COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 29

THE GEOLOGY OF THE SOUTH-WESTERN CANNING BASIN, WESTERN AUSTRALIA

BY

D. M. TRAVES, J. N. CASEY, and A. T. WELLS

Issued under the Authority of Senator the Hon. W. H. Spooner,
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Minister: SENATOR THE HON. W. H. SPOONER, M.M.

Secretary: H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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REPORT 29

CORRIGENDA

Contents	insert GEOMORPHOGENY p.37	
	Appendix D for RUDALI read RUDALL.	
p. 1	l.1, for southern read south-western.	
	l.13, for separately read separated.	
p. 7	l.8, for (1861) read in 1861	
	l.20, for (1897) read in 1897.	
Fig. 5 facing p. 10,	north is at the bottom of the picture.	
p.12,	l.3, for southern read south-western.	
p.13,	l.3 from the bottom; for Patorson read Paterson.	
p.15,	l.8, for Coongon read Coongan.	
	l.14, for West read East.	
	l.7 from the bottom, for (Fig.8) read (Fig.9).	
p.18,	l.1, for Baramine read Barramine.	
p.19,	l.10, for eastern read western.	
	l.16, for eastern read western.	
p.21,	l.2, for p.402 read p.21.	
p.24,	l.6, for years read yards.	
p.27,	l.10 from the bottom; for recent read Recent.	
p.28,	l.27, should read _Johnstonia_, _Cladophlebis_, _Pagiophyllum_, ---- _Dictyophyllum_, ---	
Fig.20, facing p.37,	figures show number of dunes in 5 miles, normal to dune direction.	
p.47,	l.16, for 1909 read 1910.	
	l.2 from the bottom; for 1902 read 1896.	
p.49,	l.16 from the bottom; underline _Johnstonia_ and _Cladophlebis_.	
p.52,	l.1 from the bottom; underline _Parallelodon_.	
p.54,	l.10 from the bottom; for _expansus_ read _expansa_.	
p.57,	for MUNDAMUMMA read MUNDAMUDDA.	
p.68,	l.14, for Seaks read Soaks.	
p.69,	l.10 from bottom; for corsists read consists.	
Table 2,	under Fitzroy Basin; for Laurel Formation read Laurel Beds.	

CONTENTS

APPENDICES

PLATES

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SUMMARY

This report describes the geology and geography of the southern part of the Canning (Desert) Basin of Western Australia between latitude 20° and 23°S., and between longitude 120°E. and 124°30'.

It contains a description of stratigraphical units of Precambrian, Permian, Jurassic, Cretaceous, Tertiary and Quaternary ages which have been delineated, and a discussion of the tectonics, geological history and geomorphogeny.

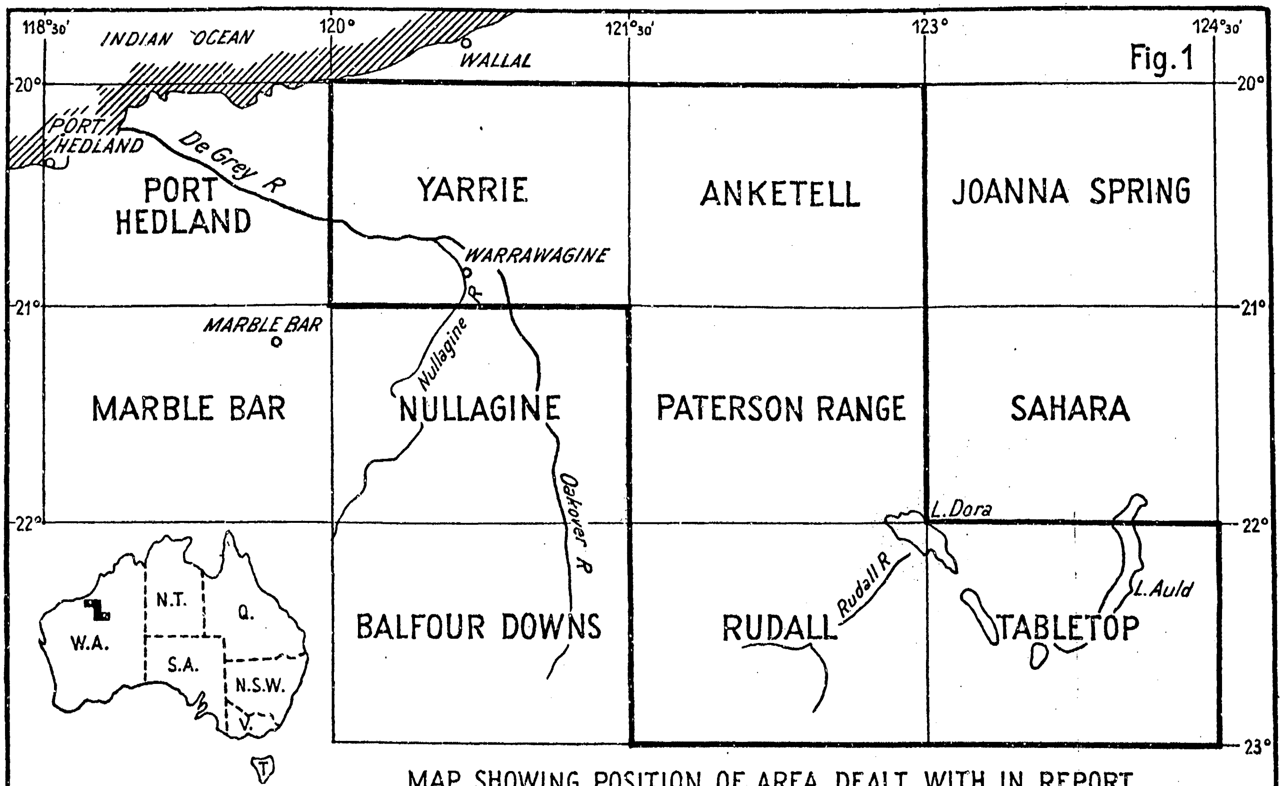
During Permian and Mesozoic times, this portion of the basin was a large, shallow epi-continental sea in which a sequence of sub-horizontal sandstone, greywacke, shale, and calcareous shale was deposited; no major unconformities separate the various units.

Marine fossils and freshwater plants have been found at seven distinct, widely separately localities, but the fossils were not numerous.

The lithology and fossils indicate that the sediments were deposited in a stable shelf area covered by a shallow sea.

Although in the south-western Canning Basin the sequence is only hundreds of feet thick compared with thousands of feet in the Fitzroy Basin, although marine fossils are scarce whereas they are numerous in the Fitzroy Basin, and although the lithology is predominantly clastic, whereas in the Fitzroy Basin it is clastic and calcareous, the various rock units mapped can be correlated precisely with units in the Fitzroy Basin.

The prospects of finding commercial supplies of petroleum in the area are very remote, but a study of the southern edge of the basin contributes to the knowledge of the whole basin, parts of which may have some petroleum potential.



MAP SHOWING POSITION OF AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN FOUR MILE MAP SERIES.

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

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INTRODUCTION

General

Mesozoic and Palaeozoic sediments were reported from the large unmapped area of desert between the De Grey and Fitzroy Rivers by several geologists, including Jones (1922), Talbot (1910), and Reeves (1949). Therefore, in 1954, a reconnaissance geological party from the Geolological Section, Bureau of Mineral Resources, Geology and Geophysics, investigated the south-western part, which includes the Four Mile Military Maps of Yarrie, Anketell, Paterson Range, Rudall, and Tabletop.

The geological party spent four months in the field, and from the traverses shown on Figure 4 prepared a regional geological map covering about 34,000 square miles. This, among other things, provides a basis for the discussion of the petroleum prospects of the area.

Two cadet surveyors from the Department of Lands and Surveys, Perth, were attached to the party. They computed latitude and longitude from astro-fix observations to provide control for the Four-Mile mosaics for use in any future detailed mapping.

Location

The region covered by the five Four Mile Sheets lies between 20° and 23° of South latitude and includes most of the area between 120° and $124^{\circ}30'$ East longitude.

The western part of the region - the Oakover Nullagine, and De Grey river systems - is pastoral country and is traversed by numerous bore and station tracks. The eastern part of the region - east of the rabbit-proof fence - is uninhabited desert, with no tracks, and a sparse vegetation of spinifex clumps interspersed with scattered low shrubs of acacias and mallee (eucalypts). Most of this area is characterized by large steep-sided seif dunes which trend west-north-west for mile after mile, and range in height from 30 feet to 120 feet..

Sheep raising and mining are carried on only in the western portion of the region. All stations now run sheep for wool (Braeside and Warrawagine were once cattle stations). The "carrying capacity" of these stations is about one sheep per twenty acres - compare western Queensland at one sheep per six acres - and all stations are over 100,000 acres. Warrawagine is 1,000,000 acres. The local government areas with the numbers of horses, cattle and sheep in 1953 are shown in Fig.2.

Gold, lead, manganese, tin, copper, columbite, tantalite, and beryl are mined by prospectors and small companies throughout the Pilbara region.

Practically no wild aborigines live in this part of the desert now: several of their tracks and a few "smokes" were seen in the Lake Waukarlycarly area, so a few must still exist. Most of their wells and rock holes had not been used for many years. Reeves (1949) reported seeing a very few aborigines near the permanent spring on Lake Blanche. Most of the tribes seem to have moved to the stations, particularly Wallal, where they work, and are cared for by the station.

Transport to the region is mainly by ship from Fremantle to Port Hedland and thence by road to the various inland stations. Two main roads lead from Perth to the northern districts: the Coastal Road passes through Carnarvon, Onslow, and Roebourne to Port Hedland; the Inland Route passes through Cue, Meekatharra, Roy Hill, Nullagine, and Marble Bar. Both these roads are formed and gravelled, but they are impassable after heavy rains. A railway that ran between Port Hedland and Marble Bar was discontinued in 1952, and road haulage is the only means of transporting heavy goods to the interior. MacRobertson-Miller Aviation Company operates a regular, almost daily, service from Perth to Port Hedland, and from there a weekly feeder service to all stations. The Flying Doctor base also operates from Port Hedland, using M.M.A. planes. Road transport costs are normally high; carriers carting manganese from Woody Woody to Port Hedland, a distance of 260 miles, charge £5 per ton: normal station deliveries cost nearly £7 per ton.

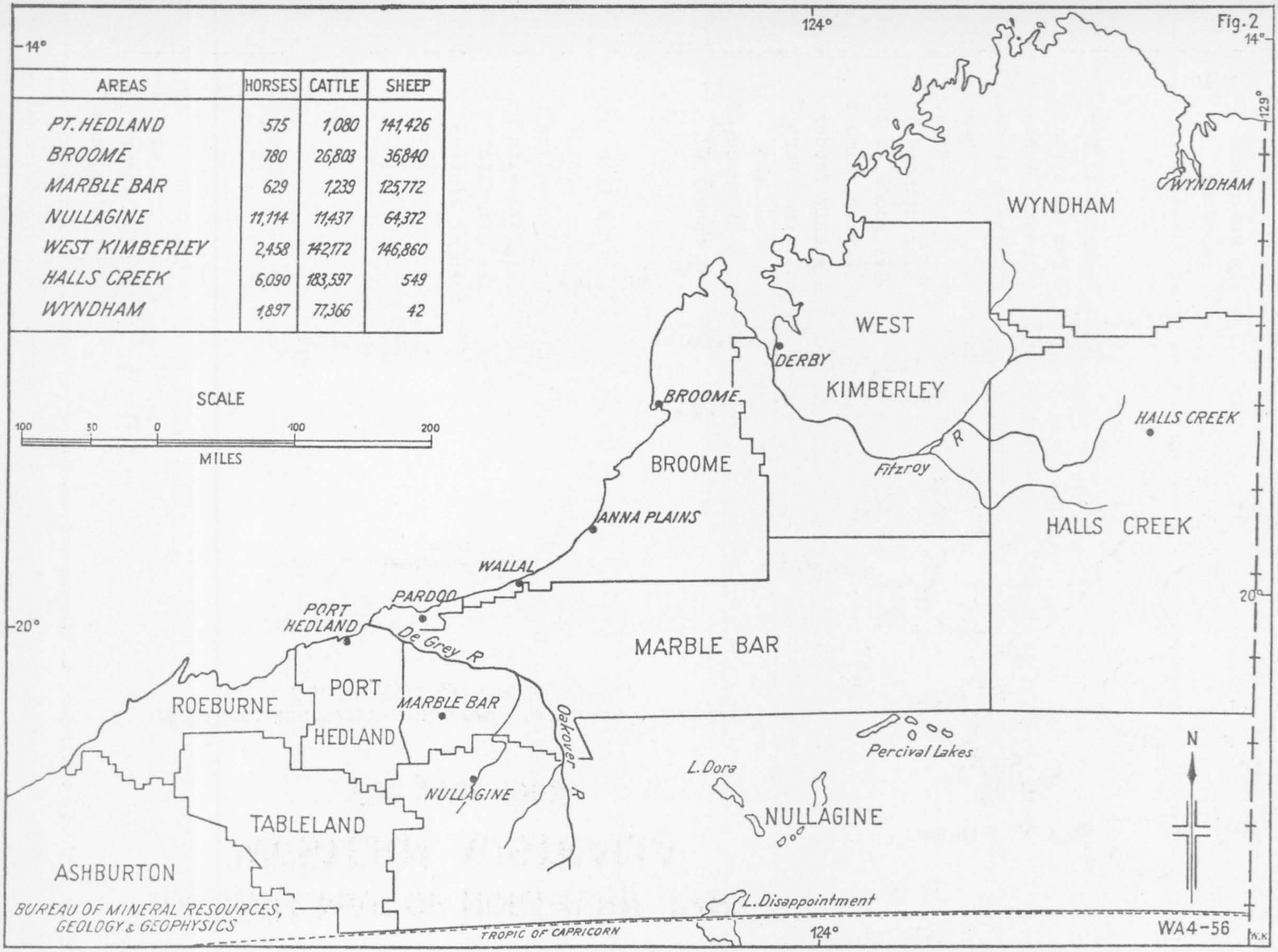
Climate

The climate of the northern and coastal parts is of the late monsoonal type, with a pronounced "wet season" continuing intermittently for three to four months, followed by a "dry season", normally extending from June to December. Inland lies an area of unreliable rainfall with no marked periodicity, which is governed by the influence of the climatic systems which prevail over the northern and southern portions of Western Australia. The climatic divisions are not distinct or easily recognised; the climatic data are given below according to areas and the information applies rather to the "coastal type" than to the "inland type".

The monthly rainfall of the De Grey area for the years 1951, 1952, and 1953 is shown below:

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total approx.
1953	½"	-	½"	1-5"	3-5"	-	-	½"	-	-	-	½"	8"
1952	1-3"	½"	½"	-	½-5"	-	½"	-	-	-	-	-	7"
1951	1"	1-3"	½-1"	-	-	-	-	-	-	-	-	-	4"

The averaged climatic data collected from the De Grey area are recorded below. The last record used to compute this average was taken in 1931. The information given for Marble Bar (21°11'S., 119° 42'E., and



AREAS	HORSES	CATTLE	SHEEP
PT. HEDLAND	575	1,080	141,426
BROOME	780	26,803	36,840
MARBLE BAR	629	1,239	125,772
NULLAGINE	11,114	11,437	64,372
WEST KIMBERLEY	2,458	142,172	146,860
HALLS CREEK	6,090	183,597	549
WYNDHAM	1,897	77,366	42

FIG. 2: LOCAL GOVERNMENT BOUNDARIES, AND STOCK FIGURES, MARCH, 1953.

(After Dept. Nat. Devel., Map of Local Government Areas, 1953.)

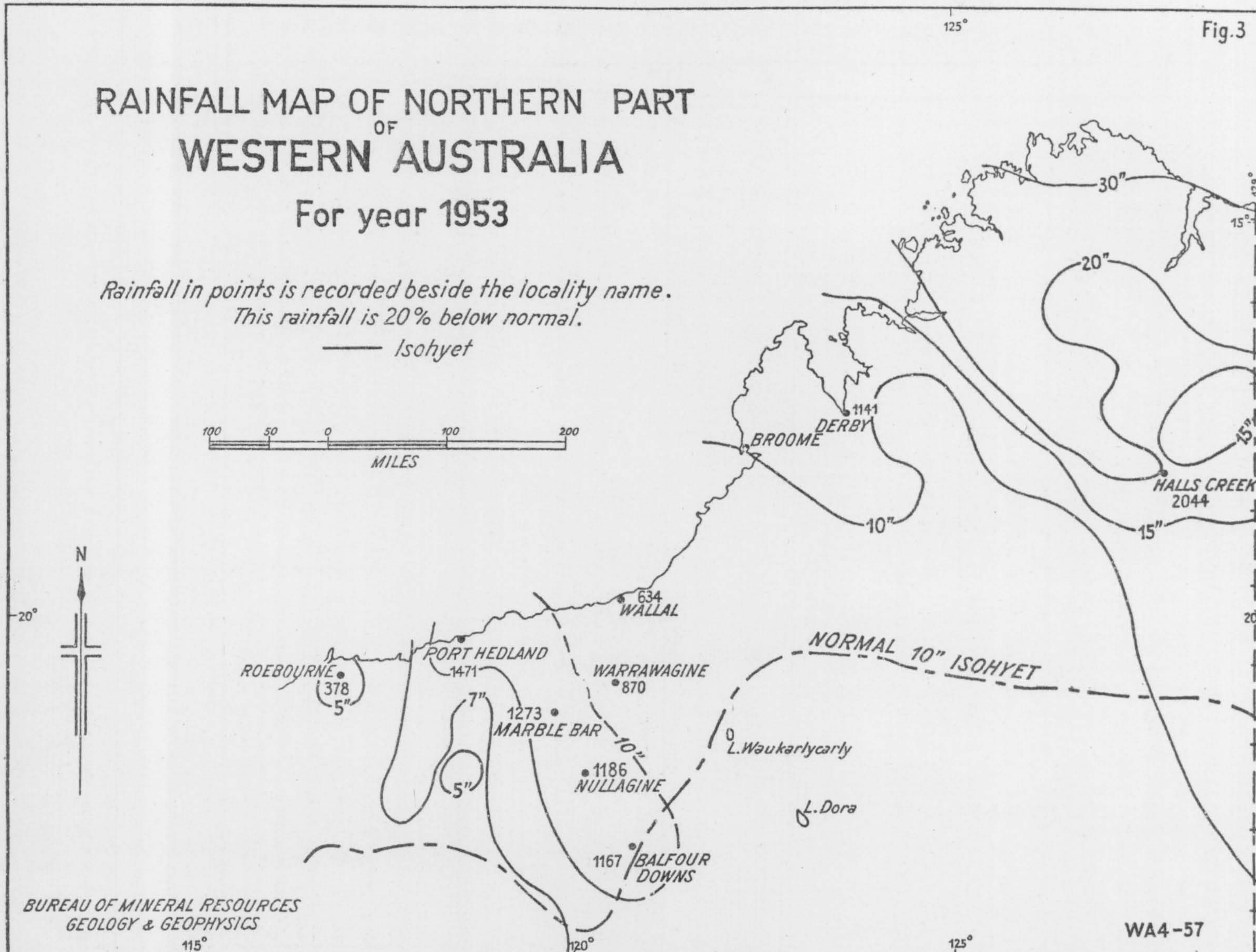


Fig.3
RAINFALL MAP OF NORTHERN PART OF WESTERN AUSTRALIA
For year 1953
Rainfall in points is recorded beside the locality name.
This rainfall is 20% below normal.
Isohyet
100 50 0 100 200
MILES
N
125°
30"
15°
129°
20"
1141
DERBY
BROOME
15"
HALLS CREEK
2044
10"
15"
634
WALLAL
20°
20°
NORMAL 10" ISOHYET
PORT HEDLAND
1471
ROEBOURNE
378
5"
WARRAWAGINE
870
7"
1273
MARBLE BAR
10"
L.Waukarlycarly
1186
NULLAGINE
5"
L.Dora
1167
BALFOUR DOWNS
BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS
115°
120°
125°
WA4-57
W.K.

altitude 595 ft.) was averaged over 29 years; for Nullagine (21°53'S., 120° 05' E., altitude 1265 ft.) over 32 years; and for Port Hedland (20° 19' S., 118° 24' E., altitude 25 ft.) over 18 years. All rainfall records were averaged over a period of 36 years.

The data were taken from C.S.I.R.O. Meteorological Data Pamphlet No.42, 1933.

Normal Mean Maximum Temperature (degrees F.)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Marble Bar	107	105	103	97	88	81	80	86	93	100	106	107
Nullagine	103	101	98	91	83	75	74	80	88	95	101	103
Port Hedland	94	94	95	93	85	80	79	82	86	89	93	93

Normal Mean Minimum Temperature (degrees F.)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Marble Bar	79	78	76	70	62	55	53	56	62	68	75	77
Nullagine	75	75	71	63	54	48	45	48	54	62	70	74
Port Hedland	79	79	78	72	63	58	57	59	63	68	74	78

Normal Mean Relative Humidity (percentage)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Marble Bar	44	47	44	39	45	48	45	40	33	30	29	36
Nullagine	37	40	39	38	43	50	49	42	33	28	27	33
Port Hedland	61	63	57	47	49	51	48	48	44	47	48	58

Average Rainfall (points) (100 points = 1 inch)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Marble Bar	255	296	196	85	74	111	60	24	1	18	37	148	12.9"
Nullagine	298	244	218	84	68	95	47	35	1	16	48	171	13.1"
Port Hedland	152	250	303	79	109	143	50	44	5	4	3	40	11.6"

During June and July in 1954, the average daily maximum temperature in the Lake Dora area was 80°F., increasing to 100°F. during August-September. The minimum temperature was approximately 40°F. at 6 a.m.; no frosts were experienced.

About ½" rain fell at Lake Waukarlycarly in June and 10 points fell at Lake Dora in July; nc other rain fell in this part of the desert between May and September.

Wind directions during the winter were normally from the S.E. and E.S.E. with slight to breeze strength. In the summer months winds from the North West Monsoon prevail.

Fig. 3 shows the rainfall for the northern part of Western Australia in 1953 (after meteorological map - Dept. of Interior, 1953.)

Flora and Fauna

The term "desert" used in this report does not mean a large area of bare sand : it refers to the extreme aridity of the country, the absence of any permanent surface water, the high annual mean and the extreme diurnal range of temperature, as well as to the paucity of vegetation. It is an area devoid of civilization, tracks, and habitation, rather than one devoid of all growth and animals.

The region consists of areas of red sand either covering distinctly undulating country, or formed into long parallel dunes. These dunes are essentially "fixed" by spinifex tussocks (Triodia), some Acacias, and, in places, "White Gums": only the top of a dune is advancing (westwards) in any marked degree.

The spinifex forms dense tussock-like masses, averaging 2 feet in diameter; they are separated by narrow patches of sand; their growth continues peripherally until the tussock is 4 yards across, and the centre then dies, producing an effect of "doughnuts" of spinifex tussocks. The drier the conditions, the more dominant does Triodia become.

On Yarrie Sheet and the western part of Anketell, the low scrub is dotted with dark green, densely foliated Desert Walnuts or Quandongs, 15 feet high. These were not seen in the other Four-Mile Sheets covered.

A collection of plants was sent to Mr.Gardner, Government Botanist, Perth, for determination, and his results are incorporated as Appendix F.

Numerous fire burns are scattered throughout the region; they are caused by the few wandering natives who burn the spinifex to catch food, or by lightning strikes. Spinifex is destroyed, for a time, and a lush growth of grasses and low flowering shrubs and bushes springs up on the burns; these are then overrun by spinifex or killed by the prolonged aridity, and Triodia again becomes the dominant type. Grasses such as Friachne ?helmsii Hartley ("Wanderie Grass"), Ichnanthus australiensis (Domin) Hughes (natives use these seeds for crushing and eating), and Eragrostis eriopoda Benth. ("Desert" or "Love" grass) grow near breakaways or after fire burns.

The country carrying stock in the eastern portion of Yarrie Sheet has fodder grasses such as "Mitchell and "Flinders", "Wire", "Wind", "Roebourne", and "Bundle Bundle".

The type and number of stock are shown in Fig.2.

The developed portion of the region carries sheep rather than cattle; the old rabbit-proof fence marks the eastern boundary of stock grazing.

In the desert area, little animal life was seen. Birds (galahs, pigeons, finches) were seen near soaks; some dingoes, kangaroos, and bustards (Epidotis), and many lizards, frequent the sand dunes. Rabbits live in large numbers in the salt-lake area, and build their warrens in travertine or unconsolidated tufa deposits close to the lakes. Some wild camels and many of their tracks were seen; they live chiefly on the juicy leaves of the samphire bush, which grows on dried-up areas of salt lakes.

Field Methods

In geological reconnaissance mapping in areas of trackless waste, it is impossible to examine all outcrops, and aerial photographs must be fully utilized in interpreting rock patterns. These interpreted patterns are then controlled by field traverses.

In 1953, the R.A.A.F. photographed the Region from 25,000 feet and supplied vertical coverage. Before field work started, these photographs were laid out in rough mosaics, and preliminary geological boundaries were drawn and tentative traverses planned. The usefulness of the traverses was reduced somewhat because, where possible, routes parallel to the sand dunes were chosen to reduce the number of dune crossings. Fortunately, most of the dunes run normal to the general geological trend of the country.

Uncontrolled mosaics at four-mile scale were prepared by the Department of Lands and Survey, Perth, and were used in the field and, later, in the office for compilation of the four-mile maps. All information obtained in the field was marked directly on to the aerial photographs, and later, in the office, boundaries of units were completed by interpolation and extrapolation. Then all information was transferred and reduced by the visual square method to the compiled four-mile maps; these four-mile maps will be published as part of the Four Mile Series by the Bureau of Mineral Resources at a later date. Plate 1, the regional geological map at 10 - mile scale, was prepared by photographic reduction of the five four-mile maps.

One Commer 3-ton four-wheel-drive truck and three Landrovers were used; modifications, performance, and recommendations for these vehicles are described by Traves and Casey (1954).

The traverse party generally consisted of two or three geologists in two Landrovers and the two surveyors in a third Landrover. The surveyors obtained astrofixes where possible near the four corners of each mosaic as well as on the tie runs of the mosaics. A continuous barometric traverse was run throughout the field season.

PREVIOUS INVESTIGATIONS

Very few geologists have investigated the rock outcrops in the desert proper, and the party made use of the journals of early explorers who crossed the sand and sand dunes with camels and horses.

Many authors, particularly the geologists of the Aerial Geological and Geophysical Survey of Northern Australia, deal in detail with the mines and mining areas of the Pilbara Goldfields: these are listed in the bibliography.

A.C. Gregory (1861) was the first surveyor to work in the desert margin, and he surveyed the area of the Nullagine and Oakover Rivers.

Colonel P.E. Warburton (1875) was the first to make an inland crossing from Alice Springs to the Oakover River, via the Musgrave Ranges and Joanna Spring, travelling mostly parallel to the dune direction. He named the Great Sandy Desert.

L.A. Wells (1896) crossed the desert from south to north at right angles to the dune direction. He travelled from Wiluna to the Fitzroy River, passing through Separation Well and Joanna Spring. His was the first expedition to suffer disaster, when two of his party perished.

W.F. Rudall (1897) covered a large part of the country near the salt lakes, searching for the lost members of Wells' party.

D.W. Carnegie (1898) traversed the south-eastern portion of the desert, through Godfrey's Tank to Halls Creek in 1897.

R.N. Smith (1898) traversed the Nullagine-Oakover area to see if artesian water could be obtained.

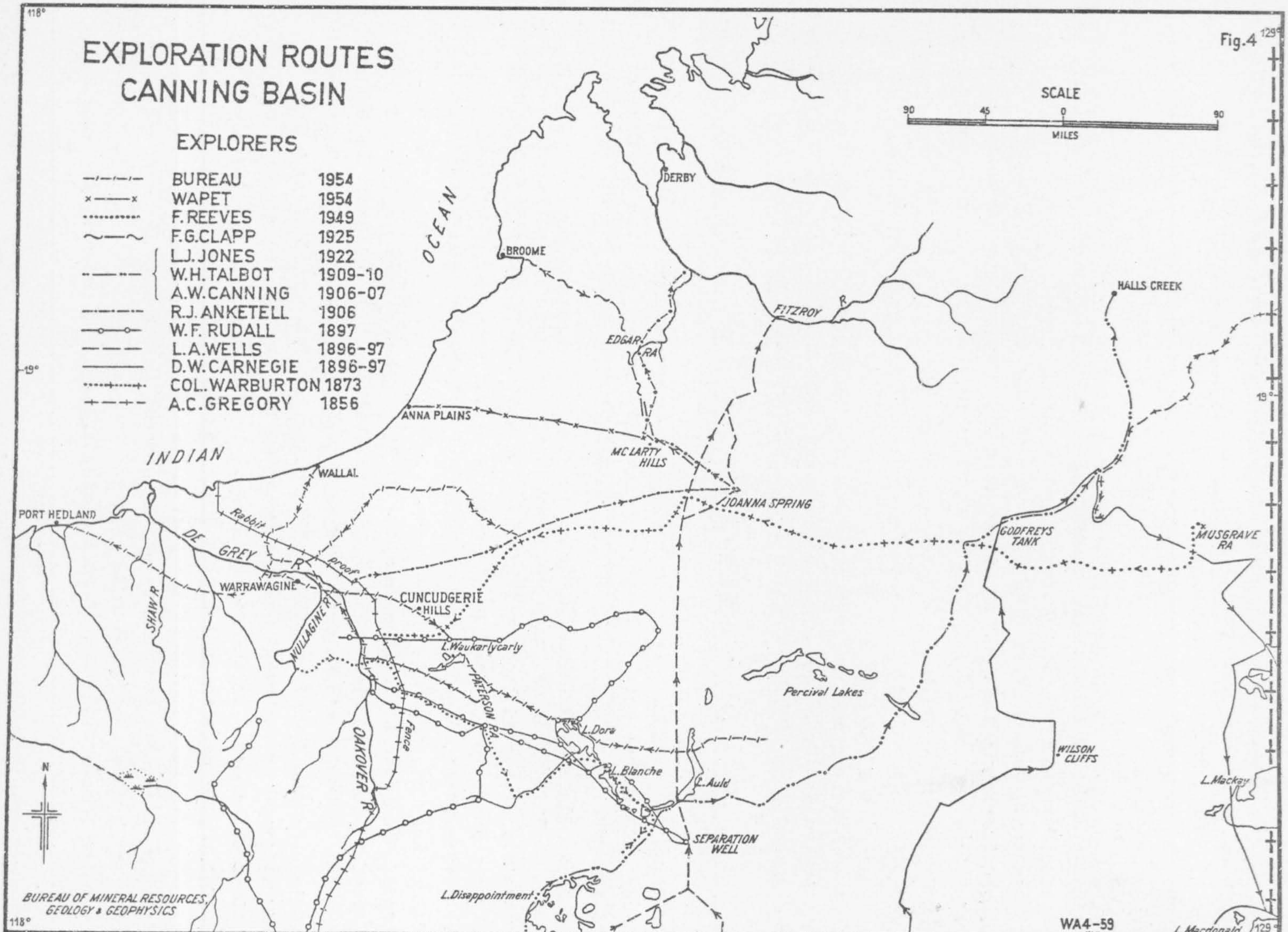
A. Gibb Maitland (1904) was the first geologist to undertake extensive and comprehensive work in the Pilbara area, and his work was the basis for all future workers in the area.

A.W. Canning surveyed the stock route in 1906-7 to bring cattle from the Kimberleys to the goldfields south of Wiluna.

W.H.B. Talbot (1910) traversed the stock route and gave the first accurate geological account of the desert area: this route was followed by L.J.Jones (1922) who investigated the oil possibilities for the Locke Oil Development Syndicate and Kimberley Petroleum Company. Jones found Permian fossils north-east of No.27 Well on the Stock Route; they were determined by W.S. Dun of New South Wales.

E. Kidson (1914) travelled the Stock Route with camels to record magnetic observations at well sites and water holes.

F.G. Clapp (1925) entered the desert fromthe north side, and reached McLarty Hills by tractor. He collected fossils near this locality.



EXPLORATION ROUTES
CANNING BASIN
Fig.4
SCALE
90 45 0 90
MILES
EXPLORERS
BUREAU 1954
WAPET 1954
F. REEVES 1949
F.G.CLAPP 1925
L.J. JONES 1922
W.H. TALBOT 1909-10
A.W. CANNING 1906-07
R.J. ANKETELL 1906
W.F. RUDALL 1897
L.A. WELLS 1896-97
D.W. CARNEGIE 1896-97
COL. WARBURTON 1873
A.C. GREGORY 1856
INDIAN
OCEAN
DERBY
BROOME
FITZROY R
HALLS CREEK
EDGAR RA
ANNA PLAINS
MC LARTY HILLS
WALLAL
JOANNA SPRING
PORT HEDLAND
Rabbit proof
DE GREY R
WARRAWAGINE
CUNCUDGERIE HILLS
GODFREYS TANK
MUSGRAVE RA
SHAW R
NULLAGINE R
L. Waukarlycarly
PATERSON RA
Percival Lakes
OAKOVER R
Fence
L. Dora
L. Blanche
L. Auld
WILSON CLIFFS
SEPARATION WELL
L. Mackay
L. Disappointment
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
WA4-59
L. Macdonald
118°
129°
19°

T. Blatchford (1924) surveyed the Precambrian margin of the desert in the Isabella Range area.

C.J. Bremner (1942) made extensive flights over the southern margin of the basin; the purpose of these flights was to delineate the southern margin of the basin and determine if Devonian limestone were present.

F.Reeves (1949) made an extensive survey of the whole of the Canning (Desert) Basin for Vacuum Oil Company. He used pack horses for his traverses from Balfour Downs station, through the Rudall country, to Lake Blancheand Lake Auld. Reeves found Permian fossils at Lake Blanche and near Well No. 26 on the Stock Route. Jurassic plant fossils from Callawa Hills added to the geological picture of the Basin, which showed it to be composed of sub-horizontal Permian and Mesozoic sediments.

The party from the Bureau of Mineral Resources in 1954 was the first to take conventional vehicles into the sand-dune country with success West Australian Petroleum, in the same year, penetrated east into the desert from Anna Plains to McLarty Hills and found Jurassic marine fossils.

TOPOGRAPHY

The area is topographically divided into: dissected hills bordering the desert, corresponding to the north-east part of the Pilbara Block; and desert area, corresponding to the southern part of the Canning Basin proper.

Dissected Hills Bordering the Desert

This division has a well-developed drainage pattern imposed on a moderately dissected land, which ranges in altitude from 1,200 feet in the Paterson Range to 350 feet on the granite plains near Muccan station. On the Yarrie Sheet, the division includes "highs" such as the Isabella and Gregory Ranges, and Bamboo Creek area. In the Paterson Range and Rudall Sheets, dissected hills rise abruptly to 350 - 500 feet above the sand plains, to form isolated units such as the Paterson, Broadhurst, and McKay Ranges. No barometric heights were taken in the Rudall area, but elsewhere ranges continue for fifty miles with a height of 900 - 1,200 feet. The general trend of the ranges in the Paterson and Rudall area is north and north-west, whereas in the Yarrie area it is predominantly east-west (except on the eastern part of the Sheet, where it is north).

For most months of the year no surface water flows in any of the drainage channels; the valleys of the streams in the Paterson and Rudall areas are narrow, almost V-shaped; where the valleys leave the hill country and enter the sand plains, short distributaries form, but very few extend far into the desert.

The Nullagine and Oakover Rivers form the major river system draining the dissected area in the southern part of the Yarrie Sheet: the system is characterized by wide alluvial flats which extend from tens of yards to six miles on each side of the river. The hills forming a gap four miles east of Yarrie Homestead rise 350 feet above plain level, and they restrict the width of the alluvial flats of the De Grey river to a mile. The flats again spread as the river emerges from the gap.

The Nullagine and Oakover Rivers flow in a northerly direction in their upper reaches, but near Warrawagine Homestead they swing north-west and join about seven miles south of Callawa station to form the De Grey River, which flows to the west.

For many months of the year the rivers are dry except for some isolated pools. The upper reaches of the Nullagine and Oakover Rivers cut through Precambrian rocks and form steep gorges in which lie permanent pools, e.g., Carawine Gorge. The channels of these two major streams average 400 yards in width and the bed of the stream is generally only about 15 feet below the level of the alluvial plain. The gradients of these rivers are as follows:

Locality		Distance (miles)	Fall (feet)	Gradient (ft.per mile)
Oakover River				
Carawine Gorge	- Braeside	20	90	4.5
Braeside	- Chooka Well	30	130	4.3
Chooka Well	- Toomingidgee Well	11	70	6
Toomingidgee Well	- Junction with Nullagine Riv.	13	35	3
Total		74	325	4.5
Nullagine River				
Pinjian Pool	- Warrawagine	10	30	3.5
Warrawagine	- Junction with Oakover River	13	85	6.5
Total		23	115	5
De Grey River				
Oakover	- Nullagine Junction to sea level.	120	365	3

Generally, the Oakover River has a greater and more rapid flow of water than the Nullagine River, because of its greater length and larger catchment area. The steep gradient between Chooka Well and Toomingidgee Well on the Oakover River explains the very rapid flow of water in this section during flood times.

The rivers are at grade and their floors are strewn with boulders and coarse sand. In some places old river courses are visible on the aerial photographs and probably represent the deserted braided course of the rivers, rather than meanders.

Desert Division

The desert area is characterized by innumerable seif dunes and playa lakes and the absence of any significant drainage channels. It has low relief and an altitude ranging from sea level at Wallal to 900 feet east of Lake Auld.

Small hills rise less than 150 feet above the level of the sand plain. Cuncudgerie Hill is a small monadnock rising 130 feet above the general level of the plain. Numerous small rounded rises scattered throughout the area are no higher than the surrounding sand dunes.

The salt lakes formed by internal drainage are characteristic of the desert. Lake Waukarlycarly lies about twenty miles north-west of Mt. Crofton, and Lakes Dora, Blanche, Winifred, George and Auld form a U-shaped group east of the Rudall River area. The Department of Lands and Surveys, Western Australia, and National Mapping Section, Canberra, have recently decided that 'Wooloomber' is an invalid name: Wells in 1896 named the elongated lake 'Auld', and the smaller lake 'George' ; these names have priority and therefore replace 'Wooloomber' and 'Auld' respectively. The bed of the lakes consists of a thin crust of salt and gypsum underlain by at least 18 inches of brine, saturated sand, and mud. The surface of Lake Waukarlycarly differs from the other lakes observed in being mostly covered with a soft powdery tufa and some salt. The salt-water level at Lake Dora was less than 12 in. below the salt crust. Only after particularly heavy falls of rain is there an appreciable quantity of surface water in any of these lakes. Lake Waukarlycarly is 670 feet above sea level, Lake Dora 650 feet, and Lake Auld 755 feet. The margins of the lakes are irregular, particularly on the eastern edges of the lakes where their salt surface extends into the valleys between sand dunes. This condition is probably caused by the encroaching sand dunes, which form a serrated edge to the salt lake. The extensions between the sand dunes commonly break into a mass of small salt lakes and clay pans which represent remnants of the lake surface.

Sand dunes cover most of the desert and form parallel ridges, mostly a quarter to half a mile apart and extending for more than fifty miles (Fig.5); they vary only slightly in direction and generally trend west-north-west; the average height is about 60 feet, but dunes twice this height were measured.

The junction of dunes is quite common; the point of the acute angle between the two in almost every case points west-north-west. They are commonly braided, giving three or four parallel crests to the one dune.

In some places small areas of perhaps 10 square miles may consist of irregular short dunes of complex pattern, but their longer axes

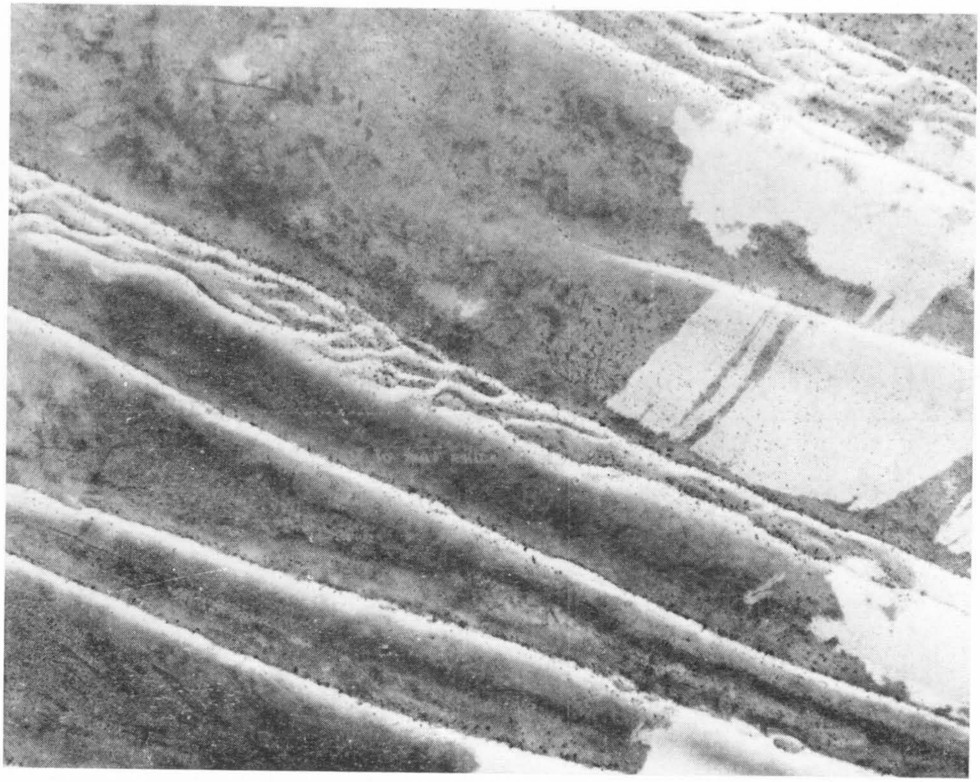


Fig. 5.—Parallel dunes with fire-burn patterns.

Scale ¾ mile to 1 inch.

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Fig. 6.—120-ft. dune, 60 miles east of Ragged Hills.

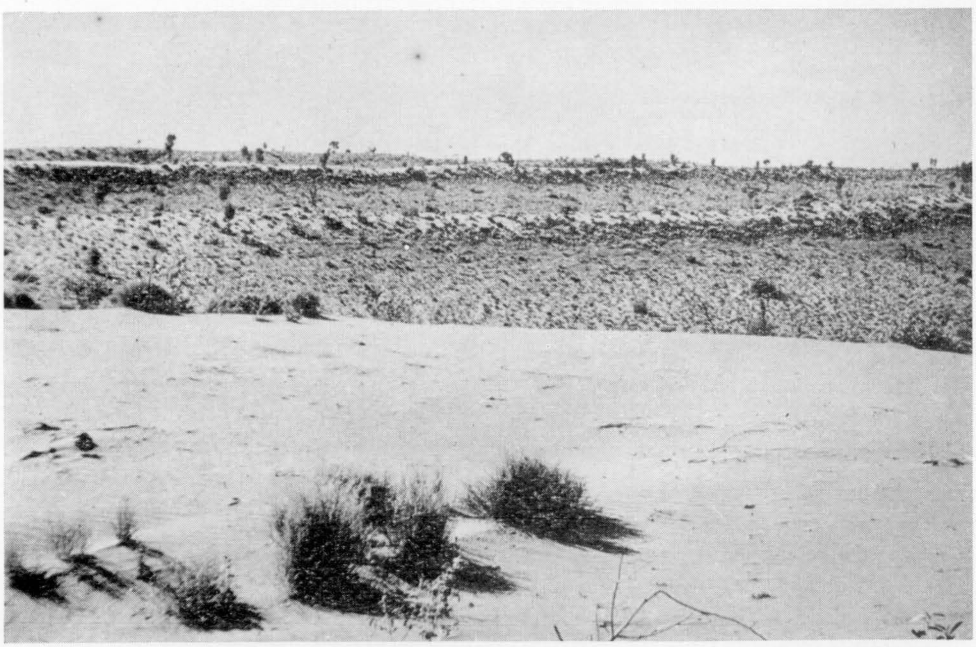

Fig. 7.—View northward across a dense field of 80-ft. dunes, 8 miles south of Mt. Crofton.

always trend in the same general direction as the others. Braiding is particularly noticeable near the western margin of the playa lakes; the dunes are generally absent in a small lane about half a mile wide adjoining the western shore of the lake. On the eastern margins of the lakes, however, the dunes are well defined and only slightly braided, and abut on the lake surface.

The dunes end abruptly against the eastern margin of any obstruction such as small hills or mountain ranges. On the western margin of the larger ranges, they are absent for a half to two miles; on the western margins of the Broadhurst and Throssel Ranges, the dunes are absent within a small lane two to ten miles wide. The dunes in places continue unobstructed over low rises.

The dunes have migrated in a west-north-westerly direction, but their movement is now somewhat restricted by the sparse vegetation which covers them.

The area almost completely lacks any drainage channels; the greater part of the drainage is subterranean. The Rudall River partly traverses the sand plain, but merges into a series of clay pans and small salt lakes in its lower reaches, its course being extremely braided. The channels reach Lake Dora, but flowing surface water seldom reaches the lake. Some drainage channels are present in small rises, monadnocks, and breakaways within the desert, but they rarely extend more than 100-200 yards.

STRATIGRAPHY

GENERAL

The Canning Basin is defined for geological purposes as the sedimentary basin between the Kimberley and the Pilbara areas of Pre-cambrian rocks: it extends north-westwards on to the present continental shelf and contains Palaeozoic and younger sediments.

The name "Great Sandy Desert" was used first for this area in 1872 by Colonel P.E. Warburton.

The name "Desert Basin" was used for the poorly defined artesian basin between the Kimberley and Pilbara Blocks in a map accompanying a "Report of the Interstate Conference on Artesian Water, Sydney, 1912" (Sydney, Government Printer, 1913). An "artesian basin" is defined in this report as meaning "the whole of an area within which artesian or sub-artesian water may be obtained by boring".

Gentilli and Fairbridge (1951) called the Palaeozoic-Mesozoic sedimentary basin between the Kimberley and Pilbara Blocks, including the extension on to the submarine continental shelf, the "Canning Basin".

The shape of the floor of the Canning Basin is practically unknown, and some individual downwarps in the floor may be sufficiently large to justify a separate name within the larger unit. The first of these areas recognised is the Fitzroy Basin in the north, between the Kimberley Block and the Fenton Fault Line.

This report deals with the stratigraphy of the southern margin of the Canning Basin, and emphasis is placed on the Palaeozoic and younger sediments: the Precambrian is treated regionally as providing the source and floor of deposition for Permian sediments, and the border to the sedimentary basin.

Precambrian, Permian, Mesozoic, and Tertiary rock units have been recognised, and the post-Precambrian sediments are represented by a small thickness of predominantly clastic sediments containing few fossils.

Units found are correlated with similar units in the Carnarvon and Fitzroy Basins in Table 2.

Existing names of rock units have been used wherever possible, with slight revision in accordance with the current Australian Code of Stratigraphical Nomenclature. New names of formations are introduced and the units are described in order, oldest to youngest, under the headings of their periods. These new names have been approved by the Western Australian Committee on Stratigraphical Nomenclature.

PRECAMBRIAN

A large area of Precambrian rock crops out in the Pilbara Block, which forms the south-western border of the Canning Basin. These Precambrian rocks have been divided into three units by Maitland (1904 and 1905). The divisions he made are, in descending order :

1. Nullagine Beds - "a series of sedimentary rocks, quartzites, grits, conglomerates, and shales, together with a series of interbedded volcanics".
2. Mosquito Creek Beds - "a series which consists of grits, shales, and fine conglomerates" and "which underlies the strata of the Nullagine Series."
3. Warrawoona Beds - "(a) altered sedimentary series (quartzites, conglomerates, quartz, and mica schists, etc; and (b) metamorphic igneous rocks (greenstones, magnetite, and serpentinous schists, and more or less altered sheared basic igneous rocks)".

Maitland, in his original description of these units and in his discussion of the geology of Western Australia in 1919, recognised the great unconformity between the Nullagine Beds and the Mosquito Creek Beds, and between the Nullagine and Warrawoona Beds: but stated that "future detailed and comprehensive fieldwork may show a very intimate and close relationship between the Warrawoona and Mosquito Creek Beds." However, he seems to contradict his predictions when he mentions that a conglomerate of the Mosquito Beds "contains numerous pebbles of laminated quartz (chert) and jaspillite which form part of the Warrawoona Beds".

Forman (1937) described the difference in strike and dip at an obscured contact of the Mosquito Creek Beds and Warrawoona Beds at Eastern Creek Pilbara district, and stated that it "confirms the inference of the unconformity between the Mosquito Creek Series and the Warrawoona Series". Finucane (1939) made a similar observation. Although Maitland used these names for rock units Fairbridge (1953), without formal definition, used the names "Nullagine System", Mosquito Creek System", and Warrawoona System ".

In the older rocks, grades of metamorphism and gneissosity have been used as age indicators.

Maitland (1904) gave a tentative age of Cambrian to the Nullagine Beds, which he correlated with the sediments of the Kimberley Plateau. Since then, most writers have referred to the "Nullagine Series, Beds, System" as Proterozoic. The more metamorphosed sediments which unconformably underlie the Nullagine Beds are generally referred to in Western Australia as Archaeozoic.

Thus the Western Australian division is:

Proterozoic	Nullagine "System"
Archaeozoic	Mosquito Creek "System"
	Warrawoona "System"

However, from fieldwork in the Northern Territory and in the Kimberleys, geologists of the Bureau of Mineral Resources have placed the sediments of the Kimberley Plateau in the Upper Proterozoic, extending possibly, even into the base of Lower Cambrian (Traves, 1956; Guppy, Lindner, Rattigan & Casey, 1956) and the metamorphosed rocks unconformably below, such as the Halls Creek Group (Traves, 1956) are placed in the Lower Proterozoic.

Because of the confusion in nomenclature and the lack of detailed mapping in the Precambrian of the area surveyed, the Precambrian rocks described in this report have not been formally named but will be broadly described under the headings of Lower Proterozoic and Upper Proterozoic. The Lower Proterozoic age may be questionable, but is used, in accordance with the present usage in the Bureau of Mineral Resources, for metamorphosed sediments which may possibly be correlated with similar rocks in the Kimberleys and Norther Territory.

Lower Proterozoic Rocks

Metamorphics

Metamorphics, predominantly "greenstone" (altered pillow lavas and sheared basic volcanics), serpentine, talc-chlorite-carbonate schist, dolomitic marble, quartzite, slate, and banded hematite jasper, crop out in the south-western portion of Yarrie Four Mile Sheet, in most of Rudall Sheet, the western portion of Patorson Range Sheet, and the southern portion of Tabletop Sheet. No subdivision of these rocks was attempted because of the complex structure and indefinite lithological boundaries.

In the Bamboo Creek area, "greenstone", calcareous schist, and marble predominate. A dolomitic marble specimen collected from locality Y52 showed no contact-metamorphic minerals and no advanced stage of recrystallization, and had the following chemical composition:

$CaCO_3$	54.6%
$MgCO_3$	37.2%
$FeCO_3$	5.0%
Acid Insoluble	3.3%

This marble is associated with sheared basic volcanics and shows some pyrite mineralization.

The calcareous schist, associated with the "greenstone" at Y58 on the Talga-Warrawagine main road, is characterized by a cubic brown mineral showing interpenetration twins, which is a pseudomorph of limonite after pyrite. The "greenstones" are weathered and altered basic lavas containing secondary chlorite and calcite. They have been sheared to form chlorite, actinolite, talc, and serpentinous schists which are carbonated near quartz veins.

East of Lake Waukarlycarly at P8, outcrops of quartzite, slate, schist, and marble were examined. The quartzites in this area are immune to granitization and in places form remnant ridges of felspathised quartzite in the granite. The recrystallized quartzite in thin section shows glassy quartz which is extensively intergrown. (See Appendix 'G' for a description of some rock samples.)

In the hills north of Yarrie, the main rock type is slate and calcareous and hornblende schists, overlain unconformably by banded hematite jasper, which, being very resistant to erosion, forms the backbone of the ranges. This banded hematite jasper ranges from almost pure banded hematite to predominantly jasper with a few thin bands of hematite. A similar rock of banded hematite jasper is faulted against slates at Mt.Cecilia. Correlations of this hematite jasper may also be made with the "Marble Bar" which cuts the Coongon River, and possibly with the banded hematite at Yampi Sound.

Schists, quartzite and "greenstone" were mapped by photo-interpretation on the Rudall and Tabletop Four Mile Sheets.

Igneous Rocks

Granitic rocks crop out in the country bordering the desert and in the desert, the main areas being the plains of Talga-Talga; between Coongon and Yarrie; east of Lake Waukarlycarly; and the headwaters of Rudall River.

The granite at Talga-Talga crops out over a large area between Bamboo Creek and Marble Bar; it is mostly a medium-grained biotite granite. Five miles south-west of Talga Homestead, hillocks of sheared basic volcanics overlie the granite, apparently forming roof pendants. The contact shows

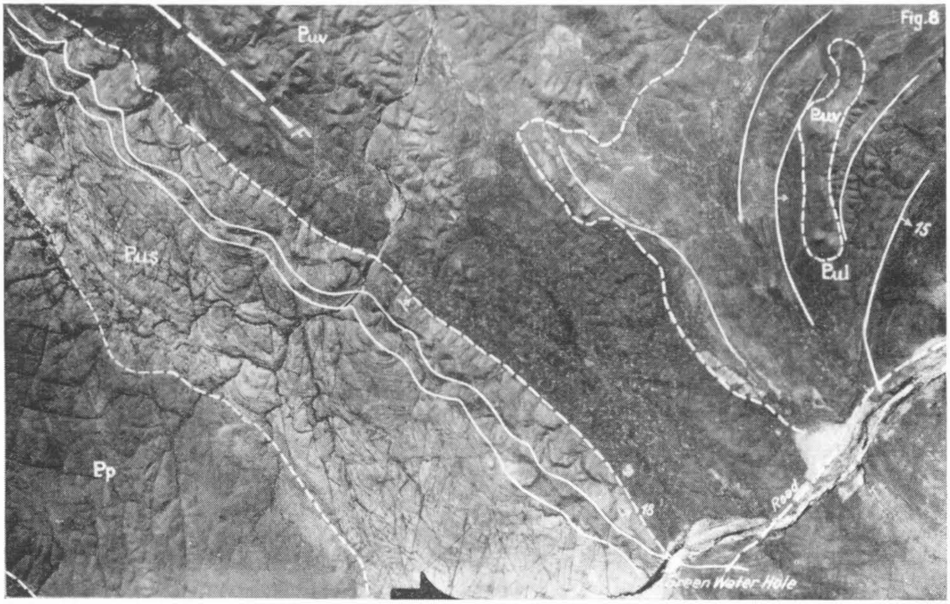

Fig. 8.—Upper Proterozoic units near Green Hole.

Scale ¾ mile to 1 inch.

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granitization of the basic volcanics. The ragged edges of structures in the metamorphics abutting on the granite show that the granite is younger than the metamorphics. Dolerite dykes cut the granite but were not seen to intrude the metamorphics. Quartz "blows" are common in the Talga area, particularly near the junction of the metamorphics and granite - e.g. near Zulus Creek.

The large area of granite bordering on the De Grey River was examined between Coongon, Yarrie, and Nimingarra. A fine-grained to medium-grained hornblende granite crops out on the plains twelve miles north-east of Nimingarra Homestead. At Black Hill, ten miles east of Nimingarra, the granite is intruded by a large northerly-trending dolerite dyke which forms a long prominent ridge. Many other dolerite dykes cut the granite, the longest dyke being fifteen miles long and 200 yards wide.

West of Lake Waukarlycarly the granite ranges from a fine-grained biotite granite with pegmatite veins to a slightly gneissic fine-grained granodiorite. Roof pendants of quartzite form hills in the otherwise low, partly sand-covered surface of the granites.

North of the Paterson Range, near P20, are outcrops of a medium-grained biotite granite cut by aplite and quartz veins. The area of granite on the Rudall Four Mile Sheet was not examined and was mapped by photo - interpretation. Reeves (1949) recorded granite on the western side of Rudall River south of Rooney Creek.

Upper Proterozoic

In many parts of the area, especially in the Yarrie Four Mile Sheet, the Lower Proterozoic metamorphics are overlain unconformably by unmetamorphosed sediments and volcanics, which are believed to be Upper Proterozoic in age. Most of these rocks may be part of Maitland's "Nullagine Beds", but, as explained before, the lack of mapping and confusion in nomenclature makes it advisable to describe sections examined without adding more unit names and correlations.

The sequence of the Upper Proterozoic rocks is shown best in the syncline bordering the eastern side of the Bamboo Creek Goldfield metamorphic belt (Figs. 8 and 9). The eastern limb of the syncline was examined along the Little De Grey River between points Y43 and Y48, and the western limb at Green Hole, and Y49 to Y51 (Fig 8.).

The Lower Proterozoic metamorphics are unconformably overlain by a well-jointed rhyolite porphyry which has an apparent dip of 18° S.W., at Y45, conformable with the overlying sandstone. The porphyry contains equigranular phenocrysts of pink felspar and clear quartz. It intrudes the overlying sandstone, as is shown by the thin quartz veins penetrating the sandstone, and by the felspathization of the basal beds at Y45.

Previous authors (Maitland, 1904, p.54; 1908, p.50; Finucane, 1936, p.3) have postulated that the porphyry is a series of flows, but, although it appears to have a stratigraphical position in the syncline, it is probably intrusive into selected beds and is roofed by the sandstone.

On the western limb of the syncline at Y50 the porphyry intrudes about 80 feet of dark grey and red soft shale which becomes fine, very micaceous sandstone towards its contact with the sandstone sequence; the porphyry and the shale are capped by 10 feet of hornblende-olivine dolerite. At Y51, quartz-felspar porphyry intrudes similar shales, and pieces of the shale appear as inclusions in the porphyry; hornblende porphyry also cuts the shale as a sill. Small quartz reefs and basaltic dykes cut the porphyry. Sills of hornblende porphyry intrude the sandstone on both sides of the syncline and at the nose at Y15 and they may be genetically related to the main mass of porphyry.

The maximum thickness of the porphyry is approximately 3,800 feet on the western limb, but it thins out on the eastern limb and does not crop out on the north-western nose of the syncline.

On the eastern limb at Y45, the porphyry is separated from the conglomeratic basal beds of a 100-foot sandstone sequence by about 10 feet of red shale, which seems to be affected by the porphyry, and a 5-foot sill of hornblende porphyry; the sandstone dips 20-25^{o} to the south-west. The distribution of the porphyry is probably governed by the selective intrusion into the shale beds. A much thicker section of the sandstone crops out on the western limb at Green Hole, Y50. At this locality 800 feet of well - bedded, well-jointed, well-cemented, poorly sorted pebbly fine conglomerate, pebble conglomerate, and coarse arkosic sandstone dip N.E. at 18^{o}. The basal beds have many felspar crystals and mica flakes; no ripple marks or cross bedding were observed. This unit is overlain by more than 300-feet of medium-bedded, friable, jointed, poorly sorted fine conglomerate, with scattered 5-inch pebbles, pebble conglomerate, and coarse sandstone, which is faulted and intruded by a sill of hornblende porphyry. The top of this unit is covered by transgressive basic volcanics which are also affected by faulting and are cut by inch-wide quartz veins. These two sandstone beds were mapped as a single unit.

The sandstones are well exposed on the western limb of the syncline but are mainly covered by basic volcanics on the eastern limb.

A unit of dolomitic limestone fills the central portion of the syncline, although in most places it is covered by basic volcanics. At Y46, a dark siliceous dolomitic limestone crops out through the volcanics and forms trend ridges. This limestone shows numerous concentric structures from half-inch to 2 feet in diameter which may be colonies of algae or slump structures.

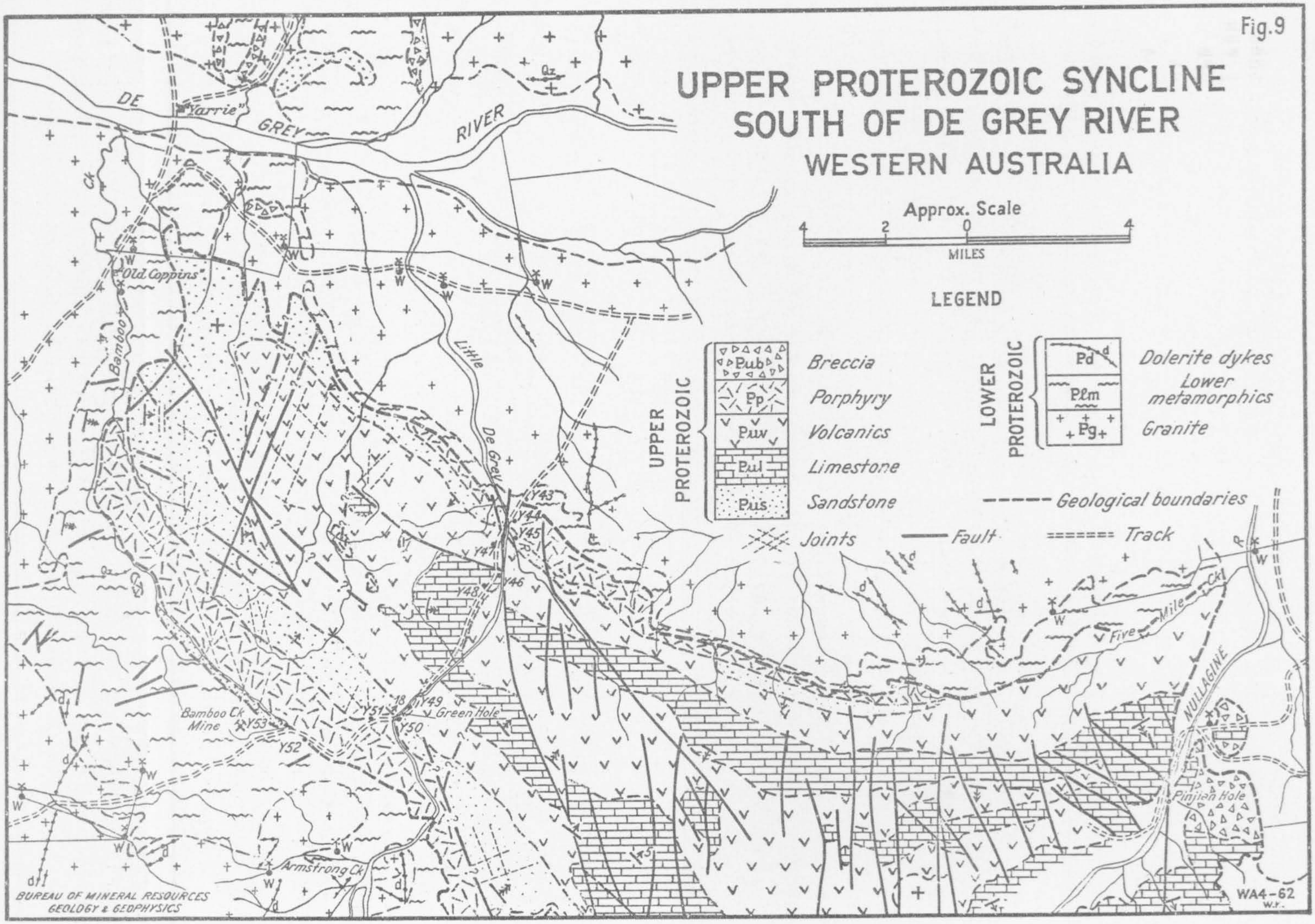

Fig.9
UPPER PROTEROZOIC SYNCLINE
SOUTH OF DE GREY RIVER
WESTERN AUSTRALIA
Approx. Scale
4 2 0 4
MILES
LEGEND
UPPER PROTEROZOIC
Pub Breccia
Pp Porphyry
Puv Volcanics
Pul Limestone
Pus Sandstone
LOWER PROTEROZOIC
Pd Dolerite dykes
Plm Lower metamorphics
Pg Granite
Geological boundaries
Joints
Fault
Track
DE GREY RIVER
Yarrie
Old Coppins
Bamboo Ck
Little De Grey
Bamboo Ck Mine
Green Hole
Armstrong Ck
Five Mile Ck
NULLAGINE
Pinjian Hole
Y43
Y44
Y45
Y47
Y48
Y46
Y49
Y50
Y51
Y52
Y53
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The dolomitic limestone on the eastern limb extends south-east to Pinjian Pool, where 150 feet of sub-horizontal dolomite containing chert nodules and plates are exposed. On the eastern side of Pinjian Pool, the dolomite is unconformably overlain by a siliceous chert breccia-a strongly cemented residue of angular chert fragments from the weathered dolomite. The relationship between dolomite and breccia is shown in Fig.10

The unit of dolomite can be correlated with the dolomite that forms the high western cliff at Carawine Pool, south of the area surveyed, and with the Upper Proterozoic dolomite that crops out with an easterly dip, west of Ragged Hills.

The breccia fills the interstices, joints, cavities, and crevices in the dolomite, and was cemented after the folding of the dolomite; it was formed as a result of the weathering of the dolomite. It ranges from dark red to light red and white, and is composed of angular fragments of chert cemented by silica or, in some places, by hematite or manganese oxides. A complete range has been seen from siliceous breccia to manganiferous breccia to manganese ore: the manganese deposits at Woody Woody, 55 miles south of Warrawagine, and the siliceous breccia belong to the same unit. The manganese appears to have been deposited in a lacustrine or possibly even marine environment, and cements or replaces the chert fragments weathered from the underlying dolomite.

The breccia is known to conform to the eroded surface of the folded dolomite, so that it is younger than the folding ofthe dolomite, which may be late in Upper Proterozoic or even early in the Palaeozoic.

The relationship of the breccia to the basic volcanics was not pbserved; no fragments of basalt were seen in the breccia. In the syncline east of Bamboo Creek, basic volcanics of an andesitic or basaltic suite unconformably overlie and transgress the Upper Proterozoic sediments, and cover most of the middle part of the syncline. These rocks are fine-grained; the surface exposure is deeply weathered to produce mainly chlorite and calcite. They are vesicular in places and contain amygdales of chalcedony, chlorite, and calcite; commonly the wall is coated with chalcedony and the rest filled with calcite. Pieces of chert, presumably derived from the limestone beds which contain chert, were found in the basaltic lava.

No ferromagnesian minerals could be recognised in the rock slides, as they have been totally broken down to chloritic masses.

The thickness of the volcanics is not known, but it is at least 400 feet. They form low, undulating topography in valley-fills with remnant trend ridges of limestone (forming inliers). Basic volcanics have been mapped also near and south of Barramine and in the area north of Yarrie and, from their appearance and position in the stratigraphical column, they both belong to the same phase of vulcanicity, which was probably late in the Upper Proterozoic or early in the Palaeozoic.

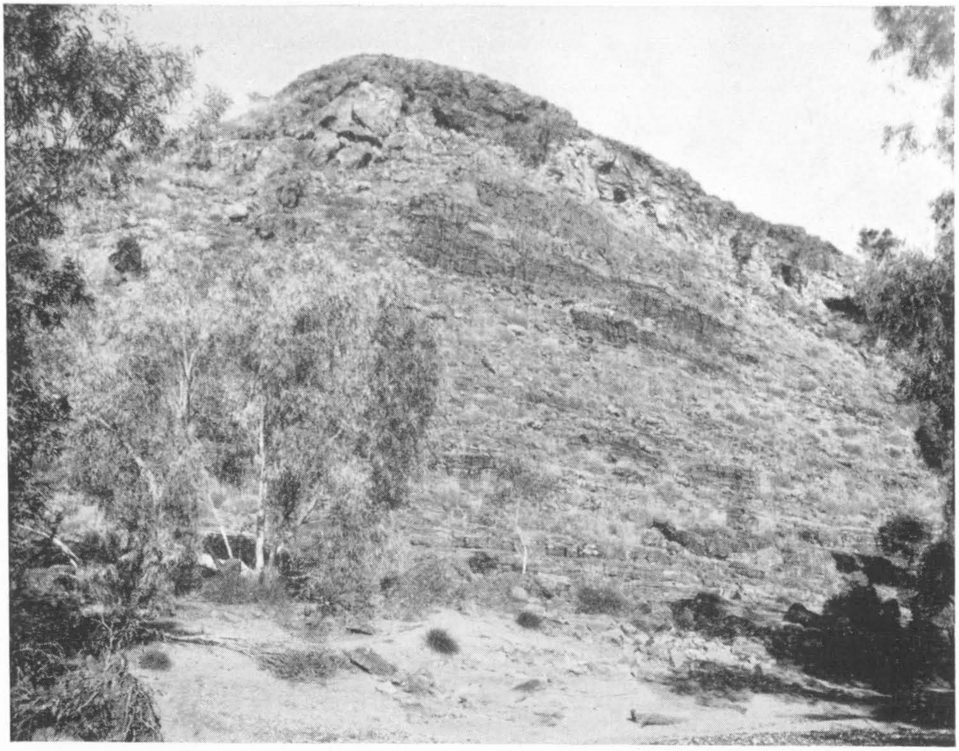

Fig. 10.—Breccia overlying dolomitic limestone, showing irregular contact.

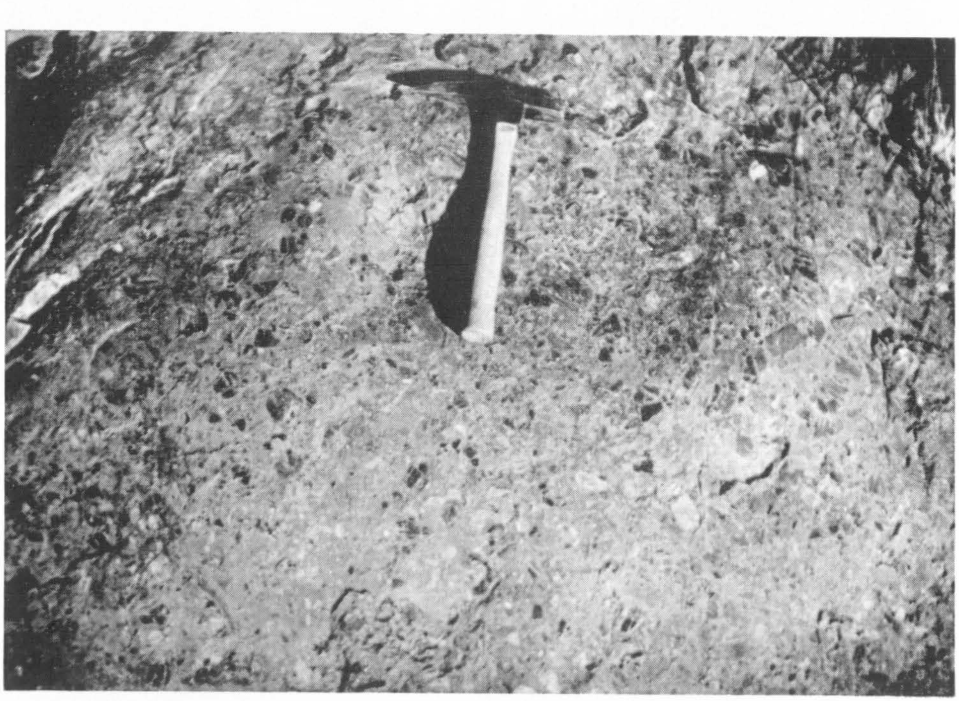

Fig. 11.—Breccia surface.

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Near Baramine, Blatchford (1924) records that "the basalt had caught up fragments of underlying quartzite".

The Upper Proterozoic sediments north of Yarrie have not been correlated with those exposed in the Little De Grey syncline; but no doubt more detailed mapping would establish the complete section for the area. In the hills between Eel Creek and Callawa Homestead at Y21, a 600-foot section of Upper Proterozoic sediments dips east-north-east at eight degrees. The section is:

	120 feet	(Jurassic) Callawa Formation.
	60 feet	(Permian) Braeside Tillite.
Upper Proterozoic	5 feet	sandstone, dark, ferruginous - represents unconformity.
	420 feet	sandstone, medium to coarse, with clay pellets, micaceous, white to yellowish, ripple marks in finer beds - ripples have amplitude of 1 inch and wave length of 6 inches, with a wave direction of 150°. Some shale bands and fine conglomerate lenses.
	2 feet	dolomite, pink, thin bedded.
	2 feet	sill or flow of basic volcanics.
	40 feet+	shale, green and dark purple, interbedded with thin beds of fine sandstone and siltstone. These basal beds of the section crop out in the banks at the head of Eel Creek.

At Y20, the section is:

	60 feet	(Jurassic) Callawa Formation.
Upper Proterozoic.	240 feet	basic volcanics, onion weathering, and ?pillow structures.
	10 feet+	shale, black and dark coloured.

The contact of the volcanics and shale in a hill a few hundred yards north-east of Y34 shows that the shale is baked to a dark slate near the contact, and that the volcanics flowed out on to an uneven surface of shale.

It is unlikely that this dark shale and locally developed slate seen in sections Y21, 20 and 34, is part of the Lower Proterozoic sequence ("Mosquito Creek Beds"); more likely it is equivalent to the shale at the base of the Upper Proterozoic section in the Little De Grey River syncline.

On the eastern side of Eel Creek at Y16, granite exposed on the valley floor is overlain by 50 feet of conglomeratic coarse sandstone with hematite and jasper pebbles. The sandstone shows current-bedding and, in places, grades into a fine conglomerate. It has been intruded by a hornblende-felspar porphyry. This section is very similar to the thick section of conglomerate sandstone which caps the hematite jasper at Y15, and forms the basal beds in the nose of the syncline (Fig.9). These two sandstones may be equated to the basal conglomerate of Maitland's "Nullagine Beds".

In the lower tracts of Eel Creek, the valley sides contain a very hard, massive chert breccia cemented with silica, which may be correlated with the breccia already mentioned. But in this area the breccia does not overlie dolomite and contains fragments of hematite jasper.

Sediments of Upper Proterozoic age crop out in the eastern portion of Paterson Range and Rudall Four Mile Sheets. The exact lithology is not known, but they are interpreted from photographs as sandstones and shales. Reeves (1949) reported a red sandstone and pebble conglomerate forming a 200-foot scarp overlying granite and "greenstone", two miles east of the well at the 759 Mile Post on the Rabbit-Proof Fence. This outcrop is on the eastern border of the Paterson Range Sheet.

The correlation of Upper Proterozoic rocks in Northern Australia is difficult because of incomplete knowledge of sequences, distributions, and orogenies; but the shales, sandstones, dolomites, and volcanics of this area distinctly resemble the King Leopold Beds, Warton Beds, Mount House Beds, and Mornington Volcanics of the Kimberley Block - a similarity noted by Maitland in 1904.

PERMIAN

Permian rocks form extensive but discontinuous outcrops throughout the Four-Mile sheets of Yarrie, Anketell, Paterson Range, Rudall and Tabletop. These Permian rocks overlap the Precambrian that forms the edge of the desert; sand-dunes , sand with "pindan" vegetation, and Mesozoic sediments cover the basin-wards (north-easterly) extension of the Permian.

Paterson Formation (Revised Name)

The formation name is derived from the type locality at Paterson Range (122° 10' E, 21° 45' S); the Range was named by W.F.Rudall in 1896 in honour of W. Paterson, the first manager of the Agricultural Bank of Western Australia.

Talbot (1920, p.71) referred to the rocks as the Paterson Range Series of sandstones and grits: "this strata is portion of the series of horizontal or slightly inclined sandstones that extend from near No.26 Well to the Kimberleys"; they were regarded as Carboniferous in age.

Reeves (1949, p.22) referring to the sandstones of the Paterson Range area, states that "granite and quartzite boulders in the rock talus at their base were not noted at higher positions and the simplest explanation of them is that they are a basal conglomerate and not glacial tillites. There .. no reason why glacial boulders should be confined to the base of a formation

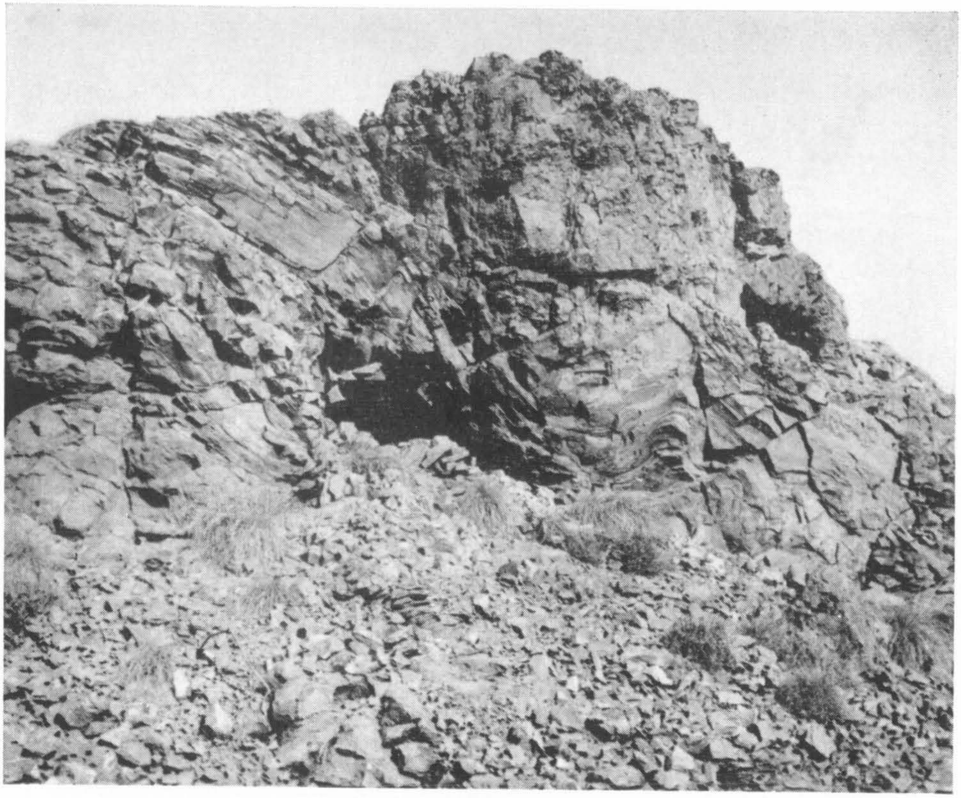

Fig. 12.—Contortion in Paterson Formation, north end of Paterson Range.

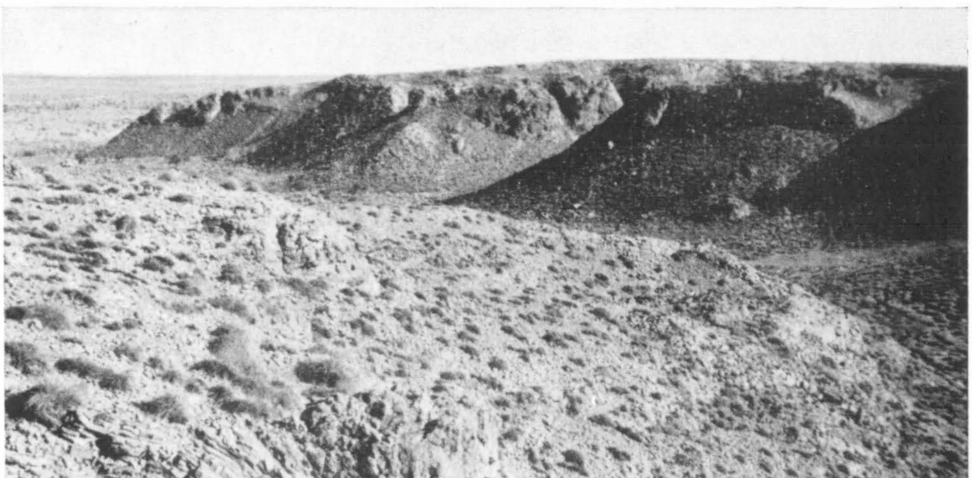

Fig. 13.—Paterson Formation, north end of Paterson Range, looking north.

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....no other evidence of glaciation was noted along the southern margin of the basin".

Fairbridge (1953) suggested that as "only sandstones and grits were described (by Talbot) it seems best to classify them as a formation, thus Paterson Range Sandstone".

The present authors suggest "Formation" rather than "Sandstone", as the sequence is of varied lithology. The lithology ranges from claystone to conglomerate: the sediments are unsorted and massive with evidence of slumping and local contortion within the beds, probably caused by over-riding icebergs. The cement is normally clayey or finely siliceous and not calcareous; in surface outcrop it is partly iron-stained, producing a mottled, pink-brown and white appearance; there is much more cement than rock fragments.

The size of the fragments ranges from less than one inch to a maximum of 3 feet; the smaller rock fragments are generally more angular than the larger ones; quartzite and granite predominate, with minor amounts of cleaved siltstone and quartz. No varved shales were observed.

The formation forms low rugged hills and mesas, capping Precambrian metamorphosed sediments. In the Paterson Range, 100 feet of glacial sediments were measured, comprising in descending order:

15 feet sandstone, medium-fine-grained (0.25 mm.), fairly well sorted.

20 feet conglomerate, unsorted, with pebbles from ½" to 6", some lenses of claystone breccia, which erodes to form caves.

5 feet sandstone, medium-grained (0.3mm.), with fine current-bedding. This grades downwards into coarser sandstone.

60 feet conglomerate, unsorted, with violet-coloured (iron- and manganese- stained) argillaceous cement. The boulders and pebbles (maximum 3 feet) are subrounded.

This was the thickest section observed in the field. Towards the top of the sections measured, intercalated stratified lenses are present; some of these lenses are contorted. Extension of the Paterson Formation over Precambrian has been mapped on the Rudall Four Mile sheet by photo - interpretation.

The Permian age of the formation is tentative; it overlies the Lower Proterozoic with a marked unconformity and in the Paterson Range area it is not capped by any younger sediment. However, owing to its position in the basin and lithological similarity, it is regarded as the equivalent of the Braeside Tillite in the Warrawagine area, which is overlain by Jurassic plant-bearing sandstone.

The glacials are correlated with similar glacial and fluvio - glacial sediments of the Grant Formation (Guppy, 1953, p.402) in the Fitzroy Basin, and with the Lyons Group of the Carnarvon Basin (Condon, 1954).

Braeside Tillite

The formation derives its name from the type locality, 2 miles north-north-west of old Braeside Homestead (121°E, 21°10'S.) on the Oakover River.

Clapp (1925) first used the name Braeside Tillite for outcropping rocks "2 miles north of Braeside Homestead and more than 100 feet below the tableland (capped by hard white opalescent quartzite) and intermediate between it and the valley bottom".

Reeves (1949) referred to the "siliceous limestones" of the Nullagine-Oakover Rivers as "Braeside Limestone " of Tertiary? age. The name Oakover Beds (Maitland, 1904) has priority for this Limestone, which is distinct from the underlying tillite named Braeside Tillite by Clapp.

The rock consists of boulders and pebbles, of varying size and angularity, set in a light grey clayey groundmass. The Tillite is exposed at the base of hills and, in the area between Warrawagine H.S. and Carawine Gorge, the exposed 60 feet of section is protected from weathering by a cap of limestone and chalcedony 30 to 50 feet thick of possible Tertiary age. Boulders and pebbles of granite, gneiss, schist, quartz, sandstone, and shale litter the plain: many of them are finely striated and their maximum diameter is 14 inches.

At Y35, 16 miles north-east of Yarrie Homestead at the head of Eel Creek, there is evidence of a glacial moraine with numerous subrounded striated boulders and pebbles of quartz, granite, gneiss, quartzite, vesicular basalt, jasper, quartz-hematite, chert-breccia, and sandstone; all these rocks crop out in the Precambrian of the Yarrie Four Mile sheet. The moraine is unsorted, unstratified, and unwashed, and is a mixture of boulders of all sizes up to 4 feet. Overlying the moraine and extending northwards (basinwards) from it is a succession of 50 feet of banded brown, red, and white varved shales; some beds contain rock fragments ranging from ¼" to 3", over and around which the fine varves have been deposited.

Five miles east of Warrawagine Homestead bores have penetrated this sequence (recognised as "blue clay with boulders" in the drillers' logs) to a depth of 334 feet at No.36 dry bore.

The total known thickness of the Tillite is approximately 400 feet (334 feet penetrated in a bore hole and 60 to 70 feet outcropping).

There is no direct palaeontological evidence for the age of this formation. Clapp (1925) stated that it is "probably of pre-Jurassic age" as it contains no chalcedony or limestone of the nearby tableland at Braeside Homestead; the tableland was regarded as possibly Jurassic by Clapp, and this is confirmed by Gibb Maitland in a personal communication to Clapp. Maitland (1904) originally ascribed a Tertiary age to the tableland. Clapp suggested that the Tillite "may be Permo-Carboniferous but it is in contrast to the very coarse, relatively dark, Lyons Conglomerate of the North-West Basin"; the other correlation Clapp made was with the possibly Cretaceous tillite, 350 miles farther south at Lake Garnegie, originally referred to by Talbot and Clarke (1917).

Teichert (1947 p.24) referred to the tillite occurrence near Braeside Homestead and suggested that it might be Permian in age.

At the head of Eel Creek, at Y22, the varved shales are overlain by the Jurassic sandstone, with a slight unconformity, and unconformably overlie the Nullagine sandstone. The Tillite is capped by the Tertiary? Oakover Beds between the Nullagine and Oakover rivers. As already mentioned the Braeside Tillite is tentatively correlated with the Paterson Formation, and also with the Grant Formation of the Kimberleys and the Lyons Group of the Carnarvon Basin; a tentative Permian age is assigned to it.

Two miles north of Carawine Gorge a glaciated pavement (roche moutonnee) was observed, and the Braeside Tillite was, at least in part, a terrestrial deposit formed by glaciers flowing down an old Nullagine-Oakover Valley; the Paterson Formation was possibly deposited in a marine environment.

<u>Cuncudgerie Sandstone</u> (New Name)

The formation derives its name from Cuncudgerie Hill (121°31'E, 21° 02'S), on the north-west corner of the Paterson Range Four Mile map; "Cuncudgerie" is an aboriginal name. The type locality is at the south-east edge of a plateau-like outcrop, 10 miles east-south-east of Cuncudgerie Hill; marine fossils were collected there.

The formation consists of a succession of sandstone, fine conglomerate and greywacke beds, the 100 feet measured at the type locality (P1 on Paterson Range Four Mile map) consisting of :

10 feet sandstone, coarse, and conglomerate, fine with pebbles $\frac{1}{4}$" in size; subrounded; dark ferruginous colour.

20 feet sandstone and greywacke, ferruginized, medium to coarse grained, ill-sorted; ripple marks, swash marks, clay pellets and worm tracks in this section. At the base of this ferruginous sequence is a 6-inch bed containing Permian marine fossils.

10 feet sandstone, medium to fine grained, well bedded, micaceous, yellow to white.

30 feet sandstone, massively bedded, medium grained, micaceous; brown-white colour; forms caves in the scarp. Indeterminate shelly fossils.

30 feet fine sandstone and claystone; well bedded; micaceous towards the base; multicoloured (violet, red, white, yellow); contains indistinct pelecypods.

The section measured at Cuncudgerie Hill totals 130 feet and is composed of :

20 feet sandstone, ferruginized, coarse to medium - grain (average grain size 2 mm.), subangular and poorly sorted; contains some pebbles 2" long; these pebbles are flat and lie in the bedding plane; current-bedding direction south-east.

30 feet sandstone, white to pink, medium-grained, with some larger quartz grains; easily eroded to form caves in the outcrops; yellowish - brown; massive beds.

50 feet sandstone, medium-grained, with worm tracks on the bedding planes and iron concretions and clay pellets; ripple-marked; beds have a distinct violet colour. Some small lenses of conglomerate in this section.

30 feet sandstone, dark, ferruginous, coarse-grained, at the base of the hill.

The total measured thickness of Cuncudgerie Sandstone is 130 feet and the known outcrop is very limited, though the formation probably extends round the basin margin, as do other Permian formations.

Thomas and Dickins (Appendix B) determined the age of the formation as Permian, from a study of the brachiopods, pelecypods, gastropods, and bryozoa.

The Cuncudgerie Sandstone is correlated with the Nura Nura member of the Poole Sandstone (Kimberley Division) and it shows a faunal link with the Callytharra Formation of the Carnarvon Basin.

Reeves (1949) reported "fragment of ?Conodont" of ?Poole Sandstone age, from a locality four miles north-east of Well 26 on the Canning Stock Route (Tabletop Four Mile Sheet). This could conceivably be a south-eastern continuation of the Cuncudgerie Sandstone; the extension of the Sandstone may conform with the edge of the basin.

Dora Shale (New Name)

The formation derives its name from Lake Dora (123°E, 22°S) one of the chain of salt-crusted "lakes" on the Tabletop Four Mile sheet; the lake was named by W.F. Rudall in 1897.

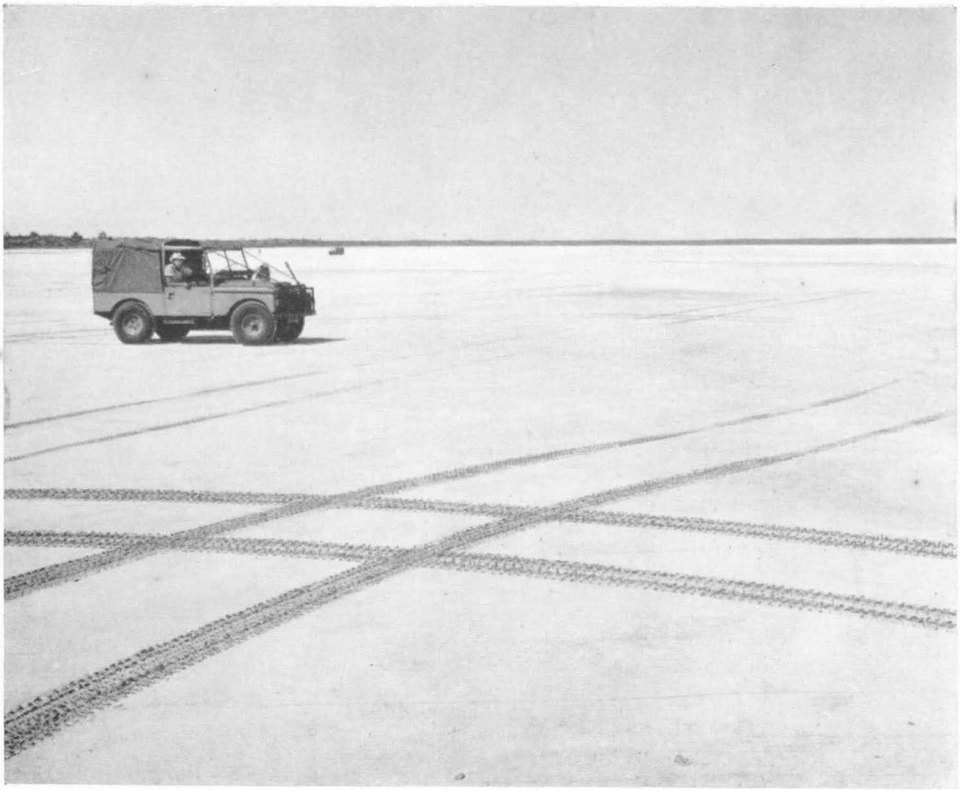

Fig. 14.—Lake Dora, showing salt crust.

Fig. 15.—Cliffs of Dora Shale, north-east shore of Lake Dora.

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The lithology is predominantly sandstone and shale; the texture, light weight, and pallid colour of the outcropping beds suggest that they may be decalcified. The known outcrops are confined to the eastern margin of the salt lakes Dora and Blanche; here they form cliffs 50 to 100 feet high, the salt crust of the lakes abutting against these cliffs. A vertical section at the north end of Lake Dora, 50 years from its margin, revealed:

0 - ½"	layer of white crystalline salt;
½" - 4"	gypsum crystals in a black silty moist matrix;
4" - 19"	sandstone, fine grained, brown, with a large quantity of salt water; contains foraminifera;
below 19"	sandstone, fine-grained, and hard shale that contains foraminifera of Permian age; this forms the bedrock of the lakes.

No sample of the bedrock of Lake Auld was taken, but it is considered that one reason for the existence of the Dora, Blanche, Auld chain of lakes is that they rest on the impervious Dora Shale.

The intermittent cliffs form only on the east edge of Lakes Dora and Blanche and no cliffs are evident on the west edge of these lakes or on either edge of Lake Auld.

The 40-foot section exposed on the north-eastern edge of Lake Dora consists of horizontal, well-bedded (beds 1 inch to 1 foot thick), micaceous, white, violet and yellowish claystone, containing thin worm trails and ?woody remains. Four beds in the section resist weathering and protrude as ledges; they are laminated ferruginous clay beds. The topmost bed consists of clay pellets and claystone breccia - the breccia is of the same material as the underlying claystone. This breccia bed is regarded as the top of the Dora Shale, over which lies the Triwhite Sandstone.

The soaks on the eastern side of Lake Dora are a result of seepage through the overlying sandstone, down to the impermeable Dora Shale. Dunn Soak, smaller soaks along creeks draining westward into the lakes, and other soaks found in depressions on the east side of the lakes, are explained in the above way.

Reeves (1949, p.32) records "flat lying shales and sandstone exposed in Scott Bluff at the northern end of Lake Blanche; similar shales and ferruginous sandstone exposed between Lake Blanche and Lake Auld show a 1-2° dip to north east ....Ammodiscus nitidus is recorded from Scott Bluff".

Miss Crespin (Appendix C) determined the microfauna from specimens collected at Lake Dora as Hyperamminoides acicula Parr and Ammodiscus nitidus Parr. These foraminifera are Permian in age and are widely distributed in the Permian rocks of the Carnarvon Basin and the Kimberleys.

Triwhite Sandstone (New Name)

The formation derives its name from three conical white-topped hills, 9 miles east of the northern part of Lake Dora at 123°30'E, 22°10'S. One mile to the west of these hills is a prominent flat-topped mesa 75 feet high, capped with conglomerate.

The known area of outcrop of the Triwhite Sandstone is very small and field evidence for its extension exists only on the Tabletop Four-Mile Sheet.

The type locality is one mile east of Dunn Soak, where fossils were collected from the iron-stained greywacke lying on the surface; at this locality the topography is gently undulating, with no mesa-like exposures.

The lithology is fine-grained to medium-grained sandstone with some fine conglomerate bands and lenses of claystone; oolitic greywacke towards the base of the section contains the marine fossils. The 65-foot section exposed in the 75-foot table-topped mesa six miles east of Dunn Soak consists of :

15 feet claystone and fine-grained quartz sandstone, micaceous, white, well-bedded.

45 feet sandstone, fine-grained to medium-grained, micaceous, white, well-bedded; gives a "holey" appearance in outcrop.

5 feet greywacke, fine-grained, micaceous, brownish, with worm tracks, ripple marks, swash marks, ironstone concretions and indistinct shelly fossil remains.

This section is capped by ten to fifteen feet of unsorted sandstone and fine conglomerate (regarded as possibly Mesozoic in age), which has a slight angular unconformity with the underlying Triwhite Sandstone.

At Triwhite Hills no shelly fossils were found, and the beds are expected to be higher in the section than the outcropping fossil bed near Dunn Soak. The dark ferruginous fine to medium-grained bedded sandstone at Triwhite Hills has many "leaf-like" worm feeding trails; these dark beds are capped by white friable sandstone.

The mesa section east of Dunn Soak was the thickest section measured; remnants of ferruginized sandstone with fossil fragments litter the rises.

The beds dip very gently to the east ($\frac{1}{2}^{\circ}$ - 1°), and if this dip is maintained for five miles until the sandstone becomes covered with the Mesozoic, a thickness of 200 feet to 300 feet may be estimated.

Glauert (1925) describes Permian fossils collected by L.Jones from "a low hill near No.27 Well, on the Canning Stock Route". These fossils could be similar to those found in the Triwhite Sandstone.

The age of the formation is based on marine fossil evidence (see Appendix B) consisting mainly of the pelecypod Astartila and gastropods Warthia and Ptychomphalina. These forms occur in the upper part of the Noonkanbah Formation and lower part of the Liveringa Formation of the Kimberley region; the Triwhite Sandstone is related to these units on fossil evidence and lithology.

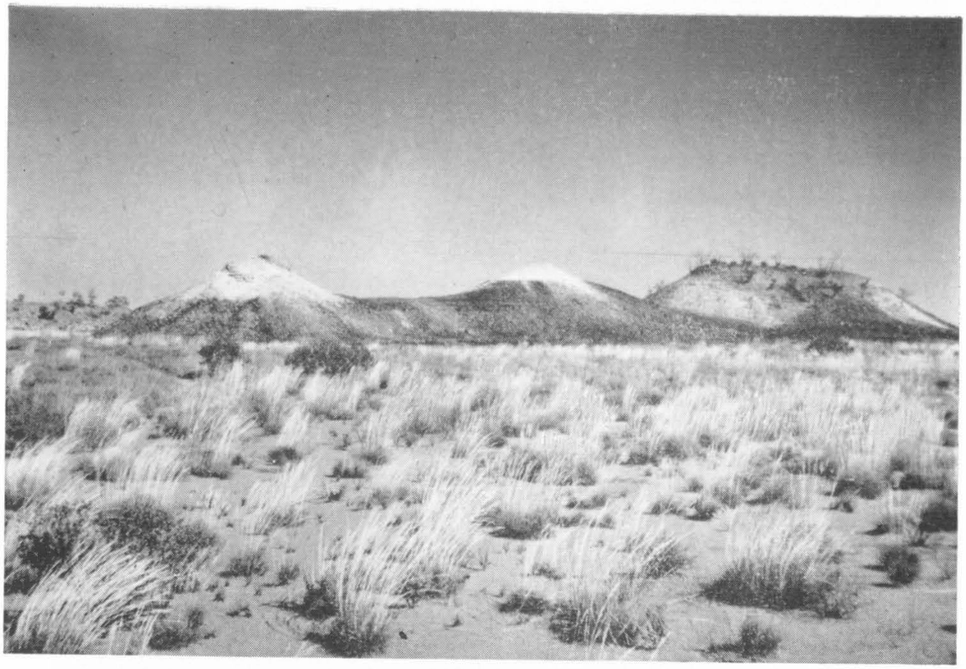

Fig. 16.—Triwhite Hills, looking south-west.

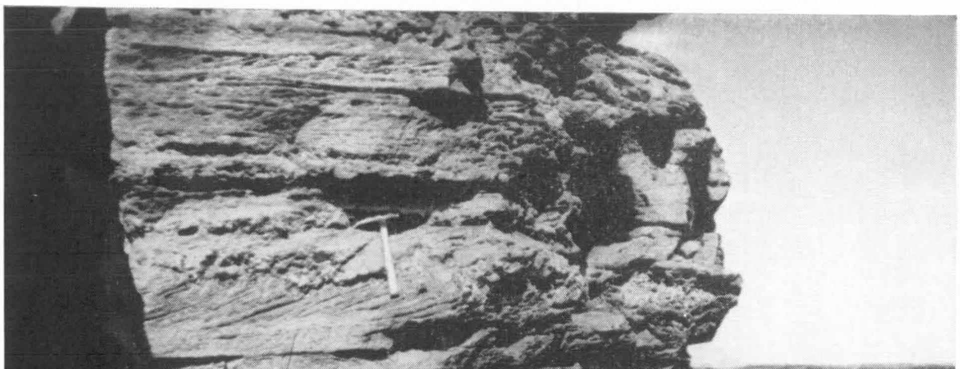

Fig. 17.—Coarse conglomerate and current bedding in Callawa Formation at Y20.

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MESOZOIC

Sediments of Mesozoic age overlie the Permian in the southern portion of the Canning Basin and extend north-eastwards towards the centre of the desert. These Mesozoic clastic sediments are largely covered with sand, seif dunes, and spinifex; the outcrops, mainly ferruginized sandstones, are scattered, intermittent, and low (rarely exceeding 100 feet). Permian and Mesozoic sediments are in many places difficult to distinguish because they are both predominantly ferruginized sandstone.

The mapped thickness of Mesozoic sediments is about 400 feet. Three lithological units are given the rank of formation; they are described in ascending order.

Callawa Formation

The Callawa Formation is named from Callawa Hills (120° 32'S, 20° 38'E) 10 miles north of Callawa Homestead; the Rabbit-Proof-Fence passes immediately to the south of these hills and the telegraph line to La Grange passes through them.

The name "Callawa Boulder Beds" was used by Reeves (1949) for a "series of cross bedded sandstones and boulder beds 200-300 feet thick forming the Callawa Hills north and north west of Callawa Station". The name is revised to "Formation" rather than "Beds" as a sequence of sandstones and conglomerates has been mapped.

The type section for the Callawa Formation is at Y22 near the head of Eel Creek on the Yarrie Four Mile sheet. The 170-foot section exposed there consists of:

70 feet conglomerate, coarse, containing rounded and subrounded boulders (6") and pebbles (3") of quartz-jasper, slate, basalt, porphyry; the beds are unsorted and have lenses of claystone; interbedded with this conglomerate are beds of medium-grained to coarse-grained sandstone (with scattered pebbles up to ¼") showing strong cross-bedding (the direction always is north or north-east i.e. basinwards). Some plant stems were found in the claystone lenses. The section is predominantly light red-brown.

100 feet claystone and sandstone, fine-grained to medium-grained; vari-coloured - white, violet, and mottled; well bedded; several beds or lenses of coarse-grained sandstones; plant stems, leaves and seeds.

This section rests unconformably on Permian glacial sediments. On the inland road to Wallal from Yarrie, two miles north of the Rabbit-Proof-Fence the conglomerate of the type section is overlain by:

45 feet sandstone, dark, ferruginized, coarse-grained, with angular quartz grains; the top 5 feet of this contains large clay pellets and plant stems measuring 1 foot long and 1 to 2 inches wide.

Two miles south of No.3 Desert Bore on the same track to Wallal, the sandstone with large plant stems is overlain by:

40 feet shale, violet and white, micaceous, breaking with a conchoidal fracture into 3-inch pieces. The top 15 feet of this section is lateritized, although the full sequence of ferruginous, mottled, and pallid zones is not evident. It is possible that this unit may represent a remnant of the younger Anketell Sandstone.

This gives a total measured section of 250 feet for the Callawa Formation.

A contact between the Callawa Formation (the conglomerate beds) and the underlying Braeside Tillite was observed at Y81 - in a low outcrop at the eastern end of the Rabbit Proof Wing Fence - and at Y85 - towards the top of an 80-foot ferruginized mesa, 15 miles north-north-east of Warrawagine Station, and near the head of Callawa Creek, where the telegraph track crosses the Rabbit Proof Fence.

The plant bearing beds of the Callawa Formation overlie unconformably a variable thickness of volcanics and baked dark shale in outcrops near the head of Eel Creek.

On the inland road to Wallal and along the Telegraph Line to La Grange the lithology of the conglomerate sequence changes very markedly ; the unsorted boulder conglomerate grades into a moderately well-sorted bedded sandstone containing scattered pebbles; in other words, the conglomerate grades basinwards into finer sediments. Less than 1 mile west of No.2 (Bilgarra) Desert Well on the track to Wallal , a hill of coarse (1-2mm. grain size), cross-bedded, ripple-marked quartz sandstone with conglomerate lenses represents the northward continuation of the Callawa Formation. This formation probably extends to Wallal, where it is overlain by travertine, clay swamps, and the recent Bossut Formation consisting of calcarenites containing many shell fragments.

The sediments are sub-horizontal; Reeves (1949, p.9) states "between Wallal and the southern margin of the (Canning) basin Jurassic sandstone and shale......show a northward dip of less than $\frac{1}{2}^{\circ}$". If the conglomeratic beds at Callawa Hills (about 600 feet altitude at the top of outcrops) are the same as those near Wallal, then the elevation difference alone indicates over $\frac{1}{4}^{\circ}$ dip to the north.

At A.11 on the central portion of the Anketell Four Mile Sheet, the conglomerate is represented by dark ferruginized coarse sandstone outcrops, 20 to 40 feet high, containing some woody remains; the outcrops are mostly below the dune crests and are visible only in the troughs between the dunes. In this area the conglomeratic sandstone is capped by the Anketell Sandstone. A similar lithology is present at T5 and between Lakes Dora and Auld on the Tabletop Four Mile Sheet.

The 50-foot section four miles east of Lake Auld at T5 consists of:

2 feet sandstones, coarse-grained, unsorted, light brown; lateritized.

5 feet conglomerate, fine (maximum pebble $\frac{1}{4}$"), with some coarse-grained sandstone. Current bedded, many clay pellets. Moderately sorted.

35 feet sandstone, medium, unsorted, light brown, with many worm tracks.

The boulder conglomerate of the Callawa Formation is confined to the northward continuation of the Oakover and Nullagine River systems, and it is suggested that it is a deltaic conglomerate deposited near a river mouth at the margin of a large fresh-water Jurassic lake; the river system probably flowed northwards during the Mesozoic era.

The Permian glacial sediments provided a ready and ample source for the large thickness of rounded boulders in the Callawa Formation.

The Callawa Formation is overlain by the Anketell Sandstone of Cretaceous age. The age of the Callawa Formation, based on plant species determined by R.O. Brunnschweiler, is possibly Jurassic, although an upper Triassic age (equivalent to the Erskine Sandstone of the Fitzroy Basin) cannot be ruled out (see Appendix A). The significant plants determined were Johnstonia cladophlebis, Paliophyllum, Sphenopteris and Dictyophylium; no Thinnfeldia was seen. Reeves (1949) records "Otozamites sp.nov. from $4\frac{1}{2}$ miles S20°E of the Rabbit-Proof-Fence gate and 14 miles NW of Callawa Station"; the present collection was made from a similar locality, but Otozamites was not recorded.

It was only the absence of Thinnfeldia that suggested a younger age than Upper Triassic (Erskine Sandstone of the Kimberley Region): the presence of Johnstonia suggests a late Triassic age, as this form occurs only in the late Triassic in Tasmania and Queensland.

The formation cannot be correlated directly with any formation in the northern part of the Canning Basin; it could represent a freshwater time equivalent to the Jurassic Alexander Formation or Jarlemai Siltstone, or it could be equivalent to the upper Triassic Erskine Sandstone.

Anketell Sandstone (new name)

The name is derived from the Anketell Four Mile Sheet, named after the explorer R.J. Anketell who crossed this area in 1906 on his way north to the Fitzroy River. The type section is at a hill T7 (124° 20'E, 22° 8'S), 16 miles east of the northern portion of the Lake Auld on the Tabletop Four Mile Sheet; this hill is 40 feet high and is part of a small dissected plateau which gradually disappears under sand cover towards the east. Beds containing numerous casts of the marine worm Rhizocorallium occur at the base of the hill.

Rocks outcropping at A8 on the Anketell Sheet have casts of Rhizocorallium and Cretaceous foraminifera, and this fossil evidence and similar lithology are a means of correlating the rocks at A8 and T7 and grouping them as the Anketell Sandstone.

The formation crops out in the eastern portion of the Tabletop Sheet, the central portion of the Anketell Sheet, and some isolated outcrops may cap the Callawa Formation in the northern portion of the Yarrie Sheet. In all places it overlies the coarse ferruginized sandstone of the Callawa Formation.

The formation consists of sandstone and shale, with several small beds or lenses of fine conglomerate. Foraminifera and Rhizocorallium indicate the Cretaceous age of the formation and prove a marine or brackish-water origin for the beds.

The 40-foot type section at T7 consists of:

23 feet sandstone, medium-grained, micaceous, pallid, lateritized. Small cracks and joints tend to produce rock holes and caves towards and on the summit of the outcrops.

2 feet sandstone, coarse-grained, ripple-marked, with many Rhizocorallium worm tracks

15 feet sandstone, medium-grained, ferruginized, bedded, ripple-marked, with some worm tracks.

On the Anketell Four Mile Sheet, a maximum of 70 feet of the Sandstone was measured; at A8 Rhizocorallium and foraminifera were found in the 30 feet hill of white fine micaceous sandstone capped with siliceous mottled clay-stone.

The total thickness of this formation is 50-100 feet. The Cretaceous age is based on fossil evidence; the formation overlies the plant - bearing ?Jurassic Callawa Formation and is capped at A-11 (Anketell Four Mile Sheet) with 8 feet of coarse sandstone containing no pebbles or worm tracks; this may be the base of a younger formation that may extend north-eastwards towards the central portion of the basin.

The presence of Rhizocorallium, a diagnostic Lower Cretaceous marine worm, common in the Rumbalara area of northern South Australia, and determined by Dr.Opik, and of arenaceous Lower Cretaceous foraminifera from A8 determined by Miss Crespin (Appendix C), proves the age and marine or brackish cold-water environment of the beds.

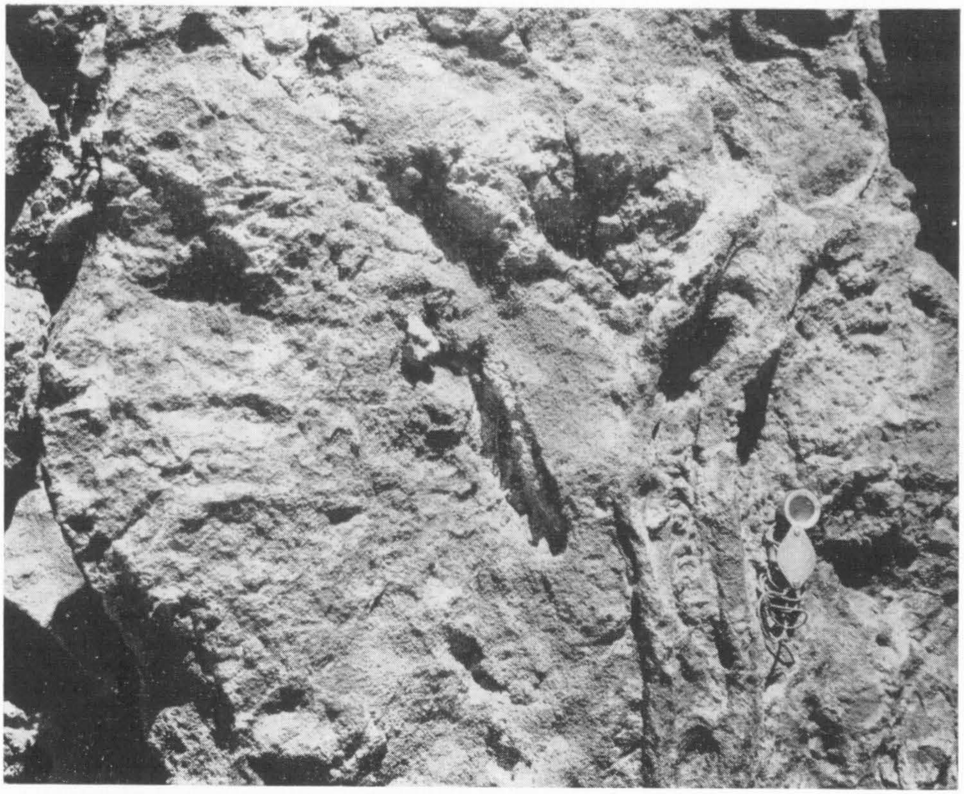

Fig. 18.—*Rhizocorallium* in Anketell Sandstone.

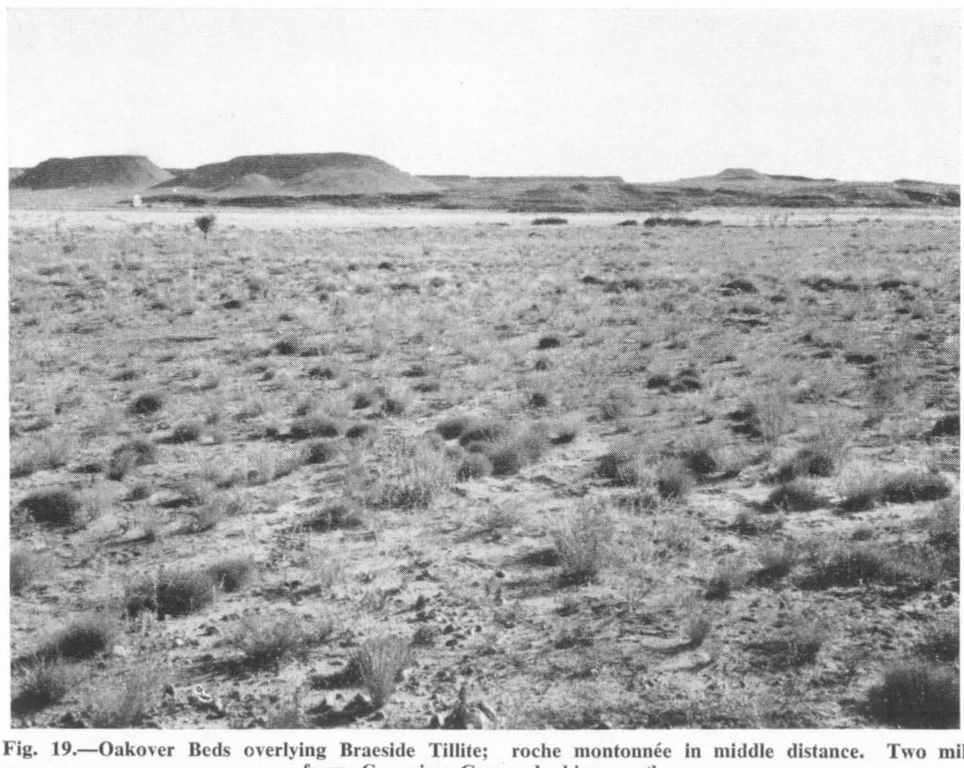

Fig. 19.—Oakover Beds overlying Braeside Tillite; roche montonnée in middle distance. Two miles from Carawine Gorge, looking south.

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The formation may be the time equivalent of the Dampier Group (Neocomian) of the Broome region.

TERTIARY

Laterite

There is no definite evidence to suggest that the area was covered with a thick mantle of laterite such as is generally found farther north, but at least some separate parts of the area were lateritized.

The occurrences of laterite are irregularly distributed. This may be due to either or both of the following reasons:

(a) a variation of lithology of the outcropping Jurassic and Cretaceous sediments: where the outcrops are of sandstone, very little lateritization can be expected - only poorly cemented iron-stone and ferruginized sandstone - but where the outcrops are of claystone, a massive resistant laterite profile may be developed;

(b) a long period of erosion since the formation of the lateritic surface.

Between Yarrie and Wallal some of the isolated sandstone hillocks show evidence of lateritization, e.g. at Y25, 2.6. miles south of Desert Bore No. 3; this hill has a 15-foot capping of ferruginous-zone laterite overlying 25 feet of mottled claystone.

Twelve miles south of the first catchment on the telegraph line north of Callawa, the hills are capped with a 12-foot ferruginous zone overlying a mottled zone of claystone.

Remnants of laterite were examined east of Lake Waukarlycarly at P8, where 20 feet of ferruginous zone overlie a mottled zone about 20 feet thick.

The northern end of Paterson Range is capped in places by laterite.

Twelve miles north of Carawine Gorge the Oakover Beds overlie 5 feet of pisolitic ironstone gravel; this gravel was possibly formed at the same time as the lake, on higher land, and was then washed into the floor of the lake before chemical deposition of the Oakover Beds began, or the gravel may have formed before the lake and therefore was older than Oakover Beds.

The sand, which masks most of the outcrops in the desert, originates either directly fromthe underlying ferruginized Mesozoic and Permian sandstones or possibly from the disintegration of a poorly formed laterite over sandstone. The red sands are composed essentially of quartz grains coated with a film of iron oxide. If they were derived from a laterite rather than from a ferruginized sandstone source, the iron oxide coating the sand grains would probably have more hydroxyl radical than hydrated oxide in its composition; chemical tests have so far been unable to prove from which source the red sands were derived.

In the Canning Basin, pisolitic bog-iron deposits, possibly of Tertiary age, may be confused with laterite; these deposits may be formed at the same time as, or immediately after, the laterite, and could therefore derive iron from it. These iron deposits are below the level of the laterite profiles. A hill 20 miles east of Port Hedland is capped with 20 feet of pisolitic ironstone which resembles a ferruginous zone of a laterite; but it contains fossil wood and probably has a lacustrine origin. Chemical analysis of this deposit shows:

	%
Loss on ignition at 100°C	13.80
SiO_2	1.89
Fe_2O_3	77.50
Al_2O_3	8.75

Oakover Beds

The name "Oakover Beds" was used by Maitland (1904) for the "sandstones, limestones, cherts etc. which form the table-topped hills in the vicinity of the Oakover River". The "horizontal beds of silica" in the Oakover River Valley had already been referred to but not named by Smith (1898).

In this report Oakover Beds is the name used for the travertinous limestone and silica which form cappings on the isolated hills in the Oakover River Valley and on the northern end of the Gregory Range. Farther south from the area surveyed, good exposures of the unit were examined near Carawine Pool, where they unconformably overlie Upper Proterozoic dolomitic limestone. Harris (1926) stated that the unit was exposed as "buttes near Braeside homestead" and was of "Jurassic Age".

Reeves (1949) referred to the unit as "Braeside Limestone", an invalid name, first because "Oakover" has priority, and secondly because the geographical name "Braeside" is preoccupied in the ?Permian Braeside Tillite.

At least 40 feet of limestone and limestone-breccia are exposed in the well two miles south of the junction of the Wing Fence and Rabbit Proof-Fence and 4 miles west of Mt.Cecilia, and 60 feet of similar sediment crop out in the surrounding hills, giving a total thickness of at least 100 feet of Oakover Beds in this area. The top 20 feet consist mainly of clear to milk-white silica in the form of common opal and chalcedony. Below this horizon the sediments are mainly calcareous, but contain nodules of silica.

In the hills two miles north-east of Carawine Pool 85 feet of Oakover Beds crop out and overlie the Braeside Tillite. The top beds consist of six feet of clear to milk-white silica overlying white to brown limestone and limestone-breccia containing silica nodules.

At Y2 two small areas of limestone capped by silica are exposed near Eel Creek, 3 miles north-east of Yarrie Homestead on the Callawa road; they are tentatively included in the Oakover Beds. The Oakover Beds are nowhere overlain by any other unit, but their contact with the underlying units of Braeside Tillite and Lower Proterozoic metamorphics was examined. The contact with the Braeside Tillite is not well defined because the calcium carbonate from the Oakover Beds has permeated the top beds of the relatively porous Tillite. A bed five feet thick containing numerous ferruginous concretions and pisolitic ironstone probably marks the base of the Oakover Beds. The Oakover Beds at the northern end of Gregory Range unconformably overlie the Lower Proterozoic metamorphics. The direct relationship of the Oakover Beds to the Callawa Formation and other associated Jurassic sediments was not seen in the field. But no boulders of silica from the Oakover Beds were seen in the conglomerate of the Callawa Formation, although the postulated source of the latter was from the south; therefore, it is reasonable to assume that the Oakover Beds are post-Jurassic.

The lithology and distribution of the Oakover Beds suggest that they are a chemical lacustrine deposit in the old Oakover River Valley. Limestone and silica were deposited from solution, and the limestone breccia indicated periods of desiccation. Deposition of most of the silica at the top of the unit shows that in the last stage of the lake's history its water was saturated with silica.

No fossils have been found in the unit, possibly because the concentration of salts inhibited life.

Maitland(1904) suggests a Tertiary age for the Oakover Beds. Clapp (1925) correlated the Beds with the conglomerate at Callawa Hills and assigned them to the Jurassic. Finucane (1938) preferred a Permo-Carboniferous age but gave no reasons.

It is known that the Beds are younger than the Braeside Tillite, that is, post-Permian; and it is highly probable that they are younger than the Jurassic Callawa Formation. The lithology and distribution suggest that the lake was formed in the Tertiary Period by a blockage of the Oakover valley by the Jurassic and Cretaceous sediments, thus indicating a Tertiary, or at least late Cretaceous, age for the Beds. This is further substantiated by the presence of common opal in the silica. The isotropic opal crystallizes with age - as a volcanic glass devitrifies - and although the time for this process must be governed by numerous physical factors, the presence of common opal suggests a post-Mesozoic age.

If the scattered pisolitic ironstone pebbles at the base of the beds have been derived from the laterite (accepted as Oligiocene-Miocene in Northern Australia) then the Oakover Beds are post-laterite.

The lithology and mode of occurrence of the Oakover Beds very closely resemble those of Tertiary deposits in the East Kimberleys and Northern Territory, but as they are all isolated lacustrine deposits occupying a small portion of Tertiary time, correlation is impossible.

QUATERNARY

Superficial deposits in great variety, probably of Quaternary age, overlie and conceal bedrock throughout the region, and as they are only a thin veneer over the older sediments they have not been given formation names; the most widespread of these deposits is wind-blown sand.

In the coastal belt near Wallal Station, the sand is white and has been blown and washed into low irregular coastal dunes that have been cemented with lime to form a "Coastal Limestone" (named the Bossut Formation by WAPET geologists in 1955) composed of quartz and fragmentary marine shells. In the interior, the sand is ironstained quartz, red and brown, and is blown into long parallel seif dunes (Bagnold, 1941, p.222) that are now partly fixed by vegetation; only patches on the summit show any tendency to migrate westwards. The sand is medium-grained, increasing to coarse-grained where it overlies (and probably originates from) granite. The interdune valleys have a floor of sand; the depth to bedrock is unknown, but travertine protrudes through the sand in places. The sand probably has not been transported far from its source because the sands are not well sorted; Permian foraminifera found in the "recent" deposits within Lake Dora have been transported a maximum of three miles which is the easterly extent of outcropping sandy shales containing these foraminifera. No extensive area of low outcrop is completely transversed by dunes. The sand is migrating from the east to the west.

An investigation of sand samples collected in the desert is being carried out by J. Ward of the Bureau of Mineral Resources; some of his results are given below. The sands, except for the small percentage of heavy minerals, have grain sizes between 0.43 and 0.25 mm. The most northerly sample, A2, is the finest; this sand was probably derived from Cretaceous fine-grained sandstone. Libyan Desert sands have a diameter of 0.8 to 0.08 mm., and Simpson Desert sands between 0.24 and 0.06 mm. There was less than 1% of heavy mineral in the samples, except for P5 which gave 2%: this sample was taken from a dune overlying granite outcrops. The median diameter of the heavy mineral grains increases from .095mm in the west to 0.154mm in the east, and these grains are poorly sorted, indicating that they are close to the original source rocks.

Only the larger river systems in the Yarrie Sheet have valleys filled with alluvium.

The floors of the large salt-pans and clay pans in the desert are covered with a deposit of thin-bedded clay or silt and evaporites; the latter will be described under "Evaporites". The silt probably only amounts to a few feet, although no excavation has been made through it to bedrock.

TECTONICS

The study of the development of the structures of the Canning Basin and the surrounding areas, since the Precambrian, may show the type and thickness of deposits to be expected in the central part of the Basin, but now obscured by wind-blown sand. Although the tectonic history of the Precambrian areas bordering the Canning Basin is only partly known, what is known must be examined for indications of the possible Precambrian and Palaeozoic history of the Canning Basin.

Unconformities show that the oldest tectonic units in the area under consideration are the Halls Creek Metamorphics of the northern margin of the Basin and the metamorphic and granitic rocks of the Pilbara region at the southern margin. Near both margins these tectonic units crop cut as inliers far into the Palaeozoic Basin.

Resting unconformably on the rocks of these oldest tectonic units, generally at some distance outside the margin of the Basin, are sediments and volcanics generally only moderately deformed. The northern Kimberley block probably derived its sediment from the south (in an area stretching from near the northern margin of the Canning Basin for an unknown distance to the south). The southern "Nullagine" sediments (Fortescue block) possibly derived from the north, within the Canning Basin. It therefore seems likely that in the Upper Proterozoic large areas of the northern and southern parts of the Canning Basin were actively eroding.

By Lower Ordovician times the northern area at least had submerged, and the areas of deposition of the Kimberley Plateau and the "Nullagine" sediments were probably land masses contributing sediment. If similar Upper Proterozoic sedimentation had taken place in the central part of the Canning Basin it is likely that that unit, too, would have emerged, and like them remained elevated and eroding to the present day.

It seems most likely, therefore, that the floor of the Canning Basin is very largely of the older Precambrian folded, metamorphosed, and granite-intruded rocks, and that the Palaeozoic sedimentation starting at latest in the Lower Ordovician covered much of the Basin and was interrupted by only minor emergences.

Airborne magnetometer investigations by the Bureau in 1954 and 1955 have indicated "depressions" in the basement which may contain 10,000 to 25,000 feet of sediment; the "depressions" are separated by "ridges" which trend west-north-west, and which may have only between 2,000 and 3,000 feet of sediment (personal communication of profiles, by Clarke, 1956). A sharp increase of 3,000 gammas (compared with about 500 for adjoining rocks) occurs about 15 miles east of Warrawagine and corresponds to the north-west-trending Isabella Range consisting of Lower Proterozoic schists, slate (with copper mineralization), and hematitic jasper, all intruded by granite. A similar "ridge" has been indicated by magnetometer work near Wallal, and it probably represents the subsurface continuation of the Isabella Range. This continuous ridge may have been an important easterly barrier to the north-flowing Oakover-Nullagine River system in pre-Permian times and the ridge may have influenced the deposition of the Braeside Tillite in this area.

A second major ridge is indicated near Anna Plains, trending south-east to the central part of the Anketell 4-mile sheet. This ridge may have a direct relation to the small faulted monocline on the Anketell sheet.

It is important to know whether the Precambrian underlying the Canning Basin sediments (outside the Fitzroy Basin) has been continuously submerged or whether it has undergone only shallow transgressions during the Permian and Mesozoic.

Fossils and lithology studied in the south-west and, more recently, in the north-east Canning Basin show that a shelf-type environment existed in Permian time. The centre of the Basin is covered by sand and Mesozoic and Permian sediments, and the behaviour of the Precambrian basement in Palaeozoic and Mesozoic time can only be surmised in a very general way.

If it was a continuous area of deposition rather than denudation it would materially enhance the petroleum prospects of the Canning Basin. A magnetometer profile drawn across the basin, showing 300-gamma increases over 10 to 20 miles, could be interpreted as showing either (a) a considerable depth of sediment over a changing Precambrian basement, or (b) a thin sedimentary veneer over a uniform basement.

Further detailed geophysical work or exploration drilling is required before an accurate picture of the pre-Permian geology of the central and south-western Canning Basin can be elucidated.

The Permian and Mesozoic sediments have been slightly affected tectonically; a small angular unconformity was observed between the Triwhite Sandstone and the Mesozoic sandstone **and** conglomerate near the Triwhite Hills. The Permian sediments were slightly folded before the deposition of the Mesozoic, and this folding is responsible for the position of the Dora Shale which forms the salt lake arc; these salt lakes trace the Shale outcrop, and show a syncline between Lakes Dora and Auld and probably an anticline between Lakes Auld and Percival. The Shale is known to have a 1° N.E. dip near Lake Blanche, and the Triwhite Sandstone dips $\frac{1}{2}^{\circ}$ to 1° E.N.E. at Triwhite Hills.

Slight tectonic movements have affected the Mesozoic; this is shown in a small north-elongated fold extending south from A 11 on the Anketell Sheet. The fold is probably monoclinal as the same bed dipping 4° to the east is repeated; only minor evidence of faulting is seen on the surface.

GEOLOGICAL HISTORY

The oldest rocks of the area are the Lower Proterozoic metamorphics, granite, and pegmatite, which form part of the Pilbara Tectonic Zone. These sediments and volcanics were severely folded, metamorphosed and granitized, and subsequently intruded first by dolerite dykes and later by quartz veins. They were eroded before the Upper Proterozoic transgression during which sandstones and dolomitic limestones were deposited. The Upper Proterozoic sediments were gently folded and uplifted before the outpouring of lavas and the possible sill-like intrusion of quartz-felspar porphyry. Perhaps, at the same time as the volcanic activity was filling valleys and areas of low relief, the chert-nodular dolomitic limestone was weathering on the higher regions to form a chert breccia and, in places, a manganiferous breccia.

The dolerite dykes may belong to a different phase from the quartz veins and pegmatites, and may be feeders for the Upper Proterozoic lavas. They were seen only in the areas of granite outcrop, and were never observed to cut the Upper Proterozoic sediments. However, the dyke direction is similar to the joint direction in the Upper Proterozoic sandstone.

No early Palaeozoic deposits have been found (unless the volcanic outpourings and breccia formation could be classed as ?Cambrian) either because all the Pilbara Tectonic Zone remained a surface of denudation until Permian times, or because lower Palaeozoic sediments had been eroded before the transgression of the Permian sea. The first post-Precambrian record was the glacial or fluvioglacial deposits of the Braeside Tillite and Paterson Formation of probable Permian age. The Permian sea may have entered from the north or north-west, and these glacial sediments may have filled the valleys formed by land glaciers as they moved towards the transgressing sea.

The marine fossiliferous Cuncudgerie Sandstone was deposited in an epeiric sea either contemporaneous with or after this glacial deposition; the Cuncudgerie Sandstone was followed conformably by the Dora Shale and Triwhite Sandstone.

Very gentle folding or uplift followed the deposition of Permian sediments. No Triassic sedimentation was recorded (except perhaps, for the freshwater Callawa Formation) but during the early Triassic the Permian rocks were slightly folded and truncated.

The late Triassic or early Jurassic Period probably began with deposition in freshwater lakes, when lacustrine sandstones and coarse conglomerates of the Callawa Formation were deposited. The Pilbara Tectonic Zone maintained a high relief and with the glacial deposits formed a source for the large deposit of pebble and boulder conglomerate and current-bedded sandstone in the Callawa Formation: this conglomerate grades into sandstone to the north and east of Callawa Hills.

In the Cretaceous Period an epeiric sea flooded the area and the Anketell Sandstone was deposited on the Triassic-Jurassic sediments with no apparent major break.

During the Tertiary, the "Oakover-Nullagine" river system, which was probably a major feature throughout the Permian and Mesozoic, was blocked, possibly by the uplift after the Cretaceous deposition, and formed a lake in which the Oakover Beds were deposited. The relief at this time was probably very low, enabling chemical deposition to take place in the lake.

This northerly-trending river system was captured by the westerly trending "De Grey" River, which resulted in the initiation of a new cycle of erosion and deposition expressed in the topography of today.

GEOMORPHOGENY

The development of the broad topographic divisions of the region is closely allied to its tectonic history, and many relics of older surfaces are now visible. The post-Cretaceous surface has probably undergone little or no tectonic change since the deposition of Cretaceous sediments.

Present day monadnocks such as Mt. Crofton and Lamil Hills are formed of steeply-dipping hard Lower Proterozoic quartzite which has been eroded to form smooth low hills - an unusual topographic expression for resistant steeply-dipping beds. These monadnocks represent remnants of an older topography and they probably even formed large islands in the Permian and Mesozoic seas. Lower Proterozoic metamorphics occupy the elevated borderland hills as well as forming the monadnocks in the desert area.

Some laterite formed probably after the emergence of the Cretaceous sediments; it was dissected and eroded and at least part of the wind erosion products formed the present sand within the Basin. In the Carnarvon Basin the main lateritization is Oligocene.

More recently seif dunes and playa lakes have developed. The dunes are younger than the laterite as they traverse the dissected laterite crusts capping the basin sediments. The dunes are now semi-permanent, which indicates that during their initiation, growth, and migration to their present position, the climate was very much more arid than at present. The iron-coated sand forming the dune has originated from the easily eroded arenaceous rocks or from the laterite or from both sources; the disintegration of the country rock has been accelerated by an arid climate; and constant prevailing bi-directional winds have formed the sand into parallel seif dunes. Bagnold (1941) summarised the evidence that seif dunes are formed by two winds blowing in slightly different directions. The Australian wind roses are not unidirectional; there is a close relation between the dune direction and the wind rose as is shown in Figure 20.

The playa lakes were probably formed in the same arid period as the sand dunes. The lakes occupy depressions in the general level of the desert, and evaporation removes a volume of water proportional to the surface area, preventing the lakes from overflowing and forming integrated systems of drainage. With the continued migration of water through the sediments of the basin, the waters of the lakes become increasingly saline and salts are precipitated from solution: in most months of the year the lakes dry up completely, leaving plains of saline silt. These shallow scattered salt lakes are termed playas and owe their existence to an impervious basement of Permian shales. The floor of such lakes gradually fills up as deposits accumulate in the basin; and floors of separate basins are entirely independent of one another.

The south-western border of the desert has developed quite differently. It probably formed the edge of most of the Palaeozoic and Mesozoic seas. The main river system (the Nullagine-Oakover) can be retraced to the Permian, when it probably formed in a valley filled with the Braeside Tillite; two miles north

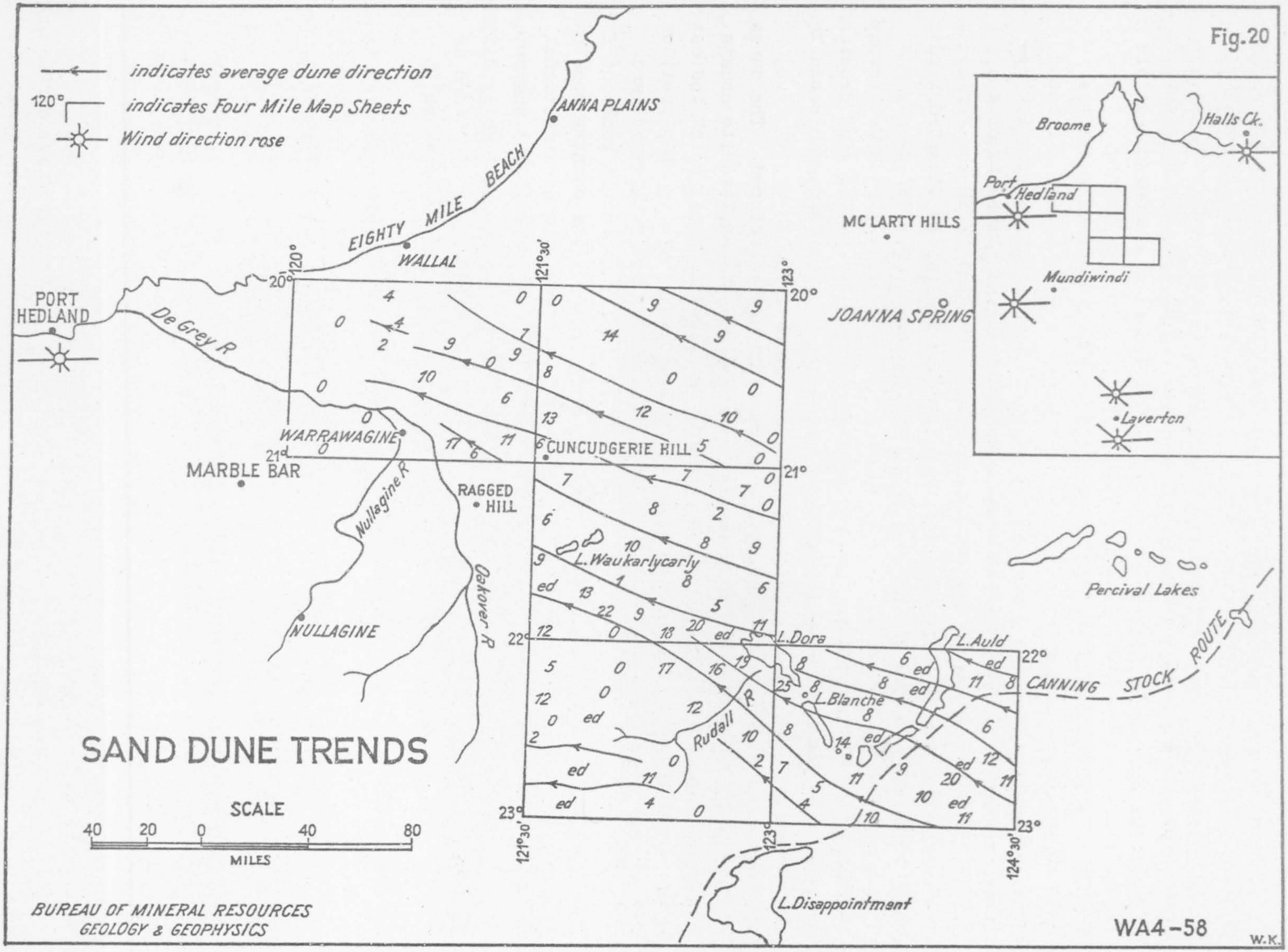
Fig.20
indicates average dune direction
indicates Four Mile Map Sheets
Wind direction rose
ANNA PLAINS
EIGHTY MILE BEACH
WALLAL
PORT HEDLAND
De Grey R
MC LARTY HILLS
JOANNA SPRING
Broome
Halls Ck.
Port Hedland
Mundiwindi
Laverton
WARRAWAGINE
MARBLE BAR
CUNCUDGERIE HILL
RAGGED HILL
Nullagine R
Oakover R
NULLAGINE
L. Waukarlycarly
L. Dora
L. Auld
L. Blanche
Rudall R
Percival Lakes
CANNING STOCK ROUTE
L. Disappointment
SAND DUNE TRENDS
SCALE
MILES
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of Carawine Gorge, a low glacially striated pavement was observed where the glacier had moved to the north-west. This river valley was again prominent in the Tertiary and was occupied by a large lake, in which were deposited the Oakover Beds. The chemical deposition of these sediments shows that the surrounding country had little relief and there was little mechanical erosion at the time.

The capture of this old north-flowing system by a west-flowing De Grey River system possibly drained the lake and initiated the present-day drainage system. Eustatic movements have allowed the rivers to cut back at their headwaters and dissect the Oakover Beds, producing 100-foot mesas and buttes. The De Grey River and the lower reaches of the Nullagine and Oakover Rivers are now mature rivers flowing through wide alluvial valleys. Granite outcrops form extensive plains over which flow major rivers; these are now independent of the underlying rocks, but the smaller tributaries are still downcutting their beds during the wet months, to produce the present dissected hills. This dissected area is semi-arid and supports little vegetation, and the ground is ineffectively protected against erosion. Well graded slopes on the hills are rare: rock outcrops and rugged hill-profiles still persist even at this stage of maturity . No piedmont plains have been formed, which indicates that the streams are capable of transporting the weathered loads. In the desert area, any piedmont deposits have been partly assimilated in the sand dunes and wind deposits of the basin.

Tertiary sedimentation and diastrophism were on a small scale; and the geomorphogeny of the area reflects many old land surfaces dating back to the Precambrian.

ECONOMIC GEOLOGY

PETROLEUM PROSPECTS

The south-western part of the Canning Basin is a sedimentary area bordering the Pilbara region of Precambrian rocks. Rock exposures at this edge of the basin indicate the type of rock units to be expected in the centre of the basin, although the area itself has no petroleum potentialities.

In the Oakover Valley, the Oakover Beds, with a maximum thickness of 150 feet, consist of lacustrine unfossiliferous limestone and chalcedony, and overlie the Permian terrestrial Braeside Tillite. The Tillite is about 400 feet thick, and probably rests directly on Precambrian rocks, so that no source rocks for petroleum exist in the valley.

Near Paterson Range, about 100 feet of Permian Paterson Formation, an unfossiliferous massive unsorted sediment of glacial or fluvio-glacial origin, overlies Proterozoic metamorphics and granite. Although cold (polar) waters favour the occurrence of diatoms and other plankton, this area cannot be regarded as a possible area for petroleum, because the base of the Formation is exposed nearly everywhere.

However, the discovery of Permian fossiliferous marine sediments (Cuncudgerie Sandstone, Dora Shale, and Triwhite Sandstone) and the freshwater ?Jurassic Callawa Formation, and the marine Cretaceous Anketell Sandstone, somewhat clarifies the stratigraphy of the centre of the Canning Basin. The presence of these Palaeozoic and Mesozoic marine sediments on the southern edge of the basin indicates the possibility of source rocks for petroleum in the basin. The sub-horizontal dips and the thinness of the units suggest that the southern part of the basin is shallow, but geophysical surveys in the basin would help to determine thickness of sediments therein.

Reconnaissance geological work in the north-eastern margin of the basin in 1955 indicated only a small section of Upper Devonian or Lower Carboniferous freshwater beds as well as Permian and Mesozoic units. Stratigraphical drilling in the Fitzroy Basin and perhaps also along the coastal edge of the Canning Basin would help in calibrating geophysical work and extending stratigraphical knowledge.

From the results of these geophysical and geological surveys the oil potential of the Canning Basin may be determined.

EVAPORITES

Quaternary non-clastic sediments deposited by chemical precipitation and evaporation include travertine (massive $CaCO_3$ deposited from solution in ground or surface waters), tufa (the cellular, porous form of travertine), rock salt (halite), and gypsum or anhydrite.

In areas adjacent to and embracing the salt lakes of Waukarlycarly, Dora, Blanche, Auld etc., deposits of travertine (Ql), tufa (Qc), and salt (Qt) have been mapped.

A vertical section dug through the salt crust at the north end of Lake Dora showed:

$\frac{1}{8}$"	white layer of salt;
2" - 3"	gypsum crystals and silt;
9" -15"	sandstone with gypsum, salt water and foraminifera (derived);
3"	sandstone, fine grained, and shale.

A chemical analysis by I.F.Reynolds of the 3-inch top layer showed it to consist of:

NaCl	48-49 %
$CaSO_4$	44-45 %
Na_2SO_4	6 %

An analysis of consolidated travertine from near Lake Dora gave 21-25% $CaSO_4$.

In places on the lake surface, $\frac{1}{8}$ to $\frac{1}{4}$ inch cubic crystals of halite occur, and an analysis of a collection of these showed :

NaCl	59 %
Na_2SO_4	4 %
H_2O	37 %

The absence of gypsum in the surface crust suggests that this mineral was precipitated before the halite; as gypsum and other less soluble salts were precipitated, the residual waters would cause precipitation of almost pure halite.

The sequence of precipitation from sea water of various salts which constitute evaporites is demonstrated by Mason (1951, p.155), who gives an order of precipitation beginning with calcium carbonate, then gypsum or anhydrite (depending on temperature and salinity), and then halite, which precipitates when the solution is concentrated to one-tenth of the original bulk. Potassium and magnesium salts precipitate normally only if the solution is concentrated to one hundredth of its original bulk.

Scruton (1953) has shown in oceanographic studies that a characteristic circulation pattern exists in estuaries and other restricted arms of the sea; surface currents flow from regions of high salinity to regions of low salinity, while currents flow in the opposite direction at depth. When high concentrations of salts are developed a strong horizontal salinity gradient exists which produces lateral segregation of different salts during precipitation; and the precipitation of these salts depends not only on the solubility product of the salt but on its density. He produces a section of an evaporation basin showing the horizontal segregation of deposition zones and stratigraphical sequence developed during increase of salinity in the basin; the section ascends from iron oxide, through limestone and anhydrite to halite. Although this work is primarily concerned with sea water and brackish water, the principles can be applied to the inland salt lakes whose salinity increases with time to a value not greatly different from that of sea water.

In the salt lakes, it may be expected that the carbonate sediments would be first precipitated (as limestone or calcareous deposits); and as the lake became more stagnant, a shale with pyrite would be laid down, and the sulphur iron of the pyrite would aid the formation of gypsum; stagnant conditions are conducive to the iron sulphide formation.

A variable but small quantity of salt water remains on the lake surface in normal months (this may be expected to contain appreciable quantities of potassium and magnesium as well as halite), but the lakes are filled during some seasons; a high water mark, indicated by dead beetles, lizards, snakes, grasshoppers, and dead vegetation, can be seen.

The adjacent Permian marine sediments provide a source for the salts; all creek beds draining from the east into Lakes Dora and Blanche are coated with a white film of salts. In contrast, Lake Auld has a salt crust not as thick or as white as Lake Dora, and the small gullies draining from the adjacent Mesozoic outcrops are not coated with salts.

A variable width of yellow-white, friable, porous tufa, containing appreciable amounts of gypsum, borders the salt crust area; this represents an older expanse of the lakes. Although it is soft, it is dry, and provides a safe surface for vehicles.

Further from the salt lakes are low outcrops of travertine, which is possibly formed from the consolidation and diagenesis of the tufa. This travertine weathers to a rough, low deposit with a tendency to form sink-holes, and it supports growth largely of ti-trees; it is in this deposit that most of the native wells are found.

A chemical analysis by Reynolds of three samples of travertine gives the following results;

	Y71	Y73	Edge of L.Waukarlycarly
Acid insolubles	1.78	12.12	27.10
$FeCO_3$	0.86	1.70	0.70
$CaCO_3$	96.22	84.50	69.75
$MgCO_3$	1.99	0.52	2.12

Y71 is farthest from a salt lake and it contains the lowest percentage of insolubles and the highest calcium carbonate content; a sample from T4, near Lake Auld, has not been quantitatively analysed, but it shows a low proportion of $CaCO_3$, and represents a transition from unconsolidated tufa to travertine.

The travertine (represented as Ql on the geological map) may indicate an ancient extension of the present salt lakes, which have gradually diminished to their present size by infilling with wind-borne and water-borne sediments, and by evaporation. The relatively insoluble calcium carbonate would be precipitated first from the original expansive lake - it is precipitated more rapidly as the temperature rises - and as the lake margin contracted, gypsum (or anhydrite) would be precipitated with lesser amounts of carbonate and some halite; the final stage in the contraction of the lake is shown by the precipitation of halite with some salts of potassium and magnesium; the present lakes have reached this last stage in their degeneration.

The Rudall River probably represented one of the major rivers draining inland into the lake system, but it is doubtful if this river still contributes much surface water to the lakes, as its mouth is now nearly barred by numerous small braided dunes. Isolated neighbouring low hills provide the run-off to fill the lakes after heavy rains, and this intake cannot compensate for the high evaporation rate and infilling by wind-blown detritus; the size of lakes must therefore decrease.

Only a small portion of the rainfall falling in the desert will be evaporated through the sands, as the surface tension of the sand will not raise water more than 40 cm. (Bagnold, 1941); except for isolated low rock outcrops there is little run-off. Most of the rainfall therefore drains underground to lower portions of the desert, where it evaporates at the surface and probably forms some of the isolated travertine deposits. This ground-water would eventually reach the salt lakes and so keep them in a very boggy state below the salt crust.

HYDROLOGY

The hydrology of the area may be conveniently divided into: natural surface water, catchments, and rockholes; and sub-surface waters.

Appendix E lists the bore data collected from the stations visited; where possible, the reason for bore failures has been given. The position of all known bores and wells, and their barometric height, where determined, were plotted on the geological 4 mile to 1 inch maps; only the more important waters are included on the 10 mile map.

Surface Water

All the large surface waters and most of the smaller waterholes lie on the Yarrie Four-Mile sheet. The larger rivers such as the De Grey, Oakover, Nullagine and Little De Grey all have large semi-permanent pools: soaks can be dug successfully in the gravels of these rivers even though the beds appear dry. Rain-water catchment tanks are placed along the telegraph line to La Grange; these tanks have a 30-foot-square galvanized iron catchment-roof. The first tank is thirty-nine miles north of Callawa Homestead: it holds about 450 gals.

In the Rudall area, there are semi-permanent large water-holes along the course of the Rudall River: the largest of these is Coondegoon Pool. Other rockholes exist at the headwaters of this river, in granite topography.

Christmas Pool, a permanent rockhole in the Paterson Range, has been a marker and reliable water-supply point for early explorers and aborigines. It is situated in a gully, at the base of the Paterson Formation, and is filled by natural catchment from the range, as well as soak-fed by the percolation of waters through the glacials to an underlying impervious clay bed.

In the desert area, rockholes were found on the top of flat-topped hills in areas of Permian and Mesozoic outcrop; they form in the pale brown leached, jointed, and partly laterized caps of the hills, and are about 2 feet by 4 feet deep and 1 foot wide; they contain a small supply of water varying from 0 to 40 gallons. The supply is obtained by natural catchment of rain water. The natives try to hide and conserve this water by covering the opening with large flat rocks; these supplies would last only for several months after rain. The rockholes in granite and metamorphic country occur normally in stream and drainage channels.

A number of soaks, yielding a good supply of fresh water, were found along the eastern margin of Lakes Dora and Blanche. Dunn Soak, Fig.22, three miles east of the northern portion of Lake Dora, yielded 60 g.p.h. of good water; this was an old native soak (evidence of old spears, coolamins, chippings, etc., in the debris) which was cleared out and cased with a 44 gal. drum.

A large soak producing a permanent spring exists three miles north of Scott Bluff on Lake Blanche, and a second soak occurs five miles east of Scott Bluff. These soaks are formed by the percolation of underground water through permeable sandstone, emerging at topographically lower places where underlying impermeable shale directs the groundwater to the surface: the soak which is reported to occur in the centre of Lake George may originate in this way. All these soaks are conspicuous by the thick, tall, green, and sometimes flowering acacias (wattles) that surround them; the presence of birds, animals, animal pads, and old native habitations gives a strong lead to their whereabouts. From air photographs, numerous fire-burn patterns indicate native hunting grounds which are not far removed from some water supply. The dense groves of vegetation at soaks are conspicuous on the photos.

<u>Underground Water</u>

In the settled western part of the area, on the Yarrie Sheet, the large sheep stations utilise sub-surface waters for their main water supplies. Bores located in granite, metamorphic, and Upper Proterozoic rocks are mostly successful, shallow (less than 150 feet), and yield large supplies of "hard" stock water.

The water level of most Warrawagine wells in this Precambrian complex is about 40 feet below the surface. The water at Simpson Well killed sheep that had been mustered onto the water or which were new to the paddock; this water is dark green with algae, and is being treated with copper sulphate, but death is due to the high proportion of soda in the water, which produces sodachosis in the sheep. It cannot be economically treated, and only sheep that normally live in the paddock and are not forced to drink should use this water.

Bores or wells sunk along the larger watercourses yield large supplies of good water; these supplies are obtained from the recent river gravels and silts, and are used as the homestead supplies for Warrawagine, Yarrie and Muccan.

Two conspicuous areas yield no fresh underground water: (i) along Callawa Creek, 4 miles south of the Rabbit-Proof-Fence, where shallow bores in metamorphics and granite yield salt water. In selecting new bore sites here to replace the failures, the geologists endeavoured to move normal to the creek to higher ground, in the hope of hitting fresh water above the underlying salt, or to move upstream along Callawa Creek, where a steeper surface topography would produce more movement in the underground shallow water.

(ii) Between the Oakover and Nullagine Rivers, north of Braeside Homestead. Here bores penetrate a "blue clay with boulders" sequence (Braeside Tillite) for about 300 feet and all yield large supplies of very salty water. A large area of well grassed country remains unstocked in this area because of the lack of suitable water; the Tanguin water scheme pipes water from well No. 28 on the Nullagine River for 4 miles into this unwatered country, and the "Twenty mile" water scheme pumps water from a well on the Little River to a reticulating tank 2 miles to the west, 22 miles south of Warrawagine. But these schemes serve only a limited area; it was suggested that a deep bore be sunk through these glacials in the hope of striking fresher water in the underlying Precambrian dolomites and breccias; the salt water found in the Tillite may be separated from any deeper water by impermeable clays (till) in the glacial sequence.

In the desert area the natives have constructed their own shallow wells; they are usually situated in travertinous country. The outcrops are low and dissected and covered with wild holly (acacia) and stunted ti-tree scrub. The early explorers always noted the association of native wells with "limestone country and stunted, not tall, ti tree scrub". There may be some association between the tall ti-tree (not a good sign for native wells) and the greater depth to ground water. The native wells are about 8 to 10 feet deep and after the well has been cleaned out yield supplies of potable water.

The possibility of obtaining supplies of underground water in the desert area is extremely good, particularly in areas covered by Permian and Mesozoic sediments. The Permian Dora Shale may prove impervious but it is probably not thick enough to hinder drilling. It is unlikely that artesian water would be encountered, but large supplies of sub-artesian water should be present.

Many successful wells were sunk on the abandoned Lochinvar station, which occupied sand-dune country along the Rabbit-Proof Wing Fence.

Wells along the Canning Stock Route mostly encounter good supplies of potable water; most of these wells are about 80 feet deep and the water level stands at 20 to 40 feet.

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Our sincere thanks are tendered to Mr.Fred Hull, of the Flying Doctor Base at Pt.Hedland, for his continued service and attention.

Figures 5 and 8 are reproductions from aerial photographs published with permission of the Dept. of Air, Melbourne.

Fig. 21.—Rockhole on top of a Mesozoic flat-topped hill, 30 miles east of Lake Waukarlycarly.

Fig. 22.—Dunn Soak.

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APPENDIX A.

Plant Fossils from the Callawa Formation, by R.O. Brunnschweiler.

Jurassic beds have previously been reported from this area by Reeves (1949). He assigned a Jurassic age to the beds on the basis of the presence of Otozamites sp.nov.

During the 1954 field season, geologists of the Canning Basin Party collected plant fossils which confirm the Jurassic age of the Callawa Formation.

Y23 - about 14 miles north-west of Callawa Homestead, Yarrie Sheet:

There is a 200-foot section of fine white shales with plant remains, and conglomerate capping the hill. The sediments overlie Upper Proterozoic black shale.

Tentative identification of the plants is as follows:-

Dictyophyllum sp. (Hausmannia?)
Cladophlebis cf. C.concinna (Prest.)
Cladophlebis sp.
?Johnstonia cf. J.dintata Walkom
Taeniopteris cf. T.wianamattae Walkom
? nov.gen. aff. Sphenozamites (may be Voltzia)
Ginkgo cf. G.digitata (Brongniart)
?Pagiophyllum sp.
Cone scales, probably Araucarites.

These forms indicate that the flora is younger than Permian, but older than Cretaceous. The genus Thinnfeldia, which is a prominent member of the flora of the Erskine Sandstone (Upper Triassic) in the same general region, is absent. However, the forms present are of Triassic type, particularly if the determination of Johnstonia and Cladophlebis are correct. Johnstonia is an exclusively Australian genus known only from the late Triassic of Tasmania and Queensland.

This flora may be either Upper Triassic or Lower Jurassic.

Y34 - About 10 miles north-west of Callawa Homestead, Yarrie four mile sheet:

The section here consists of -

60 feet conglomerate
20 feet ferruginous coarse sandstone with plant remains
40 feet micaceous shale with chert fragments
10 feet ferruginous material

This section overlies Lower Proterozoic hematite-jasper.

The few forms present are ;-

Pagiophyllum cf. P.peregrinum (Lindley and Hutton)
? Brachiophyllum sp. (Voltzia-like, but may also be Araucarites).
Sphenopteris sp.
Seeds of ?Samaropsis type.
Wood ind.

The Pagiophyllum sp. mentioned under Y23 is not similar to the species in this sample. Nothing like this Pagiophyllum peregrinum has been described from either Western Australia or the Northern Territory, though similar forms are known from the Eastern Australian Jurassic. Sphenopteris has little significance, particularly as only the terminal pieces of the pinnules are available for examination. The genus occurs both in the Erskine Sandstone and in the much younger Broome Sandstone (Lower Cretaceous). Brachiophyllum (or Araucarites) is common in the Mesozoic plant sandstones of the N.T.

CONCLUSIONS

Those specimens do not indicate floral connexions with assemblages described from the north of the Basin. The plant fossils, particularly those from Y23, are possibly Triassic or Jurassic in age. The dissimilarity between Y23 and Y34 may indicate a slightly different environment of deposition as from their structural position and lithology they appear to be contemporaneous in origin.

APPENDIX B

PERMIAN MACROFOSSILS FROM THE SOUTH-WEST MARGIN OF THE CANNING BASIN. WESTERN AUSTRALIA.

by

J.M. Dickins and G.A. Thomas.

Late Palaeozoic fossils have been recorded previously from near the south-west margin of the Canning Basin. Glauert (1926, p.43-48) records and lists brachiopods and a nautiloid collected by L.J. Jones from near No.27 well, Canning Stock Route, north-east of Lake Disappointment. Reeves (1949, Appendix, p.34) records Ammodiscus nitidus collected by him from Scott Bluff, north end of Lake Blanche. He considered that the rocks here were equivalent to the Noonkanbah Formation of the Fitzroy Basin.

During the 1954 field season the Bureau Field Party operating in the Canning Basin collected, from two additional localities, marine shelly fossils which were handed to the authors for identification and age determination. The two collections prove the presence of marine Permian rocks in this area.

DESCRIPTION OF MATERIAL

T 1 - 4 miles east of the Central Portion of Lake Dora,
1 mile east-south-east of Dunn Soak - 319 miles south-east of Port Hedland.

The sediment enclosing the fossils from this locality consists of a predominantly fine-grained micaceous brownish greywacke. The rock is considerably ferruginized and the fossils are preserved only as impressions and limonitic replacements. The fossils were found on a low ferruginous rise and consist only of molluscs, mostly of a single species of Astartila. The fossils can be identified as follows :-

Pelecypoda

Astartila blatchfordi (Hosking) 1931
Pelecypoda gen. indet

Gastropoda

Warthia cf. micromphala (Morris) 1845
Ptychomphalina maitlandi Etheridge Junr. 1903

In the Fitzroy Basin Astartila blatchfordi is known only from the upper part of the Noonkanbah Formation and doubtfully from the lower Liveringa Formation. Warthia cf. micromphala has a long range. Ptychomphalina maitlandi occurs in the Noonkanbah Formation of the Fitzroy Basin, and in the Carnarvon Basin is not known with certainty below the Bulgadoo Shale or above the Norton Greywacke. The fossil evidence would thus indicate that this locality is equivalent in age probably to the upper part of the Noonkanbah Formation or possibly to the Lower Liveringa Formation.

P 1 - 9 miles east-south-east of Cuncudgerie Hill about 206 miles east-south-east of Port Hedland.

The outcrop is elongated north-south with the "scarp" side to the east, and continues to the west as low ferruginized rises. Fossils are represented from two horizons :-

1. 100 feet from the top of the hill, where "Sanguinolites - like" impressions occur in a reddish micaceous rock of fine sandstone grain-size. The impressions are of no value for age determination except that they are of a type commonly found in Permian rocks. But they do indicate the presence of a marine environment.

2. A 6 - inch band 30 feet from the top of the hill.

Here the rock enclosing the fossils is an ill-sorted fine-grained to medium-grained greywacke. It contains abundant mica and grains of a white kaolinitic material perhaps representing weathered felspar. As well as fragmentary and whole fossils "mud balls" of material similar to the body of the rock and also of finer material are included. The rock is very much weathered and partly ferruginized and silicified, and the fossils, comprising abundant bryozoa, pelecypods, gastropods and a few brachiopods, are present as impressions and replacements. On the whole the fossils are rather fragmentary, and although the number of specimens is considerable there are not many representatives of any one species.

The following forms can be identified :-

Brachiopoda:

cf. Pseudosyrinx sp.nov. Two incomplete specimens probably belong to this genus. One is a brachial valve of a young specimen close to forms of the same growth stage from the basal Poole Sandstone in the St.Georges Range. The other is of a somewhat more mature pedicle valve. A similar species occurs in the Callytharra Formation and upper part of the Lyons Group in the Carnarvon Basin.

Spiriferellina cf. papilionata Hosking. One incomplete internal mould of a brachial valve probably belongs to this species, which occurs in the Callytharra Limestone.

Neospirifer sp. ind. An incomplete impression of a pedicle valve of Lower Permian type.

cf. Krotovia sp. Two specimens of spinose productids probably belong to this genus but are inadequate for closer comparison.

Pelecypods:

Nucula sp. A.(with a sharp apex) cf. N. sp. from the marine horizon near the base of the Poole Sandstone in the St.Georges Range and the Coyrie Formation of the Carnarvon Basin.

Nucula sp. B.(non-prominent apex) cf. N. sp. from marine horizon near the base of the Poole Sandstone in the St.Georges Range.

Nuculana sp. cf. N. sp.nov. from Nura Nura Member of the Poole Sandstone.

Nuculana cf. N.lyonsensis Dickins from Lyons Group of the Carnarvon Basin.

Parallelodon sp. indet.

<u>Astartila</u> cf. <u>A</u>. <u>danai</u> (de Koninck) from the "Upper marine" of N.S.W.
<u>Stutchburia</u>? sp. nov. cf. <u>S</u>. sp.nov. from Marine Horizon near the base of Poole Sandstone in the St.Georges Range.
<u>Astartella</u>? sp.nov. (this may be a new genus) cf. <u>Astartella</u>? sp.nov.from marine horizon near the base of the Poole Sandstone in the St.Georges Range and Nura Nura Member.
<u>Streblochondria</u> sp. nov.
<u>Aviculopecten</u>? sp. indet. (non-specialized ribbing of two orders with filae).

Gastropoda:
<u>Bellerophon</u> sp. indet
<u>Bellerophontidae</u> gen, indet.
<u>Warthia</u>? sp.indet.
<u>Ptychomphalina</u> sp. nov.
<u>Platyceras</u> sp.
<u>Pleurotomaridae</u> gen. indet.

Conulariidae:
<u>Conularia</u> sp.

Unfortunately the preservation of the material is not good. However, as shown above, the pelecypods and brachiopods indicate that this fossiliferous bed is close in age to the Nura Nura Member of the Poole Sandstone and the marine horizon near the base of the Poole Sandstone in the St.George Range. The brachiopods suggest also faunal links with the Callytharra Formation of the Carnarvon Basin of approximately the same age as the Nura Nura horizon and the marine horizon near the base of the Poole Sandstone in the St.Georges Range (Thomas and Dickins, 1954, p.214).

CONCLUSIONS

These samples prove the occurrence of marine Permian beds near the southwest margin of the Canning Basin. The fossiliferous beds of T 1 are equivalent in age probably to the upper part of the Noonkanbah Formation or possibly to the lower Liveringa beds of the Fitzroy Basin and the upper horizon of P 1 is very similar in age to the marine beds near the base of the Poole Sandstone.

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APPENDIX C

Microfossils from the South-West part of the Canning Basin, Western Australia.

by

I. Crespin

During the 1954 field season, geologists of the Canning Basin Party collected rock samples from the southern portion of the Canning Basin, Northwest Australia, in the hope that microfossils might be present to assist in the determination of age of these beds. Permian foraminifera were found in a sample fro Lake Dora and Lower Cretaceous foraminifera in a sample from a locality on the Anketell 4 mile sheet. Foraminifera have not previously been found in this part o the Canning Basin. Ammodiscus nitidus was recorded in material collected by Dr. Reeves from the cliff of Scott Bluff on the eastern edge of Lake Blanche in 1949.

Samples of hard white sandy siltstone were examined in thin section from Paterson Range, Tabletop and Yarrie 4 mile sheets for radiolaria. Rounded bodie were present; these could only be referred doubtfully to radiolaria.

The foraminifera which have been identified in the two samples mentioned above are given below.

Northern end of Lake Dora - Dora Shale.

2 inches below the base of the salt crust (Registered No. MF.948)

Purplish micaceous sandy shale with angular quartz grains and arenaceous foraminifera.

Foraminifera;

- Ammodiscus nitidus Parr (f)
- Ammobaculites cf. woolnoughi Crespin and Parr (r)
- Hyperamminoides acicula Parr (f)
- Hyperamminoides cf. expansus Plummer

This assemblage of Permian species of arenaceous foraminifera is charact istic of the beds in the Wandagee Formation of the Carnarvon Basin and of the Noon kanbah Formation of the Kimberley area. Hyperamminoides acicula is very common in the ferruginous rocks of both Basins; as it can usually be seen in hand specimen, is a useful species for the determination of a Permian age.

Anketell 4-mile sheet. Photo Run 5/5026

A. 9 - Anketell Sandstones (Registered No.MF.972)

Purplish-red and white micaceous sandstone with numerous arenaceous foraminifera. Many tests are fragmentary and could not be determined specifically

Foraminifera:

- *Ammobaculites fisheri* Crespin (r)
- *Ammobaculites minuta* Crespin (f)
- *Ammobaculoides romaensis* Crespin (f)
- *Reophax* sp. (f)
- *Spiroplectammina cushmani* Crespin (c)
- *Spiroplectammina edgelli* Crespin (c)
- *Trochammina* cf. *minuta* Crespin (f)
- cf. *Trochammina*

This assemblage of arenaceous foraminifera is typical of that found in the Lower Cretaceous deposits of the Great Artesian Basin. The species occur in the deposits around Roma and in many bores in the Great Artesian Basin of northern New South Wales, south Australia, and Western Queensland. Such an assemblage of arenaceous genera suggests a brackish-water environment.

APPENDIX D

Origin of Names on the Four Mile Sheets of Yarrie, Anketell, Paterson Range, Tabletop, Rudall, W.A.

by

Department of Lands and Surveys, Perth.

ANKETELL SHEET

WEENOO SOAK	A Native name given by R.J. Anketell, 1906.
CUNCUDGERIE HILL	Native name.

YARRIE SHEET

BULGAMULGARDY SOAK	Native name given by Line Inspector W.Grant, 1925 (during construction of Telegraph Line).
TALGA TALGA STATION	Native name means "plenty of Cadjebut trees".
WARRAWAGINE STATION	Native name of big water hole.
MUCCAN STATION	Shortened from Muccanoo.
LOCHINVAR STATION	Possibly named after a notable horse of this name, bred on Mackay Bros' stud on Nichol River.
GREGORY RANGE	Originally named Rawlinson Ranges by F.T.Gregory 1861 after Sir Henry Rawlinson,President of the Royal Geographical Society.
ISABELLA RANGE	Named by Col. Warburton, 1873.
TARAMAH SOAK	Native name collected by R.J.Anketell, 1906.
DEGREY RIVER	Named by F.T.Gregory, 1861, after Lord De Grey, Marquis of Ripon, President of the Royal Geographical Society.
OAKOVER RIVER	Named by F.G. Gregory, 1861.
NULLAGINE RIVER	Native name by F.S. Brockman, 1878.
COPPIN'S GAP	The Coppin family have for long been pastoralists in this area.
BLACK HILL	Probably named by F.S.Brockman who established a trigonometrical station on it.
BAMBOO OR CHUGARRI CREEK	Probably from the number of native bamboos growing there. The native name means "red river mulga".
ULALLING HILLS	Named by F.T.Gregory, 1861
CARDOMA ROCK HOLE	Native name given by Line Inspector W. Grant, 1925.
PINJIAN POOL	Native name, F.S.Brockman, 1884.
COORACOORAWINE POOL	Native work "coorir" means "Pine mulga".
CHUKUWALYEE POOL	Native name (meaning - "big hills and plenty of water") collected by F.S.Brockman, 1884.
CALBINE POOL	Native name collected by F.S.Brockman, 1884.
TOOMBINGIDGEE POOL	" " " " " "

YULADING POOL (not Yalading)	Native name collected by F.S. Brockmann, 1884.
NGUMBERAMURING POOL	" " " " " "
WONGAWOBBIN POOL	" " " " " "
NGARRIN CREEK	" " " " " "
NIMINGARRA CREEK	" " " " " "
DELUBUNINE POOL	" " " " " "
EEL CREEK	Most probably named by F.T. Gregory, 1861. as it is shown on the map of his explorations.
KOOKENYA CREEK	Native word for "hawk".
CARLUBORONG POOL	Native name collected by F.S. Brockman, 1884.
BALANTINE SPRING	" " " " " "
MUCCANOO POOL (not Muccanu)	Native name by Alex Forrest, 1878.
COONIEENA CREEK	" " " " " "
COONIENAKER	This is an error for Coonieena Creek.
COOLCOOLINNARRINER	Native name by Alex Forrest, 1878.
NGANBERAMINING POOL	An erroneous spelling of Ngumberamuring.
CORDOOIN POOL (not Coordooin)	Native name by F.S. Brockman, 1884.

PATERSON RANGE SHEET

LAKE WAUKARLYCARLY	Native name collected by W.F.Rudall, 1847.
LAMIL HILLS	Named by French Expedition 1801-3.
MUTTABARTY HILL	Native name collected by W.F.Rudall, 1897.
BARNICARNDY HILLS	" " " " " "
MT.CROFTON	Named by W.F.Rudall 1896-1897, after A.H.Crofton, 2nd.Assistant in Calvert (Wells) Search Expedition.
TROTMAN HILLS	Named by W.F.Rudall, 1896, after H.Trotman, Assistant in Calvert Search Expedition.
PATERSON RANGE	Named by W.F.Rudall, 1896, after W.Paterson, first manager of the Agricultural Bank of W.A.
MT.MACPHERSON	Named by F.T.Gregory, 1861, after an early colonist of W.A.
COOLYU NATIVE WELL	Native name by W.F.Rudall, 1897.
MUNDAMUMMA (CHRISTMAS POOL)	By W.E. Rudall, Christmas 1896. (Mundamudda - native name.
CHIRIT NATIVE WELL	Native name (Chirit - bird) by W.F.Rudall, 1897.
ROUND HILL	Named by F.S.Brockman, 1884.

TABLETOP SHEET

LAKE AULD	Named by L.A. Wells, 1896, after W.P. Auld of Adelaide, a member of John McDougall Stuart's Expedition.
THRING ROCK	Named by L.A. Wells, 1896 (Calvert Expedition).
KING HILL	Named by L.A. Wells, 1896, after Stephen King, of S.A. Survey Dept., and a member of Stuart's Expedition across the continent.
DUNN SOAK	Named by Traves et al. 1954, after W. Dunn, tracker and stockman from Marble Bar.
LAKE BLANCHE	Named by W.F.Rudall, 1897.
SCOTT BLUFF	" " " "
LAKE DORA	" " " "
SEPARATION WELL	Named by L.A. Wells (Calvert Expedition), the spot where C.F. Wells and G.L. Jones separated from the main party, to perish eventually 1896.
TRIWHITE HILLS	Named by Traves et al. 1954, after three white-topped hills east of Lake Dora.
LAKE WINIFRED	By W.F. Rudall, 1897.
NANGABBITTAJARRA	Native name collected by A.W. Canning 1906-7.
DUNDA JINDA WELL	" " " " " "
JUJINGERRA WELL	" " " " " "
NURGURGA WELL	" " " " " "

RUDALL SHEET

THROSSELL RANGE	Named by W.F. Rudall, 1897, after Geo.Throssell, Minister for Lands.
MT.ISDELL	Named by F.H.Hann, 1897, after an early settler of the Kimberleys.
TABLETOP HILL	Descriptive of Mt.Isdell.
BROADHURST RANGE	By F.H. Hann, 1897, after a citizen of W.A.
COOLBRO CREEK	Native name collected by W.F. Rudall, 1897.
YANDAGOOGE CREEK	" " " " " "
WOORA WOORA HILLS	Native name by W.F.Rudall, 1897.
WELLS RANGE	After L.A. Wells, leader of the Calvert Expedition, 1896.
EMU RANGE	So named by F.H. Hann, 1897, because "he saw five emus on it".
MCKAY CREEK	By F.H. Hann 1897, after a friend, Mr.S.L. McKay.
MT.CONNAUGHTON	Named by W.F. Rudall, after one of the members of his search party for lost members of the Calvert Expedition.
HARBUT RANGE	By F.H. Hann, 1897.
YENEENA CREEK	Native name by W.F. Rudall, 1897.

WHYLAGGRA POOL	Native name collected by W.F. Rudall, 1897.
COONDEGOON POOL	" " " " " "
NUMERAGUARRA POOL	" " " " " "
POONEMERLARRA SOAK	" " " " " "
WATRARA POOL	" " " " " "
CURRUNCURRUN ROCK HOLE	" " " " " "
CHOORUN WATER HOLE	" " " " " "
NOOLOO SOAK	" " " " " "
GARGOONYA WATER HOLE	" " " " " "
MOONGOONGUNYAH ROCK	" " " " " "
BOCRABEE HILL	" " " " " "
YERAWANYAH ROCK HOLE	" " " " " "
MARLOO MARLOO ROCK HOLE	" " " " " "
YANDANUNYAH ROCK HOLE	" " " " " "
PINDINYAH ROCK HOLE	" " " " " "

MISCELLANEOUS

YILGALONG POOL	Native name by F.S. Brockman, 1884.
MEJAJAGEE POOL	" " " " "
YOWNAMA CREEK	" " " " "
MIDGENGADGE POOLS	" " " " "
MT.SYDNEY	Apparently named by F.T. Gregory, 1861, as it is shown on map of his exploration expedition.

APPENDIX E.

Water Supply - Bore Data of :

Callawa	)	
Nimingarra	)	
Warrawagine	)	Stations.
Wallal	)	
Yarrie	)	

CALLAWA, H.S. Alt. 450 feet.

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
Eva Mill	½ ml.S.E. of H.S.						Spoils of schist, quartz, amphibolite.
Matts Mill	3 ml.E. of H.S.		60 ft.	50 ft.		Good water	Spoils of schist, etc.
Callawa Mill	6 ml.E. of H.S.			50 ft.		"Sweet, burning" water ? NaOH	? Old river with travertine on surface.
Donison Bore	E. side of Callawa Ck. (not equipped)		80 ft.	60 ft.			? In river gravels.
Wattle Creek Mill.	7 ml.W.N.W. of H.S. Fences at 80° and 120°			35 ft.		Good water.	Travertine on surface, ? in creek alluvium.
Salt Mill	7 ml. W. of H.S. on Yarrie road; mill on W. of Wattle Creek.					Bad, but clear with taste of H_2S	Spoils of green schist, shale and quartzite.
Wonga Wadda Mill	4 ml.S.E. of H.S.			30 ft.		Fair-good	Travertine on surface, spoils of dark green basic volcanics and slates.
Moxam Mill	4 ml. W. of H.S.			40 ft.	small	Poor water	? Upper Proterozoic, red fine sandstone, some coarse bands, micaceous, round grains well bedded, ripple marks and green on bedding planes.
"The Bore"	2 ml. N. of H.S.		85 ft.	65 ft.	Good	Excellent water	? In granite.
Dud Well	4 ml. N.N.W. of Donison Bore, ¼ ml. S. of E.W. fence		40 ft.			Salty water in 1942 after floods of 1941	? Metamorphics; old native well in Callawa Creek nearby gave good water.
Dud Well	2½ ml.N.of "The Bore" on N.S. fence				No supply	Salt water	Spoils of pegmatitic granite, some hornblende schist, boulders of vesicular basalt.
Dud Bore	3½ ml. N.of "The Bore"		150 ft.		Dry		Spoils of granite and grey schist.

WARRAWAGINE H.S. Alt. 490 ft.

	Situation	Altitude.	Total Depth	Water Level	Yield	Analysis	Strata
Sears Well	14 ml. N. of H.S.			40 ft.		Fair, slightly sodaic, Good stock water	
Desert Well	9 ml. E.N.E. of Sears Well.	455 ft.		40 ft.		Fair, good stock water.	
Well	2 ml. S. of wing fence junction on Rabbit-Proof-Fence	540 ft.		30 ft.		Good	Tertiary limestone.
Lochinvar Well	At Lochinvar old H.S. beside a claypan	545 ft.					Spoils of Tertiary limestone and travertine. Now fallen in.
Salt Well	12 ml. N. of H.S.	380 ft.		40 ft.		Slightly salty, quite sodaic - little worse than Sears Well. Sheep flock on it.	(No.3 Well). Faintly alkaline 259 grains per gallon total soluble salts.
Little Toomingidgee Well	8½ ml. N. of H.S.	395 ft.	70 ft.			Good, sweet water Corroded tank	
20 mile Water Scheme Well.	22 ml. S. of H.S. Near junction of Little River and Oakover			30 ft.		Fair, slightly alkaline	Tertiary limestone and chalcedony.
Toombingee Bore	10 ml. E.N.E. of H.S.					Very salty	
Tragedy (No.2) Bore	5 ml. E.S.E. of H.S.					Neutral reaction	833 grains per gallon.
Little Junction Mill	8 ml. S.E. of Callawa ½ Ml. N. of Oakover R.	365 ft.	42 ft.	30 ft.		Fair to good	Probably in river gravels overlying granite.
Simpsons Well	2½ ml. W. of Bonnhams 2 ml. S. of Simpsons is a dud well in granodiorite on a N.S. fence. Depth of 95 ft.	350 ft.		25 ft.		Alkaline. Water very green through algae and too much soda for new sheep	Spoils of granodiorite. (No.4 Well.) Faintly alkaline. 137 grains per gallon.
Bamboo Well	4 ml. S.S.E. of Simpsons	415 ft.	147 ft.	60 ft.	Unlimited Supply	Good	Spoils of pink aplitic granite.
6 Mile Well	6 ml. W of H.S. Near 6 Mile Creek. There is also a soak in the creek bed.	430 ft.		25 ft.		Much muscovite in the water	Spoils of gneissic granite.

WARRAWAGINE H.S. (Cont'd)

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
Mill	8 ml.E. of Nullagine River, on N-S fence. Has old fallen-in well nearby. Also a sheep and cattle yard.			50 ft.		Good water, slightly magnesic	Spoils of Tertiary limestone.
Old Well	¼ ml.E.of Nullagine River, near Pinjian Pool.	520 ft.		30 ft.	Not used		Spoils of travertine cemented river gravels.
Chocka Well	11 ml.E.of H.S. on bank of Oakover River	500 ft.		35 ft.		Good	
Rodneys	16 ml.E.of H.S. On edge of sand dunes			26 ft.		Good	
Wileys Well	4 ml.N. of H.S.	395 ft.		42 ft.		Good stock water.	Spoils of limestone and opaline boulders.
Big Toomingidgee Well	1 ml.S. of Little Toomingidgee Well			40 ft.		Good	Well now fallen in. Probably in river alluvium.
Oakover Bore	4 ml.W. of Salt Well.	370 ft.		40 ft.	Large supply		
Sweet Well	5 ml.W.of Oakover Bore	370 ft.		35 ft.	Poor supply	Sweet-salty taste. Sheep flock on it.	Travertine on top; then 9 ft. of grey "pug".
Oakover Well	11 ml.W.N.W. of H.S.			28 ft.		Best water on station	
Big Junction Well	5 ml.E. of Nullagine-Oakover River junction. First well in district.	370 ft.	40 ft.	25 ft.	Unlimited supply	Good	Spoils of gneissic granite and quartzite.
Bonums	2 ml.S.of Oakover-Nullagine River junction. ½ ml.E.of this is an unequipped well, W.L.35 ft. in white clay and travertine	360 ft.		35 ft.		Was salty,now fair; this change occurred after the dry spell of 1949.	

NIMINGARRA STATION ALT. 285 ft. (100,000 acres, 4,000 sheep in 1955)

	Situation	Alti-tude	Total Depth	Water level	Yield	Analysis	Strata
Cabbage Gum Mill	8 ml. E.N.E. of H.S.	350 ft.		30 ft.		Fair water	Spoils of granite, travertine on surface.
Gorge Mill	4 ml. E of Cabbage Mill.						Spoils of granite.
Marshalls Mill	4 ml.S. of Cabbage Mill						Well.
Chooks Mill	4 ml.N.E. of H.S.			50 ft.		Fair-sodaic	Well.
Blue Hills Mill	4 ml.N. of Chooks						Well.
Duffs Mill	2 ml.N.E. of H.S.			20 ft.		Fair-sodaic clear water	Vertical greenish quartzite and schist.
Pinger Well	2 ml. W. of H.S.					Good	
Boundary Well	3 ml.S.W. of H.S. on Etrick-Nimingarra boundary					Good	
Quartz Mill	1½ ml. S. of H.S. at Coongan turn-off					Fair	Well nearby. Spoils of quartz.
Homestead and Woolshed Mills						Excellent	Wells.
Egg Mill	6 ml.S.S.W of H.S. Near Egg Creek.						

WALLAL H.S. Alt. 80 ft.

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
No.2 Desert Mill (Bilgarra Well)	50 ml.N.of Yarrie on the Wallal road	245 ft.		150 ft.		Good	
Eliamulgarra Bore	8 ml.E.of Bilgarra		130 ft.		Dry		
Sussacus Mill	9 ml.E.of No.2. At junction of N-S and 75° fences	285 ft.		150 ft.		Excellent	Well. Spoils of fine conglomerate and coarse sandstone with white fine sandstone with plant remains.
Lungera Mill	Intersection of two fences. Has two palm trees	190 ft.		60 ft.		Fairly good slightly sodaic	Well.
Tank Mill	On edge of grey clayey soil with Ti-trees.			20 ft.		Salty.	
Chirrup Bore	$\frac{1}{4}$ ml.W. from main north highway	160 ft.		15 ft.		Good.	

YARRIE H.S. Alt. 326 ft.

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
Monitor Well	2½ ml.N. of H.S.			40 ft.		Fair, salty	Spoils of granite and olivine basics.
Cundaline Mill	5 ml. N. of H.S.			20 ft.		Fair	Spoils of granite and green basics.
4 Mile Well	5 ml.E. of H.S. on Eel Creek	330 ft.				Good	
8 Mile Well	10 ml.N.E. of H.S. on Eel Creek	390 ft.	60 ft.			Good	Spoils of pink granite.
Reids Mill	6 ml. E. of Cattle Mill.						
Cattle Mill	14 ml.N. of H.S.	426 ft.					
No.3 Desert Mill	35 ml. N. of H.S. on the Wallal road.	485 ft.	310 ft.			Good water (not pumping in 1954)	Bore; probably in Mesozoic.

APPENDIX F.

Plants from the South Western Canning Basin.

Determinations by C.G. Gardner
Descriptions by J.N. Casey

The inter-dune areas are covered by a varying concentration of many types of:-

Acacias (yellow button flower and elongate flower):
A. pyrifolia D.C. ("Spiney-leaf Wattle");
A. dictyophleba F.Muell. (Native Spear tree, grows 12 ft. high with a stem ½" in diameter);
A. impressa F.Muell. ("Millirichie," with hard curly bark yellow button flowers and flat leaf - the river millirichie has long yellow flowers and narrow leaf);
A. salicina Lindl.;
A. translucens A.Cunn. ("Poverty bush", height 3 ft. and very bushy);
A. pachycarpa F. Muell. ("Turpentine" with sticky olive green leaves;
A. xylocarpa A.Cunn. (long thin leaves pointing upwards or outwards).
Eucalyptus gamophyta (characteristic of Mallee scrub, and grows to a straggly 6 ft.);
E. aspera F.Muell. (a vivid white-barked "Gum" with small bunches of "sand-paper-like" leaves);
Gyrostemon tepperi (F.Muell.) C.A. Gardn. (true "Narrow leaf Poison", dangerous to any stock;)
Grevillea stenobotrya F.Muell. (common "Narrow leaf Poison", silvery coloured bark);
G. wickhamii Meissn. ("Wild Holly", with spiney leaves and clusters of red flowers);
G. refracta R.Br. ("Caustic Bush", rough bark, broad silver strap-shaped leaf, and height 6-10 ft.);
Grevillea eristachya Lindl. (with a long yellow brush flower and needle leaves; natives soak the flowers in water and extract a sweet syrup);
Codonocarpus cotinifolius (Desf.) F.Muell. ("Desert Maple", 12-15 ft. tall, smooth bark, straight trunk, conical outline);
Petalostyles labicheoides R. Br. var. cassioides Benth. ("Sugar Bush" with a yellow flower, and white "sugar" crystals on the limbs in spring which natives utilise);

"Turkey Bush" (Cassia desolata F.Muell., C.oligophylla F.Muell., C.glutinosa D.C.);
"Fuchsia" (Eremophila sp., E. spathulata W.V. Fitzg., E.Latrobei F.Muell. - "Georgina Poison Bush");
Brachysema chambersii F.Muell.(cluster of red flowers at its base);
Thryptomene Maisonneuvii F.Muell.;
and various species of Ti-tree - the taller, broader leafed Melaleuca lasiandra F.Muell. is in contrast to the low (3 - 4 ft.) darker, narrower-leaved variety that is common near native wells. The Ti-tree is common in travertine country and has a "paper bark" and white "bottle brush" flower. Some Loranthus Preissii Miq. ("Mistletoe") grows on acacias growing near soaks.

Low bushes and shrubs that grow on fire burns are:-

Indigofera monophylla D.C. ("Indigo" with mauve-red flower and lucerne-like leaf);
Jacksonia aculeata W.V. Fitzg. (small 2 ft.), wiry branches, yellowish flowers, no leaves);
Tephrosia uniovulata F.Muell. (green-blue velvet leaf and red slipper-shaped flower);
Kerandrenia integrifolia Stend.(blue flowers with yellow centre);
Dicrastyles gilesii F.Muell. (lavender flowers, rough leaf, 2 ft.high, spreads rather than grows vertically);
Trichinium obovatum Gand. ("Blue Flannel Bush");
T. calostachyum F.Muell. ex Benth. (Lavender pointed flower at the extremities, few leaves);
Anthobolus exocarpoides F.Muell.;
Dicrastyles ochrotricha F.Muell. (yellow-green velvet leaf).

On the sand dunes grow the "Bird Flowers" (Crotalaria cunninghami R. Br. - greenish yellow flower - and Tephrosia sp. - red flower); Swainsona microphylla A. Gray; as well as various acacias, gums, and spinifex.

APPENDIX G

DESCRIPTIONS OF ROCK SPECIMENS

by

Kerry Lovering.

Y2: Tertiary Limestone and Chalcedony.

The hand specimen is a yellowish fine oolitic limestone: the yellow colour is given by limonite to the oolites. Chalcedony, which protrudes on the weathered surface, replaced limestone extensively.

The thin section reveals an oolitic limestone which is being replaced by chalcedony. The cores of the oolites are composed of dense granular calcite. Around the margins is frequently a limonite coating which gives the yellow colour to the hand specimen. The oolites are then cemented by granular calcite.

Chalcedony in its granular and fibrous forms replaces much of the limestone. Occasionally amorphous silica (opal?) fills in spaces between limestone and chalcedony.

Y82: Tertiary limestone with opal

The hand specimen is a white hard rock, brecciated in part.

The rock consists of calcareous and clay nodules which are cemented together by calcite. This cement has been mostly replaced by granular chalcedony. Some opal is present.

Y72: Travertine and chalcedony in clay pan.

The hand specimen is a fine white rock. Clay oolites are surrounded by calcite, which is replaced by fine-grained chalcedony.

P8: Calc-silicate marble.

The hand specimen is a fine green-grey marble.

The thin section shows a fine-grained rock with a hornfelsic texture. The rock corsists of calcite (30%), quartz (30%), actinolite (10%), melilite (10%), diopside (10%), vesuvianite (5%), sphene (2%), and epidote (2%).

Originally the rock was an impure calcareous sediment.

P9a: Actinolite Marble

The rock consists mainly of interlocking grains of calcite (average grain size 0.35 mm.). Amongst these grains is 5% of actinolite and 5% of quartz. Accessory minerals include muscovite mica and limonitic flakes.

P9b: Argillaceous sandstone

The grey massive rock consists of fine angular quartz grains distributed in a fine clay matrix.

P10: Calcic hornfels.

The rock is grey, porphyritic, and massive.

The thin section reveals a hornfelsic texture. Individual grains are usually fine but accumulations of grains indicate the relict texture of the rock. The rock had an original porphyritic texture, and now consists of blastoporphs of actinolite (33%) and diopside (40%), in a background of orthoclase (15%), and quartz (7%), with accessory sphene, muscovite and some idocrase. Epidote and calcite are usually associated with the actinolite.

Originally the rock was dioritic in composition and may have been a hornblende diorite-porphyry.

P3: Quartzite.

The rock is massive, and pink in colour.

The thin section reveals a quartzite in which the quartz grains have been reconstituted; many of them show evidence of deformation by wavy extinction. Muscovite grains have also been reconstituted.

Y31: Quartzite.

The hand specimen is a fine-grained quartz-rich rock, with a red colouration given by hematite.

Quartz grains, showing markedly wavy extinction, have been under stress, and many have been extensively cracked. Hematite, magnetite, and sericite replace former ferromagnesian minerals, many of which have also been cracked. Magnetite, partly replaced by hematite, and fragments of muscovite and quartzite are accessory minerals.

The large grains are set in a groundmass of fine granular quartz.

Y39: Pink and White Banded Chert.

The hand specimen is pink and white and very fine grained. Above the chert is a conglomerate with quartz pebbles and felspar phenocrysts. In the chert, fine angular fragments of quartz are in a cryptocrystalline groundmass.

On top of the chert is a hematitic layer about 0.5 mm thick. Above this is a fine conglomerate cemented by magnetite which replaced a fine clay matrix. The conglomerate is composed mainly of quartz pebbles. Some zircon and some quartzite pebbles are present.

The colour banding of the chert is caused by the concentration of fine hematite.

The origin of the chert cannot be determined by microscopic examination.

Y20a: Shale.

The rock is fine grained and uniform. It is composed of sericite fibres and fine quartz grains. A thin limonitic film coats many grains. The lamination is shown by concentrations of limonite.

Y20b: Quartz-olivine Dolerite

The hand-specimen is a mottled black and white rock, with a medium grain-size.

The texture of the rock seen in thin section is intergranular. The grain-size is uniform and ranges from 1 to 2 mm. Laths of labradorite (35%), of composition An58, surround irregularly shaped grains of augite (25%). Euhedral grains of olivine (15%), are altered to green chrysotile fibres. Magnetite (10%) fills in spaces in the rock. A very little alkali felspar is present; it always occurs in a myrmekitic relationship with quartz (5%). Accessory minerals are biotite and apatite.

The presence of quartz with olivine makes this an unusual rock. The olivine must have crystallised before the rest of the rock.

Y13: Granite.

The hand-specimen is a pinkish-grey granite. It is very coarse-grained, with a few porphyritic phenocrysts of pink orthoclase.

The thin section reveals a medium grained granitic rock. The rock consists of quartz (45%), microperthite (25%), plagioclase (15%), biotite (10%), epidote (5%).

The quartz always shows wavy extinction. The granite may have suffered some deformation.

The plagioclase occurs often as inclusions in poikilitic plates of microperthite. It is an oligoclase of composition An25, and is commonly altered to fine-grained epidote and clay minerals. The biotite is being replaced by molecules of penninite chlorite. It shows abnormal interference colours. Acessory primary epidote is medium grained, yellowish, and pleochroic.

Y16: Granodiorite porphyry.

The hand-specimen for this rock is missing. The field name is hornblende-felspar syenite. The examination of the slide suggests a granodiorite with a porphyritic texture. Euhedral plagioclase phenocrysts and small subhedral and anhedral grains of orthoclase and amphibole are set in a fine groundmass.

The plagioclase (48%) is a zoned oligoclase. Also present are untwinned orthoclase phenocrysts (15%) which are noticeably more altered to clay minerals than the plagioclase phenocrysts, some of which are altered to sericitic material. The sericitic alteration is selective, and emphasises the zoning of the oligoclase.

The amphibole (10%), is a strongly pleochroic, deep blue-green to lime-green hornblende. A few euhedral grains remain, but most are partly replaced by quartz. Many are altered to chlorite. Small euhedral diopside phenocrysts make 5% of the rock. These phenocrysts occur in a matrix of fine quartz grains (15%) less than 0.1 mm. in size. Also in the matrix are magnetite grains (3%), and apatite needles (2%). Around many of the grains is a thin hematitic film. Sphene (2%) is accessory and is altered to leucoxene.

Y14: Quartz Dolerite.

The rock is medium grained, dark grey in colour, and mottled with white minerals.

The texture is hypidiomorphic granular, and the grain-size is regular (about 1 mm.).

Subhedral and anhedral grains of augite (45%), and laths of plagioclase (30%), make up most of the rock. The plagioclase is labradorite. It is well twinned on albite and pericline laws. It is sometimes altered to fine clinozoisite and clay minerals. The augite is extensively uralitised. Myrmekitic intergrowths of felspar in quartz are common. Quartz grains (10%) fill in spaces, and usually contain rutile needles. Rutile and apatite needles and magnetite are accessory minerals.

Y47: Vesicular Basalt.

The hand specimen is a dark grey fine-grained rock with large vesicles filled with quartz and calcite.

The thin section reveals an intersertal texture in which laths of felspar (50% of the rock) about 0.5mm long surround irregularly-shaped masses of green penninite (20%), limonite (10%) and spherules of pseudo-leucite (20%).

The rock is very vesicular and the vesicles are filled with fine granular quartz and calcite.

Y50a: Sheared Granitic Rock.

The rock is coarse-grained and sheared.

The thin section reveals sheared and broken quartz grains in a fine matrix of sericite flakes. In places vague outlines of other minerals, now pseudomorphed and sheared, can be seen.

Y50b: Altered Dolerite.

The rock has a dark grey-green aphanitic groundmass with some medium-sized phenocrysts.

The slide shows that the rock is very much altered. Original phenocrysts of amphibole have been altered to sphene and chlorite, biotite to chlorite and limonite, felspar to calcite, sericite, and chlorite. The groundmass, which originally consisted of fine laths of amphibole and felspar, now consists of pseudomorphs of these minerals together with some quartz grains and epidote granules. Pyrite grains and globules of prochlorite occur in the groundmass. The rock was probably a dolerite.

Y51a: Altered andesite.

The rock is greenish grey with green amphibole phenocrysts.

The rock is considerably altered. Magnetite grains and pseudomorphs of euhedral amphibole phenocrysts lie in a groundmass consisting of microlites of felspar, tremolite, calcite, and sericite. The amphibole phenocrysts are altered to tremolite, sericite, and magnetite.

Y51b: Metamorphosed granodiorite porphyry.

The hand specimen is greenish grey with coarse grains of quartz and pink felspar.

The slide reveals irregularly-shaped grains of cracked and stained quartz and of perthite, and magnetite. Remnants of ferromagnesian minerals are pseudomorphed by sericitic fibres and clay minerals. Perthite is slightly altered to sericite and clay minerals.

These phenocrysts are set in a fine-grained granulated groundmass of felspar, quartz and chlorite.

The rock has been subjected to stress. It was a granodiorite porphyry.

Y55a: Amphibolite.

The rock is green in colour and fibrous in texture. It appears to be monomineralic. Thin section shows that the rock consists almost entirely of actinolite fibres, with a few anhedral grains of sphene.

Y55b: Monzonite and mica schist.

The contact between a black biotite schist and a pink monzonite can be seen in hand specimen.

The mica is a green biotite which is being replaced by molecules of penninite chlorite near the junction of the two rocks. Accessory zircons have pleochroic haloes about them.

The monzonite is medium grained, holocrystalline, with a granitic texture. It consists chiefly of andesine and microcline-perthite, both of which are very much altered. Accessory minerals consist of muscovite, apatite, epidote, garnet, and a metamict unknown mineral.

The orientation of mica plates in the schist perpendicular to the monzonite contact suggests their formation while the granite was intruded.

Y56: Adamellite.

The hand specimen is a pale grey adamellite. The rock is medium-grained with a slight suggestion of deformation.

The thin section reveals a granitic texture for the rock. Most of the quartz (35%) shows wavy extinction and appears to have been deformed. Oligoclase (20%), and microcline-perthite (15%), are present. The plagioclase has sericitic alteration products. Biotite fragments (10%) are being replaced by penninite chlorite, and altered in part to epidote (5%). Epidote granules appear throughout the rock. Accessory minerals are apatite, sphene and muscovite.

Y66: Altered basic volcanic.

The dark grey rock has inclusions (amygdales?)of coarse felspar, quartz crystals, cubic hematite crystals, and black rounded inclusions.

The thin section suggests that the rock is an altered basic volcanic. In parts, the original fine intersertal texture can be seen. Felspar microlites are usually replaced by calcite. Penninite chlorite and calcite have replaced other minerals.

Throughout the rock are irregularly shaped patches which may be amygdales of calcite, penninite chlorite surrounded by calcite (the black inclusions seen in hand specimen), and quartz surrounded by calcite.

Y68: Granitic granophyre.

The rock is coarse-grained and weathered to a deep red colour.

In thin section it consists of quartz, orthoclase, and microcline, with minor amounts of green biotite, magnetite, hematite, zircon, and sphene.

Y65: Altered basalt.

The hand-specimen is a fine grained dark greenish-grey rock with a strong tendency towards conchoidal fracture.

The thin section shows the intersertal fabric of the rock. Laths of calcic plagioclase which have suffered alteration to calcite and albite surround masses of green chlorite and some calcite. Rounded grains of sphene have probably been altered from ilmenite.

P7: Granite (metamorphosed).

The rock is gneissic in texture with a pegmatitic vein through it, and consists of medium-grained minerals in a granitic texture. Quartz showing wavy extinction has been partly reconstituted. Microcline, microcline-perthite, and albite are the felspars present. Many of the felspar grains have been deformed and some have been reconstituted. The felspars are altered; alteration products are clinozoisite and clay minerals. Brown biotite, with pleochroic haloes about zircon, is the ferromagnesium mineral. Muscovite is accessory.

Y58a: Serpentinite.

The hand-specimen is a lime-green rock with a granular texture.

The thin section shows the structure of the serpentinite. It is made up of discrete accumulations of the serpentine minerals antigorite and chrysotile, which may pseudomorph original olivine grains. Between these pseudomorphs, and sometimes incorporated in them, are large blebs of magnetite. There are a few remnants of amphiboles.

Between the pseudomorphs are aggregates of vesuvianite. The rock was probably originally a peridotite.

Y58b: Altered Serpentinite.

The rock is black and massive with a vitreous lustre. The surface is altered to a red iron oxide.

This rock is extremely altered. The general appearance and texture of the rock is that of an altered serpentinite. It consists mainly of hexagonal-shaped aggregates of sericite. These aggregates are surrounded by chrysotile fibres and magnetite particles.

STRATIGRAPHY OF THE SOUTHERN PART OF THE CANNING BASIN, 1954. TABLE 1

	AGE	FORMATION	THICKNESS	LITHOLOGY	TOPOGRAPHY.
QUARTERNARY	RECENT		Approx. 50'	Alluvial clays, gravels, and boulder beds	Confined to valley floors and river systems.
			2'	Evaporites	Playa lakes
			130'	Aeolian sand	Forms parallel long seif dunes and covers principally the Palaeozoic and Mesozoic sediments.
			10'	Tufa and travertine	Confined mostly to inland areas around salt lakes.
TERTIARY		OAKOVER BEDS	100'	Marls and limestone with chalcedonic capping. Lacustrine.	Mesas and buttes.
		LATERITE	10'	Pisolitic ironstone	Caps flat-topped dissected hills of Palaeozoic and Mesozoic sediments. Breakaway topography.
MESOZOIC	CRETACEOUS	ANKETELL SANDSTONE	0-5'	Conglomerate at A.II	
			100'	Marine sandstones and shales containing <u>Rhizocorallium</u> and foraminifera.	Low small flat-topped outcrops.
	JURASSIC-TRIASSIC	CALLAWA FORMATION	250'	Current-bedded coarse sandstone, alternating with coarse conglomerate. Freshwater plants probably passing into marine basinwards.	Mesa and buttes, low rises.
				U N C O N F O R M I T Y	
PALAEOZOIC	PERMIAN	TRIWHITE SANDSTONE	60-300'	Marine fossiliferous ferruginous sandstone and greywacke.	Small 50-100' hills.
		DORA SHALE	50'	Marine fine sandy shales with foraminifera. Probably decalcified.	Forms beds of playa lakes and 40' cliffs.
		CUNCUDGERIE SANDSTONE	130'	Ferruginous coarse to fine sandstone, richly fossiliferous in restricted bands. Marine.	Some small peaks, coarse sandstone. Rather resistant.
		PATERSON FORMATION	100'	Unsorted sandstone and shale with striated boulders. Normally massive. Some varves. Fluvioglacial. Shows slumping and contortion.	50' hills overlying Precambrian.
		BRAESIDE TILLITE	400'		Low relief capped by Oakover Beds.
				U N C O N F O R M I T Y	
PROTEROZOIC	UPPER	BRECCIA	20'	Coarse breccia with angular chert fragments.	Follows topography of dolomite
		VOLCANICS	500'	Basaltic lavas, probably of different ages and separate flows.	Valley flows producing undulating country.
		QUARTZ-FELSPAR PORPHYRY.	100-3800'	Intruded into base of Upper Proterozoic succession; hornblende porphyry sills invade sandstones.	Undulating hills and small plateaux.
		DOLOMITIC LIMESTONE	1000'	Contains ?algal colonies, and slump structures. Very sandy in some sections.	Linear low ridges, rugged topography due to differential hardness.
		SANDSTONE	1200'	Arkosic, well jointed, medium to coarse grained.	Sharp ridges, high elevation due to surface silicification.
		SHALE	100'	Dark red or greenish, blocky fine micaceous sandstone and shale overlain by sandstone.	In gullies at base of sandstone ridges.
				U N C O N F O R M I T Y	
	LOWER	LOWER META-MORPHICS	Thousands of feet	Basic volcanics, quartz-mica schist, talc-chlorite-carbonate schist, dolomitic marble, banded haematite jasper, slate and possibly pillow lavas. Whole intruded by subsequent batholiths of granite; the latter cut by dolerite dykes, quartz reefs and pegmatite veins.	Quartz schists and quartzites form dissected mountain ranges; softer volcanics more weathered to form low hills with moderate relief. Granite forms large open plain country; dolerite dykes and quartz reefs form distinctive linear outcrops.

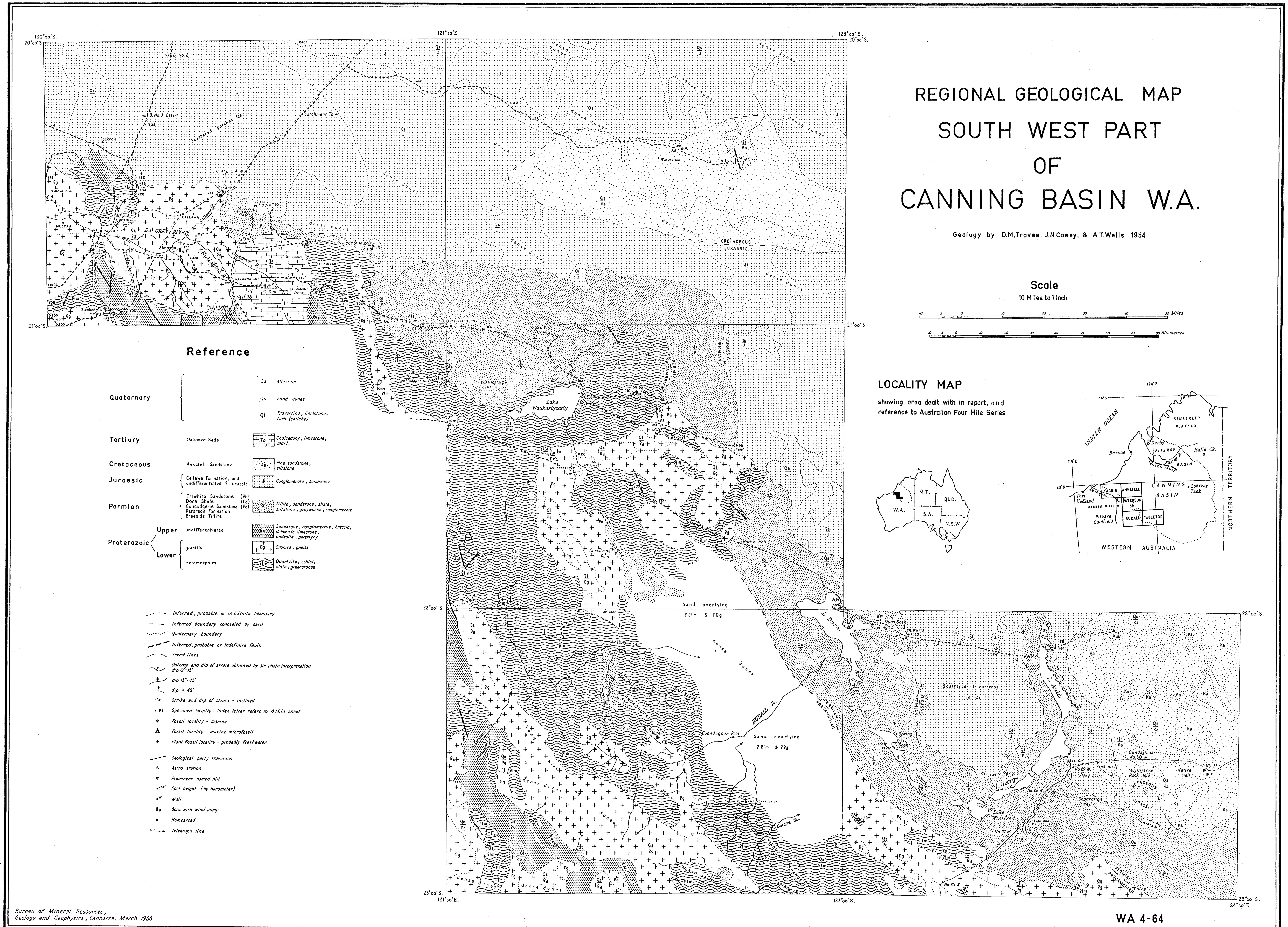
STRATIGRAPHIC CORRELATION. TABLE 2.

Era	Period	CARNARVON BASIN (after Condon, 1954)		S.W. part of CANNING BASIN		FITZROY BASIN and south of "Fenton Fault". after Guppy et al., 1956	
QUARTERNARY	Qp-Qr	40'	Alluvium, limestone, conglomerate, etc.	60'	Alluvium, travertine, sand evaporites etc.	150'	Alluvium etc. Warrimbah Conglomerate.
TERTIARY	Te-Tp	20' 200-1700'	Laterite (Oligocene) Yardie Group Cape Range Group	100' 0-10'	Oakover Beds Laterite	5'	Pisolitic Ironstone
MESOZOIC	CRETACEOUS	430' 745' 100'	Cardabia Group Winning Group Birdrong Formation	0-5' 50-100'	Conglomerate at A.II Anketell Sandstone		Dampier Group (Brunnschweiler, 1956)
	JURASSIC	25'		250'	Callawa Formation	300' 180' 60'	Jarlemai Formation Alexander Formation Jurgurra Sandstone
	TRIASSIC					60-110' 1000'	Erskine Sandstone Blina Shale
PALAEOZOIC	PERMIAN	2735'	Kennedy Group	50-300'	Triwhite Sandstone	2400'	Liveringa Formation
		3000-4000'	Byro Group	50'	Dora Shale	1200'	Noonkanbah Formation
		250' 180' 760'	Wooramel Sandstone Cordalia Greywacke Callytharra Form	130'	Cuncudgerie Sandstone	200-1300'	Poole Sandstone
		3700-5700'	Lyons Group	100' 400'	Paterson Formation Braeside Tillite	8800'	Grant Formation
	CARB.	2510'	Sandstone, limestone, greywacke			650'	Laurel Formation.
	DEVONIAN	5120'	Sandstone, limestone, siltstone			4120' 2000'	Upper Devonian Limestone, congl.etc. Pillara Formation.
PALAEOZOIC	ORD.					2800	Prices Creek Group
	CAMB.						Hart Basalt
PRE-CAMBRIAN	PROTEROZOIC Upper		)Basic dykes)quartzite, limestone, slate,)schist, granite,)gneiss	20' 500' 100-3800' 1000' 1200' 0-300'	Breccia Volcanics Porphyry Dolomitic Limestone Sandstone Basal Conglomerate and Shale		Mt.House Beds) Walsh Tillite) Warton Beds) Mornington Volcanics) King Leopold Beds)
	PROTEROZOIC Lower				Basic Dykes Granite Lower Metamorphics		Lamboo Complex

- - - - Unconformity

- - - - Disconformity

(Not to Scale)



REGIONAL GEOLOGICAL MAP
SOUTH WEST PART
OF
CANNING BASIN W.A.
Geology by D.M.Traves, J.N.Casey, & A.T.Wells 1954
Scale
10 Miles to 1 inch
Miles
Kilometres
LOCALITY MAP
showing area dealt with in report, and reference to Australian Four Mile Series
INDIAN OCEAN
KIMBERLEY PLATEAU
Derby
Broome
FITZROY
Halls Ck.
CANNING BASIN
Godfrey Tank
Port Hedland
YARRIE
ANKETELL
PATERSON RA.
RUDALL
TABLETOP
Pilbara Goldfield
WESTERN AUSTRALIA
NORTHERN TERRITORY
N.T.
QLD.
W.A.
S.A.
N.S.W.
VIC.
Reference
Quaternary
Qa Alluvium
Qs Sand, dunes
Ql Travertine, limestone, tufa (caliche)
Tertiary
Oakover Beds
To Chalcedony, limestone, marl.
Cretaceous
Anketell Sandstone
Ka Fine sandstone, siltstone
Jurassic
Callawa Formation, and undifferentiated ? Jurassic
J Conglomerate, sandstone
Permian
Triwhite Sandstone (Pt)
Dora Shale (Pd)
Cuncudgerie Sandstone (Pc)
Paterson Formation
Braeside Tillite
P Tillite, sandstone, shale, siltstone, greywacke, conglomerate
Proterozoic
Upper
undifferentiated
Pu Sandstone, conglomerate, breccia, dolomitic limestone, andesite, porphyry
Lower
granitic
Pg Granite, gneiss
metamorphics
Plm Quartzite, schist, slate, greenstones
Inferred, probable or indefinite boundary
Inferred boundary concealed by sand
Quaternary boundary
Inferred, probable or indefinite fault.
Trend lines
Outcrop and dip of strata obtained by air-photo interpretation dip 0°-15°
dip 15°-45°
dip > 45°
Strike and dip of strata - inclined
Specimen locality - index letter refers to 4 Mile sheet
Fossil locality - marine
Fossil locality - marine microfossil
Plant fossil locality - probably freshwater
Geological party traverses
Astro station
Prominent named hill
Spot height (by barometer)
Well
Bore with wind pump
Homestead
Telegraph line
120°00'E.
121°30'E
123°00'E.
124°30'E.
20°00'S.
21°00'S.
22°00'S.
23°00'S.
De Grey River
Lake Waukarlycarly
Christmas Pool
Sand overlying ?Plm & ?Pg
dense dunes
Coondegoon Pool
RUDALL R.
L. Dora
L. Auld
L. George
Lake Winifred
Scattered J outcrops in Ka
CRETACEOUS
JURASSIC
PERMIAN
PRECAMBRIAN
Bureau of Mineral Resources, Geology and Geophysics, Canberra. March 1956.
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