt that the deposits along the east coast have been transported substantial distances. Those along the west coast, and inland, could

well have been transported only slightly and where deposits are thin, it is not always easy to distinguish them from residual clays on weathered bedrock. In the Moonta area it seems likely that the two occur together. Eastward between Paskeville and Kulpara, laterite occurs under kunkar and as very occasional remnants on the higher ground; and the exposed Proterozoic is usually lateritized. This laterite and lateritization could be of the same age as that which may have affected the Ardrossan Clays and Sandrock.

At Ardrossan, red sandy clays with alunite seams overlie the Ardrossan Clays and Sandrock disconformably. These overlie gravels at Ardrossan and are the "adhesive clays" of Tepper. He noted the presence of "thin, parallel bands of white pipeclay . . . to the number of three or four, . . . persistent for considerable distances." The "pipeclay" is usually nearly all alunite with some kaolinite. At Ardrossan the formation is abnormally thick (20-25ft.) and unusually gravelly. Elsewhere it is normally 6-8ft. thick and is a sandy clay with only rare gravel bands; but the alunite seams invariably occur. It is likely that it is derived largely from the Ardrossan Clays and Sandrock, from which it is distinguished slightly in colour and by absence of mottling as well as by a boundary varying in erosional intensity. It has nearly always a vertical prismatic structure, with a development of clay "skins" on the prisms. The formation has been seen at various points on the east coast and on the south coast at Port Moorowie. Fine exposures occur in the Balgowan cliffs and at Moonta Bay (plate XXIX), and it is recorded between Wallaroo and Tickera. It is not invariably found with the preceding formation, but it has never been found very far from a known occurrence of it.

The remarkable feature of this deposit is the persistence and regularity of the thin alunite seams. The seams in this red clay are much too thin to be of economic value but their origin is of great interest. The nature of the clay and the invariable horizontality of the seams suggests an origin in playa lakes as an evaporite-type deposit close to the surface within the lacustrine clay. The rhythmic succession of thin seams separated by clay could be due to precipitation by annual desiccation or at the climaxes of much longer periods of intense aridity. In the absence of other evaporites this suggests very unusual circumstances. The horizontality over wide areas makes an origin as part of a soil profile much less likely. In the cutting leading down to the dolomite loading quarry at Ardrossan, the red clays appear to have been eroded before being covered by calcareous loess, and have a slightly undulating upper surface. The alunite seams in the clays swing up and down in sympathy with though not at constant depth below this eroded surface, suggesting that it might have influenced their formation, by controlling the vertical movement of alunite-bearing water. On the other hand, the undulations may be due to minor folding since the alunite was formed. The occurrence lies near a tectonically disturbed zone (the Ardrossan-Kulpara scarp) although such folding so near to a coastal cliff could be superficial, *i.e.*, non-tectonic.

Younger Pleistocene and Recent

A wide variety of deposits is recognized within this general age group.

At present much more is known about the deposits themselves and their distribution than is known about their time relationships. Mapping of these deposits on the peninsula is difficult because of low relief and the almost complete masking by kunkar, which is by far the most common material.

Kunkar

The placing of this category at the base of the Pleistocene-Recent column is not intended to imply that it is invariably the oldest deposit of the sequence, though in many parts of the peninsula kunkar does immediately overlie older Pleistocene,

Tertiary, and older rocks. The category includes kunkar* of any age and it will be appreciated that this includes materials of different genesis. It should be added that, on the Maitland sheet, aeolianite is included in the category for cartographic convenience. On the (later) Investigator sheet, where it is much more common, aeolianite is separately shown, but because it is invariably kunkarized or overlain by kunkar to some degree, outcrops are restricted to the coastal cliffs.

The origin of kunkar has been discussed by several previous workers. Jack (1917), Howchin (1901, 1918), and Woolnough (1927) considered that it is necessarily associated with calcareous bedrock and is produced by evaporation of water raised by capillarity. Crocker (1946) pertinently demonstrated its existence overlying non-calcareous bedrock (in Yorke Peninsula, quoting examples where it overlay laterite and glacial clays). He suggested a loessal, and therefore, extra-peninsular origin, and considered that all kunkar on the peninsula, except for aeolianite kunkar, was so derived. The present mapping in general confirms Crocker's theory, although calcareous bedrock is locally an important contributing factor. Kunkar frequently shows evidence of reworking both by solution and reprecipitation, and by mechanical transportation and subsequent re-cementation, so that the kunkar profile is locally quite complicated.

A typical form of occurrence is shown in plate XXXII, taken $\frac{1}{4}$ mile north of Port Julia jetty. This section shows kunkar which has three horizons; an upper nodular bed, a middle massive bed or sheet, and a lower nodular bed. Approximately 1ft. of soil overlies 1ft. 6in. of nodules varying in size from $\frac{1}{2}$ in. to 8in., which are cemented together to a greater or lesser degree so that the bigger nodules are composed of smaller. Some very small (less than 1in.) nodules occur in the base of the soil, which is nevertheless quite distinct from the nodular bed. The nodular bed is sharply separated from a massive limestone 2ft. 6in. thick, which has a flat upper surface. Below this is another bed of nodules, in a matrix of calcareous clay. About 6ft. of this is exposed, and a further 5ft. unexposed, resting on 8ft. of red clays, overlying Ardrossan Clays and Sandrock. The lower limit of the massive bed is less sharp than its top, and the bed is evidently a cemented mass of nodules considerably modified in texture and now very dense.

This type of kunkar can be seen all along the east coast of the peninsula, and is the typical form of occurrence inland. The upper nodular bed usually lacks much matrix, while the lower one may consist of little but matrix, when it is often described as "marl" or "marl-earth". Farther north of Port Julia this is well seen. The thickness of the whole sequence varies from less than 2ft. to over 20ft., and the middle bed may become very thick and solid.

The three horizons are not always present (plate XXXIII) or poorly developed (plate XXXIV). Half a mile north of Port Julia, 8ft. of "marl" is recorded overlying 7ft. of rounded cobbles of kunkar (not nodules) resting on shells and shell sand on mottled clay. Inland, a "marl" horizon often occurs alone.

Along the west coast the sequence is more complex. The main difference is that a distinction exists between an underlying massive thick pink kunkar—with "nodule within nodule" structure—and an overlying suite of alternating "marls" and thinner sheet kunkars which are paler, much less hard, and are often mere lines of nodules. These are undoubtedly developed within the seif dunes

* The term "kunkar" is used for all material formerly known as surface limestone, limestone crusts, lime rubble, travertine, travertine rubble, nodular travertine, nodular limestone, caliche, tufa, marl, and marl-earth; and is therefore used in a wider sense than in India, where the word—meaning "gravel" in Bengali—was applied to nodular limy concretions in clays and at the surface. Much of the material is what is commonly known as calcrete in South Africa, a term applied there by Lamplugh, who, however, first used it for describing lime-cemented gravels in the Dublin district of Ireland. The use of "caliche"—as is common in U.S.A.—is undesirable because of a prior and continued use of that word to describe nitrate deposits, and other uses for non-calcareous material. No better term than kunkar seems to be available at present for the group of deposits as a whole.

(see below). They show arching, while the massive bed is flat-lying, though it can have gentle dips as a unit. A typical sequence can be seen in the Moonta Bay cliffs.

At Port Rickaby the simplest example is seen—

- | | |
|---|-------------|
| f. Mobile sand (blown inland and concealing any remnant seif dune topography) | up to 15ft. |
| e. Upper thin kunkar. Very pale orange, friable nodules up to 1ft. diameter, retaining shell fragment texture | 1ft. |
| d. Sand | 6ft. |
| c. Shell bed ("raised beach") | 6in. |
| b. Massive pink kunkar of "nodule within nodule" texture, with deeply pot-holed upper surface | 5ft. |
| a. Pale-green calcareous crumbly claystone freworked Permian till (several erratics found on beach) | 4 seen |

The shell bed (formation c) is correlated with that which was recorded by Crocker (1946a) overlying massive kunkar at Brown Point (The Bluff).

That all these occurrences of kunkar may be ultimately derived from loess can be demonstrated in the Minlaton-Wauraltee area, where there is an extensive spread of loess on the coastal plain. Three miles west of Minlaton calcareous dune sand exists, with aeolian bedding. Half a mile east of this, trenching showed a structureless loess, almost entirely calcareous, with soft nodules up to ½ in. in size. This might be described as incipient kunkar. The trenches showed a gradual transition between the two deposits. Farther north, between Mount Rat and Wauraltee, on section 12, hundred of Wauraltee, roadside pits showed 1ft. of light-brown soil with small nodules on 6in.-1ft. of sheet developing from nodules, overlying 6ft. of loess containing innumerable nodules less than ½ in. in size. All these occurrences are on loess which is probably younger than much of that on the peninsula, and which is only now developing gradually into typical kunkar.

A fine Quaternary sequence is exposed in the cliffs north of Balgowan (plate XXXVI). Above the older red and brown Pleistocene clays, previously described, is a whole series of pale brown-coloured calcareous deposits. As soft nodules of incipient kunkar occur in the lowest bed, either concentration of lime is going on now, at 30ft. below the surface, or was arrested after having started.

This section shows that there were repeated accumulations of loess and that considerable modification of each accumulation took place before the succeeding one was deposited. Locally some of this material was eroded and transported before being again covered by loess. Variations in thickness are mostly due to differences in the amount of loess accumulated, variations inherent in the mode of deposition.

It seems very difficult to account for the production of the hard middle horizon of the typical simple profile without invoking the movement of calcium carbonate in solution, but rather than a capillarity effect, it is due primarily to downward leaching associated with oolite-pisolite development carried to an extreme.

The massive middle horizons, and the massive sheet kunkar of the west coast, are thought to have been formed by the superimposition and coalescence of nodular horizons, by leaching of repeated thin—and almost flat—accumulations of loess, at a time when arid periods were short and humid periods long. The coalescence is revealed by the "nodule within nodule" structure. By contrast, the several distinct layers of "single generation" nodules of the seif dunes are interbedded with scarcely altered material, the accumulation of which, in dunes during longer arid periods, was too thick to permit complete "kunkarization" in the alternating and now shorter humid periods. The eroded and pot-holed upper surface of the massive coastal kunkar sheet, and the frequent presence of a shell

bed on this surface, shows that there was a marked break in time between the two types of accumulation, and that this break was associated with changes in sea-level.

The abnormally thick middle horizons which are frequently noticed on the peninsula, *e.g.*, at Minlaton (25ft.), and in the area about 6 miles west-southwest of Pine Point, are possibly due to accretion of extra material by horizontal transference in solution; these areas of very thick, massive sheet kunkar often occur in physical depressions towards, and into which, carbonate-rich water is (and was) bound to be directed. Limited development of pisolites and nodules in the lowest of the three horizons—the marl—is explained by the restricted penetration of waters to that level because of the relatively impermeable middle horizon, which is formed at a level determined by the physical factors involved.

Kunkar is usually white, greyish white, pale pink or (less commonly) yellowish on the weathered surface, but commonly pink on a fresh broken surface, often showing less colour towards the outer “skin” which is denser and free from the gritty impurities of the core material. Occasionally it is dark grey or contains angular or rounded fragments of dark-grey, even black, kunkar which is rich in organic matter. North of Kadina—on Adams Plain—the kunkar consists entirely of 2in. x 2in. size nodules with a thin white “skin” but dark grey or black nucleus. Much of the kunkar of the southwest contains much similar dark material though in angular fragments. There is too much for it to be explained by charring caused either by lightning or aborigines’ fires.

A strange feature is the occasional presence of fragments of (non-calcareous) bedrock in kunkar float overlying several feet of often massive kunkar itself concealing bedrock. The fragments usually form very much less than 1 per cent of the float and perhaps less than 0.1 per cent. An unevenness of bedrock surface, especially in the upland regions, might explain it, but south of Wallaroo such float has been found where the bedrock surface is almost certainly practically level and smooth. An example is on section 1443, hundred of Wallaroo. A probable explanation is evident in the northern of the two Brealey stone quarries on section 1809. There, although the surface of the flat-lying massive Proterozoic quartzite is quite level and smooth, and the overlying kunkar 4ft. thick, angular fragments of the quartzite, much too large to have been wind-deposited, occur at various levels in the kunkar up to the present surface. Examination shows that veins of kunkar are penetrating into the quartzite, wedging up angular blocks which become broken up (plate XL). Thus a vertical movement of non-calcareous matter has evidently occurred, which is not inconsistent with downward leaching of lime.

Kunkar which is derived from calcareous bedrock occurs widely, but in much of the peninsula it is difficult to assess how much kunkar derived from loess is associated with it. Kunkar derived directly from Cambrian limestone is generally thin, forming a crust, rarely reaching more than 1ft. in thickness, and sometimes a mere skin of less than 1in. This is less true of the Tertiary limestone which is usually much less dense and lends itself more easily to reconstitution.

Kunkar derived from aeolianite and kunkar in the fixed desert seif dunes is described under those headings.

Chemical analyses of kunkar show that it is commonly too impure for chemical use. A little is burnt for lime and it is widely used as roadstone.

Fixed Desert Seif Dunes and Associated Sand Spreads*

Next in importance in areal extent are seif dunes with associated sand spreads. The largest unbroken area of these extends from Moonta to Balgowan and spreads inland almost to Arthurton and Maitland. An equally large, but more broken

* This term refers to longitudinal sand ridges (Bagnold, 1941, p. 189).

belt, occupies much of the Wallaroo one-mile sheet area and indeed extends north and east well beyond its limits. Another large area occurs between Minlaton and Stansbury. A smaller belt lies between Curramulka and Urania; and along the eastern side of the peninsula a discontinuous zone extends from the Corrodgergy trig area north to Kulpara and beyond to Bute, where it connects with the dune belt as shown on the Wallaroo sheet.

The seif dunes are everywhere oriented at 290-300 deg. with only very minor local variations. Individual dunes are rarely more than $1\frac{1}{2}$ -2 miles long; the dune height is of the order of 25-40ft.; and the frequency about four to a mile. On the maps every dune crest has been plotted.

The dunes are of desert origin and are comparable with those of Central Australia. Similarly oriented seif dunes occur widely on the Adelaide Plains and on Eyre Peninsula. They were formed under arid conditions associated with high winds.

The dunes are truncated by the present coast in the northwest, indicating an origin at a time of lower sea-level than that of the present day. It is almost certain that similar dunes once existed on large parts of what is now the sea-bed of both gulfs.

Unlike modern dunes, the seif dunes show development of layers, leaching having left a decalcified pale-brown sand above a layer of kunkar which rises in sympathy with the crest of the dune. Some of the decalcified sand has been blown eastward and become concentrated on other seif dunes of the same suite (plate XXXVII). The dunes are palest in the west and southwest and reddest in the northeast and east. Occasionally this stripping of decalcified sand is complete and only bare kunkar-covered dune remnants remain. The swales in any case tend to be thinly covered kunkar sheets, and thus bare but undulating kunkar country locally exists within the seif dune-belt outcrops. In the north the swales are sometimes bared to reveal Pleistocene clays which underlie most of the seif dune sands in that part of the peninsula. In the south, the dunes northwest of Stansbury are developed—at least to some extent—in Permian sand which may have been reworked in Tertiary time, and where the sand cover is thin and underlain by Permian boulder till, swales and deflated areas are often occupied by salt lakes or swamps.

On the northwest coast (as at Moonta Bay) the seif dunes, with several nodular arched white kunkar horizons, overlie a flat massive pink kunkar (plate XXXVII). The upper kunkars are less than a foot thick, but the pink kunkar (which contains "nodules within nodules") is more than 4ft. thick, and rests on a pale-orange calcareous sandstone. By contrast, on the west coast, at Balgowan, the seif dune complex rests on a pale-orange soft rock which is very calcareous, shows no bedding, contains soft nodules of lime, and perhaps was formed by the sudden accumulation of calcareous aeolian material in water, and has subsequently been changed, with incipient nodule formation.

Aeolianite and Aeolianite Kunkar

Along the west coast of the foot of the peninsula, especially towards the south, all the cliff apart from occasional low Archaean outcrops consists of aeolianite or aeolianite changed to kunkar (plate XLIV). From Corny Point (plate V) to Daly Head this is about 30-60ft. thick. From Royston Head to Cape Spencer (plate XLII) it reaches over 200ft. in thickness. Similar material forms the high cliffs on the Althorpe Islands. The rock is a calcarenite, composed almost entirely of extremely well-rounded shell fragments. It usually shows aeolian

bedding and is very pale brown in colour. The repetition of layers clearly seen in the photograph is accentuated by the kunkarization which has affected the upper part of each layer. Lime commonly extends farther down along rootlets. The present cliff top is invariably kunkarized, the kunkar containing many angular and rounded dark patches rich in organic matter, and weathering to loose slabs. The dark material is derived, in part at least, from fossil soils.

The magnificent Cape Spencer section has not been examined in detail, but a more accessible section 1 mile south of Royston Head showed—

	ft.
f. Mobile sand.	
e. Strongly false-bedded aeolianite	15
d. Horizontal kunkar layers	20
*c. Unbedded, but vertically fluted soft aeolianite with kunkarised tree branches at base	10
*b. Greyish-orange kunkar, with numerous black nodules up to 1½ in. diameter	5
a. Dense yellowish aeolianite limestone, with deeply pot-holed upper surface; some of the pot-holes containing formation b. On beach to north, shows strong false bedding	12 (extends below sea-level)

Inland, aeolianite is poorly exposed and is usually seen only in road cuttings where it is invariably overlain by kunkar (plate XLIII). Most of the western part of the foot of the peninsula is underlain by these materials; in places the kunkar is very thick and massive, but locally, dunes of quite unconsolidated white loess occur.

Older Alluvial Clays

Older alluvial clays, with ferruginous pisolites and felspathic and quartz grit, have been mapped in Yorke Valley and to the northeast. These clays are poorly exposed and borehole information is meagre. They contain transported material but are probably in part lacustrine. It is considered likely that Yorke Valley is filled with alluvial clays which may at one time have been deposited in a lake gradually developing into a playa. Tepper (1882) refers to 170ft. of clays and gravels "similar to those met with in the Ardrossan cliffs", and it is indeed likely that the valley contains representatives of the Ardrossan Clays and Sandrock and the overlying red alunitic clays, overlain with the younger alluvial clays shown on the map.

Similar deposits are thought to occur in another almost perfectly flat-bottomed area 4 miles northeast of Maitland, in an analogous position east of the Maitland-Arthurton fault. For purposes of description this nameless area has been called the North Maitland Flat.

Alluvial clays are also mapped on the Cunningham Plain, north of the Maitland-Ardrossan road, and underlie much of the adjacent kunkar outcrop. These also occupy a one-sided graben and are presumably in part lacustrine. These clays are known to be up to 105ft. in thickness, probably including representatives of the older Pleistocene.

Similar deposits may exist under kunkar farther south, and others have been mapped west of Clinton Centre. An area east of Melton is included, though this appears to be mostly transported material.

Raised Beaches and Related Features

The term "raised beach" here implies deposits which are high relative to those of the present day; and connotes not only true beach deposits but also shell beds. Raised beaches in this sense occur widely, but most are too small in extent

* Seen in plate XXXVIII.

to show on the map. Clark (1928) described an example near Point Turton. Five to six feet of shelly sand, more or less indurated, occurs for 2 miles near the base of the low cliffs west of Fish Point, overlying Oligo-Miocene limestone in places, and everywhere capped by kunkar. Another was described by Crocker (1946a) at Brown Point (The Bluff) west of Minlaton. This consists of a 6-8in. shell bed overlying 16ft. of kunkar of which the lowest 2ft. forms an extensive reef covered only at high tide. The shell bed is capped by thin kunkar and aeolian sand.

Raised beaches were recorded also by Dickinson and King (1951) near the boat sheds at Cable Bay, 3 miles west of Stenhouse Bay, and also north of West Cape.

Near Ardrossan, at Parara Point, shelly beds with *Lithothamnion* occur at Owen's pit, on the seaward side of a degraded low, former coastal cliff of Pleistocene mottled clays 6-20ft. in height. These beds are up to 5ft. thick, 100yds. wide, and only about 5ft. above high-water mark. Similar material north of Ardrossan is mostly covered by low dunes.

Another example occurs $\frac{1}{2}$ mile north of Port Julia where 4ft. of shells and shell sand overlies 2ft. of mottled clays and is covered by up to 10ft. of kunkar marl.

Elsewhere on the east coast, narrow strips of raised beach exist at Pine Point, about $\frac{1}{2}$ mile long, at the foot of the cliffs east and north of the town; southwards for $\frac{1}{4}$ mile from the jetty at Pine Point; and at Sheoak Flat between Port Julia and Port Vincent. Various smaller ones occur, one being clearly displayed in section in a creek on section 925, hundred of Wallaroo, about one mile southeast of Point Riley. Here, well rounded cobbles (3-12in. in diameter) of Archaean gneiss and Tertiary limestone form a bed overlying Pleistocene mottled clay, rising inland at 12-15 deg. and thinning. The bed is overlain by a wedge of kunkar marl, also thinning inland, enerusted by hard kunkar and the whole capped by loose sand (plate XLVI). North of Tickera, at the northern limit of the coast of the Wallaroo sheet, similar cobbles occur on the present-day shore at the foot of low cliffs largely of sand. The shore is exceedingly gentle in slope. It is suspected that these have been washed down by occasional torrents from raised beaches concealed by dune sand, and left stranded on the shore.

A wave-cut notch was recorded in the Ardrossan cliffs at about 6ft. above the present base of the cliffs. Another was seen at about 12ft. above the base of the cliff 2 miles east of Port Moorowie, in Tertiary sandstones overlying Permian till.

A fine example of an emerged wave-cut bench forms the upper surface of the outcrop of the Archaean rocks at Corny Point, where a smooth surface of gneiss extends around the point and is now not covered by high tides.

Recent marine shelly limestones have been included with raised beaches for cartographic convenience. They are an insignificant feature of the peninsula and not commonly seen. The best section recorded is between Edithburgh and Coobowie at the south end of a small bay opposite section 3, hundred of Melville, where 5ft. of grey sandrock, very rich in pelecypod shells, is exposed, dipping slightly towards the sea; the beach is formed of the same material.

The cusped forelands on which Port Vincent and Stansbury are built have also been placed in this category. These features are confined to the sheltered east coast and to that part of it which is opposite particularly shallow water in the gulf. A study of the Admiralty charts suggests that Oyster Point (near Stansbury) is growing out towards the southern end of Arontes Bank and Surveyor Point (Port Vincent) towards the middle of the bank; each under the influence of tidal currents, longshore drift, or waves. While an origin of such features due to tidal currents is now generally abandoned in favour of building up by wave action, waves are of little importance on this sheltered side of the Gulf, whereas tides are very strong in the extremely shallow water.

These cusped forelands are almost identical in shape. Each has a northeasterly trending straight southern coast, and a concave northern coast which appears to be undergoing very slight erosion. In other words, the forelands are gradually developing into the basal parts of spits of an early stage of development. Neither shows any distinctive ridging.

The larger cusped foreland which ends in Black Point is rather different. Its northern coast is again smoothly concave, with a transition from a rocky, gently sloping beach near Rocky Point to a steeper sandy beach with abnormally deep water close to the shore, and then again gradually to a shallow beach with the apparent beginning of the development of a spit. South of Black Point however, the coast is mainly aligned north-south, with a northeasterly stretch only near the point. Moreover, prominent dune ridges occupy the foreland, parallel to each coast, and with an apex the movement of which has been northeastward. Behind these dunes is an area now occupied by sand blown from the dunes, but originally probably a lagoon, *i.e.*, this was not strictly a cusped foreland but a cusped barrier. The matter is complicated because this coastal feature is built against the northern side of a true promontory of rounded outline, 2 miles wide, which is thought to be part of the lower limb of a monoclinical fold, and in which all bedrock is masked by kunkar, as can be seen in low cliffs north of Port Julia.

Sultana Point, south of Edithburgh, is still more complex; though it is related to Troubridge Shoals it has at different times suffered erosion on both north and south sides. It, too, has a lagoon behind the dune ridges, which connects with the south coast.

The only comparable foreland on the south coast is Point Davenport at the western end of Sturt Bay, clearly related to Davenport Shoal. This exceptional occurrence on the south coast—which is much more open to erosional attack—is in the lee of the Hillock Point-Yorke Point Archaean cliff outcrop.

Beach Dune Ridges

Between Corny Point and Point Souttar (and, to a lesser degree, east of Point Turton), beach dune ridges are strongly developed. Other smaller areas occur near Port Victoria and Cape Elizabeth, with narrow zones between Moonta and Wallaroo. On the 4-mile maps only a proportion of the ridges can be shown, but the relative spacing is correct and the cutting of the earlier by later sets can be clearly seen. The unnamed point 5 miles west of Point Souttar is constantly moving its position.

The dune ridges are usually about 15-20ft. high—but may be less—and show remarkable regularity of height. Those between Corny Point and Point Souttar are backed by a single dune about 50ft. high, which is a little less regular in its height. The dunes east of Point Turton are similarly regular, but are interrupted towards the east by more recent irregular dunes up to 30ft. high. These are now fixed on the landward side.

The beach dune ridges mapped south of Port Victoria are more widely spaced and occupy an area which is now separated from the sea by a stretch of low mobile dunes over a mile in width. They are not certainly correctly attributed; the area is oddly shaped, extending over 2 miles farther inland from the inner edge of the mobile dunes and yet scarcely 2 miles in length. The ridges may mark the positions of a migrating lake now masked by younger coastal dunes. The former coastal morphology of this part of the peninsula is very difficult to work out because of the mask of loess kunkar; but there is little doubt that at one stage in the Quaternary, the coast was very much farther east than it is now, and the former rivers draining into this area from the north have possibly affected the detail of the coastline.

Farther north, beach dune ridges are fragmentary.

Downwash, High-Angle Slope Deposits, and Fault Scarp Debris

These need little comment. They are colluvial, having the usual content of angular fragments of whatever bedrock from which they are derived, with a matrix which is usually very calcareous. They are a minor feature of the peninsula and best displayed between Paskeville and Winulta. Narrow zones of similar deposits occur elsewhere but are too small to be shown on the four-mile scale; for example, the degraded cliffs behind the raised bench south of Ardrossan show two cycles of such downwash material, and in the gully above the Ardrossan golf clubhouse, five sedimentary horizons occur with downwash sandwiched among aeolian material.

Recent Dunes and Sand Spreads

Mobile dunes of sand which varies from almost pure white to very pale orange occur almost continuously along the west coast from Tickera to the north-western end of Peesey Swamp, varying in width from less than 300yds. to over 2 miles. They are prominent again along the west coast of the foot, especially south of Daly Head, and are moderately well-developed along the south coast. Dunes are absent along the east coast south of Port Julia, except for very minor accumulations on the cusped forelands and small flats, such as Sheoak Flat, between Port Vincent and Port Julia. North of Port Julia, dunes occur on the Black Point foreland. Low dunes are continuous, but narrow, from Rogue Point to the limit of the Maitland sheet, broken by the cliff coast near Ardrossan.

These dunes are all transverse dunes, though with a far from regular pattern. In the area south of Port Victoria, towards Port Minlacowie, their eastern boundary is difficult to determine, as repeated accumulations have taken place, with much redistribution of sand. The older dunes and redistributed sand spreads have been shown by red dotted areas on the Maitland and Investigator sheets. A similar notation has been used for the older dunes of Peesey Swamp which was formerly a marine strait; no strict correlation is intended.

In the area west of Wauraltee the red dotted areas (shown on the plans) are largely old dunes, confused in pattern. West of Minlaton, much of the area is calcareous loess blown east from the dunes and not yet changed to kunkar, and the rest of the outcrop is of similar material in which the process of change is more complete. It will be appreciated that no sharp distinction can be made, and also that the older more perfectly developed kunkar derived, it is thought, from "long distance loess" is masked in the eastern part of the Minlacowie-Wauraltee coastal plain by "short distance loess" derived from the reworking of coastal dunes, so that the total thickness is rather greater than over much of the peninsula. North of Wallaroo, the modern dune sands are thin and are spread over the older seif dunes, which still dominate the topography.

The most recent dunes vary very much in calcium carbonate content. Where derived from beach sands, which are themselves the product, in part at least, of Archaean rocks (as at Wallaroo North beach) the silica and felspar content is fairly high, but elsewhere a higher carbonate content is known. The purest are those on Wardang Island, worked by The Broken Hill Associated Smelters Pty., Ltd., for flux; these are derived from beach sand produced by marine erosion of very calcareous aeolianite, and those worked in 1950 (King, 1952a) varied from 70 to 85 per cent CaCO_3 .

The highest dunes seen are those south of Daly Head which are estimated to be 100ft. high.

Saline Swamps, Salt Flats, and Salt Lakes

Saline swamps, salt flats, and salt lakes are a very important feature of the peninsula, and can be divided into five groups as under:

- (a) Coastal saline swamps.
- (b) Peesey Swamp.
- (c) The gypsum lake district.
- (d) The salt lake district.
- (e) Other salt lakes.

Coastal Saline Swamps

Coastal saline swamps are absent from most of the east coast, occurring only at Price and in Salt Creek Bay north of Edithburgh. Both these are now artificially controlled, the Price area being a suite of salt pans, and the inlet of Salt Creek Bay permanently dammed. On the south coast, Tea Tree Swamp is the only important area. This contains flour gypsum over sandy clay with *Posidonia* weed.

Those at Wallaroo contain salt but are scarcely large enough to repay working. Similar lagoons north of Tickera are rich in gypsum (King, 1951; Solomon, 1953), and massive gypsum nodules—up to 6ft. in diameter—seen at Myponie Point, in solution cavities in the Tertiary, are thought to be of related origin. Along the north coast of the foot of the peninsula the swamps are now well inland and vestigial; *e.g.*, Coutts Lagoon. They are absent along the west coast of the foot except near Royston Head, where they form part of group (c), and near Daly Head. Those near Daly Head are peculiar in containing several feet of a natural whiting which is dolomitic (Jack, 1928; Weir, 1960), a sample showing 46 per cent calcium carbonate and 44 per cent magnesium carbonate by weight, with 4.5 per cent amorphous silica. The deposits are not now worked. Similar deposits occur at Marion Bay on the south coast, and in various lakes in the gypsum lake district.

Peesey Swamp

Peesey Swamp (plate LII) is a remarkable feature extending from Hardwicke Bay to Sturt Bay, about 15 miles long by 5 miles wide; sharply distinguished on its western side from the Warooka plateau and the lower ground to the south of it; and less obviously on its eastern side from the salt lake district and the lakeless area southwest of Brentwood. The swamp is barred from the sea in Hardwicke Bay by a complex of beach dune ridges, more recent fixed transverse dunes and older dunes, and from the sea in Sturt Bay by dunes overlying kunkar.

The area is that named the Great Salt Marsh by Tate (1890) who described the general geology, and noted also that—in spite of climatic and other resemblances—of 235 species of plants recorded west of Peesey Swamp, 41 were at that time unrecorded in the rest of the peninsula. Tate suggested that the swamp was a former marine strait, a “deserted sea-way”; and contemplated a former connection of the western part of the foot with Eyre Peninsula and possibly Kangaroo Island.

The concept of a former marine strait is supported by the presence of low ridges of kunkarized shells and shell sand, extending parallel to the swamp discontinuously on either side. Those on the western side merge towards the north with east-west trending dunes which indicate former positions of the head of Hardwicke Bay.

Between the dunes, the surface is exceedingly flat, with samphire swamps and salt flats which are wet in winter but dry out in summer and are worked periodically for salt at two localities near the Yorketown-Warooka road.

A borehole was put down 1½ miles east-northeast of Warooka on section 121, hundred of Moorowie, on behalf of Peninsula Oil Syndicate in 1931-1933, and passed through "Recent marine sediments" (Ward 1944) between the surface and 138ft. No Tertiary rocks were noted, the hole then passing into material regarded as Permian glacials.

Such a thickness of Quaternary deposits is quite abnormal, whereas the Permian is very much of the order of thickness known in the area to the east; to the west it is known to be much thinner and to become a mere film farther west. It seems probable that the swamp is a tectonic feature unless it is the western part of a deep Permian glacial valley, in which case it is still necessary to explain the remarkable thickness of Quaternary. The author regards it as a fault-angle depression, with a normal fault extending along the east side of the Warooka plateau. This concept is supported to some extent by the maps of aeromagnetic intensity, which show a marked asymmetrical linear arrangement of isopleths.

A much narrower sinuous swamp extends inland from the coast between Point Souttar and Fish Point along the west side of the Warooka plateau and then swings east to the south of it, almost joining Peesey Swamp near Moldarby salt lake. This has been termed Orrie Cowie Swamp by the author after the old Orrie Cowie Station on its western margin. It drains northwards. The origin of this feature is uncertain, and is discussed in chapter 3, "Structure and Tectonics".

The Gypsum Lake District.

This is a low-lying area in the extreme southwest of the peninsula, extending for about 6 miles from the coast near Royston Head to the coast near Stenhouse Bay, and about 4 miles wide. Like Peesey Swamp it is barred from the sea at each end by modern dunes; it is essentially flat, though less so than Peesey Swamp because of the more confused pattern of older dunes; and it is occupied not by salt flats but definite lakes, of which Marion Lake is the largest, and which is still below sea-level. The area is described in detail by Dickinson and King (1951). The lakes are rich in gypsum, which at Marion Lake forms a rock bed up to 5ft. thick overlain by flour gypsum up to 8ft. thick, both very uniform in quality. These deposits are economically important, especially at Marion Lake, where they have been worked since 1889.

Dickinson and King recorded the following section in the workings near the centre of Marion Lake:

	ft.
Flour gypsum	8
Rock gypsum	4
Black sandy ooze, with <i>Posidonia</i> weed fibres and <i>Diala lauta</i> shells	2
Hard sandy travertine limestone.	

The rock gypsum shows a vertical coarse prismatic structure with a horizontal but wavy banding following the crystal faces. In plan view, it shows a mosaic pattern (plate XLVIII). The mass is made up of translucent laminae ¼-½in. thick, separated by much thinner opaque slightly powdery layers which in one specimen contained more than ten times as much lime as the translucent laminae. Major partings form distinct and extensive floors having a smooth flat surface which on a very small scale shows relief related to the mosaic pattern. These separate layers of rock gypsum are up to 1ft. thick.

The flour gypsum or "caso" is of fine-sand size, uniform in quality and sometimes showing bedding. Some *Posidonia* weed occurs.

Jack (1921) regarded the deposits as formed in an arm of the sea cut off by a bar, using a modification of the bar theory of Oehsenius. Instead of continuous but restricted influx, Jack suggested that sea-water entered only periodically, either annually or at longer intervals. These influxes would be represented by

the carbonate-rich layers of the rock gypsum. Dickinson and King suggested a further modification of the theory, excluding any direct link with the sea. They pointed out that no extraneous material such as sand or marine fossils are found in the gypsum, though they would be expected if tidal waters came in. They regarded the high purity and regular crystal form as indicating continuous uniform conditions, with the fine banding caused by seasonal changes in salinity, and the major partings by abnormal changes of short duration. They suggested that oceanic waters penetrated through porous sands blocking the entrance, and that brines drained away to the sea with circulating groundwater. Summer and winter changes in mean sea-level could account for the fine banding, and eustatic changes for the major partings. After a particularly low sea-level, crystallization is thought to have ceased and weathering, re-solution and redeposition affected the rock gypsum and produced the flour gypsum, partly an aeolian and partly a lacustrine deposit.

Salt has recently been discovered under the rock gypsum in the western part of the lake. This is an abnormal relationship. It has been suggested (J. Klug, personal communication) that this is ultimately derived from old salt-pan brines which have penetrated between the bands of rock gypsum. It may however be due to an earlier period of crystallization and its apparent restriction to low-lying parts of the lake suggests that small natural salt pans might have existed before the onset of the main period of the evaporite formation.

Spider Lake has a deposit which is entirely flour gypsum; at 2-3ft. from the top rock gypsum is beginning to crystallize.

Nothing is known of the sequence of beds under the gypsum lakes, but a bore put down at Stenhouse Bay—on low ground near sea-level—passed through sediments—shell beds, “sandstones” (? aeolianite), “coral rock” and clays with gravel to 220ft. Below this it was in rocks almost certainly forming part of the Archaean basement. From the drillers log (the only one available) it is possible that some part of the sediments are Permian, but the description “shells and rock” for samples from 218-220ft. suggests not. It is possible that some Tertiary is present; but there is in any case a substantial thickness of Quaternary deposits, which suggests that the gypsum lake district possibly occupies a structural feature comparable with that of Peesey Swamp and though smaller in extent, with a downthrow of much the same order.

The Salt Lake District

This area is of great interest. It covers the western halves of the hundreds of Dalrymple and Melville and the eastern half of the hundred of Moorowie. According to Jack (1921) the three hundreds “contain between 120 and 130 lakes in which salt crystallizes in the summer, in addition to a considerable number of shallower depressions—or swampy areas—which carry a more or less saline vegetation. The area in which these lakes occur is about 160 sq. miles in extent, and feeds the scattered lakes with seepage water. There are salt lakes amounting in all to about 8,715 acres, of which 5,859 acres were estimated by the writer to be covered by a salt crust averaging 0.47in. in thickness and ranging from over 2in. in some lakes to $\frac{1}{2}$ in.”.

The principal feature of the salt lakes, after their number, is their form. Nearly all approach a circular shape. Some elongation along a NE.-SW. axis occurs, with the boundaries nearly always forming exceedingly smooth curves (frontispiece and plate LIII). The prominent exceptions are the largest lake (Lake Fowler), and also Diamond Lake and Weaver Lagoon, but the south and east boundaries of these lakes have the characteristic curves.

Many of the lakes are linked together by linear swamps along a general ENE.-WSW. direction, drainage being to the WSW. towards Peesey Swamp.

Origin of the Salt Lakes.—The origin of the lakes is still uncertain. Howchin (1901) was the first to discuss it and argued that an initial origin by solution of the Tertiary led to the development of lakes with an impermeable Permian clay floor. This was followed by deflation, which would explain the excavation of the Permian, evident in many lakes. Howchin noted that “the prevailing winds are from the southwest” (p. 8) and stated that the lower banks of the lakes were on the northeast side, *i.e.*, in the windward direction. He was however puzzled by an 80-ft. high “hill of granular gypsum” on the southern side of Lake Fowler.

Jack (1921) recognized that the latter feature is a dune of aeolian origin and in fact is on the southeastern rather than southern side. A similar dune exists on the same side of Diamond Lake and smaller ones elsewhere. These are extreme forms of lunettes and were described by King (1952b). The Lake Fowler dune is 350ft. wide and 1 mile long, and built of flour gypsum and seed gypsum (plate XLVII).

Jack (p. 18) writes of “wind action, erosion and solution” as the cause of the lakes. He pointed out that such Tertiary limestone as remains in the lake district is much thinner than it is in the coastal cliffs at Point Turton or north of Edithburgh, and that it is mostly absent. He noted a “very persistent bed of alunite half an inch thick” under 10ft. of red clay and resting on 2ft. of clay overlying the Permian at Munkowurlic Lagoon. Comparing this with the larger alunite occurrences on the east coast which show Tertiary limestones just below, he thought that the 2ft. of clay might be residual from the solution of limestone. He noted “sandy loam” above the clays and stated that this occurred in a WSW.-ENE. dune system “approximately at right angles to the prevailing strongest winds”, the direction of which is not stated. Jack regarded these dunes as composed of Permian and Tertiary clays (*i.e.*, the “residual” clay and the overlying one) mixed with aeolian sand, with the lakes as aligned along these interdune valleys, explaining the cliffed north and northwestern shores as eroded by wave action under the influence of the “prevailing winter winds . . . coming chiefly from the south and southeast.” This, he thought, produced a more circular type of lake and was aided by wind-borne material blowing “across the interdune valleys and filling the ends of the lake bed.” He also related a thicker salt crust on the northern side to such winds, by their having blown the brine towards it. The gypsum dune he explained by “desiccating northerly winds that blow at intervals during the summer” and the large amount of gypsum suggested to him that the age of the lakes was “considerable”.

It is of interest that Howchin stated that “dolomitic travertine,” *i.e.*, kunkar, is very generally distributed over the district and made no mention of any clay other than the Permian. Howchin regarded the kunkar as reconstituted Tertiary limestone. Jack, however, regarded its formation as “the most recent phase” and derived it by capillarity from calcareous matter in the sand or from the Tertiary limestone.

There is no doubt that solution and deflation have played their part in the origin of the lakes, but the exact mode and sequence of events is difficult to establish. The Tertiary limestone of the coastal cliffs is clearly much affected by solution, and contains pockets of yellow-brown clay. The kunkar which directly overlies the limestone in places is not (except to a very small degree) reconstituted limestone, because elsewhere it is seen to overlie red clays, themselves resting on the limestone. It is, in fact, material developed *in situ* from loess of aeolian origin.

That the Tertiary has almost certainly been removed largely by solution is suggested by the existence of sink-holes and uvalas which have deepened to the Permian floor, as has already been demonstrated. It is tempting to suggest that the lakes were originally sited by such sinks and uvalas—possibly the unusual shape of Lake Fowler is due to an uvala, though it could have been formed by

the amalgamation of smaller lakes after they had developed. It is possible that the straight sides of such lakes as Weaver Lagoon are due originally to especially intense solution along zones of weakness such as joint planes. But although residual masses of Tertiary limestone occur on the margins of some lakes, no definite proof of such siting has been obtained.

Concerning the later deflation, the existence of a system of ENE.-WSW. dunes seems uncertain. There are indeed ridges between the lakes, which commonly extend in that direction, and there is undoubtedly a drainage in a general west-southwest direction towards Peesey Swamp, in sympathy with the hydraulic gradient as established by Jack. But whether this is only a drainage pattern consequent upon structural tilting of the whole area during the formation of the Peesey Swamp depression, or whether the drainage on such a tilted block was controlled in a particularly linear manner by the pre-existence of a WSW.-ENE. dune system is arguable. Such a system could be related to the very definite WNW.-ESE. seif dune system of the adjacent Yacca sand-dune belt, as evidence from central Australia shows.

Examination of the ridges provides no conclusive evidence in so far as they are only in part built of aeolian material, not certainly unaffected by erosion. The Permian is commonly exposed in the lake cliffs and ridge slopes, and is usually rotted, with a hard crust possibly due to lateritization. On the south coast near Port Moorowie strongly mottled Permian under mottled clay is suggestive of lateritization. Tertiary limestone is not often seen and always shows solution effects. Above, the Quaternary material is in places entirely aeolian (current-bedded sand capped by kunkar "marl-earth" and nodular kunkar) but may be largely argillaceous. On the south side of Lake Fowler's western limb, for example, alunite-bearing red clay occurs at 18ft. above lake-level and is capped by no more than 8ft. of aeolian material. This alunite is probably the equivalent of that recorded by Jack in Munkowurlie Lagoon, and because of its mode of occurrence, as a persistent thin bed, seems likely not to be the equivalent of the large but local deposits immediately overlying the Tertiary limestones of the east coast, but of the thin persistent seams noted there and elsewhere at a higher stratigraphic horizon in the Pleistocene. Its occurrence suggests that playa lakes, much more extensive than the salt lakes, once existed, and were locally covered by aeolian deposits. It is not to be assumed that this necessarily took place after the complete removal of the Tertiary—as the east coast sections demonstrate—but the evidence of a hardened (if not lateritized) Permian surface suggests that considerable areas of Permian were so stripped. The ridges were then formed largely by erosion of the combined materials, though they were no doubt locally increased in height by aeolian accretion. Some lakes were formed in solution holes; all were, sooner or later, deflated and modified by wave action.

In the northern part of the salt lake district are fragmentary remains of the 280-290 deg. seif dune system, well developed to the north. In this area linear swamps in a general southwesterly direction are dominant, but some obstruction has been caused by the seif dune remnants and there are some shorter linear swamps extending almost at right angles to the dominant ones. Farther south such obstructions are absent and the dominance of southwesterly trending swamps linking the lakes is unchallenged.

The Origin of the Salt.—The problem of the origin of the salt in the lakes was discussed by Howchin (1901) and Jack (1921). Howchin assumed it to derive ultimately from the Tertiary limestones, on the grounds that "considerable saline and gypseous ingredients" are associated with them in South Australia, and suggesting that the almost complete absence of drainage made this area especially favourable for their concentration. Actually, gypsum and salt are not associated with those limestones except as infillings in solution cavities, in quantities quite insufficient for the purpose. Jack discussed the problem very thoroughly. He

pointed out that any salt in the Tertiary limestones would have been leached out prior to the eventual solution of the rock; any beyond the limit of leaching being very small in quantity. As for the Permian itself, he pointed out that glacier ice is free from salt, so that till derived from it would also be free. Since then, admittedly the Permian has been found to contain marine, or at least, deltaic beds in the Minlaton stratigraphic bore and certainly these would, like all marine sediments, contain salt. The quantity would be small. A higher concentration might be present in the Quaternary red alunitic clays.

Jack also discarded any theory of derivation from actual beds of rock salt. Since his survey, evaporite beds have been found farther north in the upper Lower Cambrian of the Minlaton stratigraphic bore. Those seen in the core contain only gypsum. The derivation of salt now in the lakes from possible Cambrian rock-salt beds seems very improbable because of the almost certain erosion of the Cambrian containing such possible beds by the Permian glaciation, and because of the blanket of Permian rocks over any that might remain.

Jack's explanation involved an ingenious theory of cyclic salt. He pointed out the especial relationship of the salt lake district to the sea; the tendency to numerous light rain showers, rather than heavy falls; the presence of an impervious clay floor; and the long dry periods of the summer permitting evaporation. He had difficulty in assessing the amount of annual rainfall which goes to form groundwater, but after making such calculations as he could, estimated it at between $\frac{1}{2}$ in. and 1 in. out of an average annual rainfall of 17.54 in. at Yorketown. He noted that the ratio of sodium to magnesium chloride in the lake and groundwaters bore a close relationship to that of oceanic water; and that a wet winter and spring is followed by a good salt season.

An objection to the theory is that the many seepages into the lakes, which can often be seen emerging from the cliffs of Permian clay which are exposed along their north and west shores are now of fresh or only slightly saline water. Clearing of natural vegetation in the area has reduced transpiration and according to Jack, has resulted in production of salt in lakes formerly barren, the killing of trees along their shores, and an improvement in the quality of some well waters. In other words, groundwater circulation has been increased. It could be that the seepages occurring at or above lake level are of water much less salty than that which reaches the lakes from lower levels.

Other Salt Lakes

Salt lakes occur on the Wauralte coastal plain west of Mount Rat, and minor lake basins—now dry—northwest of Wauralte. These all have floors of impervious Permian clay. Although Tertiary limestone probably once covered this area, it is probable also that a Pleistocene high sea-level occupied the coastal plain and the lakes can be explained by deflation alone. Small lakes of probably the same origin as those in the southeast occur at and near Minlaton, where Tertiary limestone is known under kunkar.

An isolated un-named salt lake in the hundred of Ramsay, 6 miles west of Port Vincent on the south side of the Curramulka road, is also floored on Permian clay. Tertiary limestone almost certainly once occurred here, but the lake is elongated NE.-SW. and modified by deflation as are the southern lakes, with a clay cliff on the northwestern side and a low shore with a gypsum dune on the southeastern side. Smaller lakes to the south are strongly influenced in shape by seif dunes between Yacca and Ramsay trigs.

The only other salt lakes occur in the north of the peninsula. A small group of lakes occupies the depression which extends southwestwards from Agery. This depression is probably tectonic. It is probable that the lakes are the last remnants of a large lake which filled the depression, regarded as a one-sided graben of the Yorke Valley type. Drainage through the steep western side of the depression

was possible by a distinct gap immediately west of two of the lakes; separate drainage of the depression occupied by the isolated lake south of the Arthurton-Weetulta road was south-southwestward to the valley which indents the contours between Kilkerran and Weetulta.

A group of small lakes and dried-up lakes south of Kadina occupy a shallow extensive depression which lies to the east of the Cunliffe-Doora fault scarp. These lie in an area which formerly drained north and then west along the alluvium-filled valley two miles south of Wallaroo, a drainage which was blocked by aeolian deposition.

Recent Alluvium

Recent alluvium is not common. The absence of any real drainage system has restricted its deposition to small areas. None occurs in the south, where such drainage channels as exist come within the category of saline swamps. A drainage channel extending from near Minlaton towards Brown Point, though quite well-defined, is floored by hard kunkar and not by alluvium.

In the centre of the peninsula the wide shallow valley, draining the eastern part of the Central Upland towards Yorke Valley, contains some alluvium. Channels draining the Pleistocene clay areas west of Maitland contain similar material, rather more calcareous. The gullies which lead towards Gulf St. Vincent, north of Black Point—such as that entering at Pine Point, Throoka Creek, Rogue Gully, etc.—all contain narrow alluvial fills which are mostly shallow areas of flat bottom with no watercourse in the upper reaches, becoming true gullies nearer the sea where up to 20ft. of alluvium is exposed in vertical walls. Much of this material is sand, but torrent-gravels are common. In Rogue Gully and Horse Gully alluvium is only patchy upstream from the coast road, but downstream it thickens to about 20 feet.

The gully at Ardrossan provides very interesting information about Yorke Peninsula drainage. In its lowest reach it is very straight, and shows—by exposure of tree roots—that several feet of alluvium was probably removed in one sudden flow in the very recent past. Near the golf house the gully sides become higher, and a little farther upstream, in a sharp meander, reach 20ft. in height.

Still farther upstream a nickpoint forms a dry waterfall about 4ft. high. Similar nickpoints occur in most creeks along the east coast, implying a recent fall in sea-level relative to the land. Farther north, alluvium fills the lower stretches of the Dowlingville dry valley, and extends eastwards to a coastal plain zone of alluvium which in the Ardrossan area includes low angle slope deposits.

Recent alluvium is absent in the Moonta area and eastwards. In the depression south of Kadina, limited by the Agery-Doora scarp, alluvium has been mapped. This area was presumably at one time connected with the alluvial channel south of Wallaroo which leads towards the sea south of Point Hughes. Connexion with the valley running through the town of Wallaroo is unlikely because of bedrock highs to the east of it.

A well-defined alluvium-filled channel extends from northeast of Kadina north-westwards and northwards to join a similar, longer but narrower channel coming in from the east, and widening towards the sea at Wallaroo North beach. This channel was used for mine drainage. It presumably had connexions also with the now disrupted drainage south from Alford. All this northern alluvium is very calcareous, as is to be expected in an area almost wholly covered with calcareous superficial deposits.

Chapter 3

STRUCTURE AND TECTONICS

GENERAL

Some description and discussion of structure has already been made under the headings of particular systems in chapter 2, as it seemed appropriate to do so. Though structures within the Archaean are locally related to those of the rest of the rocks of the peninsula, the Archaean as a whole needs to be considered in a wider context, in relation to the Archaean of Eyre Peninsula and of the much smaller outcrops of Fleurieu Peninsula and the Mount Lofty Range. The trends in Yorke Peninsula and Eyre Peninsula are sympathetic, but the relationship with the area to the east is obscure, and a possible major structural break makes it more difficult to establish.

With the exception of the Cambrian of the Dalrymple Basin, all succeeding formations are thin. Thus for much of the peninsula the use of the term "basement" for the Archaean insufficiently emphasizes its significance, as a glance at the cross-sections will show.

In the north, the flat-lying Proterozoic (*i.e.*, the shield Proterozoic) and Cambrian rocks lie on steeply dipping Archaean. The shield Proterozoic and the Cambrian are almost everywhere associated. But the Cambrian overlaps the Proterozoic, for the latter thins westward and is absent both at Wallaroo railway-yard and in the westernmost diamond-drill hole at Balgowan, and its transgression is mapped also north of Kadina. In the absence of fossils in the Proterozoic we cannot be certain that it is everywhere of the same age, but, assuming that it is, the relationship with the underlying Archaean is one of overstep, possibly with a slight degree of marine onlap.

POST-CAMBRIAN FOLDS

Proterozoic and Cambrian strata are preserved in broad shallow synclines in the centre of the peninsula. The axes of these synclines vary in direction. The dominant direction in the north is NW-SE. The most important is the Cunliffe syncline which is associated with a parallel but shorter Dowlingville syncline to the south. The Ardrossan outcrops suggest another parallel structure. The Cambrian basin at Wallaroo can be regarded as a separated extension of the Cunliffe syncline; the basin north of Kadina is of uncertain relationship but is comparably shallow.

Another syncline, also aligned NW-SE., occurs west of Maitland; and another, parallel to it, north of Urania. Cambrian occurrence at Balgowan could be regarded as a separated extension of the latter.

All these structures could be produced by gentle open folding.

In the south, structural information is extremely poor. Data from the Minlaton and Stansbury stratigraphic bores, together with limited outcrop information, have been used to infer the existence of the Dalrymple Basin, as shown on the tectonic sketch of the Maitland sheet. It has not been drawn to the southern limit of the tectonic sketch because of a total lack of deep subsurface information in the southeast corner of the peninsula.

AGE OF THE POST-CAMBRIAN FOLDING

The broad folding of the Proterozoic and Cambrian presumably occurred at the time of much more intense deformation of rocks of the same age in the Adelaide Geosyncline. The age of that deformation is tentatively Lower Palaeozoic. However, the distribution of Pliocene and early Pleistocene deposits suggests that slight folding along NW-SE. axes has been taking place.

FAULTING

The peninsula displays a very distinctive pattern of scarps regarded by the present writer as due to faulting which is of Tertiary-Quaternary age (possibly in part older). These scarps are responsible for the larger features of present-day topography. The scarps are east-facing, and the surfaces of the fault blocks are tilted westwards.

Many of the assumed faults are shown on the Maitland 4-mile sheet, but more are shown on the later 8-mile sheet on which it has been possible to insert those unknown or of uncertain existence at the time of publication of the Maitland sheet. On figure 3 the faults are named.

As can be seen on this plan, the two-dimensional pattern is of en echelon sets aligned either almost N-S. and NE-SW., with a subsidiary direction approximately NW-SE. appearing in the north and in the foot.

The N-S. direction is dominant in the central part of the peninsula. The scarps tend to tail out at the southern end with a slight curve to the southwest. At the northern end they commonly meet in a cusp with branches aligned NE-SW. Both are usually slightly convex to the east.

North of the latitude of Arthurton, N-S. scarps do not occur except in the marginal zone of Bute and the Hummocks and Barunga Ranges. The pattern changes and the NE-SW. alignment is dominant, with NW-SE. branches as strong subsidiaries.

All the scarps are regarded as due to faults or monoclinical folds which down-throw on the east side; the only possible exceptions being much less certain minor structures near Kulpara, and a linear but exceedingly gentle slope forming the eastern limit of the Koolyurtie-Minlaton depression.

Nowhere can any fault plane be seen. It is not known whether the scarps are true fault scarps or fault-line scarps, nor whether the faults are gravity faults or reverse faults. It is possible that the scarps, at least in part, represent monoclinical folds in the Cainozoic and Permian rocks, passing into faults in the older rocks. A monoclinical fold in the Port Julia cliffs passes inland as a typical scarp.

The probable throw of the Ardrossan Fault at Ardrossan is less than 300ft., increasing northwards to an effective displacement by this and the Kulpara Fault to approximately 1,000ft. This fault system has important effects on the distribution and thickness of Tertiary deposits, as already stated. It continues northerly into the horst structure of the Hummocks and Barunga Ranges.

Whatever the age of the beginning of movement of these and other north-easterly trending faults to the west, there is no doubt, from the description of a drainage which had previously eroded sheets of kunkar, that substantial movement took place in later Quaternary time.

The Maitland-Minlaton system of faults extends for the length of the peninsula, and these have a throw of 200-400ft. The most important member is the Maitland-Arthurton Fault (*see* fig. 3). This scarp continues southwards to Urania, and south of this in broken sections to Mount Rat and Minlaton.

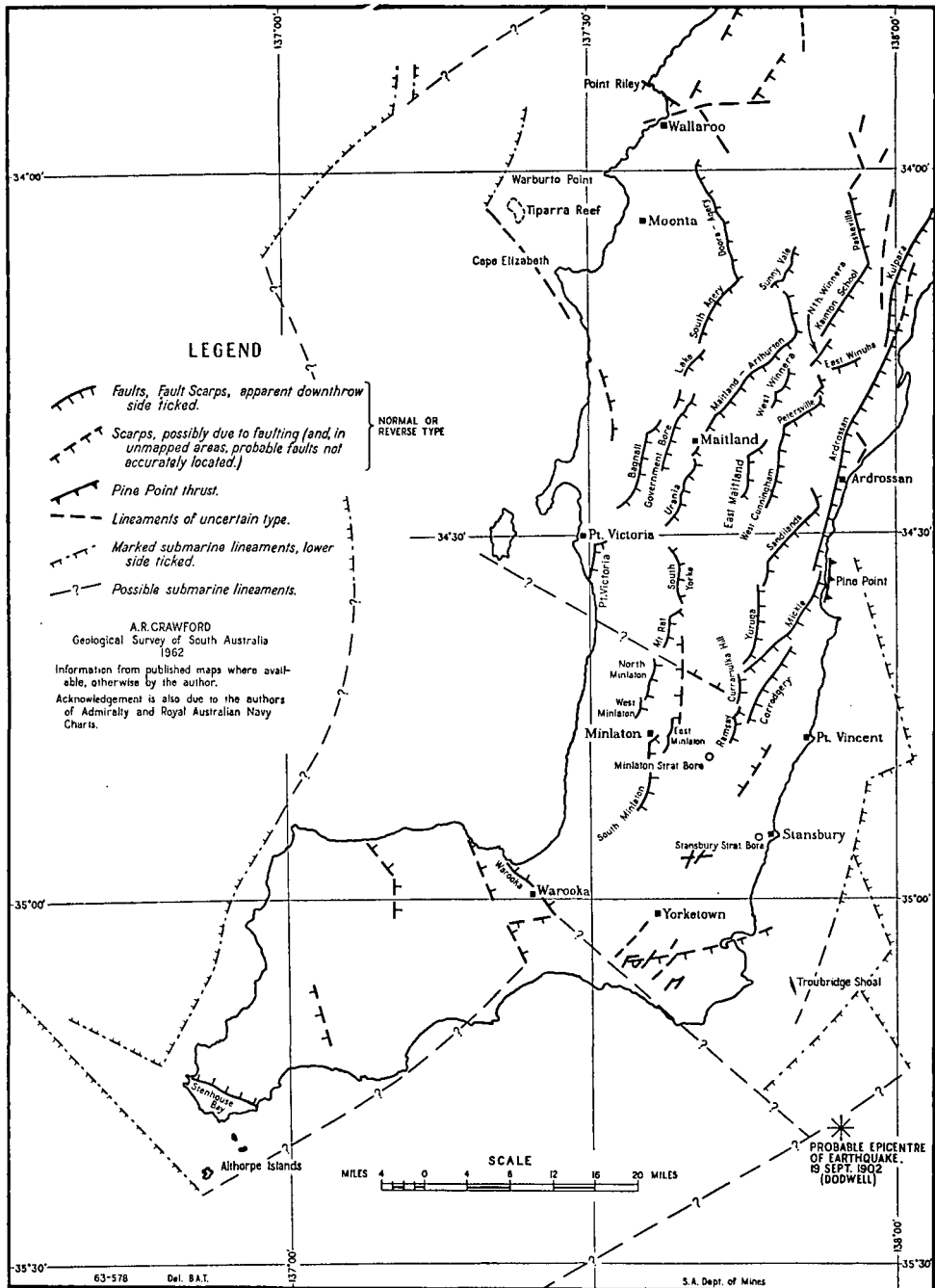


Fig. 3—Map of Yorke Peninsula—Showing faults and associated lineaments

A further major fault scarp system—of smaller throw—runs west of and approximately parallel to the Maitland-Minlaton system extending from Port Victoria to Agery, and thence north-northwesterly towards Wallaroo (the Doora-Agery Fault, with throw about 100ft. in the south reducing to less than 50ft. at the Doora mine).

The combined effects of the Maitland-Minlaton system, and the system to the east, have been to produce the complex fault angle depression or tectonic valley of the Yorke Valley, the North Maitland flat to the northeast of Maitland, and the Minlaton-Koolywurtie depression. This led, in the two former cases, to ponding of drainage followed by accumulation of clay, which, as it may have been accompanied by some deep subsurface solution of Cambrian limestone in Yorke Valley, has left it “perched” and with no outlet. The pattern of the faults in the Minlaton-Koolywurtie depression probably never permitted actual ponding, and the drainage, though disrupted by faulting, was still further disrupted by the development of smaller depressions due to solution of Tertiary limestone. These include those enclosed areas or basins below 200ft. as shown by contours 6 miles north of Minlaton.

To the south, the best-defined fault scarp is the Warooka Fault. This is aligned NW-SE, affects Permian glacials, and has strongly influenced the thickness of Quaternary deposits. The scarp lacks definition beyond about 3 miles southeast of Warooka, and this fault may have been offset westerly (fig. 3).

OFF-SHORE FAULTS

Figure 3 shows certain lineaments in the off-shore area. These are drawn after careful study of the nautical charts. In the case of the western part of Gulf St. Vincent, use has been made of a study by R. Cooper (graduate student, University of Adelaide) which incorporated more recent naval information on depths. These lineaments are necessarily much less reliable than scarps on land, and may be due to causes other than faulting; but the pattern of them is in general sympathy with that of the land scarps and in the writer's opinion most are likely to be fault scarps, and movement along the faults is likely to have taken place in Quaternary time.

AGE OF THE FAULTING

The age of the widespread pattern of assumed faulting is difficult to establish. There is little doubt that some movement of some of the faults has post-dated the establishment of the widespread thick kunkar (*i.e.*, is definitely Quaternary). The Eocene beds would appear to have been influenced in their distribution by at least one fault. The total lack of any rocks of between early Permian and early Tertiary age makes it especially difficult to discover whether any faults date back to the Mesozoic.

A pre-Tertiary and perhaps Palaeozoic age of some of the structures at least seems inherently probable, in so far as the pattern of faults appears to be part of a larger pattern which covers the “South Australian Shatter Belt” including Eyre Peninsula and Yorke Peninsula, the Mount Lofty Range, and the seas between. In the eastern part of this belt, Palaeozoic faults were rejuvenated in the Cainozoic. Although there the scale of faulting is greater, it seems reasonable to postulate some analogous small-scale Palaeozoic faulting in what is now Yorke Peninsula and its surrounding seas. Such faults may have influenced the pattern now so dominant over the peninsula.

WIDER IMPLICATIONS OF THE SUBSURFACE STRUCTURE OF THE WALLAROO-MOONTA AREA

In the only area where subsurface structural information is available, namely, the Wallaroo-Moonta area, Dickinson (1942) made a study of the recorded evidence. His comment (p. 9) that there is an "absence of evidence of post-mineral faulting in the Cambrian rocks" is based on a thorough study of records from what is nevertheless a small area, the northern part of which is especially ill-known. The statement of Dickinson that "the assumption may generally be accepted that the district has behaved as a single unit in post-mineral tectonic activity" is one with which the author agrees; but because Dickinson's area of study is so relatively small, this does not rule out the occurrence of Palaeozoic faults elsewhere which may, indeed, form the limits of the very area concerned.

One important point in respect of the Wallaroo-Moonta area, stressed by both Jack (1917) and Dickinson, is the strong difference in structural pattern between the Moonta mining district and the Wallaroo Mines district. The immediate speculation arises, are these different detailed structural patterns on either side of a major but concealed structure or are they related to purely local influences? This matter is discussed in a later chapter.

THE PINE POINT THRUST

The occurrence at Pine Point, and northwards, of sedimentary breccias of unusual type, much folded and fractured, has been described above (p. 27). These are correlated with a somewhat similar conglomerate at Rocky Point nearby to the south, but only the breccia exposures reveal any structural relationship with the Archaean basement, as Tertiary and Quaternary material blankets the cliff and much of the beach outcrop. The breccias have been provisionally correlated (in agreement with the suggestion of B. P. Webb) on lithological grounds—including microscopic comparisons—with an upper Lower Cambrian conglomeratic sequence in the Minlaton stratigraphic bore. Similar material exists in the Stansbury stratigraphic bore.

No detailed mapping of the complex stretch of coast at Pine Point has yet been possible, but at this stage it seems best to postulate a strong structural break along the coast, the surface trace of which is, for most of its length, along the middle or upper part of the beach, and which separates "typical" (though much altered) Yorke Peninsula basement on the west side from the breccias and their local variants on the east. From the evidence of three cliff exposures of the breccias, the structure was mapped as a thrust which dips at a high angle to the east. On the cross-sections some indication of an eastward flattening is given; this is conjectural. The breccias appear to have been thrust over and against the Archaean, but the great confusion of shattered and altered material does not rule out the possibility that this is a mere fragment of the imbricate zone of a complex thrust, and that the relationship is one in which, locally at least, the breccias are thrust into and partly under some fractured Archaean.

Whatever the structure is in detail, it is certainly linear on the larger scale extending N-S. approximately in line with the Yararoo thrust of the Wakefield sheet (Horwitz, 1961). At the time of mapping the author was inclined to regard it as an extension of that thrust and a major structure which continues along the same alignment southward. For this reason, it was shown in the cross-section D-D' on the Maitland sheet as affecting pre-Permian rocks under Stansbury. There is, however, no certainty that it is pre-Permian. This is inferred only from the non-disturbance by the Yararoo thrust of possible but uncertain Permian boulder beds on the Wakefield sheet. It is, of course, pre-Tertiary.

Other interpretations are possible, but the field evidence is sparse and equivocal. It is possible to regard the structure as a normal fault, or a tilted unconformity (as suggested to the author by B. P. Thomson). It is also conceivable that it is a wrench fault, with an effective horizontal sinistral shift of the order of 20 miles, a major structure forming the real structural eastern boundary of the peninsula. This very speculative interpretation implies a squeezing-out of a peninsula mass consequent upon the approach together of the shield and the Archaean basement which underlies the Adelaide Geosyncline, with a complementary dextral wrench fault in Spencer Gulf.

NOTE ON THE EARTHQUAKE OF 1902

A moderately severe earthquake affected Yorke Peninsula on 19th September, 1902. According to G. F. Dodwell, the epicentre was in Gulf St. Vincent off the heel of the peninsula, at a point shown on fig. 3. However, Sir Charles Todd drew isoseismals with a centre at Warooka. Damage was severest at the Troubridge Lighthouse, then a wooden structure, which was destroyed by fire, and at Warooka. The shock was felt widely in the South-East of South Australia and as far north as Orreroo, and stopped the Glenelg Town Hall clock.

The usual difficulty in defining the epicentre because of lack of instruments was perhaps enhanced by the possibility that the Warooka Fault may extend—as a buried structure—into Gulf St. Vincent to the vicinity of Dodwell's epicentre. A shock centred anywhere in that vicinity would also tend to be felt rather in a northerly direction than in any other, though in the author's opinion there is also a probable deep structural lineament, of very ancient origin, extending on the one hand northwestwards to form the western boundary of a major fault block in the Gawler Range, and on the other, southeastwards (possibly through Backstairs Passage) to parallel the coast of the South-East between Cape Jaffa and Cape Northumberland. The Warooka Fault and its possible extension would be a mere portion of this lineament, on which other earthquake epicentres are known at Beachport (10th May, 1897) and 10 miles northwest of Beachport (8th April, 1948).

Chapter 4

GEOLOGICAL HISTORY

The history of the area in earliest Precambrian time is obscure, but during what is called Archaean time in South Australia—and which may extend well into the Lower Proterozoic time of other regions—the area had become one of geosynclinal deposition, with thick sandy sediments together with accumulations of limy and muddy material. We have no knowledge of the form of the space in which this sedimentation took place, as we have certain knowledge of neither the thickness of sediment nor the extent of the area of sedimentation. The similarity of the rocks to those of Eyre Peninsula suggests that the area of sedimentation extended far to the west, but there is no evidence that it did not extend far in all other directions also. There is no certain evidence of contemporaneous vulcanism.

The mere accumulation of these sediments in substantial thicknesses resulted in some lithification, and this diagenetic change was followed by more profound changes during folding of the rocks. Evidence for the type of folding is meagre but the rocks as they are today show a persistent verticality, and, on the large scale, appear to be bent in a great arc sympathetic to that of the Archaean rocks of Eyre Peninsula.

Thus the folded area, like the area of sedimentation, extended far beyond the present limits of the peninsula.

The Moonta Porphyry was intruded into these changed and folded sediments, probably as a great stock of dacite. Some rhyolite was extruded on the surface. Complementary dykes were almost certainly emplaced in the vicinity. To a large extent the porphyry was pushed between rock layers and opened out a space for itself, but some of the intruded material was incorporated and assimilated.

Relatively soon afterwards, widespread feldspathization and scattered but variably intense plutonic intrusion took place at depth, and this also led to local crushing and squeezing of the rocks.

Later in the Precambrian, this complex became peneplaned, but the material eroded may well have been reworked many times before being finally deposited, during the latter part of Precambrian time, as a thin pebbly sand now indurated to the conglomeratic sandstone known as the "shield Proterozoic". This was probably deposited over most of what is now the peninsula, but some islands of Archaean rocks may have remained, never to be covered by the shallow seas. Much of the material is comminuted debris of Archaean rocks, and many well rounded quartz pebbles indicate the amount of attrition received in the wave-dominated waters.

This environment probably persisted throughout upper Precambrian times, but there may have been long periods of non-deposition.

In early Cambrian time a major transgression of the sea began, extending beyond the limits of the known shield Proterozoic. Whether the Proterozoic was in part eroded before this transgression or whether the deposits of the transgression merely extended across them is uncertain, as no sections exposing their relationships are known.

This transgression was one in which calcareous sedimentation rapidly became dominant. Shallow lagoons extended over a vast "shelf" area, extending far to the north and east and becoming very shallow in what is now the eastern part of Spencer Gulf. The most westerly shore of the sea in the north was probably somewhere near the position of Tiparra Reef, but in the south its position is unknown. Some islands of Archaean rocks, in places capped by shield Proterozoic, perhaps still persisted during this period.

In the shallow seas in which the Kulpara Limestone was deposited, the environment was not at first conducive to life but late in Kulpara time archaeocyatha, brachiopods, sponges, and hyolithids flourished.

This environment persisted, but, in the south a subsidence of the Archaean basement permitted much greater accumulation of sediment in the Dalrymple Basin area. But the similarity of type of sediment suggests that for most of Lower Cambrian time this subsidence was gradual and constant, so that the seas remained shallow while the deposits thickened. The sediments changed in type, becoming more muddy and less limy, the environment of the Parara Limestone. Trilobites were common in the seas of this time. Subsidence ceased temporarily in late Lower Cambrian time and the sea-bed was exposed. Gypsum was deposited in desert lakes, accompanied by beds of angular debris of very local and torrential origin. As this debris contains material of Archaean type, as well as dolomitic limestone fragments of Lower Cambrian type, it seems probable that deep gully erosion of hilly land was in progress.

Following this, in Middle Cambrian time a further transgression of the sea took place and calcareous sediments were again deposited. These sediments (which became the Ramsay Limestone) are identical with the later, more muddy calcareous deposits of Lower Cambrian time. They are of a very characteristic banded nodular type which, together with their known distribution over areas far to the northeast and well to the east, suggests periods of extremely tranquil sedimentation, though the precise mode of formation remains uncertain.

There is uncertain evidence of a further regression of the sea after the deposition of the Middle Cambrian limestones, leading to another period of continental erosion and deposition.

For the immense period of time between the Middle Cambrian and the late Carboniferous there is no record of any sedimentation and the geological history is a blank. As the Adelaide Geosyncline, to the east, became orogenic in late Cambrian time it is likely that the gentle folding of the Cambrian rocks of the peninsula took place during this orogeny, which may, however, have continued through much of Lower Palaeozoic time. Some block faulting may have begun during this period.

In late Carboniferous time the mean temperature fell and glaciation set in, persisting throughout the lower Permian. Glacial deposits were probably laid down over the whole area though varying in thickness and type. In the south and centre, ice moving from a southeasterly direction brought with it material torn off from areas it had previously passed over, and later dumped this material as till. The Minlaton stratigraphic bore shows a lower till separated from an upper by beds of deltaic type with a marine fauna. This may indicate a merely local aqueoglacial deposit, but could also be interpreted to suggest that the ice at that time in the area concerned was in the form of a piedmont glacier, with perhaps a floating ice barrier, the rest of the area being covered by land ice of sub-continental extent.

After the Permian glacial period nothing is known of the geological history until the early Tertiary. The absence of any Mesozoic sediments suggests that the area was again land, from which the glacial deposits were gradually being eroded, the eroded material being deposited beyond the present limits of the peninsula.

The earliest Tertiary deposits are of freshwater type and contain lignites, but give way to those deposited in areas affected by periodic incursions of sea-water. This was the beginning of the earliest Tertiary transgression, leading to extensive deposition of Oligo-Miocene sandy limestones (the Port Willunga Beds), largely the product of bryozoan colonies. The extent of this transgression is uncertain, as block faulting developed during Tertiary time and may have started (if indeed faults were not already in existence) at the beginning of that era. Thus the

absence of any Oligo-Miocene beds in the northwest and the high ground of the centre of the peninsula is perhaps due to non-deposition rather than erosion. A primeval peninsula had by this time emerged, of lesser southerly extent than that of today, with a small island where the western part of the foot is now.

Still in lower Miocene time, another quite distinct transgression took place, depositing the sandy limestones of the north (the Melton Limestone). The relationship of this to the earlier Tertiary transgression represented only in the south is uncertain. The southern limits of deposits of this second transgression are mere remnants near Kainton, although Tertiary of unknown type occurs under Quaternary in the Minlaton area. But as the older beds in the south have everywhere been deeply affected by erosion and solution it is quite possible that the second transgression affected all that area, which later became elevated and was entirely stripped of the Melton Limestone (or its equivalent) cover.

By early Pliocene time the peninsula had developed an outline not unlike that of today, though the western part of the foot was probably still separated from the leg by a wide strait occupying what is now Peesey Swamp. A smaller strait probably occupied the Stenhouse Bay area; the Cape Spencer-Althorpe Islands area being an island. At this stage a minor and short-lived transgression of the seas resulted in the deposition of very thin sandy or oyster-bearing limestones (the Hallett Cove Sandstone) along much of what is now the southern and part of the western coast. The absence of this formation along the east coast and much of the west coast suggests that the central part of the peninsula was already higher than areas to the north and south, as it is today.

Later in the Pliocene, the peninsula came under the influence of a humid climate which led to widespread accumulations of clayey gritty sands (the Ardrossan Clays and Sandrock) which, as they show no evidence of bedding, are thought to have formed not in water but by slow creep down the very gentle slopes characteristic of the relief at this time. These deposits blanketed vast areas of the peninsula.

Almost immediately after their deposition, lateritization of the whole land surface commenced, with the progressive concentration of iron at the surface, mottling of the immediate subsurface, and bleaching and kaolinization of the underlying material.

Soon after, the climate became drier, with the development of playas in which red clays with rhythmic alunite bands were formed. These were restricted to low-lying areas or structural depressions, the older lateritized material still being exposed on the higher ground. One such playa occurred along what is now the east coast plateau as a long narrow feature, but there were many other quite separate playas.

The climate then became more arid. Wind-blown sand was ubiquitous, though perhaps it never rested for long on the highest and most exposed ground. It was deposited by winds of a general west-northwesterly direction, in the form of long straight dunes approximately parallel to the wind direction. As these dunes are cut by the present coast and are clearly part of the same suite as others of the same alignment on Eyre Peninsula and the Adelaide Plains, they were presumably produced at a time of lower sea-level. This possibly explains their very high content of calcareous material. Much calcareous dust from the same ultimate source was also deposited, and in the southwest stronger winds from that general direction resulted in the piling up of accumulations of coarser comminuted-shell debris, rapidly decreasing in thickness to leeward.

The detailed interpretation of this part of the history is difficult because these deposits became changed by soil-forming processes, losing their identity; except in the southwest where the great thicknesses of the coastal dunes remained largely unchanged. There it is evident from the very marked horizontal layering of the

deposits—as distinct from the aeolian bedding within each—that intervals between accumulation were long enough to allow formation of soils. During their formation the climate was humid, and much of the calcareous matter was leached downwards to form a layer of kunkar. The remaining largely siliceous and organic material was then mostly blown away eastward before the next accumulation of shell debris, but some remained to become incorporated into later kunkar, which in this area often contains fragments of darker material. But in most of the peninsula the smaller thickness of aeolian material—and perhaps also a difference in climate, with slower soil forming processes—resulted in the superimposition of the calcareous layers formed by downward leaching. Thus a kunkar which at first was nodular, and later by coalescence and accretion often became a continuous and thick sheet, is now the only representative of alternating dry and wet periods during which the sea-level may also have fluctuated considerably. There is local evidence of the erosion of kunkar—as, for example, between Port Julia and Black Point—where rolled pebbles of kunkar overlie thin raised beach deposits.

There was then a marked change of climate. A consistently humid period began, during which a definite drainage system was established, possibly partly incorporating an older system. It was during this period that the dry but sharply defined valleys of the northeast and the centre were cut. In many areas the erosion cut into the kunkar crusts, leaving flat “islands” of hard crust on the interfluves, and probably removing much of any kunkar which existed on the highest ground. Considerable accumulations of rather calcareous alluvium were spread on the lower ground. At this time the peninsula was much less broken up by blockfaulting, and the central zone containing Yorke Valley and North Maitland Flat had a definite drainage. This was probably to the west coast; the watershed of the leg of the peninsula was rather nearer to the east coast than the west.

Then blockfaulting became very pronounced. The blocks were tilted and the drainage disrupted. This led to the protection of deposits in the fault-angle depressions, with further accumulation, and produced a topography which is little changed today. The erosive power of streams draining to the east coast became nullified where they crossed the blocks now dipping against the direction of flow and, as for example, in Six-Roads depression, this led to accumulations of lime as accretion to kunkar probably already present, and so the development of very thick sheet-rock. West-flowing streams, in contrast, became ponded against the fault scarps. Lakes occupied the newly created Yorke Valley, North Maitland Flat, the valley southwest of Agery, and perhaps also the associated minor depressions to the south.

Once full, these lakes overflowed through the most convenient channel, but their histories vary, not only because the positions of such channels depended often on the disposition of the faults, but because of the nature of the underlying bedrock. Yorke Valley, for example, was drained through the Urania Gap. This existed as a true gap between faults of different alignments, but was perhaps deepened by headward erosion of a stream reactivated by backward tilting from the southern fault. But some lowering of the valley may have resulted from solution of Tertiary and Cambrian limestones. This certainly occurred in the Minlaton-Koolywurtie depression in which it seems unlikely that a lake ever formed, and where a further disruption of drainage was caused by collapse due to solution.

An increasing aridity, however, assisted the disappearance of these very temporary lakes, and their sites are now occupied by clay developing thin kunkar in its overlying soil. Alluvium accumulates only at the mouths of gentle tributary valleys. The occasional wetness of the valley bottoms, and the small residual lakes southwest of Agery, testify to the former condition.

The block faulting and its associated tilting had marked effects on the coasts. On the east coast, these mask the effects of all Quaternary sea-level changes except the last slight regression. Off the east coast, the Orontes Bank and Troubridge Shoal were created. The backward tilting of blocks led inevitably to erosion producing a cliffed coast, with the prominent exception of Black Point peninsula created by monoclinical downfolding, and the later cusped forelands on which Port Vincent and Stansbury are located.

In contrast, on the west coast the gentle slopes of the backwardly tilted fault blocks reveal peculiarly well the changes of sea-level. In places these are concealed by later material blown in from coastal dunes. The effects of sea-level change are seen especially well in the north near Cape Elizabeth and Warburto Point, and also between Balgowan and Port Victoria. The detailed history of these changes—which are of particular importance in the study of the deposits of the gypsum lake district and Peesey Swamp—remains to be worked out; but no certain Quaternary marine deposits have been found at more than 50ft. above present sea-level, while Quaternary deposits (not absolutely certainly post-Tertiary) are known to 138ft. below sea-level in Peesey Swamp. Kunkar, which can form only on land, exists widely around the coasts below high-water mark and is known on Tiparra Reef.

In very recent time the inland features of the peninsula have been very little modified. The blanket of aeolian material acts as a sponge and prevents significant fluvial erosion, though occasional torrential storms may cause creeks to run. Drainage is, however, often subterranean—the Winulta Creek, for example, has a distinct though normally dry watercourse above Winulta, but downstream the presence of Cambrian limestone below the Quaternary has led to the development of a dry valley. In other areas, stream courses are clogged with travertine formed by evaporation, as for example, in the shallow valley which once drained the Minlaton-Koolywurtie depression towards Brown Point. But, except in the north-east, valleys with definite watercourses are rare. The salt lake district is an area of largely fossilized topography, unchanged since the drier periods when the gypsum dunes were formed.

The coast of the leg of the peninsula almost everywhere shows evidence of a slight fall in sea-level, so that cliffs are subject either to very little or no marine erosion. Only on the west coast of Wardang Island, and south of Stansbury on the east coast, is there any significant undercutting—elsewhere it is common to find narrow dunes or beaches at the base of the cliff. The foot of the peninsula is rather different. Marine action is very strong along the western and more exposed southern coasts, but the common presence of very hard Archaean rocks at the base of the aeolianite cliffs protects the headlands; in the bays dunes accumulate, those south of Daly Head being much the biggest and most mobile. Around the heel of the foot, a prominent kunkar layer overlies soft sediments being undercut, but the broken blocks of hard kunkar provide much protection. Thus coastal changes are nowhere very rapid, and commonly exceedingly slow.

Chapter 5

COMMENTS ON MINERALIZATION

MAGNETITE MINERALIZATION AND AEROMAGNETIC ANOMALIES

Fig. 4 shows the distribution of aeromagnetic anomalies. Uniform representation of them was impracticable; for technical reasons a break extends east-west along latitude $34^{\circ} 30' S$.

There are very pronounced linear anomalies in the northwest. The three most prominent are at Balgowan, near Weetulta, and north of Kadina. A large area of moderately high anomaly exists north of Curramulka in the central part of the peninsula. The Balgowan anomaly extends into Spencer Gulf, in the north-central part of which "magnetic disturbances" are reported on Admiralty charts. Anomalies comparable with those of Yorke Peninsula are known in northeastern and central Eyre Peninsula.

Drilling of the Balgowan and Weetulta anomalies (Anon., 1957; Crawford, 1957b) has shown that they are caused by magnetite in the Archaean rocks, commonly associated with amphibolite. Drilling has been insufficient to assess the structure.

G. F. Whitten and G. R. Heath (pers. comm.), from numerous investigations in central Eyre Peninsula and elsewhere, suggest that the magnetite of linear anomalies is due to planar bodies. In the areas investigated these have been syngenetic iron formations. Such iron formations could occur on Yorke Peninsula.

The large area of moderately high anomaly north of Curramulka was investigated geophysically by Seedsman (1957), using both ground magnetometer and gravity methods. Results were inconclusive.

MINERALIZATION AT MOONTA-WALLAROO AND THE MOONTA PORPHYRY

The mineralization at Moonta-Wallaroo has been discussed by Lockhart Jack (1917), Dickinson (1942) and briefly by Bacon (1948). It has recently been studied by McBriar (1962).

Lockhart Jack thought that the mineralization was entirely a long-distance effect of the intrusion of a postulated "Arthurton Granite", the role of the Moonta Porphyry being purely that of a host rock. Jack suggested that the differences between the Moonta- and Wallaroo-type mineralizations were due to differences in the host rock.

Dickinson stated (*op. cit.*) "there is nothing . . . to prohibit the possibility of the mineral vein formation being a late phase of the porphyry intrusion", specifically adding that this referred to both areas.

Bacon recognized extrusive volcanic rocks (lavas and tuffs, of intermediate to basic composition) in drill core from lodes in the Wallaroo area. Andesite was noted at the Doora mine. He also reported much diorite. Bacon nevertheless followed Jack in respect of the Moonta mineralization at least. He raised the possibility of the Wallaroo mineralization being "a regional phenomenon" but then added, rather contradictorily, that "the only reasonable geological hypothesis is that the [Moonta and Wallaroo] lodes are genetically related".

The present author could find no evidence to suggest that the Arthurton Granite is a batholithic body. Pegmatite and granite undoubtedly occur in the area between Arthurton and Winulta, but they are common elsewhere on the peninsula

and cannot be differentiated from the rest of the Archaean on a 4-mile map. In much of the area shown by Jack as Arthurton Granite, float is gneissic and most is paragneiss. The alleged wide zone of thermal metamorphism is difficult to substantiate. It cannot be said that where copper mineralization is known elsewhere it is readily relatable to granitic or pegmatitic bodies; nor that where those bodies occur, mineralization is observed to accompany them.

It is possible to regard the mineralization at Moonta, at Pine Point, and the occurrence of porphyry noted by Jack at Thrington, as concentrically disposed about an "Arthurton Granite"; with a smaller concentric control for the mineralization at the Parara mine near Ardrossan, the Maitland (Yorke Valley) mines, and the Penang mine near Agery. But although this concept is given some support at Moonta by the disposition of the lodes, which occur in parallel axes and dip outwards, the other occurrences are on a very small scale and provide no supporting evidence. At Pine Point, for example, the mineralization is much more likely to be related to the known strong meridional structure following the coast.

The association of the copper mineralization with the Moonta Porphyry makes it necessary first to speculate on the habit of that body. The main mass has a width of sub-Quaternary outcrop of about 15,000ft. and a length of about 35,000ft. It has been proved in the mines to a depth of over 2,000ft. As the relationship with the surrounding Archaean is obscure it is by no means certain that the mass has in fact the shape indicated on section A-A' on the Maitland sheet. It is conceivable that it is wholly or in part extrusive. The volcanic extrusives recognized by Bacon were not stated by him to be variants of the porphyry, but extrusive rhyolite was noted by Fander and this is regarded as a variant.

If the body was wholly extrusive it is necessary to decide whether the extrusion took place during the Archaean, *i.e.*, was followed by further deposition of sediments now para-gneisses, or whether it was post-Archaean and was an extrusion on to an eroded surface of Archaean rocks. The first would necessitate regarding the porphyry as a strongly tilted flow of great thickness, but apparently of very limited extent. In itself this seems improbable, but it is in any case made more improbable by the implied strong but simple folding of the Archaean, of which the flow would structurally and stratigraphically be a part.

The second concept seems more worthy of serious consideration. It implies either a central feeding pipe and a radial thinning of a volcanic pile; or, to explain the almond-shaped "outcrop", a feed pipe more linear in cross-section, though hardly long enough to be a fissure source. Erosion of the extruded mass would leave what might appear to be an intrusive stock, *i.e.*, a subjacent body.

Jack suggested that the Moonta Porphyry was the intrusive equivalent of the Gawler Range Porphyry. The two are similar in composition and are probably related. Recent work shows that the Moonabie Porphyry, lying geographically between the two, is also partly extrusive and is probably related. All are essentially volcanic, with a great development of extrusives in the Gawler Range. In that area, extrusion is apparently controlled by major lineaments which are often aligned along the centres of very large intersecting circular structures, some of which at least have been arcuate fissure sources.

MINERALIZATION IN THE CAMBRIAN

The unconformity between the Cambrian and the shield Proterozoic is a zone of mineralization, and the Cambrian dolomitic limestones contain minor copper and lead mineralization. No deposits of economic interest are known. Early prospects in the Cunliffe syncline proved poor. The occurrences are of considerable geochemical interest.

Phosphate deposits are confined to the Cambrian rocks, where they occur as deposits in fissures or collapsed caves. The environment in which the Cambrian was deposited was no doubt at times conducive to phosphate deposition, as apatite is a prominent constituent of the Archaean rocks, some of which were probably being worn down in Cambrian time and contributing to the deposition. The origin of the known deposits is nevertheless uncertain as their mode of occurrence in cavities is clearly not directly depositional, and may be of post-Cambrian date.

MINERALIZATION IN THE CAINOZOIC

The only significant mineralization in the Cainozoic rocks—apart from the important Recent evaporites dealt with in chapter 2—was the alunite deposition which is known as minor occurrences in the coastal Blanche Point Marls equivalents and as a more substantial occurrence in Quaternary clayey sands near Port Vincent. The larger occurrence, 5 miles south of Port Vincent, is of discontinuous lenses in the lower part of a “wash out” of the Tertiary limestones now occupied by an abnormal thickness of Quaternary clayey sands. This occurrence is thought to be an accumulation formed in the clayey sands after their deposition by precipitation from waters draining east from a pre-existing playa-type deposit. The later very widespread, but extremely thin, occurrences in younger Quaternary clays of much more constant thickness are thought to be playa-type deposits still preserved as such.

Chapter 6

THE MINERAL INDUSTRY OF YORKE PENINSULA*

Yorke Peninsula has made important contributions to the wealth of the State for over 100 years. From 1860, when copper was first found near Wallaroo—and shortly after, at Moonta—it was the location of the major underground mines of the State. In 1874, mining of gypsum, for plaster manufacture, began from salt lakes and dunes near Yorketown, though in recent years gypsum has been won mainly from the southwestern part of the peninsula. Commercial salt production began in 1890. Since 1910, lime-sand from Wardang Island has been used by The Broken Hill Associated Smelters Pty. Ltd. at the Port Pirie smelters. From 1948, Cambrian dolomite has been quarried on a large scale near Ardrossan by The Broken Hill Proprietary Co. Ltd., and this seems likely to remain the principal source for the Australian steel industry.

Tertiary limestone is quarried at Klein Point, south of Stansbury, by the Adelaide Cement Co. Ltd., being shipped direct to Port Adelaide.

Cambrian limestone is quarried for road metal, particularly at Curramulka, and small roadside pits in the ubiquitous kunkar are very common.

Small phosphate deposits were quarried near Clinton in the past. White kaolin-clay has been mined locally. Tertiary lignitic coals, near Clinton, are too deep to mine at present. Natural whiting has been produced from a lake in the southwest, and alunite was mined on the east coast during the potash shortage in the first World War.

Estimated nominal value of the mineral production to date exceeds £40,000,000. Comparison of the annual outputs from 1948 to 1961, inclusive, reveals much expansion, some outputs having doubled. (See table below.)

MINERAL PRODUCTION—YORKE PENINSULA
1948 to 1961

Year	Mineral Product							
	Dolomite	Gypsum		Limestone				Salt
		Rock	Seed	Cement	Lime	Roads	Sand	
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
1948...	2,953	108,395	9,032	64,837	6,500	25,591	20,894	38,511
1949...	—	97,807	10,682	68,520	7,070	23,651	20,777	45,553
1950...	21,128	104,067	10,573	78,700	8,018	5,889	18,839	60,236
1951...	52,450	101,498	6,003	74,900	7,960	7,771	25,428	71,718
1952...	83,873	122,035	10,660	66,494	12,522	36,835	17,594	51,246
1953...	84,811	132,155	12,630	70,531	12,962	19,812	18,144	61,546
1954...	118,612	143,569	12,338	100,533	17,993	40,063	10,531	68,639
1955...	97,398	140,284	14,099	120,341	15,710	24,063	24,022	80,126
1956...	101,496	178,689	19,604	132,670	14,596	83,033	18,784	87,974
1957...	180,237	184,601	23,380	142,532	15,240	95,128	25,880	82,891
1958...	129,315	206,586	25,454	167,000	8,122	75,566	24,918	80,688
1959...	181,393	190,684	19,986	180,134	10,518	68,680	26,387	72,526
1960...	217,305	213,271	16,760	196,000	7,790	105,295	20,837	71,735
1961...	219,190	194,348	18,435	234,000	8,344	88,318	17,462	73,915

* This chapter is based on published and unpublished reports by the late C. M. Willington, whose constant interest and co-operation the writer wishes to acknowledge.

COPPER—AND ASSOCIATED METALLIFEROUS MINERALS

Copper mining on a commercial scale ceased in 1923. The industry was exhaustively described by Lockhart Jack (1917), but as Jack's *Bulletin* is now out of print it is desirable here to quote the main facts on this industry. Dickinson (1942, 1953) described it briefly, and a popular account has recently been published (Pryor, 1962) under the title "Australia's Little Cornwall".

It is important to note that early records are few, and are summarized by Franklin (1880) who compiled his account from notes provided by H. R. Hancock, general manager of Moonta Mines and of the amalgamated companies from 1864-1898.

The discovery of the mineralization was an early example of a geobotanical approach; wood being used for fuel by shepherds being noticed to burn with a green flame. Copper ore was found later in mounds thrown up by burrowing marsupials. Development was rapid, and the district became the most important mining field in South Australia. An estimate of the tonnage of ore extracted in the 63 years of operation is 6,250,000 tons, with a value of £20,500,000.

At first, numerous small companies existed, but in 1889 the two principal companies amalgamated to form the Wallaroo and Moonta Mining and Smelting Company Limited. At the peak of operations the annual output of crude ore was approximately 200,000 tons. The grade was about 30 per cent in the early days, but fell to below 4 per cent by 1908. Gold and silver were recovered as by-products.

The Moonta lodes—in the Moonta Porphyry—are in three concentric arcs convex to, and dipping at 40-65 deg. to, the northwest. These were narrow but widened to 40ft. in places, and were mined over a horizontal distance of 2,500ft. and to a dip depth of 2,000ft. Below this depth the lodes narrowed and the ore changed from chalcopyrite to pyrite. Bornite was important at first, in the richer ores.

The Wallaroo lodes are fewer but longer, and strike slightly south of east. They occur in schists and phyllites. The horizontal extent of the workings was 5,000ft., mining being carried to a depth of 2,900ft. Some galena and scheelite occurred with chalcopyrite, the principal copper mineral.

A combination of poor grade, low reserves, and low copper prices with high mining costs led to the closing of the mines in 1923. Intermittent subsequent investigations, particularly by geophysical methods followed up by drilling, has not resulted in significant discoveries. While the known mineralized area has been thoroughly prospected at the surface, it is difficult not to believe that major undiscovered orebodies might exist. Conventional exploration is handicapped by the complete Quaternary cover. Interpretations of the structure cannot readily be verified.

The successful development of copper mining in the northwest led to much prospecting of the older rocks elsewhere, but although many small prospecting pits testify to the thoroughness of the search, few attempts were profitable and all were shortlived. The Parara mine, northwest of Ardrossan, and the Hillside mine, 9 miles south of Ardrossan, were among the richest.

DOLOMITE AND LIMESTONE

Dolomite for the Steel Industry

Cambrian dolomitic limestone extensively outcropping—or under thin Quaternary—in the Ardrossan district was explored by diamond drilling in 1948 by The Broken Hill Proprietary Co. Ltd. A large quarry was developed $1\frac{1}{2}$ miles southwest of Ardrossan. A three-stage crushing plant and 7,500-ton storage bin were erected on the coast immediately south of the town, and a 3,000-ft. jetty with

Limestone for Building

Kunkar was used almost invariably in early housing, except locally in the northeast where some sandstone was available. The dense nodular masses provided crude but cheap block stone. None is used now. Some development of Tertiary limestone in the Coobowie area has been tried.

LIME SAND

Calcareous dune sand from the west side of Wardang Island has been used in the Port Pirie lead smelters since 1910. (King, 1952a.) The annual output is 20-25,000 tons; to date, 1,165,000 tons have been won. The deposit forms dunes of loose sand 70-80ft. high—though the consolidated aeolianite was formerly used. It is stored near the jetty on the northeast coast of the island and periodically shipped by 1,000-ton barge. Reserves are about 12 million tons. A typical analysis is—

	per cent
CaCO ₃	75.0
CaSO ₄	0.4
Fe ₂ O ₃	0.3
Insolubles	20.0

The settlement on the island communicates with Port Victoria by launch.

Other deposits are briefly mentioned, with analyses, by Johns (1961a) and Nixon (1961).

GYPSUM

The important gypsum industry of South Australia was pioneered in the salt-lake district of southern Yorke Peninsula. Commercial production was first recorded in 1874; today the bulk of the Australian gypsum needs comes from Yorke Peninsula. Since recorded production commenced in 1905, about 4,500,000 tons have been produced.

At first, production was from seed gypsum dunes lying on the southeast sides of salt lakes in the Yorketown district. In particular, the large Lake Fowler dune was worked. This was used mostly for plaster manufacture and was shipped from Edithburgh. Later a company quarried rock gypsum from the lakes (especially Marion Lake) in the Stenhouse Bay district in the extreme southwest. This gypsum was found to be exceptionally pure and especially suitable for the manufacture of plaster and plaster products. The district is now the main source of gypsum on Yorke Peninsula, shipment being from Stenhouse Bay. A small amount comes from Peesey Swamp, while the Lake Fowler dune continues to be worked intermittently.

The Marion Lake deposit is described in chapter 2. The crystalline gypsum (about 4ft. thick) is overlain by several feet of seed, flour, and weathered gypsum which was once left as waste but is now used after beneficiation.

Typical analyses are—

	Rock gypsum	Gypseous overburden
CaSO ₄ , 2H ₂ O	94.20	91.99
NaCl	0.50	0.85
CaCO ₃	4.38	5.57
SiO ₂	0.20	0.12
Fe ₂ O ₃ and Al ₂ O ₃	0.20	0.15
	99.48	98.68

The original deposits were estimated to be 6 million tons of rock gypsum overlain by 3 million tons of gypseous overburden. The annual output is over 200,000 tons; remaining reserves are 2½ million tons of rock gypsum and 3 million tons of overburden, but other lakes probably hold about 2 million tons (Dickinson and King 1951).

The present practice is to strip—and separately wash—the overburden, and to drill and blast the crystalline rock gypsum. It is then loaded by dragline and carried by diesel tramway to a coastal washing-plant.

The Lake Fowler dune is 70ft. high and a mile long (*see* chapter 2). It originally held 1,750,000 tons of seed gypsum. The material was first used mainly for cement making in New Zealand. About 25,000 tons are now taken annually. Smaller dunes at Diamond Lake are not now worked but several hundred tons a year are obtained from Peesey Swamp.

Small gypsum deposits occur near Tickera, beyond the limits of the area mapped, and large masses of nodular gypsum are common in solution cavities in the Tertiary limestone cliffs between Tickera and Wallaroo.

SALT

The salt industry of Yorke Peninsula was originally the principal source of supply for South Australia, about 7,000 tons per annum being produced before 1891 from seasonal scraping of the floors of the salt lakes by local farmers. Production became concentrated in the Edithburgh-Yorketown district between 1891 and 1900 and rose to 40,000 tons per annum. This continued for many years until the establishment of salt pans at Port Price and elsewhere in South Australia led to severe competition, so that today lake production is almost entirely confined to Lake Fowler. Harvesting is mechanized and totals approximately 10,000 tons annually. The lake industry was described by Lockhart Jack (1921).

The principal salt producing centre is now at Port Price, at the head of Gulf St. Vincent, where Ocean Salt Pty. Ltd. established a salt works and refinery in 1930 for the production of salt by the solar evaporation of sea-water. This site was selected to gain the natural benefits of low rainfall, high evaporation rate, and increased salinity of the impounded gulf waters, together with the favourable topography for the construction of level evaporation-areas. The present output is 65,000 tons annually, with a potential output close to 100,000 tons. Harvesting operations are fully mechanized and electrified throughout.

Underground brines from the Stenhouse Bay lakes and from Peesey Swamp are also used to produce salt by solar evaporation. The brine occurs at shallow depths and contains up to 30oz. of salt per gallon—as compared with sea-water at 4½ ounces. About 10,000 tons annually is produced by Waratah Gypsum Pty. Ltd., being crystallized out on Snow Lake from brine pumped from the gypsum-mining plant. The output is planned to be increased ultimately to 30,000 tons per annum. The salt is shipped from Stenhouse Bay. At Peesey Swamp, about 5-6,000 tons of crude commercial salt is produced annually.

Total salt production is about 100,000 tons per annum.

PHOSPHATE

Rock phosphate was discovered in 1900 in small pocket and fissure deposits near Clinton. These were worked for artificial manures, but have become exhausted. They were described by Lockhart Jack (1919). Recent shortages have resulted in further searches, so far unsuccessful (Forbes 1961).

KAOLIN CLAY

A white kaolin-rich clay (a kaolinized aplitic granite) occurs in the sea-cliffs north of Pine Point, 8 miles south of Ardrossan. (Crawford, 1959; Ellerton, 1959.) This was investigated by the Department of Mines from 1950 onwards, and about 300,000 tons of kaolinized aplite proved to exist under 55ft. of soft overburden. The clay contains much quartz, but, by washing, about 66,000 tons of high-grade white kaolin clay could be produced. No commercial exploitation has yet been undertaken.

Other white kaolin-rich clays have been noted in the Ardrossan area where they underlie kunkar and Tertiary sands and overlie Cambrian limestone, but these are thin and irregular in distribution.

Clay resulting from alteration of Precambrian rocks was worked south of Wallaroo and southeast of Kadina, for use in the copper-smelting industry. Production was from shallow pits.

MONTMORILLONITE CLAY

Montmorillonite-rich clay was noted by A. A. Gibson in foundation investigations for water tanks at several points in central Yorke Peninsula in 1958. In 1960, the writer sampled clays associated with gypsum which fills solution cavities in the Tertiary limestone cliffs north of Point Riley, and this was found to be montmorillonite rich. No economically valuable deposits are known, but the deposit at Point Riley was of very high grade. A brief review, with details of tests, is given by Hiern (1962).

ALUNITE

Alunite occurs as nodular seams in Quaternary (or late Tertiary) clayey sands and clays forming sea-cliffs between Stansbury and Port Vincent, and also north of Port Vincent. The deposits between Stansbury and Port Vincent were described in *Mining Review* 28*, and were developed during the potash shortage in the first World War. Peacetime development was unsuccessful. Adits were driven into the sea-cliffs above high water-mark, and shafts were sunk from the top of the cliffs.

The deposits north of Port Vincent are immediately south of Sheoak Flat, a short stretch of cliffless coast. These were thought to be possibly better than the southern occurrence, though they are less evident in the cliff.

LIGNITE

The lignite deposits common in the Tertiary elsewhere in South Australia are known to occur on Yorke Peninsula only in the northeast between Price and Clinton, where they have been detected and investigated by boring. In 1923, 32,000,000 tons of lignite were proved in a 21-ft. seam at a depth of 292ft.—under clay and sand. (See *Mining Reviews* 37, 39†).

A typical analysis was—

	per cent
Moisture at 105°C., after air-drying	16.71
Sulphur, after air-drying	3.26
Moisture at 105°C.	51.69
Volatile matter	24.51
Fixed carbon	15.55
Ash	8.25
Bitumen	0.96

* Jack, R. L., *Mining Review* 28, pp. 51-53, 1918.

† *Mining Review* 37, Government Drilling Operations, pp. 29, 41-47, 55-57, 1923. *Mining Review* 39, Government Drilling Operations, p. 34, 1924.

A review of the St. Vincent Basin deposits was made by Parkin (1947), who pointed out that the net tonnage will be only a fraction of the gross tonnage because of alternations of sand and clay with the seams. Closer boring was suggested.

A stratigraphic bore put down in 1956, on section 336, hundred of Clinton, intersected a 12-ft. seam between 212ft. and 224ft. Further boring undertaken between 1959 and 1961 is regarded as still insufficient to permit the accurate assessment of reserves (Johnson 1960, 1962).

NATURAL WHITING

Jack (1928) briefly describes a natural whiting which occurs as a lake deposit 2 miles east of Daly Head. Several feet of material are present over about a square mile. This was worked by A. H. Hasell. Recent tests by Weir (1960) show that the material is dolomitic (CaCO_3 , 46.23 per cent; MgCO_3 , 44.75 per cent by weight). It does not conform to normal specifications, but Weir recommends trials.

CONCRETE SAND

Sources of concrete- or building-sand are confined to the north-east, and their geology is described in chapter 2 (p. 32). Further descriptions are given by Johns (1961b). Another actively worked deposit lies 5 miles north of Kulpara and is of comparable type. Output from these pits is very variable.

Chapter 7

BIBLIOGRAPHY

- Anon [Crawford, A. R.], 1957—"Balgowan Geophysical Anomaly—Hundred of Kilkerran." *S. Aust. Min. Rev.* 103, pp. 26-33.
- Australia—Bureau of Meteorology, 1961—"Climatological Survey: Region 9—Yorke, South Australia." Issued by the Director of Meteorology, Melbourne.
- Bacon, W. R., 1948—"Geological Report on Wallaroo-Moonta, S.A." Unpub. rep., Zinc Corporation Ltd.
- Bagnold, R. A., 1941—"The Physics of Blown Sand and Desert Dunes." London (Methuen).
- Barnes, T. A. and Kleeman, A. W., 1934—"Notes on fossiliferous Cambrian near Kulpara, South Australia." *Trans. Roy. Soc. S. Aust.* 58, pp. 7-9.
- Basedow, H., 1901—"On the occurrence of Miocene limestones at Edithburgh, and their stratigraphical relationship to the Eocene of Wool Bay with description of a new species by Professor R. Tate." *Trans. Roy. Soc. S. Aust.* 25, pp. 145-148.
- Basedow, H., 1902—"Descriptions of new species of fossil mollusca from the Miocene limestone near Edithburgh." *Trans. Roy. Soc. S. Aust.* 26 (2), pp. 130-132.
- Bedford, R. and Bedford J., 1937—"Further notes on archaeos (Pleosporgia) from the lower Cambrian of South Australia." *Mem. Kyancutta Mus.* 4, pp. 27-38.
- Bedford, R. and Bedford, J., 1939—"Development and classification of archaeos (Pleosporgia). *Mem. Kyancutta Mus.* 6, pp. 67-82.
- Bleys, C., 1960—"Groundwater Investigation—Hundred of Warrenben." *S. Aust. Min. Rev.* 109, pp. 113-122.
- Broadhurst, E., 1945—"Moonta Mines—Drilling Programme." *S. Aust. Min. Rev.* 81, pp. 81-84.
- Brown, H. Y. L., 1884—"Report on general geology of Yorke's Peninsula." *Parl. Pap. S. Aust.* 134, 1884, pp. 1-2.
- Brown, H. Y. L., 1899—"Geological Map of South Australia, 1 inch/16 miles." *Adel. Surv. Gen. Off.*, 1899.
- Brown, H. Y. L., 1902—"Report of the Government Geologist on the phosphate discovery, Hundred of Clinton, Yorke's Peninsula." Adelaide (Govt. Printer), 2p.
- Carey, S. W., 1954—"The Rheid Concept in Geotectonics." *J. Geol. Soc. Aust.* 1, pp. 67-117.
- Chapman, F., 1918—"Ostracoda from the Upper Cambrian limestone of South Australia." *Proc. Roy. Soc. Vict.* 31 (N.S. 1), pp. 108-112.
- Clark, E. V., 1928—"A Recent raised beach near Point Turton, Yorke Peninsula." *Trans. Roy. Soc. S. Aust.* 52, pp. 189-190.
- Condor, H., 1912a—Report of Mr. Hartwell Condor on the Yelta Mine. *Parl. Pap. S. Aust.* 36, 1912, pp. 1-6.
- Condor, H., 1912b—Report of Mr. Hartwell Condor on the Wandilta Mine. *Parl. Pap. S. Aust.* 37, 1912, pp. 1-5.
- Cornelius, H. S., 1938a—"Moonta Mining Scheme." *S. Aust. Min. Rev.* 67, pp. 93-94.
- Cornelius, H. S., 1938b—"Moonta and Wallaroo Districts." *S. Aust. Min. Rev.* 68, pp. 74-75.
- Cornelius, H. S., 1939a—"Moonta Extended Mines." *S. Aust. Min. Rev.* 69, pp. 79-80.
- Cornelius, H. S., 1939b—"Wallaroo Mines Prospecting." *S. Aust. Min. Rev.* 69, pp. 72-73.
- Cornelius, H. S., 1939c—"Moonta Mining Scheme." *S. Aust. Min. Rev.* 69, pp. 74-78.
- Crawford, A. R., 1957a—"Ardrossan (Pine Point) Clay Deposit—Progress Report." *S. Aust. Min. Rev.* 104, pp. 22-23.
- Crawford, A. R., 1957b—"Diamond Drilling of a Magnetic Anomaly at Weetulta, Yorke Peninsula." *S. Aust. Dept. Mines* (unpublished report).
- Crawford, A. R., 1959—"White clay deposit—Ardrossan (Pine Point)." *S. Aust. Min. Rev.* 106, pp. 42-50.
- Crawford, A. R., 1961—"The candle-eating mammal of the Curramulka Cave." Unpub. poem.
- Crespin, I., 1954—"Stratigraphy and micropalacontology of the marine Tertiary rocks between Adelaide and Aldinga, South Australia." *Rep. Bur. Min. Resour. Aust.* 12, 65 p.
- Crocker, R. L., 1941—"Notes on the geology and physiography of south-east South Australia with reference to late climatic history." *Trans. Roy. Soc. S. Aust.* 65 (1), pp. 103-107.
- Crocker, R. L., 1946a—"Notes on a Recent raised beach at Point Brown, Yorke Peninsula, South Australia." *Trans. Roy. Soc. S. Aust.* 70 (1), pp. 108-109.

- Crocker, R. L., 1946b—"Post-Miocene climatic and geologic history and its significance in relation to the genesis of the major soil types of South Australia." *Bull. Coun. Sci. Industr. Res. Aust.* 193, 56 p.
- Daily, B., 1956—"The Cambrian in South Australia." *Rep. Internat. geol. Congr.* (20th), Mexico, 1956. *El sistema Cambrico, su Paleogeografía Y el Problema de su Base*, 2, pp. 91-147.
- David, T. W. E., 1932—"Explanatory notes to accompany a new geological map of the Commonwealth of Australia." *Syd. Coun. Sci. Industr. Res. Aust.*, 1932, 177 p.
- David, T. W. E. and Browne, W. R., 1950—"The geology of the Commonwealth of Australia." London (Edward Arnold).
- Denholm, L. S., 1957—"Geological Survey of limestone deposit—Point Turton." *S. Aust. Min. Rev.* 103, pp. 106-110.
- Dickinson, S. B., 1942—"The Structural Control of Ore Deposition in some South Australian Copper Fields." *Geol. Surv. S. Aust. Bull.* 20, 99 p.
- Dickinson, S. B., 1953—"The Moonta and Wallaroo Copper Mines." *Emp. Min. Met. Congr.* 5th, Aust. N.Z. (1), pp. 487-504.
- Dickinson, S. B. and King, D., 1951—"The Stenhouse Bay Gypsum Deposits." *S. Aust. Min. Rev.* 91, pp. 95-113.
- Edwards, A. B., 1943—"The Copper Deposits of Australia." *Proc. Aust. Inst. Min. Metall.* 130, pp. 105-169.
- Elford, H. S., 1926—"Electrical prospecting and the Wallaroo and Moonta Field." *Chem. Eng. and Min. Rev.* 18, pp. 433-440.
- Ellerton, H., 1959—"Final Report on Ardrossan (Pine Point) Clay." *S. Aust. Min. Rev.* 106, pp. 51-52.
- Etheridge, R., 1890—"On some Australian species of the family Archaeocyathinae." *Trans. Roy. Soc. S. Aust.* 13 (1), pp. 10-22.
- Etheridge, R., 1898—"A further Cambrian trilobite from Yorke Peninsula." *Trans. Roy. Soc. S. Aust.* 22 (1), pp. 1-3.
- Fletcher, A. W., 1890—"Cambrian fossils from Yorke Peninsula." (Exhibited Cambrian fossils from Curramulka and Ardrossan), *Trans. Roy. Soc. S. Aust.* 13 (2), p. 249.
- Flinders, M., 1814—"A voyage to Terra Australis. Undertaken for the purpose of completing the discovery of that vast country and prosecuted in the years 1801, 1802 and 1803, in His Majesty's ship the *Investigator* and subsequently in the armed vessel *Porpoise* and schooner *Cumberland*." London (G. & W. Nicol).
- Forbes, B. G., 1961—"Results of Search for Phosphate Deposits." *S. Aust. Min. Rev.* 112, pp. 84-88.
- Fowler, W., 1880—"Sections of strata traversed by wells at Yarrow." *Trans. Roy. Soc. S. Aust.* 3, p. 181.
- Franklin, H. M., 1880—"A Glance at Australia." London.
- Gaffney, T. N. Burke, 1951—"Seismicity of Australia." *J. Roy. Soc. N.S.W.* 85 (2), pp. 47-52.
- Gibson, A. A., 1959—"Geochemical Prospecting in the Moonta Area." *S. Aust. Min. Rev.* 106, pp. 33-34.
- Glaessner, M. F., 1953a—"Conditions of Tertiary sedimentation in southern Australia." *Trans. Roy. Soc. S. Aust.* 76, pp. 141-146.
- Glaessner, M. F., 1953b—"Some Problems of Tertiary geology in southern Australia." *J. Roy. Soc. N.S.W.* 87 (2), pp. 31-45.
- Glaessner, M. F. and Parkin, L. W. (Ed.), 1958—"The Geology of South Australia." *J. geol. Soc. Aust.* 5 (2), 163 p.
- Glastonbury, J. O. G., 1939—"The Geology of the Cape Spencer area, Yorke Peninsula." *Trans. Roy. Soc. S. Aust.* 63 (1), pp. 14-16.
- Greenlees, J., 1923—One hundred photographs, illustrating the Cambrian and Permian-Carboniferous Glacial Rocks of South Australia, collated and mounted by Mr. J. Greenlees and presented by him to the University of Adelaide, September, 1923.
- Greenway, T. C. and Phillipps, H. T., 1902—"Notes on the geological features of Southern Yorke Peninsula." *Trans. Roy. Soc. S. Aust.* 26, pp. 268-277.
- Harris, J. L. and Milton, B. E., 1959—"Seismic Reflection and Refraction Tests—Lower Yorke Peninsula." *S. Aust. Min. Rev.* 107, pp. 57-68.
- Hiern, M. N., 1959—"Dead Horse Bay Uranium Prospect." *S. Aust. Min. Rev.* 107, pp. 80-81.
- Hiern, M. N., 1962—"Occurrence of Activable Clay in South Australia." *S. Aust. Min. Rev.* 114, pp. 51-56.
- Higgs, S., 1872—"Some remarks on the mining districts of Yorke's Peninsula." *Trans. R. geol. Soc. Cornwall*, 9 (1), pp. 122-131.
- Hillwood, E. R., 1960—"Concentrations of Heavy-Mineral Sands on South Australian Beaches." *S. Aust. Min. Rev.* 109, pp. 123-129.
- Hinde, G. J., 1891—"Note on specimens of cherty siliceous rock from South Australia." *Geol. Mag.*, N.S. Decade 3 (8), pp. 115-116.

- Horwitz, R. C., 1959—Geological atlas of South Australia, Wakefield sheet, 1 inch/1 mile (1: 63,360). *Geol. Surv. S. Aust.*
- Horwitz, R. C., 1961—"The geology of the Wakefield military sheet." *Geol. Surv. S. Aust. Rep. Invest.* 18, 32 p.
- Horwitz, R. C. and Daily, B., 1958. See Glaessner, M. F. and Parkin, L. W.
- Howchin, W., 1900—"Evidence of extinct glacial action in southern Yorke's Peninsula." *Trans. Roy. Soc. S. Aust.* 24 (1), pp. 71-80.
- Howchin, W., 1901—"Suggestions on the origin of the salt lagoons of Southern Yorke Peninsula." *Trans. Roy. Soc. S. Aust.* 25 (1), pp. 1-9.
- Howchin, W., 1903—"Report of the South Australian Glacial Investigations Committee." *Rep. Aust. Ass. Advanc. Sci.* 9, pp. 194-200.
- Howchin, W., 1907—"A general Description of the Cambrian Series of South Australia." *Rep. Aust. Ass. Advanc. Sci.* 11, pp. 414-422.
- Howchin, W., 1918—"Notes on the Geology of Ardrossan and neighbourhood." *Trans. Roy. Soc. S. Aust.* 42, pp. 185-225.
- Howchin, W., 1925—"The geographical distribution of fossiliferous rocks of Cambrian Age in South Australia, with geological notes and references." *Trans. Roy. Soc. S. Aust.* 49, pp. 1-26.
- Howchin, W., 1931—"The dead rivers of South Australia—Part 1, The Western Group." *Trans. Roy. Soc. S. Aust.* 55, pp. 113-135.
- Jack, R. Lockhart, 1917—"The Geology of the Moonta and Wallaroo Mining District." *Geol. Surv. S. Aust. Bull.* 6, 135 p.
- Jack, R. Lockhart, 1919—"The Phosphate Deposits of South Australia." *Geol. Surv. S. Aust. Bull.* 7, 136 p.
- Jack, R. Lockhart, 1921—"The Salt and Gypsum Resources of South Australia." *Geol. Surv. S. Aust. Bull.* 8, 118 p.
- Jack, R. Lockhart, 1923—"The Building Stones of South Australia." *Geol. Surv. S. Aust. Bull.* 10, 73 p.
- Jack, R. Lockhart, 1924—"The Salt Lakes of South Australia." *Proc. R. geogr. Soc. Aust. (S. Aust. Br.)* 24, pp. 92-106.
- Jack, R. Lockhart, 1926—"Clay and Cement in South Australia." *Geol. Surv. S. Aust. Bull.* 12, 120 p.
- Jack, R. Lockhart, 1928—"Pigment Minerals in South Australia." *Geol. Surv. S. Aust. Bull.* 13, 70 p.
- Jaeger, J. C. and Browne, W. R., 1958—"Earth tremors in Australia and their geological importance." *Aust. J. Sci.* 20 (8), pp. 225-228.
- Jameson, R. G., 1838—"Report of a visit to Yorke's Peninsula by Messrs. Cock and Jameson." *South Australian Gazette and Colonial Register*, Adelaide, 8th Dec., 1838.
- Johns, R. K. and Solomon, M., 1953—"The Age of The Gawler Range Porphyry." *Trans. Roy. Soc. S. Aust.* 76, pp. 41-44.
- Johns, R. K., 1959—"Dolomite and Limestone deposits." *S. Aust. Min. Rev.* 107, pp. 10-17.
- Johns, R. K., 1960—"Gypsum Deposit—Sections 72-74 and 78, Hundred of Melville." *S. Aust. Min. Rev.* 109, pp. 57-60.
- Johns, R. K., 1961a—"Calcareous Aeolianites of South Australia." *S. Aust. Min. Rev.* 111, pp. 11-17.
- Johns, R. K., 1961b—"Ardrossan Sand Deposits." *S. Aust. Min. Rev.* 111, pp. 110-112.
- Johns, R. K., 1961c—"Geology and Mineral Resources of Southern Eyre Peninsula." *Geol. Surv. S. Aust. Bull.* 37, 102 p.
- Johns, R. K., 1962—"South Australian Rock Phosphate Deposits." *S. Aust. Min. Rev.* 114, pp. 22-30.
- Johnson, W., 1960a—"Future Oil Exploration—Gulf St. Vincent Region." *S. Aust. Min. Rev.* 110, pp. 126-133.
- Johnson, W., 1960b—"Coal Exploration, Northern End of the St. Vincent Basin." *S. Aust. Min. Rev.* 110, pp. 134-144.
- Johnson, W., 1962—"Coal Exploration—Clinton North Coal Field." *S. Aust. Dept. Mines unpub. rep.*
- King, D., 1951—"Gypsum Deposits—Hundred of Tickera." *S. Aust. Min. Rev.* 91, pp. 149-158.
- King, D., 1952a—"Wardang Island Lime-Sand Deposit." *S. Aust. Min. Rev.* 92, pp. 67-70.
- King, D., 1952b—"Lake Fowler Gypsum Deposits." *S. Aust. Min. Rev.* 92, pp. 60-67.
- King, D., Sprigg, R. C., and Campana, B., 1954—"Geological atlas of South Australia, Kingscote sheet, 1 inch to 4 miles (1: 253,440)." *Geol. Surv. S. Aust.*
- Kobayashi, T., 1942a—"Cambrian faunas in South Australia with a brief note on the history of the Nullagine Basin." *Proc. imp. Acad. Jap.* 18 (8), pp. 484-491.
- Kobayashi, T., 1942b—"Two Cambrian trilobites from the Parara Limestone in the Yorke's Peninsula, South Australia." *Proc. imp. Acad. Jap.* 18 (8), pp. 492-498.

- Longbottom, M. E., 1950—"The salt and gypsum industry of southern Yorke Peninsula." *Proc. R. geogr. Soc. Aust.* (S. Aust. Br.) 51, pp. 16-26.
- Ludbrook, N. H., 1957a—"Permian foraminifera in South Australia." *Aust. J. Sci.* 19 (4), pp. 161-162.
- Ludbrook, N. H., 1957b—"A reference column for the Tertiary sediments of the South Australian portion of the Murray Basin." *J. Roy. Soc. N.S.W.* 90 (4), pp. 174-180.
- Ludbrook, N. H., 1959—"A Widespread Pliocene molluscan fauna with *Anodontia* in South Australia." *Trans. Roy. Soc. S. Aust.* 82, pp. 219-233.
- Ludbrook, N. H., 1963—"Correlation of the Tertiary rocks of South Australia." *Trans. Roy. Soc. S. Aust.* 87, pp. 5-15.
- Mawson, D., 1907—"Mineralogical Notes." *Trans. Roy. Soc. S. Aust.* 31, pp. 119-124.
- McBriar, E. M., 1962—"Primary Copper Mineralization at Moonta and Wallaroo, South Australia." Thesis submitted to Univ. of Adelaide.
- Moulden, J. C., 1895—"Petrographical observations on some South Australian rocks." *Trans. Roy. Soc. S. Aust.* 19 (1), pp. 70-78.
- Nixon, L. G. B., 1961—"Some Recent and Tertiary Limestone Deposits on Yorke Peninsula." *S. Aust. Min. Rev.* 111, pp. 65-70.
- Noakes, L. C., 1957—"Upper Proterozoic and sub-Cambrian rocks in Australia." *Bull. Bur. Min. Resour. Aust.* 49, pp. 213-238. This report was originally published in *Rep. Internat. geol. Congr.* (20th) Mexico 1956 (2), pp. 213-238.
- Opik, A. A., 1956—"Cambrian palaeogeography of Australia." *Rep. Internat. geol. Congr.* (20th) Mexico (2), pp. 239-284.
- Parkin, L. W., 1947—"The St. Vincent's Gulf Brown Coal Fields." S. Aust. Dept. Mines unpub. rep.
- Pegum, D. M., 1956—"Magnetic investigations in the Kadina-Wallaroo and surrounding areas." *S. Aust. Min. Rev.* 101, pp. 79-87.
- Pritchard, G. B., 1892—"On the Cambrian Rocks at Curramulka." *Trans. Roy. Soc. S. Aust.* 15 (2), pp. 179-182.
- Pryor, O., 1962—"Australia's Little Cornwall." Adelaide (Rigby).
- Radcliff, S., 1906—"Radium at Moonta Mines, South Australia." *Trans. Roy. Soc. S. Aust.* 30, pp. 199-204.
- Reynolds, M., 1953—"The Cainozoic succession of Maslin and Aldinga Bays, South Australia." *Trans. Roy. Soc. S. Aust.* 76, pp. 114-140.
- Rutt, W., 1882—"Notes upon a boring at Port Wakefield." *Trans. Roy. Soc. S. Aust.* 4, pp. 41-44.
- Seedsman, K. R., 1957—"Magnetic and gravity investigations at Curramulka." *S. Aust. Min. Rev.* 103, pp. 116-121.
- Segnit, R. W., 1940—"Geology of Hallett Cove and district with special reference to the distribution and age of the younger glacial till." *Trans. Roy. Soc. S. Aust.* 64 (1), pp. 3-45.
- Singleton, F. A., 1941—"The Tertiary Geology of Australia." *Proc. Roy. Soc. Vict.* 53 (N.S. 1), pp. 1-125.
- Sokoloff, V. P., 1949—"Geochemical Reconnaissance in the Wallaroo Mining District, South Australia." *S. Aust. Min. Rev.* 88, pp. 32-71.
- Sokoloff, V. P., 1951a—"Geochemical exploration for copper in the Wallaroo mining district, South Australia." *Geochem. et cosmochem. Acta* 1 (4, 5 & 6), 284-298.
- Sokoloff, V. P., 1951b—"Exploration for copper in Wallaroo mining district, South Australia." *Chem. Eng. & Min. Rev.* 43, pp. 331-341.
- Solomon, M., 1953—"Gypsum Deposits near Port Broughton and Tickera." *S. Aust. Min. Rev.* 95, pp. 93-95.
- Sprigg, R. C., 1952—"Sedimentation in the Adelaide Geosyncline and the formation of the continental terrace." *Sir Douglas Mawson Anniv. Vol., Univ. of Adel.*, pp. 153-159.
- Stephens, C. G. and Crocker, R. L., 1946—"Composition and Genesis of Lunettes." *Trans. Roy. Soc. S. Aust.* 70 (2), pp. 302-312.
- Tate, R., 1880—"Graphic Granite." *Geology. Trans. Roy. Soc. S. Aust.* 3, pp. 180-181.
- Tate, R., 1881—"Silurian fossils from the Parara Limestone near Ardrossan." *Miscellaneous contributions. Trans. Roy. Soc. S. Aust.* 4, p. 145.
- Tate, R., 1882—"The Geology about Port Wakefield." *Trans. Roy. Soc. S. Aust.* 4, pp. 45-46.
- Tate, R., 1884—"Trilobites from South Australia." *Bibliographical notices. Miscellanea. Trans. Roy. Soc. S. Aust.* 7, p. 76.
- Tate, R., 1886—"Post-Miocene climate in South Australia." *Trans. Roy. Soc. S. Aust.* 8, pp. 49-59.
- Tate, R., 1890—"On the geological and botanical features of Southern Yorke Peninsula, South Australia." *Trans. Roy. Soc. S. Aust.* 13 (1), pp. 112-120.
- Tate, R., 1892—"The Cambrian fossils of South Australia." *Trans. Roy. Soc. S. Aust.* 15 (2), pp. 183-189, pl. II.

- Tate, R., Howchin, W., and David, T. W. E., 1896—"Report of the Research Committee appointed to collect evidence as to glacial action in Australia." *Rep. Aust. Ass. Advanc. Sci.* 6, pp. 315-320.
- Taylor, T. Griffith, 1907—"Preliminary note on Archaeocyathinae from the Cambrian 'Coral Reefs' of South Australia." *Rep. Aust. Ass. Advanc. Sci.* 11, pp. 423-437.
- Taylor, T. Griffith, 1910—"The Archaeocyathinae from the Cambrian of South Australia with an account of the morphology and affinities of the whole class." *Mem. Roy. Soc. S. Aust.* 2 (2), pp. 55-186.
- Tepper, J. G. O., 1879—"Introduction to the cliffs and rocks at Ardrossan, Yorke's Peninsula." *Trans. Phil. Soc. S. Aust.* (for 1878-9) 2, pp. 71-79.
- Tepper, J. G. O., 1880—"On the Characteristics and Distribution of the Native and Naturalised Plants About Ardrossan, Yorke's Peninsula." *Trans. Roy. Soc. S. Aust.* 3, pp. 25-34, plus app. and section on pl. IV.
- Tepper, J. G. O., 1882—"Sketch of the geological and physical history of the hundred of Cunningham and neighbouring regions." *Trans. Roy. Soc. S. Aust.* 4, pp. 61-70.
- Thomson, K. W., 1955—"The changes in function of former mining settlements: the Wallaroo copper belt. *Proc. R. Geogr. Soc. Aust.* (S. Aust. Br.), pp. 47-58.
- Thyer, R. F., 1943—"Report on the Geophysical Surveys at the Wallaroo-Moonta Copper Fields." *S. Aust. Min. Rev.* 77, pp. 41-48.
- Tilley, C. E., 1921a—"The graphite rocks of Sleaford Bay, South Australia. *Econ. Geol.* 16 (3), pp. 184-198.
- Tilley, C. E., 1921b—"The granite-gneisses of southern Eyre Peninsula (South Australia) and their associated amphibolites." *Quart. J. Geol. Soc. Lond.* 77, pp. 75-134.
- Tilley, C. E., 1921c—"Precambrian para-gneisses of southern Eyre Peninsula, South Australia." *Geol. Mag.* 58, pp. 251-259.
- Wade, A., 1915—"The supposed oil-bearing areas of South Australia." *Geol. Surv. S. Aust. Bull.* 4, 54 p.
- Ward, L. K., 1914—"The geology of Moonta and its District." *Ann. Rep. Govt. Geologist for 1913, Parl. Pap.* 87, pp. 6-8.
- Ward, L. K., 1944—"The Search for Oil in South Australia." *Geol. Surv. S. Aust. Bull.* 22, 40 p.
- Ward, L. K. and Jack, R. L., 1912—"The Yelta and Paramatta Mines." *Geol. Surv. S. Aust. Rep.* 1, 18 p.
- Weir, L. J., 1960—"Tests on Whiting from Daly Head—Yorke Peninsula." *S. Aust. Min. Rev.* 110, pp. 123-125.
- Willington, C. M., 1960—"The Mineral Industry on Yorke Peninsula." *S. Aust. Min. Rev.* 110, pp. 5-11.
- Woodmansee, W. C., 1957—"Radiometric reconnaissance of copper mines dumps—Northern Yorke Peninsula." *S. Aust. Min. Rev.* 102, pp. 76-83.
- Woods, J. E. Tenison, 1862—"Geological observations in South Australia: principally in the district south-east of Adelaide." London (Longman, Green—Longman, Roberts & Green).
- Woodward, H. P., 1884—"Notes on the remains of trilobites from South Australia." *Geol. Mag.*, N.S. Decade 3 (1), pp. 342-344.
- Woolnough, W. G., 1927—"The duricrust of Australia." *J. roy. Soc. N.S.W.* 61, pp. 1-53.

Appendix

MINLATON AND STANSBURY STRATIGRAPHIC BORES

Subsurface Stratigraphy and Micropalaeontology

By N. H. LUDBROOK, M.A., Ph.D., D.I.C., F.G.S., Senior Palaeontologist

Abstract

Minlaton bore intersected 596ft. of Lower Permian (?lowest Sakmarian) glaciogenes and then a lower Middle to Lower Cambrian succession 2,459ft. thick consisting in downward sequence of Ramsay Limestone (105ft.), red bed clastics (456ft.), Parara Limestone (934ft.) and Kulpara Limestone (964ft.). From 3,075ft. depth to the bottom at 3,261ft., the well is considered to have passed through beds transitional between the Lower Cambrian and the Pound Quartzite.

Stansbury bore intersected 119ft. of Miocene calcareous sandstone and bryozoal limestone equivalent to the lower part of the Port Willunga Beds, before passing into Lower Permian (?lowest Sakmarian) glaciogenes 776ft. thick. At 910ft., the well entered a red-bed sequence of current bedded sandstones and chocolate shales considered to be Upper Proterozoic (Marinoan Series). Boring ceased in these beds at 1,370 feet.

Introduction

Minlaton No. 1 and Stansbury No. 1 stratigraphic bores were drilled in 1956 by the Department of Mines as part of an oil exploration programme, which has been reviewed by Johnson (1960). The Permian sequence in the Minlaton bore was studied by the present writer who reported (Ludbrook, 1957) the occurrence of foraminifera in these sediments, giving the first evidence of marine influence in the South Australian Permian.

The Cambrian section was examined by Daily (1957, unpublished) who selected fossiliferous core samples for further study.

The present report is the result of the re-logging of both bores by B. P. Thomson and N. H. Ludbrook in the light of recent further discoveries of marine Permian strata in South Australia (Ludbrook, 1961) and studies of the transition beds between the Lower Cambrian and Upper Proterozoic principally by B. P. Webb, R. Horwitz, and B. P. Thomson (Webb and Horwitz, 1959; Horwitz, Thomson, and Webb, 1959; Thomson, 1961 unpublished).

Both the Tertiary and Permian sections of the Stansbury bore have been examined in detail for microfaunas, an important result of which is the confirmation of the occurrence of marine Permian on southern Yorke Peninsula by the recovery of foraminifera over two main intervals between 205 and 855ft. in this bore.

Stratigraphic Summary

Stratigraphic units intersected in the two wells are—

	Minlaton	Stansbury
	Depth (feet)	Depth (feet)
Port Willunga Beds (Miocene)	—	15-134
Lower Permian glaciogenes (lowest Sakmarian).....	20-616	134-910
Ramsay Limestone (Lower Middle Cambrian)	616-721½	—
Red bed clastics (Lower Cambrian)	721½-1,177	?
Parara Limestone (Lower Cambrian)	1,177-2,111½	—
Kulpara Limestone (Lower Cambrian)	2,111½-3,075	—
Transitional beds (Lower Cambrian)	3,075-3,261½	—
? Marinoan Series (Upper Proterozoic)	—	910-1,370

Port Willunga Beds—Miocene

Stansbury bore intersected 119ft. of fossiliferous calcareous sandstone and sandy bryozoal limestone under 15ft. of surface cover. Foraminifera are common, generally consisting of a few individuals of many species. The assemblages over the interval 30-130ft. are characterized by the presence of *Sherbornina atkinsoni* in association with *Notorotalia crassimura*, *Cibicides vortex*, *Eponides repandus*, and *Anomalina perthensis*. They are of Miocene age, representing the lower part of the Port Willunga Beds. (Table I.)

Lower Permian Glacigenes

Both Minlaton and Stansbury bores intersected Permian boulder clays and clayey sands, in which quartz grains ranging from angular to rounded and often with etched and pitted surfaces are abundant with accessories usually garnet, pyrite, biotite, and chlorite. Small pebbles of varying sizes and of diverse origins are usually present; these are commonly granite, schist, limestone, quartzite, and sandstone. The matrix is either bluish-white clay or chocolate clay, the latter presumably derived from chocolate shales of the Precambrian in a similar way to the chocolate clay bands in the glacial sequence at Hallett Cove.

Foraminifera occurred in the Minlaton bore abundantly between 500 and 535ft., and sporadically between 535 and 594ft., at the base of the glacial sequence. In the Stansbury bore, foraminifera occurred abundantly between 205 and 230ft., between 361 and 375ft., and less abundantly near the base of the glacigenes between 770 and 855ft. Only arenaceous forms are present, principally *Hyperammia acicula*, *Ammodiscus oonahensis*, *Ammovertella inclusa* and *Tolypammia undulata*. So far no plant spores have been found associated with the foraminifera. The additional evidence of the presence of foraminifera in the glacigenes, combined with their discovery in the glacigenes elsewhere in the State (Ludbrook, 1961) permits the dating of the Permian sediments as lower Sakmarian. Conditions of deposition were suggested earlier (Ludbrook 1957) as deltaic, but it now appears more probable that on Yorke Peninsula they were, in part at least, marine, with piedmont glaciers shedding their loads into the sea.

Identification of the foraminifera has been aided by Crespin's (1958) monograph of Permian foraminifera of Australia. The assemblage appears to be most nearly related to that recorded by Crespin (*op. cit.*, pp. 14, 27) from a section in the Lower Permian Quamby Mudstone from near Onah, Tasmania.

The glacigenes were 596ft. thick in the Minlaton bore and 776ft. thick in Stansbury bore. (Table II.)

Cambrian

Most of the Cambrian sequence in the Minlaton bore was determined by Daily (1957) before drilling ceased and the bore still in progress correlated with other Cambrian sections (Daily, in Glaessner and Parkin, 1958, fig. 14, p. 54). A general interpretation of the section was published by Johnson (1960, p. 130). The present report reinterprets principally the lowest part of the section below 3,075ft., which is considered to have intersected transitional beds and not the Pound Quartzite.

Ramsay Limestone—Lower Middle Cambrian

Between 616ft. and 721ft. 6in., the bore intersected grey, mainly concretionary limestone with stylolites. *Redlichia* was reported in this interval by Daily.

Red Bed Clastics—Lower Cambrian

Below 721ft. 6in. occurred 455ft. 6in. of chocolate and grey siltstones, grey limestone with elastic bands, and gypsum interbeds to 1,088 feet.

A conglomerate band was intersected between 1,088 to 1,116ft. 6 inches.

TABLE I

TERTIARY FORAMINIFERA—STANSBURY STRATIGRAPHIC BORE

Depth in feet	30-35	35-40	40-45	45-50	50-55	75-80	80-85	95-100	125-130
<i>Guttulina irregularis</i> d'Orbigny	v	—	—	—	—	—	v	v	—
<i>Guttulina bartschi</i> Cushman	v	f	—	—	—	—	—	—	—
<i>Rotorbinella cycloclypeus</i> (Howchin & Parr)	v	f	—	—	—	—	—	—	—
<i>Glabrata globigeriniformis</i> (H.A. & E.)	v	v	r	r	v	—	v	—	—
<i>Eponides repandus</i> (Fichtel & Moll)	r	r	f	—	—	f	a	r	v
<i>Cibicides pseudoconvexus</i> Parr	r	r	v	—	—	—	—	—	—
<i>Cibicides vortex</i> Dorreen	r	c	c	v	c	—	r	—	—
<i>Anomalina perthensis</i> Parr	r	r	v	—	v	—	v	v	—
<i>Elphidium crispinae</i> Cushman	v	v	v	—	—	—	—	—	—
<i>Notorotalia crassimura</i> Carter	c	r	f	—	v	v	f	—	—
<i>Sherbornina atkinsoni</i> Chapman	c	f	r	v	r	—	r	—	—
<i>Lagena hexagona</i> Williamson	—	r	r	r	f	—	—	f	—
<i>Lagena</i> sp.	—	v	v	v	—	—	—	—	—
<i>Fissurina</i> sp.	—	v	r	r	—	—	—	—	—
<i>Dimorphina janjukensis</i> Crespin	—	v	—	v	—	—	—	—	—
<i>Guttulina problema</i> d'Orbigny	—	v	—	v	v	—	v	—	—
<i>Cassidulina laevigata</i> d'Orbigny	—	v	—	—	—	—	—	—	—
<i>Parvicarinina tenuimargo</i> (Brady)	—	v	—	—	—	—	—	—	—
<i>Gyroïdina</i> sp. A	—	v	—	—	v	—	—	—	—
<i>Cibicides lobatulus</i> Walker & Jacob	—	v	r	v	r	—	f	—	—
<i>Cibicides pseudoungarianus</i> (Cushman)	—	r	—	—	—	—	f	v	—
<i>Cibicides brevoralis</i> Carter	—	r	—	—	f	—	r	—	—
<i>Anomalina glabrata</i> Cushman	—	f	v	f	v	—	—	—	—
<i>Planorbulina mediterraneensis</i> d'Orbigny	—	v	r	v	r	—	—	—	—
<i>Guttulina jarvisi</i> Cushman & Ozawa	—	v	v	—	—	—	—	—	—
<i>Discorbis floridana</i> Cushman	—	v	v	—	v	—	—	—	—
<i>Baggina philippinensis</i> (Cushman)	—	v	v	—	—	—	—	—	—
<i>Stomatorbina concentrica</i> (Parker & Jones)	—	v	v	—	—	r	c	—	v
<i>Vagocibicides</i> cf. <i>maoria</i> (Stache)	—	v	v	—	—	—	—	—	—
<i>Gypsina globulus</i> Reuss	—	v	v	—	—	—	—	—	—
<i>Astronomion australe</i> Cushman & Edwards	—	—	r	v	r	—	—	—	—
<i>Cibicidella variabilis</i> (d'Orbigny)	—	—	—	v	—	—	—	—	—
<i>Dyocibicides biserialis</i> Cushman & Valentine	—	—	—	—	r	—	—	—	—
<i>Heronallenia parri</i> Carter	—	—	—	—	v	—	—	—	—
<i>Cibicides umbonifer</i> Parr	—	—	—	—	—	v	r	f	—
<i>Textularia</i> sp.	—	—	—	—	—	—	v	—	—
<i>Dorothia</i> sp.	—	—	—	—	—	—	v	—	—
<i>Sphaeroidina bulloides</i> (d'Orbigny)	—	—	—	—	—	—	v	—	—
<i>Heronallenia lingulata</i> (Burrows & Holland)	—	—	—	—	—	—	v	—	—
<i>Carpenteria rotaliformis</i> Chapman & Crespin	—	—	—	—	—	—	—	v	—

v—Very rare	1-2	} Specimens
r—Rare	2-5	
f—Frequent	6-10	
c—Common	11-25	
a—Abundant	25+	

TABLE II

PERMIAN FORAMINIFERA—STANSBURY AND MINLATON STRATIGRAPHIC BORES

Depth in feet . . .	STANSBURY BORE												MINLATON BORE											
	205-210	210-215	215-220	220-225	225-230	361-361' 9" Core	370-375	385-390	770-775	810-815	825-830	835-840	840-845	850-855	500-530	530-535	535-540	543-552	552-554	554-560	565-566	567-570	590-594	
<i>Hippocrepinella aperta</i> Crespin	v														r		v							
Cf. <i>Psammosphaera pusilla</i> Parr	r																							
<i>Hyperammina acicula</i> Parr	a	f	f	r	f	a	c	—	f	r	r	f	c	—	a	c	—	v	v	—	v	v	v	v
<i>Ammodiscus oonahensis</i> Crespin	c	f	r	v	v	v									v									
<i>Ammovertella inclusa</i> (Cushman & Waters)	f	f	—	r	—	v	—	—	c	v	c	f	c	—	a	r	—	—	—	—	—	—	—	v
<i>Textularia</i> sp.	v																							
Cf. <i>Trochammina</i> sp.	v																							
<i>Thuramminoides sphaeroidalis</i> Plummer	v	v	—	—	—	—	—	—	—	f	—	—	—	—	f	—	—	—	—	—	—	—	—	—
<i>Tolypammina undulata</i> Parr	—	v	—	—	—	—	—	—	c	—	v	r	r	—	c	f	—	—	—	v	—	—	—	—
Cf. <i>Hyperammina expansa</i> (Plummer)				v																				
Cf. <i>Hyperammina</i> sp.								v																
Cf. <i>Lugtonia thomasi</i> Crespin									v						r									
<i>Ammodiscus multicinctus</i> Crespin & Parr															v									
<i>Trochammina</i> cf. <i>pulvula</i> Crespin & Parr															a									
Cf. <i>Ammobaculites woolnoughi</i> Crespin & Parr																				v				
<i>Ostracode</i>														v										
? <i>Fish fragment</i>									v	v														

98

v—Very rare	1-2	} Specimens
r—Rare	2-5	
f—Frequent	6-10	
c—Common	11-25	
a—Abundant	25+	

Parara Limestone—Lower Cambrian

The grey concretionary fossiliferous Parara Limestone occurred between 1,177 and 2,111ft. 9in., with fossils, including *Parararia* selected by Daily for further study, between 1,177 and 1,254ft. *Archaeocyatha* occurred abundantly between 1,254 and 1,288ft. 6in. and between 1,304 and 1,485ft. Splashes of pyrite in massive limestone characterized the lower part of the Parara Limestone from 1,721 to 2,111ft. 9 inches.

Fossils were recorded by Daily at the following depths:

1,687ft. 6in.—*Parararia* sp., *Pelagiella* sp., *Conchostraca*, brachiopods, hyolithids.

1,740ft.—*Yorkella* sp., *Hyolithes* sp., brachiopods, *Pelagiella*, *Helcionella tatei*.

1,931ft.—*Yorkella australis*, *Ophileta subangulata*, *Helcionella tatei*, *Hyolithes* sp.

Calcite veins occur at 2,111ft. 9in. where the contact of the Parara Limestone and the Kulpara Limestone is interpreted.

Kulpara Limestone

Below 2,111ft. 9in., the Minlaton bore passed into light-grey dense limestone with abundant stylolites, which are highly carbonaceous when broken open. From 2,360ft., the bore passed downwards through darker-grey limestone with splashes of galena, stylolites, and calcite veinlets, to grey dolomitic limestone and dolomite with abundant carbonaceous stylolites and calcite veinlets. No fossils were observed in the dense dolomitic limestone.

Transitional Beds

From 3,075ft., the bore intersected a sequence of dense dolomite, dolomitic limestone, dolomitic arkose, and grey arkose with carbonaceous partings. These are considered to be transitional beds at the base of the Cambrian.

The Minlaton bore was terminated in these beds at 3,261ft. 3 inches.

?Marinoan Series—Upper Proterozoic

Below 910ft. the Stansbury bore entered a red-bed sequence of cross-bedded sandstone, buff fine-grained sandstone, and chocolate shale in which the bore was terminated at 1,370 feet.

These are considered by Thomson and Ludbrook to be Upper Proterozoic rocks of the Marinoan Series, but as suggested by Johnson (*op. cit.*, p. 128-129) and by the columnar sections at the end of this report, they may be equivalent to the red bed clastics between 721ft. 6in. and 1,177 ft. in the Minlaton bore. The thickness penetrated in the Stansbury bore, as will be seen from the sections, was insufficient to determine with certainty the correlation of the red beds with the Marinoan.

Minlaton Bore—Lithological Log

MINLATON NO. 1 BORE

Location—Section 153, hundred of Ramsay

Percussion Drill

Depth		Description		
From	To			
ft.	in.	ft.	in.	
Surface		10	0	Pale-buff sandy marl.
10	0	20	0	Red, slightly calcareous and ochreous sandy clay.
20	0	34	0	Red clayey sand.
34	0	45	0	Red-brown sandy clay.
45	0	55	0	Buff medium clayey sand, with some grit, consisting of quartz grains mostly medium sized and subrounded; the larger grains subrounded and polished; the fine to medium grains sometimes cemented with limonitic ochre.

Depth		Description
From ft. in.	To ft. in.	
55 0	64 0	Pale-buff gritty and clayey sand, with medium subrounded quartz grains either polished or pitted; limonitic ochre staining.
64 0	75 0	Pale-buff clayey sand, with medium subrounded quartz grains and some rounded, mostly with finely pitted surfaces and rather flat faces; some ironstaining. Granite pebble at 65ft., fragment of sandstone, mica, black mineral.
75 0	85 0	Yellow coarse gritty sand, with pebbles up to 8 mm. diameter derived from various sources—granite, gneiss, sandstone, quartz, etc., the quartz grains all worn and faceted with dull finely pitted surfaces. Some ironstaining.
85 0	100 0	Yellow coarse gritty sand, with large ill-sorted grains to pebble size. Pebbles faceted and of various origins; granite, quartz, schist, etc.
100 0	110 0	Pinkish-brown medium quartz sand, the quartz grains worn and faceted with dull surfaces; ironstaining.
110 0	117 0	White to grey gritty sand, with pink feldspar grit and pebbles as above.
117 0	120 0	Pale-grey gritty clay.
120 0	126 0	Pale blue-grey gritty clay.
126 0	132 0	Blue-grey gritty sand and clay, with broken fragments of pebbles of various origins—granite, quartz, etc.—up to 10 mm. diameter.
132 0	140 0	Blue-grey clayey sand, with pebbles up to 15 mm. of quartz, sandstone, quartz-mica schist, etc., all worn with dull surfaces and mostly faceted. Medium quartz grains subrounded to rounded with dull surfaces.
140 0	160 0	Pale-grey clayey sand as above.
160 0	170 0	Grey pebbly sandy clay, with pebbles to 15 mm. diameter of various kinds, worn and faceted with dull surfaces; medium grain similar to 132-140 feet.
170 0	190 0	Brown pebbly clay.
190 0	193 0	Buff clay, with some fine sand.
193 0	225 0	Blue-grey and chocolate sandy and pebbly clay, with broken pebbles up to 18 mm. diameter of various kinds—granite, etc.—faceted, with dull surfaces.
225 0	260 0	Blue-grey pebbly clay.
260 0	349 0	Chocolate gritty and pebbly clay and clayey sand, with pebbles of diverse origins.
349 0 (core)		Chocolate pebbly sand, with a little clay, consisting mainly of medium quartz grains with pebbles of diverse kinds, many broken by the drill, otherwise faceted and worn, with dull surfaces; the chocolate colour originates from the clay which appears to be derived from glaciation of Precambrian chocolate shales.
349 0	450 0	Chocolate sandy and pebbly clay as above.
450 0 (core)		Chocolate sandy clay, with small pebbles, mostly faceted with flat surfaces, of diverse kinds—granite, quartz-mica schist, quartz, etc. Fine fraction mainly of clear quartz grains with uneven pitted surfaces.
450 0	500 0	Chocolate sandy and pebbly clay as above.
500 0	530 0	Dark bluish-grey siliceous claystones, with abundant arenaceous foraminifera. The washed residues consist almost entirely of broken and deflated tests of <i>Hyperammina</i> and <i>Ammonovertella</i> , with medium subrounded to subangular quartz grains, mostly pitted on the surface, pyrite, garnet, rutile.
530 0	535 0	Bluish-grey sandy claystone, with chocolate-brown bands, medium subangular to subrounded quartz grains, grains of miscellaneous rock material, garnet, rutile. Foraminifera dominated by <i>Hyperammina acicula</i> .
535 0	543 0	Greenish-grey and grey claystones, less arenaceous than above, with small pebbles including one of dark blue-grey limestone. A single broken test of <i>Hyperammina</i> .
543 0	552 0	Light chocolate claystone, with irregular arenaceous partings, miscellaneous pebbles and a single test of <i>Hyperammina</i> .
552 0	554 0	As above.
554 0	565 0	Claystones as above.
565 0	566 2	Green-grey claystones as above, with <i>Hyperammina acicula</i> .

Depth		Description
From ft. in.	To ft. in.	
566 2	567 0	Medium-white calcareous quartz sandstone, with abundant heavy minerals mostly garnet and rutile, with accessories chalcocopyrite, biotite, epidote, azurite, magnetite, zircon, limonite.
567 0	575 0	White gritty, quartz sand, with limestone and chocolate shale pebbles, and heavy minerals as above. <i>Hyperammina</i> present 567-570 feet.
575 0	595 6	Light-brown gritty calcareous fine sand and grit, with heavy minerals as above, and foraminifera.
595 6	605 0	Light-brown fine calcareous sand and grit.

Diamond Drill

		Diamond drilling commenced at 616ft., continuous core being recovered below this depth.
616 0	620 0	Dark-grey dense crystalline limestone, irregularly banded in light and dark grey, with abundant stylolites.
620 0	629 9	Dark-grey and grey finely banded concretionary dense limestone.
629 9	632 0	Dark-grey concretionary finely banded limestone.
632 0	634 0	As above, with calcite vein.
634 0	639 0	Dark-grey dense concretionary limestone.
639 0	640 3	
640 3	655 0	Dark- and light-grey finely bedded dense limestone, with stylolites.
655 0	659 3	Dark-and light-grey concretionary limestone.
659 3	664 10	Dark- and light-grey finely banded limestone.
664 10	681 5	Dark- and light-grey finely banded limestone, with stylolites.
681 5	721 6	Banded concretionary limestone as above, with bands of gypsum interbedded with dolomite at 711ft. (Petrological Report A1364/56).
721 6	742 0	Grey argillaceous limestone, with pyrite on the laminae; sandy in places, with small slump structures; red in colour and more arenaceous at 725 feet.
742 0	743 0	Red and grey mottled limestone.
743 0	748 10	Grey argillaceous and somewhat cellular limestone.
748 10	750 8	
750 8	766 2	Grey finely laminated argillaceous limestone.
766 2	772 0	Grey banded argillaceous limestone and calcareous shale with gypsum bands and dolomite; some barite. (Pet. Rep. P69/60.)
772 0	810 0	Chocolate banded dense siltstone, with calcite, dolomite and gypsum bands (P. 70/60).
810 0	815 11	Grey fine siltstone, slightly calcareous in bands; some irregular bedding.
815 11	864 6	Grey fine siltstone as above, with lighter coloured calcareous bands (Pet. Rep. A.1369/56).
864 6	871 0	Dark-grey impure cellular limestone, with white flecks of calcite; some small vughs. Galena at 864ft. 6in. and 871 feet.
871 0	884 0	Dark reddish-grey and grey finely irregularly bedded dense siltstone.
884 0	884 6	Dark-red and reddish-grey elastic arkosic band.
884 6	898 10	Dark reddish- and greenish-grey siltstone; red at 886-887ft. 6in.; small slump structures at 888ft. and 897ft. Evidence of cross-bedding at 898 feet.
898 10	915 7	Siltstone as above; grey colour continues to 902ft. and then reddish with occasional small slumps to 909ft. 6in., then light-brown and grey with fine cross-bedding for 3ft.; then fine-grained mottled greenish-grey dense siltstone.
915 7	928 0	Six feet reddish, then banded light- and dark-grey, with calcareous band.
928 0	938 0	Reddish, then grey cross-bedded with elastic band at 935 feet.
938 0	941 6	Reddish-grey dense (not bedded) very fine massive siltstone, with traces of pyrite.
941 6	945 8	Siltstone as above, with well-marked calcareous bands.
945 8	948 9	Massive siltstone.
948 9	982 4	Eighteen inches laminated and somewhat irregularly banded siltstone, with minor elastic bands $\frac{1}{2}$ in. at 963ft., becoming massive and faintly banded to 982ft. in alternating red and green.

Depth				Description
From	To	ft. in.	ft. in.	
982	4	1,053	6	Six feet banded as before, with calcareous zones; minor clastics at 989ft.; greenish to 994ft. 6in., then reddish only to 1,053ft. 6in., with minor clastic bands and some cross-bedding and slumping (P.87/59).
1,053	6	1,088	0	Chocolate banded siltstones with 2-in. band of coarse clastics at 1,053ft., 1,055ft. (gradual increase in grain size), 1,062ft. 6in., 1,066ft., 1,067ft., 1,070ft., 1,070ft. 6in., 1,071ft. 6in., 1,076ft., 1,077ft., 1,080ft. 6in., 1,081ft. 6in., 1,085ft. 9 inches.
1,088	0	1,116	6	Coarse conglomerate, with light grey-white and pink pebbles of quartzite, limestone (some fossiliferous) of various sizes with interbedded red finer clastic bands grading to siltstone.
1,116	6	1,151	0	Chocolate fine-grained fissile shale breaking into $\frac{1}{4}$ -in. laminae—well laminated, becoming greenish-grey and mottled at 1,140ft. 9in., and then passing into greenish-grey shale at 1,151 feet.
1,151	0	1,177	0	Green-grey laminated shale.
1,177	0	1,194	0	Grey dense limestone.
1,194	0	1,254	0	Grey and light-grey concretionary limestone, with occasional stylolites.
1,254	0	1,288	6	Grey to pink limestone, with abundant archaeocyatha; solution cavities; pyrite at 1,279 feet.
1,288	6	1,303	6	Grey irregularly banded limestone changing to green and pink-buff.
1,303	6			Pale-green shale—3-in. band.
1,304	0	1,485	0	Light-grey massive limestone, with abundant archaeocyatha, and occasional stylolites.
1,485	0	1,504	0	Pinkish mottled massive limestone.
1,504	0	1,578	0	Dark- and light-grey concretionary limestone; calcite veins at 1,560ft. 6in.; limestone coarsely crystalline with numerous calcite veins to 1,578 feet.
1,578	0	1,721	0	Concretionary limestone as above.
1,721	0	2,111	9	Lighter grey, massive, less concretionary than above, becoming banded 1,742-1,746ft. Splashes of pyrite at 1,818-1,819ft., 1,828ft., 1,907 feet.
2,111	9	2,118	3	Only 2ft. recovered; mainly calcite veins.
2,118	3	2,360	0	Light-grey dense limestone, with abundant stylolites; intermittently irregularly banded with carbonaceous material at 2,137ft., 2,153ft.; purple colour of fluorite at 2,209ft.—pyrite traces 2,210ft.; slump and sedimentary breccia structures at 2,221ft.; calcite flecks at 2,230ft.; darker colour at 2,234ft.; sedimentary breccia at 2,316ft.; grey and dark-grey banded, with breccia zones at 2,320ft., continuing to 2,360 feet.
2,360	0	2,362	0	Light pinkish-grey dense finely banded limestone.
2,362	0	2,384	0	Darker-grey limestone, with traces of galena at 2,370ft. 6in. to 2,371ft. in small quartz-calcite veinlets; fluorite at 2,364ft. 6in., lighter band with stylolites 2,373-2,384 feet.
2,384	0	2,386	9	Dark-grey concretionary limestone.
2,386	9	2,409	9	Dark-grey limestone, with sedimentary breccia at 2,405ft., and irregular calcite veinlets.
2,409	9	2,415	9	Vertical irregular calcite vein of varying width containing brecciated limestone fragments.
2,415	9	2,426	0	Dark-grey limestone with calcite veinlets.
2,426	0	2,432	0	Recovered 1ft. dark-grey dense limestone.
2,432	0	2,443	0	Recovered 3ft. dark-grey, interbedded with light pinkish-grey, dense banded limestone.
2,443	0	2,461	9	Light pinkish-grey irregularly banded limestone, with stylolites.
2,461	9	2,469	0	Dark-grey limestone, with calcite veinlets, changing to light-grey limestone with some breccia at 2,465ft., and trace of pyrite at 2,469 feet.
2,469	0	2,480	0	Dark-grey limestone, with calcite veinlets.
2,480	0	2,518	0	Dark-grey dolomitic limestone, with lighter-grey band 2,496-2,498ft. 6in.; calcite vein at 2,498ft. 6in.; carbonaceous material on stylolite parting at 2,506ft. 9 inches.
2,518	0	2,530	0	Mostly dark-grey dolomitic limestone, with calcite veinlets; trace of pyrite at 2,526 feet.

Depth				Description
From	To	ft. in.	ft. in.	
2,530	0	2,547	3	As above, with light dolomitic bands and small slump-breccia structures—2ft. at 2,530ft., 1ft. at 2,540ft.; band at 2,541 feet.
2,547	3	2,558	0	Very pale-grey well-banded dolomite, with darker bands.
2,558	0	2,578	0	Dark-grey brecciated dolomite, with solution cavities at 2,565ft. 6in.-2,567ft.; calcite veins at 2,573 feet.
2,578	0	2,583	0	Light-grey dolomite or dolomitic limestone.
2,583	0	2,594	0	Dark-grey confused dolomite becoming fairly well bedded at 2,591 feet.
2,594	0	2,597	6	Dark-grey flaggy dolomite, with small cavities.
2,597	6	2,635	0	Light-grey, changing gradually to dark-grey dense dolomite, with trace of pyrite at 2,599ft.; carbonaceous material on stylolite parting at 2,602ft.; calcite veinlets at 2,610ft., 2,630ft.; cavities with quartz and calcite at 2,598ft., 2,616ft., 2,639ft., 2,656ft. (P.33/58).
				ft. ft.
				2,611-2,630—7ft. core recovered.
				2,630-2,637—6ft. core recovered.
				2,637-2,654—6ft. core recovered.
				2,654-2,664—5½ft. core recovered.
2,635	0	2,816	3	Grey dense dolomite, with small cavities containing carbonaceous material and calcite; calcite veinlets at 2,741ft. 8in.; 2,744ft. 4in.; trace of pyrite at 2,734ft. 6in.; carbonaceous material on stylolite parting at 2,746ft., 2,748ft., 2,761ft.; breccia zones at 2,759ft., 2,764ft.; black material in breccia zones at 2,789ft.; splash of pyrite in calcite veinlet at 2,810ft. 9in., 2,813ft. 9in. (P.32/58).
2,816	3	2,840	9	Light-grey and grey dolomite, with stylolites masked by carbonaceous material at 2,816ft. 3in., 2,817ft. 3in. and between 2,818ft. and 2,834ft. 3in.; micro-faulting at 2,840 feet.
2,840	9	3,029	0	Dark-grey dense dolomite, with calcite veinlets; carbonaceous matter relatively rare and occurring at 2,861ft., 2,867ft., 2,880ft. 6in., 2,900ft., 2,925ft., 2,933ft. 6in., 2,934ft. 6in., 2,943ft., 2,950ft. 6in.; galena at 2,895ft. 7in.; at 2,895ft. 10in., a ¼-in. vein of carbonaceous material, with calcite and pyrite specks; two slightly shaly bands between 2,896ft. and 2,898ft.; fine crowded stylolites, with traces of carbonaceous material on the partings at 2,918ft.; slump structures at 2,984ft. 5in.; fractured, brecciated, and carbonaceous at 2,990ft. 6 inches.
				ft. in. ft. in.
				2,968 0 - 2,973 6—2ft. core recovered.
				2,973 6 - 2,977 6—1ft. 6in. core recovered.
				2,981 3 - 2,983 5—4in. core recovered.
				2,993 2 - 3,001 9—2ft. 6in. core recovered.
				3,001 9 - 3,004 4—2ft. 3in. core recovered.
				3,004 4 - 3,013 5—1ft. 3in. core recovered.
				3,013 5 - 3,018 5—1ft. 3in. core recovered.
3,029	0	3,075	0	Light-grey massive irregularly bedded dolomite, with stylolites becoming very abundant at 3,046ft. (P.213/53).
3,075	0	3,096	0	Light-grey grading to pinkish-grey dense dolomite, with thin grey partings at 3,079ft.; pyrite at 3,083ft.; colour light pinkish grey to 3,096 feet.
3,096	0	3,121	0	Pinkish-grey hard massive banded dolomite, with red and grey shale band at 3,104ft.; pink bands of fine arkose with pink pellets and pyrite at 3,118ft. 6in. (P.214/58, P.215/58).
3,121	0	3,141	9	Pink and grey irregularly banded dolomitic arkose, with coarse dolomitic limestone at 3,125ft. 6in., 3,131-3,131ft. 8in., and 3,133-3,134ft. 9in.; pyrite scattered in small flecks at 3,137ft.; dolomitic sandstone 3,130-3,138ft.; grit 3,139-3,141ft. 9 inches.
3,141	9	3,174	0	Fine- or medium-grained irregularly banded arkose with pyrite at 3,143ft.; locally calcareous and dolomitic; coarse band 3,147-3,147ft. 6in., with large pink felspars to 10 mm. (P.216/58).

Depth		Description
From ft. in.	To ft. in.	
3,174	0	3,176 0 Dark-grey calcareous and carbonaceous siltstone.
3,176	0	3,184 0 Grey coarse- to medium-grained arkose with pink feldspars.
3,184	0	3,261 0 Grey arkose—finer grained—becoming coarse again at 3,193ft., and then medium to fine at 3,196ft.; carbonaceous at 3,191ft.; coarse grained with carbonaceous pellets at 3,214ft. 9in.; continuing fine- to medium-grained arkose, with black irregular banding and pink feldspars abundant again at 3,255ft.; dark carbonaceous partings at 3,255ft. 6in.; 3,256-3,258ft. arkose as above, with carbonaceous shale partings.
3,261	3	Coarse-grained grey arkose, with pink feldspars to 4 mm. length and grit quartz to 4 mm. End of hole at 3,261ft. 3 inches.

Australian Mineral Development Laboratories Petrology Reports have been issued for the intervals indicated above by sample numbers, e.g., 2,656ft. (P.33/58).

Stansbury Bore—Lithological Log

STANSBURY NO. 1 BORE

Location—Section 117, hundred of Dalrymple

Percussion Drill

Depth		Description
From ft. in.	To ft. in.	
Surface	0 6	Brown sandy loam soil and surface kunkar.
0 6	15 0	Buff sandy marl and nodular kunkar.
15 0	20 0	Buff calcareous sand and kunkar, with sub-rounded to angular quartz grains, nodules of kunkar, calcite fragments, occasional garnet grain. <i>Elphidium advenum</i> present.
20 0	25 0	Buff calcareous sand and kunkar, with <i>Cibicides refulgens</i> .
25 0	30 0	Buff calcareous sandstone and kunkar, with a few foraminifera.
30 0	35 0	Yellow calcareous sandstone, with abundant foraminifera and bryozoa. <i>Sherbornina atkinsoni</i> and <i>Notorotalia crassimura</i> dominant.
35 0	40 0	Yellow sandy bryozoal limestone, with abundant foraminifera of many species including <i>Sherbornina atkinsoni</i> and <i>Cibicides vortex</i> .
40 0	45 0	Yellow sandy bryozoal limestone, with abundant foraminifera of many species, dominated by <i>Sherbornina atkinsoni</i> , <i>Cibicides vortex</i> , <i>Notorotalia crassimura</i> .
45 0	50 0	Yellow sandy bryozoal limestone, with similar microfauna.
50 0	55 0	Yellow sandy bryozoal limestone, with microfauna as above.
55 0	75 0	Yellow sandy bryozoal limestone, with <i>Sherbornina atkinsoni</i> , <i>Cibicidella variabilis</i> , <i>Planorbulina mediterraneensis</i> , <i>Heronallenia lingulata</i> .
75 0	80 0	Yellow sandy bryozoal limestone, with <i>Eponides repandus</i> , <i>Stomatorbina concentrica</i> , <i>Cibicides umbonifer</i> .
80 0	85 0	Yellow sandy bryozoal limestone, with abundant foraminifera dominated by <i>Stomatorbina concentrica</i> .
85 0	90 0	Yellow fairly hard partially recrystallized bryozoal limestone; meagre foraminiferal assemblage.
90 0	100 0	Yellow bryozoal limestone, with some glauconite, rutile; foraminifera include <i>Cibicides umbonifer</i> , <i>Anomalina perthensis</i> .
100 0	115 0	Brown-yellow ferruginous sandy limestone, with fragments of ironstained calcite, bryozoa, etc., polished quartz grains stained with limonite, garnet. <i>Cibicides umbonifer</i> , <i>C. vortex</i> , and associated species of <i>Cibicides</i> , <i>Angulogerina</i> .
115 0	125 0	Brown-yellow ferruginous limestone, with polished quartz grains. Echinoids <i>Fibularia</i> and <i>Scutellina</i> .
125 0	130 0	Yellow-brown calcareous grit, with sub-rounded and polished quartz grains of grit size, abundant limonite; few foraminifera.

Depth		Description
From ft. in.	To ft. in.	
130 0	134 0	Yellow-brown calcareous gritty sandstone, with worn bryozoa subangular mostly polished quartz grains, grains of limonite; few isolated foraminifera. Fragments of schist.
134 0	145 0	Brown-grey gritty clay. Sludge workings consist of a mixture of water-worn quartz sands, bryozoa, etc., with fragments of schist, polished quartz grains, limonite.
145 0	171 0	Brown-grey sandy to gritty clay, with limonitic polished subrounded to subangular quartz grains, pink garnet, biotite, grey quartz, granite, schist and cavings from overlying Tertiary.
171 0 (core)	171 9	Grey sandy to gritty boulder clay, with clear quartz grains, angular to subrounded with flat faces, opalescent quartz grains, quartz-mica schist, pyrite, biotite, garnet, opaque minerals, quartzite, and granite pebbles.
171 9	185 0	As core above.
185 0	190 0	Brownish-grey boulder clay, with subrounded or subangular quartz, mainly with etched surfaces, grit size pebbles of various origins, garnet, biotite.
190 0 (core)	190 9	Brownish-grey sandy boulder clay, with intergrowths of pyrite and gypsum and some calcite. Pebbles of various origins, pyrite dodecahedra.
190 9	205 0	As core above.
205 0	210 0	Brown-grey sandy boulder clay, with pebbles of various origins, pyrite, garnet, opaline quartz, chlorite-schist. First Permian foraminifera dominated by <i>Hyperammina acicula</i> and <i>Ammodiscus oonahensis</i> .
210 0	225 0	Grey sandy clay, with angular to rounded clear quartz grains with etched and pitted surfaces, garnet, pyrite, biotite, rutile, schist particles, opaline quartz; abundant arenaceous foraminifera dominated by <i>Ammodiscus oonahensis</i> , which is sometimes replaced by pyrite; pyritized wood.
225 0	250 0	Dark-grey clay, with pebbles of Cambrian limestone and grey sandstone, abundant pyrite, white calcite aggregates, quartzitic limestone with pyrite intergrowths, garnet.
250 0	258 0	Brown-grey sandy clay, as core below.
258 0 (core)	258 8	Brown-grey sandy clay, with subangular to rounded quartz, opaline quartz, garnet.
258 8	262 6	Brown-grey sandy clay, as above.
262 6	270 0	Grey sand, with patches of blue-grey calcareous sandy clay.
270 0	285 0	Greenish sandy clay, with fine to medium-coarse angular to rounded quartz grains mostly with etched and pitted surfaces, pyrite, rutile, garnet.
285 0	365 0	Light-greenish sand and light-grey sandy clay, with pockets of blue-grey clay, abundant rounded to angular clear quartz and pyrite, grey limestone, garnet, quartz-mica schist.
365 0	365 9	Blue-grey sandy clay, with pyrite nodules, pebbles, garnet, etc. Abundant <i>Hyperammina acicula</i> ; <i>Ammovevertella</i> encrusting pebble.
365 0	370 0	Blue-grey sandy clay.
370 0	375 0	Blue-grey sandy clay, with <i>Hyperammina acicula</i> .
375 0	385 0	Blue-grey sandy clay, with assorted pebbles, coarse rounded to subrounded clear quartz, fine angular clear quartz, pyrite, garnet, rutile, quartz-pyrite nodules, biotite.
385 0	390 0	Light-grey sandy bedded clay, with angular to subrounded medium to coarse quartz, garnet, pyrite, chlorite, miscellaneous pebbles and grit, pyrite and quartz intergrowths.
390 0 (core)	390 9	Light-grey bedded clay and sand, with white specks, angular to subangular quartz grains with etched surfaces. Small pebbles of miscellaneous origins, garnet, biotite, rutile.
390 9	400 0	Grey fine sandy clay.
400 0 (core)	401 0	Light-grey bedded sand and clay, with pebbles.
401 0	410 0	Grey sandy clay.
410 0 (core)	411 6	Grey sandy clay, with medium and some fine clear quartz, subrounded and of uniform size with etched and pitted surfaces; garnet, rutile, pyrite, granite, and schist pebbles. Scratched pebble.

Depth		To	Description
From	ft. in.		
411	6	420 0	Light-grey sandy clay.
420	0	420 9	Grey sandy boulder clay, with medium to coarse rounded to subangular quartz to grit size; pebbles of various origins, sometimes faceted.
	(core)		
420	9	430 0	Boulder clay, as above.
430	0	430 6	Grey sandy boulder clay with pebbles of greywacke, schist, etc.; spherical pyritic nodules, garnet, rutile.
	(core)		
430	6	445 0	Boulder clay, as above.
445	0	445 6	Grey sandy boulder clay, with assorted pebbles.
	(core)		
445	6	464 6	Grey sandy boulder clay, as above.
464	6	465 0	Grey sandy boulder clay.
	(core)		
465	0	466 3	Grey silt, clay, and fine sand, with assorted pebbles.
466	3	466 11	Grey sandy clay and fine sand, with subangular to subrounded medium-coarse quartz grains, various pebbles, opaline quartz, garnet, rutile, pyrite.
	(core)		
466	11	483 0	Core at 470ft. 4in.-471ft. and 482ft. 6in.-483ft. Sandy boulder clay, as above.
483	0	505 0	Light-grey clayey sand, with pebbles.
505	0	506 6	Light-grey clayey sand, with medium rounded to subrounded quartz, garnet, rutile, abundant pyrite, pebbles of pyritic sandstone, granite.
	(core)		
506	6	515 0	Light-grey clayey fine sand.
515	0	535 0	Brownish-grey clayey sand, with coarse rounded quartz grains, some small granite pebbles, chlorite, medium subangular to subrounded quartz grains.
535	0	536 1	Light-grey and light-brown clayey sand, with some small grey sandstone pebbles, medium rounded to subrounded quartz grains, pyrite, garnet, rutile; matrix kaolinitic.
536	1	600 0	Light blue-grey boulder clay, as above, with medium coarse subrounded fairly well sorted quartz grains, occasional pink garnet, pyrite, occasional granite and quartz pebbles.
600	0	619 0	Light blue-grey sandy boulder clay, as above, with rounded to subrounded polished and angular quartz, grit size grains of various origins—schist, granite, quartzite, garnet, pyrite.
619	0	624 0	Light blue-grey sandy boulder clay, as above, with pyrite nodule 20 mm. long.
624	0	657 0	Light blue-grey sandy boulder clay.
657	0	(core)	Brown-grey boulder clay, with chocolate coloured clay matrix.
657	0	664 0	Brownish-grey boulder clay; chocolate matrix.
664	0	669 0	Brownish-grey boulder clay, with pebbles of granite, quartz, etc.; pyrite; chocolate matrix.
669	0	684 0	Boulder clay, as above.
684	0	689 0	Grey boulder clay, with dark-grey pebbles; calcareous and pyritic.
689	0	714 0	Boulder clay, as above, with grit size pebbles.
714	0	770 0	Grey sandy boulder clay, as above, with mainly granite and quartzite pebbles.
770	0	775 0	Grey sandy boulder clay, with few small pebbles of granite and other rocks; coarse to medium rounded to subangular quartz, pyrite, pink garnet. Abundant foraminifera dominated by <i>Tolypammina undulata</i> and <i>Ammovertella inclusa</i> .
775	0	800 0	Grey sandy boulder clay, with abundant dark-grey pebbles, medium to coarse subrounded quartz, garnet.
800	0	810 0	Brown-grey sandy boulder clay, with abundant pebbles of granite and dark-grey metamorphic rocks, quartz and others of diverse origins—medium to coarse subangular quartz grains, garnet. Matrix chocolate coloured.
810	0	815 0	Grey sandy boulder clay, with small pebbles of various kinds, much ferruginous matter, pyrite, subrounded coarse to medium quartz; few tests of <i>Ammovertella inclusa</i> and <i>Hyperammina acicula</i> .
815	0	825 0	Boulder clay, as above, with abundant quartzite and granite pebbles.
825	0	830 0	Boulder clay, as above, with foraminifera dominated by <i>Ammovertella inclusa</i> .

Depth		Description
From ft. in.	To ft. in.	
830 0	840 0	Pale-grey boulder clay, with <i>Hyperammmina acicula</i> , <i>Ammovertella inclusa</i> , <i>Tolypammmina undulata</i> .
840 0	845 0	Pale-grey boulder clay, as above, with abundant foraminifera, principally <i>Hyperammmina acicula</i> and <i>Ammovertella inclusa</i> .
845 0	855 0	Boulder clay as above; one ostracode.
855 0	920 0	Grey sandy boulder clay, with abundant pebbles of various kinds, rounded to subrounded quartz, pyrite, garnet.

Diamond Drill

Diamond drilling commenced at 920ft., below which the well was cored.		
920 0	932 0	Reddish fine-grained sandstone, with $\frac{1}{2}$ -in. calcite band at 921ft. 6 inches.
932 0	952 9	Reddish-buff sandstone, calcareous at 934ft. 6in.; green band below, with green clay flakes at 952ft. 9 inches.
952 9	1,003 9	Red and buff cross-bedded sandstone, grading to alternating green and red sandstone with chocolate and green clay flakes at 964ft.; calcite vein at 965ft.; finer grained and cross-bedded at 991ft., 971-993ft. 3in. Two feet core recovered.
1,003 9	1,072 0	Banded red and buff fine-grained sandstone, cross-bedded in places; calcite vein at 1,050ft.
1,072 0	1,135 0	Buff fine-grained sandstone, with green clay flakes at 1,076ft.; arkosic and slightly calcareous at 1,091ft. and 1,097ft.; becoming redder and somewhat mottled below 1,111 feet.
1,135 0	1,150 6	Recovery, 5ft. 6in.—slightly inclined to bedding. Chocolate shale, highly crushed and brecciated.
1,150 6	1,164 0	Core recovery, 6 inches.
1,164 0	1,181 0	Reddish-brown well-banded slightly calcareous sandstone.
		ft. ft.
1,181 0	1,234 0	1,181-1,201—5 $\frac{1}{2}$ ft. core recovered. 1,201-1,210—1ft. 6in. core recovered. 1,210-1,220—1ft. core recovered. 1,220-1,234—1ft. 6in. core recovered.
1,150 0	1,210 0	Sludge samples—chocolate shale.
1,210 0	1,370 0	Reddish-buff fine to medium sandstone, with fine mica flakes and chocolate shale band at (?)1,345 feet.
End of hole at 1,370 feet.		

References

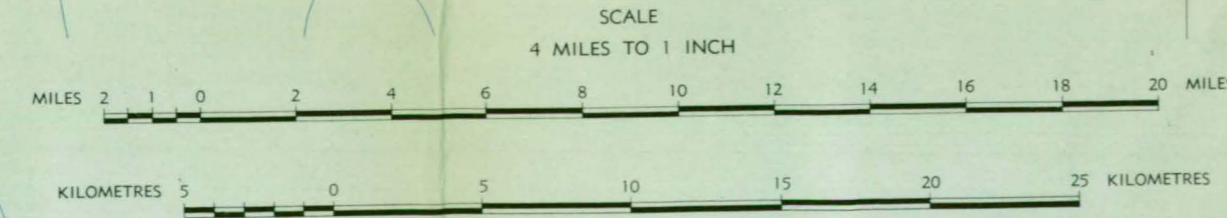
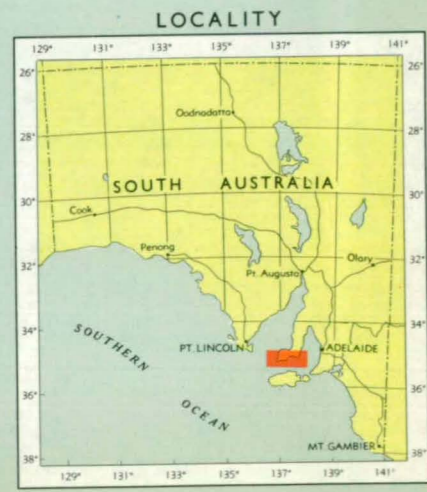
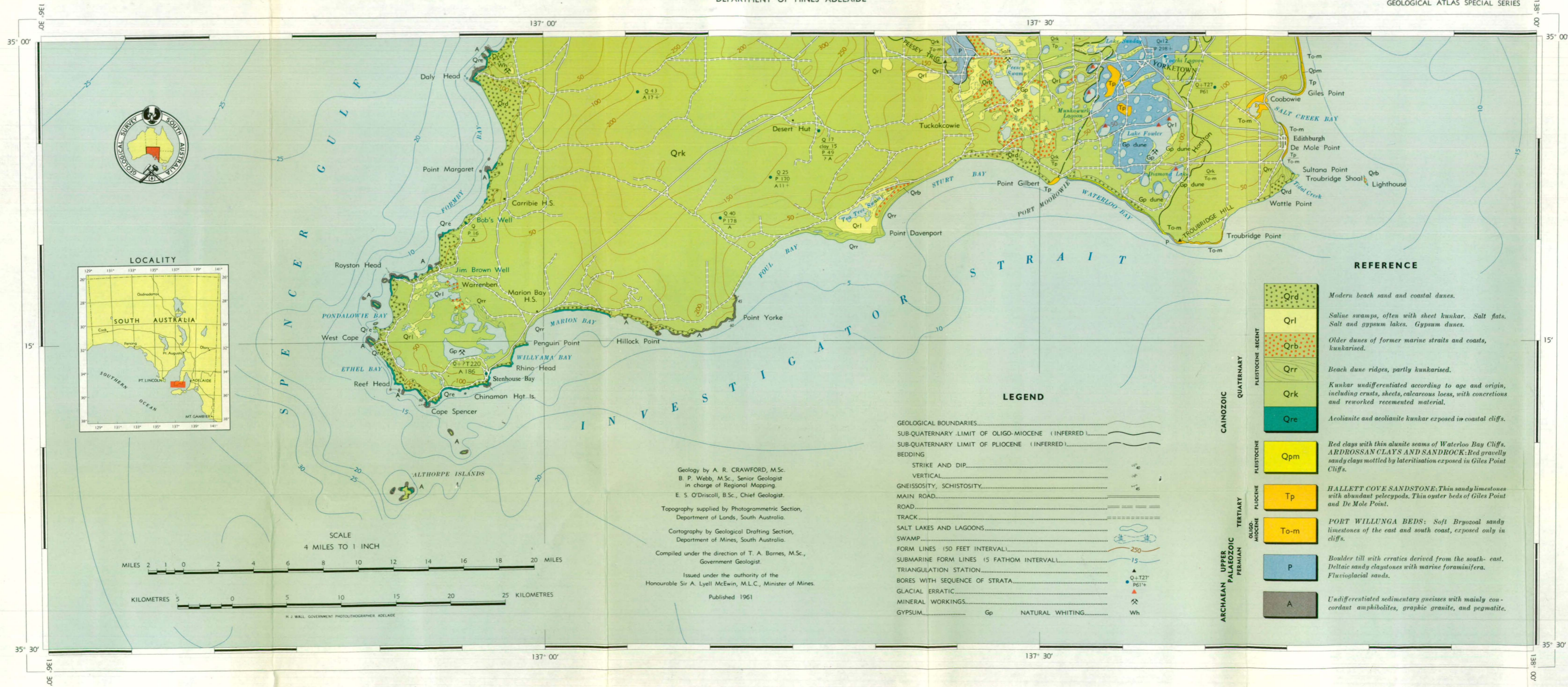
- Crespin, I., 1958—'Permian Foraminifera of Australia.' Dept. Nat. Dev., *Bur. Min. Res. Geol. Geoph. Bull.* 48, pp. 1-207, pls. 1-33, tab. I-X, map.
- Daily, B., 1957—'Progress report on the Cambrian Sequence met with in the Minlaton Stratigraphic Bore 1, Section 153, Hd. Ramsay, Yorke Peninsula, South Australia.' (Unpublished.)
- Glaessner, M. F. and Parkin, L. W. (Ed.), 1958—'The Geology of South Australia.' *J. geol. Soc. Aust.* 5 (2), pp. 1-163, figs. 1-26, pls. 1-11, 5 maps.
- Horwitz, R. C., Thomson, B. P., and Webb, B. P., 1959—'The Cambrian-Pre-cambrian boundary in the eastern Mt. Lofty Ranges Region, South Australia.' *Trans. Roy. Soc. S. Aust.* 82, pp. 205-218, pls. 1-3.
- Johnson, W., 1960—'Future oil exploration—Gulf St. Vincent Region.' *S. Aust. Min. Rev.* 110, pp. 126-133.
- Ludbrook, N. H., 1957—'Permian foraminifera in South Australia.' *Aust. J. Sci.* 19 (4), Feb., pp. 161-162.
- Ludbrook, N. H., 1961—'Permian to Cretaceous Subsurface Stratigraphy between Lake Phillipson and the Peake and Denison Ranges, South Australia.' *Trans. Roy. Soc. S. Aust.* 85, pp. 67-80.
- Thomson, B. P., 1961—'Syngeneses in ore deposition as related to the Cambrian geology of South Australia.' (Paper presented to A.N.Z.A.A.S. meeting, Brisbane 1961, unpublished).
- Webb, B. P. and Horwitz, R. C., 1959—'Notes on the boundaries of the Marinoan Series of the Adelaide System.' *Aust. J. Sci.* 21 (6), p. 188.

18th August, 1961.

INVESTIGATOR

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES ADELAIDE

GEOLOGICAL ATLAS SPECIAL SERIES



Geology by A. R. CRAWFORD, M.Sc.
B. P. Webb, M.Sc., Senior Geologist
in charge of Regional Mapping.
E. S. O'Driscoll, B.Sc., Chief Geologist.

Topography supplied by Photogrammetric Section,
Department of Lands, South Australia.

Cartography by Geological Drafting Section,
Department of Mines, South Australia.

Compiled under the direction of T. A. Barnes, M.Sc.,
Government Geologist.

Issued under the authority of the
Honourable Sir A. Lyell McEwin, M.L.C., Minister of Mines.

Published 1961

LEGEND

GEOLOGICAL BOUNDARIES.....

SUB-QUATERNARY LIMIT OF OLIGO-MIOCENE (INFERRED).....

SUB-QUATERNARY LIMIT OF PIOCENE (INFERRED).....

BEDDING

STRIKE AND DIP.....

VERTICAL.....

GNEISSOSITY, SCHISTOSITY.....

MAIN ROAD.....

ROAD.....

TRACK.....

SALT LAKES AND LAGOONS.....

SWAMP.....

FORM LINES (50 FEET INTERVAL).....

SUBMARINE FORM LINES (5 FATHOM INTERVAL).....

TRIANGULATION STATION.....

BORES WITH SEQUENCE OF STRATA.....

GLACIAL ERRATIC.....

MINERAL WORKINGS.....

GYPSUM..... Gp NATURAL WHITING..... Wh

REFERENCE

CAINOZOIC

QUATERNARY

PLEISTOCENE-RECENT

Qrd Modern beach sand and coastal dunes.

Qrl Saline swamps, often with sheet kunkar. Salt flats. Salt and gypsum lakes. Gypsum dunes.

Qrb Older dunes of former marine straits and coasts, kunkarised.

Qrr Beach dune ridges, partly kunkarised.

Qrk Kunkar undifferentiated according to age and origin, including crusts, sheets, calcareous loess, with concretions and reworked recent material.

Qre Aeolianite and aeolianite kunkar exposed in coastal cliffs.

PLEISTOCENE

Qpm Red clays with thin alunite seams of Waterloo Bay Cliffs. ARDROSSAN CLAYS AND SANDROCK: Red gravelly sandy clays mottled by lateritisation exposed in Giles Point Cliffs.

PLIOCENE

Tp HALLETT COVE SANDSTONE: Thin sandy limestones with abundant pelecypods. Thin oyster beds of Giles Point and De Mole Point.

OLIGO-MIOCENE

To-m PORT WILLUNGA BEDS: Soft Bryozoa sandy limestones of the east and south coast, exposed only in cliffs.

TERTIARY

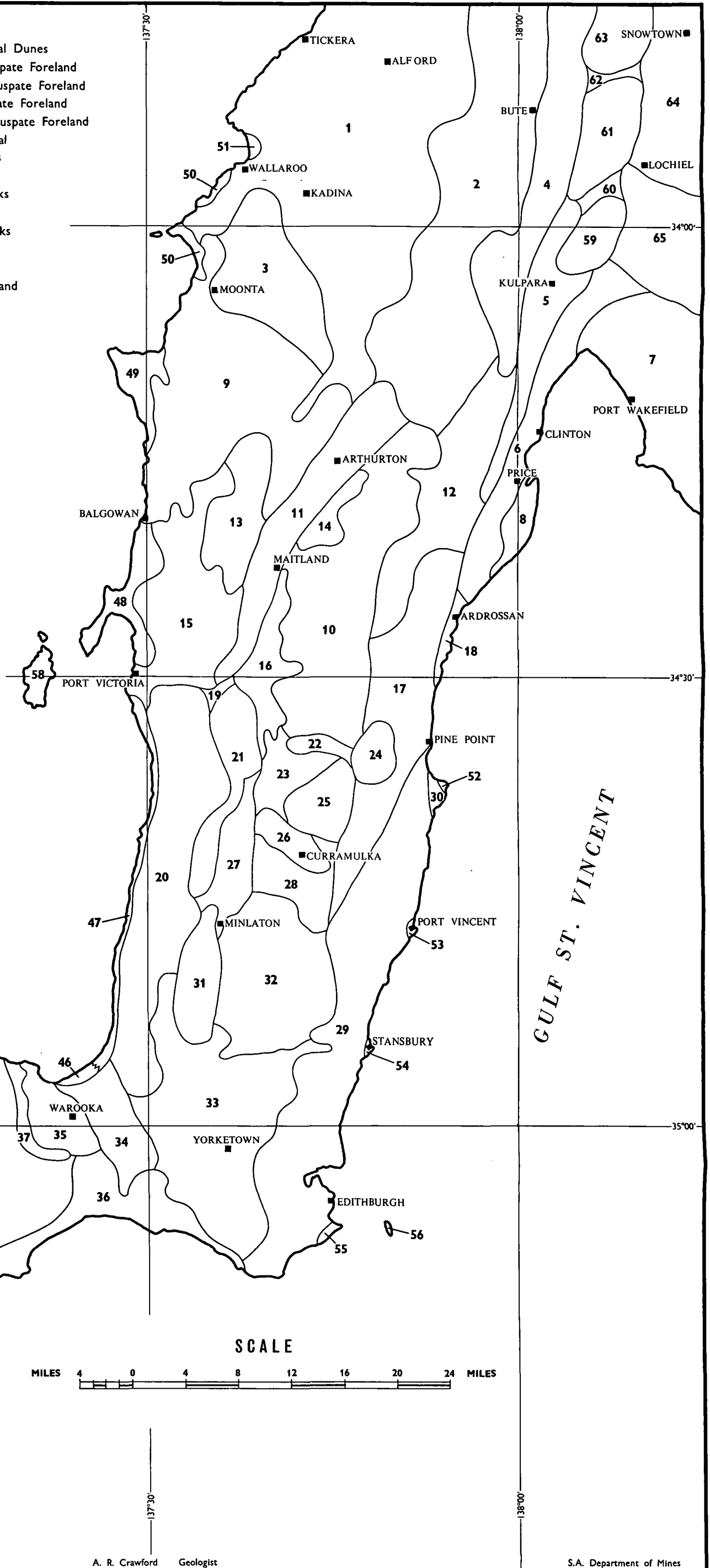
PERMIAN

P Boulder till with erratics derived from the south-east. Dellaic sandy claystones with marine foraminifera. Fluvio-glacial sands.

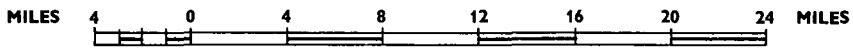
A Undifferentiated sedimentary gneisses with mainly concordant amphibolites, graphic granite, and pegmatite.

KEY

- 1 Kadina Plain
- 2 Paskeville-Bute Plateau
- 3 Moonta Plain
- 4 Melton-Ninnes Valley
- 5 Kulpara Plateau
- 6 Clinton Coastal Slope
- 7 Port Wakefield Coastal Plain
- 8 Price Mangrove Swamp
- 9 Tiparra Seif Dune Belt
- 10 Central Highland
- 11 Arthurton-Maitland Ridge
- 12 Cunningham Plain
- 13 Bagnall Highland
- 14 North Maitland Flat
- 15 Mission Plain
- 16 Yorke Valley
- 17 Eastern Upland
- 18 Ardrossan Coastal Slope
- 19 Urania Gap
- 20 Wauraltee-Minlacowie Coastal Plain
- 21 Mount Rat Ridge
- 22 Teemu Gap
- 23 Central Seif Dune Belt
- 24 Six Road Depression
- 25 Yuruga Highland
- 26 Curramulka Basin
- 27 Koolywurtie-Minlaton Depression
- 28 Ramsay Upland
- 29 East Coast Plateau
- 30 Port Julia Coastal Plain
- 31 Roger Ridge
- 32 Yacca Seif Dune Belt
- 33 Salt Lake District
- 34 Peesey Swamp
- 35 Warooka Plateau
- 36 Davenport-Moorowie Coastal Complex
- 37 Orrle Cowie Swamp
- 38 South Western Upland
- 39 Wurlie Swamp Basin
- 40 Deberg Plain
- 41 Marion Basin
- 42 Gypsum Lake District
- 43 Cape Spencer Plateau
- 44 Daly Coastal Swamp
- 45 West Soultter Beach Dune Ridges
- 46 Hardwicke Beach Dune Ridges
- 47 Rickaby Coastal Dunes
- 48 Point Pearce Coastal Complex
- 49 Cape Elizabeth Coastal Complex
- 50 Warburto Coastal Complex
- 51 Wallaroo Coastal Dunes
- 52 Black Point Cuspate Foreland
- 53 Port Vincent Cuspate Foreland
- 54 Stansbury Cuspate Foreland
- 55 Sultana Point Cuspate Foreland
- 56 Troubridge Shoal
- 57 Althorpe Islands
- 58 Wardang Island
- 59 South Hummocks
- 60 Lochiel Gap
- 61 North Hummocks
- 62 Barunga Gap
- 63 Barunga Range
- 64 Bumbunga Lowland
- 65 Magulla Plateau



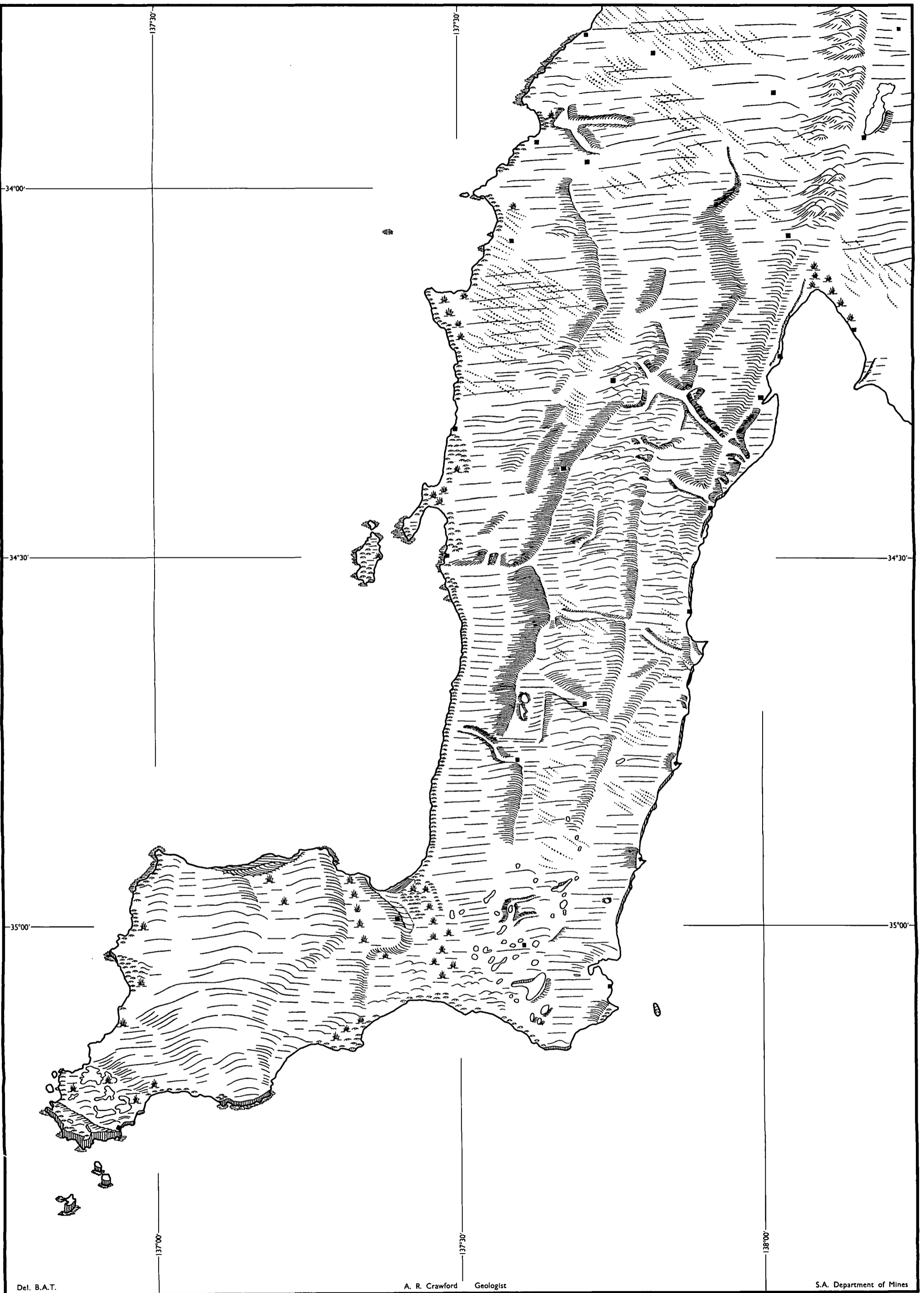
SCALE



A. R. Crawford Geologist

S.A. Department of Mines

Fig. 6— Geomorphic Units



Del. B.A.T.

A. R. Crawford Geologist

S.A. Department of Mines

Fig. 5 — Geomorphic Sketch

Geology of Yorke Peninsula

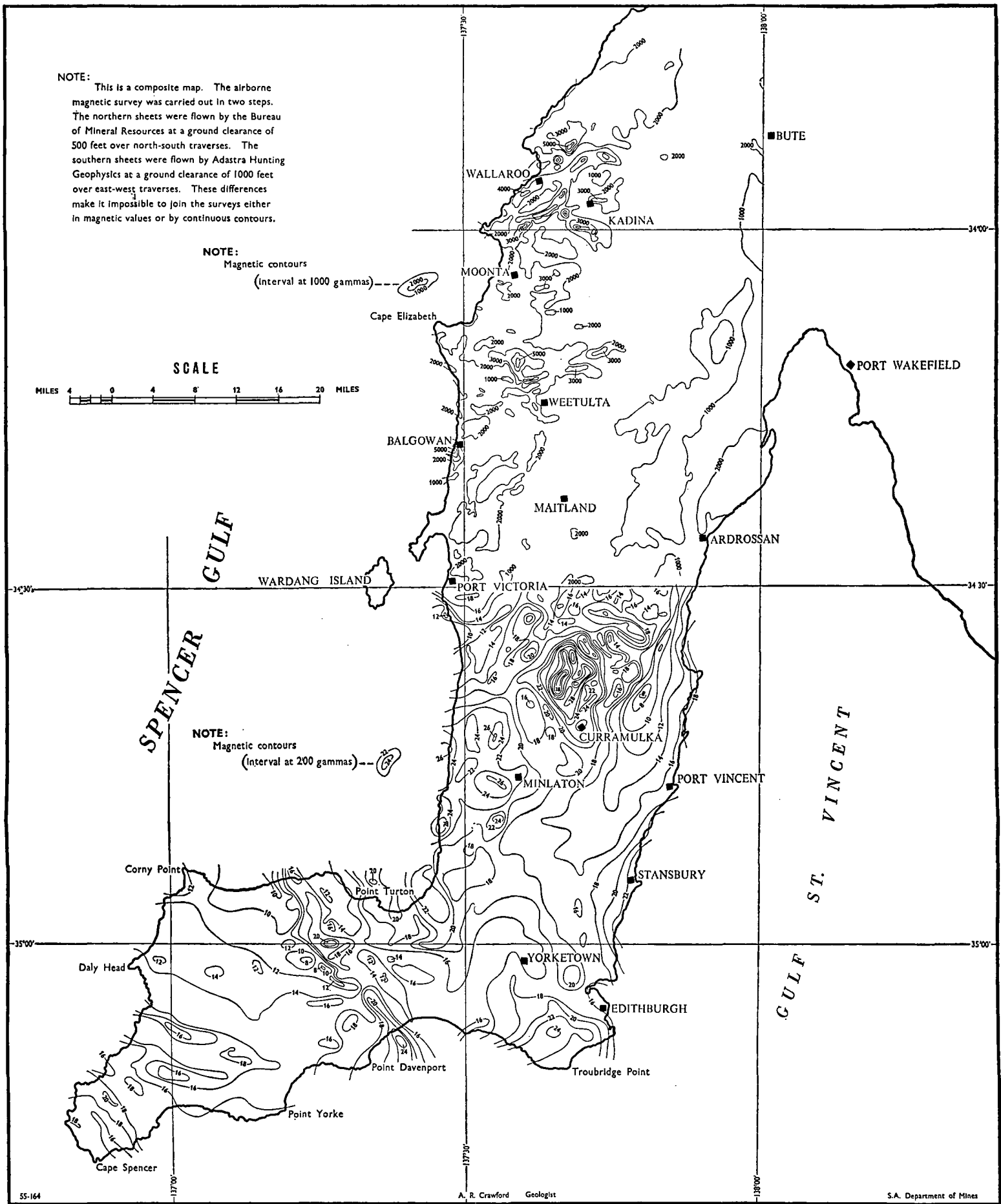
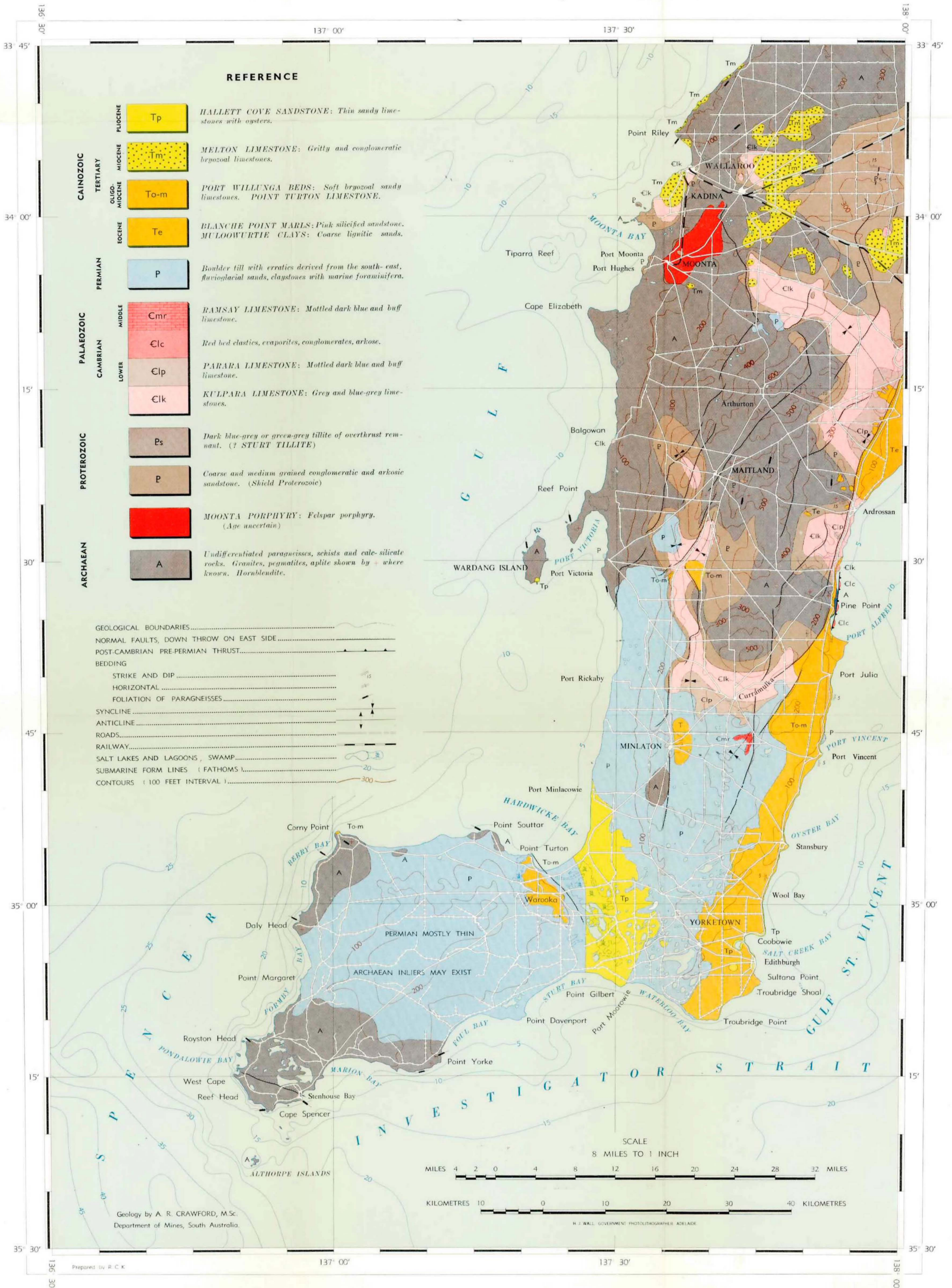


Fig. 4—Map of Yorke Peninsula—Showing aeromagnetic anomalies

YORKE PENINSULA

GENERALISED GEOLOGICAL MAP OF PRE-QUATERNARY ROCKS



MAITLAND

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES ADELAIDE

AUSTRALIA 1:253,400
Map Corners from data available at publication

4 MILE GEOLOGICAL SERIES SHEET 1 5312 ZONE 5

FIRST EDITION 1960



REFERENCE

	Alluvium and low angle slope deposits.
	Saline swamps, often with sheet heath. Salt flats. Salt lakes with gypsum dunes.
	Beach and back shore dunes.
	Older dunes of former marine strait in Peasey Swamp. Redistributed sand spreads and low dunes. Downwash. High angle slope deposits and fault scarp debris.
	Raised beaches and marine shelly limestones. Beach dune ridges.
	Older alluvial clays with ferruginous pisolites and feldspathic and quartz grit.
	Older level desert soil dunes, often strongly hummocked internally. Associated sand spreads.
	Kunkur, undifferentiated according to age and origin, including crabs, shells, calcareous loess with concretions and riverbed, reworked material. Coastal alluvium.
	Red current-beded often gravelly sandy clays with thin silty seams of coastal shales. ADELIAN CLAYS AND SANDROCK. Indurated gritty sandy mottled clays and silts with gravel bands.
	HALLETT COVE SANDSTONE. Thin sandy limestones with abundant pelecypods.
	MELTON LIMESTONE. Sandy and gritty limestone and conglomeratic cross-bedded bryozoan limestones with Leptodactylina.
	PORT WILLUNGA BEDS. Soft bryozoan sandy limestones of the east coast, overlapping PORT JULIA GREENSAND. Limestone of France. POINT TURTON LIMESTONE with Victoriaia.
	BLANCHE POINT MARLS. Yellow and pink silty shales with Turritella alabone of the Adelaide-Price area. Quarternary sandstone of Rocky Point. MULDOONWURTE CLAYS. Obolous sandy clays with lenses of shaly limestone. Cross-bedded coarse sands with lignite of Kulpura. Price and Ardrossan.
	Boulder till with erratics derived from the south-east. Deltic sandy claystones. Fluvio-lacustrine sands.
	RAMSAY LIMESTONE. Mottled dark blue and buff argillaceous limestone with Trirachia and Eridactylina.
	Red bed clastics and evaporites. Conglomerates, sandstone breccias and arkose of Rocky Point and Pine Point.
	PARARA LIMESTONE. Mottled dark blue and buff argillaceous limestone with Paramia and Archaeonectria.
	KULPARA LIMESTONE. Grey and blue-grey limestones with "Collenia" and Archaeonectria in upper part. White shales at base.
	Massive quartz conglomerates and feldspathic cross-bedded sandstones, locally passing upwards into fine-grained red sandstones and shales.
	Undifferentiated sedimentary gneisses, schists and calc-siliceous rocks. Granites, pegmatites, aplite (shown by symbol +). Hornblende. MOONTA PORPHYRY (unexposed).

	OBSERVED
	APPROXIMATE
	SUB-QUATERNARY LIMIT OF TERTIARY DEPOSITS
	SUB-QUATERNARY LIMIT OF PERMIAN DEPOSITS
	PROBABLE
	INFERRED
	SUB-QUATERNARY AND CAMBRIAN BOUNDARY BETWEEN PROTEROZOIC
	PROBABLE
	INFERRED
	SUB-QUATERNARY AND PROTEROZOIC BOUNDARY BETWEEN ARCHAEOAN
	PROBABLE
	INFERRED
	SUB-QUATERNARY OUTCROP OF MOONTA PORPHYRY
	NORMAL FAULTS, DOWN THROW ON EAST SIDE
	SCARPS FACING EAST, PROBABLY NORMAL FAULTS
	BEDDING
	STRIKE AND DIP
	HORIZONTAL
	VERTICAL
	GEOSTRUCY, SCHISTOSITY
	VERTICAL
	MAIN ROAD
	ROAD
	TRACK
	RAILWAY
	PERMANENT STREAM
	SWAMP
	SALT LAKES AND LAGOONS
	SUBMARINE FORM LINES (5 FATHOM INTERVAL)
	CONTOURS (50 FEET INTERVAL)
	SELF DUNE CRESTS
	TRIANGULATION STATION
	QUARRY
	BORES WITH SEQUENCE OF STRATA
	MINE SHAFT OR PROSPECTING PIT
	GLACIAL ERRATIC
	IRON
	COPPER
	ALUMINE
	PHOSPHATE

Geology by A. R. CRAWFORD, B.Sc.
B. P. Webb, M.Sc., Senior Geologist
in charge of Regional Mapping
E. S. O'Donoghue, B.Sc., Chief Geologist

Topography supplied by Photogrammetric Section,
Department of Lands, South Australia.

Cartography by Geological Drafting Section,
Department of Mines, South Australia.

Compiled under the direction of T. A. BARNES, M.Sc.,
Government Geologist.

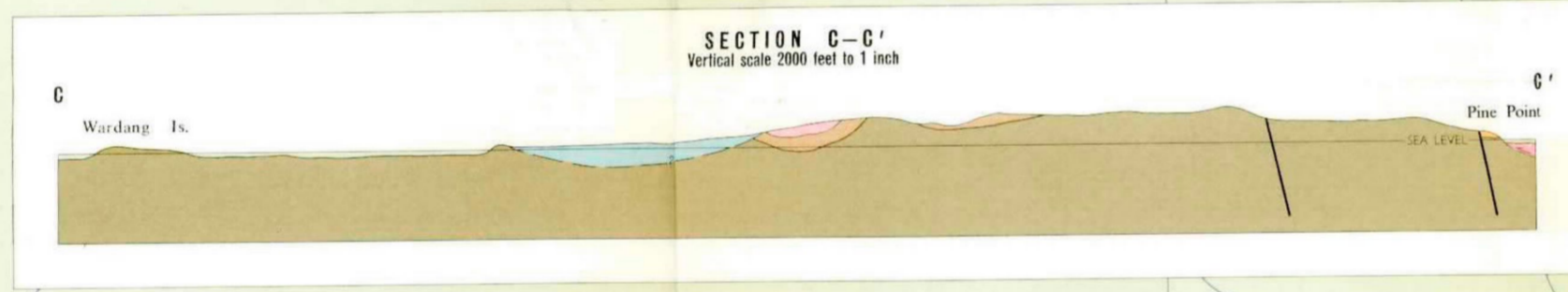
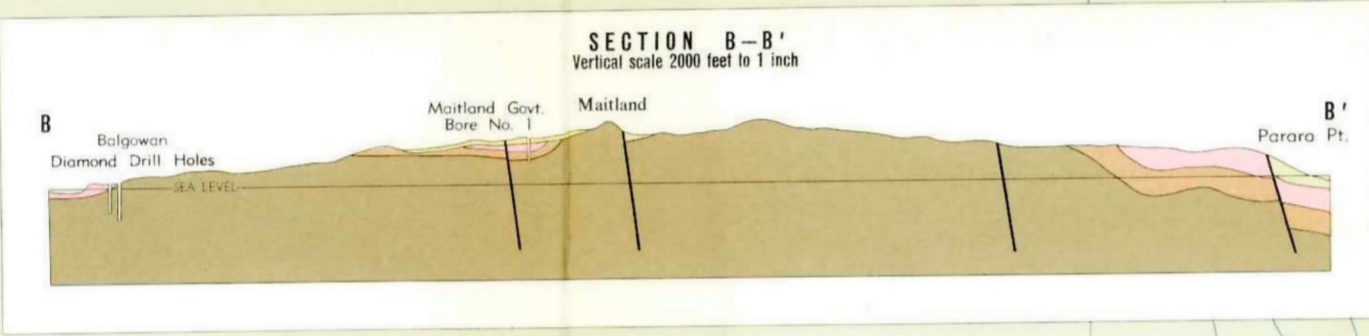
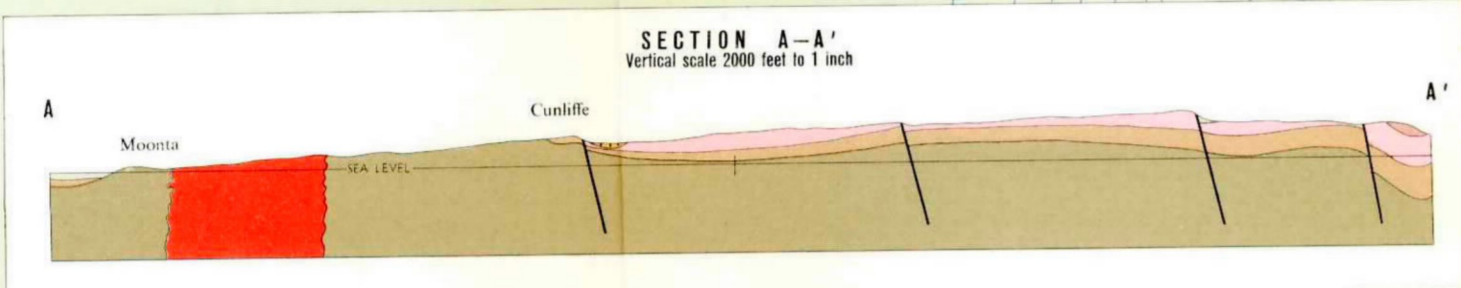
Issued under the authority of the
Honourable Sir A. Leif McEwin, M.L.C., Minister of Mines

Published 1960

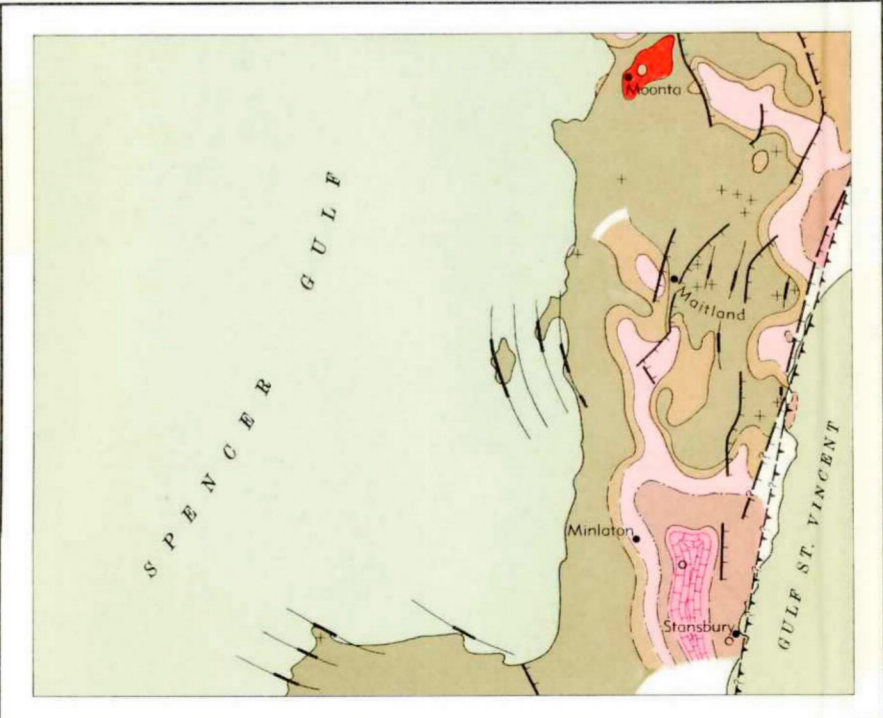
Copies of this map may be obtained from the Geological Survey
of South Australia, Department of Mines, Adelaide, or the
Bureau of Mineral Resources, Geology and Geophysics,
Canberra, A.C.T. Printed for the Geological Survey of South
Australia as a contribution to the 4 Mile Geological Map Series
of the Commonwealth.

MAITLAND
SHEET 1 5312

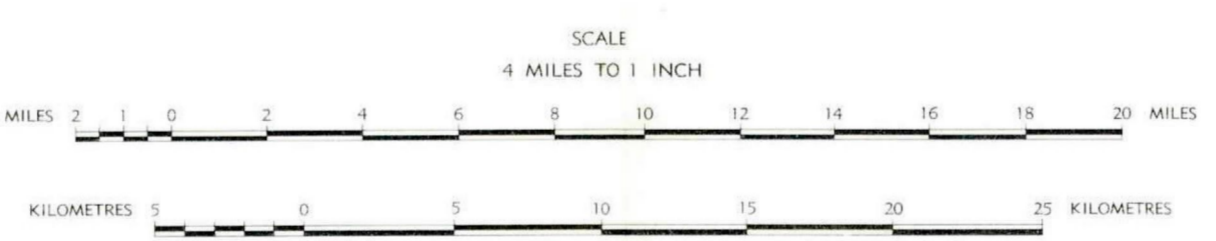
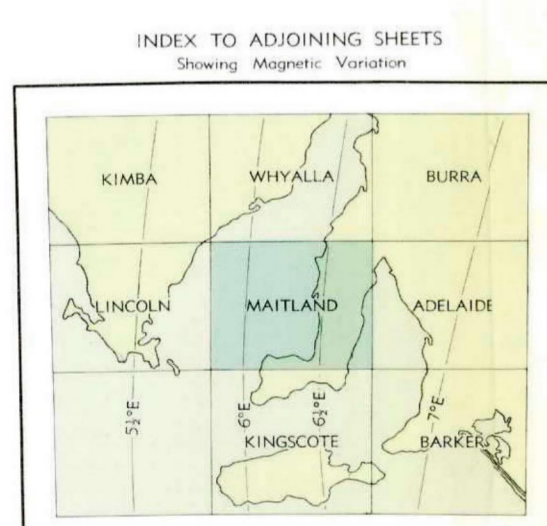
SECTION E-E'
Vertical scale 4000 feet to 1 inch



TECTONIC SKETCH



	Middle Cambrian (Pinnacled Limestone, clastics and red beds)
	Lower Cambrian (Kulpura Limestone)
	Proterozoic
	Archaean
	Moonita Porphyry (unexposed)
	Granites, Pegmatites
	Bedding foliation of gneisses and schists
	Concretion: Normal Faults or Monoclines
	Post-Cambrian Pre-Permian Thrust
	Stratiographic Bore



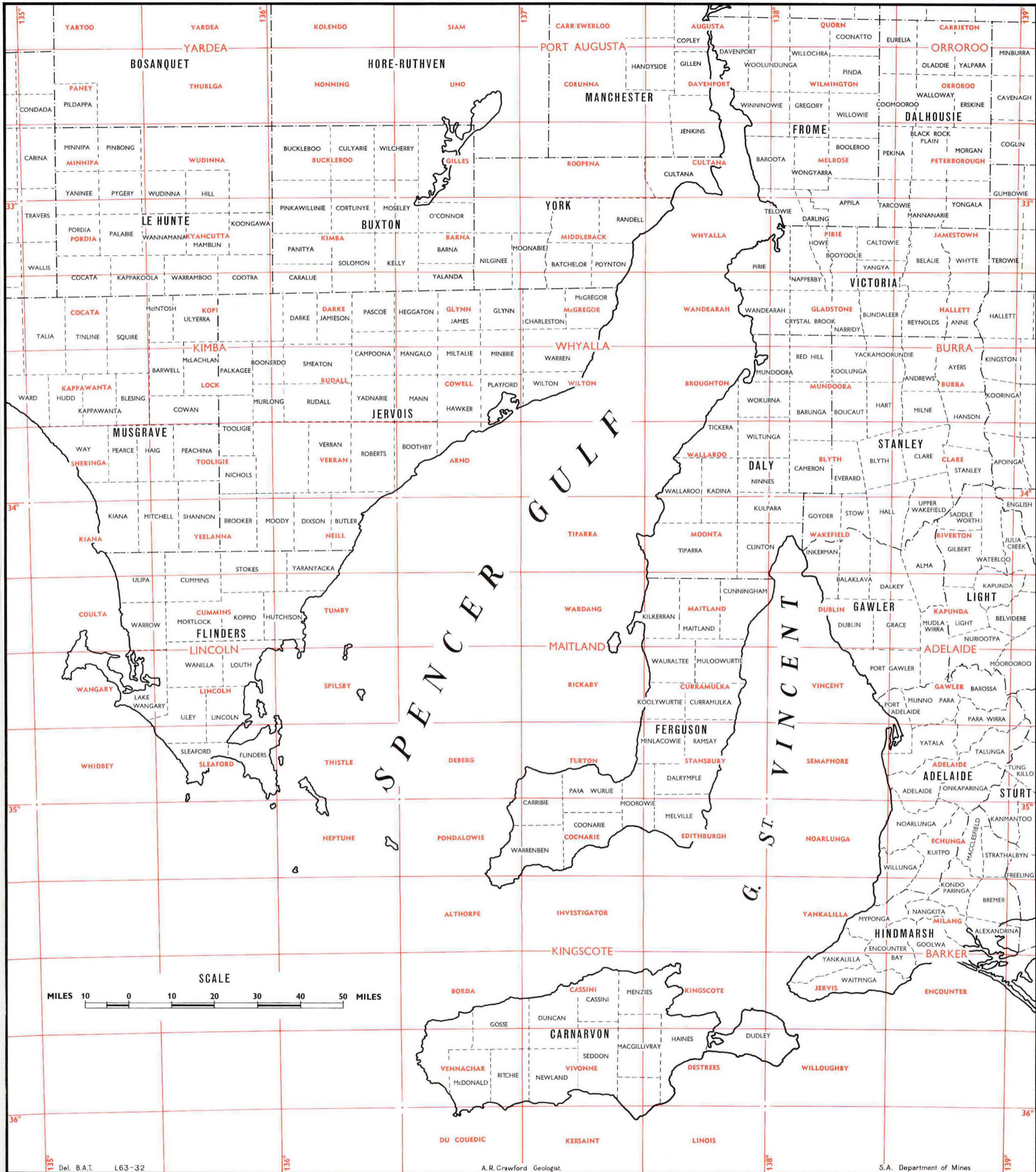


Fig. 1—Map showing location of Yorke Peninsula with Administrative Divisions and Geological Sheets.