



DEPARTMENT OF MINES
SOUTH AUSTRALIA

Geological Survey of South Australia

BULLETIN No. 41

**Geology and Mineral Resources
of the
Andamooka-Torrens Area**

by

R. K. JOHNS, M.Sc.,
SUPERVISING GEOLOGIST

Issued under the authority of
THE HON. S. C. BEVAN, M.L.C.
MINISTER OF MINES



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Letter of Transmittal

*Geological Survey Office,
Department of Mines,
Adelaide, South Australia, 5000.
16th August, 1967.*

Sir,

I submit a report by Supervising Geologist R. K. Johns on the Geology and Mineral Resources of the Andamooka-Torrens area.

This report is based on field work extending over a period of five years, culminating in the preparation and publication of geological maps of the Andamooka and Torrens 1:250,000 map areas. The present compilation describes in some detail, the geological features of those two map areas, which are only sparsely populated, and utilised principally for pastoral pursuits.

The record of mineral activities and of stratigraphic information contained in this report will be a useful guide to any future investigations.

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

T. A. BARNES, Government Geologist.

To the Honourable S. C. Bevan, M.L.C., Minister of Mines.

Approved,

S. C. BEVAN, Minister of Mines.

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Geology and Mineral Resources of the Andamooka-Torrens Area

Explanatory Notes to accompany Andamooka and Torrens 1:250,000 Geological Maps

Chapter 1

INTRODUCTION

The area embraced by the Andamooka and Torrens 4-mile geological sheets is defined by Long. 136° 30'—Long. 138° 00' and Lat. 30° 00'—Lat. 32° 00' and comprises an extensive partially dissected plateau west of Lake Torrens, the Lake Torrens Sunklands and part of the Willouran Range. The 24 one-mile map sheets included in this area are indicated in fig. 1. It is an area of low rainfall being in the 4½ in. to 8 in. per annum range, and constitutes part of the northwest pastoral district of South Australia. To the north of the vermin fence which transects the Andamooka sheet, on Stuart Creek and Billa Kalina pastoral stations, cattle are raised while to the south the area includes all or part of the following stations which are devoted to sheep and wool production: Witchelina, Mulgaria, Andamooka, Roxby Downs, Parakylia, Purple Downs, Arcoona, Bosworth, South Gap, Pernatty, Oakden Hills, Yalymboo, Mahanewo, Yudnapinna, Yadlamalka, Myrtle Springs and Wirraminna. Stock are dependent on indigenous perennial plants—the staple fodder comprising salt bush and blue bush with a carrying capacity of less than 25 sheep per square mile.

There are only two townships in the area—Woomera with a population of 5,000 and Andamooka with a “floating” population which in November, 1964 numbered 1,000 persons, including 150 aboriginals.

The Transcontinental Commonwealth Railway line (4ft. 8½in.) connecting Port Pirie and Kalgoorlie passes through the area, with fettlers and control staff located at a number of sidings along the route. The main road connection between Port Augusta and Alice Springs, the Stuart Highway, more or less parallels the railway line in this region. It is a graded dirt and gravel road whose general condition varies greatly from time to time depending on seasonal conditions, usage and degree of maintenance. The section of the main road between Wirrappa R.S. and Woomera village and certain installation access roads within the “restricted area” have been sealed. The road connection northwards to the opalfield at Andamooka is generally kept in good repair as are the tracks that serve as access routes to the various station home-steads.

Mineral output has been sporadic, and, apart from the production of opal, of no great importance.

Great strategic importance has been conferred on this region by the joint decision of the British and Australian Governments to establish on the fringe of the desert, within reasonable distance of laboratories, research and assembly facilities at Salisbury, a land range for the testing, firing and recovery of long range weapons and guided missiles (*see frontispiece*). Woomera village, located in the central western part of the area and located in a “prohibited area” in which access and movement are restricted, was created as a township to serve the range. The generally desolate, flat terrain, free of natural barriers, has provided an ideal site.

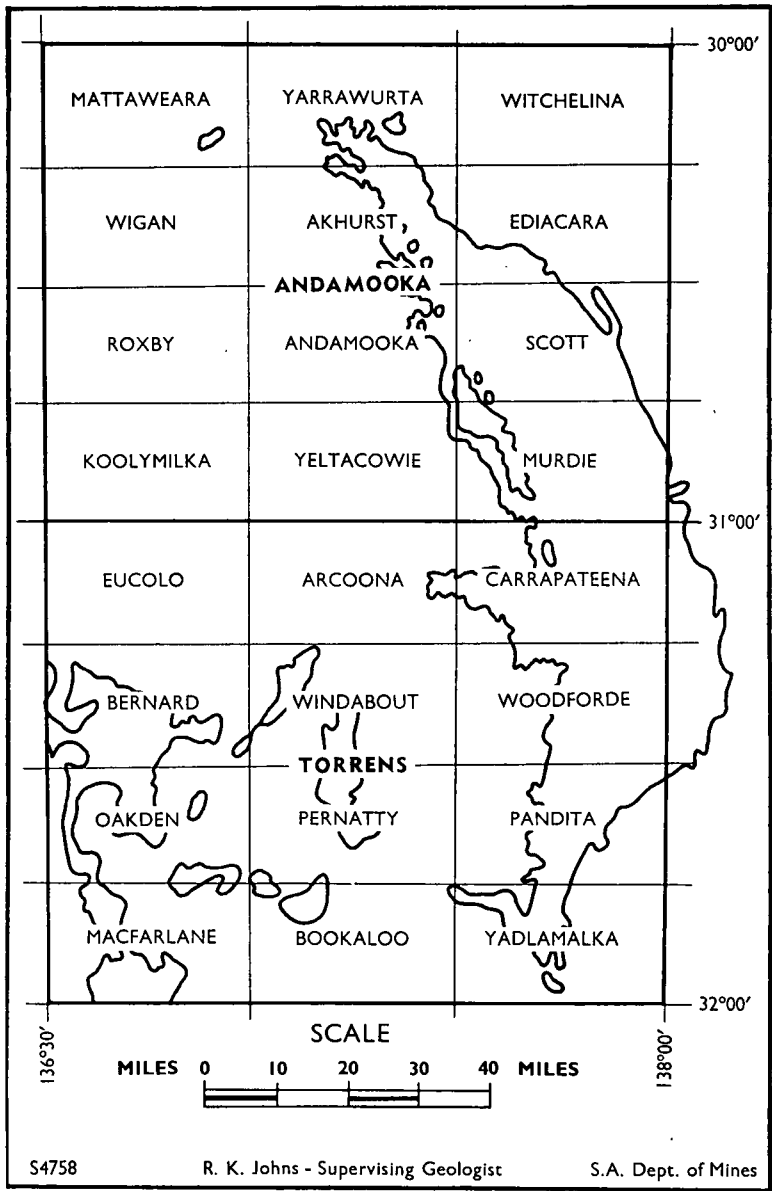


FIG. 1—ANDAMOOKA-TORRENS AREA
Plan showing 1-mile map series

PRESENT INVESTIGATION

Regional geological mapping of the area was initiated in 1959 and was completed in 1964; field work occupied 30 man weeks. The writer was assisted at various times during the course of the work in the field by M. N. Hiern, L. G. Nixon, B. G. Forbes and J. G. Olliver. All tracks in the area were traversed and detailed mapping confined to critical localities and to areas where this was considered desirable. Geological boundaries were thus delineated, spoil from all wells and dams was examined and attention was given to mineral occurrence, particularly to the copper and manganese deposits of the Pernatty Lagoon-Mount Gunson district and to opal at Andamooka.

Further subdivisions of the Adelaide System in the region were made following formal definition of these units in the Copley region by R. P. Coats, and the writer benefited greatly from co-ordination with him in map preparation.

The following report records the geological investigations and includes notes on physiography, climate, vegetation, hydrology and mineral resources of the region.

PREVIOUS GEOLOGICAL INVESTIGATIONS

A geological map of the State of South Australia published on a scale of 16 miles to an inch under the authorship of H. Y. L. Brown in 1899 shows outcrops of quartzite, sandstone, grit, shale, conglomerate etc. "of undetermined age" extending between Lake Torrens and Island Lagoon southwards to Point Lowly on the western shore of Spencer Gulf. Brown named the Tent Hill Series and (1908) compared them to Ordovician rocks at Tempe Downs, south of the MacDonnell Ranges, N.T. Later, R. L. Jack (1922) who was concerned chiefly with hydrological investigations in this region referred to these flat or very gently folded sediments as non fossiliferous "Ordovician "dolomitic limestone; quartzite with shaly bands; greenish shale weathering to brown; massive siliceous conglomerate". Limestone chippings from a depth of 212ft.-214ft. from Yarrowurta bore (located near the northern extremity of Lake Torrens) were referred to F. Chapman in 1925 who reported the presence of "various types of Archaeocyathinae", thus the occurrence of Cambrian sediments in this area was established though the relation of these to the other rocks was unknown and their significance was generally overlooked.

Geological survey maps to 1928 following Jack (1922) showed the "Tent Hill Series" to the west of Port Augusta and their northerly extensions on the western side of Lake Torrens, as belonging "tentatively to the Ordovician". However, the Geological Map of the Commonwealth of Australia (David 1932) assigned to these formations an Upper Precambrian age.

R. W. Segnit (1939) described geological features of the region encompassed by Andamooka, Roxby Downs and Parakylia stations and of the region between Iron Knob and Whyalla and assigned a Lower Cambrian age to the limestones and shales on the western side of Lake Torrens which in this region succeed Upper Precambrian sandstone-quartzites and purple shales of the "Tent Hill Formation".

Mawson (1947) also referred to the transgressional Proterozoic sediments located to the west of the Lake Torrens Sunkland as the Tent Hill Formation—the conglomerates and quartzites of the Corunna Range, etc., being considered as representing phases of this formation. He equated the Corunna Range rudaceous and arenaceous sediments with those of the Emeroo Range (the basal member of the Adelaide System 50 miles east of this locality), and considered that the "Tent Hill Formation to the west of Port Augusta represents shallow water sediments of the early stages of marine transgression over the coastal fringe of Yilgarnia, and corresponding to the basal formation of the Adelaide Series".

Work undertaken in the Iron Knob-Whyalla-Port Augusta region by Miles, Johns and Solomon (1952, 1953, 1954, 1955) demonstrated that above the "Archaean basement" which comprises gneisses, schists, jaspilites etc. were an older (Moonabie) Group of sediments and a younger group of sediments whose basal member was the Corunna Conglomerate. The Corunna Conglomerate in the type area north of Iron Knob comprises sandstones with thin shales and conglomerate near the base. To the eastward and extending south of Pandurra to Mount Whyalla, what were considered to be correlatives of the Corunna Conglomerate, but which have been shown by Crawford (1963) to be a younger formation, comprise a predominant gritty facies with red and cream cross-bedded and fine-grained sandstones carrying numerous bands of well-rounded pebbles. These are succeeded by "Tregolana Shale" and "Lincoln Gap Flagstones", the last named being lithologically identical with what were then considered to be basal members of the Cambrian System and were equated with the Pound Quartzite.

Exploratory oil boring activities by Santos Ltd. (King, 1956; Santos files, unpublished) revealed that Cainozoic sediments of the Torrens Sunklands are underlain by limestones with a lower Cambrian fauna (including trilobites, gastropods, hyolithids and brachiopods). The Pound Quartzite which elsewhere underlies this formation is absent. Geological staff of Santos Ltd. after mapping in the Lake Torrens region generally agreed that rocks comprising the "Tent Hill Formation" in this locality and elsewhere about the eastern, southern and western margins of Lake Torrens belonged to the Marinoan Series of Upper Proterozoic age. As the Pound Quartzite formation was proved absent in boring operations, the quartzite which caps the tablelands in this region was equated with the A.B.C. Range Quartzite—this quartzite being up to 1,060ft. in thickness in the type area (Mawson, 1939).

Sprigg (1949) has described the sediments and structures of rocks exposed in the Willouran Range.

A number of workers have made contributions on various aspects of stratigraphy, mineral occurrence, hydrology, oil prospects etc. in the region and references to these are acknowledged in the following report.

HISTORY OF EXPLORATION, SETTLEMENT AND DEVELOPMENT

The following record of exploration and pastoral settlement in the region is drawn from Threadgill (1922) and more especially from the useful history by Richardson (1925) who has documented the period 1856 to 1914 in some detail.

Edward John Eyre first sighted and named Lake Torrens from Mount Eyre in 1839. In the same year on a second expedition he traversed along 90 miles of its eastern border.

In 1842 C. Dutton, endeavouring to follow Eyre's tracks round the head of Spencer Gulf, disappeared; 20 years later his remains were found close to the now named Dutton Bluff.

In 1846 J. F. Horrocks, attempting to reach the interior of the Continent by a route to the west of Lake Torrens, penetrated the country to the west of Beda Hill and reached Lake Dutton when he was killed by the accidental discharge of his gun while mounting his camel. This expedition was notable in that this was the first use of a camel in Australian exploration.

In 1858 Babbage led a Government-sponsored party to explore the country at the head of Spencer Gulf and to the northwest between Lake Gairdner and Lake Torrens but his progress was slow.

John MacDouall Stuart also steered an expedition into this country at the same time but he and Babbage never met, though Stuart was in the Yeltacowie-Bottle Hill vicinity when the remains of a squatter, Coulthard, (one of an independent party of three) were found by Babbage on Pernatty Creek. Stuart aided solely by William Finke, one of the northern settlers, in 1858 penetrated nearly 240 miles northwest beyond Babbage's camp. He went up the Elizabeth through Andamooka, and beyond Yarrowurta Cliff to Stuart Range, thence southerly to Denial Bay via Mount Eba, Lake Younghusband and the Warburton Range and had thus encircled the operations of Babbage. This expedition occupying only four months was a notable achievement and contrasted so sharply with the progress being made by the painstaking Babbage that the reprimand despatched with A. C. Gregory was replaced by instructions to Major Warburton to supersede Babbage in command; before his arrival, however, Babbage had pushed on from his camp on the Elizabeth and penetrated to west of Lake Eyre.

In 1862 when Stuart crossed the continent to the Gulf of Carpentaria he again traversed the country west of Lake Torrens. At about this time Charles Swindon accompanied by an aboriginal brought back specimens of gold allegedly discovered near Andamoka (now Andamooka).

Though the country on the east side of Lake Torrens was generally occupied for pastoral purposes by 1860 and had been so for some years all that was known at that time of the vast extent of "Swindon country" to the west of Lake Torrens, northwest of Port Augusta, was what had been gleaned by the explorers—Charles Swindon, Babbage, Oakden, Hulkes, Stuart, Warburton and others—and many of the accounts were misleading.

J. F. Hayward, William Brown and William Marchant explored the country for a short distance west of Lake Torrens, while Oakden and Hulkes in 1859 explored farther westward and reported having found good pastoral country. Oakden named two mesas after himself and he and Hulkes took a lease covering part of this region. They were driven out by drought and the country was not leased again until the late 60's.

The years 1857-1858 were wet and all explorers of this time reported the occurrence of freshwater lakes and running streams of water. Goyder (1859) undertook triangulation surveys, exploring and well sinking in country discovered by Stuart and Warburton and considered the Lake Torrens district "a stockholders Paradise in winter. In summer it was still to be proved".

In the 60's John Bosworth took sheep to the Elizabeth country north of Pernatty Lagoon. Shallow wells sunk by him were failures and as the surface waters dried up, he was forced to make a hasty exit. He decided to cross Lake Torrens and reached the eastern shore near the old Panditta station, losing his few sheep in the crossing. Only once before had an attempt been made to cross Lake Torrens and that was in 1856 when Hayward, Brown and Marchant had accomplished this feat but had left their packhorse bogged in the middle of the lake.

Yudnapinna was the settlement farthest from Port Augusta in the late 60's and in 1868 James Bowman and Phillip Hiern took out a lease on behalf of H. J. Richman of about 200 square miles through which ran Pernatty Creek—this was "Pernatty" which was stocked with sheep in 1871. In the following year leases were taken up near the Elizabeth (Yeltacowie), about Lake Campbell and round some good natural waterholes at Phillip Ponds. Later, leases were taken up at Andamooka, Carrapatina, South Gap (1872) (formerly part of Kanyaka), Whittata, Punt Hill, Chances Swamp (later Roxby Downs), Monalena (1874), Mahanewo (1878) Parakylia, Arcoona

(1874), Bowen Hill (1880), the Pines and Purple Downs. John Ross in 1873 took up country the southern boundary of which is now defined by the vermin fence (Billakalina, Stuart Creek).

The first Government trigonometrical survey of this area was undertaken by Joseph Brooks during the years 1875-1876 and of the area west of Lake MacFarlane by W. Barron in 1877. In 1876 Ernest Giles, who was equipped by Sir Thomas Elder, travelled round the north of Pernatty Lagoon, thence westwards beyond the northern shores of Lake Hart to Perth. On the return journey he passed across the northern end of Lake Torrens.

Sir Thomas Elder introduced camels for carrying purposes on the western side of Lake Torrens in 1878 and in the 80's well sinking, dam sinking, hut building and fencing construction were in hand everywhere and a few stations had their boundaries fenced.

In 1885 a Government party commenced cutting and clearing a track from Tent Hill via Gibsons Camp, Monalena, Oakden Hills, Warrapa (Wirrappa) and the Pines to Phillip Ponds where it connected with the original track which went via the Elizabeth.

Pastoral affairs reached their peak in the region by 1888. Several years later many pastoral leases expired and by the latter 1890's all of the original northwest leases had expired. Since that date many places that were originally worked as distinct runs have become outstations and have been absorbed into larger holdings.

To the east and northeast of Lake Torrens pastoral leases were taken up as follows—Yadlamalka (1851), Kallioota (1853), Pandita (1857), Ediacara (1863), Witchelina (1863), Mulgaria (1864).

Mining operations commenced near Pernatty Lagoon in 1898, some 23 years after the discovery of copper at Mount Gunson in 1875. The ores were hauled by horse-donkey- and camel-drawn wagons to Port Augusta and in 1912 the Bottrill motor tractor, the remains of which are still at Mount Gunson, was introduced (see *Mining Review* 15, facing p. 8 for photo.). Manganese deposits located in the same district came into production in 1915.

The Transcontinental railway line, construction on which began in South Australia at Port Augusta in 1912, reached Woocalla in 1914 and was finally opened to through-traffic in 1917. The mining industry was stimulated for a time by the construction of the railway and a route for a spur line was surveyed (though never constructed) to handle the copper, manganese and barite ores of Pernatty Lagoon. To justify this branch line attention was given to the construction of evaporating pans for the recovery of salt. Though commercial production of salt was not achieved at Pernatty Lagoon, and little more at Woocalla, production at Lake Hart had some success.

Precious opal was discovered at Andamooka in 1927 and this field has now become one of the principal opal producers in the Commonwealth. For 30 years the gougers worked with picks and shovels and hauled with buckets on crude windlasses and lived in an assortment of semi-dugouts but the past decade has seen the introduction of pneumatic spades, air-operated winches and occasional bidders, belt conveyors, dump cars, auger and mechanized shaft-sinking equipment. The population, though very variable, now approximates 1,000 Europeans and 150 aborigines.

In April 1946 Lt. Gen. J. F. Evetts led a mission to Australia to select a site for the establishment of a range for the testing and development of guided weapons and in 1947 the site for the village of Woomera was chosen near Phillip Ponds. On April 1st, 1947, the Weapons Research Establishment (W.R.E.) officially began as a joint project of the British and Australian Governments. Woomera is a "closed" village with a

population of 5,000 and is linked with a rail spur to the Transcontinental railway line at Pimba, 5 miles to the south. Airfields have been constructed, and roads, pipelines and telephone lines now span vast distances along the range. Water was drawn for the provision of construction teams at first from Lake Richardson which had been filled after exceptionally good summer rains but a permanent source of supply is now provided by a pipeline from Port Augusta which connects with the Morgan-Whyalla pipeline. The town is linked to the E.T.S.A. power station at Port Augusta by a high-tension line.

Ranges have been established for a number of purposes, but the most important functions are carried out at the missile range with a launching area near Lake Koolymilka, 26 miles northwest of Woomera. On the northern shores of Lake Hart, launching pads have been set up to develop Britain's Blue Streak rocket for putting communications and other satellites into orbit by E.L.D.O. (European Launcher Development Organisation). At Island Lagoon, 17 miles southeast of Woomera, a deep-space instrumentation facility for tracking satellites in orbit has been constructed in conjunction with N.A.S.A. (American National Aeronautics and Space Administration Agency), (see plate I, fig. 1). The Red Lake tracking station north of Woomera was an Australian link in the chain of tracking and monitoring stations around the world for the U.S. (Man-in-Space) Project Mercury.

The history, development and the conduct of trials at Woomera have been recently dealt with in some detail by Southall (1962).

CLIMATE

The climate of the region comprises a low and erratic rainfall with no marked seasonal incidence, a mean annual temperature of about 65°F, a large diurnal temperature range and a high evaporation rate, particularly during the summer months.

There is no regular seasonal rainfall as the area occupies a position on the fringe of both the monsoonal (summer rain) and antarctic (winter rain) systems; it receives some rain from both systems but does not derive much benefit from either. The mean annual rainfall and average monthly registrations for a number of recording stations in this and adjacent areas are tabled on pages 14 and 15: (Hollerith listings of monthly rainfalls supplied by the Commonwealth Bureau of Meteorology).

Station	Monthly Average (Points)												Yearly Average (Points)
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Hesso (1916-1960)	55	78	55	63	76	79	74	65	56	69	63	51	772
Bookaloo (1916-1961)	61	87	62	40	76	94	76	72	54	71	71	64	818
Witchelina (1898-1961)	46	69	55	30	49	68	34	31	38	47	45	46	561
Edeowie (1885-1961)	67	73	69	53	100	127	82	84	67	66	70	67	910
Farina (1879-1961)	60	68	68	40	59	42	36	38	41	49	49	55	638
Finniss Springs (1921-1960) . .	56	76	63	36	45	52	31	28	32	51	37	67	559
Myrtle Springs (1897-1959) . .	52	86	66	31	62	88	43	44	51	51	52	66	796
Parachilna (1931-1960)	74	108	65	41	66	79	65	65	51	65	67	53	786
Stuarts Creek (1877-1930) . .	50	44	53	40	56	62	25	26	34	32	45	34	506
Ediacara (1881-1938)	45	30	45	46	70	61	29	40	41	41	55	65	574
Arcoona (1911-1950)	55	51	38	41	79	88	39	33	61	38	46	38	607
Oakden Hills (1904-1950) . . .	49	55	35	58	74	92	49	56	68	55	64	47	692
Whittata (1905-1950)	51	48	43	58	84	99	57	63	66	48	50	50	717
Port Augusta (1881-1950) . . .	54	50	72	77	114	117	71	87	95	85	69	59	950
Woomera (1950-1961)	44	90	71	76	81	59	66	65	48	63	62	48	683
Woocalla (1916-1951)	60	77	48	43	65	67	53	64	54	63	57	67	714
Wirrappa (1916-1961)	62	84	49	37	59	69	48	49	46	57	54	67	665
South Gap (1882-1961)	50	66	50	45	73	72	52	52	48	49	54	48	655
Roxby Downs (1931-1959) . .	50	74	63	29	43	53	33	48	26	54	38	35	548

Station	Monthly Average (Points)												Yearly Average (Points)
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Purple Downs (1903-1961) ..	53	78	46	33	62	67	40	38	51	43	56	59	625
Pimba (1916-1961)	66	85	36	49	62	71	50	54	53	62	58	53	693
Pernatty (1928-1961).....	49	92	58	41	52	59	50	57	36	58	59	58	660
Parakylia (1937-1961)	67	105	63	26	31	44	31	33	40	51	63	66	603
Millers Creek (1930-1959) ..	46	91	42	34	35	43	32	39	22	42	38	36	488
Mahanewo (1911-1961)	48	65	56	35	68	87	62	56	57	66	59	61	714

The figures quoted below from Patterson (1961), though they relate to a limited period (1952-1959) for Woomera, may be taken as a guide to conditions generally pertaining to the region:

Evaporation 96-100in. per annum.

Average monthly maximum humidity varied 64-75 per cent.

Average monthly minimum humidity varied 24-32 per cent.

Average daily hours of sunshine varied 8.6-9.4.

Average maximum temperature throughout these years 77.1°F.

Average minimum temperature throughout these years 53.9°F.

Average number of days over 100°F was 18—February is the hottest month.

As Jessup (1951) has pointed out rainfall reliability is low. Good years alternate with periods of severe drought and in some years the whole year's rainfall may fall within a few days, while in others it may be scattered through several months in a number of ineffectual falls.

In summer there are considerable extremes of temperature, the intense heat of the day being rapidly lost at night by radiation. In winter there are still greater extremes of heat and cold and ground frosts are fairly common on clear nights for several months of the year.

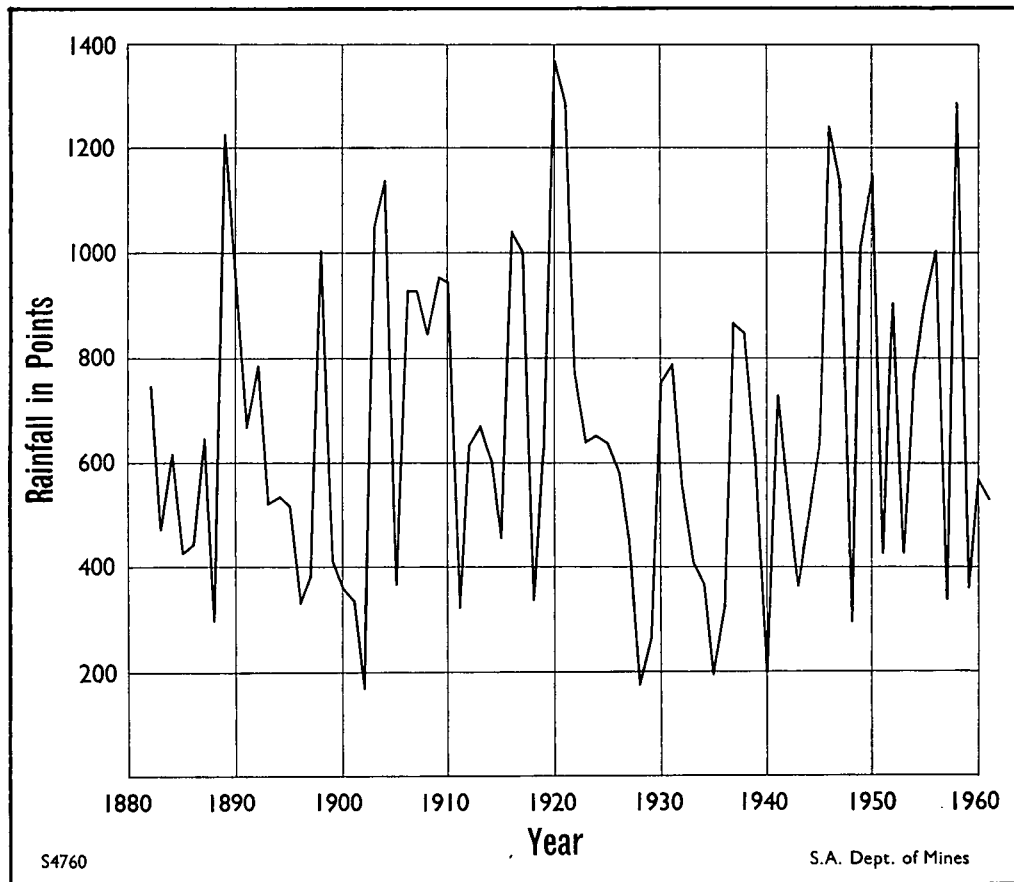


FIG. 3—GRAPH SHOWING ANNUAL RAINFALL, SOUTH GAP STATION—1882-1961

VEGETATION AND SOILS

Cleland (1930) traversed the area west of Lake Torrens to ascertain the distribution and abundance of commercial sandalwood (*Eucarya spicata*) and made notes on the flora encountered. A more systematic study of the vegetation of the plateau west of Lake Torrens was made by Murray (1931).

A regional soils and vegetation study was undertaken by Jessup (1951) of the area lying to the west of Lake Torrens and north of the latitude of Pernatty H.S., while Jackson (1958) has studied in some detail a smaller area lying to the south of the above on Yudnapinna pastoral station. The climate, soils, plant ecology etc. of the W.R.E. area have been recently discussed by Patterson (1961).

West of Lake Torrens there are broadly three main types of habitat each characterized by distinct types of vegetation as under:

- (1) Gibber tablelands, tableland remnants and stony hills with saltbush steppe.
- (2) Red sand dunes with mulga scrub and saltbush.
- (3) Loamy or sandy depositional plains or flats with myall scrub and blue bush.

The principal landscape features are mostly well defined and relate directly to geology though vegetation associations are commonly grouped together to form association complexes.

Tablelands

The gently rolling high-level Arcoona Plateau and its dissected remnants and the lower stony hills extending southwards and westwards from the Pernatty Lagoon locality cover most of South Gap, Pernatty, Bosworth, Arcoona and Andamooka stations. These are generally mantled by heavy, fine-textured, red, clay soils with a gibber-strewn surface almost devoid of all tree and shrub growth except along shallow water courses.

The tableland shelf areas constitute a very arid and saline environment over large expanses and support only sparse growth; they are characterized by low grey vegetation dominated by salt bush (*Atriplex vesicarium*) which is the main fodder plant (plate I, fig. 2).

The soils exhibit gilgai micro-relief in which depressions, ranging from small more or less shallow circular crab-holes to large dongas, are completely or partially rimmed by low puffs, mounds or shelves. These depressions collect surface water following rains and then harbour a more varied and nutritious flora (annuals, Mitchell grass, etc.) than the surrounding shelves.

A feature of the tableland landscape is the number of small creeks outlined by the tableland myall (*Acacia rigens*) with which are associated other acacias (including *A. brachystachya*, *aneura*, *tetragonophylla* (dead finish), *cassia* sp., *casuarina* sp., *eremophila* sp., *pittosporum* sp., *hakea* sp., and *dodonaea* sp.

The black oak (*Casuarina lepidophloia*) is often found in large depressions, up steep-sided gullies and on escarpments marginal to the tablelands.

Sand Dunes

On sandy soils and on sand plains which occupy depressed areas within and marginal to the tablelands and flanking the major lakes, the vegetation is dominated by mulga (*Acacia aneura*). Mulga trees, 15-25ft. high, form woodlands of variable density with a wide variety of associated shrubs and ground cover with salt bush and blue bush (*Kochia sedifolia*) common. The sandhill country supports a particularly valuable plant community following winter rains when a dense growth of ephemeral species including parakeelya (*Calandrinia* sp.) is produced.

The vegetation of the flats, where the soils vary from sandy or light red sandy loam merging into clay pans, show a greater variety and abundance of species than do the sand dunes.

Oak (*Casuarina cristata*) is commonly associated with mulgas on sandhills in the Oakden Hills locality.

Native pines (*Callitris glauca*) are of widespread occurrence. They occur with mulga scrub on the flats and slopes and partly or completely replace them on the sand ridges. Pine forests on Arcoona (the Pines), Roxby Downs, Purple Downs, Andamooka and Mulgaria were formerly more extensive but they have been largely cut down to provide building materials, telegraph poles, firewood and fencing materials.

Loam Flats

Over large areas of the depositional plains and low dissected tablelands, particularly south of the Arcoona plateau, myall (*Acacia sowdenii*) is the dominant tree 15 to 30ft. in height and generally in association with blue bush (*Kochia sedifolia*) (plate II, fig. 1). The myall-blue bush association is widespread on the loamy clay flats with mulga-salt bush in sandy areas. Common associated shrubs include *Eremophila* sp., *cassia* sp., sandalwood and bullock bush.

Both myall and mulga are extremely drought resistant and provide a reserve of feed during prolonged droughts when the associated shrubs become defoliated. Myall is only slightly palatable, however, whereas the foliage and seed pods of the mulga provide useful fodder.

Severe tree death has occurred in the woodlands and little regeneration of the dominant trees (mulgas and myalls) is taking place, though mulgas have suffered more than myalls. Jessup (op. cit.) concluded that "though periods of drought, overstocking and the depredations of the rabbit have had some effect neither stock nor rabbits are primarily responsible for the absence of widespread regeneration and that the fundamental fact is that there is actually a lack of germination". Both types of trees are slow growing.

Eucalypts are of restricted occurrence; mallees are common in the Willouran Range while red gums (*Eucalyptus rostrata* and *E. camaldulensis*) are the only common large trees along the major drainage channels—Willochra, West Mount, Tilterana, Yarrowurta, Yeltacowie, Pernatty, Elizabeth and Whittata creeks.

There are distinct flora associations on the claypans, round freshwater swamps, salt marshes, lagoons and lakes. Dense thickets of mulga occur in small depressions liable to inundation while some of the larger swamps carry broombush (*Melaleuca uncinata*) and tea tree (*Melaleuca pauperifolia* or *M. pubescens*) as dominant species. A number of freshwater swamps which are subject to frequent flooding are characterized by canegrass (*Eragrostis australasica*) up to 4ft. high as the dominant species, sometimes with mulgas, *Melaleuca* sp., dead finish and prickly acacia (*Acacia victoria*) in a marginal fringe.

Chapter 2

PHYSIOGRAPHY AND DRAINAGE

The area may be conveniently divided into five principal physiographic divisions; because of simplicity of structure the broad geologic divisions coincide with these geographic units.

The outstanding physiographic features include:

- (1) Lake Torrens Sunklands.
- (2) Arcoona Plateau.
- (3) Stuart Range Plateau.
- (4) Bookaloo Lowland.
- (5) Willouran Range.

The various units are described below.

LAKE TORRENS SUNKLANDS

The most conspicuous physiographic feature of the region is Lake Torrens, a normally dry salina 125 miles in length and up to 25 miles in width with an arcuate outline resembling a compressed letter D. The surface of the lake is elevated 112ft. above sea-level. There is no surface movement of lake water to the sea during times of flooding though a connection obviously formerly existed.

Gregory (1906) conceived the "Great Rift Valley of South Australia" with Lake Torrens occupying an arcuate fault-bound graben with the Flinders Range horst along its eastern side and separated from it now by alluvial plains. But Fenner (1930) argued against the "rift" valleys concept and instead proposed the name Torrens Sunklands for the prolongation of the Spencer Gulf depression to which it is connected by the narrow "Port Augusta Corridor". He named the western boundary fault the Torrens Fault—an extension of the Lincoln fault system which determines the western shores of Spencer Gulf (Miles, 1952).

Both Halligan (1924) and Madigan (1930) flew over the lake and commented on the nature of the surface and on possible connections between this and Lake Eyre.

The western, southern and northern margins are flanked by rising ground and occasional low cliffs. Though the western shore is controlled by a strong lineament (the Torrens Fault), in detail the shores have a number of irregular embayments—the most prominent of these being Carrapateena Arm and Beda Arm. Andamooka Island and Murdie Island are conspicuous near the western shore while other smaller islands exist.

The eastern shore is generally ill-defined. Though, locally, there are low cliffs developed, sand spreads and banks of kopi generally separate the flat expanse of the lake floor from the Torrens Plains proper. These plains separate the lake from the Flinders Ranges to the east and comprise tracts of aligned sand dunes (plate II, fig. 2) superimposed on and separated by gently rising broad alluvial outwash fans built up by creeks which debouch from the Flinders Ranges and, when flooding, finally empty their silt-laden waters into the lake. The major creeks, including the Mulgaria, Depot, Warrioota, Brachina, Hookina and Willochra creeks have built up deltaic fans on the lake shores. Upper Proterozoic and Cambrian sediments similar in facies but of reduced thickness to those of the adjoining geosynclinal area outcrop in isolated gently folded inliers in the younger cover.

The floor of Lake Torrens is covered by soft brown gypseous silts with salt absent or forming little more than paper-thin surface films. From the air the lake surface is irregularly marked by brown and white streaks and irregular patches and rounded areas of white, marking limits of former pools and sheets of brine which have been

swept across the surface of the lake by wind (plate III, fig 1). On evaporation to dryness the intensity of "whiteness" is dependent on the thickness of salt encrustation and amount of included silt giving patchy and mottled areas of brown and white. Water-transported silt and wind-blown dust cover most of the lake surface. The lake has been the site of active sedimentation in Tertiary and Quaternary time—this is discussed in a later chapter.

The presence of springs in the lake floor were reported by Madigan (op. cit.) to be similar in appearance to those of Lake Eyre but here they are less definitely circular in plan, they are not built up at the rims and are surrounded by much larger salt-pan areas. Two prominent springs were described as being midway between the shores and 24 and 27 miles respectively north of the mouth of Willochra Creek. The presence of a number or other springs is now inferred, (Johns, 1964). The more or less alignment of springs southeasterly from Andamooka Island defines an outlet for waters under pressure in aquifers below the floor of the lake.

ARCOONA PLATEAU

Elevated some 600-800ft. above sea-level and flanking the western shore of Lake Torrens is an extensive tableland, here called the Arcoona Plateau but referred to previously on some maps as the "Andamooka Ranges". It constitutes part of the stable Precambrian foreland (the Stuart Stable Shelf of Sprigg 1952)—a platform of essentially undisturbed Upper Proterozoic (Adelaide System) sediments which are capped by a resistant quartzite member. Erosional remnants of this tableland are preserved in a number of mesas or buttes *e.g.* Mount Gunson (850ft.), Oakden Hill South (851ft.), Emu Bluff, Bottle Hill (plate III, fig. 2) or as isolated pinnacles—*e.g.*, the islands of Island Lagoon (410ft., 500ft., 559ft., 596ft.)—while relicts of this dissected, formerly very extensive, peneplain are traceable southerly beyond Beda Hill (655ft.) and Dutton Bluff (920ft.) to the Tent Hills and along the western shores of Spencer Gulf to near Whyalla. The hills in this region, even where erosion is advanced, are almost invariably flat topped (plate III, fig. 2) and steep sided with modified cliffs in the upper part of their outline and extensive screes below. Being devoid of trees the tableland surfaces maintain flat even skyline profiles and fairly constant levels over long distances in most directions so that many of the trig. stations have elevations little in excess of the surrounding terrain. This surface has a very gentle regional tilt to the north.

The surface of the plateau is strewn with gibbers which comprise flat quartzite slabs where derived from underlying Adelaide System quartzites, or rounded quartzite boulders or quartz gravels where they are derived from later Mesozoic or Cainozoic veneers. The gibbers are concentrated at the top of a heavy red clay soil profile which invariably mantles the flat or gently rolling upland surfaces. The underlying rocks are masked over enormous areas by clay soil, sand, gravels and gibber deposits with outcrops being generally restricted to cliffs and escarpments on the flanks of salt lakes and the sides of more deeply incised watercourses (plate V, fig. 1).

A dendritic drainage pattern has evolved over much of the plateau proper, though a regular joint system exerts a strong control. Numerous, short channels with steep gradients radiate from the margins of the main tablelands and also round the peripheries of the many mesas and buttes. Round these are coalescent scree and outwash fans but, after rain, streams are soon dissipated in the surrounding sand plains. In the upper levels of the tablelands, drainage channels are wide, shallow and generally ill-defined and surface waters are mostly collected in gilgai depressions, or occasional canegrass swamps. At lower levels drainage channels coalesce to form prominent tree-lined creeks and, when stream erosion has proceeded to the stage where basement rocks are exposed, cliffs are commonly developed.

The whole region is one of internal drainage and all streams ultimately drain into swamps, lagoons or lakes or are dissipated on sand plains in the locality. Major creeks rising on the Arcoona Plateau include the Elizabeth and the Pernatty.

To the north and northwest the regular bare plateau surface pitches below a sand dune covered terrain which has a sensibly constant though somewhat lower surface level. (Plate IV, fig. 2). Sand dunes may form dune complexes on the tableland surface, occupy depressions along eroded valley floors or occur as single isolated ridges at all elevations. The dunes rise 10ft. to 30ft. above the general level with a single crest; they are more or less parallel and individual dunes may be traceable for many miles. Within the sand dune tracts drainage channels are rare; surface waters are absorbed within sandy swales or collect in claypans which may range in area from a few square yards to several square miles (*e.g.*, Lake Blanche).

The underlying strata may comprise quartzites, shales, limestones, sands, gravels or their silicified derivatives.

STUART RANGE PLATEAU

To the north and northwest of Lake Torrens partially dissected tablelands mark the limits of an extensive surface traceable to the northwest beyond the area under review to Stuart Range. Yarrowurta Cliff, Arthur Hill and Porter Hill are eminences on the southernmost limits which overlook the Lake Torrens Sunlands.

BOOKALOO LOWLANDS

The area which flanks the Arcoona Plateau on its southern aspect and extends southerly to Port Augusta comprises low undulating alluviated plains with sand plains and areas of sand dunes with clay, loam or sand flats punctuated by low stony rises. It is noteworthy for the occurrence of a number of brackish water swamps, salt-water lagoons and large salt lakes including Island Lagoon, Lake MacFarlane, Lake Windabout, Pernatty Lagoon, Lake Hart, Lake Dutton, Lake Finnis and Lake Blyth. The western shores of these lakes are generally defined by low cliffs of bedrock while the eastern shores are characterized by banks of kopi and sand dunes. The northern shores of Lake Hart and Island Lagoon are flanked by escarpments up to 250ft. high. (Plate V, fig. 2.)

Where there are large continuous exposures of bed rock in this region these show a base levelled profile related to a period of peneplanation later than that reflected by the Arcoona Plateau. This is exemplified by the low tableland, elevated some 400ft. above sea-level, which margins the western shores of Pernatty Lagoon. Elevations elsewhere in this belt are generally in the range 250ft. to 470ft., *e.g.*, Belo Hill 467ft., South Hill 469ft., Pernatty Ridge (a sand dune) 359ft., while the floors of the lagoons are generally 200ft to 250ft. above sea-level.

Isolated remnants of the Arcoona surface are conspicuous in this region *e.g.*, Oakden Hills (851ft.), Mount Gunson (850ft.).

Drainage channels are rare and creeks draining into the major lakes have short courses. The origin of the lakes is discussed in a succeeding chapter.

WILLOURAN RANGES

The northeastern sector of the map area is occupied by the Willouran Ranges. The foothills of the ranges are generally low and rounded but these give way to the higher South Hill—Mount Norwest and Termination Hill ridges where elevations exceed 1,000ft. above sea-level.

Drainage is here controlled by geological features and results in a modified trellis drainage pattern consequent on the trend of the underlying strata.

Chapter 3

GEOLOGY

The rocks exposed in the region may be broadly separated into four main geological age classifications, *viz.*, a more or less continuous sedimentary succession of Upper Proterozoic (Adelaide System)-Cambrian rocks, remnants of Jurassic-Lower Cretaceous strata marginal to the Great Artesian Basin, a variety of Tertiary sediments and of Quaternary strata.

Sedimentation and tectonic activity in the region during and since Precambrian times have been controlled by three distinct elements which are now defined by:

- (1) The Flinders Range chain—the locus of almost continuous sedimentation during the Upper Proterozoic and extending into the Middle Cambrian. These sediments have been intensely deformed by folding and faulting.
- (2) The Stuart stable shelf—an undeformed stable platform marginal to the Adelaide Geosyncline and separated by the Torrens meridional line of faulting from (1) above by—
- (3) The Torrens Sunklands—a hingeline shelf bridging (1) and (2) above and underlain by gently folded late Precambrian and Cambrian strata.

UPPER PROTEROZOIC—ADELAIDE SYSTEM

Sedimentation in the Adelaide Geosyncline occurred principally as continental terrace outgrowths from the ancient West Australian Continental Shield, excluding certain deposition by glacial and fluvioglacial agencies (Sprigg, 1952). Rocks forming a basement to the system outcrop to the west and to the south of this region and comprise gneisses and metasediments of the Flinders Group and Hutchison (Middle-back) Group, a younger group of sediments (Moonabie Grit, Corunna Conglomerate) and the Gawler Range Porphyry. The nearest exposures of crystalline basement rocks comprise feldspar porphyry which outcrops on the shores of Lake Gairdner, some 15 miles from the western boundary of the mapped area (Johns 1965).

Though Beda bore is reported (Jack, 1930) to have intersected "porphyry" from a depth of 439ft. to the limit of boring (1,099ft. 6in.) the original log in departmental files describes this interval as "Trap (felspathised schist)?" A later pencilled note, presumably Jack's suggested "Gawler Range Porphyry?" While basement may be present under shallow cover in this locality, the writer considers that these rocks are more likely to include lavas of the Willouran Series (Callana Beds) similar to those exposed at Depot Creek (Brunnschweiler, 1956) and at Old Roopena H.S. (Miles, Johns and Solomon, 1952).

Because of dissimilarity in conditions during and since sedimentation between the shelf area west of Lake Torrens and the geosynclinal trough which was the focus of more or less continuous sedimentation east of Lake Torrens, the two environments are considered separately below.

EAST OF LAKE TORRENS—ADELAIDE GEOSYNCLINE

Callanna Beds (Willouran Series)

In the extreme northeast of the map area in the cores of dislocated anticlinal structures in the Willouran Ranges are exposed remnants of some of the oldest beds of the Adelaide System. Mawson (1927) first reported on the rocks of this region while Sprigg (1949) after reconnaissance mapping described thrust structures of the

Witchelina area. These authors (Mawson and Sprigg 1950) named the Willouran Series while formal definition has only recently been made by Thomson and Coats (1964).

Approximately 2,000ft. of slates with minor dolomites and quartzites occupy the core of the South Hill drag fold (Sprigg, *op. cit.*). The strata are intruded by a number of dolerite plugs and are generally similar to rocks mapped north of Witchelina H.S. (Johns, 1956, 1958). Mapping by Coats (1964 in preparation), however, suggests that the South Hill structure is overturned and that the rocks in the core are younger than formerly believed. A wedge of slates with sandstones underlying the Witchelina Quartzite and bound by splinter faults from the Nor'west fault, are exposed some 6 miles to the west on the eastern flanks of Stony Range.

Burra Group (Torrensian Series)

Conformably succeeding the Callanna Beds is the basal formation of the thicker and far more extensive Burra Group of sediments (Mirams and Forbes, 1964)—the Witchelina Quartzite which is correlated with the Aldgate Sandstone of the Adelaide area. The Witchelina Quartzite has been folded, truncated and generally distorted by major fault structures in this region. The Nor'west Fault occupies the near axial position of a tight anticlinal fold in steeply dipping quartzites which display a series of minor drag folds in Stony Range. To the east, the same formation is vertically disposed in the South Hill drag fold. (Plate VI, fig. 1.)

The quartzite is flaggy to massive and is composed of well sorted fine to medium quartz grains. The formation is at least 6,600ft. in thickness and is a prominent ridge-former in the region. The beds, being uniform in composition and hardness, weather into rounded hills; the most conspicuous ridges are in the South Hill locality and those which constitute Stony Range and culminate to the south east in Termination Hill, 1 mile beyond the limits of the mapped area (Parkin and King, 1952b).

The overlying rocks comprise an un-named grey-green dolomitic siltstone formation ranging from 1,000 to 2,000ft. in thickness and the Skillogalee Dolomite equivalent which includes a typically thin-bedded brecciolitic magnesite sequence. The lower beds of this sequence comprise thin brown and buff dolomites, flaggy cross-bedded and ripple-marked sandstone-quartzites and slates. These pass up into dolomitic slates, dolomites and magnesites with sandstones subordinate. Almost 5,000ft. of these strata are exposed in a synclinal basin south of South Hill where there are three prominent beds of magnesite ranging from 3ft. to 12ft. in thickness. (Plate VI, fig. 2.)

The wedge of Torrensian Series sediments overlying the basal quartzite and confined by the Nor'west Fault and South Hill Fault include only thin magnesite beds; the dolomitic facies here is succeeded by an unnamed formation, 17,000ft. in thickness, which comprises drab grey-green coloured siltstones. These are unconformably overlain by tillite beyond the northwestern corner of the mapped area.

Umberatana Group (Sturtian Series)

To the west of the Nor'west Fault the Burra Group is succeeded by the Umberatana Group (Coats, 1964), the contact being a disconformable one. The Yudnamutana Subgroup (Coats, *op. cit.*) comprises tillitic developments, pebbly quartzites, grits and sandstones with shales totalling 3,300ft. in thickness. (Plate VII, fig. 1.) These are succeeded by the thin (almost 200ft. thick), persistent, Tindelpina Shale Member, a finely laminated dark-grey shale.

Conformably overlying these rocks is the Tapley Hill Formation, a succession of drab grey-blue-green slates and siltstones with occasional thin dolomitic beds at least 9,500ft. in thickness overall, though the top is not exposed.

Some 10,000ft. of the Amberoona Formation are exposed in the core of the anticline between Hedley Hill and Arthur Hill. Rocks of this formation include green siltstones, yellow-weathering gritty dolomite, calcareous grits and sandstones some 10,000ft. in thickness.

The Elatina Formation is a poorly outcropping unit traceable for a distance of only 2 miles in a depressed belt east of Stuart Creek opalfield. The outcrop is only 20ft. in width and is separated from the underlying rock exposures by almost 300ft. of sand and alluvium along its mappable extent. The formation comprises purple and white gritty sandstones and purple siltstones with red granules.

Wilpena Group (Marinoan Series)

The Wilpena Group (Dalgarno and Johnson, 1964) is preserved in the Lake Arthur-Lake Piddleomina locality with outcrop being sufficient for study of the complete section. Yellow-weathering dolomite 15ft. in thickness is the basal unit of the marker Nucaleena Formation. It is overlain by thin purple shales which pass up into green and purple siltstones of the Brachina Formation, almost 1,500ft. in thickness.

Elongate ridges which culminate in Arthur Hill and Hedley Hill respectively are underlain by ABC Range Quartzite. On the western limb of the anticline the full thickness is not disclosed owing to faulting but on the eastern limb the formation is 2,000ft. thick. The formation is typically composed of red-brown, thin-bedded sandstone-quartzite with shale casts. Adjacent to Lake Arthur the beds are truncated on the extended Torrens Fault and abut fossiliferous Cambrian limestones.

In the Lake Piddleomina vicinity, red and green shales of the Bunyeroo Formation 1,000ft. in thickness are succeeded by the Wonoka Formation which is approximately 2,000ft. thick. The Wonoka Formation comprises yellow and purple flaggy limestone and green calcareous shales; purple and green siltstones are common near the base.

Pound Quartzite is preserved in subdued outcrop around the margins of a claypan 2 miles northeast of Hedley Hill. The formation is some 400ft. thick and includes thin-bedded sandstones with shale casts and minor ferruginous gritty sandstone. The top is capped by duricrust.

On the eastern side of Lake Torrens there is thus exposed a fairly complete Adelaide System succession above the Callanna Beds to the base of the Cambrian; the Cambrian System rocks are considered in later pages.

WEST OF LAKE TORRENS—STUART SHELF

(?)Umberatana Group Equivalents

Pernatty Grit

The oldest strata exposed in this region comprise grits, sandstones, arkoses, quartzites and pebbly quartzites with minor slates and siltstones for which the name Pernatty Grit is proposed. They outcrop discontinuously as low stony hills and in abrupt "breakaway" scarps on the edges of salt lakes (plate VII, fig. 2) over the extent of the Bookaloo Lowlands, the most continuous exposures being in the Pernatty Lagoon locality. The relief between hill tops and surrounding pediments seldom exceeds 100ft. These rocks are characteristically cross-bedded and in places rhythmically bedded to give a varved appearance.

The strata appear to be horizontally disposed throughout, though they generally show torrent bedding structures on small to large scale. (Plate VIII, fig. 1.) Because of the low relief in this tract, seldom is more than 100ft. of section exposed at any one place and because of discontinuity of exposures, lack of marker beds and uniformity of lithology, it is impossible to estimate the thickness of this formation. The most reliable section is that disclosed by Woomera No. 1 bore at Phillip Ponds

where 1,220ft. 6in. of this formation were penetrated without disclosing its base. The full thickness therefore is in excess of 1,220ft. A log of the relevant section intersected in Woomera No. 1 bore is as follows:

Depth		Description
From ft.	To ft.	
784½	1,066	Pink and purple grits, medium to coarse grained; quartz grains rounded to sub-rounded, feldspathic; finer-grained bands occur; friable in part; cross-bedding apparent.
1,066	1,074	White quartz grits with brown shale.
1,074	1,118	White quartz grits; well-rounded grains, cross-bedded; grey shale at 1,110ft.-1,110ft. 6in.; occasional pebbles up to ½in.
1,118	1,122	Grey siltstone breccia.
1,122	1,375	Finely laminated dark-grey shaly siltstone; slump bedded in part.
1,375	1,490	Finely laminated dark-grey shaly siltstone with thin light-coloured fine-grained siliceous bands.
1,490	1,491	White pebbly feldspathic and shaly grit; pebbles up to ½in; pyrite at 1,491ft.
1,491	1,542	White, pink and brown feldspathic grits with occasional pebbles up to ½in.; manganese and pyrite in part between 1,508-1,514ft.
1,542	2,002	Purple feldspathic grit; few pebbles up to ½in., occasional light-coloured fine-grained bands of sandstone-quartzite; micaceous in part.
2,002	2,005	Medium to coarse-grained sandstone-quartzite.

A typical laminated gritty sandstone taken from near Whittata H.S. was submitted to The Australian Mineral Development Laboratories (AMDEL) for petrological examination, for comments on the constituent pebbles, the possibility of their derivation from the Gawler Range Porphyry and on a fluvioglacial origin for the grits. P. J. Sweeney (AMDEL) reported that the feldspathic sandstone showed, "graded bedding between fine and medium to coarse sand grades. The finer material is moderately well sorted although the bands contain some grit sized grains and rock fragments, while the bands of coarser material are poorly sorted. The latter show variations in grain size from fine to grit grades, but the bulk of the material falls in the medium-coarse range. Quartz is the dominant mineral present; the grains were originally subrounded or rounded . . . feldspar is present as microcline and plagioclase with the former predominant . . . sericite, . . . tourmaline and opaques are accessory.

"The rock fragments are mainly igneous, both fine and medium to coarse grained, some porphyritic with resorbed phenocrysts of quartz and feldspar. They show some affinities with the Gawler Range Porphyry but no definite correlation can be made. Some quartzitic fragments occur. The bands of coarser material indicate deposition in torrential conditions but no definite evidence for a fluvioglacial origin can be found".

Petrological reports on other sandstones, arkoses and gritty arkoses from the same sequence describe similar features: the subrounded to rounded nature of the grains, cementation of grains by secondary quartz in optical continuity with the original grains, presence of feldspar, and poorly sorted nature of the sediments generally. A calcareous matrix was reported in several samples. The pebbles often exceed ½in. in diameter and include angular or rounded fragments of quartzite, porphyry and chert—these are generally rounded.

At Kotabera H.S. a shallow well penetrated pebbly grey-green siltstones which resemble a facies of Sturtian tillite. Petrologically this rock was described by D. Smale (AMDEL) as an arkose whose main constituents "are quartz and feldspars (microcline and oligoclase). The interstitial cementing material is . . . dolomite . . . and . . . secondary silica . . . in optical continuity around the original grain. Occasional grains of tourmaline and zircon are also present. The rock has a poorly sorted texture. Grains range from silt grade . . . to coarse sand grade . . . show a considerable range of angularity . . . with grains of dolomite and chert up to 2in."

A characteristic dense red-brown quartzite which outcrops on and along the western shore of Pernatty Lagoon and is exposed in the Woocalla ballast quarry shows peculiar banding (plate VIII, fig. 2 and plate IX, fig. 1) which may transect the bedding at acute or oblique angles and is considered to be a phenomenon of weathering. The bands are determined by concentrations of iron oxides in evenly spaced parallel bands which may be straight or gently curved and in some specimens they are difficult to discern from bedding. There have been suggestions (log of Woomera Bore, 1960) that the grits are tuffaceous. For comments on this aspect and on the distinctive banding, a specimen of this quartzite was forwarded to P. J. Sweeney (AMDEL) who reported that the rock showed "graded bedding from fine (0.16 mm.) through medium (0.48 mm.) to coarse (1.0 mm.) sand grades with quite good sorting within the bands. The grains, principally quartz with a few rock fragments, are set in a matrix of clay. Most show secondary overgrowths of quartz and some, where in juxtaposition, have sutured together by recrystallization. A ring of inclusions outlining the shape of the original grain shows them to have been quite rounded. Extinction on some grains is markedly undulose while on others it is sharp; this probably indicates different origins for the grains. The clay matrix shows evidence of recrystallization with the formation of some sericite . . . The rock fragments occur principally in the coarser bands; they are mainly metamorphic types—quartzitic or gneissic—but some are possibly volcanic varieties. They are not, however . . . tuffaceous. Oblique to the bedding another set of bands are present, formed by variations in amount of iron oxide. The oxide is very finely divided and occurs surrounding the quartz grains and sometimes filling intergranular spaces; in some cases it has caused embaying of the quartz intergrowths. The bands seem to show a fairly constant thickness throughout their length but the width varies from one band to another. The origin of the oxide is doubtful; it may have been introduced from external sources or may be original and simply redistributed by percolating ground waters".

The Pernatty Grit is an extension of the formation mapped previously in the Pandurra H.S.-Mount Whyalla locality on upper Eyre Peninsula (Miles, Johns and Solomon, 1952) when it was considered to be a facies of the Corunna Conglomerate; it has since been named Pandurra Formation (Crawford, 1964). In that area it overlies the Roopena Lavas, since dated by W. Compston (unpublished report, 1964), at 1,350 m.y.

Although tillites have not been recognized, the pebbly grits bear strong resemblance to the Elatina Formation of the Parachilna area (Dalgarno, 1964). There are also marked similarities between these rocks and the pebbly grits of the Yudnamutana Sub-Group mapped near West Mount Hut. However, erratic boulders of red quartzite bearing a strong resemblance to the Pernatty Grit have been observed within the Sturtian glacial sequence (R. P. Coats pers. comm.) suggesting that the Pernatty Grit is therefore older.

Woocalla Dolomite Member

Dolomites outcrop along the western shore of Pernatty Lagoon, as low islands on the floor of that lagoon, and at intervals southerly to near South Hill trig. A further occurrence has been reported from Oakden Hills (R. Dalgarno, pers. comm.). They are best studied in the ballast quarries at Woocalla where over 50ft. of yellow-brown, buff or grey, bedded massive to occasionally thinly laminated dolomite have been exposed. (Plate X, fig. 1.)

There are breaks in continuity of exposures and the strict age equivalence of the different occurrences might therefore be questioned. The dolomite is variable at the different localities; near Mount Gunson it is pisolitic; at the margin of the lagoon near the manganese workings it is essentially a continuous stromatolite reef; at the Sweet Nell mine it is a normal stratified and finely banded blue grey dolomite. These fabrics can be co-ordinated with differences in characteristics of the covering and underlying rocks.

At Woocalla the dolomites display a contorted bedded form with undulations of the bedding having amplitudes of up to 10ft. and wave lengths of 30ft. (Plate X, fig. 1.) The crenulated bed rests unconformably on Pernatty Grit at the ballast quarries; elsewhere a similar relationship is not directly observable but may be inferred. The unconformity at Woocalla was recorded by Jack (1917) although Dickinson (1942) could not "support such a judgment".

Immediately south of Woocalla R.S. at Magazine Hill the dolomite is succeeded by grey and white shales of the overlying Tent Hill Formation. Similar relationship has been observed immediately east of Oakden Hills. At these localities the dolomite would appear to occupy the same stratigraphic position as does the Nuccaleena Formation elsewhere. Some 9 miles to the east of Woocalla a bore is reported (Dickinson, 1942) to have penetrated dolomite from 300ft. to 488ft. without disclosing its full thickness.

The dolomite is more or less manganiferous throughout. Manganese occurs in fractures and bedding planes and in irregular patches, while marked concentrations are notable at the base of the bed at Woocalla ballast quarry and also near the top of the bed at Magazine Hill. It is the host to manganese deposits at Pernatty Lagoon where it overlies pebbly quartzites, and to copper deposits at Mount Gunson and at the Sweet Nell prospect. At Mount Gunson workings, Brennan Shaft disclosed a bed of oolitic dolomite up to 40ft. in thickness and overlain by shaly sandstone. In the Sweet Nell mines the dolomite, 10ft. in thickness, is underlain by 4ft. of grey dolomitic shales which overlies red-brown quartzite.

The bed appears to be lenticular and at a number of localities it thins abruptly to zero or has been faulted into position. Evidence for structural dislocation is lacking.

Intraformational breccias occasionally developed within this member and the presence of asymmetric ripple marks (plate X, fig. 2) suggest that it was deposited in a shallow water environment; its crenulated bedded form and abrupt terminations suggest a stromalite reef. A "cylindrical" and "wavy laminae" form of *collenia sp.*, best exposed at the manganese workings, appears to be similar to forms described by Robertson (1960) from Queensland. The surface on which dolomite was deposited appears to have been an irregular one and there was obviously a break in sedimentation at this time.

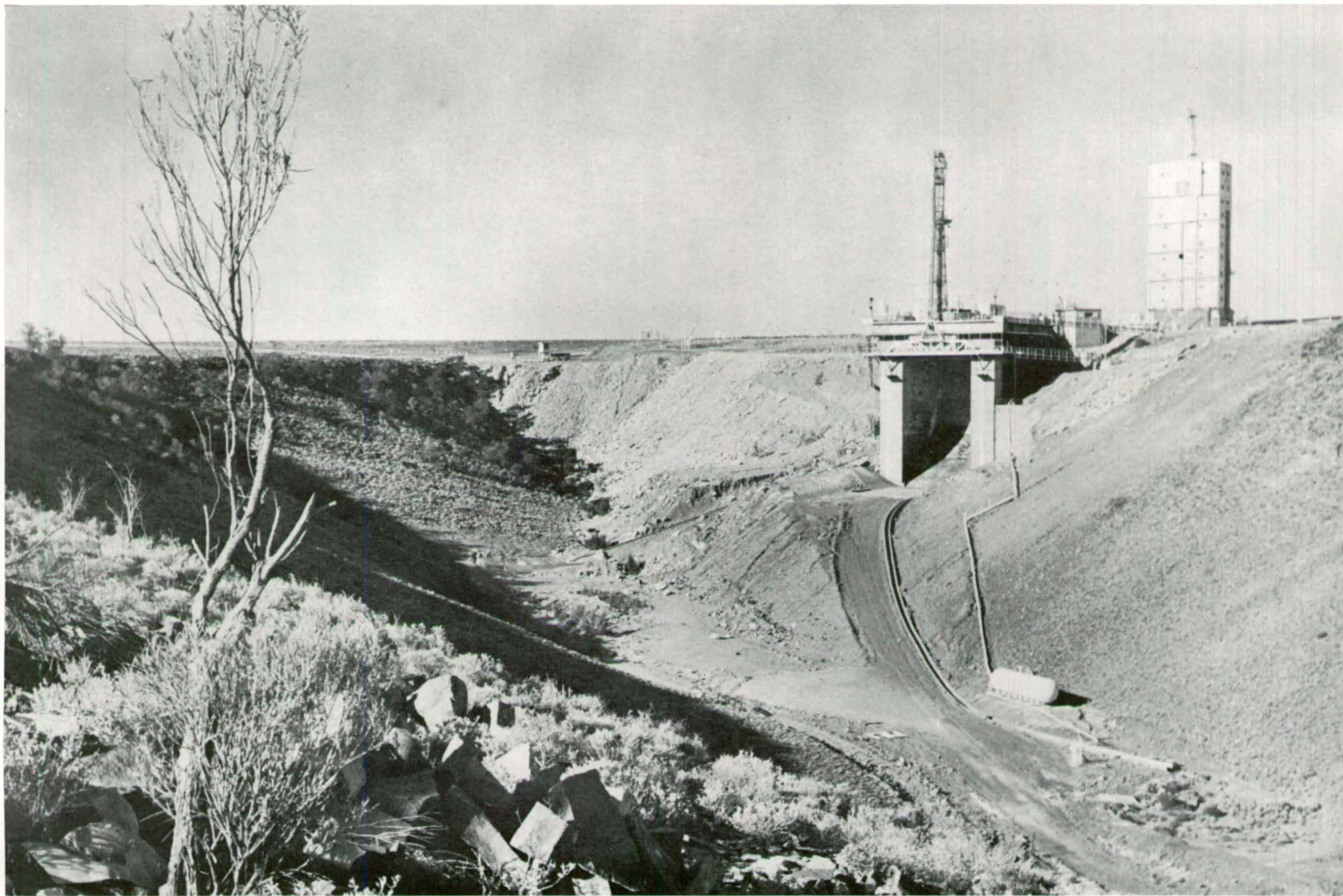
Samples of dolomite were taken from a number of localities and submitted to AMDEL for chemical analyses; minor variations in composition are evident in the following table.

Location of Sample	CaCO ₃	MgCO ₃	SiO ₂	P ₂ O ₅	Mn
	per cent	per cent	per cent	per cent	per cent
Northern end, Lake Dutton	56.3	21.9	12.1	0.16	0.60
Woocalla quarry	48.7	38.9	4.2	0.05	1.17
Sweet Nell	47.6	36.3	8.2	0.04	1.39
Near Pernatty Lagoon manganese deposit	48.3	37.2	1.1	0.08	1.76
Two miles north of Woocalla Reservoir	49.6	30.6	0.2	1.15	2.36
Dolomite workings, Mount Gunson..	51.7	38.4	1.9	0.06	2.05

In the vicinity of the Mount Gunson tableland workings a white sandstone bed which includes fragments of red Pernatty Grit rests disconformably on Pernatty Grit. This sandstone overlies dolomite but its extent has not been mapped.

Tent Hill Formation—Wilpena Group Equivalents

The Tent Hill Formation was first named from the hills northwest of Port Augusta by Brown (1885) and since that time the formation has been variously noted by Jack (1922, 1927, 1930), Mawson (1939, 1947) and Segnit (1939). Miles (1954)



Launcher 6A, Lake Hart. Arcoona Quartzite Member overlies siltstones of Tent Hill Formation.

coined the name Lincoln Gap Flagstones for the upper part of this formation to include a persistent upper quartzite member but excluding a lower unit, the Tregolana Shales, which rest directly on equivalents of the Pernatty Grit. Sprigg and his co-workers (1958) referred these rocks to the Marinoan Series and equated the topmost quartzite member with the A.B.C. Range Quartzite.

In the Cultana area Crawford (1964) divided the Tent Hill Formation into two units, the upper being named the Simmens Member and comprising dense current-bedded quartzites and the lower, named the Corraberra Member, consisting of dark red-brown micaceous shaly sandstone.

The Tent Hill Formation is here defined to include the shale-siltstone-sandstone, quartzite sequence which succeeds the Pernatty Grit and is capped by the equivalent of the A.B.C. Range Quartzite. The formation comprises (from below) the Woomera Shale Member, an unnamed siltstone sequence and the Arcoona Quartzite Member. The formation varies from 400ft. to over 1,200ft. in thickness. In the field, a reduced section may be studied at Oakden Hills but the most complete and thickest section has been disclosed by Woomera No. 1 bore.

During the course of mapping and map preparation doubts were entertained regarding correlations of the now-named Arcoona Quartzite Member with the A.B.C. Range Quartzite and this is reflected in the legend of the Torrens map where equivalence with the Pound Quartzite is suggested (Johns, 1963a.)

Woomera Shale Member

The Woomera Shale Member is named from Woomera No. 1 bore which penetrated a dense, remarkably well sorted, evenly bedded and typically laminated sequence of purple, brown and green shales 548ft. 6in. in thickness above Pernatty Grit. In boring it was intersected between 236ft. and 784ft. 6in.

This member is equivalent to the Brachina Formation of the Flinders Ranges and to the "Tregolana Shales" of the Port Augusta-Whyalla region (Miles, 1954). The same shales were penetrated in boring at Wilkatana, some 10 miles beyond the south-eastern limit of the Torrens map area. Wilkatana No. 1 bore intersected laminated, purple, red-brown and green shales and intraformational breccias between 1,344ft. and 2,199ft. 3in. without disclosing the base.

The known maximum thickness in the area under review is 548ft. but the shales thin considerably in the Oakden Hills-Mount Gunson-Emu Bluff region where they appear to be less than 50ft.; elsewhere the thickness is unknown. The pronounced thinning of the shales in the Mount Gunson locality is related to an erosional "high" composed of Pernatty Grit.

Where unweathered the shales are purple, red or brown in colour with green shale partings. The predominantly red or purple colour probably reflects deposition under oxidising conditions with the production of green bands due to fluctuating reducing conditions and the formation of ferrous compounds. The shales weather readily and are seldom seen in outcrop. They have been penetrated in well and dam sinking and in water boring operations but are generally obscured over most of their extent on the Bookaloo Lowlands by sand, talus and alluvium. Where exposed in this region they are generally weathered to friable clay-shale often containing secondary crystalline gypsum. Where these rocks form the pallid zone of the duricrust profile they have been bleached to a light grey or white colour. At Magazine Hill shales directly overlie the Woocalla Dolomite Member. Only 18ft. of shale are preserved and these are finely laminated, varve-like, closely crumpled and show numerous minor fault dislocations. (Plate XI, fig. 1.) They are similar in texture to the Tregolana Shale near Whyalla (Miles, 1954), and to the deposits of the Port Augusta-Lincoln Gap district (Johns, 1960).

Unnamed Members

The base of these units is fixed by the first appearance of coarser clastics. Woomera No. 1 bore disclosed a section 236ft. in thickness below the succeeding Arcoona Quartzite Member—the relevant part of the log of this bore is as follows:

Depth		Description
From ft.	To ft.	
Surface	118	Green-purple and red-brown shaly micaceous siltstones; occasionally cross bedded, slumped and showing intraformational breccias.
118	118½	Shaly sandstone.
118½	138	Finely and rhythmically laminated green-purple and red-brown siltstones showing slumped bedding, cross-bedding and thin shale breccias.
138	141	Pink shaly sandstone with shale breccias (rounded and angular slate fragments up to 1½ in. diameter in shale matrix).
141	152	Fine-grained pink silty sandstone.
152	165	Green-purple shaly siltstone with thin sandy bands and breccias, shale pebbles and lenses.
165	177	Green-purple shaly sandstone with shale lenses and shale fragments.
177	182	Purple shale.
182	187	Pink silty sandstone.
187	194	Pink silty sandstone with grit bands.
194	217	Fine-grained pink sandstone-quartzite.
217	236	Brown-purple finely banded siltstone.
		Woomera Shale Member.

Rocks of this sequence constitute the escarpments marginal to the Arcoona Plateau and of the dissected remnants beyond and outcrops extend almost continuously along the western shore of Lake Torrens, at the margins of the dissected Arcoona Plateau and remnant mesas and buttes to the south. The most continuous exposures, in a vertical sense, form the northern shores of Island Lagoon (plate IV, fig. 1) and Lake Hart—elsewhere the slopes are more subdued and the rocks are largely obscured by scree. Southwards, these strata are traceable beyond the Tent Hills to Point Lowly.

The section exposed in tableland margins comprises an upper unit almost 100ft. in thickness of white clayey sandstones and siltstones, generally laminated and invariably containing fine white mica. The lower slopes of the escarpments comprises a lower unit almost 200ft. in thickness of thin-bedded fissile, brown and purple micaceous siltstones and fine-grained micaceous sandstones. These rocks split readily along bedding planes into paper-thin sheets or into "flagstones" from ½ in. up to 2 in. in thickness. Where exposed to wind and rain a typical "honeycomb" weathering results.

There is a general reduction in grain size downwards throughout the formation, so that on the lowermost slopes, in depressed areas along creek channels and lake margins, red-brown-green shales and siltstones are common while sandstones are subordinate. The most extensive, exposures of fissile, micaceous, cross-bedded shaly siltstone occur at Willaroo Lagoon, Shell Lagoon, along Salt Creek, at Phillip Ponds and Fred's Swamp. (Plate XI, fig. 2 and plate XII, fig. 1.) Cross-bedding on large and small scales is a common feature (plate XII, fig. 2), as are ripple marks, slump bedding structures, load casts (plate XIII, fig. 1) and intraformational breccias (plate XIII, fig. 2 and plate XIV, fig. 1).

The shaly beds are commonly dolomitic while fairly pure dolomites have been mapped in the valleys of Salt Creek, Bosworth Creek and Andamooka Creek; they are only a few feet thick and are lenticular. On partial chemical analysis the Bosworth Creek dolomite showed CaCO₃ 51.5 per cent, MgCO₃ 39.8 per cent, SiO₂ 4.3 per cent, P₂O₅ 0.03 per cent and Mn 0.40 per cent.

Throughout, the Tent Hill Formation displays sedimentary structures indicative of shallow-water sedimentation and strong current action during deposition; these include ripple marks, cross-bedding on all scales of magnitude, convolute and intrastratal slump bedding, load casts, and sedimentary breccias.

Arcoona Quartzite Member

The topmost member of the Tent Hill Formation caps the Arcoona Plateau throughout the region and from this is derived its name. It is particularly well exposed on Arcoona station along the shores of Island Lagoon, Lake Richardson (plate XIV, fig. 2) etc. and elsewhere along drainage channels and on tableland rims.

At the southernmost exposures (at Beda Hill, Dutton Bluff etc.) these quartzites comprise a thickness of somewhat less than 100ft., thickening to the north where they attain 250ft. in the Woomera locality; they appear to maintain a fairly constant thickness over the extent of the Arcoona Plateau.

The Arcoona Quartzite Member comprises an even-grained sandstone-quartzite of fine to medium grain size; less commonly it is coarse grained and gritty with rounded quartz grains. Although frequently silicified and hardened to dense quartzite on exposed weathered surfaces, it is more friable and less strongly consolidated elsewhere, and frequently carries kaolin presumably derived from the breakdown of feldspar. The rock is typically well bedded with prominent flaggy bedding plane partings at intervals of from 1in. to 6in. It is generally white in colour but this is variable to yellow, brown, red, purple or greenish; thin purple or brown shale bands or partings are common. Throughout the region a characteristic feature of the quartzite is the presence of what are commonly referred to as "clay-gall" impressions. Overall these are remarkably uniform in appearance comprising flat tabular impressions, rounded and usually $\frac{1}{2}$ in. to 1in. in diameter but occasionally attaining several inches; they are seldom more than $\frac{1}{2}$ in. deep but occasionally range up to $\frac{3}{4}$ in. In freshly broken rock, the "galls" invariably comprise elements of reworked purple, green or yellow shale derived from underlying strata.

The quartzite is locally ripple marked and is commonly strongly current bedded. Fine-grained white mica is often discernible.

In the Adelaide geosyncline to the east of Lake Torrens, A.B.C. Range Quartzite is succeeded by Bunyeroo Formation, Wonoka Formation and Pound Quartzite before the appearance of Cambrian limestones. But on the shelf to the west of Lake Torrens the Cambrian limestones in most instances rest on the Arcoona Quartzite Member with some 20ft. of shales, grits pebble beds and in some areas a thin boulder bed separating them.

Yarloo Shale

Along the northern banks of Tea Tree Creek, northeast of Andamooka Opalfield, are exposed purple shales 50ft. in thickness for which the name Yarloo Shale is proposed. They are overlain disconformably by Cambrian limestones (plate XV, fig. 1).

This formation would correlate with Bunyeroo Formation. Alluvium, and outwash derived from a veneer of Cretaceous rocks isolate these outcrops so that relationships to the Arcoona Quartzite Member are not observable; faulting is a further complication (plate XV, fig. 2).

CAMBRIAN SYSTEM

Andamooka Limestone

The name Andamooka Limestone is here proposed for the fossiliferous Cambrian limestone which generally overlaps the Arcoona Quartzite Member—the name is derived from the 4-mile sheet over which it is largely exposed. It may be equated with the Ajax Limestone of the Flinders Ranges.

The Upper Proterozoic-Lower Cambrian contact is sharp and generally suggestive of a break in sedimentation. The passage beds, 10-20ft. in thickness, include calcareous and (?) glauconitic grits, shales and sandstones and often a boulder bed. The boulder bed may range to 2ft. in thickness and contain cobbles of rounded elements of limestone, sandstone and of red-brown and green shales up to 6in. in diameter. These beds mark a surface of disconformity with the underlying sandstones.

The base of the carbonate sequence is best exposed round the margins of Purple Lake and along the western shore of Coorlay Lagoon. (Plate XVI, figs. 1 and 2 and

plate XVII, fig. 1.) The contact is also exposed along Tea Tree Creek (plate XV, fig. 1) near Andamooka Opalfield, at Lake Campbell and near Lake Mary. Numerous wells have penetrated Upper Proterozoic quartzite below this limestone on Andamooka, Purple Downs, Roxby Downs and Parakylia stations—here the limestone forms a veneer seldom more than 40ft. in thickness and is devoid of obvious fossils. The basal members north of Lake Campbell include an algae, *Ephilphyton*, in limestone from this locality. (Dr. B. Daily—pers. comm.)

The thickest and most complete Cambrian section is exposed at the northern extremity of Lake Torrens immediately to the west and north of Lake Arthur. (Plate XVII, fig. 2.) Here, almost 1,000ft. of laminated flaggy to massive buff, brown, grey limestones are preserved and, though they are faulted against A.B.C. Range Quartzite, the section appears to be fairly complete. Adjacent to the fault the beds are dragfolded and are inclined at steeper angles than normal. The lowermost 300ft. of the formation comprise apparently unfossiliferous, flaggy, well-bedded, yellow-brown, fine-grained, sandy, thinly laminated, dolomitic limestone with the basal beds being shaly or sandy with gritty intercalations. The succeeding 700ft. comprise massive, grey, purple, pink, brown and yellow limestone with an abundance of perfectly preserved *Archaeocyathinae* making their first significant appearance some 300-400ft. above the base. These massive limestones (plate XVIII, fig. 1) are less obviously fossiliferous towards the top though the topmost 20ft. comprise yellow-brown dolomitic limestone with algal colonies (plate XVIII, fig. 2).

West of Lake Torrens, though a similarly complete sequence is probably represented, the disposition of the strata, low relief and cover of Mesozoic strata and younger sand dunes leaves this in doubt. The presence of *Archaeocyathinae* were noted over a wide area to the north and northeast of the opalfield; fragments of trilobites (*Pararaia* (?)) occur in limestone near the shore of Lake Torrens.

The lower part of the section is commonly oolitic while intraformational breccias occur over wide areas.

The presence of chalcedonic nodules typify the limestone in a number of areas; these comprise buff, grey, pink or red-brown concretions which protrude from the weathered surfaces of the limestone. Where erosion has proceeded to a further stage these may be strewn over large areas, even where no limestone is visible.

Chip samples taken over successive 50ft. intervals by W. Johnson across the limestone which is exposed in the Yarrowurta section (from the base to the top total 1,150ft.) showed the following on partial chemical analysis:

Sample No.	CaCO ₃ per cent	MgCO ₃ per cent	Insolubles per cent	P ₂ O ₅ per cent
1	52.0	39.7	4.6	0.06
2	95.4	0.7	3.3	0.06
3	97.1	0.7	1.9	0.15
4	96.7	0.3	2.5	0.05
5	52.5	39.5	6.8	0.03
6	73.6	17.4	7.7	0.03
7	85.7	9.0	4.7	0.01
8	97.2	0.3	1.6	0.02
9	98.6	0.6	0.7	0.01
10	97.2	1.3	1.2	0.03
11	56.3	40.7	1.4	0.02
12	88.6	7.0	3.0	0.05
13	94.5	1.8	2.4	0.10
14	94.1	2.2	2.4	0.08
15	93.1	3.3	3.1	0.01
16	96.9	0.7	1.6	0.01
17	98.4	0.5	0.3	0.01
18	95.4	2.2	1.4	0.01
19	79.6	15.6	1.2	0.01
20	77.4	19.4	1.0	0.01
21	97.6	0.4	1.1	0.02
22	93.0	1.5	4.5	0.01
23	78.2	17.8	2.0	0.03

Yarrowurta Shale

Apparently conformably succeeding the carbonate sequence north of lake Torrens are preserved approximately 400ft. of red bed clastics for which the name Yarrowurta Shale is proposed, from the prominent cliff in the vicinity. At the northernmost extremity of Lake Torrens these gently undulating beds form low cliffed escarpments (plate XIX, fig. 1). They comprise micaceous, calcareous, red-brown, pink, purple or green-grey shales and siltstones; they are fissile, thinly bedded, laminated in part, often flaggy and show fine cross-bedded laminations and ripple marks. No fossils were detected.

Chip samples taken from the Yarrowurta section (total 400ft.) over successive intervals of 50ft. showed the following carbonate contents on partial analysis:

Sample No	CaCO ₃ per cent	MgCO ₃ per cent
1	15.5	3.6
2	6.7	6.4
3	18.9	1.5
4	5.8	4.8
5	32.2	5.9
6	10.9	9.8
7	11.6	8.8
8	19.9	9.8

This formation is correlated with the Billy Creek formation.

MESOZOIC SEDIMENTS

Algebuckina Sandstone Equivalent

Exposures of sandstones, grits and conglomerates which are generally regarded as being of upper Jurassic-lower Cretaceous age are found widely about the margins of the Great Artesian Basin in South Australia, around the Precambrian inselbergs of Mount Dutton and the Peake and Denison Ranges, west of the Stuart Range southwards to Kingoonya, and round the northern flanks of the Flinders Ranges.

In the Andamooka-Torrens region are exposed remnants of a sandstone-grit formation which occur as thin discontinuous outcrops below Cretaceous (Aptian) sediments on the shelf area west of Lake Torrens and as erosional remnants on the western flanks of the Willouran Range. They are similar to and are equated with the Algebuckina Sandstone (Sprigg *et al*, 1958) of the Peake and Denison Ranges which has been more recently described by Wopfner and Heath (1963). Segnit (1939) first recorded even-grained white feldspathic Jurassic (?) sandstone 12ft. in thickness and resting on Precambrian quartzites at Andamooka Opalfield. A nearby well penetrated 14ft. of similar sandstone and 2ft. of black ferruginous sandstone above basement. Similar ferruginous sandstones outcrop in the bed of Opal Creek downstream from the settlement.

Approximately 50ft. of cross-bedded white sands and grits showing minor discontinuities and cut-and-fill structures are preserved at Trig Bluff, a prominent tableland several miles east of the opalfield. Numerous strap-like plant impressions are present, with occasional leaves. A specimen submitted to W. K. Harris for palynological examination consisted "of pinnae and pinnules of *Microphylopteris minuta* Medwell. The frond is bipinnate with pinnae up to 3 cm. long and 2 mm. broad. Pinnules very small, rounded and attached by the whole base, less than 1 mm. wide. It is a common long-ranging form in upper Jurassic to Cretaceous rocks" (Harris—Dept. of Mines, unpublished report, 1963).

Sandstones and grits have also been mapped south of this locality near the western shore of Lake Torrens and at Willaroo Lagoon where they appear to fill up depressions on an old land surface. They are generally gritty, occasionally calcareous and they have been often silicified. The near-basal beds generally comprise red-brown or black ferruginous sandstones. Along the southeastern margin of Willaroo Lagoon ferruginous

sands and gravels overlie yellow gypseous clays and carbonaceous sands. (Plate XIX, fig. 2.) In water boring operations between Andamooka H.S. and the opalfield, ferruginous sands, grits and boulder beds, probably comprising part of this sequence have been recorded.

On the flanks of the Willouran Ranges, 1 mile west of West Mount Hut a lone outlier of calcareous sandstone, 15ft. in thickness, is preserved in a small mesa at The Pile. (Plate XX, fig. 1.) The sand is coarse to gritty and generally well rounded and rests on weathered grey Sturtian shales. Similar sandstones with rounded gravels which comprise porphyry, gneiss, quartzite etc., have been noted beyond the boundary of the mapped area at the margin of the ranges towards Bopeechee.

The constituent grit grains, pebbles and boulders are almost everywhere well rounded and waterworn and consist largely of milky quartz.

Elsewhere throughout the region these basal sands were not recognized or are absent. A study of bore logs from the Purple Downs-Andamooka region reveals in a number of bores the occurrence of sands, grits and gravels above basement quartzite (*see* Appendix). In the absence of diagnostic lithologies and fossils and hampered by paucity of outcrop, veneers of duricrust, soil and sand dunes, these have been mapped as "undifferentiated Cretaceous".

Carbonaceous, pyritic and mottled red, yellow, blue and black clays encountered in boring on Billa Kalina station near Angle Swamp and the freshwater lignitic clays intersected in Yarrowurta bore (45ft.-212ft.) and in Mirrabuckina bore (68ft.-153ft.) may be Algebuckina Sandstone equivalents though they could conceivably underlie the Jurassic sands and be extensions of the Permian lignite bearing beds disclosed in Lake Phillipson bore, (Ludbrook, 1961).

The Algebuckina Sandstone equivalents appear to have been generally thin and to have filled up depressions in the early Mesozoic land surface under shallow-water lacustrine and, in part, fluvial conditions prior to shallow marine transgression.

Marree Formation Equivalent

Undifferentiated Cretaceous sediments (Aptian, Marree Formation equivalents) (Forbes, 1965) have been mapped in discontinuous outcrops over a large part of the area. These are a shallow-water marine or brackish-water facies marginal to the Great Artesian Basin which overlap the Stuart Shelf and are characterized by conglomerates and boulder beds near the base and by the presence of "erratic" boulders sporadically distributed throughout an otherwise fine-grained sequence. The surface is characteristically strewn with rounded and faceted boulders (mainly quartzite) which have been derived from weathering and their occurrence has been widely used to determine the limits of the formation in the absence of outcrops of the parent materials. (Plate XX, fig. 2.) A number of workers including Brown, Jack, Ward and David have discussed the origin of these "erratics". References to these and a case for a glacial origin have been presented by Woolnough and David (1926). Previously Brown (1905) at Stuart Creek had noted "erratics resting on soft Cretaceous shale and silt and comprising quartzite, clay, siliceous slate, feldspar porphyry, sandstone and quartz which measured up to 5ft. x 4ft. x 1½ft. and that larger but shattered blocks occurred". These he concluded "without doubt have been transported to their present position by ice action, which seems to have, at sometime since the Mesozoic period, been in operation all over this region". The problem has been more recently summarized by Parkin (1956) following investigations in the Peake and Denison Ranges. It is now generally conceded that the faceted and subrounded boulders were derived from erosion of basement rocks and from Permian erratic fields and were incorporated in succeeding shallow-water sediments in a normal marine environment marginal to the Great Artesian Basin.

From the Mirrabuckina bore, located 8 miles to the northeast of Lake Torrens, Howchin (1893) has recorded marine Cretaceous foraminifera, fragments of molluscs (*Lingula*) and fish remains.

Exposures of Marree Formation equivalents are best studied in dissected tableland scarps at Yarrowurta Cliff (plate XXI, fig. 1) and in the opal workings at Andamooka.

At Yarrowurta Cliff the Mesozoic section above the Cambrian Yarrowurta Shale is 90ft. thick and comprises a basal unit of sands and siltstones 40ft. in thickness succeeded by 50ft. of white kaolinitic and micaceous siltstones with occasional pebbles and boulders. Opal occurs and has been mined from a gravel horizon some 40ft. above the base of the section.

These outcrops are traceable in dissected tablelands northwards, towards Lake Eyre and to Stuart Range. In the northwestern part of the mapped area occasional erosional scarps reveal shales of this formation. The shales were bleached and kaolinized during the period of duricrust formation in the Tertiary and remnants of duricrust mantle the tablelands. The surface in this tract is largely obscured by sand dunes but between the dunes and especially at the margins of claypans derived water-worn boulders are ubiquitous while occasional outcrops of shale or silicified grit are present.

From the bare flat tableland surface of the Yarrowurta locality the formation is traceable (largely under a cover of dune sands) to Andamooka Opalfield where sand dunes are more widely separated and typical partially dissected tableland topography pertains. At this opalfield the following section has been disclosed from the surface.

Depth		Description
From ft.	To ft.	
Surface	40	White kaolinitic even-grained sandy clay, clayey sandstones and siltstones; generally hard and massive and showing no trace of bedding. Faceted boulders and waterworn rounded, subrounded to subangular pebbles or boulders up to 4ft. diameter, are sporadically distributed throughout—pebbles comprise chiefly quartzite but shale is also common. Concentrations of pebbles occur locally in conglomerate beds a few inches in thickness.
40	42	Massive dense conglomerate—includes boulders almost exclusively of waterworn and commonly faceted quartzite. Thickness variable from 3in. up to 2ft. This is a marker horizon over the extent of the opalfield.
42	43	Purple, red, brown, grey or green clay (which whitens on exposure), with ironstained partings. Rounded pebbles may be present—Opalization at interface with conglomerate above. Thickness variable from 6in. up to 2ft.
43	63	White kaolinitic siltstones and sandstones with scattered pebbles. Conglomerate beds and thin varicoloured clays occur.
—	—	Algebuckina Sandstone equivalents.

The microfaunal assemblage of this sequence has been discussed by Ludbrook (1961) who noted that arenaceous foraminifera were particularly rich in the mottled clay which occurs immediately below the opal horizon. Fossil wood and opalized bivalves have occasionally been recovered from this level and in December 1963 opalized ribs and vertebrae of a plesiosaur were found at Tea Tree Flat.

Boring for water supplies to the south and west of the field has disclosed a Mesozoic section up to 102ft. in thickness but from the lithologies it is impossible to determine whether these include Algebuckina Sandstone equivalents. A similar problem is presented in the Red Lake Project area where boring indicated a thickness of up to 83ft. of sandy clays, grits and gravels.

Dissected remnants of the formation occur as thin veneers southwards to the Woomera-Island Lagoon locality; quarrying near Bernard trig has exposed siltstones with enclosed quartzite boulders to a depth of 10ft. (Plate XXI, fig. 2.) The formation may be preserved more extensively than is indicated on the geological plans but the mantle of younger sediments and consequent lack of outcrops makes the location and tracing of boundaries an arduous and at times impossible task.

TERTIARY SEDIMENTS

Lacustrine

Fresh and brackish water lacustrine sediments of Tertiary age have been proven by boring to underlie the Lake Torrens Sunklands although their full extent and thickness have not been determined.

Attention was first drawn to carbonaceous sands underlying the Pirie-Torrens Basin in 1926 when obscure traces of oily material were recorded from a water bore in lower Tertiary lignitic sands at Wilkatana (Sprigg, 1955) some 10-15 miles south of the area under review. Subsequent drilling in 1955 and 1956 by Santos Ltd. disclosed that 100-200ft. of multicoloured piedmont clays overlie lower Tertiary silty mudstones, sands, lignites, sandy clays 200-300ft. in thickness and that these rest on Cambrian limestones. Lignite beds attain a thickness of 25ft.; plant spores were identified and an early Tertiary age established. The basal beds were gritty with a pebble conglomerate at the bottom.

In the period 1960-1964 drilling was undertaken to investigate the sediments and enclosed brines beneath the bed of Lake Torrens (Johns, 1964). Boring to a depth of 887ft. at bore 3A which is situated some 3 miles east of the boundary of the sheet (as indicated in the cross-section on Torrens map) has revealed a sequence hitherto not suspected. Below 261ft. of what are regarded as Quarternary sediments, the following Tertiary section has been intersected:

ft.	ft.	
261	493	Pale grey-green to white dolomitic mudstones with silty mudstones and brecciolitic dolomites.
493	608	Grey mudstones passing down into finely laminated siltstones; lignitic fragments throughout; dolomitic in parts; fragmentary shells at 539ft. to 540ft.
608	887+	Grey-brown fine to coarse quartz sands with mudstone beds; more or less carbonaceous throughout.

The dolomitic sequence is similar to that encountered in boring at Lake Eyre (Johns, 1963) where the Etadunna Dolomite 150ft. in thickness comprises dolomite, dolomitic mudstones and intraformational dolomite-clay breccias. The lakes appear to have provided separate basins of accumulation and though the dolomitic sediments are not necessarily of the same age they were deposited in similar environments with repeated exposure and drying of shallow brackish water lagoons. Remnants of similar dolomite are preserved in adjacent areas near Callana, Billa Kalina and Maralinga—again, equivalence in age cannot be demonstrated.

Carbonaceous sediments encountered in boring have been examined by W. Harris (Palynologist) who concluded (unpublished Dept. of Mines report, 1964) that the sandy sequence below 600ft. is of lower or middle Eocene age.

Fluviatile

Well-rounded and polished pebble conglomerates, grits and sandstones of what were formerly known as Eyrian or "desert sandstones" are distributed as veneers over a wide area of far northern South Australia and particularly over the Great Artesian Basin. The cementing material may be siliceous or ferruginous; they are commonly "duricrusted" by the advent of silica and form protective cappings to mesas. In the Woomera area remnants of these presumably Tertiary formations characterized by quartz, chert and chaledonic grits, have been mapped and several fossil stream channels have been located. These Tertiaries have been largely derived from the weathering and resorting of Jurassic and Cretaceous sands, grits and pebble beds and the lithologies are therefore often similar and were it not for the presence of characteristic water worn grits and in isolated instances a distinctive flora they would be inseparable.

Extending westerly from Woomera township towards Hiern Hill and also in the Koolymilka locality are preserved thin remnants of silicified Tertiary plant-bearing beds. These rocks comprise coarse conglomerates with boulders often exceeding 1ft.

in diameter, grits, and white, buff or red quartzites. The finer-grained members particularly, carry traces of silicified leaf and stem impressions while some parts are crowded with stem and trunk impressions or silicified fossil leaves (plate XXII, figs. 1 and 2) including *Eucalyptus* sp. and *banksia*. sp. The author's attention was first drawn to these occurrences by Mr. Colin Van Senden (Dept. of the Interior) who has observed plant beds widely in the region towards Mount Eba. Obscure ?plant impressions have been noted at Eucolo and South Tank dams on Arcoona station in grey siltstones while silicified plant remains have been observed some 10 miles south of the map area near Hesso R.S. and in the northern extremity near Angle Swamp.

Silicified leaf specimens preserved in sandstone or quartzite have been collected from the Arcoona region at various times and the material presented to the Tate museum, University of Adelaide. Specimens were collected as under:

1876, W. L. R. Gipps from Bottle Hill and Andamooka.

1883, Wentworth Hardy, from Bottle Hill, with *Banksia* sp.

1883, Clement Sabine, from Lake Gairdner and Elizabeth River, with *Bombax* sp., *Quercus* sp. and *Eucalyptus* sp.

1888, H. Y. L. Brown, from Arcoona, with *Eucalyptus* sp.

These were determined by Tate and Watt (1896) as being from the "desert sandstone—supra-Cretaceous" which is the "topmost stratum of table-topped hills south of Oodnadatta and extending into the basins of Lakes Torrens and Gairdner".

The material was submitted to Chapman (1937) who identified and figured many of the leaf impressions which showed "the utmost delicacy of structure"; to them he assigned a lower Oligocene age.

Fossil stream channels, choked with boulders or sand, have been identified at several localities on the Arcoona Plateau. On the southern bank of Mungappie Creek, 2 miles southeast of Koolymilka Lake, remnants of an old stream channel filled with sand have been exposed in quarry operations. The sand (plate XXIII, fig. 1) where exposed over a thickness of 15ft. is clean, coarse, and ideally suited for use as fine concrete aggregate though thin clay lenses occur. The coarse sand is overlain by 6ft. of very fine sand. The topmost 6ft. of the exposed section comprises gibbers and kopi with mottled yellow and white clay (12in.), duricrust (6in.) and very fine sand with rounded nodules (4ft. 6in.).

Southeast of Woomera, within a few miles of Island Lagoon the traces of two old stream channels, now choked with coarse boulders, have been mapped. Both are elevated at 550ft. and are similar in nature (plate XXIII, fig. 2 and XXIV, fig. 1); the boulders which fill the old drainage channels comprise closely packed angular quartzite blocks which have a siliceous matrix and have the general appearance of a tectonic breccia. The channels of both are traceable over a length of several hundred yards; they have been eroded in quartzite in each case and have steep-sided walls.

The depressed belt extending northeasterly from Koolymilka Lake and along the valley occupied by Andamooka Creek to Lake Torrens marks the trace of an old stream channel and quartz, agate and chalcedonic grits are widespread in this tract. Adjacent to the shore of the lake, approximately 1 mile north of the mouth of Andamooka Creek intensely folded flaggy quartzites and shales of the Tent Hill Formation are unconformably overlain by white, yellow and red-brown sands with thin grits and basal boulder beds. (Plates XXIV, fig. 2 and XXV, fig. 1.) The Tertiaries range in thickness from 10ft. to 50ft.; they have been silicified at the surface to dense chalcedonic quartzites. The underlying loosely consolidated sands are in part kaolinitic, occasionally calcareous, and at the base include 2ft. of grey and yellow-brown silty clay.

Conglomerates and sandstones which have been observed in the western bank of Island Lagoon Creek 4 miles south of Pimba, conglomerates which outcrop on the western shore of Pernatty Lagoon, and the ferruginous grits and boulder beds northeast

of Emmie Bluff, are presumed to be of the same general age. The section in Island Lagoon Creek includes ferruginous and calcareous sandstones (12ft.), boulder conglomerate (12ft.) and white sandstone (10ft.).

Older Sand Dunes

To the west of Lake Torrens in the northwestern sector of the mapped area an old dune system imposes a conspicuous physiographic pattern resultant from their strong control on the surface drainage. (Plate XXV, fig. 2.) The dunes trend generally north-south, but they have a somewhat arcuate pattern towards the southern limits where the trend is south-southwest.

A younger longitudinal dune system related more closely to the present wind regime is superimposed—the trend of this system being nearly at right angles to the older. Though there is no defined surface drainage system, storm waters collect in elongated claypan depressions which parallel the old dune system.

The old dunes comprise silicified and in part calcified (kunkar) quartz sands and thus they predate at least the latest period of silicification in the region. The spacing of the parallel dunes is fairly regular and ranges from 100yds. to $\frac{1}{2}$ mile. They have low relief, being generally less than 10ft., the ridge form having been greatly modified since their accumulation.

Farther north towards Stuart Creek, near the margins of breakaway scarps, the channelling of surface waters along dune corridors has exerted a strong control on erosion patterns to develop steep-sided parallel consequent valleys separated by elongated, tongue-shaped hills. These erosional features have been cut into flat-lying duricrusted Cretaceous sediments during the initial stages of erosion. On maturity a normal dendritic pattern has developed.

The dune system has been related by Webb and Wopfner (1961) to former shore lines of an ancestral Lake Torrens and a Plio-Pleistocene age assigned. This relation is a purely speculative one, and no evidence is forthcoming to support that contention.

QUATERNARY ACCUMULATIONS

Sand Plains and Sand Dunes

Red quartz sand piled into regular systems of sub-parallel longitudinal dunes are a feature of the whole region (*see* plate II, fig. 2). They have encroached over the Arcoona Plateau along eroded valley floors and at high levels and blanket wide-spread areas of the surrounding Bookaloo Lowlands and the Torrens Plains; they have transgressed over the soil profile and partly or completely mantle rocks of late Tertiary and preceding ages (plate XVI, fig. 1). The dunes may be spaced at intervals of several chains to many miles but within any one area the height and spacing between the dunes tend to be uniform but these are variable from one area to another. The dunes rise to a single crest of variable height between 10 and 50ft. with 25ft. being a common height above the level of the intervening, open, sand-free corridors. The southern slopes are somewhat more gentle than the northern. Individual dunes may be traceable for many miles. They have a constant trend east-west in the southern half and veering to northeast-southwest in the northern, parallel to the direction of the prevailing winds at the time of their accumulation though convergence and bifurcation of the dunes is a common morphological feature.

Over large areas, particularly in the southern part of the area, extensive sand plains are common. In these tracts dunes are less commonly developed and are replaced by continuous sand spreads.

Some translation of sand is occurring at the present time but mostly they are stabilized fossil dunes, fixed by the growth of vegetation—mulgas, native pines, wattles, low shrubs and perennial grasses. The sandhills vary from bare drifting sand masses with local migrations at their extremities and on the dune crests through various stages of colonization to the more or less stabilized dunes covered with the stable but

open association of the mulga scrub as outlined by Jessup (1951). Their climatic development is considered by Sprigg (1963) to relate to glacial phases of the Pleistocene. However, King (1960) has suggested that they were related to excavation from unconsolidated sandy detritus (rather than deposition) during "Quaternary Arid Cycles". This contention cannot be supported in the Lake Torrens region where it is obvious that they are depositional and have transgressed over all formations regardless of terrain or nature of underlying rocks. Much of the sand is obviously locally derived from erosion of underlying upper Proterozoic sandstones, Mesozoic and Tertiary sands and through deflation of lake sediments. Invariably the eastern shores of the lakes of the region are bound by complexes of silica sand and kopi or they give way to trains of sub-parallel dunes. (Plate XXVII, fig. 1.)

Separating the ridges of sand are loamy or clayey flats, gibber plains, more or less continuous exposures of bedrock or claypans.

Lacustrine Features, Lake Sediments

Claypans are miniature lacustrine features which occur as flat shallow depressions in close association with sandhills. They are often nearly circular, devoid of vegetation and are commonly littered or rimmed with gibbers. They vary in diameter from a few yards up to several miles but a common dimension is 50 to 100yds. They are shallow, the depth of the bottom below the general level of the surrounding plains or sandhill base being usually less than 1ft. The area drained by any claypan is limited to a very narrow peripheral belt and as a rule they hold water for only limited periods through the largest may take several months to dry out. The water of the claypans generally has a reddish-yellow colour due to suspended clay and silt; on evaporation of the water, the clay dries on the claypan floor with a "glazed" surface.

Lakes, lagoons and swamps of the region differ from the claypans in being generally larger and deeper and in having a more extensive drainage system. The western, northern and southern shores are commonly determined by steep bedrock escarpments of variable height while the eastern shores are invariably less well defined and merge into a series of gypseous mounds or sand dune spreads. Following heavy rains these basins receive run-off from adjoining tablelands; the water may be held in some of these for several years with the salinity of the water stored varying from lake to lake.

The surfaces of the lakes varies greatly—some are enlarged claypans (*e.g.* Lake Blanche), some have bedrock exposed over most of the floor area—Coorlay Lagoon, Mirage Lagoon (Lake Bessie)—some have salt crusts (Island Lagoon) while most have silty or clayey floors. In size and shape they show great variations; those lying on the Arcoona Plateau have a fairly regular rounded outline and are seldom more than 3 miles in diameter while those which occupy the depressed belts of the Bookaloo Lowlands are of irregular shape and are mostly quite extensive. The thickness and nature of the lake sediments is unknown but in general they are expected to be only thin.

Lake Torrens, the dominant physiographic feature of the region, is different in many respects from the other lakes of the region apart from size. The lake has an origin related to tectonics and owes its existence to a graben-like subsidence determined on its western aspect by the Torrens lineament and several subparallel splinter faults and on the eastern side by a fault which is assumed to parallel this lake shore marginal to the Flinders-Willouran Ranges. Subsidence of almost 2,000ft. is inferred and sedimentation has been in progress more or less continuously since early Tertiary time. The surface of Lake Torrens is normally dry and, after flooding, lake waters are driven across the surface by the wind; on evaporation these leave only thin films of

salt. Removal of salt from the surface may be achieved either by wind deflation or more likely by solution through the agency of subsurface waters which are suspected to have an outlet to Spencer Gulf along the "Port Augusta Corridor" (Johns, 1964).

Occasional cliffs up to 40ft. in height expose kunkar, kopi and red-brown clay on the eastern shore. The surface of the lake comprises soft brown gypseous silt except near the margins where wind-blown sand is entrained.

Boring, by the Department of Mines at bore 3A, 3½ miles from the eastern shore, has penetrated the following Quaternary sequence.

Depth		Description
From ft. in.	To ft. in.	
Surface	4 0	Brown sandy clay.
4 0	19 6	Chocolate-brown clay.
19 6	20 6	Blue clays, sandy in part; gypsum crystals up to lin.
20 6	54 0	Brown, occasionally blue, clays with sporadic gypsum crystals; some thin beds of silt and fine sand.
54 0	97 0	Pale yellow-brown seed gypsum; little sand and clay.
97 0	115 0	Brown silty clays.
115 0	116 0	Sand.
116 0	234 0	Light to dark brown silty clays, finely laminated in part; gypseous between 124ft.-127ft.
234 0	261 0	Red-yellow-brown and mottled clayey sands with laminated silt-stones.

The development of the other lakes in the region may be traced successively from gilgai depressions to canegrass swamps to shallow lagoons and finally to sizable lakes. The smaller, shallow swamps and lakes within the Arcoona Plateau often contain appreciable quantities of useful water after exceptionally heavy rains. Lakes Koolymilka, Campbell, Richardson and Arcoona have registered depths of up to 16ft. of water, and have contained potable water for several years but most of the other lakes are generally brackish to highly saline. The floors of the principal lakes appear to be at about the same elevation but in the absence of accurate levels over most of the region this fact cannot be established. This suspected constancy in level (250 to 300ft. above sea-level in the Woomera locality) would suggest a relation to groundwater table throughout the region and that this is therefore the limiting factor on depth of erosion of the lake floors. The absence of salt on the surfaces of the lakes may be due largely to percolation of brine underground to the groundwater table. In seeking a cause and the mechanics of erosion of these lake areas, that considered most plausible is deflation by the agency of wind. It is pertinent that invariably the western shores are defined by low cliffs comprised of bedrock while the eastern shores are gently sloping and give way to sand spreads or to fans of dune sands. (Plate XXVII, fig. 1.) The occurrence of kopi along these shores is to be expected and results from the mechanical breakdown of gypsum swept from the dried lake beds under the influence of prevailing strong westerlies. The ultimate origin of the gypsum perhaps should be sought from cyclic sources.

Glacial scour during the Permian has been considered as an erosive agency but evidence is lacking.

Jointing in the underlying bed rocks appears to exert a control on the shaping of the shores and it is evident that well defined lineaments exist along certain lake margins (fig. 4). The shores of Lake Torrens are almost certainly fault bound but many of the other lineaments are possibly related to jointing in the basement strata.

Duricrust, Silicification, Peneplanation, Gypsite

Duricrust formation associated with widespread mid-Tertiary peneplanation has resulted in the formation of porcellanite, or quartzitic duricrust over large tracts to the west, north and north-east of Lake Torrens (plate XXVII, fig. 1). Duricrusted fossil

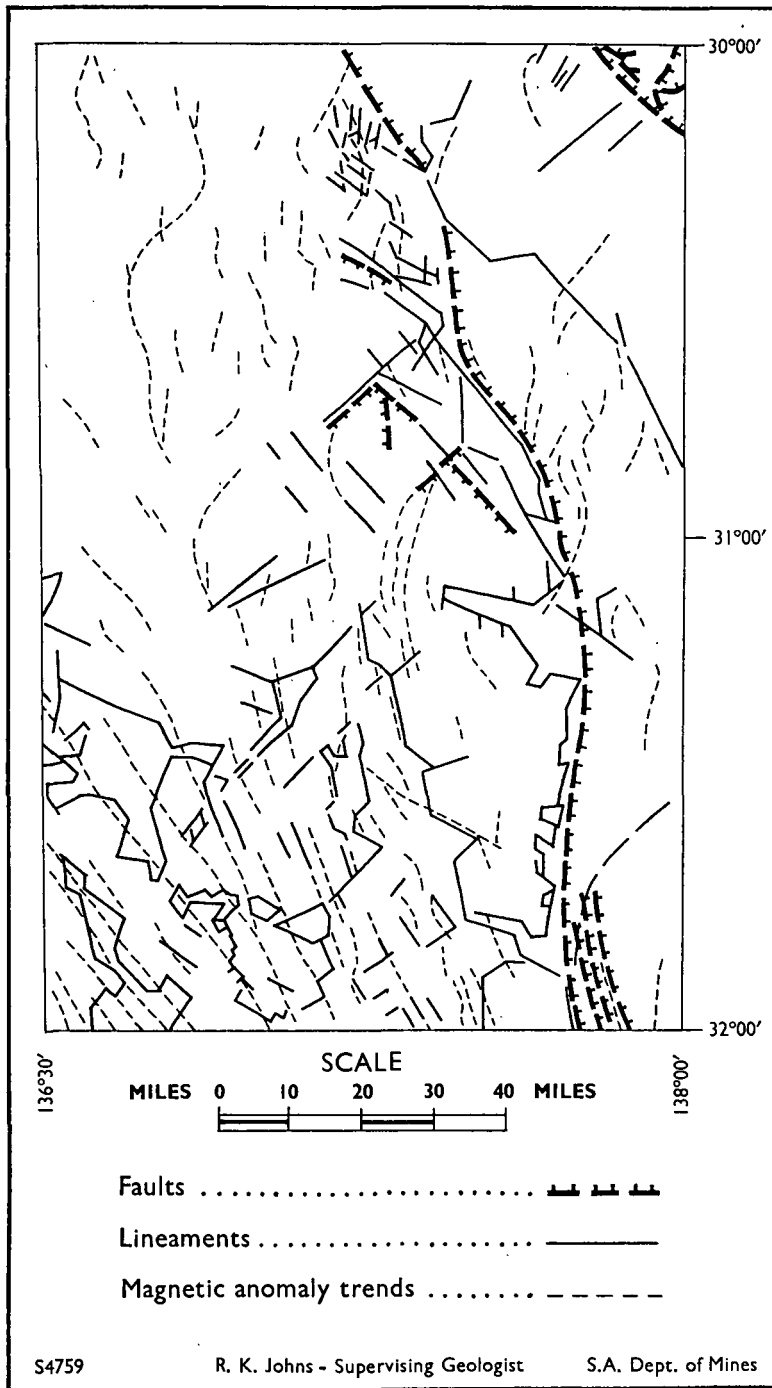


FIG. 4—ANDAMOOKA-TORRENS AREA
Map showing major lineaments

soil surfaces are not stratigraphic in a depositional sense but they are mappable surfaces of flat disconformity which have truncated the Mesozoic beds, silicified early Tertiary leaf beds and the older dunes. The pallid zone of this profile comprises bleached white or pale-coloured kaolinitic shales and siltstones with irregular patches of iron oxide.

Subsequent erosion has resulted in the partial dissection of the siliceous B horizon. To the northeast and northwest of Lake Torrens the dominant topographic features are the more or less preserved tableland areas which, on denudation, have given way to isolated flat-topped residual hills at a similar elevation that are scattered through what is now lower country. These residuals extend to south of Woomera on the one side of Lake Torrens while to the eastward these butt on to the flanks of the Willouran Range and in fact transect the drainage divide between Termination Hill and Stony Range where this surface is co-extensive to Farina and beyond. Break up of the duricrust has given rise to large blocks and to accumulations of glazed rounded or subangular gibbers on stony plains.

There is evidence of at least one later period of peneplanation and throughout the region are remnants of a lower, younger surface of erosion. These have not been mapped or differentiated. Relicts of high-level gravels in and adjacent to the Willouran Range and gypsite surfaces here and elsewhere have been noted. Gypsum might in part be derived *in situ* through the evaporation of sulphate waters but the importance of contributions from deflated lake floors should not be overlooked—the wind blown gypsum being subsequently modified and transported by groundwaters.

Alluvium, Clays, Soils Etc.

Creek gravels and alluvium associated with the major drainage channels in the region are generally thin (possibly seldom exceeding 30ft.) and are occasionally important as providing aquifers for storage of underground water.

Throughout the region the area of rock outcrop is comparatively small especially north and west of Lake Torrens where this is limited almost solely to tableland escarpments. Elsewhere the tableland areas are mantled by dune sands or by heavy, poorly drained, red-brown clay soils characterized by the development of crabholes with puffs or mounds around their margins showing strong microrelief and the surface concentration of gibbers, derived from break-up of the underlying strata. If the underlying rocks include quartzite then the ground surface is invariably strewn with closely packed slabs of quartzite which resemble an artificial pavement. (Plate XXVI, fig. 2.) Where underlain by Mesozoic or Tertiary sediments, the gibbers comprise duricrust, silicified grits or discrete rounded gravels or boulders. (Plate XX, fig. 2.)

A feature of the soil profile, which may be up to 12ft. thick is the concentration of gibbers at the surface with only sporadic occurrence elsewhere throughout the profile. Jessup considered (1960, 1961, 1962) that the stony layer on the ground surface was due to some form of vertical movement of the stones through the soil and that the parent material of the soils (excluding the stones) is a wind-blown deposit. As "the soils show no relation to the various topographic elements of the landscape and is found on the highest levels, its source clearly postdates the evolution of the major land forms. The possibility of an alluvial, lacustrine or marine origin for the parent material must, therefore be rejected".

Ollier, however, contended (1961, 1962) that the gibber plain is a lag deposit, the gibbers being not derived from the underlying rocks. Wind is supposed to have "removed finer material from a mixed deposit, leaving behind any heavy particles such as gravel and stones. Pebbles thus become concentrated on the surface until they eventually touch each other forming a continuous "desert armour" which protects the underlying material from further erosion". Though this might seem at first sight a more palatable explanation, the concept that all the soil could be accounted for by weathering of the underlying rock *in situ* cannot be accepted.

The clay loam soils of the tablelands contain heavy gypsum in the subsoil whereas in the well-drained sandy soils gypsum is absent. Gypsum may occur as minute grains or large crystal aggregates in the soils, as fine flour (kopi) over wide areas and particularly adjacent to the saline lakes, and as fibrous spar occupying bedding-plane fractures or as joint in-fillings in shales, siltstones or quartzite. (Plate XXVII, fig. 2.) Drilling undertaken by the Department of Mines in connection with testing of soils along the route of the Port Augusta-Woomera transmission line penetrated red-brown clay soils ranging from 2ft. to 12ft. in thickness on the tablelands. Sulphate contents ranged from 0.5-4.0 per cent and moisture contents 11-20 per cent. By comparison, sandy soils which exist southwards beyond Pernatty showed gypsum contents to be very low or absent with moisture content 1-7 per cent.

Accumulations of lime were noted in the soils particularly in the southern and northwestern sectors of the mapped area.

Chapter 4

STRUCTURE

The region is divisible into three principal structural divisions on the basis of degree of tectonic disturbance of the basement rocks. In the northeast are the Willouran Ranges wherein folding and faulting of Upper Proterozoic strata are intense; steep to vertical disposition of the beds is normal and transcurrent translations due to faulting are measurable in miles. The Torrens Sunklands are underlain by gently deformed basement rocks while farther west the Stuart Shelf comprises a horizontal stable platform where dips over large areas are imperceptible and range from 1-5 deg. with a general regional tilt of formations to the northward.

FOLDING

Axial lines are generally oriented in a northwest-southeast direction in the Willouran Range—the major fold structures being here influenced and largely disrupted by faulting. The Nor^West Fault is almost coincident with the axial plane of a major anticline along the crest of Stony Range. Drag folding on this fault and on the South Hill group of splinter faults is quite spectacular, the beds being generally steeply inclined in these structures.

To the north and west of Lake Torrens fold axes trend in the same general direction; folding is gentle and open with dips being only low to moderate and seldom exceeding 15 deg. Where dips are high or bedding locally strongly contorted, as near Woomera and in the Andamooka Creek-Bosworth locality, faulting is known or suspected. In the Andamooka Creek area early Tertiary sandstones unconformably overlie tightly folded Precambrian slates, etc.

Throughout the region the folds show small and undulating pitch changes.

Open folding of the Torrens sunklands is further demonstrated in extensions of this zone to the immediate east at Ediacara, Nilpena, Wilkatana and southwards from Port Augusta to the head of Gulf St. Vincent at Mounts Gullett, Grainger, Mambray, Ferguson and in the Hummocks. This represents the intermediate or hinge zone between the Flinders Ranges Horst and the Stuart Stable Shelf.

From the evidence displayed in this area orogenic movements post-date the lower Cambrian and are pre-Mesozoic in age. The general absence of later Palaeozoic sediments in this part of the Continent precludes the accurate dating of this orogenic cycle, and it is generally referred to as "Lower Palaeozoic".

FAULTING

The major faults mapped in the region are shown in the tectonic sketches. The Torrens Fault, though shown as a single fault plane defining the western shores of Lake Torrens, may in fact be a compound. Drilling has confirmed that at the southern extremity of Lake Torrens there are a number of down-faulted segments in the basement which are in part filled with Tertiary and Quaternary accumulations. Extensions of the Torrens Fault to the northwest beyond Lake Arthur through the series of mound springs between here and the Peake and Denison Ranges, and southwards towards Port Augusta, are inferred but the trace has been obscured by Tertiary-Quaternary accumulations. Marginal to Lake Arthur it has a reverse form and a hinge at this locality is inferred. Sedimentation has proceeded in the lake at least since early Tertiary (Eocene) times which fixes a limit on the lower age of active subsidence of the Sunklands. The inferred net subsidence exceeds 2,000ft.

Tectonic readjustments along meridional lines of faulting marginal to the Torrens Sunklands are still taking place. Australian earthquake epicentres plotted by Burke-Gaffney (1952) indicate that, though negligible compared with the minor seismic

zones of the earth, the "Great Rift Valley from Spencer Gulf to Lake Eyre, is the region most subject to disturbance in Australia".

In the Bosworth-Andamooka H.S.-Willaroo Lagoon locality faulting is evidenced by truncation and local upturning of strata, brecciation and introduction of iron oxides. Minor fault dislocations and monoclinical flexures have been observed elsewhere but tracing these is inhibited by paucity of outcrop. The regular configuration of the Arcoona Quartzite Member on the plateau, however, precludes other than minor, strictly local, dislocations. Elsewhere, faulting has not been recognized and, if present, is probably of no regional importance. An airborne magnetometer survey was undertaken at a height of 500ft. with a flight line spacing of 1 mile in 1962 by the Bureau of Mineral Resources. Traverse profiles show no abnormalities which might be referable to faulting except over the Torrens Fault in the Andamooka region. Other variations in the profile appear to be related to varying magnetic susceptibility of a bedded sequence of basement rocks concealed below the Upper Proterozoic shelf sediments. The profiles of total magnetic intensity show a smoothing east of the line of the Torrens Fault. To the west of this line the magnetic trends show two distinct types of magnetic basement (*see* fig. 4). In the southwestern part of the region, elongate, low-amplitude, aeromagnetic anomaly trends are of consistent strength and character, oriented N 40 deg. W. and commonly extending for 50 miles; basement is considered to lie within 1,000ft. of the surface. In the central northern part of the region anomalies, characterized by well-developed magnetic trends which have amplitudes commonly exceeding 500 gammas and lengths rarely exceeding 10 miles, relate to magnetic basement within 2,000ft. of the surface; there anomalies follow three dominant trends, N 40 deg. W., N-S, N 40 deg. E. (Young, 1964).

Minor faulting affecting the Cretaceous sediments at Andamooka Opalfield is presumed to reflect basement faulting at shallow depth.

The Nor'West Fault (Sprigg, 1949b) is a major tectonic feature of the Willouran Range area; this and associated splinter faults have extensively dislocated the Upper Proterozoic sediments. In the Stony Range the fault occupies the axial position of an anticline expressed in outcrop by the Witchelina Quartzite. This fault is traceable some 50 miles to the southeast where overthrusting of this quartzite has eliminated some 40,000ft. of sediments near Aroona (Parkin and King, 1952). A wedge of Torrensian sediments enclosed by the Nor'West and South Hill faults has moved relatively southwards accompanied in part by severe attenuation and elsewhere by crumpling. The Witchelina Quartzite stands vertically and in spite of its relative competency has been contorted into spectacular dragfolds (plate VI, fig. 1).

Chapter 5

GEOLOGICAL HISTORY

Sedimentation during the Upper Proterozoic commenced in the subsiding Adelaide Geosyncline with the deposition of the Callanna Beds. These are represented in the Willouran Range by slates, sandstones and dolomites but are characterized elsewhere (Roopena, Depot Creek, Wooltana, Peake and Denison Ranges) by volcanic lavas and amygdaloidal melaphyres. These are succeeded by thick clean quartzite (Witchelina Quartzite), the basal formation of the Burra Group, and a sequence characterized by shallow seas and oscillating sea-levels with the development of beds of brecciolic magnesite. These are succeeded with gentle unconformity in the Willouran Range by the Umberatana Group and the intermittent appearance of boulder tillites and clastics of fluvioglacial origin and a thick sequence of laminated blue-grey-green slates with minor dolomites. A normal, though reduced, Wilpena Group comprising red-bed siltstones, quartzites, carbonates and grits follows.

In the west a crossbedded pebbly grit formation (Pernatty Grit) was deposited on a stable foreland shelf marginal to the active subsiding Adelaide Geosyncline. Following these is a red-bed sequence of finely laminated shallow-water sediments, the Tent Hill Formation. Sandstones terminate this succession, culminating in the Arcoona Quartzite Member (probable A.B.C. Range Quartzite equivalent). To the northeast of Lake Torrens a reduced section of the Wilpena Group is preserved, the topmost formation, Pound Quartzite, being 400ft. thick. West of Lake Torrens the upper formations of the Wilpena Group were completely stripped by erosion prior to the Lower Cambrian.

The base of the Cambrian is marked by a disconformity with the underlying Arcoona Quartzite Member and a new cycle of sedimentation, commencing with local thin conglomerates and grits, gave place to massive *Archaeocyathinae* bioherms which covered the site of the Adelaide Geosyncline and adjoining shelves (Sprigg 1952). In this area carbonate rocks, oolitic and brecciated at the base, pass up into massive limestones (Andamooka Limestone); these are overlain by red-brown silty shales (Yarrowurta Shales).

Cambrian sedimentation closed with the collapse of the geosyncline. The line of the Torrens Fault separates the stable horizontal platform (Stuart Shelf) from the more intricately folded and faulted geosynclinal belt now occupied by the Flinders Ranges, folding along the hinge line in the Torrens Sunklands being gradational between the more or less undeformed shelf area and the tighter folds of the mountain ranges.

There is a further record of sedimentation in the region to the northwest of Lake Torrens in the Permian when glacially overdeepened basins were filled with up to 3,000ft. of glacial sediments, tillites, clays, sands, shales and coal measures (Campana and Wilson, 1955). These sediments may have been encountered in boring in this area but they have not been recognized in outcrop.

During the Mesozoic era broad downwarping of near peneplained basement rocks over the centre of the continent heralded the onset of a period of more or less continuous lacustrine and/or marine sedimentation with the accumulation of up to several thousand feet of strata in and beyond the limits of the present Great Artesian Basin. Basal sediments include sands, grits, and boulder beds with plant remains (equivalents of the Blythesdale Group) which in this region are thin marginal deposits marking the limits of an extensive upper Jurassic-lower Cretaceous lake. There are now preserved only remnants of this formation which occupy depressions in the bedrock floor—they are therefore absent over large areas. The Cretaceous Roma Formation (Aptian) which in the basin proper comprises blue-grey shale, mudstones

etc. with obvious marine affinities, is here a shallow-water shelf development. Boulder beds are common towards the base and there pass up into sandstones, siltstones and shales.

The early Tertiary is envisaged as being a humid pluvial period when the centre of the Continent was covered by a number of extensive lakes fed by fast-flowing rivers. Sedimentation follows with an erosional break on the Mesozoic strata. (?)Eocene boulder beds, gravels, grits and sandstones with leaves and plant impressions mark the site of former shallow lakes. Fossil stream channels which have been carved into quartzite basement rocks are choked with boulders in some places and sands and grits elsewhere. There relation suggests that the topography was then almost as it is now. Where spans of millions or hundreds of millions of years are available for successive modifications of outcropping rocks without much denudation, difficulties of stratigraphic interpretation arise and it is considered that the area occupied by Tertiary lakes was larger than might be interpreted from the present disposition of the outcrops. The differential block movements of uplift and depression forming the Torrens Sunklands are assumed to have commenced in the early Tertiary and to have continued periodically since that time with further emphasis in the Pliocene-Pleistocene. Sedimentation in a fresh or brackish water lagoonal environment followed the foundering of the Torrens Sunklands.

The area was reduced to a peneplain during the Miocene(?) when duricrust was widely developed.

A system of fossil sand dunes oriented at right angles to the current wind regime were stabilized by a succeeding (?late Tertiary) period of silicification.

During the ?Upper Pliocene-Pleistocene other erosion surfaces were developed and these have been preserved throughout the region. Pleistocene-Recent sub-aerial erosion has further dismembered these and older surfaces; lakes have developed largely by deflation and sands derived from these and from the underlying rocks elsewhere have been piled into regular longitudinal sand dunes under the influence of the prevailing winds.

Chapter 6

MINERAL DEPOSITS

At the present time the only important centre of mineral production is the Andamooka Opalfied where in 1964 the value of opal production totalled £633,248.

Metallic and non-metallic mineral deposits which are being worked or have been formerly exploited are discussed below.

MOUNT GUNSON—PERNATTY LAGOON COPPER DEPOSITS

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Introduction

The copper deposits situated on and near the western shores of Pernatty Lagoon, 90 miles north-northwest of Port Augusta and 13 miles northeast of Birthday R.S.

were discovered in 1875 by a Mr. F. Young. Claims were taken out at Mount Gunson in 1898 and at intervals during the succeeding 40 years small parcels of picked ore were mined from a number of separate deposits and transported to Port Augusta for shipment. The ore was at first hauled by horse-drawn wagons and in 1912 a Bottrill motor tractor was commissioned (1912a). Ore was later railed from Birthday R.S.; a branch line was surveyed into the mine but this was never constructed.

A reverberatory furnace was erected at Mount Gunson in 1905 and a leaching plant in 1916 but neither operated successfully "owing to the siliceous nature of the ores and excess of silica in the ironstone flux". The leaching plant (plate XXVIII, fig. 2) was erected on the edge of the lagoon adjacent to the lagoon workings and a tramline laid out to the deposits; the ore was treated by a chloridizing process and precipitated on scrap iron. In 1937 it was reported that the ore was amenable to dilute sulphuric acid leaching and recovery by scrap iron precipitation.

Production prior to 1937 comprised chiefly dressed ore containing 8 to 16 per cent Cu and this was shipped interstate (Cockle Creek, N.S.W.) or overseas for treatment—the total recorded output for this period being 3,250 tons.

During World War II owing to a shortage of copper in Australia open-cut mining operations recommenced at Mount Gunson and during the period 1941-1943 some 32,380 tons of ore overaging 3.5 per cent Cu were mined by the Zinc Corporation Ltd. for treatment at the Broken Hill Associated Smelters at Port Pirie. From this ore 1,084 tons of copper and 14,523 oz. of silver, valued at £1,831 and averaging 0.45 oz./ton were recovered. Work was discontinued when the minimum grade of 2.5 per cent Cu could no longer be maintained by open cutting. (Plate XXIX, figs. 1 and 2.)

In 1950 the Australian Mining and Smelting Co. took out a special lease to re-appraise the deposits (King, 1950) and during 1951-2 scout drilling was undertaken. Desultory mining operations and leaching of exposed ore has been undertaken since but copper production has been negligible.

The Copper Deposits

The copper deposits comprise shallow, almost horizontal, more or less tabular bodies of generally low grade that occur in sandstones, quartzites and in the Woocalla Dolomite Member. The deposits have been detailed by Dickinson (1942).

The main known ore horizon is confined to red and white gritty sandstones adjacent to the unconformity and, patchily, in dolomite. The highest concentrations of copper are in thin-bedded friable sandstone where it occurs as a cement to rounded quartz grains. These were obviously more favourable as a host than the underlying massive dense red-brown banded quartzites where it occurs along bedding and joint planes and irregular minor fractures. Copper occurs in dolomite with barite (and in places with manganese) in irregular closely spaced fractures and also below the dolomite bed in sandstones and shales in nodules and irregular seams. The silver content ranges from 0.3 to 2 oz./ton but averages 0.45 oz./ton; cobalt contents range from 0.01 to 0.10 per cent while gold varies from nil to 2 dwt./ton in the several samples which have been assayed.

Copper has been mined from a number of groups of shallow workings; these with their recorded production prior to 1912 include the following:

	Tons
Gunyah (Lagoon and bornite workings)	390
Ramsay	39
Gunytot	72
Mount Gunson (Young shaft, Brennan's etc.) . .	2,701
The Gun	74
Dolomite	50
Sweet Nell (considered separately below)	100

The locations of these are shown in figs. 5, 6.

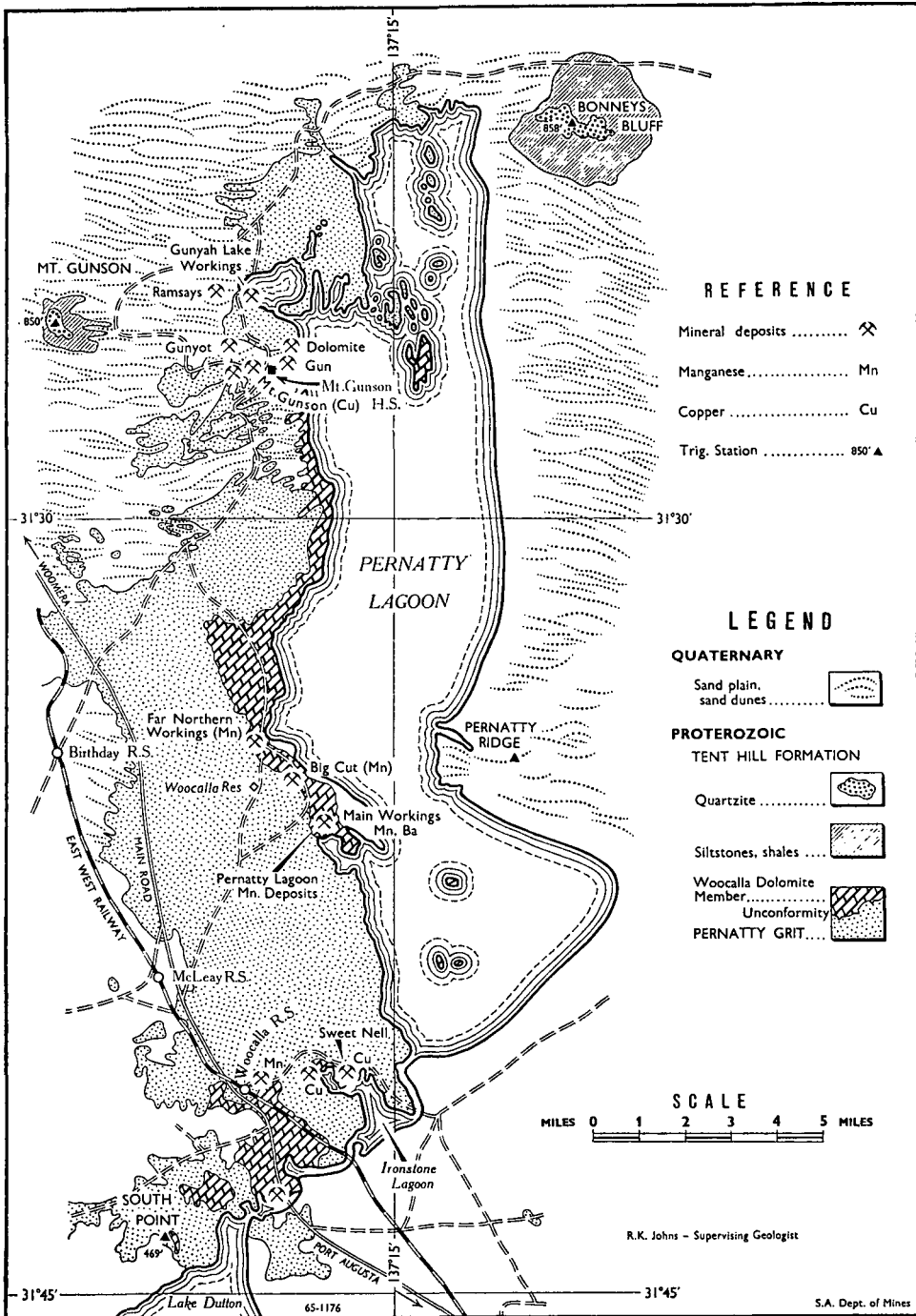


FIG. 5—PERNATTY LAGOON AREA
Geological map

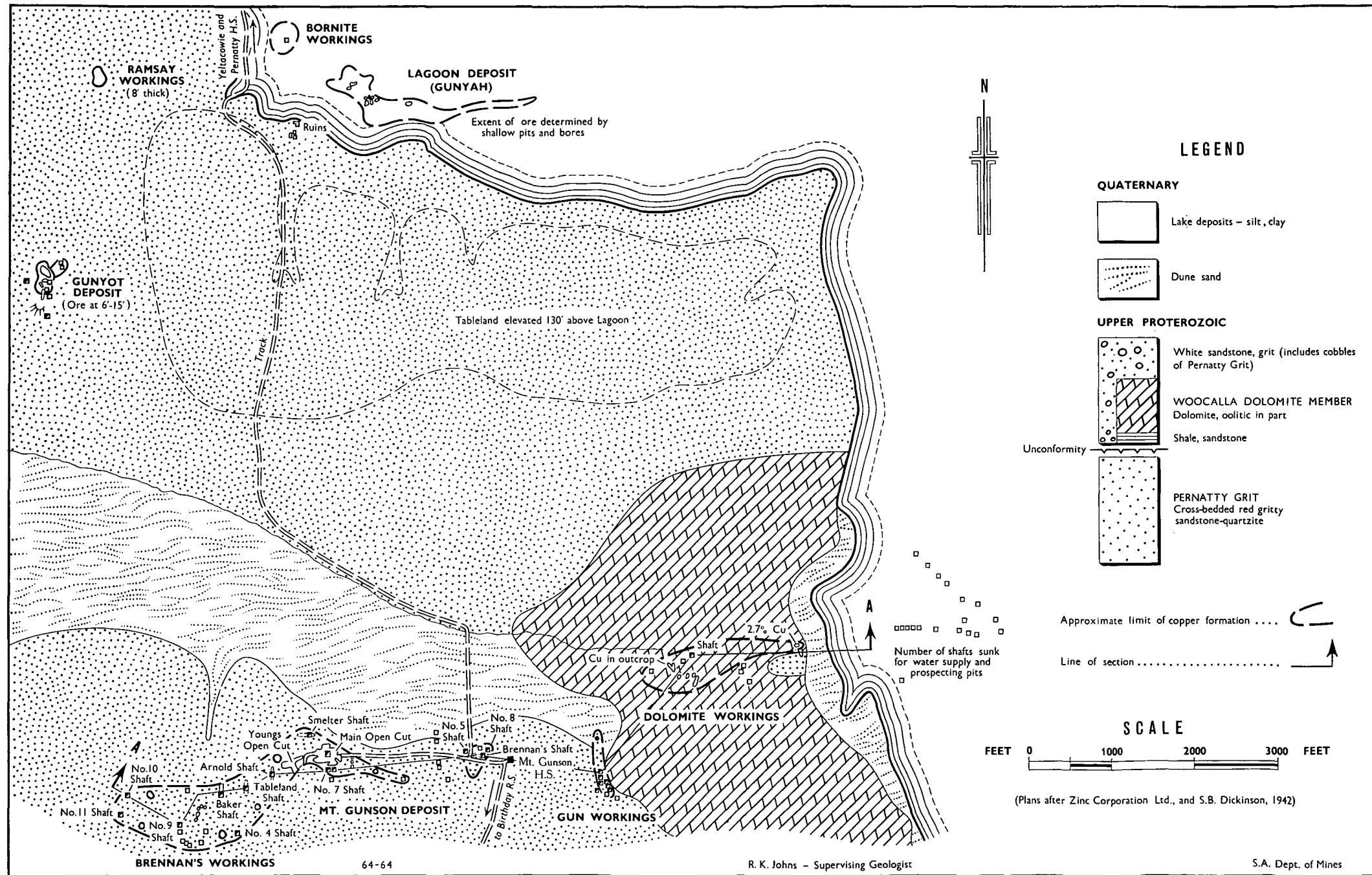


FIG. 6—MOUNT GUNSON COPPER DEPOSIT
Geological plan

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Mineralization is not confined to any particular stratum or stratigraphic horizon but the ore "seams" are almost coincident with the unconformity. At the Gunyah, Ramsays, Gunyot and Mount Gunson localities ore is concentrated in sandstones and gritty quartzites. At the Gun locality ore occurs at the sandstone-dolomite contact while at the Dolomite workings uneconomic concentrations occur within the dolomite. At the Sweet Nell prospect copper occurs immediately below the dolomite. In the workings the grade of copper was reported to vary from nil up to 50 per cent with widths ranging up to 14 feet.

The orebodies are covered by up to 50ft. of overburden and appear to occupy two distinct levels, one approximately 70ft. above the level of Pernatty Lagoon and the other at that level (fig. 7; plate XXX, fig. 1). They bear no relation to the present day topography, the outcrops being accidents of erosion. They are elongated in an east-west direction.

The main orebody disclosed in the Mount Gunson workings is about 70ft. above lagoon level. The copper minerals include malachite, chrysocolla and chalcocite as nodules or as a cement to friable sandstones over a thickness of up to 14ft. with grades up to 9 per cent Cu. The ore horizon is exposed in outcrop and has been exploited in Young's and the Main open cut over an area of 120ft. x 100ft. to a depth of 10ft. and it extends southwest to Brennan's workings where it closely follows a contact between red gritty quartzite and an overlying bed of white sandstone. Adjacent to the ore occurrences the sandstone includes fragments of the underlying Pernatty Grit. To the east in Brennan's shaft, ore occurs in sandstone immediately above dolomite. Ore indicated by Brennan's workings, Bakers, Arnold and Tableland shafts was considered by the Zinc Corporation Ltd. in 1940 to total almost 50,000 tons recoverable in underground mining operations and disposed as below:

	Tons	Ore Thickness ft.	Grade Cu per cent
Brennan's Workings ..	7,500	3	4.5
Baker's Shaft	11,000	4	3.0
Tableland Shaft	19,000	3	3.2
Arnold's Shaft	12,200	7	4.5

At this time open-cut reserves were estimated at 18,000 tons with thickness approximately 4ft. and grade 4-5 per cent. The main open-cuts have since yielded 23,080 tons (average 3.66 per cent Cu) and approximately 9,000 tons of 3.0 per cent ore.

At the Gun workings, several feet above lagoon level, atacamite and bornite occur with manganese (up to 15 per cent MnO₂) and iron oxides (up to 17 per cent Fe₂O₃) in sandstone, the orebody being about 5ft. in thickness and 12ft. below the surface. Pockets of ore with up to 15.6 per cent Cu occur in the irregular surface of the underlying dolomite though samples overall showed between 1 per cent and 5 per cent Cu. The recorded production, from five closely grouped vertical shafts to 30ft. and driving, amounted to 74 tons. To the northeast of these workings and adjacent to the lagoon copper carbonate outcrops and has been disclosed in the Dolomite workings. About 50 tons of 14 per cent Cu ore were marketed from small irregular seams and patches of copper carbonates and chalcocite. These are associated with barite and calcite which occur in the 8ft. thick bed of dolomite and also in underlying sandstone.

The Gunyot deposits exposed in an open-cut 350ft. x 115ft. over a thickness of up to 5½ft. are similar mineralogically and in elevation to those of Mount Gunson. The ore is principally atacamite and this occurs at a depth of from 6 to 16ft., averaging 2 per cent Cu. Production amounts to 72 tons.

The Gunyah workings are situated 1½ miles to the north of Mount Gunson H.S., near the southern shore on an arm of the lagoon. Sandstones which outcrop on the floor of the lagoon or have a thin cover of lake silt carry up to 6.7 per cent Cu as covellite, bornite, atacamite, malachite and chalcocite over a thickness of 5ft. The ores

occur as a cement to quartz grains and in irregular masses of high-grade sulphide from which 15-20 per cent Cu ore were hand picked. Beneath the sandstone is a hard dense red quartzite which carries chalcocite in joint and bedding planes but not universally impregnating the rock. The deposit yielded 390 tons of ore from a number of shallow openings to a depth of about 7ft. and with 3 per cent Cu content. The workings extend over an elongate area 2,500ft. x 60ft. to 300ft. on the lagoon floor—the largest excavation being an inclined cutting 15 chains from the shore which was carried for a length of 270ft. over a width of 8ft. to develop a face 15ft. high. The lagoon workings are now filled with silt. Wainwright (1914) estimated the reserves here to approximate 135,000 tons of 2.7 per cent Cu ore from the known exposures and from a programme of pitting and shallow boring undertaken on the floor of the lagoon.

Drilling—Reserves

A drilling programme designed to test the continuity of the copper-bearing horizon throughout the large area of widely dispersed and abandoned workings was undertaken in the period October, 1951-May, 1952, when 16 holes (totalling 1,069ft. of drilling) were completed. The bores ranged in depth from 30ft. to 120ft. Of nine bores spaced at intervals of 400ft. or 800ft. along a north-south traverse and selected to provide a comprehensive cross-section over a distance of 5,000ft. between the Mount Gunson and the Gonyah workings, three encountered copper but none proved economic ore. Two of these were located close to the main open-cut and the third on the southern slope of the northern tableland.

Three holes were drilled $\frac{1}{2}$ mile west of the most westerly workings to test a possible extension of the trend suggested by the alignment of the eastern lagoon, Dolomite, Gun, Brennan's shaft, Main cut and Tableland shafts but no copper was detected.

Three shallow holes which were drilled about the Ramsay workings also failed to encounter copper.

Insufficient exploration has been undertaken to derive reliable reserve estimates for the various copper deposits and a current assessment is further inhibited by collapse and silting of many of the workings, particularly on the lagoon floor where they are subject to flooding. It is obvious that none are exhausted but the known ore is low in grade and of no great thickness and unless new ore is discovered at shallow depth the deposits cannot be cheaply developed and mined. King (1950) concluded that 150,000 tons of 3 per cent Cu might be expected from the known exposures in this locality.

Origin of Ore

Copper, manganese and barytes occur in close proximity to the Woocalla Dolomite Member. At Mount Gunson, copper deposits occur along an unconformable surface between dense Pernatty Grit and a younger sandstone adjacent to what is considered to be a *collenia* reef. Tectonic structures appear to have no control, they are not related to the present surface, intrusive rocks are absent and the rocks are unmetamorphosed. The origin of the ore has been discussed previously (1914, 1942, 1950, 1953), the authors generally agreeing that sulphide deposition took place from metal-rich surface waters either from a lake or from streams. In the latter case, deposition would be restricted to definite channels and so might account for the east-west elongation of the two principal deposits.

The ultimate origin of the economic minerals is not known but the early Marinoan shoreline provided a sedimentary control on copper deposition. The significance of the dolomite reef and mineral localization in this environment are matters for speculation.

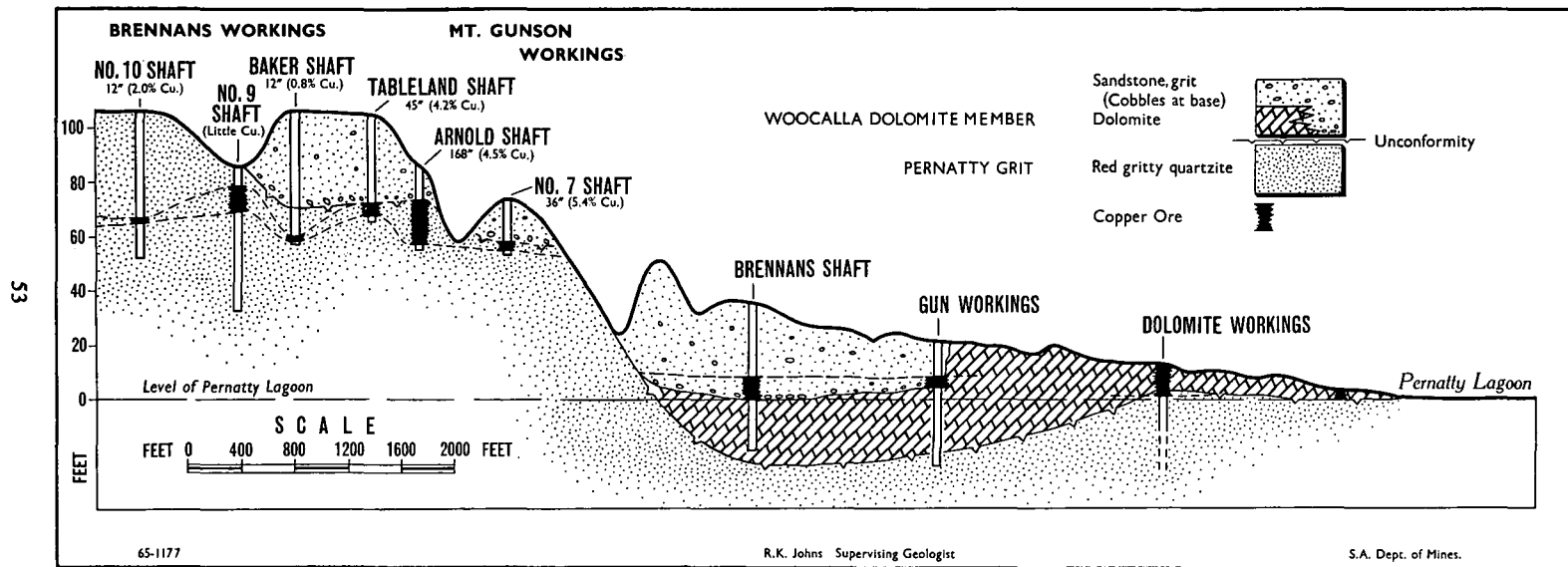


FIG. 7.—CROSS-SECTION THROUGH MOUNT GUNSON WORKINGS

A number of samples of dolomite were taken at points removed from mining operations and submitted for chemical analyses. Results of these are tabled below with those for other dolomites and limestones which outcrop in the region for comparison.

	CaCO ₃	MgCO ₃	SiO ₂	P ₂ O ₅	Ba	Cu	F	Mn
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Woocalla Dolomite Member								
One mile southeast of Woocalla	56.3	21.9	12.1	0.16	0.16	0.48	0.07	0.60
Woocalla quarry	48.7	38.9	4.2	0.05	0.16	0.01	0.05	1.17
Sweet Nell	47.6	36.3	8.2	0.04	0.33	0.02	0.02	1.39
Near Main manganese mine	48.3	37.2	1.1	0.08	0.24	0.001	0.02	1.76
Near Northern manganese mine	49.6	30.6	0.2	0.15	1.17	0.003	0.03	2.36
Mount Gunson area	51.7	38.4	1.9	0.06	0.35	0.13	0.02	2.05
Dolomites of Tent Hill Formation								
Salt Creek	51.5	39.8	4.3	0.03	0.07	0.001	0.01	0.40
Bosworth Creek	51.3	41.4	5.1	0.03	—	0.001	—	0.40
Andamooka Limestone								
Phillips Ridge (breccia)	55.4	37.3	4.7	0.05	—	0.0002	—	0.08
Phillips Ridge (oolitic)	52.4	44.1	0.3	0.02	—	0.001	—	0.15
Phillips Ridge (breccia)	49.4	40.5	7.5	0.04	—	0.0003	—	0.30
Wirrda Well (breccia)	46.2	37.3	14.1	0.06	—	0.0004	—	0.10
Wirrda Well (oolitic)	51.3	42.3	4.8	0.03	—	0.001	—	0.30
Wirrda Well (gritty)	43.1	35.9	18.2	0.04	—	0.0005	—	0.25
Coorlay Lagoon	35.8	29.4	31.6	0.08	—	0.0004	—	0.30
Coorlay Lagoon	38.0	30.8	27.2	0.09	—	0.0005	—	0.30
Yarrowurta section	52.0	39.7	4.6	0.06	0.008	0.001	—	0.03
Yarrowurta section	95.4	0.7	3.3	0.06	0.02	0.0006	—	0.01
Yarrowurta section	97.1	0.7	1.9	0.15	0.02	0.001	—	0.01
Yarrowurta section	96.7	0.3	2.5	0.05	0.008	0.0005	—	0.005
Yarrowurta section	52.5	39.5	6.8	0.03	0.05	0.007	—	0.01
Yarrowurta section	73.6	17.4	7.7	0.03	0.03	0.0008	—	0.008
Yarrowurta section	85.7	9.0	4.7	0.01	0.03	0.0006	—	0.01
Yarrowurta section	97.2	0.3	1.6	0.02	0.004	0.002	—	0.01
Yarrowurta section	98.6	0.6	0.7	0.01	0.02	0.001	—	0.01
Yarrowurta section	97.2	1.3	1.2	0.03	0.02	0.001	—	0.01
Yarrowurta section	56.3	40.7	1.4	0.02	0.005	0.001	—	0.12
Yarrowurta section	88.6	7.0	3.0	0.05	0.02	0.001	—	0.01
Yarrowurta section	94.5	1.8	2.4	0.10	0.008	0.002	—	0.0005
Yarrowurta section	94.1	2.2	2.4	0.08	0.01	0.003	—	0.02
Yarrowurta section	93.1	3.3	3.1	0.01	0.03	0.003	—	0.002
Yarrowurta section	96.9	0.7	1.6	0.01	0.03	0.005	—	0.01
Yarrowurta section	98.4	0.5	0.3	0.01	0.01	0.001	—	0.003
Yarrowurta section	95.4	2.2	1.4	0.01	0.002	0.004	—	0.005
Yarrowurta section	79.6	15.6	1.2	0.01	0.04	0.005	—	0.08
Yarrowurta section	77.4	19.4	1.0	0.01	0.07	0.005	—	0.12
Yarrowurta section	97.6	0.4	1.1	0.02	0.04	0.001	—	0.01
Yarrowurta section	93.0	1.5	4.5	0.01	0.006	0.008	—	0.01
Yarrowurta section	78.2	17.8	2.0	0.04	0.02	0.001	—	0.05

SWEET NELL COPPER MINE

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The Deposits

The Sweet Nell (including Fair Nell and Monalena) group of workings are situated 2 to 2½ miles east of Woocalla and are disposed round the margin of a small tableland peninsula which juts out into Ironstone Lagoon. (Plate XXX, fig. 2.)

During the period 1904-1907 it was reported that a "considerable quantity of fairly high-grade ore was extracted and sent to market and that the second grade ore left, and amounting to many hundreds of tons, was left on the surface at the mine".

Available production figures show that by 1908, 50 tons of 30 per cent Cu ore had been sold and that overall production amounted to 100 tons of 10-20 per cent Cu ore.

The peninsula on which the workings are based is approximately 10 chains wide, $\frac{1}{4}$ mile in length and it rises about 15ft. above the surface of the lagoon; it is capped by a flat-lying bed of grey and buff to brown and in part manganese-stained dolomite. The dolomite directly overlies the ore-bearing shale and this is underlain by (Pernatty Grit) red arkosic sandstone-quartzite.

The dolomite ranges in thickness from 20ft. at the westernmost exposure to about 10ft. on the peninsula proper—it is ripple marked and carries *collenia* and displays crumpled bedding structures.

The dolomite passes down into a bed of grey cupriferous shale (plate XXXI, fig. 1), the interface being manganese rich. The horizontal soft argillaceous bed is about 4ft. thick; it carries thin stringers, veins and pockets of green copper ore which appears to be chiefly malachite. The ore was worked over a thickness of 3ft. to 4ft. from numerous galleries, drives and tunnels driven under the dolomite from the margins of the peninsula several feet above the floor of the lagoon.

It was reported that the shale bed was fully impregnated up to a width of 3ft. with nodules and veins of high-grade green copper carbonates which could be easily selected and dressed up to 30 per cent Cu. This seems a rather optimistic view considering the existing exposures.

A shaft located mid-way across the peninsula and near its southern extremity was sunk to a depth of 47ft. and disclosed 9ft. of dolomite and 3ft. of shale over red sandstone.

Records show that a sample of ore from this area contained 0.28 per cent V with Pb, As and Sb, nil.

O.K. COPPER MINE

Reference

Record of the Mines of S. Aust. (1908) p. 109.

The Deposits

Situated at the northern end of Lake Torrens about 2 $\frac{1}{4}$ miles east of Yarrowurta Cliff are the O.K. mine workings which consist of two shafts about 25ft. in depth and a number of shallow pits and costeans. Malachite and chalcocite associated with iron oxides have been worked from narrow veins in massive Andamooka Limestone. The veins occupy a system of joints which have been enlarged by solution and there is no defined lode. It is reported that about 40 tons of 54 per cent Cu ore were disposed of.

MANGANESE—PERNATTY LAGOON

References

Review of Mining Operations 21, (1915) p. 7, General notes.

Review of Mining Operations 22, (1915) p. 9, General notes.

Review of Mining Operations 23, (1916) p. 58, H. Jones.

Review of Mining Operations 25, (1917) frontispiece and pp. 55-63, L. K. Ward and R. L. Jack.

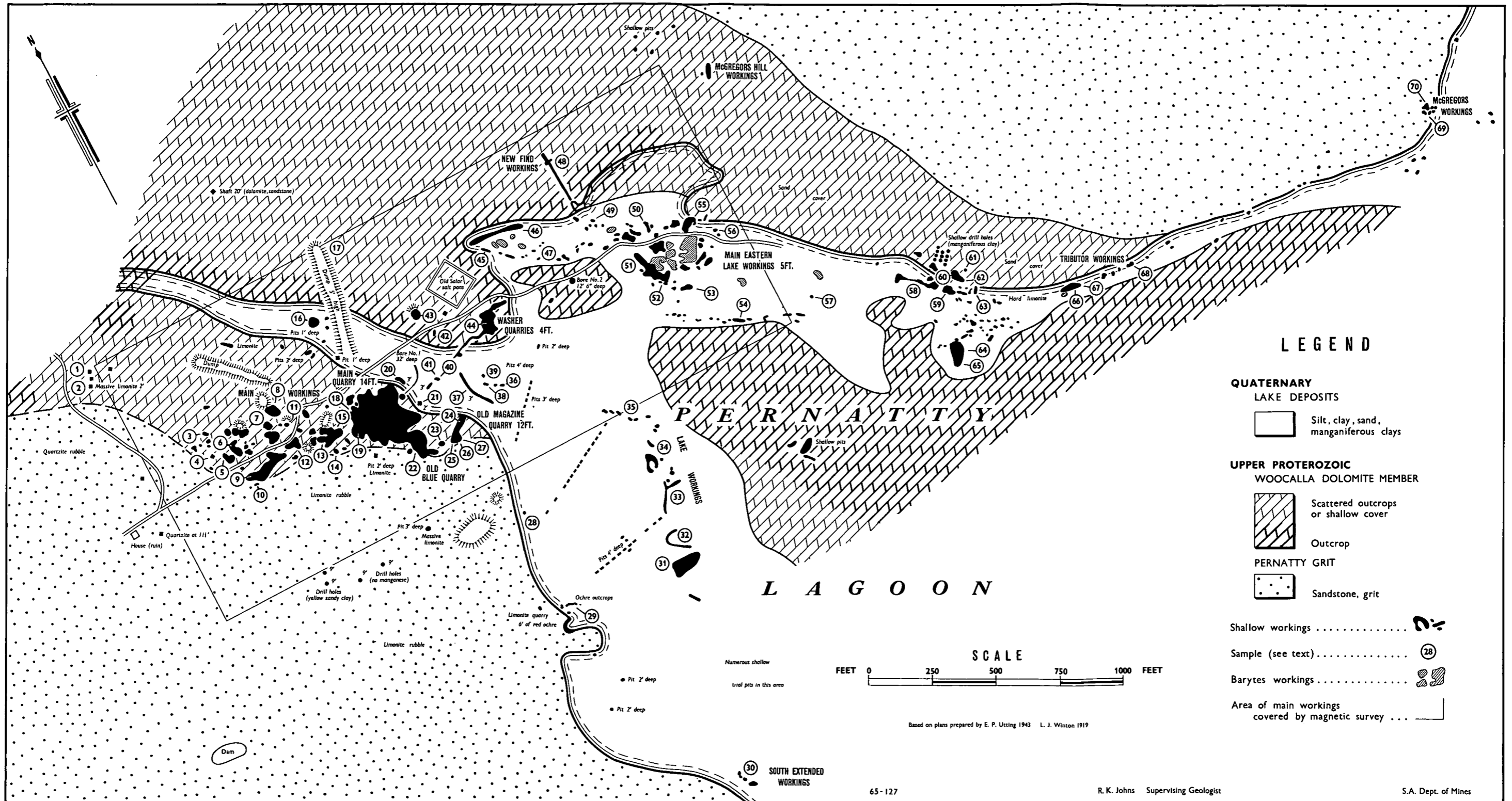


Fig. 8 Geological Plan of Main Area of Manganese Workings – Pernatty Lagoon

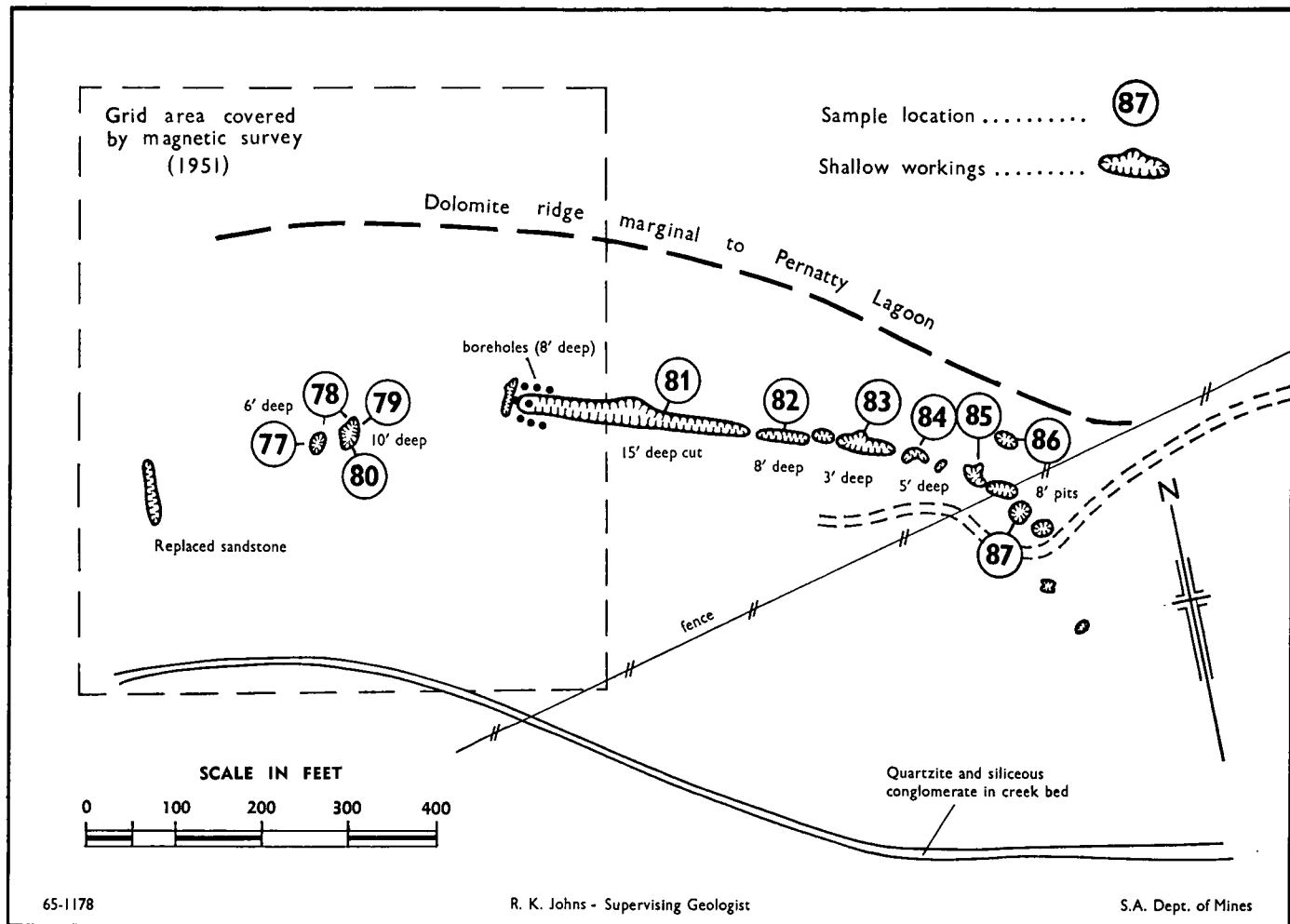


FIG. 9—PERNATTY LAGOON MANGANESE
North Lease Workings

The Deposits

The main group of shallow workings is situated on the lagoon floor and adjacent shore over a length of almost 1 mile in an embayment on the western side of Pernatty Lagoon. The ore deposits occur as irregular masses or nodules of varying size in the residual clay resulting from the decomposition of manganiferous dolomite. Dolomite outcrops along the shore and in the lake bed where it rests disconformably on non-manganiferous Pernatty Grit. In the lagoon floor pits show up to 2ft. of saline sandy mud over manganese (plate XXXI, fig. 2) while, on the shore, soil or sand from almost nil up to 15ft. in thickness mantle the deposits. Immediately west of the workings limonitic ironstone gravels are strewn over the surface over a large area.

The orebodies are reported to show some tendency to parallel the rudely rectangular joint system in the dolomite, the orientation of the major joints in the principal manganese bearing area being northwest-southeast but more nearly east-west at the northern workings. The deposits are generally covered with lake silt or sand and this renders prospecting difficult in view of the irregular distribution of the ore. Little ore is known beyond the worked faces.

The main workings include the Big Quarry (plate XXXII, fig. 1) which was formerly about 14ft. deep and covers an area of almost an acre; this and the other lake workings are shown in fig. 8. The manganese at the Big Quarry is reported to have occurred in layers which differed in quality, thickness and appearance; the limit of the deposit was reached only on the southern extremity. The necessity of maintaining grade resulted in a large amount of gouging (plate XXXII, fig. 2) and most of the pits exposed either ironstone or dolomite below the manganese.

Manganese minerals comprise psilomelane and pyrolusite—the ore ranging from hard and black to soft and blue, earthy or wadlike. The harder nodular high-grade ores and the more or less cellular or cavernous ores with loose pulverulent iron oxides in the openings were readily separable. Separation from enclosing limonitic clays was achieved by hand picking and trimming off adherent impurities or by simple washing. The softer ores which occurred in clay but which were not intimately mixed were separated by selective hand mining. The high-grade finely divided ores were difficult to separate from impurities which include clay, quartz, limonite, gypsum, barite and hematite. No satisfactory method of concentration by simple mineral-dressing processes was found; beneficiation of the ore using gravity concentration, magnetic separation, tabling and flotation failed (Blaskett 1942, 1943, Jackson, 1954) while more recent hydro-metallurgical methods had limited success (Hopkins, 1956). A crusher, screens, and washing and bagging plants were erected at the deposits when they first came into production but these either have been dismantled or have fallen into disrepair.

Barite which occurs in close proximity to the manganese deposits has been exploited at the main eastern lake workings (see under Barite).

Manganese ore was found to be fairly uniformly distributed over appreciable areas on dolomite or in irregular pockets formed along joint planes surrounded by undecomposed dolomite—the contacts may be sharp or ill defined. The crude ore produced contained 35-57 per cent Mn and it was estimated that one ton of ore required the removal of up to two tons of ferruginous ore and overburden; thickness and quality of the ore varied widely.

The northern deposits (fig. 9) situated some 2½ miles to the northwest were developed in 1940. This deposit was of irregular width (16 to 34ft.) and thickness (4 to 10ft.). The open-cut 260ft. long disclosed yellow clay in the bottom and low-grade manganiferous clay in the sides. The production here totalled 9,000 tons valued at £14,600. This deposit differs from the main deposit in being located some 70ft above lagoon level.

Minor production was achieved at the Big Cut area (fig. 10) situated to the north of the main lagoon workings, and also at Woocalla. Manganese also occurs 3 miles east of the Gnyah copper workings on the northwestern shore of the lagoon but this has not been explored.

Ore which was marketed from these deposits showed the following ranges of composition:

	Per cent	Average per cent
Mn	40-57	46
Fe	0.4-14.6	4
Insolubles	0.5	3
P	0.02-0.09	0.05
S	0.01-1.0	0.3

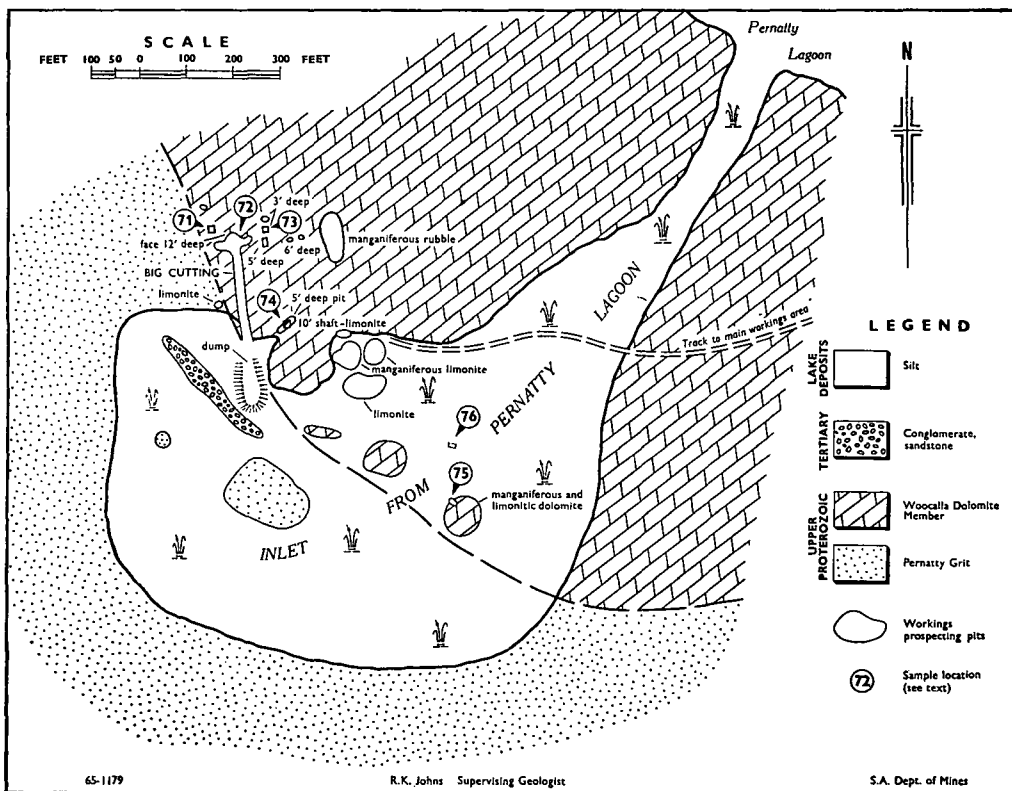


FIG. 10—PERNATTY LAGOON AREA
Plan of Big Cut area

Surface samples were taken from the principal working areas by Winton (1920) and by E. P. Utting (1943, unpublished); the location of these are shown in figs 8-10 from plans prepared by those authors. The results are table below.

Sample	Mn	Fe	Insolubles	P	S	Remarks
	per cent	per cent	per cent	per cent	per cent	
1	44.0	8.3	5.4	0.03	—	Limonitic ore, north of house
2	41.2	8.4	5.1	0.04	—	Limonitic ore, 2ft. sample
3	22.8	11.4	27.2	0.04	—	Dumps, main workings area
4	42.6	6.6	11.4	0.02	—	Dumps, main workings area
5	35.5	10.5	14.8	0.03	—	Dumps, main workings area
6	37.7	7.7	13.0	0.02	—	Dumps, main workings area
7	36.7	9.1	10.6	0.01	—	Dumps, main workings area
8	37.5	9.4	9.2	0.02	—	Dumps, main workings area
9	33.3	10.8	17.2	0.02	—	Dumps, main workings area
10	33.8	11.5	14.0	0.02	—	Dumps, main workings area
11	37.1	9.6	11.6	0.02	—	Dumps, main workings area
12	34.7	14.5	3.8	0.03	—	3ft. face in pit, main working
13	36.1	11.1	9.9	0.02	—	Dumps, main workings area
14	38.1	8.0	12.1	0.02	—	Dumps, main workings area
15	38.9	8.2	8.4	0.02	—	Dumps, main workings area
16	42.3	10.1	9.2	0.04	—	1ft. pit near old dumps
17	30.2	10.3	13.3	0.03	—	Old dump
18	36.5	9.1	12.0	0.02	—	Dump, main workings area
19	36.0	11.0	10.5	0.02	—	Dump, main workings area
20	51.5	0.9	0.5	0.04	0.01	Main quarry, dressed and washed ore
21	52.3	2.4	1.9	0.03	—	Ore nodules picked from limonitic clay
22	39.5	2.5	11.3	0.04	0.67	Blue Quarry, ore with clay
23	40.7	8.7	5.1	0.06	0.34	Magazine Quarry, 4ft. ore clay, dolomite
24	46.4	8.2	2.5	0.10	0.01	Near main quarry, 2ft. sample
25	56.2	0.7	1.5	0.06	0.18	Magazine Quarry, dressed and washed ore
26	34.5	11.8	9.2	0.06	0.56	Magazine Quarry, ore, clay strip samples
27	50.5	2.5	2.2	0.05	0.01	Magazine Quarry, ore below water level
28	21.9	24.8	—	—	—	Limonitic wad, lake bed
29	—	—	—	—	—	Red ochre, lake shore
30	—	—	—	—	—	South extended workings
31	49.8	4.1	1.9	0.08	0.13	Lake workings, sorted ore
32	45.1	3.5	2.8	0.06	0.24	Lake workings, sorted ore
33	51.7	3.1	1.4	0.07	0.20	Lake workings, sorted ore
34	50.9	2.9	1.8	0.05	0.08	Lake workings, sorted ore
35	46.5	8.9	1.5	0.06	0.06	Lake workings, roughly sorted ore
36	47.4	7.5	2.8	0.04	—	Nodules picked from earthy wad
37	19.0	14.6	21.1	0.06	—	Manganiferous clay (excluding ore nodules)
38	27.6	18.9	14.9	0.06	—	Worked concentrate of Sample 37 (Recovery 25 per cent)
39	47.8	7.2	3.0	0.04	—	Sorted nodules of ore
40	19.3	20.7	18.9	0.06	—	Worked concentrate from 3ft. pit
41	13.2	15.2	29.6	0.06	—	Lake bed sample manganiferous clay
42	53.0	2.8	2.5	0.05	0.10	Pit south of salt pans, sorted ore
43	54.1	2.6	2.6	0.08	0.10	Pit south of salt pans, sorted ore
44	49.8	4.1	2.2	0.05	0.12	South of Washer quarries, sorted ore
45	49.1	4.0	3.1	0.04	0.21	Barite workings, sorted ore
46	46.6	7.4	2.5	0.04	—	Selected surface nodules
47	37.7	17.0	2.1	0.05	—	1ft. ore under clay
48	47.5	2.1	6.4	0.06	0.20	New find workings, sorted ore
49	43.0	11.4	6.2	0.05	—	Dumps, main eastern lake workings

Sample	Mn	Fe	Insol- ubles	P	S	Remarks
	per cent	per cent	per cent	per cent	per cent	
50	37.7	15.0	7.3	0.06	—	Dumps, main eastern lake workings
51	34.3	16.6	9.2	0.10	—	Dumps, main eastern lake workings
52	30.9	24.7	3.8	0.10	—	Dumps, main eastern lake workings
53	32.2	21.3	4.5	0.10	—	Outcrop, main eastern lake workings
54	48.1	6.1	3.1	0.05	0.09	Roughly sorted ore
55	35.4	15.3	8.9	0.07	—	Dumps, near barites workings
56	33.3	19.7	5.8	0.07	—	Dumps, near barites workings
57	33.9	16.3	8.0	0.07	—	Mixture of hard ore and wad
58	49.5	6.2	1.8	0.04	0.05	Roughly sorted ore
59	51.1	4.0	1.9	0.04	0.06	Roughly sorted ore
60	47.8	5.5	3.7	0.02	—	Ore in clay (3ft.) under 3ft. overburden
61	35.5	18.1	—	—	—	Shallow pit west of Tributor workings
62	41.3	7.7	7.2	0.04	—	Ore from under sand cover near workings
63	46.8	8.5	—	—	—	Ore from under 1ft. overburden
64	53.7	3.6	1.5	0.04	—	Ore from 3ft. pit (underlain by dolomite)
65	48.0	7.6	—	—	—	Ore from 3ft. pit
66	51.3	3.7	1.9	0.06	0.17	Tributor working, roughly sorted
67	56.9	2.3	0.8	0.06	0.01	Tributor working, dressed ore
68	52.7	3.4	0.9	0.07	0.01	Tributor workings, sorted ore
69	55.5	1.8	2.6	0.08	0.01	Near McGregor workings, sorted ore
70	—	—	—	—	—	McGregor's workings
71	50.9	4.3	1.9	0.05	0.23	Big cutting, sorted ore
72	53.0	2.9	1.4	0.06	0.05	Big cutting, 6½ft. depth of face
73	37.3	14.6	2.3	0.05	0.63	Big cutting
74	49.7	7.8	1.3	0.05	0.01	Big cutting, bottom 6ft. of pit, sorted ore
75	49.9	6.0	1.1	0.06	0.01	Pit southeast of Big cutting, roughly sorted
76	51.9	4.8	1.2	0.06	0.01	Pit southeast of Big cutting
77	37.5	3.5	—	—	—	North lease workings, 3ft. blue and black ore
78	32.0	5.3	2.5	0.03	—	North lease workings, ore with sandstone
79	44.1	5.2	7.0	0.03	—	North lease workings
80	30.8	5.0	—	—	—	North lease workings ore in sandstone
81	39.3	6.3	12.8	0.03	—	North lease workings Main cut 15ft.
82	39.6	5.9	13.7	0.03	—	North lease workings 8ft. pit
83	43.0	2.2	12.8	0.03	—	North lease workings 8ft. pit
84	37.6	3.6	23.7	0.05	—	North lease workings 5ft. pit
85	25.6	2.5	40.0	—	—	North lease workings ore with sandstone
86	34.2	6.2	17.7	0.04	—	North lease workings
87	37.5	9.6	9.4	0.04	—	North lease workings

Magnetic observations conducted by McPharlin (1951) showed that the existing workings correspond to areas of considerable magnetic anomaly believed to be due to low grade manganiferous material remaining in and around the workings. He concluded that the anomalies were due to flat lamellar ore bodies of not very great thickness and recommended drilling in several areas at the eastern lake workings. Further anomalies were located south of the main open-cut area under heavy limonite float. At the northern workings there was no indication of any new deposit of worthwhile extent. Drilling was subsequently undertaken (1951). Bore No. 1

adjacent to the main quarry penetrated manganese ore with ferruginous and manganiferous clay (Mn 24.6 to 38.6 per cent) to 28ft. while bore No. 2 situated 800ft. east of No. 1 bore and adjacent to the main eastern lake workings penetrated manganese-stained dolomite and clay to 1ft. 6in. overlying dolomite.

Origin of Manganese

Concentrations of manganese on the bed or near the margin of Pernatty Lagoon and at an elevation of some 70ft. above lagoon level at the northern deposits appear to be residuals from decomposition of manganiferous dolomite—the higher levels possibly marking a former lake level. The Woocalla Dolomite Member throughout is somewhat manganiferous and manganese is everywhere discernible from mere specks and dendritic markings up to appreciable concentrations. Marked, though uneconomic, concentrations have been observed at the Sweet Nell locality at the base of this member, at the Woocalla ballast quarries at the dolomite-quartzite interface, in the Gun Workings and at Magazine Hill at the top of the bed. Manganese concentrations are insignificant elsewhere, the strongest outcrop enrichment being related to several successive periods of erosion marginal to Pernatty Lagoon. The table shows that the manganese content of the dolomite generally ranges from 0.6 to 2.3 per cent.

OPAL

General

Opal is an amorphous form of silica (SiO_2) containing variable amounts (2-13 per cent) of water. Its physical properties vary with water content so that its hardness ranges from 5.5 to 6.5 (quartz 7), S.G. from 1.9 to 2.3 and R.I. 1.44 to 1.48. Precious opal is characterized by vitreous, pearly or resinous lustre and a brilliant play of colours which give it a distinctive appearance when cut and polished as a gem stone. The colours are caused by diffraction from a regular three dimensional structure arising from the regular packing of spherical particles of silica with incomplete filling of the voids by silica (Sanders, 1964). The commercial value of a stone depends on its size, soundness from flaws, colour, pattern, range and intensity of colour and demand, and current values range up to over £200 an ounce for rough uncut stone. "Potch" and "matrix" are forms of opaline silica formerly more or less valueless as gemstones though they are utilized in mounting doublets. Organic carbon and dyes have been introduced artificially into pore spaces of "matrix" to produce "black" opals and these have recently become of commercial importance (Males, 1965).

Occurrence in Andamooka—Torrens Region

In the early 1890's excitement was aroused by the reported discovery of precious opal on the southwestern shores of Lake Hart (Richardson, 1925) but although there were supposed to be "good indications" nothing of value was found. Potch opal here was reported by Brown (1908) to occur in veins up to 1in. in thickness in sandstone.

The first authentic find of precious opal in the State was reported (Brown, 1908) from "near Charleys Swamp", 30 miles south from Bopeechee rail siding where inferior stone occurs in "rock formations of similar age (upper Cretaceous) to that in which opal is found in New South Wales and Queensland, and consists of horizontal beds of white and bluish siliceous shale and sandstone capped with jasper rock, flint and porcellanized shale". Formerly known as Charleys Swamp it is now more widely known as Stuart Creek opalfield. Recorded value of production amounts to £967; years for which production is officially recorded are 1947 (£147), 1956 (£20) and 1960 (£800).

Precious opal floaters were discovered 20 miles north of Andamooka H.S. in 1930 by Sam Brooks and R. Shepherd at what is now called Treloar Hill. The first miners on the field included the discoverers and in 1933 opal worth £962 was produced. Since that time production has steadily increased so that this field now rivals Coober

Pedy (almost 200 miles to the northwest in the Stuart Range) in importance, having produced opal worth £2,656,617 to and including 1964. Statistics of opal production are provided by the buyers and are incomplete so that the officially recorded annual values of production quoted below particularly for the years prior to 1959 are useful as a guide only.

Year	Value £	Year	Value £
1933	962	1949	22,215
1934	656	1950	31,119
1935	1,049	1951	23,932
1936	1,067	1952	18,606
1937	3,687	1953	22,290
1938	2,258	1954	23,237
1939	4,001	1955	34,120
1940	9,022	1956	71,094
1941	9,553	1957	76,982
1942	4,790	1958	85,554
1943	11,637	1959	172,154
1944	8,797	1960	183,459
1945	11,317	1961	350,444
1946	17,292	1962	377,086
1947	21,180	1963	405,827
1948	17,982	1964	633,248
		Total	<u>£2,656,617</u>

Potch opal fragments were noted during the course of regional mapping on Roxby Downs and on Arcoona, near Woomera, and though the writer received various reports of finds of precious opal in those areas they have not been authenticated.

Stuart Creek

Intermittent prospecting has been carried out since discovery in 1904 but the difficulty of access to the field, lack of water and generally poor quality of the opal recovered have inhibited continuous mining operations. The field is situated some 4 miles from the northern extremity of Lake Torrens and 5 miles northeast of Yarrowurta Cliff and may be approached from Bopeechee, Farina or Andamooka by way of unimproved tracks. Charlies Swamp proper is situated north of Stuart Creek field beyond the limits of the map area—there are reports of opal occurrence in that vicinity also, but no production.

Precious opal has been disclosed in a number of openings which are disposed round the southern margin of the dissected Cretaceous tablelands on low undulating ground. (Plate XXXIII, fig. 1.) Though the opal displays good colour it occurs at shallow depth and may be weathered. Much of the stone that has been recovered is gypsum-shot and cracked badly on exposure to the atmosphere thus precluding its use as a gemstone. An opalized tree trunk was recovered (Howchin, 1919) but this disintegrated on exposure.

A number of parties were engaged in gouging at this locality in 1964 and though no official production figures are to hand it is reported that a quantity of high-grade precious opal was marketed.

Andamooka

The field is situated near the southeastern margin of the Cretaceous tableland in an area with gently undulating hills and low topographic relief being elevated some 200-300ft. above sea-level. (Plates XXXIII, fig. 2 and XXXIV, fig. 1.) Mining is being carried out over an area of some 20 square miles on the broad flat spurs formed by Opal Creek and its tributaries. The field is expanding rapidly, however, over undissected terrain. Approximately 800 gougers are actively engaged in mining operations at the present time, and the population during 1964 varied between 1,000 and 2,000 persons. The recent greatly expanded mining activity has resulted from

buoyancy in the market coupled with the introduction of air compressors, air-operated winches and spades etc. Most of the current production is derived from Tea Tree Flat, virgin ground in 1962 and now extending over a distance of 1 mile.

Precious opal occurs sporadically in a more or less undisturbed horizontally disposed bed at a well-defined predictable horizon which outcrops round the peripheries of the dissected tablelands so that prospecting could be a regular and less erratic operation than it is at Coober Pedy. Prospecting, gouging and mining are being undertaken from shafts up to 60ft. deep, from large-diameter boreholes, from open cuts excavated by heavy earth-moving machinery and from adits driven on the opal level from tableland margins. (Plates XXXV and XXXVI, fig. 1.) In underground mining operations a wide variety of hand tools, windlass and bucket, pick and shovel, pneumatic spades, rock cutters, drills, dump cars and power hoists (petrol and air-driven) are utilized—even a pony-drawn wagon was tried, unsuccessfully, for dirt haulage.

Opal occurs sporadically and unpredictably in seams within a bed of clay designated "toe dirt" or "gouge"—which occurs immediately below a constant bed of conglomerate. The toe dirt ranges from 6in. to 2ft. in thickness and it is in the topmost 3 in. that most of the opal occurs. The seams of opal range from thin unrecoverable films up to 4in. thick veins which may extend over an area of 50 square feet. Opal also occurs as encrustations around pebbles in the interstices of conglomerate, or it may seal fractures in dense broken chalcedonic quartzite boulders ("painted ladies") at this level, while more rarely it is found as a replacement of pebbles, fossil wood and bones. Seams of massive fibrous secondary gypsum ranging up to 1ft. in width are commonly present within the sequence at about this level. Precious opal is generally associated with potch or matrix.

Large areas adjacent to the known field remain unprospected because of the reluctance on the part of the miners to work far from established finds: new discoveries will undoubtedly be haphazard and will involve more intensive prospecting.

The sequence of sedimentation represented at the field is as under.

ft.	ft.	
Surface	5	Red-brown clay with gibbers of duricrust (thickness variable).
5	40	White kaolinitic clayey sandstones and siltstones, even-grained sandy clays. Generally hard and massive and showing no trace of bedding. Faceted boulders and waterworn rounded and subangular pebbles are scattered throughout—the pebbles comprise chiefly quartzite but shale is also common. Concentrations of these occur locally in thin conglomerate bands. Gypsum veins are common.
40	42	Massive dense conglomerate. Boulders are almost exclusively waterworn, commonly faceted and range up to 4ft. across. Thickness variable from 3in. to 2ft.
42	43	"Toe dirt". Purple, red, grey or green clay. This is the main opal level. Pebbles occur. Thickness variable from 6in. to 2ft.
43	63	White kaolinitic siltstones and sandstones with scattered pebbles. Conglomerate beds, veins of gypsum and a lower opal horizon in varicoloured clays occur.
63	82	Soft to hard white to pale yellow feldspathic sandstone, fine and even grained and generally micaceous. A bed of black ferruginous (hematite sandstone 2-4ft. thick), occurs near the base. Quartzite, disconformity—Arcoona Quartzite Member.

It should be noted that opal may occur at several levels but only one is generally exploited.

The stratigraphy at the opal field was first detailed by Segnit (1935, 1939) and later by Nixon (1960), it being long recognized that the opal-bearing beds were of Cretaceous age.

The present survey has outlined the limits of these formations. When drilling for water at a site 8 miles southwest of the opalfield, thin seams of green opal were reported (Nixon op. cit.) to occur in fine-grained chalcedonic quartzite at a depth of 29ft. Four shafts were subsequently sunk about the bore at 100ft. centres to further

explore this "find". It was subsequently learned that the opal was introduced into the samples during boring operations and the discovery something of a hoax. All shafts showed a similar profile as below.

ft. in.	ft. in.	
Surface	16 0	Light-brown to red-brown sandy clay.
16 0	21 6	Grey sandy clays with occasional rounded quartzite pebbles.
21 6	28 6	Boulder bed; rounded waterworn quartzite pebbles and boulders up to 1ft. in diameter, with interstitial fine grey sand.
28 6	30 0	Fine grey sand, little clay.

The survey undertaken by Nixon demonstrated the essentially flat-lying character of the opal-bearing shale. Faulting was recorded by him with a suggestion that there may be displacement due to gravity collapse consequent on erosion marginal to the tablelands though there are no surface indications.

There appears to be some structural control of deposition of opal within the favourable horizon. Opalization has taken place at the base of a bed of conglomerate above impermeable clay, commonly on the down-thrown side adjacent to faults. Faulting is more widespread than earlier workers believed with displacements of up to 8ft. being evident in many of the accessible workings. Gougers now generally accept the minor faults as being guides to pockets of precious opal with reliable opinion generally favouring deposition in down-thrown blocks adjacent to the faults; however, there are other schools of thought and diviners practice their "art". Corroboration of these facts would require mapping of the structures and of opal occurrence as mining development proceeded to note relationships, though the reluctance of gougers to disclose their finds impedes scientific enquiry into establishing their existence.

The various occurrences of opal in Australia have a number of features in common and many workers have contributed to an understanding of these (*see* Croll, 1950). Following a recent study of the Coober Pedy field Hiern (1965) has made further observations on general occurrence. It is apparent that the deposits occur within the pallid zone of a mature laterite profile which developed on a continent-wide peneplain in Tertiary time. Opalization is everywhere localized at the interface between porous (sandy) beds and underlying impermeable (claystone) strata, implying that downward moving silica-laden groundwaters deposited silica in pre-existing openings, fractures etc. in the host.

At Andamooka faulting would have facilitated movement of meteoric waters by providing channel ways for the downward movement of silica-laden waters. These would have been dammed at an impervious barrier provided by the "toe dirt" clay on the down-thrown side of the faults. Subsequent deposition of opaline silica might be dependent on a change in pH. Such a hypothesis involves fault movements not related to present topography. The continuity, attitude, frequency and trace of the faults is unknown. That there are no surface indications on the undissected peneplain precludes their being gravity collapse structures consequent on erosion marginal to the tablelands.

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BARITE

Barite is closely associated with manganese in the bed of Pernatty Lagoon (plate XXXVI, fig. 2) where it originally formed a rise elevated almost 1ft. above the general lake level over an area some 1-2 chains across and traceable as a succession of patches a distance of almost $\frac{1}{4}$ mile. Its surface form appeared to be that of a long, relatively narrow lode with irregular bulges and bifurcating at its northwestern extremity. Its vertical dimensions are unknown.

It occurs in massive coarsely crystalline aggregates, glassy to white, yellow, or pink in colour and has clay-filled joints and partings.

The ore was formerly mined and washed to free it from adhering clay and associated gypsum to give a fairly pure grade of barite, a typical analysis of which follows:

	Per cent
BaSO ₄	98.25
SiO ₂	0.80
Al ₂ O ₃	0.24
Fe ₂ O ₃	0.12
CaO	0.44
MgO	0.10
Loss on ignition	0.05

Production for the following years are officially recorded—

	Tons	Value £
1917-1924	197	494
	225	437
	402	1,302
1938-1939	724	1,478
Total	<u>1,548 tons</u>	<u>£3,711</u>

Lake Windabout

Claims were pegged on Lake Windabout in 1920 but there was no production.

Island Lagoon

Island Lagoon, occupying an area of over 200 square miles, is second in area only to Lake Torrens and has a crust of salt covering almost the whole bed.

Investigations by Patterson (1949) suggested that the surface of the main body of the lake was covered with a crust of white salt thickening from $\frac{1}{4}$ in. at the southern margin and attaining 2 ft. at a distance of 2 miles from shore and constant thereafter towards the centre of the lagoon. Considering the effective area of salt crust to be 200 square miles (128,000 acres), salt to weigh 120 lb./cub. ft. and the average salt thickness 1 ft., the approximate tonnage of salt present on the surface was estimated to be three million tons.

Salt is immediately underlain by soft black mud but the nature and thickness of the underlying lake sediments is unknown; as bedrock outcrops at intervals at the margins and as islands (plate XXXVII, fig. 2) it is considered that lake sediments are generally shallow.

Gypsum

Fine-grained crystalline gypsum occurs at or near the surface of a number of the lakes examined in the region while veneers of kopi commonly occur about their eastern shores.

Lake Blyth

The surface of Lake Blyth is composed largely of fine gypsum crystals in a matrix of dark-grey mud. Boring undertaken by Patterson proved up to 6 ft. of gypseous clay above chocolate-brown muds and silts.

Lake Finnis

Lake Finnis is similar to Lake Blyth except that there is a thin salt crust present over parts of the surface of Lake Finnis.

Lake MacFarlane

Though connected to Island Lagoon by a narrow elongate channel the surface of Lake MacFarlane is, in contrast, quite soft and salt free. The surface of Lake MacFarlane is covered by gypseous silt.

Lake Torrens

Boring has proved the persistence of a bed of gypsum some 40 ft. in thickness over a distance of 4 miles from the eastern shore at a depth of about 50 ft. This bed is overlain by brown clays containing sporadic gypsum crystals—these extend to the surface. Partial analyses of the gypsum bed are as follows:

Bore No. 3A		
Depth		CaSO ₄ .2H ₂ O
ft. ft.		per cent
54—56	32.6
56—59	33.7
59—81	52.9
81—84	77.9
84—97	57.5

The main contaminant is silica sand.

Lake Brines

Brines have been utilized previously to a limited degree for the recovery of salt but the ready availability of salt elsewhere in the State made these operations uneconomic.

Tabled below are available analyses of lake waters and of brines held in lake sediments; analyses of waters from several freshwater lakes are included for comparison.

Grains per Gallon	Cl	SO ₄	CO ₃	Na	K	Ca	Mg	Br	Total Salts
Lake Campbell	8	3	13	15	15	2	Tr	—	42
Arcoona Lake	14	6	10	17	17	1	1	—	49
Lake Koolymilka	185	18	3	107	107	9	7	—	329
Lake Richardson	346	38	3	212	212	13	10	—	623
Lake Finnis	4,905	451	—	2,881	38	162	163	—	8,600
Lake MacFarlane	5,584	540	—	3,159	40	152	276	—	9,752
	9,614	779	—	5,463	61	73	542	—	16,532
	12,338	686	—	6,958	116	51	659	—	20,808
Island Lagoon	13,302	291	—	8,406	43	102	116	—	22,260
Lake Dutton	6,508	793	—	3,853	29	80	338	—	11,602
Pernatty Lagoon	11,239	651	1	6,405	70	53	567	—	18,989
	6,835	365	3	390	—	79	310	1.0	11,507
	9,472	647	3	4,893	494	115	523	—	16,146
Ironstone Lagoon	7,965	539	3	4,775	37	117	255	0.4	13,694
Lake Hart	13,375	345	—	8,294	45	149	176	—	22,385
Lake Torrens—									
Bore 5									
8ft.	3,444	428	—	2,098	4	121	107	0.5	6,198
77ft.	8,946	627	—	5,660	4	99	174	1.7	15,506
110ft.	7,788	582	—	4,930	4	102	150	1.7	13,552
Bore 4									
7ft.	11,082	515	—	6,906	7	83	229	1.5	18,815
147ft.	7,228	403	—	4,480	4	105	148	1.4	12,364
Bore 3A									
5ft.	11,113	500	—	6,966	12	80	206	1.3	18,865
26ft.	11,287	637	—	7,094	10	71	238	1.7	19,327
67ft.	10,886	589	—	6,832	8	77	223	1.9	18,607
450ft.	4,088	144	6	2,542	4	39	72	1.2	6,892
500ft.	3,052	84	9	1,893	5	35	49	0.9	5,121
546ft.	1,244	25	17	782	3	16	16	0.5	2,101
600ft.	1,175	19	17	739	3	14	16	0.6	1,980
609ft.	1,159	25	18	731	4	13	17	0.5	1,962
650ft.	1,657	42	12	1,036	4	17	25	0.7	2,791
700ft.	1,672	45	13	1,045	4	19	25	0.6	2,819
750ft.	2,189	62	10	1,362	5	27	34	0.8	3,684
800ft.	2,965	103	8	1,842	5	45	45	0.8	5,008
850ft.	1,854	54	11	1,145	5	31	30	0.6	3,125
857ft.	2,163	60	5	1,343	5	28	32	0.7	3,631

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WOOCALLA CLAY (MAGAZINE HILL)

Situated less than $\frac{1}{4}$ mile southwest of Woocalla railway siding is a low more or less circular flat-topped mesa rising 25-30ft. above the general ground level in which a horizontal bed of highly plastic weathered shale (ball clay) has been mined since about 1920 (fig. 11). Annual recorded production since 1931 is as follows:

	Tons	Value £		Tons	Value £
1931	54	28	1948	249	373
1932	50	25	1949	96	144
1933	36	18	1950	322	483
1934	36	18	1951	236	354
1935	36	18	1952	356	534
1936	105	53	1953	416	624
1937	54	27	1954	480	988
1938	63	32	1955	360	850
1939	168	88	1956	373	933
1940	216	135	1957	441	845
1941	175	109	1958	266	665
1942	197	295	1959	293	732
1943	244	366	1960	445	1,112
1944	122	183	1961	419	1,047
1945	—	—	1962	253	505
1946	220	330	1963	382	950
1947	187	280			
			Total .. .	<u>7,250</u>	<u>£13,142</u>

The hill is capped by up to 8ft. of gypseous brown clay and gritty porcellanite remnants of a peneplaned surface which overlie the clay, the uppermost 3ft. of which are iron-stained. This clay has been proved by boring to attain a thickness of 18ft. and to have gross recoverable reserves of over 40,000 tons (Miles, 1950).

The clay-shale at present being mined from several benches on the southeastern side of the hill is grey-white to pale olive-brown in colour when freshly broken but it whitens on exposure. Finely laminated bedding simulates varves. The shales are crumpled and have been dislocated by small-scale faulting.

The base of the bed is generally manganese stained where it gives way to dolomite.

The clays are derived from weathering of Upper Proterozoic (Woomera Shale) and represent the pallid zone of the Tertiary duricrust profile. They are similar lithologically, have the same origins and occupy a similar stratigraphic position as the Tregolana Shales, being mined by the Broken Hill Proprietary Company Limited 12 miles north of Whyalla (Miles, 1954 p. 170) and those of the Port Augusta district, Sunman and Paull deposits (Gaskin and Samson, 1951, Johns, 1960). Similar clays have been recorded from Lake Hart, Hesso etc.

The deposit was originally mined from adits driven into the hill on the clay bed (see photos. in *Geol. Surv. Bull.* 12, p. 94) but it is now an open-cut mining operation: the overburden has been removed by bulldozing and the clay is picked from the face and bagged for transport to Adelaide. (Plate XXXVIII.)

Being highly plastic, grit-free, fine in texture and burning to a reasonably white colour, it has found a ready use for the manufacture in Adelaide of pottery, porcelainware, electrical ware etc. Though the firing colours are not good (white to cream) its plasticity and easy vitrification are desirable features.

The clay comprises kaolin and illite, with quartz, white mica, iron oxides and occasional crystals of gypsum. Trial beneficiation and burning undertaken by Abell and Gartrell (1938) suggested that gypsum was not separable by simple washing. Now, when crystalline gypsum is present in quantity, the clay is discarded, but fine disseminated gypsum is inevitably present in small amounts throughout all clay mined.

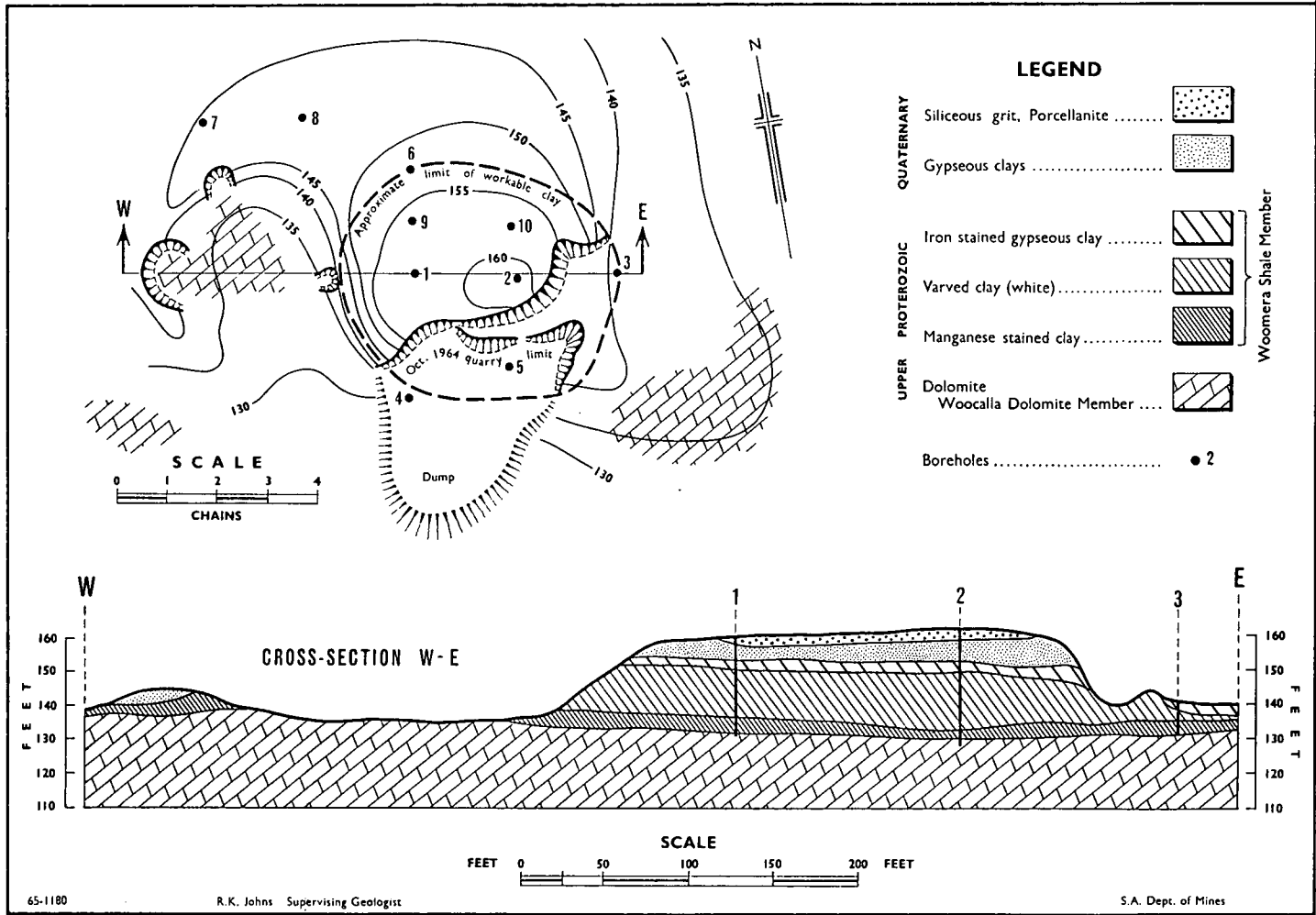


FIG. 11—WOCALLA CLAY DEPOSITS—MAGAZINE HILL

Firing characteristics and ceramic properties of the clay have been discussed by Gaskin and Samson (1951). They described it as a highly plastic clay compared to most of the South Australian types and classed it as a ball clay.

The following analyses are available (Nos. 1-4 are from Magazine Hill; analysis No. 5 refers to a greyish-white ball clay from the east of Lake Hart and is reported (Samson and Gaskin op. cit. p. 79) to have good plastic properties. Although it was rather ferruginous and contained large amounts of soluble salt it was not refractory.

	Sample No.				
	1	2	3	4	5
	per cent	per cent	per cent	per cent	per cent
SiO ₂	54.16	56.98	52.04	48.50	53.04
Al ₂ O ₃	29.74	28.60	30.87	27.03	23.30
Fe ₂ O ₃	1.04	1.14	0.88	0.71	1.44
MgO	0.74	0.18	0.18	0.90	0.90
CaO	0.30	0.26	0.22	0.38	0.02
Na ₂ O	1.05	0.56	1.47	0.60	1.10
K ₂ O	1.69	2.12	2.04	1.98	2.32
Water @ 100°C	1.71	1.28	1.60	9.23	0.21
Water + 100°C	7.76	7.82	9.82	9.35	10.45
TiO ₂	1.05	0.90	0.47	0.86	1.02
SO ₃	0.08	—	0.26	0.38	—
Cl	1.31	0.16	1.25	0.91	1.45
MnO	—	0.53	—	—	—
	100.34	100.53	100.82	100.83	95.25

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CONSTRUCTION MATERIALS, AGGREGATE, ETC.

Even-bedded sandstones and quartzites throughout the region have provided a ready supply of stone suitable for walling construction at the opalfield and in station homesteads, outbuildings, tanks etc. while silty flagstones have been used in paving and flooring.

At Woomera, diamond drilling was undertaken in 1948 at a number of sites to test the suitability of materials for road and construction aggregate before quarry operations commenced near Phillip Ponds in sandstone-quartzite of the Tent Hill Formation. The stone is crushed and screened at the site and used widely throughout the W.R.E. area. Base-course material is derived from pits in Cretaceous siltstone near the village.

Sand for use in fine concrete aggregate at the range is quarried from a pit on Mungappie Creek. Elsewhere throughout the region creek sand is utilized as required.

Ballast for construction and maintenance of the Transcontinental Railway line has been quarried from quartzite and, more extensively, from dolomite at Woocalla; extensive reserves remain.

Chapter 7

HYDROLOGY AND WATER SUPPLIES

The low rainfall, high evaporation rate and concentration of cyclic salts in a region of internal drainage of waters of local origin are factors which are not conducive to the occurrence of large supplies of groundwaters suitable for stock, and all pastoral stations can point to failures of deep and shallow bores to provide adequate supplies of useful water. They are therefore largely dependent on dams constructed on suitable catchments to store surface waters for their requirements.

UNDERGROUND WATER

A number of wells, mostly now abandoned, were sunk in the early days and provided the basis of settlement. Creek bed alluvium and basement quartzites generally store small supplies of water; in an attempt to increase the storage capacity, drives have been constructed in a number of these. More intensive boring undertaken since that time has mostly yielded disappointing results. The location of all bores and wells in the region are shown in fig. 12.

Water stored underground in the rocks of the region permeates after rainfall from the surface through pore spaces and along bedding and joint planes and open fractures; in Andamooka Limestone solution channels and occasional caves are developed. Intake is expected to be at an optimum along the major drainage channels while much of the water reaching swamps, lagoons etc. will ultimately replenish local groundwaters—the salinity of these waters, however, is mostly high.

Shales and siltstones which underlie enormous areas provide notoriously poor aquifers because they are dense, fine grained and non porous; permeability is at a minimum and clays derived by weathering further seal inherent planes of weakness. It is noteworthy that most of the wells or bores abandoned as being dry are located in shaly rocks.

Where the underlying strata are more sandy and coarser grained, and kaolin is an unimportant constituent, somewhat better supplies might reasonably be expected—sites located on favourable drainage channels are undoubtedly augmented in places by underflow from gravels.

The absence of structural disturbance, of heavily fractured zones or faults denies provision of openings for storage of water underground over great expanses. At Willaroo Lagoon adjacent to an area of local faulting the Willaroo Lagoon bore and well flows at the surface—the water is, however, saline.

In elevated areas on the Arcoona Plateau wells constructed in quartzite yield only small supplies of water, water-yielding capacity being dependent on the frequency of open bedding and joint planes. Records suggest that the main valleys and deep depressions should be avoided, as they are generally underlain by salt water. Less-brackish water is more likely to exist under the valleys of tributary creeks and high-level depressions that are well fed by surface floods. Water percolating very freely may displace the saline water both laterally and vertically and so form an extensive "fresh" water area or it may percolate through joints to lie as a layer, only a few feet in thickness, upon the normal saline groundwater. Jack (1927) observed that many wells in the Andamooka area had been spoilt by too great deepening; this "is well exemplified by the numerous adjoining "horse" and stock wells seen, the former being shallower, and thus sacrificing quantity for quality. There is also some evidence to show that the extreme headwaters of flat streams may overlies salt water, probably because water has not collected in sufficient bulk to percolate in quantity to the groundwater table".

Because of poor intake conditions, lack of surface runoff and underlying impervious rocks the areas occupied by sand plain and by shales have failed to provide adequate supplies of stock water. Large areas comprising the Bookaloo Lowlands, the Cretaceous Tablelands and much of the Torrens Sunlands are undoubtedly underlain by sediments containing saline groundwater due to meagre local intake to the "aquifers".

Limestones have provided useful supplies of good-quality water where conditions are favourable for replenishment of a generally thin aquifer *e.g.*, Chances Swamp, Purple Swamp, Phillips Ridge—elsewhere the waters are mostly saline.

The Lake Torrens Sunlands constitutes part of the Pirie-Torrens Basin (Chebotarev, 1958), the northern limits of which were difficult to define because of the inadequacy of subsurface information and the low intensity of drilling. In the southeastern extremity of the map area, however, the survey indicated a regular predictable occurrence of subartesian water. In the Lake Torrens H.S. locality, excellent stock waters are provided by bores 200-300ft. in depth. The pressure waters deteriorate towards old Pandita H.S. while adjacent to the shore of the lake and along the Willochra Creek channel they are unsuitable for stock.

In the Willouran Range judicious selection of bore sites, having regard to geological conditions and adequacy of re-charge, should provide adequate supplies of water suitable for stock.

The provision of potable water for residents at the Andamooka Opalfield has presented problems as the steadily expanding community makes further demands on what appears to be a limited supply of underground water. A number of shallow wells (30-75ft. deep) and bores located on Opal Creek channel provide small supplies of water while somewhat brackish water is drawn for the settlement from a bore at North Swamp.

In the Appendix are tabled available relevant data relating to bores and wells throughout the region.

SURFACE WATER

Because of the lack of extensive underground water supplies the pastoral industry is dependent on the catchment and storage of surface waters. The development and availability of heavy earthmoving equipment has revolutionized the technique of water conservation and large-capacity dams are now occasionally combined with reticulation schemes which distribute the water to several paddocks.

Suitably impervious, easily excavated strata are generally available throughout the region for construction of dams of a capacity commensurate with the probable runoff. In many instances clay pans provide the only available catchment.

A number of lakes, swamps etc., collect and store large supplies of freshwater for extended periods. Surface waters which drain into salt pans represent an absolute loss in the water economy of a station and most of the lakes and lagoons are of this type. Other swamps or lagoons may collect freshwater after flooding and deteriorate in quality as the water evaporates. Few, however, collect and store fresh water for quite long periods. During the period 1947-1949 the lakes of the region were inundated; Lake Richardson was 16ft. deep; Lake Campbell held water up to 20ft. which lasted for over 2 years and remained fresh to the last; (30 gr./gall. in March, 1949). Lake Koolymilka was initially fresh (100 gr./gall. in October, 1947) but became brackish (420 gr./gall. in March, 1949) and finally salt; Arcoona Lake was fresh throughout the period 1947-1952 when it became dry; Fred's Swamp (52 gr./gall.) and Winjaby Lake (23 gr./gall.) also held water in 1949; by 1952 most were dry and remained so until useful rains in 1963.

Tabled below are available analyses of water taken from Lake Richardson (which held up to 16ft. of water) and Arcoona Lake during the period 1947-1950.

Date Sampled	Dissolved Saline Matter	
	Arcoona Lake grains/gallon	Lake Richardson grains/gallon
29/5/47	—	136
15/8/47	20	—
1/10/47	—	168
9/3/48	—	267
24/3/48	28	—
12/5/48	32	305
22/5/48	—	318
8/7/48	33	329
22/7/48	34	333
25/8/48	36	—
12/9/48	—	355
15/10/48	41	—
17/11/48	42	—
24/11/48	46	—
10/12/48	—	482
4/2/49	79	612
8/2/49	80	—
25/2/49	80	666
24/9/49	40	547
27/9/49	35	—
10/11/49	44	542
5/12/49	48	623
28/1/50	68	768
31/1/50	70	—
28/2/50	42	682
25/3/50	46	736
8/5/50	50	829
25/7/50	52	—

Chapter 8

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APPENDIX

DETAILS OF BORES AND WELLS

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks	Log		
				Ft.	Ft.	Ft.				Ft.		
..	Stuart	Billa Kalina ..	P.L. 2021, 2m. N. Angle Swamp	108	42	51-63	½oz.	Small	2m. N. bndy. Mattaweara—abandoned	Q K ?J ?P	0-3 3-6 6-20 20-33 33-63 63-108	Sandy loam Quartzite boulders Mottled clays Sand, silt, grey clay Sandstone Mottled red, yellow, blue and black clay carbonaceous and pyritic
—	Stuart	Billa Kalina ..	P.L. 2021, 2m. N. Angle Swamp	95	51	71, 90	1½oz.	Small	Adjacent to above—abandoned	K ?P	0-43 43-61 61-95	Gypseous grey clays Brown and grey clays Mottled red, yellow, blue and black clays; some carbonaceous and pyritic
1	Mattaweara .	Billa Kalina ..	P.L. 2021, N. side of Angle Swamp	155	—	90, 150, 153	2¼oz.	Good	Abandoned	Q K Pm	0-5 5-42 42-54 54-94 94-96 96-155	Red clay White sandstone, very hard to 22ft. Grey, black clays Grey, black clays, with fine grained sandstone Grey, black clays with red boulders Hard red rock
2	Mattaweara .	Billa Kalina ..	P.L. 2021, S. side of Angle Swamp	183	—	136	4oz.	Large	Abandoned	T K Pm	0-3 3-30 30-40 40-136 136-183	Red clays with laterite nodules Grey sandy clays, gypseous Grey hard sandstone Grey rock Blue, green, brown, red shales

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth		S.W.L.	Water Cut	Salinity	Supply	Remarks	Log			
				Ft.	Ft.									
3	Mattaweara .	Stuart Creek ..	9m. N. Mattaweara Lagoon	—	—	—	—	—	—	Abandoned	K	In blue and chocolate-coloured clays, limonitic		
4	Mattaweara .	Stuart Creek ..	7m. N. Mattaweara Lagoon	—	—	—	—	—	—	Abandoned	K	In grey sandy shales		
5	Yarrowurta ..	Stuart Creek ..	—	—	—	—	—	—	—	Well.....	C	In limestone		
6	Yarrowurta .	Mulgaria.....	Yarrowurta bore	214	13	12	Salt	—	Abandoned. Position only approximate	K	0-32	Gypseous clays and gravel		
						130	Salt	—					32-45	Brown sandy clay
						184	19oz.	Big			?	45-50 Bands of lignite 50-125 Blue, brown and yellow clays 125-130 White clay 130-145 Yellow-brown clays 145-185 Brown sandy clay 185-191 White clay 191-193 Lignite 193-210 White sandy clay 210-212 Very hard sandstone		
						191	Brackish ...	Very small						
						210	1,280gr./gall.	Large						
													C	212-214 Fine-grained purple limestone with pyrite (Archaeocyathinae identified)
7	Witchelina ..	Stuart Creek ..	Mirrabuckinna bore	1,635	6	401	Salt	—	Abandoned (Howchin 1893)	K	0-68½	Blue clay with boulders		
					6	662	Salt	—						
					+ 3ft. above	1,015	—	—			?	68½-130 Brown clay with lignite at 95ft., 105-108ft., 113-115ft. (fine-grained conglomerate at 128ft.) 130-153 Sandy clay		
8	Witchelina ..	Mulgaria.....	Sisters Wells.....	30	20	—	755gr./gall...	Small	—	—	Pm	153-1,635 Hard brown, blue, shales		
9	Witchelina ..	Mulgaria.....	Sisters Wells.....	23	20	—	811gr./gall. .	—	—	—	Pm	In green calcareous slate below 15ft.		
10	Witchelina ..	Mulgaria.....	Flagstaff bore....	147	7	—	Salt	—	—	—	Pm	Penetrated bedrock slate		
11	Witchelina ..	Witchelina	Bore ¼m. NNW. West Mount Hut	—	—	—	Salt	—	Abandoned	—	Pt	In dolomitic slates		
12	Witchelina ..	Witchelina	West Mount well.	60	25	—	648gr./gall. .	—	190ft. of drives ..	—	Ps	Alluvium over slate		
12A	Witchelina ..	Witchelina	Old well	40	—	—	Salt	—	¼m. downstream from 12	—	—	—		
12B	Witchelina ..	Witchelina	Horse well	—	—	—	Salt	—	1m. upstream from 12	—	Q	In alluvium		

13	Witchelina ..	Witchelina	Bore 3m. SE. West Mount Hut	—	—	—	Salt	—	Abandoned.....	—	
14	Witchelina ..	Witchelina	Glen View well ..	70	—	—	732gr./gall. .	—	21ft. drive	Ps	In alluvium and weathered slate
15	Witchelina ..	Witchelina	Berlina well	116	70	—	1½oz.	Fair	132ft. drives at 73ft.	Pt	In alluvium and slates with thin quartzites
15A	Witchelina ..	Witchelina	New Tilterana ..	60	—	—	—	—	55ft. drives	—	—
16	Witchelina ..	Witchelina	Coronation bore	—	—	—	¾oz.	400 gr/gall. .	96ft. drives	Pt	In dolomites and quartzites
17	Witchelina ..	Witchelina	Old Tilterana well	126	70	—	775gr./gall. .	—	—	—	—
18	Witchelina ..	Witchelina	3rd Tilterana well	77	—	—	—	—	—	—	—
19	Witchelina ..	Witchelina	Busheowie well ..	76	—	—	—	Large.....	83ft. drives	Ps	In alluvium and weathered blue slates
20	Witchelina ..	Mulgaria.....	Homestead bore .	128	—	—	2,300gr./gall.	Very small ..	—	—	—
21	Witchelina ..	Mulgaria.....	Homestead well ..	46	36	—	—	Good.....	—	—	—
22	Witchelina ..	Mulgaria.....	Near homestead bore	89	84	—	1,300gr./gall.	+ 300 g.p.h.	—	—	—
23	Witchelina ..	Mulgaria.....	On Niroona Creek	80	43	43	Salt	—	Abandoned	Q	0-42 Red and white clays
										Pm	42-80 Green blue slate
24	Witchelina ..	Mulgaria.....	On Niroona Creek	48	40	40	Salt	—	Abandoned	Q	0-6 Red clay 6-22 Sand 22-38 Yellow clay
										Pm	38-48 Green blue shale
25	Witchelina ..	Mulgaria.....	Near Middle dam	81	61	77	2,900 gr/gall.	200 g.p.h. ..	Abandoned	Q	0-20 Sandy clay 20-22 Sand
										Pm	22-81 Chocolate-coloured shale
26	Akhurst	Andamooka ..	N. Swamp well ..	200	80	—	—	100gall./day .	Drives	C/Pm	In limestone and red quartzites with shales
27	Akhurst	Andamooka ..	N. Swamp bore .	270	—	—	—	—	—	C/Pm	In limestone and red quartzites with shales
28	Akhurst	Andamooka ..	N. Swamp well ..	180	—	—	—	—	Abandoned	C	In limestone
29	Akhurst	Andamooka ..	Bore, 5m. E. of 26	180	—	—	Salt	—	Abandoned	C/Pm	In limestone and quartzite
30	Akhurst	Andamooka ..	Bore 6m. ESE. of 26	150	—	—	Salt	—	Abandoned	C/Pm	In limestone and quartzite
31	Akhurst	Andamooka ..	Horn Ridge well .	200	—	—	Salt	—	Abandoned	Pm	In purple quartzite

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water	Salinity	Supply	Remarks		Log	
					Ft.	Cut					Ft.	Ft.
32	Akhurst	Andamooka ..	3m. SW. opalfield	170	—	—	Salt	—	Dry	Q	0-4	Brown silt
												4-15 Red fine to coarse sand, little clay
										K	15-25	Fine sandy clay, gypseous
											25-38	White, yellow clay
											38-42	Clays with quartzite boulders
											42-60	Cream clayey very fine sand
											60-70	Grey quartzite boulders and gravel
											70-94	Cream very fine sand and clay
										Pm	94-143	Purple sandstone-quartzite
											143-146	Dark brown slate
											146-170	Purple sandstone-quartzite
33A	Akhurst	Andamooka ..	At opalfield, nr. Costers	70	—	—	Salt	—	Abandoned			—
33B	Akhurst	Andamooka ..	Station wells	40	36	—	114.....	350gall./day .	70ft. drives			—
33C	Akhurst	Andamooka ..	—	64	—	—	109.....	350gall./day .	—			—
33E	Akhurst	Andamooka ..	Howe's Well	30	—	—	—	Very small ..	—			—
33F	Akhurst	Andamooka ..	Gouger's well No. 1	60	27	27 55	38gr./gall. .. 51gr./gall.	150gall./day .	Well 0-30ft. and 46ft. drives Bore 30-60	K	0-30	Siltstone, shale (in well)
										Pm	30-40	White sandstone with green shale partings
											40-55	Shaly sandstone
											55-60	Red-brown sandstone
33G	Akhurst	Andamooka ..	Albertoni's well ..	—	—	—	—	Very small ..	—			—
33H	Akhurst	Andamooka ..	Well 29 chains S. of 33	30	—	—	Salt	—	—			—
33I	Akhurst	Andamooka ..	Gouger's well No. 2	75	25	30 55	21gr./gall. .. 26gr./gall.	60 gall./day .	Well 0-40ft. Bore 40-75ft.	Pm	40-75	Red sandstone
33J	Akhurst	Andamooka ..	Barnes No. 1 bore	44	22	—	1,064gr./gall.	—	—	Pm	0-44	Sandstone
33K	Akhurst	Andamooka ..	Barnes No. 2 bore	60	15	18 55	42gr./gall. .. 59gr./gall. ..	300gall./day . 1,000gall./day	—	Q	0-18	Gravels
										Pm	18-30	White and brown sandstone
											30-60	Shaly sandstone
34	Akhurst	Andamooka ..	Bore	320	—	45 60 140	Salt	800gall./day .	Three bores in this locality, salt and abandoned	Q	0-25	Alluvium
										Pm	25-60	Purple quartzite
											60-380	Purple slates

35	Akhurst	Andamooka	Bore	44	34	40	1,600gr./gall.	5 g.p.h.	Abandoned; position only approximate	Q	0-2	Red gravelly clay
										Pm	2-33 33-40 40-44	Brown, purple sandstone, quartzite Purple slates Purple sandstone-quartzite
36	Ediacara	Mulgaria	Two wells, 6m. SW. H.S.	—	—	—	—	—	—			—
37	Ediacara	Mulgaria	—	—	—	—	—	—	—			—
38	Ediacara	Mulgaria	House well	—	—	—	—	—	—			—
39	Ediacara	Myrtle Springs	West side well	—	—	—	929gr./gall.	—	—			—
40	Ediacara	Myrtle Springs	Mt. Victory well	100	90	—	486gr./gall.	Good	—			—
41	Ediacara	Mulgaria	Bore 3m. W. of No. 36	—	—	—	Salt	—	Abandoned; position approximate			—
42	Ediacara	Myrtle Springs	Bore 6m. SW. of H.S.	—	—	—	Salt	—	Abandoned; position approximate			—
43	Ediacara	Myrtle Springs	Oliver's bore 3m. SE. of No. 42	—	—	—	Salt	—	Abandoned; position approximate			—
44	Ediacara	Myrtle Springs	Landmark well	—	—	—	—	—	—			—
45	Roxby	Roxby Downs	½m. N. of Sunday Well	—	—	—	—	—	Abandoned	C		In limestone (purple and grey sandy and argillaceous)
46	Roxby	Roxby Downs	Sunday well	145	140	—	6oz.	—	Abandoned	C		In limestone (purple and grey sandy and argillaceous)
47	Roxby	Parakylia	Nolan's well	170	150	—	497gr./gall.	—	—	C		In grey limestone
48	Roxby	Parakylia	3m. NNW. of No. 47, bore	170	100	—	—	Very large	Abandoned			—
49	Roxby	Parakylia	Wendt's bore	174	—	—	1.3oz.	Small	—			—
50	Roxby	Roxby Downs	Bore, 8m. N. of H.S.	239	—	120	1.5oz.	30 g.p.h.	Position only approximate	Q	0-39	Clay
										C	39-120	Dense blue limestone with caves at 100ft.
										Pm	120-239	Hard quartzite
51	Roxby	Andamooka	Phillips Ridge	50	50	—	½oz.	Small	Drive in limestone	C	0-50	Limestone, oolitic, brecciated
										Pm		Red quartzite
52	Roxby	Andamooka	Phillips Ridge	61	56	—	½oz.	Small	—	C	0-56	Limestone, oolitic and brecciated
										Pm	56-61	Red quartzite

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks		Log
				Ft.	Ft.	Ft.					
53	Roxby	Andamooka ..	Phillips Ridge ...	92	30	—	168 gr./gall. .	Small	—	C	0-30 Limestone, oolitic and brecciated
										Pm	30-92 Red quartzite
54	Roxby	Andamooka ..	Old wells, 3½m. SW. of Sisters wells	51	—	—	—	—	Two wells	Pm	In red quartzite
55	Roxby	Roxby Downs	Sisters Wells	105	60	—	1½oz.	2,000gall./day	6ft. drive at 65ft.	C	0-105(?) Grey oolitic limestone
56	—	—	—	64	—	—	Fresh	300gall./day .	—	Pm	Quartzites
57	Roxby	Roxby Downs	Bambidge well ..	—	—	—	—	—	—	C	In oolitic grey limestone
57A	Roxby	Roxby Downs	Bore 2½m. SE of H.S.	150	—	—	Salt	—	Abandoned		—
58	Roxby	Roxby Downs	Chances Swamp well	120	60	—	Fresh	7,000gall./day	Subject to flooding	C	In limestone
59	Roxby	Andamooka ..	Coorlay Lake bore	125	—	—	331gr./gall. .	—	Position only approximate	Pm	In quartzite
60	Andamooka	Andamooka ..	1m. E. of Phillips Ridge	—	—	—	—	—	Abandoned	C/Pm	In limestone, grits and red quartzite
61	Andamooka	Andamooka ..	5m. SW. of opal-field	110	—	—	—	—	Abandoned	Q {	0-6 Red-brown gravelly clay 6-9 White clay with boulders 9-11 Pale-grey clay
										K {	11-30 Light-grey pebbly clay 30-32 Light-grey sandstone 32-44 White-brown sandy clay
										Pm	44-110 Grey, cream, purple, brown and red sandstone-quartzite with shale bands at 50-51ft. 58-60ft., 64-67ft., 83-87ft. and 91-94ft.

62	Andamooka	Andamooka ..	3½m. S. of No. 61	162	7	72	1,900 gr./gall.	100 g.p.h. ..	Abandoned. Four shafts sunk to test erroneous report of opal find (30ft. each, 100ft. apart)	Q	{	0-4 4-16	Light brown sandy clay Red brown sandy clay
												16-21½	Grey sandy clays with rounded quartzite pebbles
												21½-28½	Boulder bed. Rounded quartzite pebbles and boulders up to 1ft. with interstitial fine grey sand
												28½-30	Fine grey sand, little clay
												30-38	Light-grey silty fine sand, some rounded pebbles
											K	38-45	Light-grey soft sandstone
												45-51	Sandy clay
												51-52	Quartzite boulder bed
												52-70	Red-brown ferruginous sandstone with clay and pebbles
												70-72	Light-brown and grey gritty clay
												72-84	Waterworn and angular quartzite pebbles with some clay
												84-90	Grey clay with quartzite boulders
												90-102	Purple sandy silt with quartzite pebbles
											Pm	102-162	Purple brown, grey and green sandstone-quartzite
63	Andamooka	Andamooka ..	Bore W. of Wirrda Hut	45	—	—	Salt	—	Abandoned				—
64	Andamooka	Andamooka ..	Old Wirrda well .	170	57	—	2,252gr./gall.	—	—	C		0-100	Limestone
										Pm		100-170	Red quartzite
65	Andamooka	Andamooka ..	Wirrda well	120	40	—	150gr./gall. .	2,500gall./day	120ft. drives	C		0-110	Limestone (oolitic, grey)
										Pm		110-120	Quartzite
66	Andamooka	Andamooka ..	Bore, 2m. N. of H.S.	47	—	—	Salt	—	Abandoned				—
67	Andamooka	Andamooka ..	Station well	16	—	—	500gr./gall. .	—	Abandoned				—
68	Andamooka	Andamooka ..	Yarloo well	104	60	—	311gr./gall. .	2,000gall./day	20ft. drives at 102ft.	Pm	{	0-102 102-104	Green and purple quartzite Red shale
69	Andamooka	Andamooka ..	Bore, 1¼m. E. of No. 68	45	—	—	Salt	—	Abandoned				—
70	Andamooka	Andamooka ..	Bore, 5m. NE. of No. 69	44	—	—	Salt	—	Position only approximate. Abandoned	Pm		0-44	Quartzite
71	Andamooka	Andamooka ..	Willaroo well ...	—	—	—	—	—	Abandoned	Q		0-8	Alluvium
										Pm			Slate
72	Andamooka	Andamooka ..	Willaroo Lagoon bore	93	Flows	—	1,204gr./gall.	10,000gall./day	—	Pm			In slate

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks	Log	
				Ft.	Ft.	Ft.					Ft.
73	Andamooka	Andamooka ..	Centenary well...	68	43	40 65	—	3,000gall./day	—	Pm	In quartzite
74	Andamooka	Andamooka ..	Myall well	107	50	—	616.....	400gall./day	Drives	Pm	In quartzite
75	Scott	Myrtle Springs.	Blina well	—	—	—	—	—	Two wells	—	—
76	Koolymilka .	Roxby Downs	McLachlans well.	63	—	—	Salt	—	Abandoned	C Pm	0-63 Limestone Red quartzite
	Koolymilka .	Roxby Downs	2m. SE. of No. 76	70	—	—	Salt	—	Abandoned	—	—
78	Koolymilka .	Roxby Downs	Campbell trial well	70	—	—	Salt	—	Abandoned	C Pm	0-5 Limestone 5-70 White quartzite
79	Koolymilka .	Purple Downs .	Well, 5m. W. of H.S.	40	—	—	—	—	Abandoned	C	0-18 Limestone 18-40 Hard quartzite
80	Koolymilka .	Purple Downs .	Well, 4½m. W. of H.S.	70	—	—	Salt	—	Abandoned	Pm	0-18 Limestone 18-40 Hard quartzite
81	Koolymilka .	Purple Downs .	Red Lake Project bore 1A	66	—	—	—	—	Abandoned	Q K	0-2 Red-brown micaceous silt 2-10 Cream, brown kunkar 10-17 Pink silt with limestone grit and gravel 17-34 Pink clay with shale, grit 34-46 Pink-white sandy clay with coarse rounded gravel 46-57 Clay with sharp quartz gravel 57-60 Buff clayey gritty and gravelly sandstone 60-66 Grey-brown sandy and gravelly clay
81A	Koolymilka .	Purple Downs .	—	70	—	—	—	—	—	Q K	0-2 Red-brown sandy clay 2-9½ Red-brown clay with kunkar nodules 9½-11 Hard siliceous gravel, conglomerate 11-18 Red-brown ferruginous sandstone with quartz grit and gravel 18-27 Shales and siltstones (ferruginized and silicified at top) 27-33 White silty kaolinitic clay with scattered waterworn pebbles 33-34 Conglomerate 34-40 White sandstone, kaolinitic and gritty with quartz gravel

82	Koolymilka	Purple Downs	Red Lake Project bore 2	215	175	175	Salt	50gall./day	Abandoned			K { 0-8 Red silt, sand and grit 8-18 Cream, brown, marly silt, kunkar and gravel 18-25 Sandy and gritty clay with ferruginous concretions 25-40 Buff silty sand with quartz grit 40-50 White-brown clay with sand and grit 50-60 Buff silt and fine sand 60-64 Green-brown fine sandy clay 64-74 Dark-brown fine sandy and gritty clay 74-76 Cream silty fine sand with grit and gravel 76-83 Light-brown gravelly clay Pm { 83-103 Brown and grey quartzite 103-112 Purple shale 112-215 Pink, purple and brown sandstone with shale partings and thin shale beds
83	Koolymilka	Purple Downs	Red Lake Project bore 4	125	103	103	Salt	70gall./day	Abandoned			K 0-3 Red fine sand Pm 3-125 Purple, red, brown, buff and grey sandstone
84	Koolymilka	Purple Downs	Red Lake Project bore 3	36	—	—	—	—	Abandoned			Q { 0-3 Brown fine silty sand with quartz gravel 3-5 Gibbers in clay Pm 5-35 Purple, brown sandstone-quartzite
85	Koolymilka	Purple Downs	Red Lake Project bore 2A	68	48	54	Salt	200 g.p.h.	Abandoned			K 0-11 Red-brown fine sand with grit, mica and quartz pebbles C 11-42 Grey, purple, brown limestone Pm 42-68 Red, brown, purple, green and grey sandstone with shale partings
86A	Koolymilka	Purple Downs	Purple well	32	12	—	—	1,500gall./day	—			C 0-32 Limestone Pm Quartzite
86B	Koolymilka	Purple Downs	Swamp well	36	—	—	1½oz.	—	—			C 0-36 Limestone Pm Quartzite
87	Koolymilka	Purple Downs	Well, 2m. E. of H.S.	40	—	—	—	—	—			—
88	Koolymilka	Roxby Downs	Pan well	95	60	60	716	4,000gall./day	54ft. drives at 90ft.	Pm		0-95 Quartzite
89	Koolymilka	Purple Downs	4m. S. of No. 78	168	—	—	Salt	—	Abandoned			—
90	Koolymilka	Purple Downs	NE. Shell Lagoon	37	—	—	Salt	—	Abandoned			—

DETAILS OF BORES AND WELLS—*continued*

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks		Log			
				Ft.	Ft.	Ft.					Ft.			
91	Koolymilka .	Purple Downs .	3½m. E. of No. 90	30	—	—	Salt	—	Abandoned		—			
92	Koolymilka .	Purple Downs .	3½m. E. of No. 90	30	—	—	Salt	—	Abandoned		—			
93	Koolymilka .	Purple Downs .	4½m. E. of No. 90	30	—	—	Salt	—	Abandoned		—			
94	Koolymilka .	Wirraminna ..	West shore Lake Koolymilka L.R.W.E.; on Wild Dog Creek	305	10	12	—	Very small .. Very small 700 g.p.h.	Abandoned	Q	0-2	Sandy clay		
				—	10	40	—				Pm {	2-60 60-305	Grey and yellow sandstone Purple and green slates	
95	Koolymilka .	Wirraminna ..	2m. NW. of No. 94	158	—	150	—	20 g.p.h. ...	Abandoned	K {	0-5	Red sandy clay and gravel Quartzite boulders in sandy clay		
											5-30			
										Pm	30-158	White quartzite		
96	Yeltacowie .	Andamooka ..	Bore, ¼m. N. Mulga Hut	58	—	—	—	—	—	C		In limestone		
97	Yeltacowie .	Andamooka ..	Pine well	15	10	—	2oz.	10,000gall./day	—	Q		In alluvium, sand		
98	Yeltacowie .	Andamooka ..	Mulga wells	17	12	—	1.69oz.	10,000gall./day	Two wells	C		In limestone		
99	Yeltacowie .	Andamooka ..	Horse well	35	20	—	616gr./gall. .	300gall./day .	—	C		In limestone		
				16	14	—	¼oz.	600gall./day						
100	Yeltacowie .	Andamooka ..	Woolshed well ..	80	70	—	—	—	Abandoned	Pm		In quartzite		
101	Yeltacowie .	Andamooka ..	Bore No. 5, 3m. SW. of H.S.	73	—	—	—	—	Abandoned	Q	0-5	Red-brown fine-medium sand with quartzite pebbles and laterite nodules		
												K	5-24	Fine-medium sandstone with small iron stained quartzitic pebbles
												Pm	24-73	Red-brown and pink sandstone quartzite
102	Yeltacowie .	Andamooka ..	Whip well	—	—	—	—	—	—	Pm		In quartzite		

103	Yeltacowie .	Andamooka ..	Tod Ridge well No. 1	90	15	—	1,056gr./gall.	—	—	Pm	In quartzite	
104	Yeltacowie .	Andamooka ..	Tod Ridge well No. 2	320	25	25 100 140	950gr./gall. .	400gall./day .	—	Pm	In green and purple quartzite	
105	Yeltacowie .	Andamooka ..	Nick-o-Time bore	97	87	—	1.61oz.	2,000gall./day	—	Q	0-13 Alluvium	
										Pm	13-97 Quartzite	
106	Yeltacowie .	Andamooka ..	Bore No. 6, 13m. ESE. of H.S.	253	247	239	1,196gr./gall.	200gall./day .	Abandoned Position only approximate	Q	0-5 5-18	Red sand and gibbers Brown silt with fragments porcellanite
										Pm	18-253	Brown, purple, buff and grey sandstone
107	Yeltacowie .	Andamooka ..	Bore No. 7, 4m. SE. of No. 106	53	40	52	2,304gr./gall.	200gall./day .	Abandoned. Position only approximate	Pm	0-53	Grey, white quartzite
108	Yeltacowie .	Purple Downs .	Centenary wells .	—	—	—	—	—	Two wells	Pm		In soft white sandstone
109	Yeltacowie .	Purple Downs .	Wilson well	100	50	—	316gr./gall. .	—	—	Pm		In pink sandstone (with purple shale)
110	Yeltacowie .	Arcoona	Horse well	64	60	—	260gr./gall. .	—	—	Pm		In sandstone
111	Yeltacowie .	Arcoona	Giles well	95	60	—	640gr./gall. .	200gall./day .	—	Pm		In pink sandstone-quartzite
112	Yeltacowie .	Arcoona	Bore, 3m. S. of No. 111	150	—	—	Salt	—	—			—
113	Yeltacowie .	Arcoona	Old whip	100	60	—	1,366gr./gall.	300gall./day .	—	Pm		In quartzite
114	Yeltacowie .	Arcoona	Well 2m. ENE. of No. 113	—	—	—	—	—	—	Pm		In purple and white sandstone- quartzite
115	Yeltacowie .	Arcoona	Bore, well 8m. E. of No. 114	150	—	—	—	Very small ..	—			—
116	Murdie	Bosworth	H.S. well	98	—	—	—	—	—			—
117	Murdie	Bosworth	North Bosworth wells	16	—	—	1½oz.	—	Five wells	Q		In alluvium
118	Murdie	Bosworth	White well	100	—	—	—	—	—			—
119	Murdie	Bosworth	Nicholls wells ...	—	—	—	Salt	—	Two wells			—
120	Yeltacowie .	Arcoona	Bore No. 5 (27/4/59)	248	222	228	1,042	—	Drilled in well ..	Pm	0-248	White, grey, red sandstone- quartzite

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks	Log		
				Ft.	Ft.	Ft.					Ft.	
121	Yeltacowie	Arcoona	Bore No. 1 (27/8/5P)	384	352	384	849.....	50 g.p.h. ...	—	Pm	0-384	Purple, brown, cream sandstone-quartzite with thin bands of slate
122A	Eucolo	Arcoona	Mungappie wells	60	50	—	226gr./gall.	250 g.p.h. ..	Two wells			—
122B	Eucolo	Arcoona	—	28	18	—	—	250 g.p.h. ..	—			—
123	Eucolo	Arcoona	Bore 1½m. SW. of No. 122	—	—	—	Salt	—	Abandoned			—
124	Eucolo	Arcoona	Bore 4m. SSW. of No. 123	—	—	—	Salt	—	Abandoned			—
125	Eucolo	Arcoona	Bore No. 2, 11m. NW. Woomera (21/11/58)	348	185	195	Salt	—	Abandoned	Pm	{ 0-280 280-348	Grey sandstone-quartzite Red-brown micaceous shale
126	Eucolo	Arcoona	Freds Swamp ...	126	75	110	1,928gr./gall.	50 g.p.h. ...	Abandoned	Pm	0-126	Green, red shale
127	Eucolo	Arcoona	Paradise well	187	100	—	421gr./gall.	1,200gall./day	—		0-160	Limestone ?
128A	Eucolo	Arcoona	Bore near Paradise well	107	74	95	996gr./gall.	—	—	Pm		In red and white quartzite
128B	Eucolo	Arcoona	Bore near Paradise well	202	65	79 108 164 190	250gr./gall. 289gr./gall. 456gr./gall. 583gr./gall.	—	—	Pm		In red and white quartzite
129A	Eucolo	Arcoona	Phillip Ponds wells	33	2	—	—	500gall./day	Bank of Ponds dam			—
129B	Eucolo	Arcoona	Phillip Ponds wells	14	2	—	215gr./gall.	1,200gall./day	—			—
130A	Eucolo	Arcoona	Phillip Ponds bore	704	4	8 35 150 200	2,046gr./gall.	5,000gall./day	—	Q	0-8	Gravel
										Pm	{ 8-106 106-121 121-220 220-704	Purple and green shales Red sandstone Red-brown shale with thin sandstone Red-brown shale

130a Eucolo Arcoona Woomera No. 1 2,005 — — — — —
 stratigraphic bore

Clarence River
 Basin Oil Co.
 DD. hole

Q	0-10	Quartzite boulders in alluvium
Pm	10-118	Green-purple siltstones occasionally cross-bedded, slumped, and with sedimentary breccias
	118-118½	Shaly sandstone
	118½-138	Finely and rhythmically laminated green and purple siltstones, slumped, cross-bedded, breccias
	138-141	Pink shaly sandstone with sedimentary breccias, slate fragments up to 1½ in. diam.
	141-152	Fine-grained pink silty sandstone
	152-165	Green, purple shaly siltstone with thin sandy beds and sedimentary breccias
	165-177	Green and purple shaly sandstones
	177-182	Purple shales
	182-187	Pink silty sandstone
	187-194	Pink silty sandstone with gritty beds
Ps	194-217	Fine-grained pink sandstone quartzite
	217-236	Brown, purple finely banded siltstones
	236-784½	Purple, brown and green shales with occasional silty bands, generally laminated in alternating green and purple bands, some slump bedding and cross bedding evident
	784½-1,066	Pink-purple grits
	1,066-1,074	White grit with brown shales
	1,074-1,118	White rounded quartz grit, cross bedded. Grey shale at 1,110ft.-1,110ft. 6in.
	1,118-1,122	Grey siltstone breccia
	1,122-1,375	Finely laminated dark grey shaly siltstone
	1,375-1,490	As above with thin light coloured fine grained sandstone bands
	1,490-1,492	White pebbly, felspathic and shaly grit. Chalcopyrite (?) at 1,491ft.
1,492-1,542	White, pink, brown felspathic grits; pebbles up to 1 in.	
1,542-2,002	Purple felspathic grits, few pebbles. Occasional bands of fine grained sandstone	
2,002-2,005	Medium to coarse sandstone-quartzite	

DETAILS OF BORES AND WELLS—*continued*

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water	Salinity	Supply	Remarks		Ft.	Log
					Ft.	Cut						
131A	Eucolo	Arcoona	D.D.H. 21	59	--	--	--	--	At site of ballast quarry	Pm	0-59	Purple brown quartzite
131B	Eucolo	Arcoona	D.D.H. 22	60	--	--	--	--	At site of ballast quarry	Pm	0-60	Purple brown quartzite
132A	Eucolo	Arcoona	D.D.H. 1	26	--	--	--	--	At site of ballast quarry	Q	0-5	Brown clay
										Pm	5-6½ 6½-10 10-13 13-26	Dense hard quartzite Slate breccia Finely laminated, cross-bedded and slump-bedded siltstone Slate
132B	Eucolo	Arcoona	D.D.H. 13	26	--	--	--	--	--	Q	0-5	Brown clay
										Pm	5-26	Shaly siltstone
132C	Eucolo	Arcoona	D.D.H. 14	26	--	--	--	--	--	Q	0-3	Brown clay
										Pm	3-5 5-10 10-26	Limonite and ferruginous quartzite Quartzite Grey-green shale
132D	Eucolo	Arcoona	D.D.H. 15	26	--	--	--	--	--	Q	0-5	Brown clay
										Pm	5-6 6-8½ 8½-12 12-26	Quartzite Shale Ferruginous quartzite Micaceous siltstone
132E	Eucolo	Arcoona	D.D.H. 16	31	--	--	--	--	--	Q	0-4½	Brown clay
										Pm	4½-11½ 11½-31	Quartzite Shale
133	Eucolo	Arcoona	D.D.H. 2	49	--	--	--	--	On ironstone bluff	Pm	0-22 22-32 32-49	Ironstone; limonite and hematite breccia Quartzite Slate
134A	Eucolo	Arcoona	D.D.H. 17	20	--	--	--	--	--	Pm	0-20	Purple and green shale and fine micaceous siltstone
134B	Eucolo	Arcoona	D.D.H. 18	20	--	--	--	--	--	Pm	0-20	Purple, green shales and micaceous siltstone
134C	Eucolo	Arcoona	D.D.H. 19	22	--	--	--	--	--	Pm	0-22	Purple and green shales and micaceous siltstone
134D	Eucolo	Arcoona	D.D.H. 20	20	--	--	--	--	--	Pm	0-20	Purple and green shales and micaceous siltstone
135A	Eucolo	Arcoona	D.D.H. 3	32	--	--	--	--	--	Pm	0-32	Quartzite

135B	Eucolo	Arcoona	D.D.H. 4	29½	—	—	—	—	—	Pm	0-29½	Quartzite
135C	Eucolo	Arcoona	D.D.H. 5	29	—	—	—	—	—	Pm	0-29	Quartzite
135D	Eucolo	Arcoona	D.D.H. 6	29	—	—	—	—	—	Pm	0-29	Quartzite
135E	Eucolo	Arcoona	D.D.H. 9	26	—	—	—	—	—	Pm	0-26	Quartzite with occasional purple shale partings
135F	Eucolo	Arcoona	D.D.H. 10	30	—	—	—	—	—	Q	0-4½	Brown clay
										Pm	4½-30	Quartzite
135G	Eucolo	Arcoona	D.D.H. 11	31	—	—	—	—	—	Q	0-10	Brown clay
										Pm	10-31	Quartzite
135H	Eucolo	Arcoona	D.D.H. 12	30	—	—	—	—	—	Q	0-5	Brown clay
										Pm	5-30	Quartzite
136A	Eucolo	Arcoona	D.D.H. 7	23	—	—	—	—	Near Lake Richardson	Pm	0-23	Quartzite
136B	Eucolo	Arcoona	D.D.H. 8	22½	—	—	—	—	Near Lake Richardson	Pm	0-22½	Quartzite
137	Eucolo	Arcoona	Bore 2m. NW. of No. 136 (Bore 4, 17/2/59)	234	53	90 234	1,010gr./gall.	—	Abandoned	Pm	0-234	White, brown sandstone-quartzite
138	Eucolo	Arcoona	Marsella well	180	100	—	2½oz.	1,000gall./day	—	—	—	—
139	Arcoona	Arcoona	Rocky well	120	90	—	518gr./gall.	500gall./day	—	—	—	—
140	Arcoona	Arcoona	Bluff well	95	65	—	0.85oz.	450gall./day	—	—	—	—
141	Arcoona	Arcoona	Arcoona Lake, bore	150	—	—	Salt	—	Abandoned	—	—	—
142	Arcoona	Arcoona	Arcoona Lake, bore	150	—	—	Salt	—	Abandoned	—	—	—
143	Arcoona	Arcoona	Near Arcoona H.S.	200	—	—	Salt	—	Abandoned	—	—	—
144	Arcoona	Arcoona	Near Arcoona H.S.	200	—	—	Salt	—	Abandoned	—	—	—
145	Arcoona	Arcoona	Engine wells	87	55	81	2.03oz.	300gall./day	—	Pm	—	In white clayey siltstone
146A, B	Arcoona	Arcoona	Two bores near Engine well	150	—	—	Salt	—	Abandoned	—	—	—
147	Arcoona	Arcoona	2m. S. of No. 146	130	—	—	Salt	—	Abandoned	—	—	—
148	Arcoona	Arcoona	1m. SE. of No. 147	150	—	—	Salt	—	Abandoned	—	—	—
149	Arcoona	Arcoona	North Station bore	184	110	—	—	200gall./day	—	—	—	—
150	Arcoona	Arcoona	2m. SE. of No. 49	140	—	—	Salt	—	Abandoned	—	—	—
151	Arcoona	Arcoona	Con Ryan's well	—	—	—	—	—	—	—	—	—
152	Arcoona	Arcoona	Elizabeth well	120	90	106	2.54gr./gall.	2,500gall./day	—	T	—	In gritty ferruginous quartzite, ochre, ironstone

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks	Log		
				Ft.	Ft.	Ft.					Ft.	
153	Arcoona ...	Arcoona	On Elizabeth Creek 10 bores and wells in locality	10-15	—	—	Salt	—	Ten shallow bores and wells, abandoned	Q	In alluvium	
154	Arcoona ...	Arcoona	Bore on Elizabeth Creek	100	—	—	Salt	—	Abandoned		—	
155	Arcoona ...	Arcoona	Old well	—	—	—	—	—	—	Q/Pm	In gravels over brown shale	
156	Arcoona ...	Arcoona	South Bosworth wells	55	35	—	—	300gall./day	Three wells	Pm	In purple, green and white shale	
157	Arcoona ...	Pernatty	Well	80	—	—	2.70oz.	Good	—		—	
158	Arcoona ...	Bosworth	Mulga bore	200	—	—	1.68oz.	5,000gall./day	—		—	
159	Carrapateena	Bosworth	Old well	—	—	—	Salt	—	—		—	
160	Carrapateena	Bosworth	Carrapateena wells	50	—	—	Fresh	—	—	Q	0-50	Sand
				90	25	—	¾oz.	2,000gall./day	Abandoned	covered by drift sand	Q Pm	0-10 10-90
161	Carrapateena	Pernatty	Tadpole well	—	—	—	—	—	—		In quartzite	
162	Parachilna ..	Motpena	Bore 3A Lake Torrens	887	—	—	—	—	5m. E. of Boundary area		See report Johns (1964) for details	
163	Bernard.....	Arcoona	C.A.R. Pimba ..	306	207	255	Salt	—	Two drainage bores	Q	0-8	Sandy clays
										Pm	8-201 201-306	Brown, grey, yellow sandstone-quartzite Purple shales with thin sandy bands
164	Bernard.....	Arcoona	Old well	—	—	—	—	—	—	Pm	In purple and green shale	
165	Bernard.....	Arcoona	White well	—	—	—	—	Small	—	Pm	In white siltstone	
166	Bernard.....	Arcoona	Four bores, Island Lagoon, deep space tracking station	35	—	—	—	—	Foundation bores		0-2	Red-brown sandy clay with gibbers
										Q	2-4	Red-brown sand and gypseous clays
											4-24	Quartzite scree with interstitial clays
										Pm	24-35	Purple, brown, yellow, white silty sandstone
167	Bernard.....	Arcoona	Collimation Tower, Island Lagoon	29	—	—	—	—	Foundation bore.	Q	0-9	Red-brown sandy clay with gibbers
										Pm	9-29	White and grey quartzite

168	Bernard	Arcoona	Bore in well	178	—	—	Salt	—	—	Pm	In sandstone
169	Bernard	Arcoona	The Pines well and bore	190	—	—	491gr./gall.	4,500gall./day	—		—
170	Windabout	Arcoona	Welcome well	60	40	—	—	2,000gall./day	—		—
171	Windabout	Pernatty	Y.M.G. wells	33	33	—	—	Small	—	Q/Ps	In clay over gritty sandstone
172	Windabout	Pernatty	Youngs well	90	—	—	—	—	—		—
173	Windabout	Pernatty	Brennans shaft, Mount Gunson	50	—	—	—	—	—	Ps	{ 0-32 32-50 Red sandstone Dolomite
174	Windabout	Oakden Hills	Old Oakden Hills H.S. (1884)	100	23	—	29gr./gall.	5,000gall./day	Drives at 35ft.		—
175	Windabout	Oakden Hills	Bellamys Govt. well	80	70	—	35gr./gall.	—	—	Q	0-50 Sand and clay
										Ps	50-80 Yellow sandstone
176	Windabout	Oakden Hills	Bellamys wells	75	45	—	131gr./gall.	8,000gall./day	Three wells connected with 49ft. drives		—
177	Windabout	Pernatty	Burgess well	35	29	—	2½oz.	—	—	Pm	In quartzite
178	Windabout	Pernatty	Bonney Bluff well	—	—	—	Salt	—	—	Pm	In purple shales
179	Windabout	Pernatty	Yeltacowie well	60	40	—	Salt	—	—	Pm	In purple and white shales
180	Windabout	Pernatty	Yeltacowie H.S. well	25	—	—	Fresh	—	Two wells		—
181	Windabout	Pernatty	Bore, 1½m. N. of No. 180	150	—	—	—	—	Dry	Pm	In slate
182	Windabout	Pernatty	Horse wells	—	—	—	—	—	Four wells	Pm	In white clayey sandstone
183	Windabout	Pernatty	Wells, 2m. NW. of Pernatty H.S.	—	—	—	—	—	Two wells		—
184	Windabout	Pernatty	Pernatty H.S. wells	50	—	—	—	—	—		—
185A	Windabout	Pernatty	Sells bore	80	—	—	1,180gr./gall	—	—		—
185	Woodforde	Pernatty	Old bore, 1m. SW. Hatch Hill	600	125	—	Salt	—	—	Q	0-10 Red clay
										Pm	10-600 Purple, brown shales
186	Woodforde	Pernatty	Old well near Woolshed	—	—	—	—	—	—		—
187	Woodforde	Pernatty	Hard well	—	—	—	—	—	—		—
188	Woodforde	Pernatty	The Woodforde wells	55	—	—	—	—	Two wells		—
189	Woodforde	Pernatty	Old well, 3m. N. of No. 188	—	—	—	—	—	—		—
190	Woodforde	Pernatty	Goodwins well	—	—	—	—	—	—		—
191	Oakden	Mahanewo	Thomas bore	36	27	—	—	—	—		—

DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks		Log
				Ft.	Ft.	Ft.					
192	Oakden	Yalymboo	Martharinga wells	15	—	—	1.54oz.	500gall./day .	Three wells	Q	In alluvium
				18	—	—	0.03oz.				
				23	—	—	0.85oz.				
193	Oakden	Yalymboo	Old bore	80	—	—	Salt	—	Abandoned		—
194	Oakden	Oakden Hills .	Lemmys well	30	20	—	Fresh	200gall./day .	—		—
195	Oakden	Oakden Hills .	Old bore	—	—	—	Salt	—	Abandoned		—
196	Oakden	Oakden Hills .	Old well	—	—	—	—	—	—	Pm	In purple siltstone and slate
197	Pernatty	Oakden Hills .	Bywater well	—	—	—	—	—	—	Pm	In purple shale
198	Pernatty	Oakden Hills .	Station wells, North	80	40	—	56.1gr./gall. .	2,000gall./day	Drives at 70ft. ..		—
				80	40	—	93gr./gall. ..	2,000gall./day	60ft. drives at 70ft.		—
				80	40	—	90gr./gall. ..	2,000gall./day	60ft. drives at 70ft.		—
199	Pernatty	Oakden Hills .	J.R.P. well	—	—	—	—	—	—		—
200	Pernatty	Oakden Hills .	Selby well	—	—	—	—	—	—		—
201	Pernatty	Oakden Hills .	Dog Hollow well.	25	15	—	Fresh	500gall./day .	—		—
202	Pernatty	Oakden Hills .	Flynn's well	—	—	—	—	—	—		—
203	Pernatty	Pernatty	Soakage well	—	—	—	—	—	—		—
204	Pernatty	Pernatty	Government well.	—	—	—	—	—	—		—
205	Pernatty	Oakden Hills ..	Old wells	—	—	—	—	—	Two wells	Q	In gypseous red clays
206	Pernatty	Oakden Hills .	Old bore	—	—	—	Salt	—	—		—
207	Pernatty	Oakden Hills .	Bore	488	—	—	Salt	—	—	Ps	300-488 In dolomite
208	Pernatty	South Gap ...	Soak well	30	—	—	—	—	—	Ps	In sandstone
209	Pandita	Pernatty	Willow wells	85	40	—	126gr./gall. .	200gall./day .	Seven wells connected by drives		—
210	Pandita	Pernatty	Two bores	—	—	—	Salt	—	Abandoned	Pm	In white fine clayey sandstone
211	Pandita	South Gap ...	Old well	—	—	—	—	—	Abandoned	Pm	In white sandy clay
212	Pandita	South Gap ...	Sandstone wells .	20	—	—	—	—	Three wells abandoned	Pm	In sandy shales
213	Pandita	South Gap ...	Old well	—	—	—	—	—	Abandoned	Q/Pm	In gravel over silty shale

214	Pandita	South Gap	Woolshed well	20	15	—	142gr./gall.	2,000gall./day	—	Pm	In white shaly sandstone
215	Pandita	South Gap	Old well	—	—	—	—	—	—	—	—
216	Pandita	Pernatty	North Tiffin wells	180	—	—	Salt	—	Dry	Pm	In purple shale
				150	—	—	Fresh	—	Two wells	Pm	In hard quartzite
217	Pandita	South Gap	South Tiffin wells	70	—	—	Good	Poor	Four wells connected by drives	Pm	In sandstone
218	Pandita	South Gap	Blackfellows well	—	—	—	—	—	Dry	—	—
219	Pandita	South Gap	South Gap H.S. well	30	20	—	Fresh	—	—	—	—
220	Pandita	South Gap	Yeings well	70	—	—	Stock	1,500gall./day	—	Pm	In quartzite
221	Pandita	South Gap	Old well	—	—	—	—	—	—	Pm	In siltstone
222	Pandita	South Gap	Beare well	—	—	—	—	—	Shallow soak	—	—
223	Pandita	Lake Torrens	Five mile bore	270	20	—	362gr./gall.	—	Formerly flowed	—	—
224	Pandita	Lake Torrens	Artesian bore	227	3	—	615gr./gall.	—	—	—	—
225	Pandita	Lake Torrens	Willows bore	222	Flows	—	607gr./gall.	—	—	—	—
226	Pandita	Lake Torrens	Spring bore	280	—	—	Salt	—	—	T/Pm	Penetrated light-green friable Precambrian claystone under dark-grey Tertiary claystone
227	Pandita	Lake Torrens	Jeffs bore	212	50	—	552gr./gall.	—	—	—	—
227A	Pandita	Lake Torrens	Bore, 7m. SW. of Willows bore	—	—	—	—	—	—	T/Pm	Penetrated light-grey finely crystalline sandy dolomitic limestone under Tertiaries
228	MacFarlane	Yalymboo	Lakeside wells	20	—	—	—	—	Two wells	Q	In gypseous grit
229	MacFarlane	Yalymboo	Old well, Yalymboo H.S.	—	—	—	—	—	Dry	—	—
230	MacFarlane	Yudnapinna	Wells	—	—	—	—	—	Three wells	Ps	In sandstone
231	MacFarlane	Yudnapinna	Bowen Hill bore	185	—	8	Salt	—	—	Q	Clay Gravel White sand
					75	185	Salt Salt	—	—	Ps	
232	Bookaloo	Oakden Hills	Well	—	—	—	—	—	—	—	—
233	Bookaloo	Oakden Hills	Windy Valley well	—	—	—	—	—	—	—	—
234	Bookaloo	Oakden Hills	Bothwell well	—	—	—	—	—	—	—	—
235	Bookaloo	Yudnapinna	Trevenna's well	—	—	—	—	—	—	Ps	In purple arkosic sandstones with shales and grit
236	Bookaloo	Yudnapinna	Ram Swamp bore	82	—	—	Salt	—	Abandoned	—	—

-DETAILS OF BORES AND WELLS—continued

No.	Military Sheet	Pastoral Station	Name	Depth	S.W.L.	Water Cut	Salinity	Supply	Remarks	Log					
				Ft.	Ft.	Ft.					Ft.				
237	Bookaloo ...	Yudnapinna ..	Magnacowie wells	—	—	—	—	—	Two wells	Ps	In purple gritty and shaly quartzite				
238	Bookaloo ...	Oakden Hills ..	Old well	—	—	—	—	—	—	—	—				
239	Bookaloo ...	Yudnapinna ..	Old well	—	—	—	0.64oz.	—	—	—	—				
240	Bookaloo ...	Yudnapinna ..	Gibsons Camp well	98	—	—	Salt	Very small ..	—	—	Q	0-20	Yellow sand and gypsum		
				253	Gibsons Camp bore	—	—				17	Stock	Ps	20-98	Yellow sandstone
						—	—				34		Q	0-25	White sandstone
						—	—				73		Ps	{ 25-75 75-253	White sandstone Hard blue rock
241	Bookaloo ...	Yudnapinna ..	Narkanna wells .	39	—	—	236gr./gall. .	8,000gall./day	—	—	—				
242	Bookaloo ...	Yudnapinna ..	Maslins well	—	—	—	—	—	—	—	Q	0-45	Red clays		
												45-58	Sand		
												58-70	Sandy clay with ironstone		
												70-128	Yellow blue and red shales		
243	Bookaloo ...	South Gap ...	Claypan well	128	25	—	Salt	—	—	Ps	In gritty sandstone				
244	Bookaloo ...	South Gap ...	Well	—	—	—	—	—	Dry	—	—				
245	Bookaloo ...	South Gap ...	Four mile wells .	30	—	—	Stock	Good	—	—	—				
246	Bookaloo ...	Yudnapinna ..	Beda bore	1,099½	146	—	3oz.	—	150ft. above sea level	—	Q	0-8	Gypseous clay		
												8-12	Gravel		
												{ 12-281 281-439	Grey sandstone quartzite Dark slates		
												439-1,099½	"Trap" (feldspathized schist?). ("Gawler Range porphyry"?)		
247	Bookaloo	Yudnapinna ..	Kootaberra H.S. well	—	—	—	—	—	—	Ps	In feldspathic sandstone, pebbly siltstone				
248	Yadlamalka	Yudnapinna ..	Well	—	—	—	—	—	—	—	—				
249	Yadlamalka	Yudnapinna ..	Well	—	—	—	—	—	Dry	—	—				
250	Yadlamalka	Yudnapinna ..	Beda Hillbore ..	264	—	137 160	6oz.	—	—	Pm	In purple and green shale				

251	Yadlamalka	Yudnapinna ..	Beda Hill well ...	90	—	—	—	—	Dry	Q	0-50	Sand
										Pm	50-90	Red shale
252	Yadlamalka	Yudnapinna ..	Well.....	—	—	—	—	—	—			—
253	Yadlamalka	Yadlamulka ..	Well.....	—	—	—	—	—	—			—
254	Yadlamalka	Yadlamulka ..	Poison bore	215	—	—	905gr./gall. .	—	—			—
255	Yadlamalka	Yadlamulka ..	Nancy well	—	—	—	—	—	—			—
256	Yadlamalka	Yadlamulka ..	Scrubby well	—	—	—	—	—	—			—
257	Yadlamalka	Warrakimbo ..	Barren well.....	155	37	84 104 134	—	20,000gall./day	—	Q/T	0-152	Sand, clays
										Pm	152-155	Quartzite
258	Yadlamalka	Yadlamalka ..	Swamp wells	—	—	—	—	—	—			—
259	Yadlamalka	Yadlamalka ..	One Gum well ..	—	—	—	—	—	—			—
260	Yadlamalka	Yadlamalka ..	Salt well bore....	72	46	—	59gr./gall. ..	5,000gall./day	—			—

Q = Quaternary
 T = Tertiary
 K = Cretaceous
 P = Permian
 C = Cambrian
 Pm = Upper Proterozoic (Tent Hill Formation)
 Pt = Upper Proterozoic (Torrensian)
 Ps = Upper Proterozoic (Sturtian)

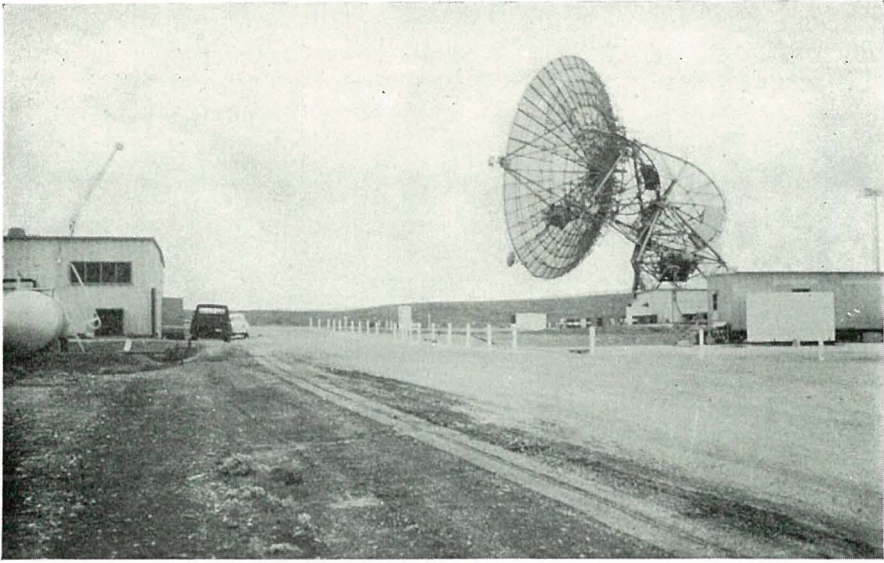


Fig. 1—Deep space instrumentation facility, Island Lagoon

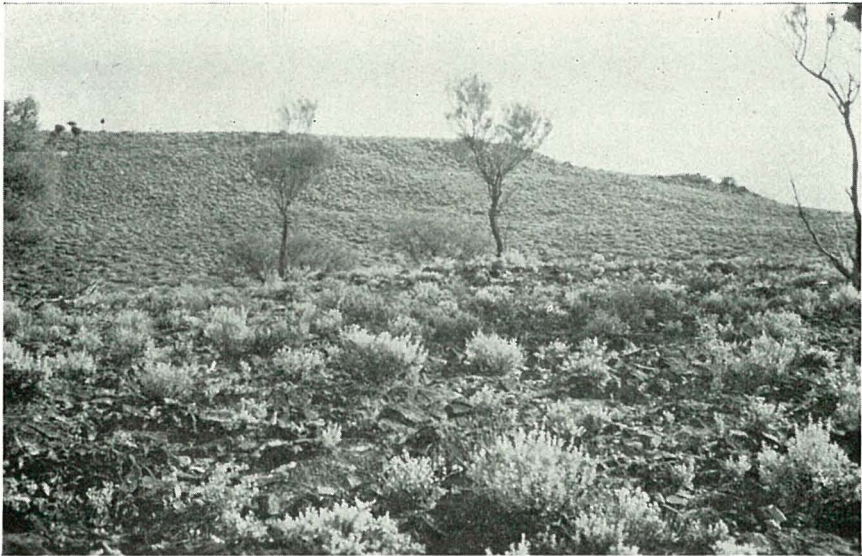


Fig. 2—Saltbush and occasional mulga near South Hill trig. Pernatty Grit on tableland; Woocalla Dolomite in foreground

PLATE II

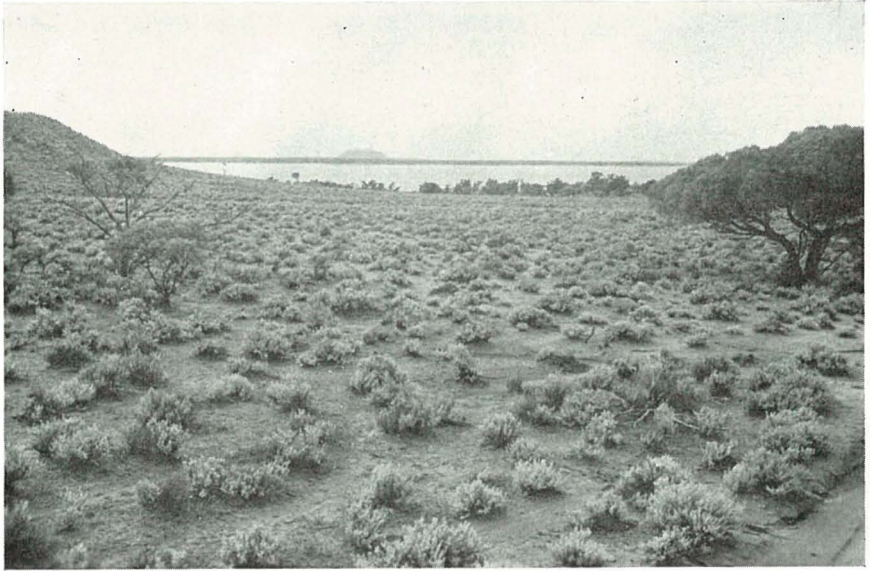


Fig. 1—Bluebush and saltbush with occasional myall on sandy soils near northern margin of Lake Finnis. Oakden Hills are discernible beyond the lake



Fig. 2—Stabilized sand dunes separated by bare claypans. Lake Torrens in distance



Fig. 1—Aerial view of surface of Lake Torrens

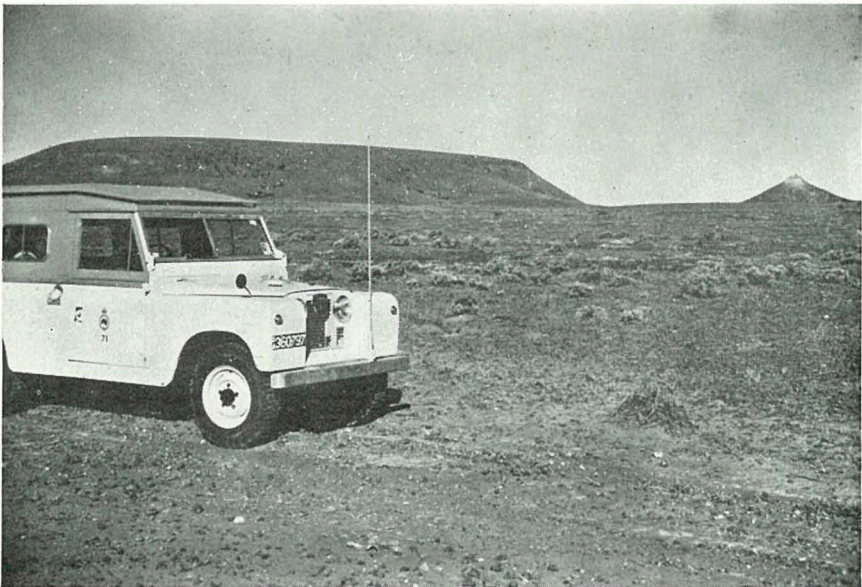


Fig. 2—Emu Bluff (left) and Bottle Hill, Dissected upper members of Tent Hill Formation

PLATE IV

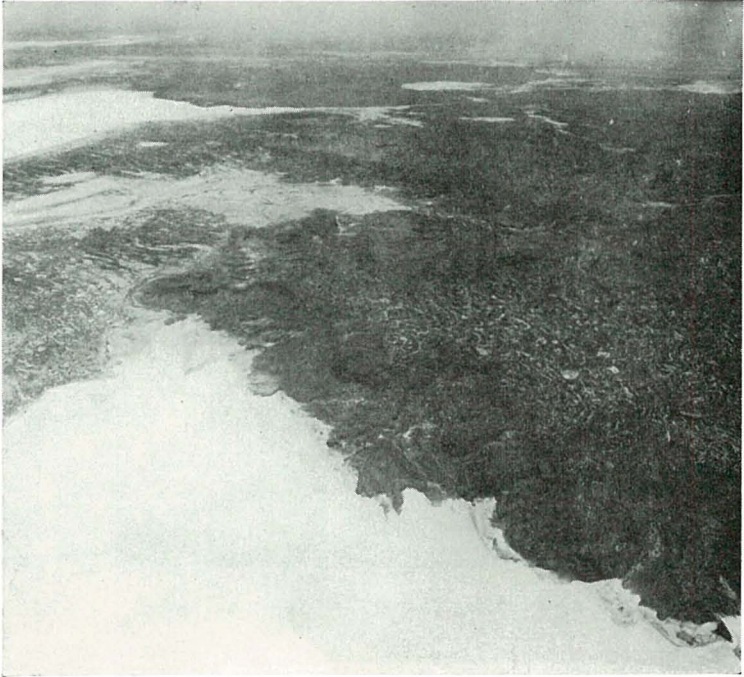


Fig. 1—Aerial photo., looking along north shore of Island Lagoon to Lake Hart. Arcoona Quartzite Member caps tableland. Note gilgai shelves on Arcoona Plateau surface



Fig. 2—Sand plain marginal to Arcoona Plateau. Arcoona H.S. in foreground



Fig. 1—Looking beyond South Gap from Beda Arm. Note restriction of trees to drainage channels and escarpment of the Arcoona tableland and to the marginal sand plain. Pernatty Lagoon at upper left; Lake Torrens at upper right

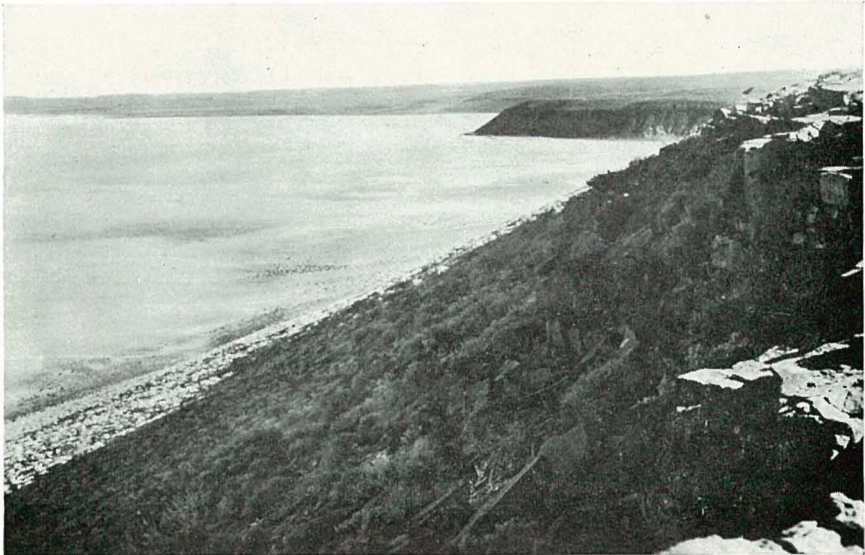


Fig. 2—Escarpment on northern shore of Island Lagoon capped by Arcoona Quartzite Member



Fig. 1—The South Hill Fault and associated drag structures



Fig. 2—Magnesite bed near Coronation Bore, Witchelina

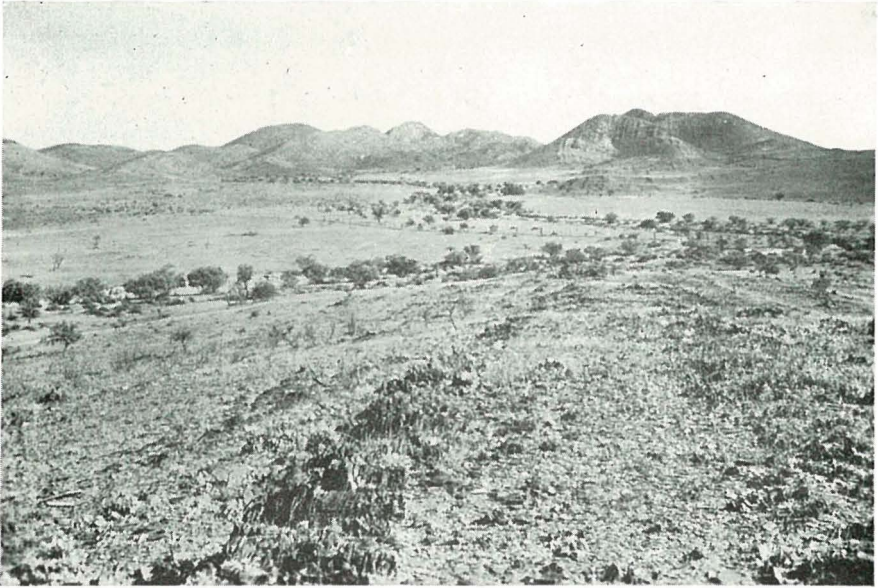


Fig. 1—Slates and sandstones of the Yudnamutana Group strike towards Mount Nor'West, Witchelina



Fig. 2—Outcrops of Pernatty Grit, northern margin of Lake Finnis, Yalymboo

PLATE VIII



Fig. 1—Pernatty Grit cross beds near Whittata H.S.

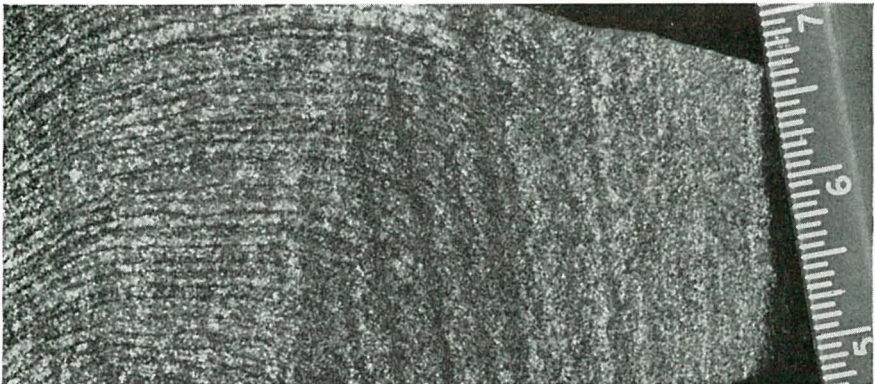


Fig. 2—Pernatty Grit—concentric bands of iron oxide cut bedding at right angles

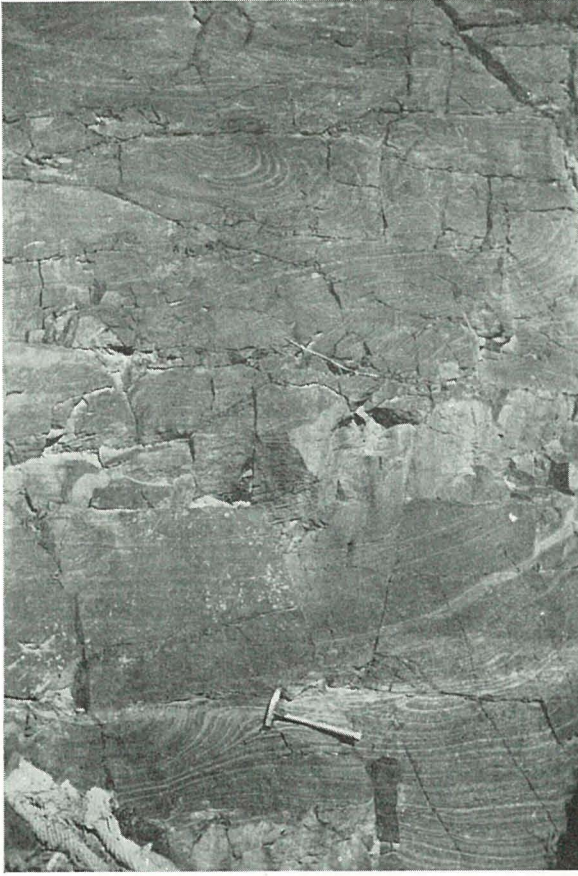


Fig. 1—Pernatty Grit—Ballast quarry, Woocalla

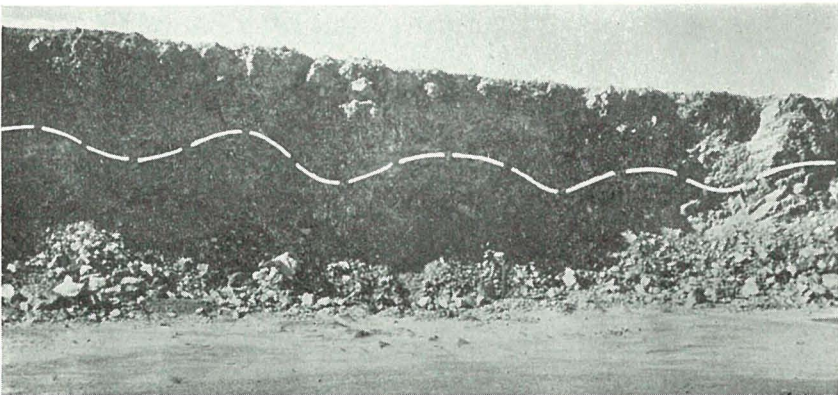


Fig. 2—Woocalla Dolomite Member exposed in Lallast quarry, Woocalla

PLATE X

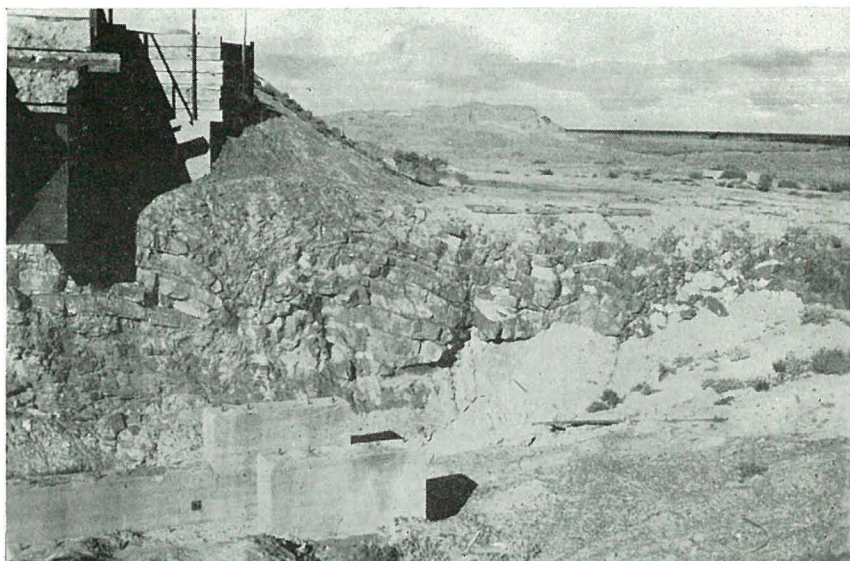


Fig. 1—Disconformable contact between Pernatty Grit (beyond concrete block) and contorted dolomite—Woocalla ballast quarry



Fig. 2—Ripple marked dolomite, Woocalla



Fig. 1—Woomera Shale Member, Magazine Hill



Fig. 2—Flagstones of the Tent Hill Formation, Willaroo Lagoon, Andamooka

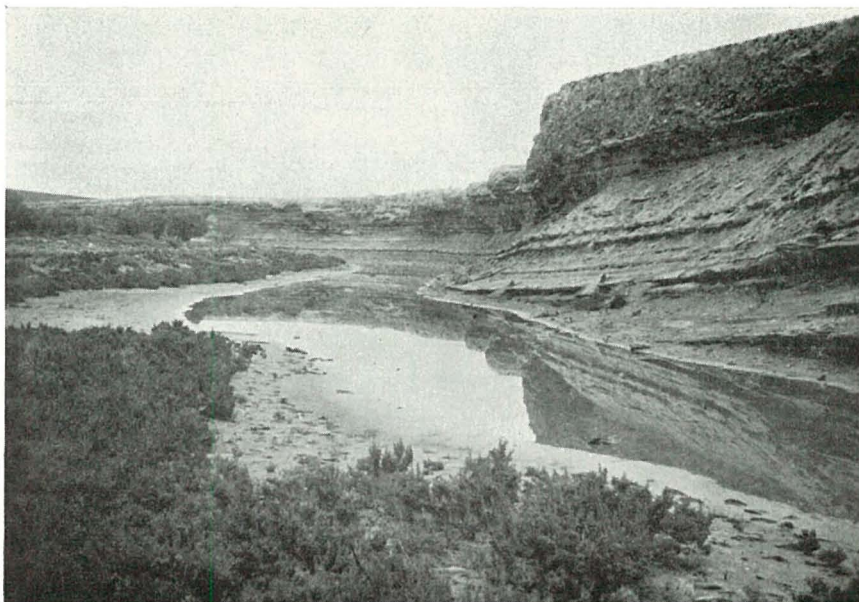


Fig. 1—Gently undulating green and purple shales, Shell Lagoon

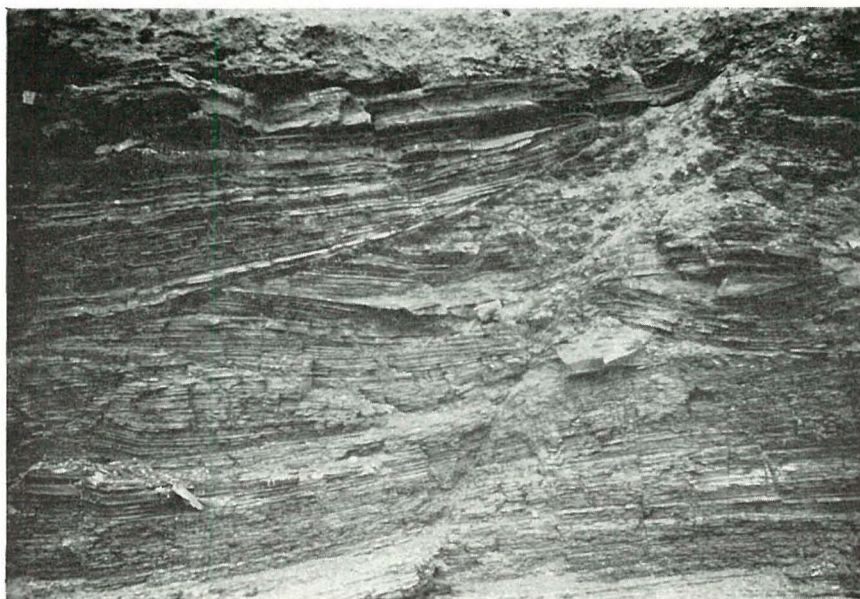


Fig. 2—Cross-bedded brown shales and siltstones on Salt Creek, Pernatty.
(Section approximately 12ft.)



Fig. 1—Load-cast sole of ripple-marked calcareous siltstone, Willaroo Lagoon

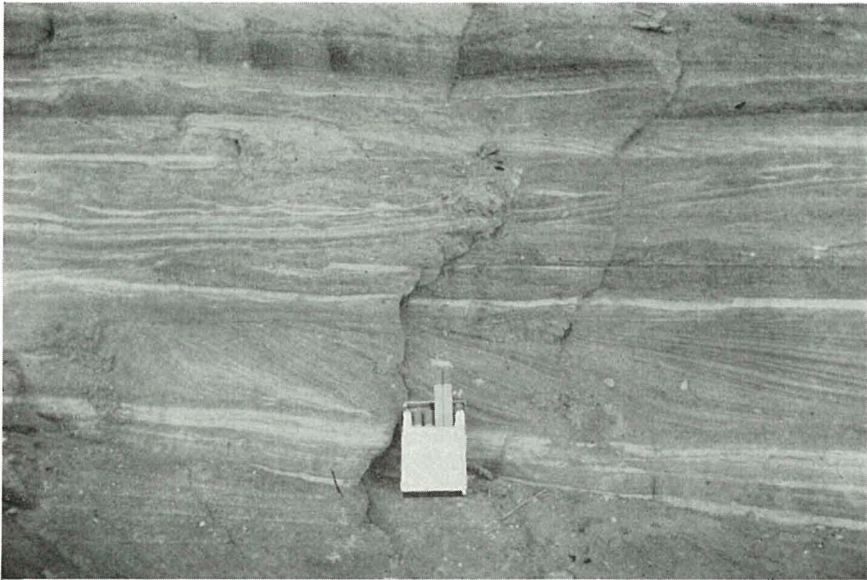


Fig. 2—Cross-bedded sandstones with clay partings, Island Lagoon

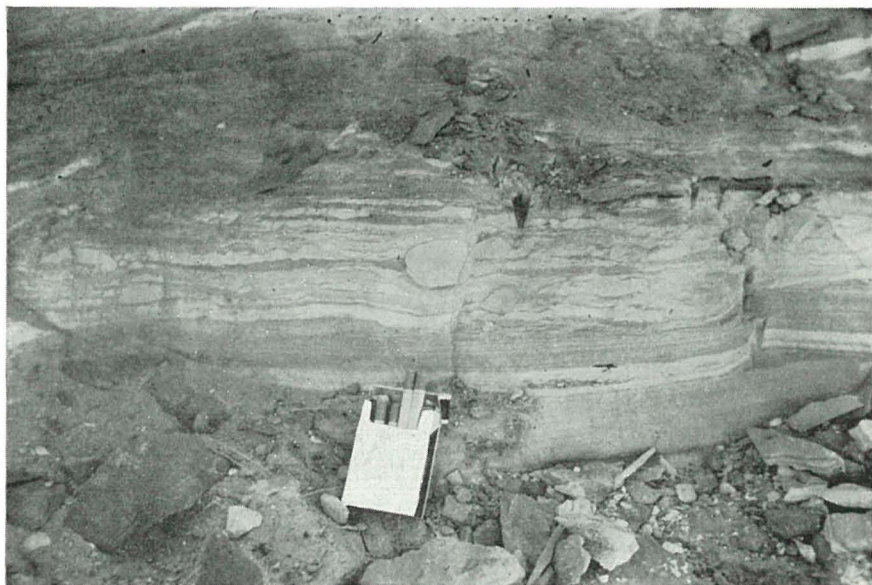


Fig. 1—Sandstones with clay lenses and intraformational breccias, Island Lagoon

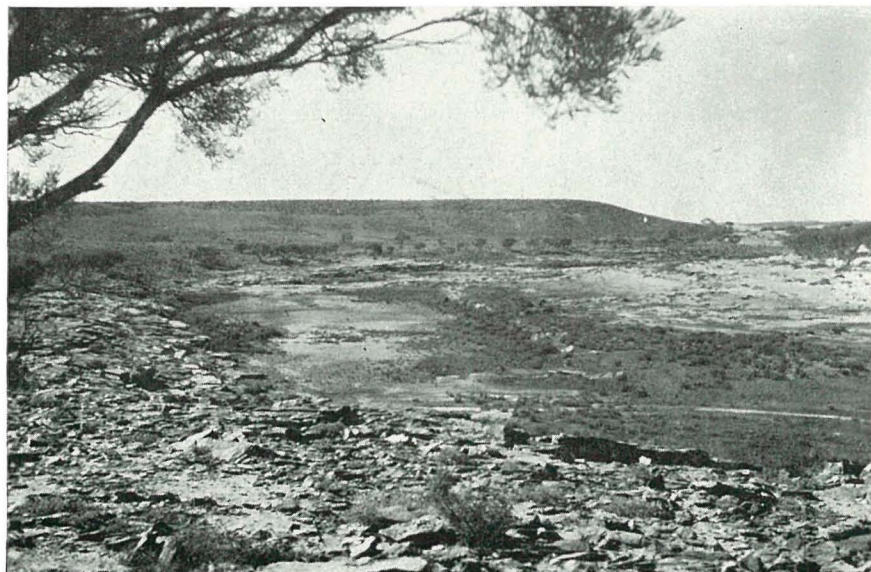


Fig. 2—Arcoona Quartzite Member, western shore of Lake Richardson

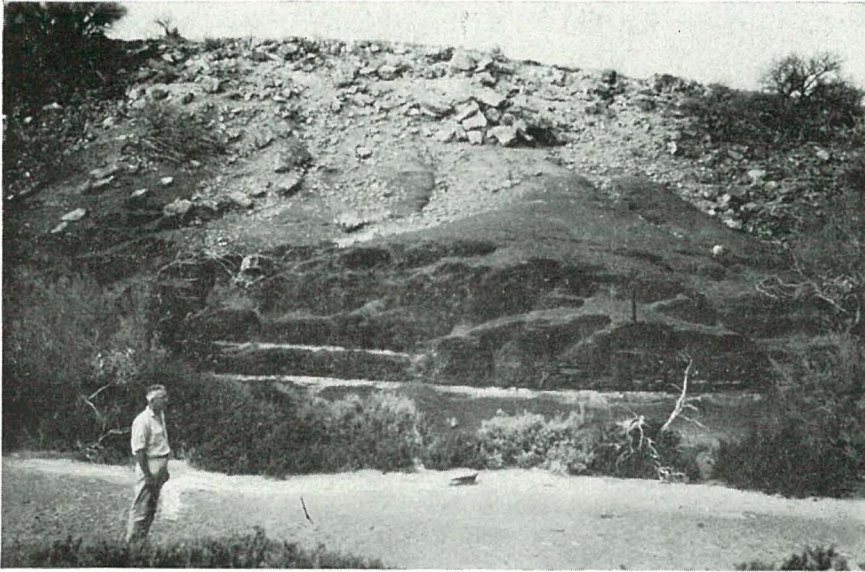


Fig. 1—Yarloo Shale, overlapped by Andamooka Limestone, Tea Tree Creek

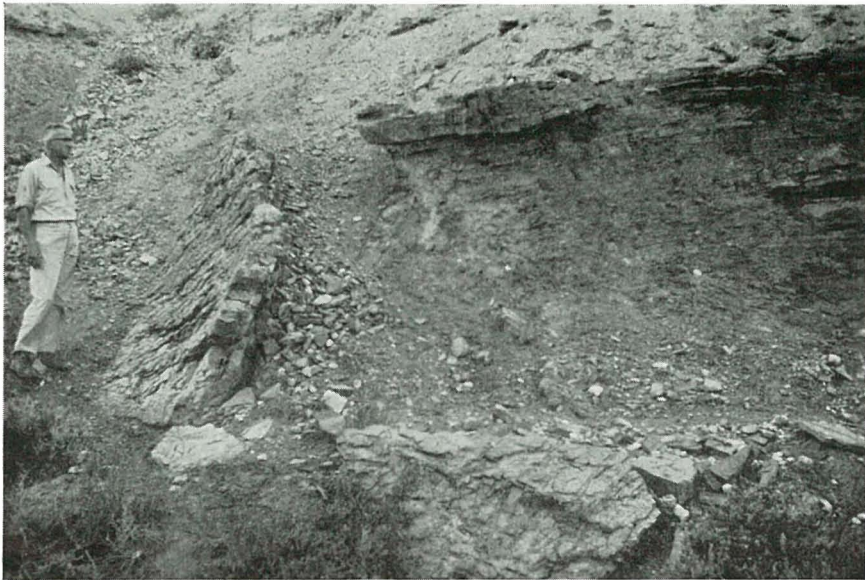


Fig. 2—Faulting in shales with quartzites, Trig Creek

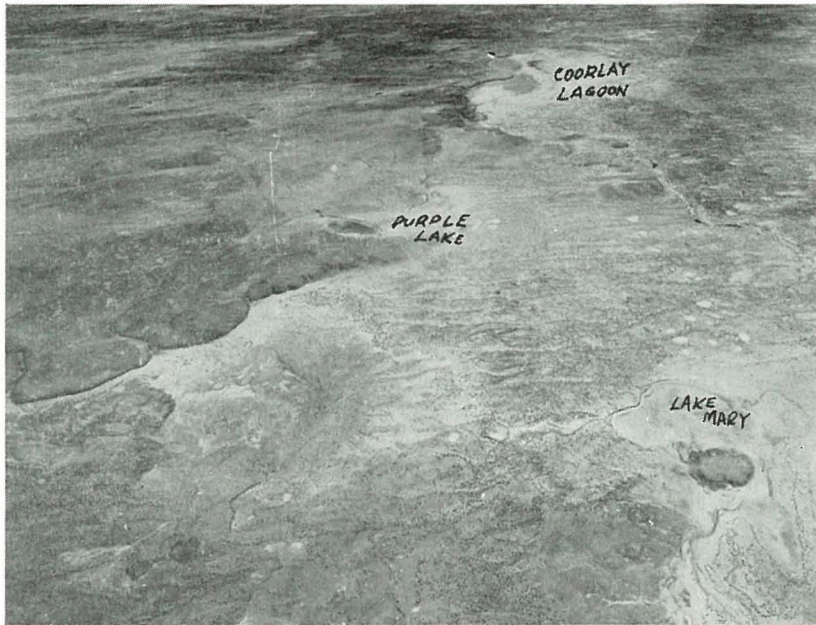


Fig. 1—Aerial photo. showing the base of the Cambrian in the Purple Downs locality

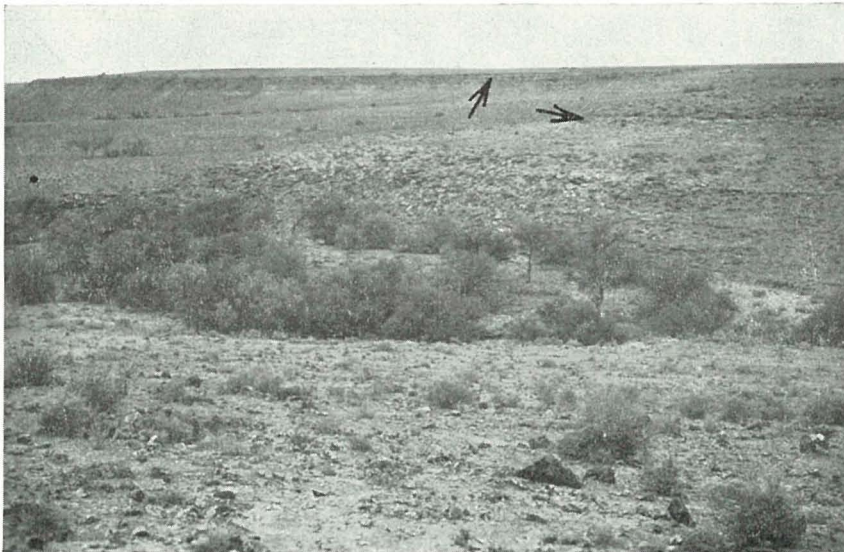


Fig. 2—The base of Andamooka Limestone (marked by arrows)—Coorlay Lagoon



Fig. 1—The base of Andamooka Limestone (marked by arrows)—Purple Lake

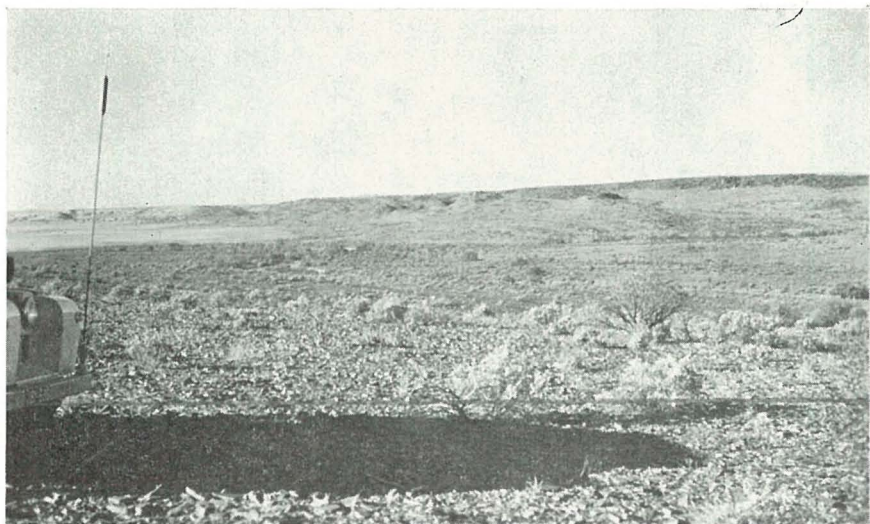


Fig. 2—Andamooka Limestone, Lake Arthur. A.B.C. Range Quartzite in foreground is truncated by an overthrust fault which coincides with near creek channel

PLATE XVIII

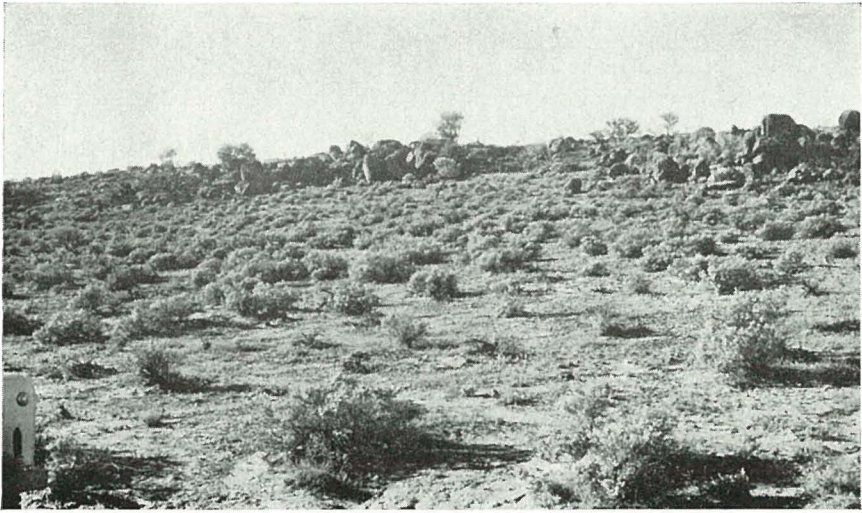


Fig. 1—Massive Andamooka Limestone near northern extremity of Lake Torrens

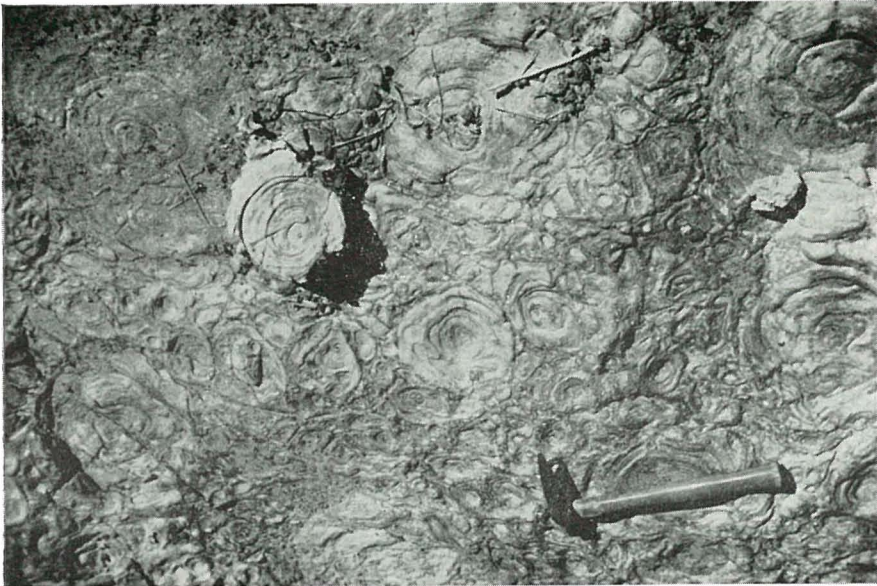


Fig. 2—Algal colony near top of Andamooka Limestone, north end of Lake Torrens

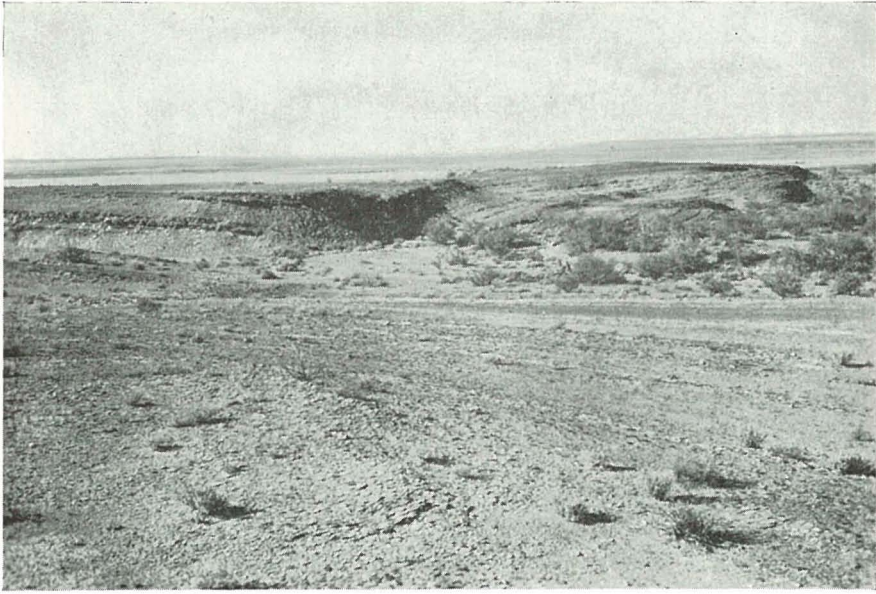


Fig. 1—Gently undulating Yarrowurta Shale, northern shore of Lake Torrens



Fig. 2—Ferruginous sandstone, Willaroo Lagoon bore

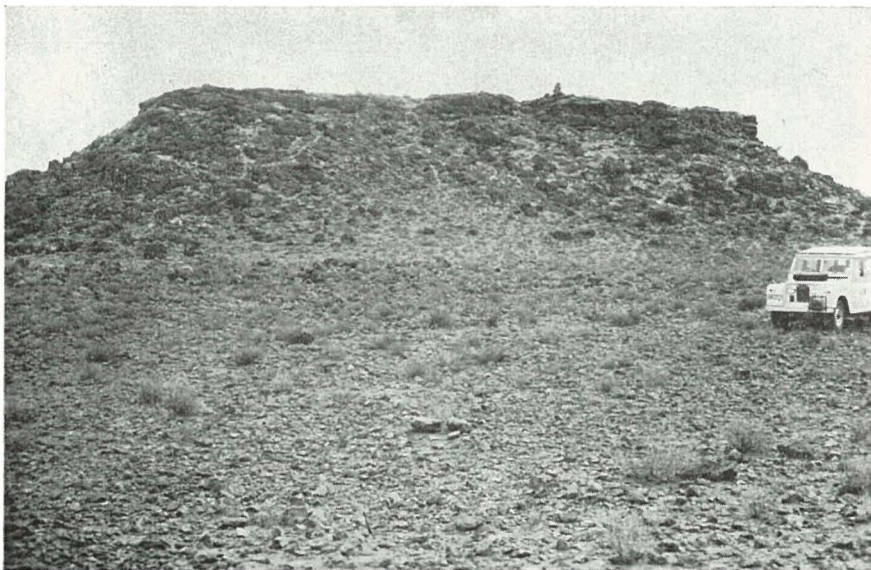


Fig. 1—The Pile, near West Mount Hut, Witchelina



Fig. 2—Rounded and faceted boulders derived from Marree Formation equivalent, near Andamooka H.S.

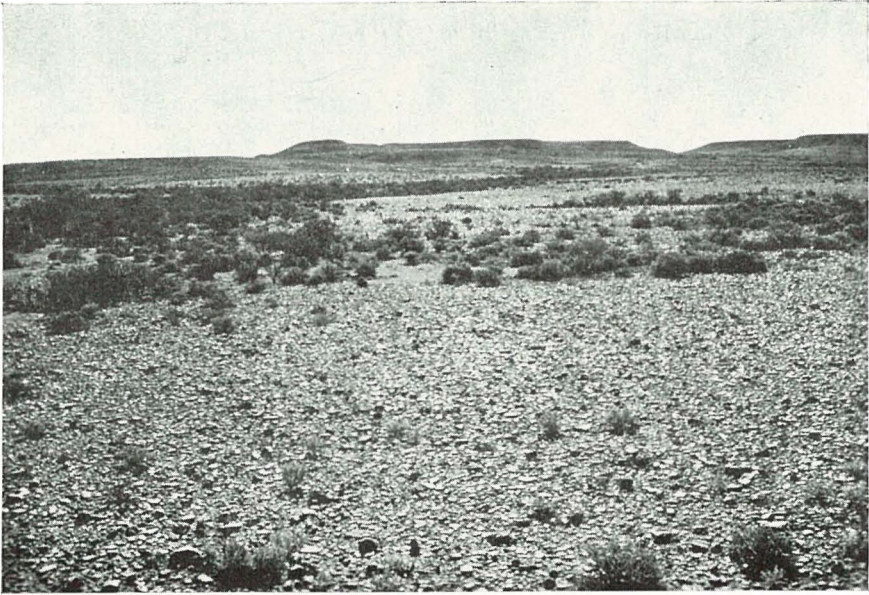


Fig. 1—Yarrowurta Cliff. Dissected tablelands of Cretaceous siltstones, etc., capped by duricrust and resting unconformably on Yarrowurta Shale

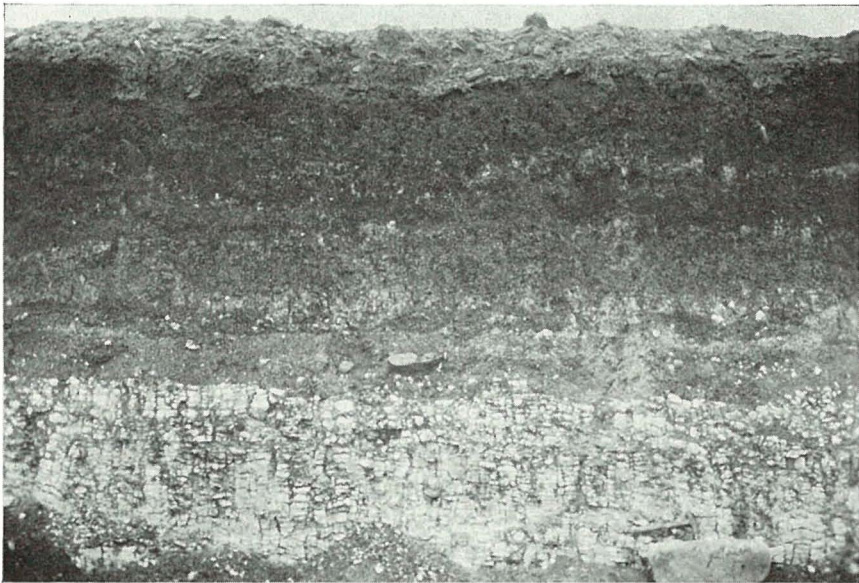


Fig. 2—Siltstones bearing faceted quartzite boulders, overlain by red clays and clay with gibbers at the surface; quarry near Bernard Hill



Fig. 1—Quartzite with fossil leaves, near Woomera

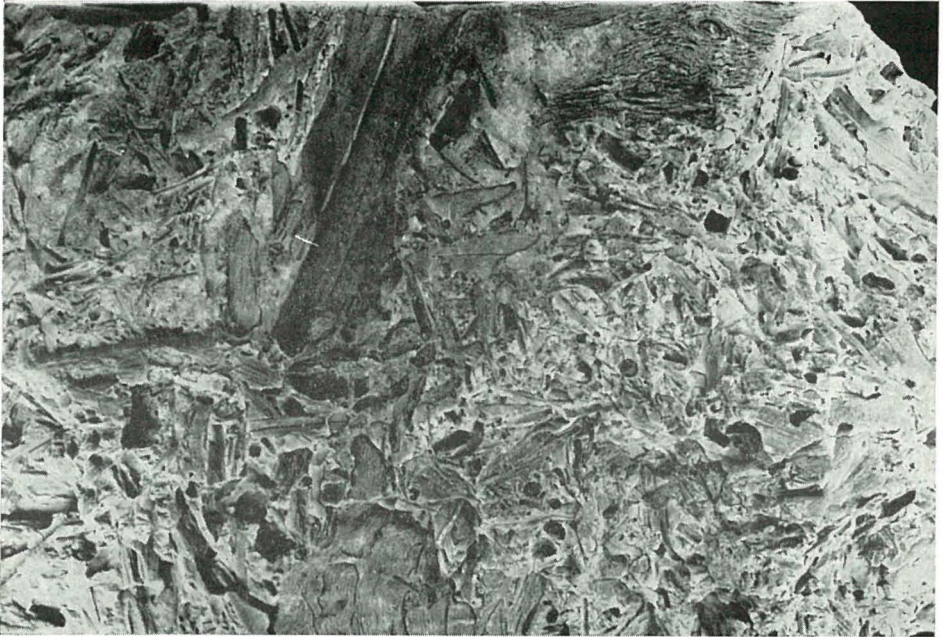


Fig. 2—Quartzite crowded with fossil leaves and fragments of tree trunks, near Woomera

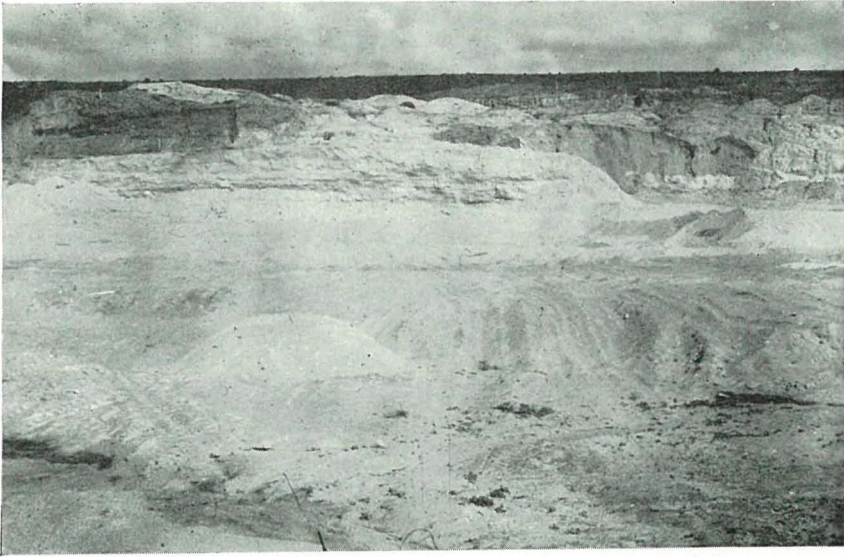


Fig. 1—Mungappie sand pit



Fig. 2—Fossil stream channel near Bernard Hill



Fig. 1—Quartzite boulder conglomerate, near Bernard Hill



Fig. 2—Contorted quartzites of the Tent Hill Formation veneered by Tertiary gravels, grits and sands (background), near Lake Torrens, north of Andamooka Creek

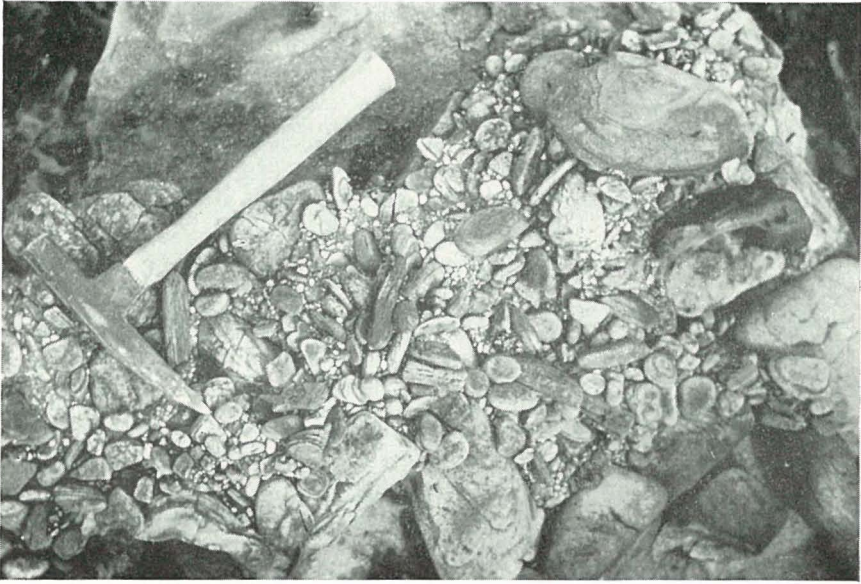


Fig. 1—Tertiary boulder beds and grits (see plate XXIV, fig. 2)



Fig. 2—Aerial photo., looking northerly along trend of older dune system, Billa Killina. Note control on alignment of claypans and superposition of younger dunes



Fig. 1—Aerial photo., looking northerly over Arcoona Plateau. Emu Bluff is in left foreground surrounded by sand dunes

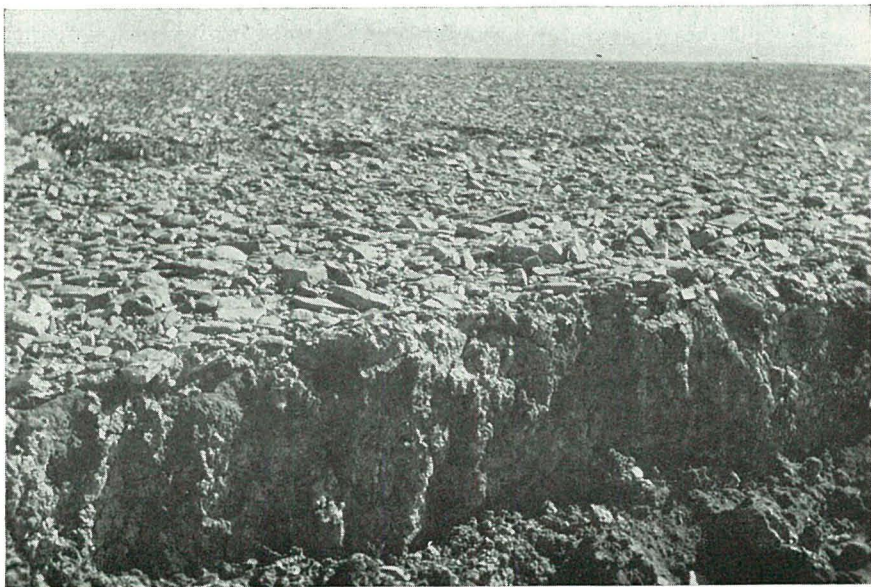


Fig. 2—Quartzite gibbers over red clay, Arcoona



Fig. 1—Aerial photo., looking south over Pernatty Lagoon

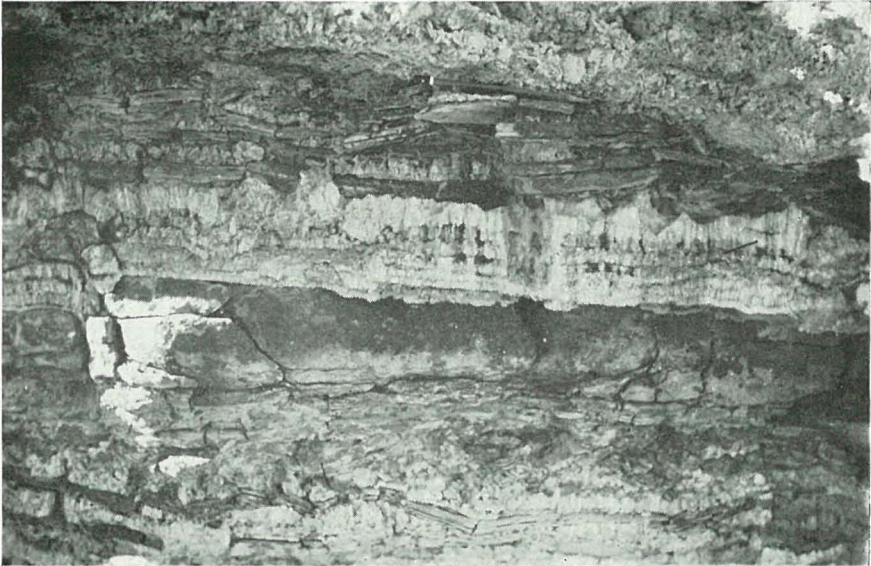


Fig. 2—Gypsum veins in quartzite near Tod Ridge, Andamooka

PLATE XXVIII



Fig. 1—Aerial photo. showing northern extremity of Lake Torrens. Lake Arthur is at centre right. Duricrusted Cretaceous tablelands (dark outcrops in middle distance) mantle Cambrian limestones and shales marginal to the lake

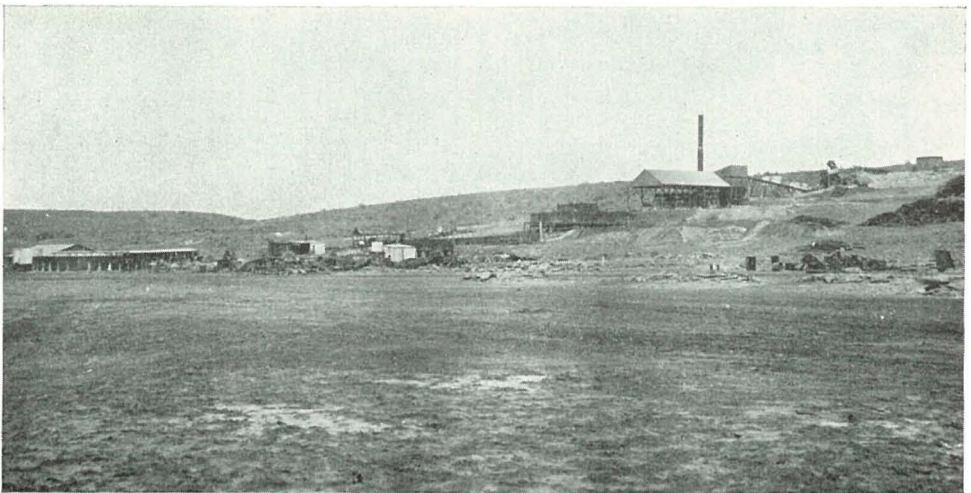


Fig. 2—Leaching plant (1916), Pernatty Lagoon

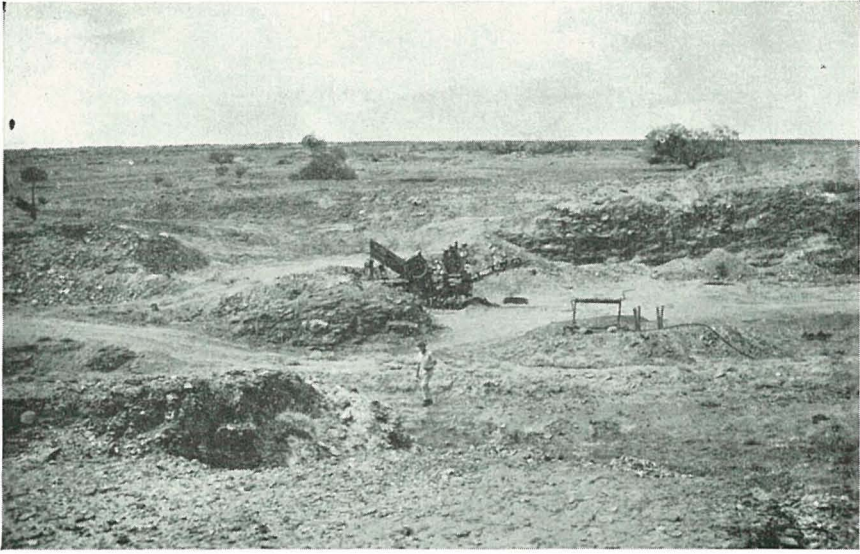


Fig. 1—Main open cut, Mount Gunson

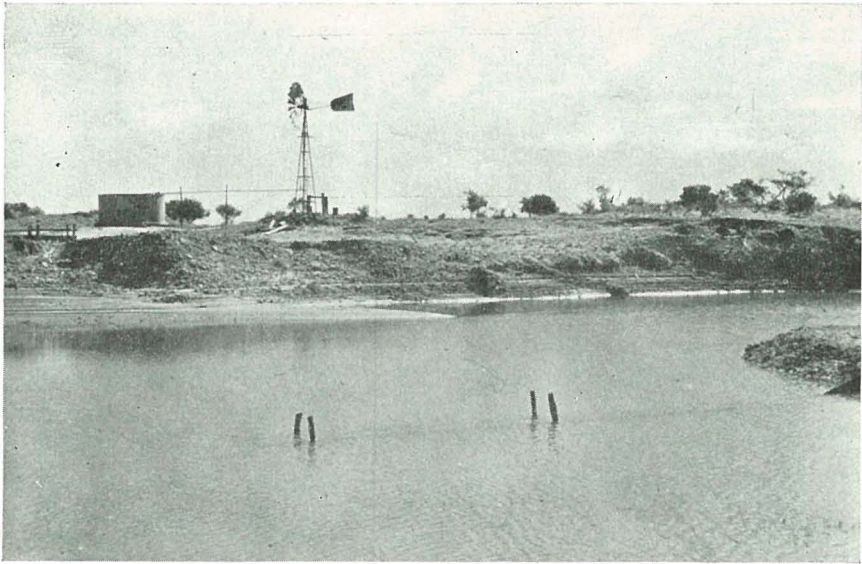


Fig. 2—Main open cut, Mount Gunson

PLATE XXX



Fig. 1—Copper workings on shore of Pernatty Lagoon, east of Mount Gunson H.S.



Fig. 2—Sweet Nell workings, Ironstone Lagoon. Distant tableland capped by dolomite, Pernatty grit in foreground

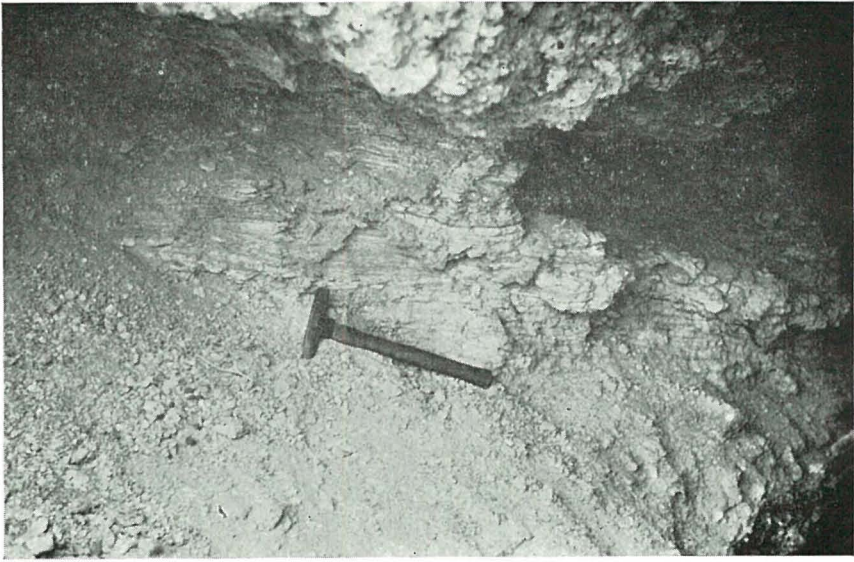


Fig. 1—Cupriferous shale underlying dolomite, Sweet Nell



Fig. 2—Manganese workings, Pernatty Lagoon, looking southwesterly

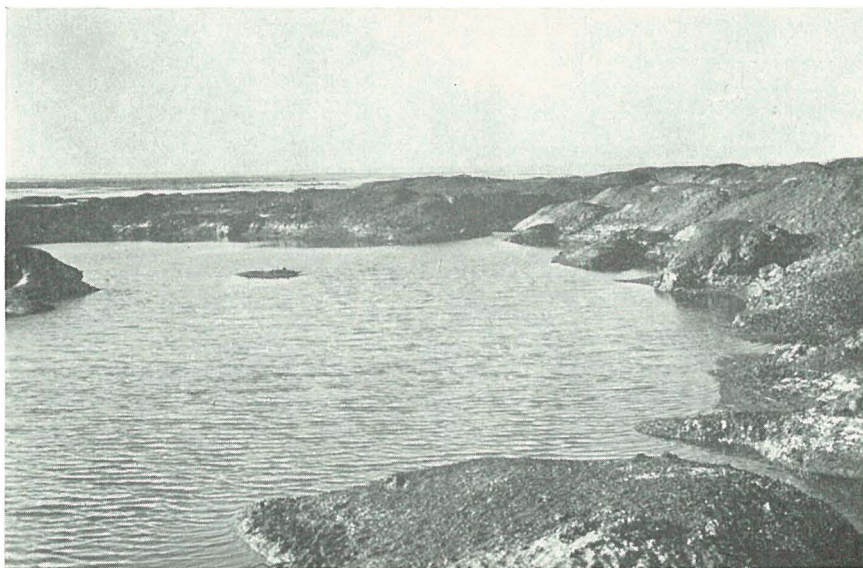


Fig. 1—The Big Quarry, Pernatty Lagoon manganese deposits. Dolomite outcrops in the floor of the lagoon beyond the flooded workings



Fig. 2—Mining operations (1916) at the Big Quarry

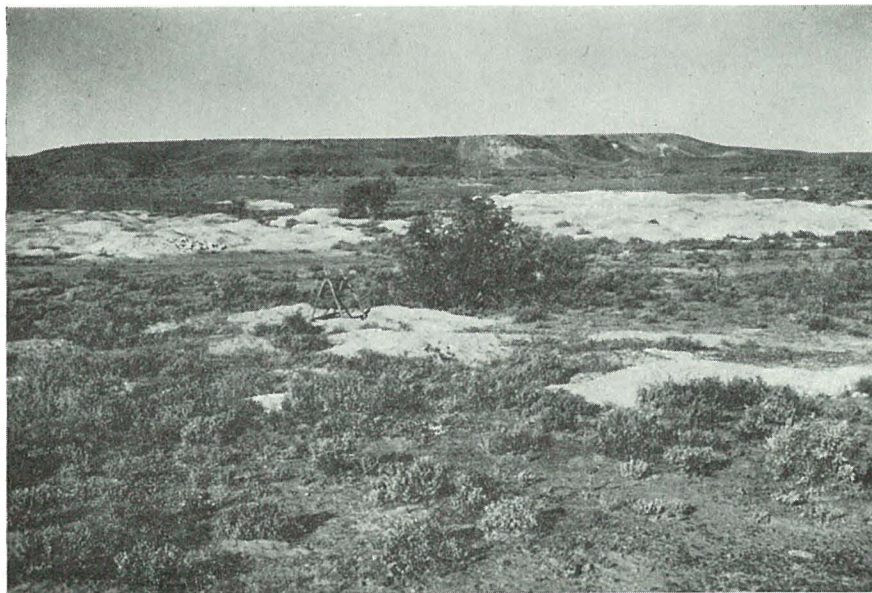


Fig. 1—Opal diggings, Stuart Creek field



Fig. 2—Aerial view of part of Andamooka township and opalfield looking towards Treloar Hill

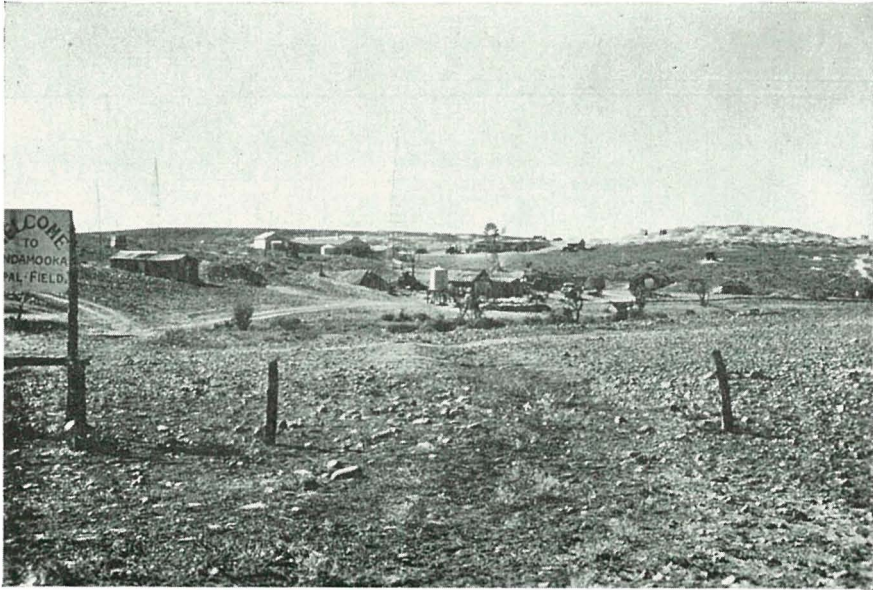


Fig. 1—Opal Creek, Andamooka Opalfield

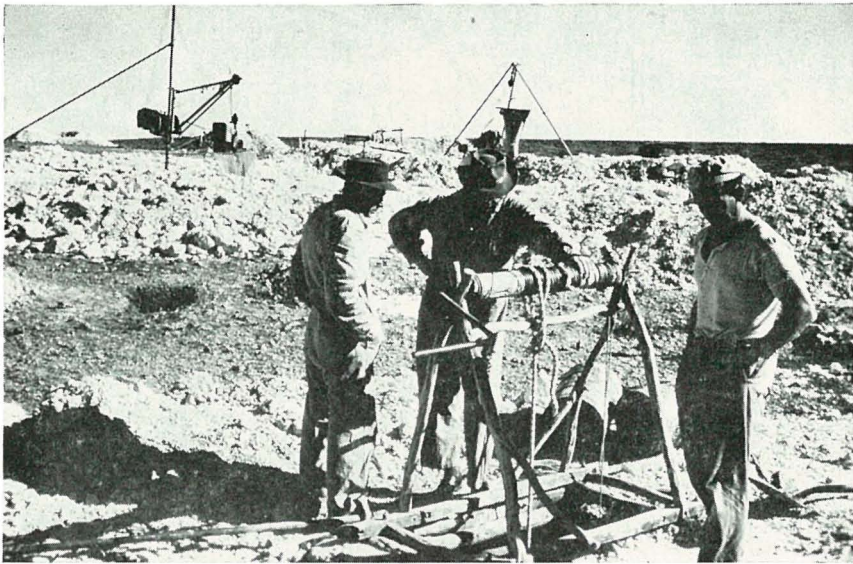
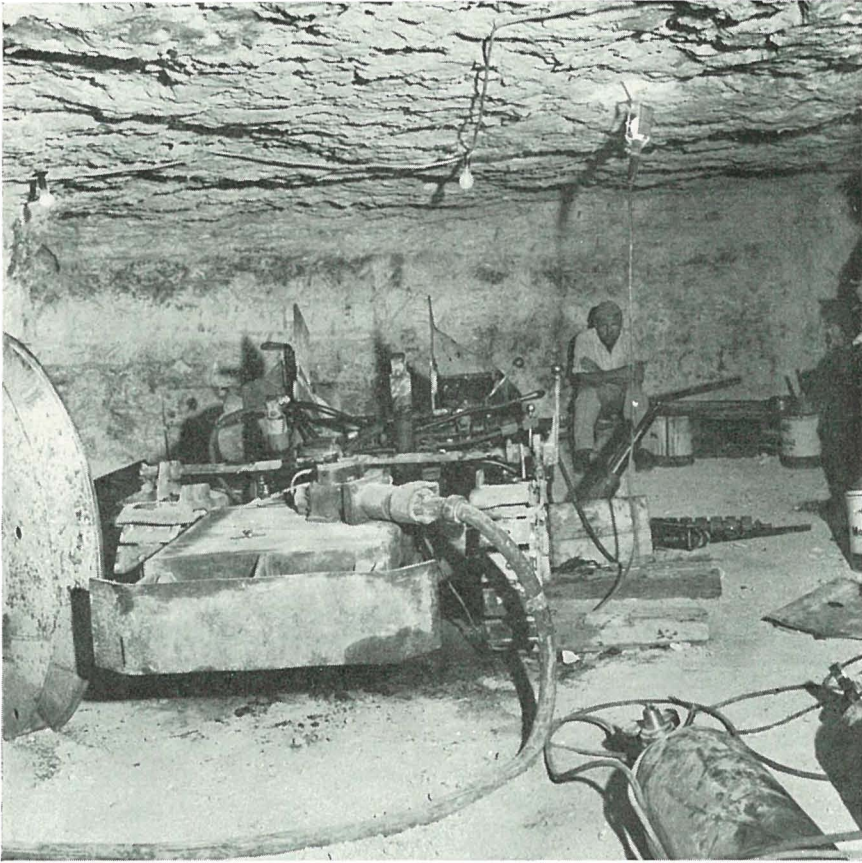


Fig. 2—Hand windlass and power hoists on the Triangle, Andamooka Opalfield



Joy loader, Andamooka Opalfield. Note dark opal level near top of face



Fig. 1—Opal diggings, Andamooka Opalfield

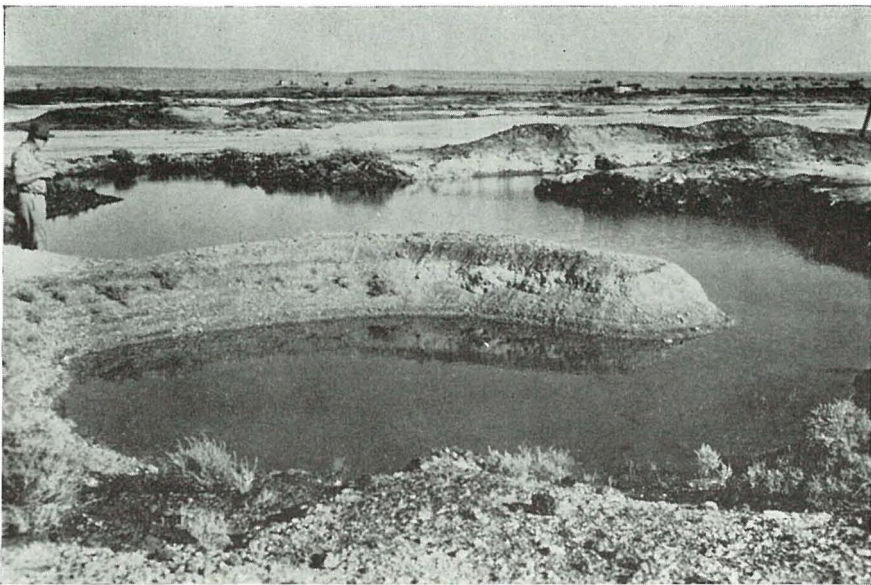


Fig. 2—Barite workings in floor of Pernatty Lagoon, looking west

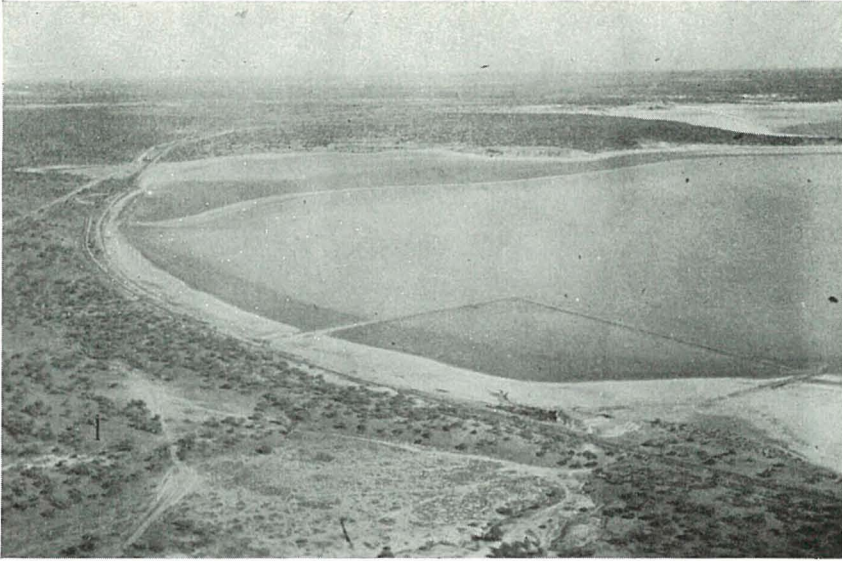


Fig. 1—Old salt pans and salt stack, southern shore of Lake Hart

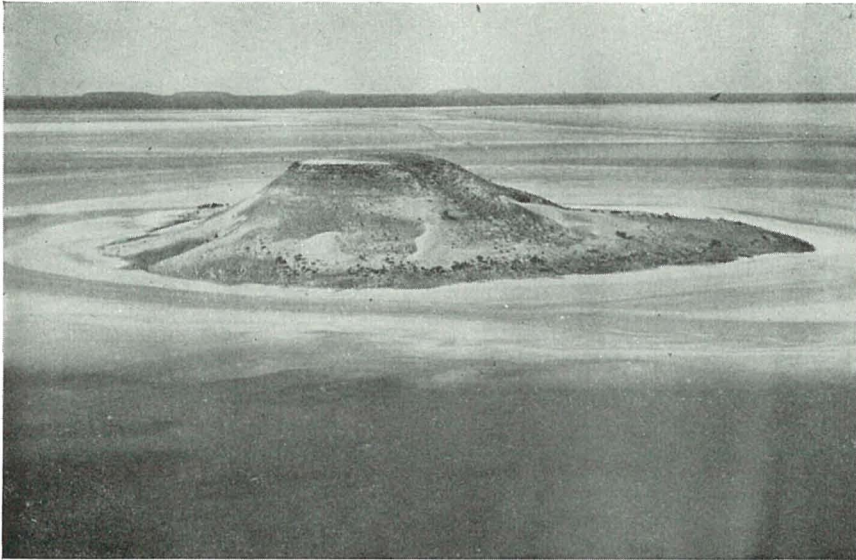
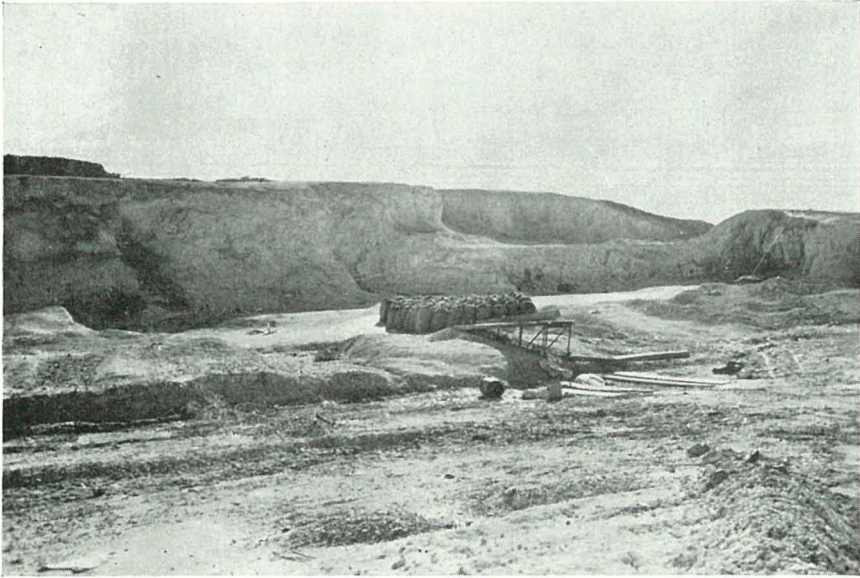


Fig. 2—Conical Hill, Island Lagoon; Oakden Hills on skyline

PLATE XXXVIII



Woocalla clay quarry, Magazine Hill