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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REC. 1955/58

Preliminary unedited and unchecked report on

THE GEOLOGY OF THE SOUTH WESTERN CANNING BASIN, WESTERN AUSTRALIA

by

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1955/58

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GEOLOGY OF THE SOUTH-WESTERN CANNING BASIN, WESTERN AUSTRALIA

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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'.

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 six distinct, widely separated localities, but the fossils were not numerous.

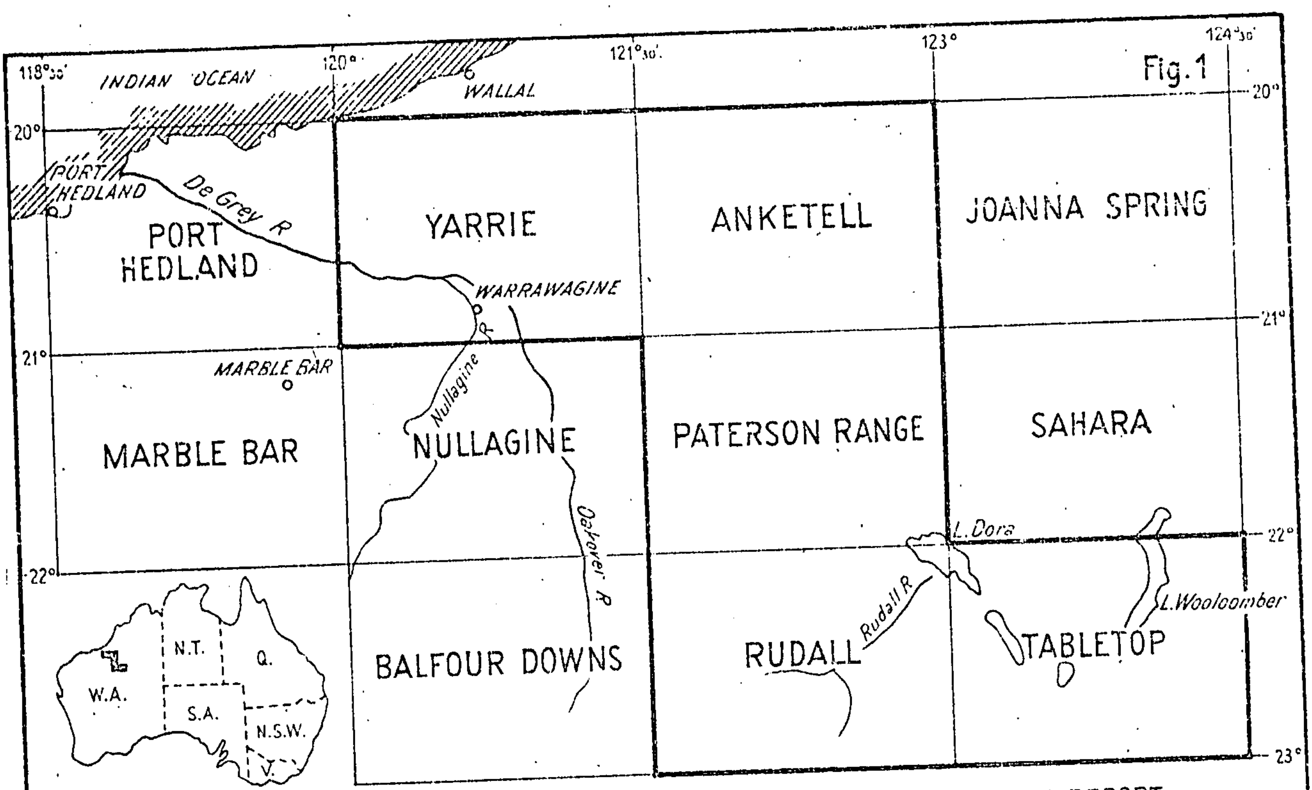
The lithology and fossils indicate that the sediments were deposited in a stable shelf area covered by a shallow sea.

Although in the south-western Canning Basin the sequence is only hundreds of feet thick compared with thousands of feet in the Fitzroy Basin, marine fossils are scarce whereas they are numerous in the Fitzroy Basin, and 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.

INTRODUCTION

General

As Mesozoic and Palaeozoic sediments had been reported from the large unmapped area of desert between the De Grey and Fitzroy Rivers, a reconnaissance geological party from the Geological Section, Bureau of Mineral Resources, Geology and Geophysics, in 1954 investigated the south-western part, which includes the Four Mile Maps of Yarrie, Anketell, Paterson Range, Rudall, and Tabletop.



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

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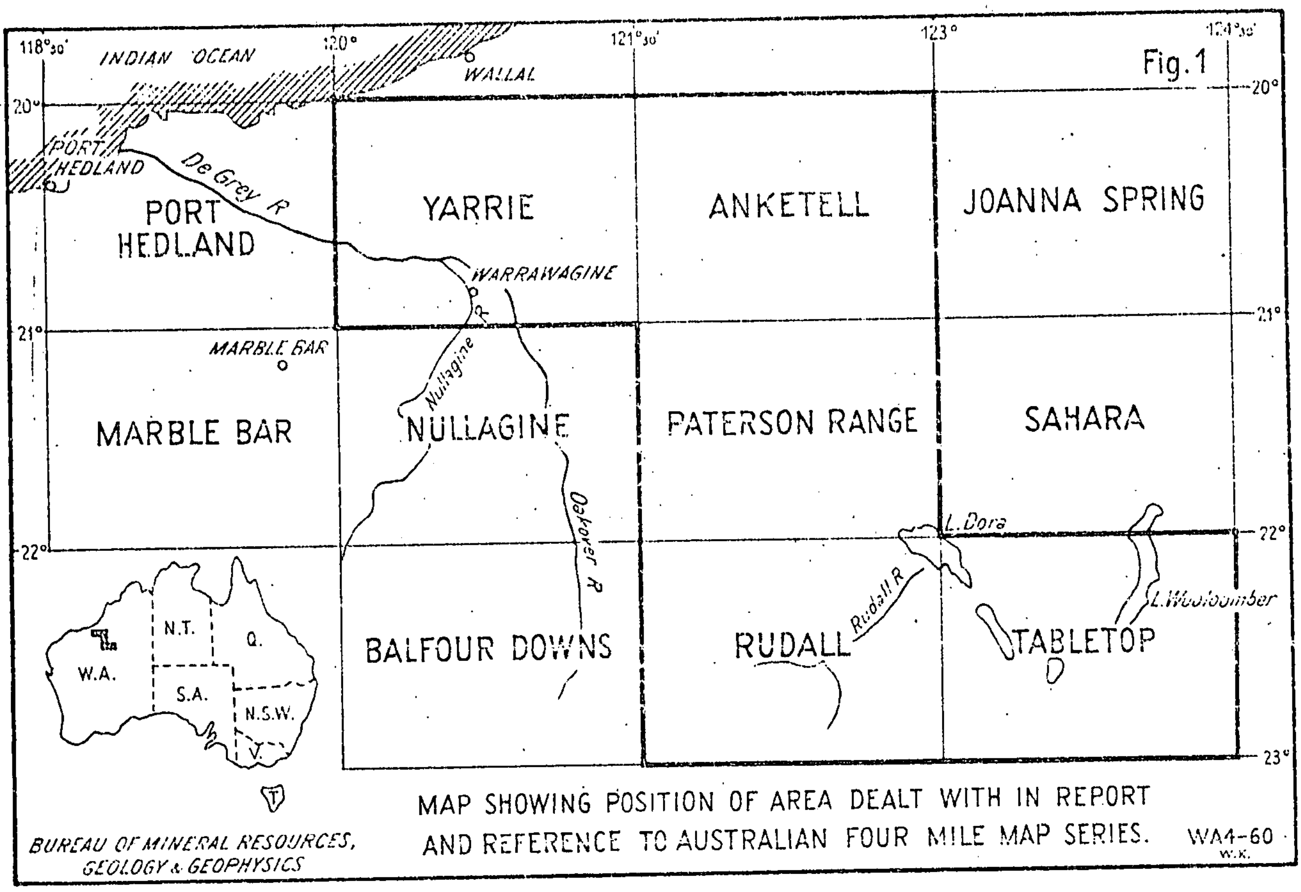


Fig. 1 shows the Locality Map of the Four Mile Sheets.

The geological party, consisting of D.M. Traves, J. N. Casey, and A.T. Wells, spent four months in the field and from the traverses shown on Figure 4 prepared a regional geological map covering about 31,000 sq. miles. This provides a basis for the discussion of the petroleum prospects of the area.

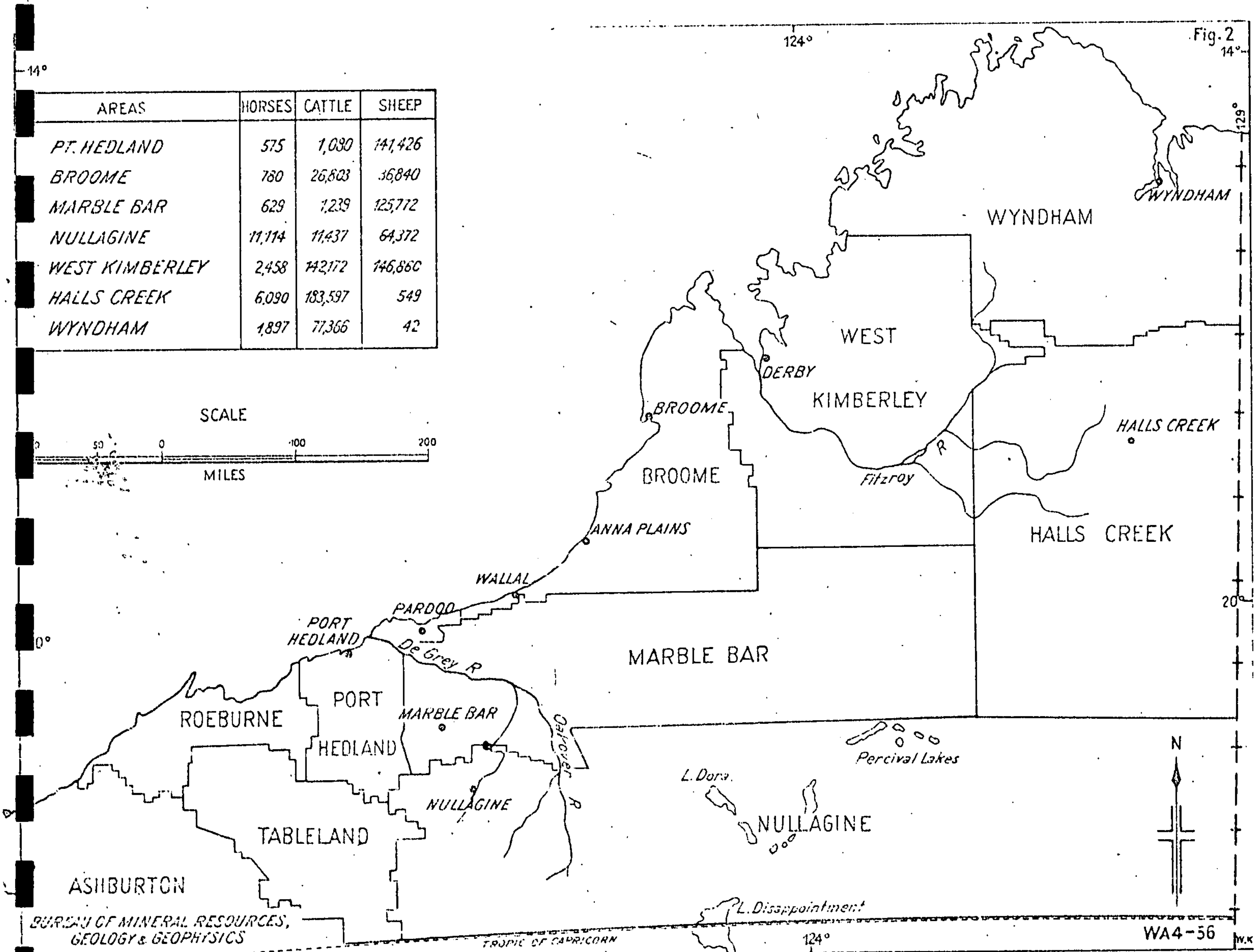
Two cadet surveyors from Dept. of Land and Survey, Perth, were attached to the party. They observed and were to compute positions astronomically, for control of the Four Mile mosaics for use in any future detailed mapping.

Location

The region covered by the five Four Mile Sheets lies between 20° and 23° of S. latitude and includes most of the area between 120° and 124°30' E. 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 W.N.W. for mile after mile, and range in height from 50 ft. to 120 ft.

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.



AREAS	HORSES	CATTLE	SHEEP
PT. HEDLAND	575	1,080	141,426
BROOME	760	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. Map of Northern Part of Western Australia showing Local Government Boundaries and Stock Figures in March, 1953 (after Department of National Development Map of Local Government Areas 1953).

Mining for gold, lead, manganese, tin, copper, columbite,

Fig. 2

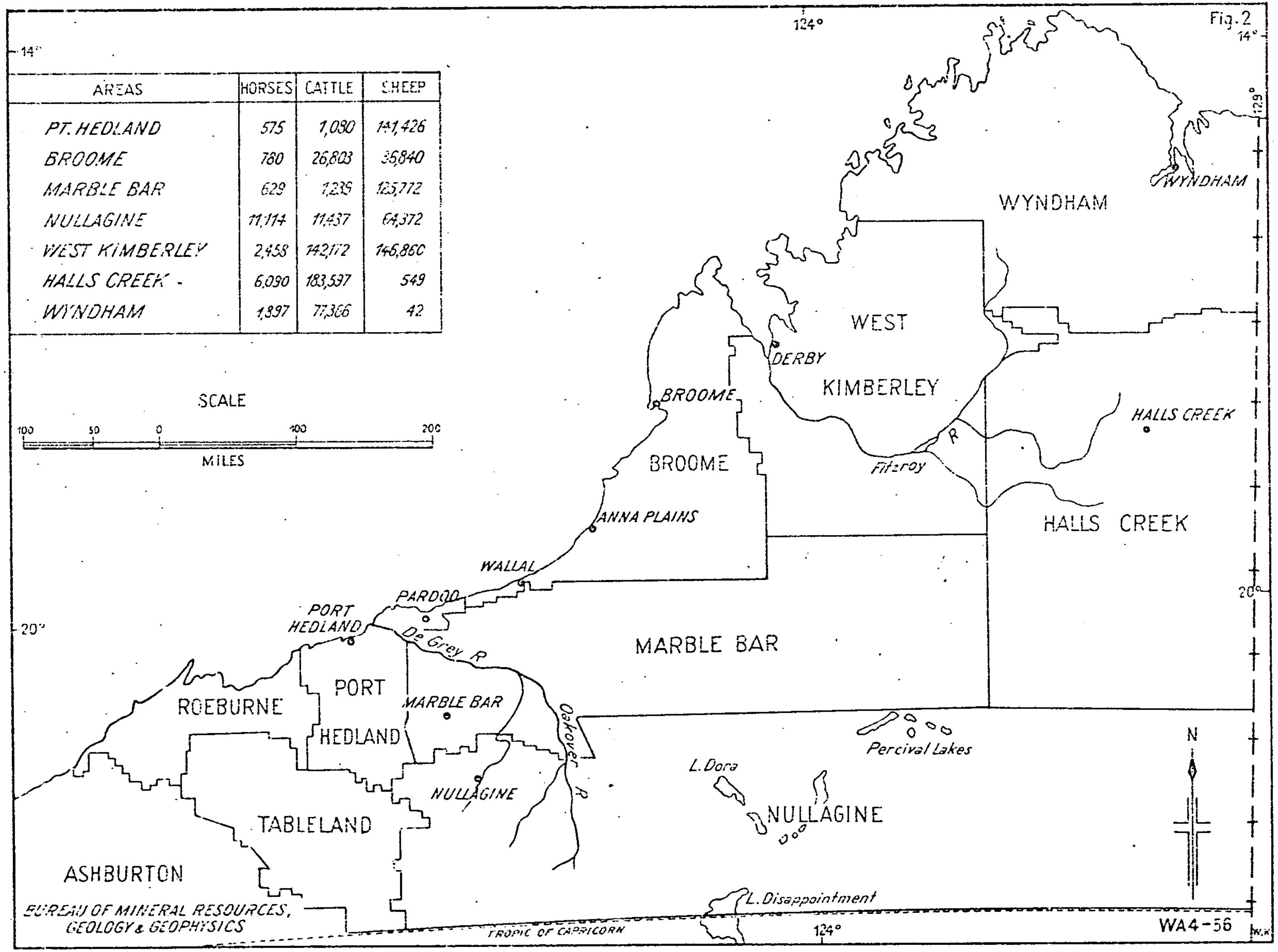


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Fig 2. Map of Northern Part of Western Australia showing Local Government Boundaries and Stock Figures in March, 1953 (after Department of National Development Map of Local Government Areas 1953).

Mining for gold, lead, manganese, tin, copper, columbite, tantatite, and beryl is carried on by local 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, and this indicated that a few of their tribe still exist in the Lake Waukarlycarly area. 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 Pt. 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 Pt. 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 did exist between Pt. Hedland and Marble Bar, but this was discontinued in 1952 and road haulage is the only means of transporting heavy good to the interior. MacRobertson-Miller Aviation Coy. operates a regular, almost daily, service from Perth to Pt Hedland and, from there, a weekly feeder service to all stations. The Flying Doctor base also operates from Pt. Hedland using M.M.A. planes. Road transport costs are normally high, but carriers carting manganese from Woody Woody to Pt. Hedland, a distance of 260 miles, charge £1 per ton: normal station deliveries cost nearly £5 per ton.

Climate

(a) The climate is partly 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: this type is more prevalent in the northern and coastal portion;

(b) 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 W.A. This climatic division is experienced in the inland southern portion, viz., Canning Stock Route and Lake Disappointment. The monthly rainfall of the De Grey area for the years 1951, 1952, 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 following shows the averaged climatic data collected from the De Grey area. The last record used to compute this average was taken in 1931. The information given for Marble Bar ($21^{o}11'$ S., 119^{o} 42'E., and altitude 595') was averaged over 29 years; for Nullagine ($21^{o}53'$ S., 120^{o} 05' E., altitude 1265') over 32 years; and for Pt. Hedland ($20^{o}19'$ S., 118^{o} 24' E., altitude 25') 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 (degree F.)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	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
Pt. Hedland	94	94	95	93	85	80	79	82	86	89	93	93

Normal Mean Minimum Temperature (degree F.)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	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
Pt. 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.	Sept.	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
Pt. 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"
Pt. 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; no 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 the North West Monsoon winds prevail.

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.

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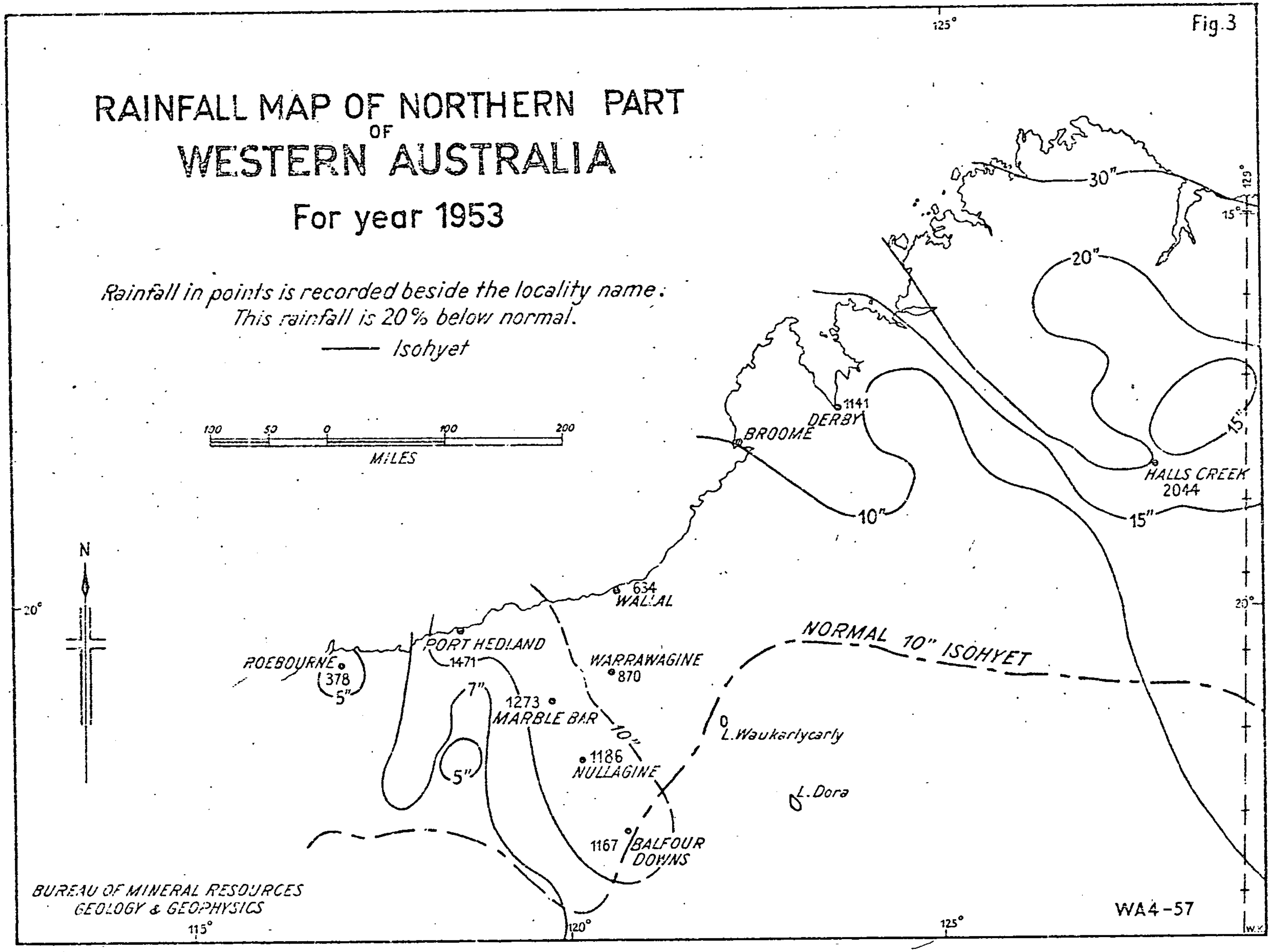

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Fig. 3 shows the rainfall for the northern part of W.A. in 1953. (after meteorological map - Dept. of Interior 1953).

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 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 by "White Gums": only the top of the dune is advancing (westwards) in any marked degree.

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

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

A collection of various plants was sent to Mr. Gardner, Government Botanist, Perth, for determination, and his results are incorporated in this report.

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

i) Acacias (yellow button flower and elongate flower);

ii. A. pyrifolia D.C. ("Spiney leaf Wattle");

iii) A. dictyophleba F. Muell. (Native Spear tree, grows 12' 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' 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');

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 leave and clusters of red flowers);

G. refracta R. Br. ("Caustic Bush", rough bark, broad silver strap-shaped leaf, and height 6-10');

Codonocarpus cotinifolius (Desf.) F. Muell. ("Desert Maple", 12-15' tall, smooth bark, straight trunk, conical outline);

Grevillea eriostachya Lindl. (with a long yellow brush flower and needle leaves; natives soak the flowers in water and extract a sweet syrup);

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;

Types of "Turkey Bush":-

(*Cassia desolata* F. Muell., *C. oligophylla* F. Muell., *C. glutinosa* D.C.);

Varieties of "Fuchsia":-

(*Eremophila* sp., *E. spathulata* W. V. Fitzg., *E.Latrobei*

F. Muell. - "Georgina Poison Bush");

Brachysema chanbersii 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') darker, narrower leafed 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.

Numerous fire burns are scattered throughout the region; they are caused by the few wandering natives burning 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. Such grasses as Eriachne ?helmsii Hartley ("Wanderie Grass"); Ichnanthus australiensis (Domin) Hughes (natives use these seeds for crushing and eating); and Eragrostis eriopoda Benth. ("Desert" or "Love" grass). Low bushes and shrubs that grow on these burns are:-

Indigofera monophylla D.C. ("Indigo" with mauve-red flower and lucerne-like leaf);

Jacksonia aculeata W. V. Fitzg. (small (2'), 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' high, spreads rather than grows vertically);

Trichinium obovatum Gand. ("Blue Flannel Bush");

T. calostachyum F. Muell. ex Benth (lavender pointer 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.

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 (plain turkey) and many lizards frequent the sand dunes. Rabbits occur in numbers in the salt-lake area, and build their warrens in travertine or unconsolidated caliche deposits close to the lakes. Some wild camels and many of their tracks were seen; they live chiefly from 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 full use of aerial photos to geologically interpret rock patterns must be made: these interpreted patterns are then controlled by limited field traverses.

In 1953, the R.A.A.F photographed the Region from 25,000 ft. and supplied vertical air-photo 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, e.g., Plates 2-6. Plate 1, the regional geological map at 8-mile scale, was prepared by photographic reduction and compilation 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 use has been made 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 it 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 S.E. portion of the desert, through Godfrey's Tank to Hall's Creek.

R. N. Smith (1898) traversed the Nullagine-Oakover area for the purposes of obtaining artesian water in this area.

Gibb A. 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 Co. Jones found Permian fossils from N.E. 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 camel to record magnetic observations at well sites and water holes.

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

C. J. Bremner (1942) made extensive aerial 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 limestones were present.

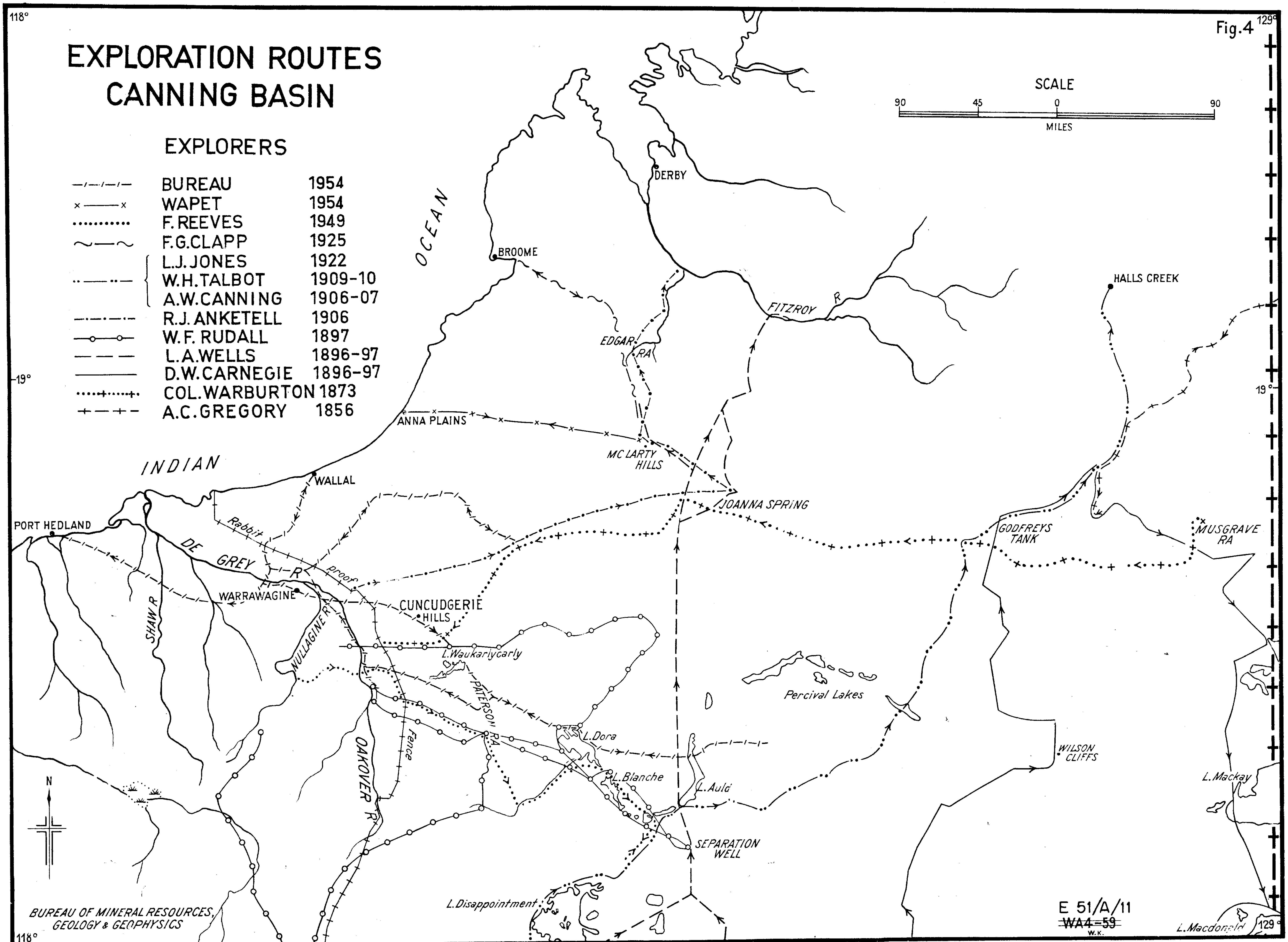

Fig. 4
EXPLORATION ROUTES
CANNING BASIN
EXPLORERS
BUREAU 1954
WAPET 1954
F. REEVES 1949
F.G. CLAPP 1925
L.J. JONES 1922
W.H. TALBOT 1909-10
A.W. CANNING 1906-07
R.J. ANKETELL 1906
W.F. RUDALL 1897
L.A. WELLS 1896-97
D.W. CARNEGIE 1896-97
COL. WARBURTON 1873
A.C. GREGORY 1856
SCALE
90 45 0 90
MILES
118°
129°
19°
DERBY
BROOME
OCEAN
INDIAN
HALLS CREEK
FITZROY R
EDGAR RA
ANNA PLAINS
MC LARTY HILLS
WALLAL
JOANNA SPRING
PORT HEDLAND
DE GREY R
Rabbit proof
Fence
WARRAWAGINE
CUNCUDGERIE HILLS
GODFREYS TANK
MUSGRAVE RA
SHAW R
NULLAGINE R
L. Waukarlycarly
PATERSON RA
Percival Lakes
L. Dora
L. Blanche
L. Auld
OAKOVER R
WILSON CLIFFS
L. Mackay
SEPARATION WELL
L. Disappointment
L. Macdonald
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F. Reeves (1949) made an extensive survey of the whole of the Canning (Desert) Basin for Vacuum Oil Co. He used pack horses for his traverses from Balfour Downs station, through the Rudall country, to Lake Blanche and Lake Auld. Reeves found Permian fossils from 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 horizontal Permian and Mesozoic sediments.

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.

Fig. 4 shows the approximate routes of explorers in the Canning (Desert) Basin of W.A.

TOPOGRAPHY

The area is topographically divided into:

(a) dissected hills bordering the desert, corresponding to the north-east part of the Pilbara Block; and

(b) desert area, corresponding to the southern part of the Canning Basin proper.

(a) 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 ft. (Paterson Range) to 350 ft. on the granite plains near Muccan station. On the Yarrie Sheet, the division includes most areas south and west of the rabbit-proof fence and includes "highs" such as the Isabella and Gregory Ranges, Ulalling Hills, and Bamboo Creek area.

In the Paterson Range and Rudall Sheets, dissected hills rise abruptly to 350 to 500 ft. above the sand plains, to form isolated units such as the Paterson, Broadhurst, and McKay Ranges.

No barometric heights are known in the Rudall area, but elsewhere ranges continue for fity miles with a height of 900 to 1,200 ft.

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 any distance 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 yards to six miles on each side of the river.

The hills forming a gap four miles east of Yarrie Homestead rise 350 ft. 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 influence of 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 Pre-Cambrian rocks and form steep gorges in which lie permanent pools, e.g., Carawine Gorge. The channels of these two major streams average 400 yds. in width and the bed of the stream is generally only about 15 ft. below the level of the alluvial plain. The gradient of these rivers is as follows:

<u>Oakover River</u>

Locality		Distance (miles)	Fall (feet)	Gradient (ft.per mile)
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
Carawine Gorge	- do.	75	330	4.5

<u>Nullagine River</u>

Pinjian Pool	- Warrawagine	10	30	3.5
Warrawagine	- Junction with Oakover River	13	85	6.5
Pinjian Pool	- do	22	115	5

<u>De Grey River</u>

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 may explain 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.

(b) Desert Division

This 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 ft. east of Lake Wooloomber.

Small hills rise less than 150 ft. above the level of the sand plain. Cuncudgerie Hill is a small monadnock rising 130 ft. above the general level of the plain. Numerous small rounded rises scattered throughout the area are not higher than the surrounding sand dunes.

The salt lakes formed by internal drainage are characteristic of the desert. Lake Waukarlycarly is situated approximately twenty miles north-west of Mt. Crofton, and Lakes Dora, Blanche, Winifred, Auld, and Wooloomber form a U-shaped group east of the Rudall River area. The bed of the lakes consists of a thin crust of salt and gypsum underlain by at least 18 in. of brine, saturated sand, and mud. The surface of Lake Waukarlycarly is distinct from the other lakes observed in that it is mostly covered with a soft powdery caliche and some salt. The salt-water level at Lake Dora was less than 12 ins. 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 ft. above sea level, Lake Dora 650 ft., and Lake Wooloomber 755 ft. 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 with 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 mainly 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 ft, but dunes twice this height were measured.

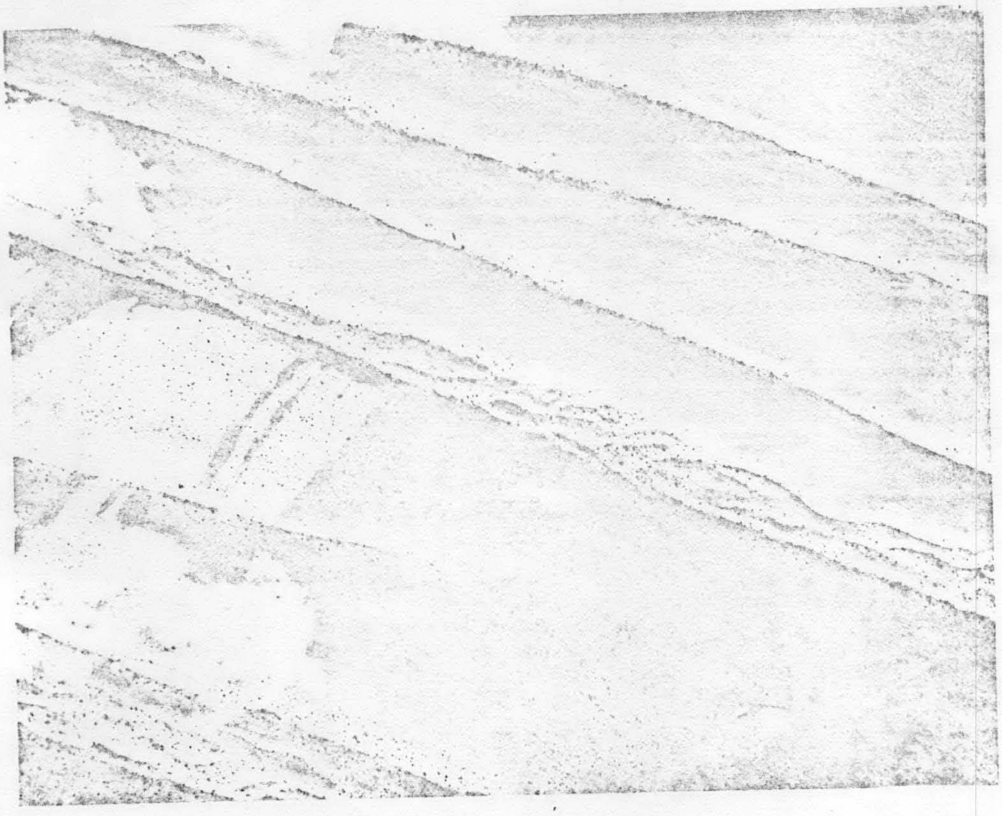

Fig. 5. Parallel sand dunes with light coloured fire burn patterns, from air photograph east of Lake Wooloomber. Scale $\frac{3}{4}$ mile = 1 inch.

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

In some cases small areas of perhaps 10 sq. miles may consist of irregular short dunes of complex pattern, but their longer axes always trend in the same general direction as the others. Braiding is particularly noticeable adjacent to 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 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.

Fig. 6. Looking N.W. along a 120 ft. high sand dune, 60 miles E of Ragged Hills.

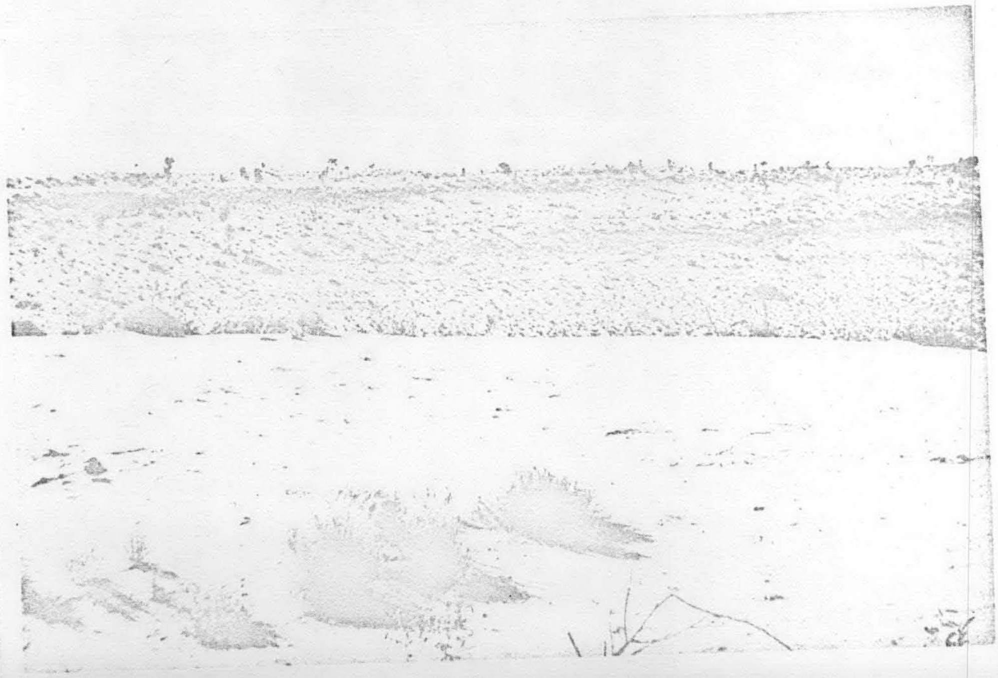

Fig. 7. Looking N. across a dense field of 80 ft. high dunes, 8 miles S. of Mt. Crofton.

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 yds.

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 continental shelf and contains Palaeozoic and younger sediments.

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

The name "Desert Basin" was used for the 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 of sufficient magnitude to justify a separate naming within the larger unit. The first of these areas to warrant an individual name is the Fitzroy Basin in the north, between the Kimberley Block and the Fenton Fault line.

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

Pre-Cambrian, Permian, Mesozoic, and Tertiary rock units have been recognised, and the post-Pre-Cambrian 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.

PRE-CAMBRIAN.

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

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, recognized 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 Creek Beds "contains numerous pebbles of laminated quartz (chert) and jasbillite 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". 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 into Upper Proterozoic and, possibly, even into the base of Lower Cambrian; and the metamorphosed rocks unconformably below, such as the Hall's

Creek Group (Traves 1955), are placed in the Lower Proterozoic.

Because of the confusion in nomenclature and the lack of detailed mapping in the Pre-cambrian of the area surveyed, the Pre-cambrian 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 Northern Territory.

Lower Proterozoic Rocks

(a) Metamorphics

Metamorphics, predominantly greenstone (altered pillow lavas), serpentine, tal-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 Paterson Range Sheet, and the southern portion of Table Top 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 inter-penetration 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.

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. Cecelia. 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, quartzites, and greenstones were mapped by photo-interpretation on the Rudall and Table Top Four Mile Sheets.

(b) Igneous Rocks

Granitic rocks crop out in the country bordering the desert and in the desert, the main areas being (1) the plains of Talga-Talga; (2) between Coongon and Yarrie; (3) east of Lake Waukarlycarly; and (4) 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 sit on the granite, apparently forming roof pendants. The contact shows granitization of the basic volcanics. The ragged edges of structures in the Metamorphics abutting 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 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 N.E. of Nimingarra Homestead. At Black Hill, ten miles E. 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 200 yds. wide and fifteen miles long.

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.

Farther south, north of 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 Roony 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 Metamorphics (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)

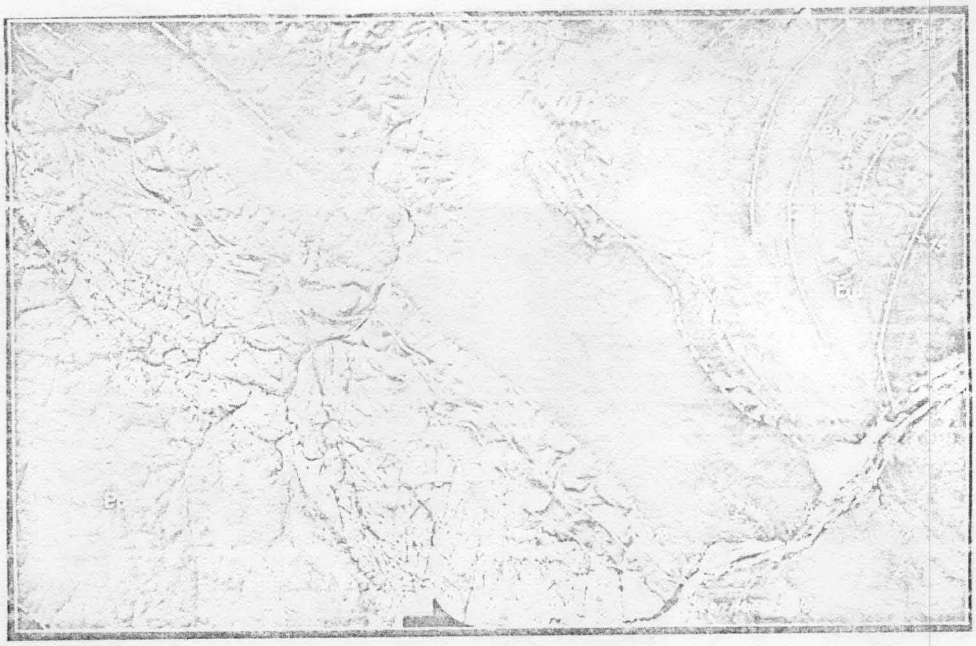

Fig. 8. Aerial view of Upper Proterozoic lithological units units near Green Hole.

Fig. 9. Green Hole synclinal belt at 4 miles = 1 in.

The Lower Proterozoic Metamorphics are unconformably overlain by a well-jointed rhyolite porphyry which has an apparent

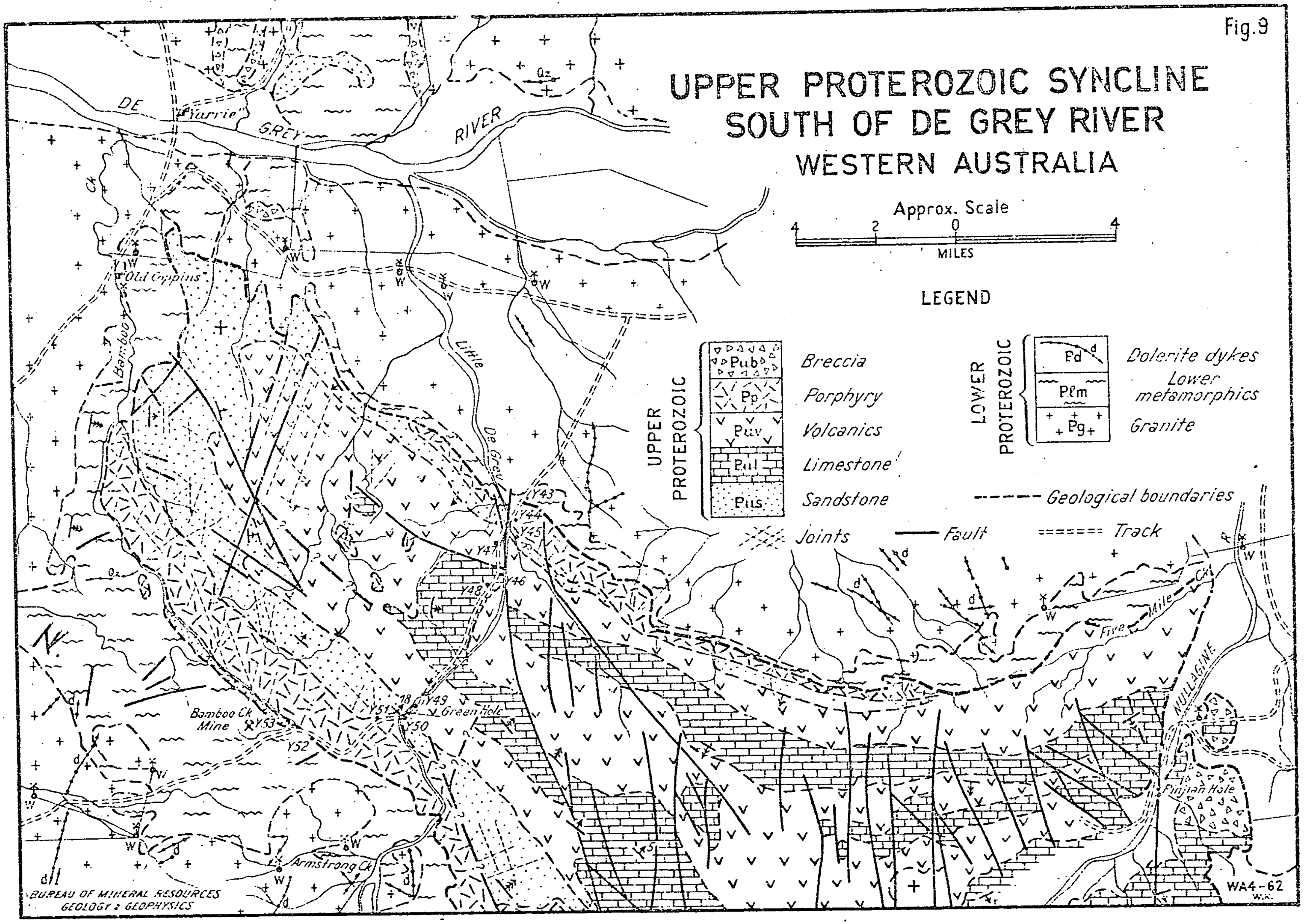
Fig.9
UPPER PROTEROZOIC SYNCLINE
SOUTH OF DE GREY RIVER
WESTERN AUSTRALIA
Approx. Scale
4 2 0 4
MILES
LEGEND
UPPER PROTEROZOIC
Pub Breccia
Pp Porphyry
Puv Volcanics
Pul Limestone
Pus Sandstone
LOWER PROTEROZOIC
Pd Dolerite dykes
Plm Lower metamorphics
Pg Granite
Geological boundaries
Joints
Fault
Track
DE GREY RIVER
Yarrie
Old Coppins
Bamboo Ck
Little De Grey
Bamboo Ck Mine
Green Hole
Armstrong Ck
Five Mile Ck
NULLAGINE
Pirijan Hole
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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 stratigraphic 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 and Y51, the porphyry intrudes a slate underlying the sandstone, and the distribution of the porphyry is probably governed by the selective intrusion into the shale (slate). 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 ft. on the western limb, but it thins out on the eastern limb and does not outcrop on the north-western nose of the syncline.

The sandstone overlying the porphyry on the eastern limb at Y45 consists of 100 ft. of coarse sandstone with some beds of fine conglomerate. A much thicker section of the sandstone crops out on the western limb at Green Hale, Y50. At this locality 800 ft. of well-bedded, well-cemented, poorly sorted pebbly fine conglomerate, pebble conglomerate, and coarse arkosic sandstone dip N.E. at 18°. This unit is overlain by more than 300 ft. of medium bedded, poorly sorted pebbly fine conglomerate, pebble conglomerate, and coarse sandstone which is intruded by a sill of hornblende porphyry. The top of this unit is covered by transgressive basic volcanics. 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 limestone and dolomite fills the central portion of the syncline, although in most places it is covered by basic volcanics. At Y46, a dark siliceous limestone crops out through the volcanics and forms trend ridges. This limestone exhibits numerous concentric structures from ½ in. to 2 ft. in diameter which could be colonies of algae or slump structures.

This limestone on the eastern limb extends south-east to Pinjian Pool, where 150 ft. 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.

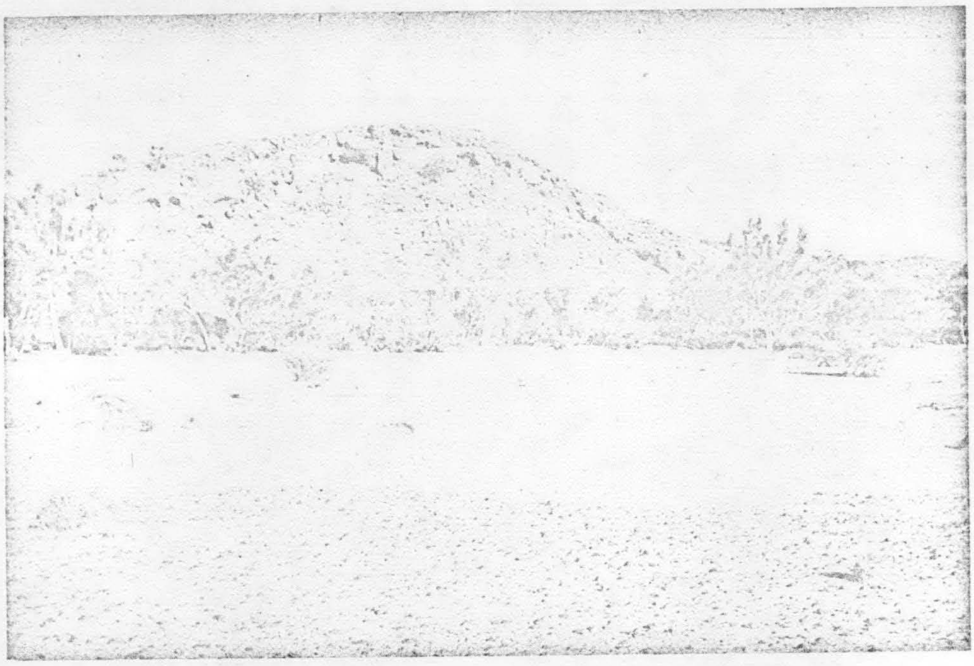


Fig. 10.

The unit of dolomite can be correlated with the dolomite that forms the high western cliff of Carrawine Pool, south of the area surveyed, and with the Upper Proterozoic dolomite which outcrops 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 this unit. It ranges from dark to light red and white, and is composed of angular fragments of chert cemented by silica or, in special cases, by hematite or manganese. A complete range has been seen from siliceous breccia to manganiferous breccia to manganese ore: the manganese deposits at Woody Woody and the siliceous breccia belong to the one unit. Their origin appears to have been chemical deposition in a lacustrine or possibly even marine environment, in places cementing the mantle of chert fragments weathered from the underlying dolomite.

or early in the Palaeozoic.

The Upper Proterozoic sediments north of Yarrie have not been correlated with those exposed in the syncline (Fig. 9); but no doubt more detailed mapping would establish the complete section for the whole area. In the hills between Eel Creek and Callawa Homestead at Y21, a 600 ft. section of Upper Proterozoic sediments dips ENE. at 8 degrees. The section is:

	120 ft	Jurassic Callawa Formation.
	60 ft	Permian Braeside Tillite.
Upper Proterozoic.	5 ft	Sandstone, dark, ferruginous - represents unconformity.
	420 ft	Sandstone, medium to coarse, clay pellets, micaceous, white to yellowish, ripple marks in finer beds - ripples have amplitude of 1 in. and wave length 6 in. with a wave direction of 150°. Some shale bands and fine conglomerate lenses.
	2 ft	Dolomite, pink, thin bedded.
	2 ft	Sill or flow of basic volcanics.
	40 ft	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 Y 20, the section is:

	60 ft	Jurassic Callawa Formation.
Upper Proterozoic.	240 ft	Basic volcanics, onion weathering, and pillow structures.
	10 ft	Slate, 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 possible that this dark shale and slate seen in sections Y21, 20, and 34, may be part of the Lower Proterozoic sequence and may, in fact, be equivalent to part of the "Mosquito Creek Beds."

On the eastern side of Eel Creek at Y16, granite exposed on the valley floor is overlain by 50 ft. 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 conglomeratic sandstone which caps the hematite jasper at Y15, and which 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, from photo-interpretation, they probably are sandstones and shales. Reeves (1949) reported a red sandstone and pebble conglomerate forming a 200 ft. 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 Rudall Sheet.

The correlation of Upper Proterozoic rocks in Northern Australia is difficult because of incomplete knowledge of sequences, distributions, and orogenies; but the sandstones, dolomites, and volcanics of this area distinctly resemble the King Leopold Formation, Warton Beds, Mt. 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 forming 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, first manager of the Agricultural Bank of W.A.

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 is... no reason why glacial boulders should be confined to the base of a formation....; 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 caused by over-riding icebergs.

Fig. 12. shows the contortion in the Paterson Formation at the north end of Paterson Range. 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 ft; the smaller rock fragments are generally more angular than the larger ones; quartzite and granite predominate, with minor amounts of cleaved siltstone and quartz.

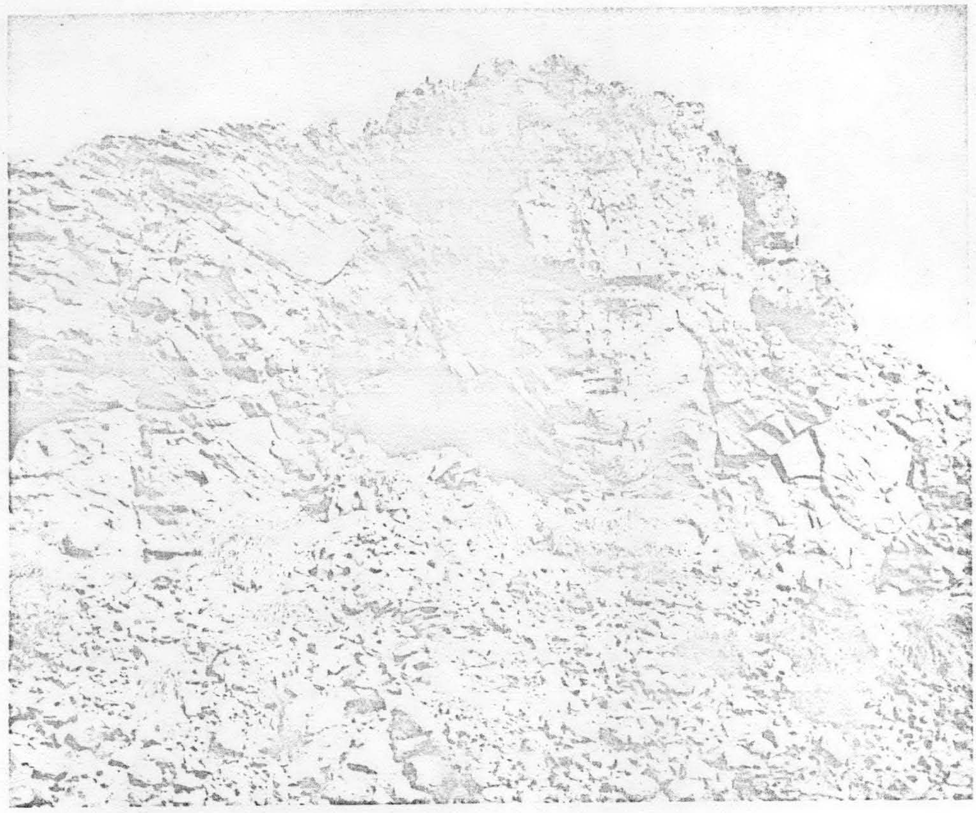


Fig.12

No varied shales were observed.

The formation forms low rugged hills and mesas, capping Precambrian metamorphosed sediments.

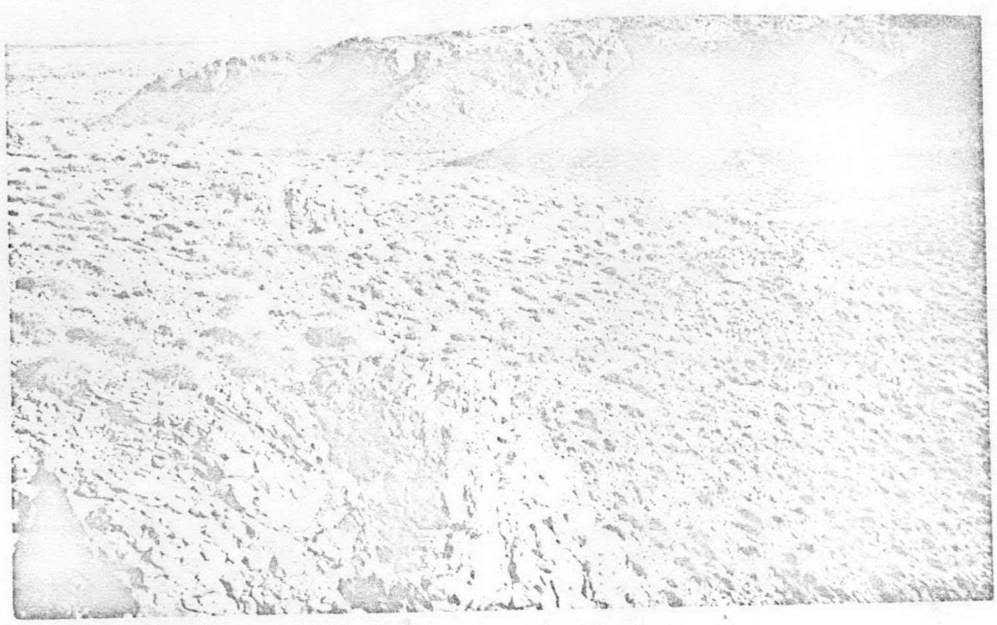


Fig. 13. Topography of Paterson Formation, north end of Paterson Ra., looking N.

In the Paterson Range, 100 ft. of glacial sediments were measured:

15 feet sandstone, medium-fine-grained (0.25mm.), 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 st ined) argillaceous cement. The boulders and pebbles (maximum 3 ft,are subrounded.

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

The Permian age of the formation is tentative; it overlies the Precambrian 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 correlated wit the Braeside Tillite in the Warrawagine area, which is overlain by Jurassic plant-bearing sandstone.

The glacials are correlated with similar glacial and fluvioglacial sediments of the Grant Formation (Guppy 1953, p.402) in the Fitzroy Basin, and with the Lyons Group of the Carnarvon Basin. (Condon, 1955).

Braeside Tillite

The formation derives its name from the type locality, 2 miles NNW 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 ft. 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 lithology 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 ft. of section is protected from weathering by a cap of limestone and chalcedony 30 to 50 ft. 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 H.S. 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 maximum diameter of these morainic boulders is 4 ft. Overlying the moraine and extending northwards (basinwards) from it is a succession of 50 ft. 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 ft. at No. 36 dud bore. The total known thickness of the Tillite is approximately 400 ft. (334 ft. penetrated in a bore hole and 60 ft. to 70 ft. outcroppin

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 Carnegie, originally referred to by Talbot and Clarke (1917).

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 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 it is possible that the Braeside Tillite was, at least in part, a terrestrial deposit formed by glaciers proceeding to the sea down an old Nullagine-Oakover valley; the Paterson Formation was possibly deposited under a marine environment.

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

The formation derives its name from Cuncudgerie Hill (121°31'E, 20°55'S) on the south-west corner of the Anketell 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 at the type locality.

The formation consists of a succession of sandstone, fine conglomerate and greywacke beds, the 130 feet measured section at Cuncudgerie Hill consisting of:

20 ft. sandstone, ferruginised, coarse to medium-grained (average grain size 2mm.), 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 ft. sandstone, white to pink, medium-grained, with some larger quartz grains; easily eroded to form caves in the outcrops; yellowish-brown; massive beds.

50 ft. 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 ft. sandstone, dark ferruginous coarse-grained, at the base of the hill.

The section measured at the type locality (P.1, reference Paterson Range Four Mile geological map) totals 100 ft. and is composed of:

10 ft. of sandstone, coarse, and conglomerate, fine with pebbles ¼" in size; subrounded; dark ferruginised colour.

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

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

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

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

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

Thomas and Dickens (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 and Rudall Four Mile sheets; the lake was named by W.F. Rudall in 1897.

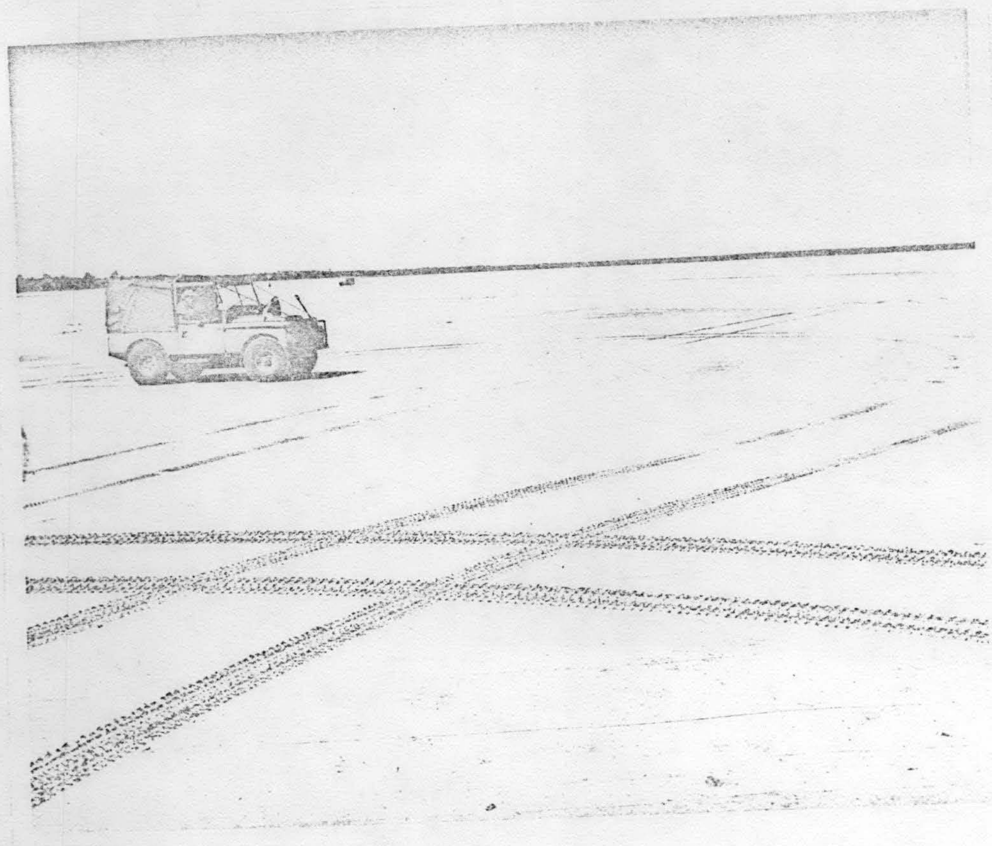


Fig. 14. Lake Dora looking south, showing salt crust.

The lithology is predominantly sandstone and shale; the texture, light weight, and palid colour of the outcroppings beds suggest that they may be decalcified. The known outcrops are confined to the eastern margin of the salt lakes of Dora and Blanche; here they form cliffs 50 ft. to 100 ft. high, the salt crust of the lakes abutting these cliffs.

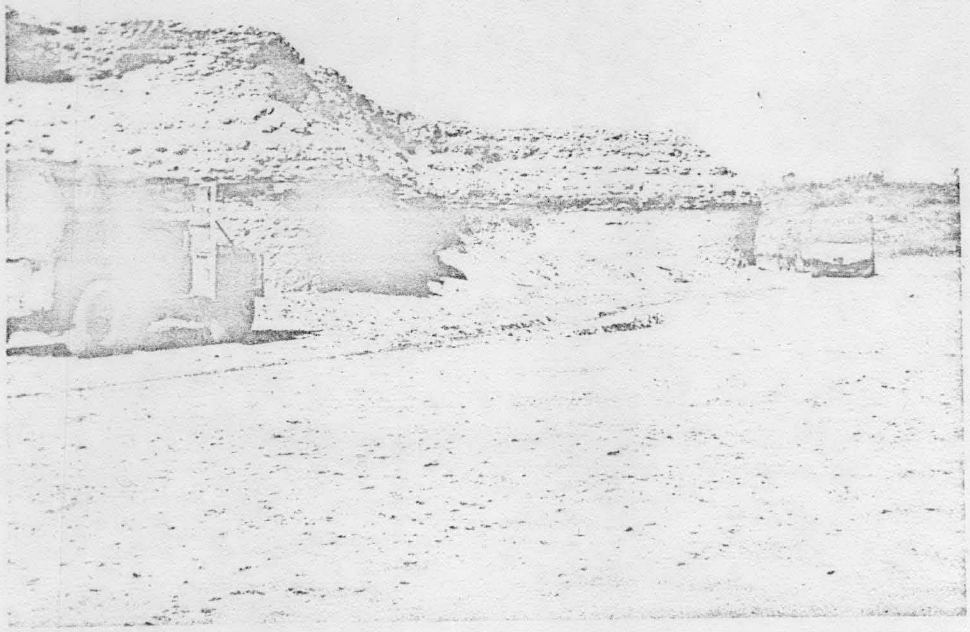


Fig. 15. Cliffs on the north east of Lake Dora exposing Dora Shale.

A vertical section was dug at the north end of Lake Dora, 50 yds. from its margin, revealing:

0 - ½"	layer of white crystalline salt.
½"- 4"	gypsum crystals in a black silty moist matrix
4"-19"	sandstone, fine grained, brown, containing 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.

A sample of the bedrock of Lake Wooloomber was not taken but it is considered that one reason for the existence of the Dora, Blanche, Wooloomber 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 Wooloomber.

The 40 ft. section exposed on the north eastern edge of Lake Dora consists of horizontal, well bedded (beds 1 in. to 1 ft. thick), micaceous, white, violet and yellowish claystone, contain-thin worm trails and ? woody remains. Four beds in the section resist weathering and protrude as ledges; these beds are laminated ferruginised claybeds. 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 westwards 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".

The Dora Shale is correlated with the Noonkanbah Formation of the Kimberleys, which has a similar lithology (though more calcareous) and microfossils.

Triwhite Sandstone (New Name)

The formation derives its name from three conical white-topped hills, 9 miles east of northern portion 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 ft. high, capped with conglomerate.

Fig. 16. shows the Triwhite Hills looking south-west in direction of Lakes Dora and Blanche.

The known area of outcrop of this 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

...ls

fossils were collected from the iron stained greywacke lying on the surface; at this locality the topography is gently undulating, with no meas-type exposures.

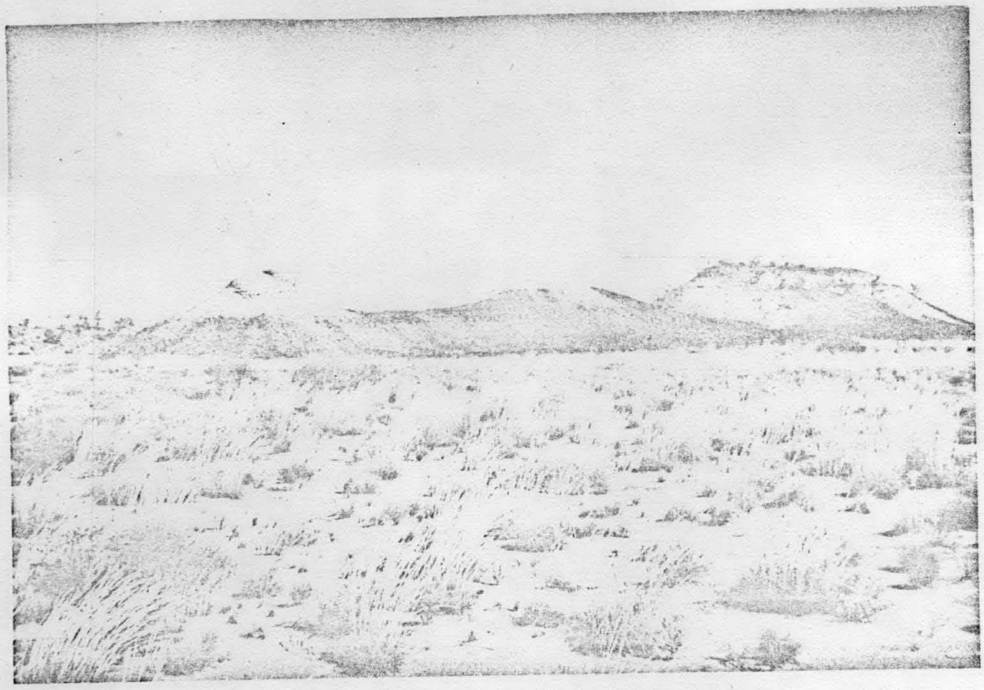


Fig. 16.

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

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

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

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

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

This was the thickest section measured; remnants of ferruginised sandstone with fossil fragments litter the rises.

The beds have a very low dip to the east, ($\frac{1}{2}^{o}$-1^{o}), and if this dip is maintained for 5 miles until the sandstone becomes covered with the Mesozoic, a thickness of 200 ft. to 300 ft. 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 Group of the Kimberley region, and the Triwhite Sandstone is therefore correlated with these units on fossil evidence and a similar lithology.

MESOZOIC

Sediments of a Mesozoic age overlie or are marginal to the Permian in the southern portion of the Canning Basin and exten northeastwards towards the centre of the desert. These Mesozoic clastic sediments are largely covered with sand, seif dunes and spinifex; the outcrops, mainly ferruginised sandstones, are scattered, intermittent, and low (rarely exceeding 100 ft.). Permian and Mesozoic sediments are often difficult to distinguish because they are both predominantly ferruginised sandstone.

The mapped thickness of Mesozoic sediments is about 400 ft. Three lithological units are given the rank of formations: they are described in ascending order.

Callawa Formation

The Callawa Formation is named from Callawa Hills (120^{o} 32'S, 20^{o} 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 "Callaws Boulder Beds" was used by Reeves (194[illegible] for a "series of cross bedded sandstones and boulder beds 200-300 ft. 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.

Fig. 17. Section of Callawa Formation at Y20, showing coarse conglomerate and current bedding.

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

70 ft. 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 $\frac{1}{4}$") showing strong cross bedding (the direction always is north or north-east i.e. basinwards). Some plant stems in the claystone lenses. The section is predominantly light red-brown.

100 ft. claystone and sandstone, fine-grained to medium-grained; vari-coloured - white, violet, and mottled; well bedded; several beds or lenses of coarse-grained sandstone; 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:

45ft. sandstone, dark, ferruginised, coarse-grained, with angular quartz grains; the top 5 ft. of this contains large clay pellets and plant stems measuring 1 ft. long and 1 to 2 ins. wide. One mile south of No. 3 Desert Bore on the same track to Wallal, the sandstone with large plant stems is overlain by:

40 ft. shale, violet and white, micaceous, breaks with a conchoidal fracture into 3 in. pieces. The top 15 ft. of this section is lateritised, although the full sequence of ferruginous mottled and pallid zones is not evident.

This gives a total measured section of 250 ft. for the Callawa Formation. Reeves (1949 p.9) states "between Wallal and the southern margin of the basin Jurassic sandstone and shale..... show a northward dip of less than $\frac{1}{2}^{\circ}$".

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 a 80-foot ferruginised mesa, 15 miles north-north-east of Warrawagine Station.

As mentioned on P.27, 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, this conglomerate grades basinwards into finer sediments. At All on the central portion of the Anketell Four Mile Sheet, the conglomerate is represented by dark ferruginised coarse sandstone, containing some woody remains; the outcrops are 20 to 40 ft. high, and are mostly below the dune crests and visible only in the troughs between the dunes. A similar lithology is present at T5 and between Lakes Dora and Wooloomber on the Tabletop Four Mile Sheet.

The 50 ft. section four miles east of Lake Wooloomber at T5 consists of:

2 ft. sandstone, coarse-grained, unsorted, light brown, lateritised.

5 ft. conglomerate, fine-grained (maximum pebble ¼") with some coarse-grained sandstone. Current bedded, many clay pellets. Moderately sorted.

38 ft. 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 fan 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.

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. Brunnschweiller, is Jurassic (See Appendix A). The significant plants determined were Johnstonia cladophlibis, Paliophyllum, Sphenopteris and Dictyophylum; no Thinnfeldia was seen. Reeves (1949) records "Otozamites sp. nov. from 4½ 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.

The absence of Thinnfeldia suggests a younger age than Upper Triassic (Erskine Sandstone of the Kimberley Region); the presence of Johnstonia suggests a lower Jurassic or late Triassic age as this form occurs only in Tasmania and Queensland in the late Triassic.

The formation cannot be correlated directly with any formation in the Fitzroy Basin.

Anketell Sandstone (New Name)

The name is derived from Anketell Four Mile Sheet, named after the explorer R.J. Anketell who crossed this area in 1906 when proceeding 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 Wooloomber on the Tabletop Four Mile Sheet; this hill is 40 ft. high and is part of a small dissected plateau with gradually disappears under sand cover towards the east. Beds containing numerous casts of the marine worm Rhizocorallium occur at the base of the hill.

Fig. 18. Close-up of a specimen of Rhizocorallium.

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 mappable Anketell Sandstone.

The formation crops out in the eastern portion of the Tabletop Sheet, the north and eastern portion of the Anketell Sheet, and the northern portion of the Yarrie Sheet. In all places it overlies or is marginal to the coarse ferruginised 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 origin for the beds.

The 40 ft. type section at T7 consists of:

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

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

15 ft. sandstone, medium-grained, ferruginised, bedded, ripple-marked, with some worm tracks.

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

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

The presence of Rhizocorallium, a marine diagnostic Lower Cretaceous worm, common in the Rumbalara area of northern South Australia, and determined by Dr. Öpik, 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.

A possible correlation may be made between this Formation and the Dampier Group (Neocomian) or Jarlemai Siltstone (upper Tithonian) of the Broome region.

TERTIARY   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 mentioned but not named by Neil Smith (1897).

In this report Oakover Beds is the unit 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 in the vicinity of Carawine Pool.

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 pre-occupied in the ? Permian Braeside Tillite.

At least 40 ft. 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 60 ft. of similar sediment crop out in the surrounding hills, giving a total thickness of at least 100 ft. of Oakover Beds in this area. The top 20 ft. 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 ft. of Oakover Beds crop out, and here they 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.

Fig. 19. shows Oakover Beds overlying Braeside Tillite with roche moutonnée in middle distance; 2 miles from Carawine Gorge, looking south.

At Y2 two small areas of limestone capped by silica exposed near Eel Creek, 3 miles north east of Yarrie Homestead on the Callawa road, are tentatively included in the Oakover Beds.

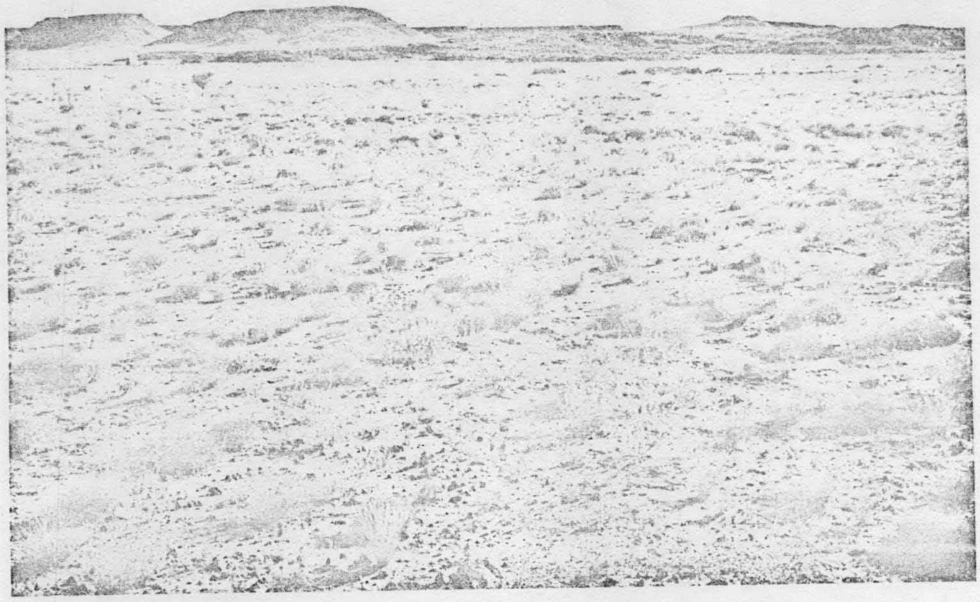


Fig. 19.

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 Conglomerate and other associated Jurassic sediments was not seen in the field.

The lithology and distribution of the Oakover Beds suggests 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 only that the Beds are younger than the Braeside Tillite, that is, post-Permian. However, 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 even 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 does suggest a post-Mesozoic age.

The lithology and mode of occurrence of the Oakover Beds very closely resembles 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.

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 isolated parts of the area were lateritized.

The occurrences of laterite are irregular. 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 ironstone and ferruginized sandstone - but where the outcrops are of claystone, a massive, resistant, laterite profile may be developed;

(b) an extensive erosional period since the formation of the lateritic surface, thereby producing the irregular distribution of laterite outcrops.

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 laterite overlying 25 feet of mottled claystone.

Along the Telegraph Line from Callawa, 12 miles south of the first catchment tank, 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 ft. thick.

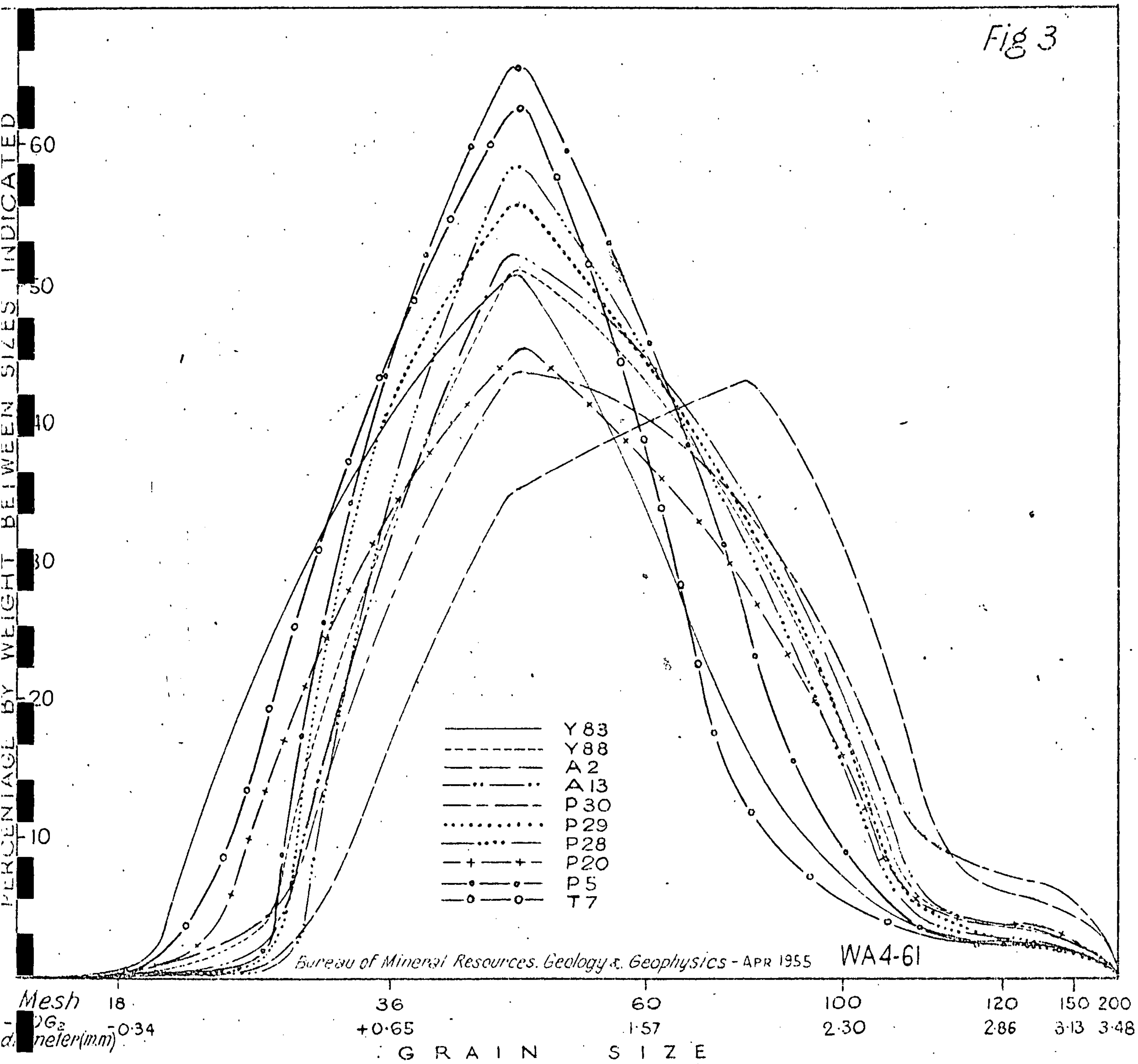
The northern end of Paterson Range is capped in places by laterite.

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

The sand, which masks most of the outcrops in the desert, originates either directly from the underlying ferruginized Mesozoic and Permian sandstones or from the disintegration of the laterite profile. The red sands are composed essentially of quartz grains coated with a film of iron oxide; this type of sand could possibly have been derived from the disintegration of the laterite profile. The red sands are composed essentially of quartz grains coated with a film of iron oxide; this type of sand could possibly have been derived from the disintegration of the "A" horizon of a laterite. A postulated ?Miocene laterite peneplain would provide a source for the extensive Quaternary sand deposits throughout the desert.

If the red sands were derived from a laterite rather than from a ferriginized sandstone source, the iron oxide coating the sand grains would probably have a high OH' radical, rather than a higher hydrated oxide in its composition; chemical tests have so far been unable to prove from which source the red sands were derived.

MECHANICAL ANALYSES OF THE CANNING BASIN DUNE SANDS



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 formation of laterite, and could therefore derive iron from the laterite. These iron deposits are below the level of the laterite profiles. A hill 20 miles east of Port Hedland is capped with 20 ft. of pisolitic ironstone which resembles a ferruginous zone of a laterite, but examination showed that it contains fossil wood and probably has a lacustrine origin. Chemical analysis of this deposit shows:

	%
Loss on ignition at 1,000°C.	13.80
S_iO_2	1.89
Fe_2O_3	77.50
Al_2O_3	8.75

QUATERNARY

A great variety of superficial deposits, 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 has been cemented with lime to form a "Coastal Limestone" composed of quartz and fragmentary tests of marine shells. In the interior, the sand is ironstained, red and brown, and is blown into long parallel seif dunes (Bagnold, 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 and diagnostic foraminifera found in the "recent" deposits within Lake Dora only occur in shales which outcrop for a maximum distance of three miles to the east of the lake. Any extensive area of low outcrop is not 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 (Bureau of Mineral Resources); some of his results are given below. The sands 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. Heavy mineral determinations showed less than 1 percent in the sample, 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 show relatively poor sorting which indicates a close proximity to the original source rocks.

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

The floor of the large salt-pans and clay-pans in the desert is covered with a deposit of thin-bedded clay or slit 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

By the study of the development of the structural elements of the Canning Basin and the surrounding areas, since the Precambrian, it may be possible to predict the type and thickness of deposits which may be expected in the central part of the Basin, but which are now obscured by wind blown sand.

The sediments of the Basin have been regarded as resting, in part at least, on the ill-defined "Pilbara Block" (Fairbridge 1953), which is a "block" in the sense of post-Precambrian sedimentation. The Precambrian history of this "block" may now be more accurately and conveniently divided into:

(a) A mobile zone containing predominantly metamorphosed geosynclinal sediments, volcanic flows and granite intrusions and hereafter referred to as the "Pilbara Mobile Zone". Such a Zone is analagous to the "King Leopold Mobile Zone, which forms the western part of the Warramunga Mobile Zone, and to the "Halls Creek Mobile Zone" (Traves 1955).

(b) A stable block, named here as to the Desert Block, which persists north from the "Pilbara Mobile Zone" to the "King Leopold Mobile Zone".

A review of the structural elements in northern West Australia at the end of the Precambrian would be:

The Kimberley Block of ? Upper Proterozoic sediments, surrounded by the Halls Creek Metamorphics on the east and the King Leopold Mobile Zone on the south; then the disputable Desert Block which is bounded on the south by the Pilbara Mobile Zone of ? lower Proterozoic sediments, and on the east by ? metamorphic sediments (based on aerial photo-interpretation in the Stansmore Range area). South of the Pilbara Zone is the Fortesque Block of ? Upper Proterozoic sediments.

These geosynclinal sediments of the mobile zones would provide the material for the adjoining broad upper Proterozoic cratonic basins whose floor is the source area of the lower Proterozoic geosynclinal sediments.

It is important to know whether the Desert "Block" has been continually negative since lower Proterozoic or earlier, or if it has been positive, undergoing only shallow transgressions during the Permian and Mesozoic.

If the Block has had a predominantly positive history, at least since Precambrian, then it is an area of denudation rather than deposition, and it would provide sediments for a Palaeozoic and Mesozoic area of deposition in the Mobile Zone areas viz. Fitzroy Basin and ? Godfrey Tank area. The lithology and the [illegible] of Permian and Mesozoic fossils shows that the southern part of this "block" was a shelf which may have extended north to the Fenton Fault which marks the south boundary of the Fitzroy Basin.

If the Block had a negative history, the petroleum prospects, particularly in the northern part, are encouraging. The Fenton Fault line in this case could represent the southern extension of a Fitzroy shelf, and continental slope and deep water type sediments would exist south of this line. The "Desert Block" would then have an ssymmetrical cratonic basin imposed on it, and sediments from the Pilbara Zone to the south, would shed into this basin during Palaeozoic and Mesozoic time.

It is important to decide whether the Fenton Fault is in fact a fault, or is it primarily a shelf edge which has experienced only secondary faulting.

The gravity profile across the fault is of two types, one with a relatively high, one with a relatively low gravity on the south side. This could indicate.

(a) a large thickness of sediments conforming to the "lows" where there is no shelf, and

(b) either large discontinuous dolomitic reef masses which grew along the shelf edge, or the presence of a shallow basement conforming to the "highs". If this "Fenton Line" is a shelf edge, the shelf conceivably corresponding to the Precambrian Mobile Zone, then the continuation of this Line to the east in direction of Godfrey's Tank must be regarded as a crucial point in elucidating any petroleum prospects in the basin.

The east-west trend of the Musgrave and Macdonnell Ranges (N.T.) may indicate a lower Palaeozoic trough continuing under the Canning Desert. The Ordovician of Prices Creek (Fitzroy) is shelf and not trough sediments and therefore there may be trough type lower Palaeozoic sediments in the centre of the Canning.

The Permian and Mesozoic sediments have been very slightly affected tectonically; a small angular unconformity is observed between the Triwhite Sandstone and the Mesozoic sandstone and conglomerate near the Triwhite Hills. The Permian sediments were slightly folded prior to 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 represent the trends of small folds. The Shale is known to have a 1^{o} N.E. dip near Lake Blanche, and the Triwhite Sandstone dips $\frac{1}{2}^{o}$ to 1^{o} E.N.E. at Triwhite Hills.

Slight tectonic movements have affected the Mesozoic; this is shown in a small north elongated fold (possibly faulted - photo interpretation) extending south from All on the Anketell Sheet.

If the Desert Block is in fact a stable block, there is a distinct possibility of obtaining a thick section of sediments overlying the Mobile Belts which border this Block; the area in the north-east part of the Canning Basin (where there is a possibility of the King Leopold, Warramunga and Halls' Creek Mobile Zone joining) should prove a pertinent area to search for a thick sedimentary section which may show the effects of a past tectonic history.

A recent airborne magnetometer survey by the Geophysical Section, from Marble Bar to Halls' Creek, reveals either

(a) that the basement is shallow and lithological changes are reflected as gentle gradients in the profile, or

(b) that the basement is deep and the thick section of sediments over basement variations produces gentle but extensive gradients in the profile.

GEOLOGICAL HISTORY

The oldest rocks of the area are the Lower Proterozoic Metamorphics, granite, and pegmatite, which form part of the Pilbara "Block". These sediments and volcanics were severely folded, metamorphosed and granitized, and subsequently intruded by dolerite dykes and quartz "blows". They were eroded before the Upper Proterozoic transgression when 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 "blows" and pegmatites, and may be feeders for the Upper Proterozoic lavas. These dykes were confined to the granite outcrop areas 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 dedeposits have been found (unless the volcanic outpourings and breccia formation could be classed as ?Cambrian), as the whole "block" remained a land surface of denudation until Permian times. 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 of the older glaciers as they advanced to the sea.

Either contemporaneous with or after this glacial deposition, the marine fossiliferous Cuncudgerie Sandstone was deposited in the epeiric sea: this 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, but during the Triassic the Permian rocks were slightly folded and truncated, and, regionally, the Permian formations are truncated by Mesozoic outcrop patterns. The Permian surface had low relief and underwent little dissection as no pronounced erosion surface exists between the two units.

The Jurassic Period probably began with deposition in freshwater lakes, when lacustrine sandstones and coarse conglomerates of the Callawa Formation were deposited. The Pilbara "Block" 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 an epeiric sea flooded the area and the Anketell Sandstone overlies the Jurassic sediments conformably.

During the Tertiary, the "Oakover-Nullagine" river system, which was probably recurrent 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. There has probably been very little tectonic change in the surface since Cretaceous times. This surface resulted from the gentle and even emergence of the Cretaceous sediments. Present-day monadnocks such as Mt. Crofton and Lamil Hills represent remnants of a much older topography. The Lower Proterozoic Metamorphics occupy the more elevated borderland hills and monadnocks in the desert area: the monadnocks possibly formed more extensive islands in the Permian, Jurassic, and Cretaceous seas. These monadnocks consist of steeply dipping hard quartzites which have been extensively eroded to form smooth, low hills - an unusual topographic expression for very resistent, steeply dipping beds.

Since Cretaceous time laterite has probably been formed and dissected, followed by aeolian arrangement of the sand (laterite or sandstone origin): the main lateritization is post-Eocene, pre-Miocene in the Carnarvon Basin.

The more recent changes in the topography of the desert area are the development of seif dunes and playa lakes. 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 seif dunes could form from the easily eroded, predominantly arenaceous country rocks helped in their disintegration by an arid climate and the products of erosion piled into dunes by the prevailing wind directions. The dunes reach their present form by two winds blowing at different times in slightly different directions. The evidence supporting the theory that such winds form seif dunes is summarised from Bagnold (1941):

(a) In open areas where barchans predominate, seif dunes are found under cliffs transverse to wind direction, where transverse gusts are present and the dune is protected from the steady effects of the prevailing wind;

(b) Disagreement on the direction of prevailing wind and relation to dune direction indicate that cross winds are essential for their continuance;

(c) Wind roses are not unidirectional in the case of Australian seif dunes;

(d) Groups of seif dunes that differ in direction and are relatively close to one another, are due to the fact that distinction between the strong and gentle winds is not well marked and that, by slight changes in their relative velocities they interchange.

The dune directions and the annual wind roses are shown in figure 20.

(Fig. 20. Numbers indicate number of dunes per 10 miles
measured normal to their strike.
"O" indicates dunes are absent or rare
"ed" " " " extremely dense.)

The playa lakes were probably initiated in the same arid period when the sand dunes were formed. 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 basin sediments, the waters of the lakes become increasingly saline and salts are precipitated from solution:

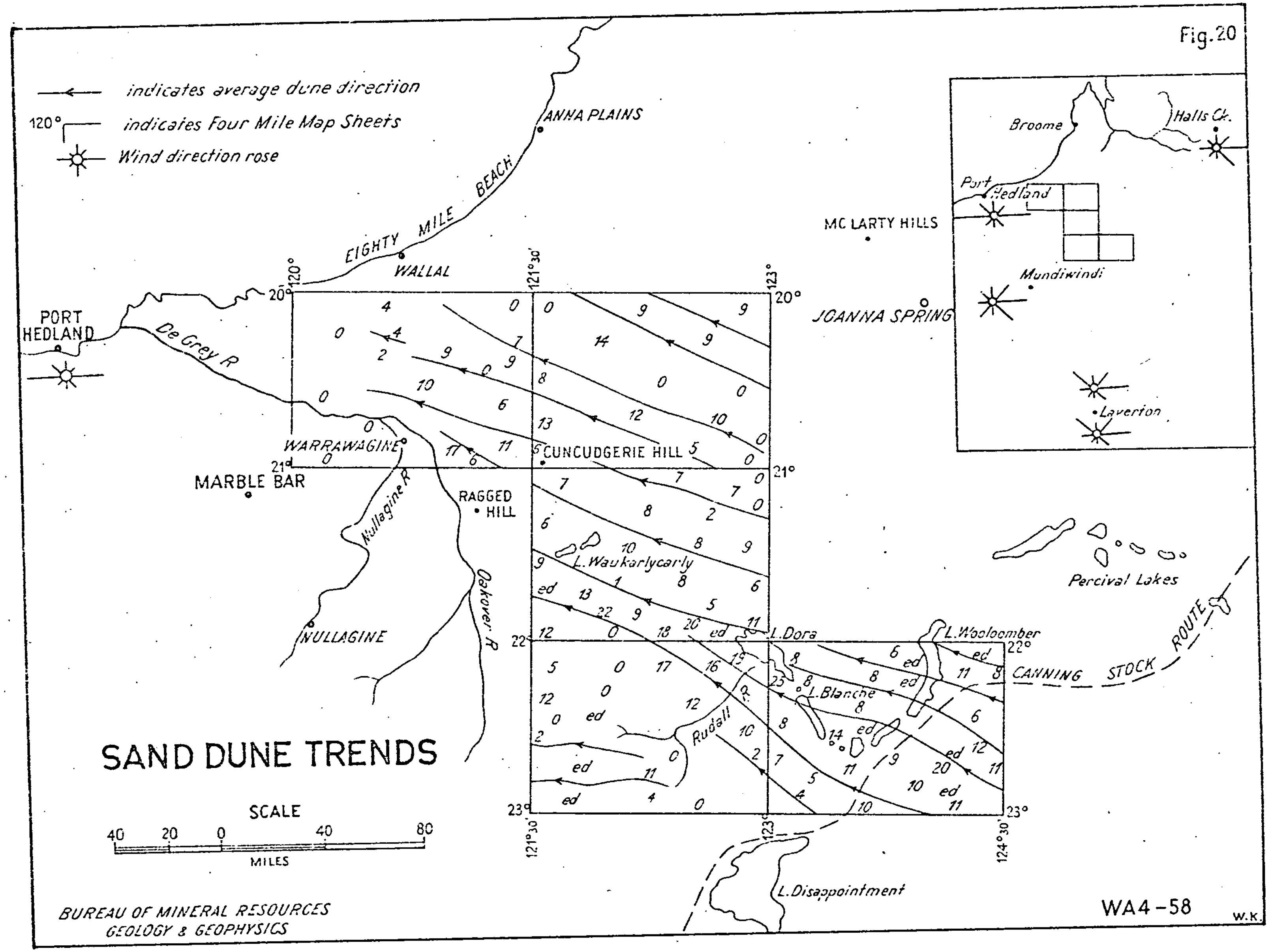


Fig. 20
indicates average dune direction
indicates Four Mile Map Sheets
Wind direction rose
ANNA PLAINS
EIGHTY MILE BEACH
WALLAL
PORT HEDLAND
De Grey R
MARBLE BAR
WARRAWAGINE
Nullagine R
NULLAGINE
Oakover R
RAGGED HILL
CUNCUDGERIE HILL
L. Waukarlycarly
L. Dora
L. Blanche
L. Wooloomber
Rudall R.
L. Disappointment
Percival Lakes
CANNING STOCK ROUTE
MC LARTY HILLS
JOANNA SPRING
Broome
Halls Ck.
Port Hedland
Mundiwindi
Laverton
SAND DUNE TRENDS
SCALE
MILES
BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS
WA4-58

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 existance to an impervious basement of Permian shales. A lake of this kind forms a temporary base level that rises as deposits accumulate in the basin; and the base levels of separate basins are entirely independent of one anoth--

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 Nullagi-- Oakover) can be retraced to Permian, when it probably formed in a valley fitted with the Braeside Tillite; two miles north of Carawine Gorge, a low glacially striated pavement was observed This river valley was again prominent in the Tertiary and formed 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 the westerly flowing De Grey River 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 a mesa and butte topography of 150 ft. relief. 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, and they have produced the dissected hills now present. 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 (situated tectonically partly on the Pilbara Mobile Zone and partly on the Desert Block) reflects many old land surfaces dating back to the Precambrian.

PETROLEUM PROSPECTS

The south-western part of the Canning Basin is a sedimentary area bordering the Pilbara region of Precambrian rocks. Rock exposures at the edge of the basin may indicate the type of rock units in the centre of the basin, although the area itself may not have any petroleum potentialities.

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

In the vicinity of Paterson Range, about 100 ft. of Permian Paterson Formation, an unfossiliferous massive unsorted sediment of glacial or fluvio-glacial origin, overlies Lower Proterozoic Metamorphics and granites. Although cold (polar) waters favour the occurrence of diatoms and other plankton (oil source organisms), 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 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 unit suggest that the southern part of the basin is shallow. Gravity surveys in the basin may help to determine thickness of sediments.

Reconnaissance geological work in the north-eastern margin of the basin may indicate the extension of the Devonian and older Palaeozoic sediments from the Fitzroy Basin. 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 and 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), "caliche" (the cellular, porous form of "travertine" and strictly termed tufa), rock salt (halite), and gypsum or anhydrite.

In areas adjacent to and embracing the salt lakes of

Waukarlycarly, Dora, Blanche, Wooloomber etc., deposits of travertine (Ql), caliche (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.P. Reynolds (B.H.R.) of the 3-inch top layer showed it to consist of:

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

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 ($CaSO_4$) in the surface crust suggests that this mineral was precipitated before (at a lower level than) the halite (NaCl); as gypsum and other less soluble salts were precipitated, the residual waters would become increasingly saline, and further evaporation would cause the precipitation of almost pure halite.

This sequence of precipitation from sea water of various salts comprising "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) gives recent oceanographic studies to show 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 and are accompanied at depth by oppositely directed currents. 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 stratigraphic sequence developed during increase of basin salinity; the section ascends from iron oxide, through limestone, anhydrite to halite. Although this work is primarily concerned with sea water and brackish water, the principles can be pertinently applied to the inland salt lakes whose salinity increases with time to a value not greatly different from the condition of sea water.

In the salt lakes, it may be expected that the carbonate sediments would be first precipitated (as limestone or calcar- deposits); and as the lake became more stagnant, a shale with pyrites would be laid down, and the sulphur ion of the pyrites would aid the formation of gypsum.

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 K and Mg, 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 Wooloomber 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 "caliche" 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 "caliche". This "travertine" weathers to a rough, low deposit with a tendency to form sink holes, and it supports a growth largely of ti-trees; it is in this deposit that most of the native wells are found.

A chemical analysis by Reynolds (B.M.R.) 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 Wooloomber, has not been quantitatively analysed, but it shows a low proportion of $CaCO_3$, and represents a transition from unconsolidated "caliche" to "travertine."

The "travertine" (represented as Ql on the geological maps) 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 contracting 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 surface waters to the lakes, as its mouth is now barred by numerous small braided dunes. Isolated neighbouring low hills provide the run-off to fill the lakes after heavy rains, and this intake can not compete against the high evaporation rate and infilling by wind blown detritus; it is therefore inevitable for the size of the lakes to 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:

(a) natural surface waters, catchments, and rockholes.

(b) sub-surface waters from bores and wells.

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 maps.

(a) 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' x 30' galvanised iron catchment roof. The first tank is thirty-nine miles north of Callawa Homestead: it holds about 450 gals. Saunders Spring is ninety miles from Callawa on the telegraph line.

In the Rudall area, there are semi-permanent large waterholes 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 for years. 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 on a pale brown leached and jointed caps of the hills, and are about 2 ft. long by 4 ft. deep and 1 ft. wide; they contain a small supply of water varying from 0 to 40 gals.

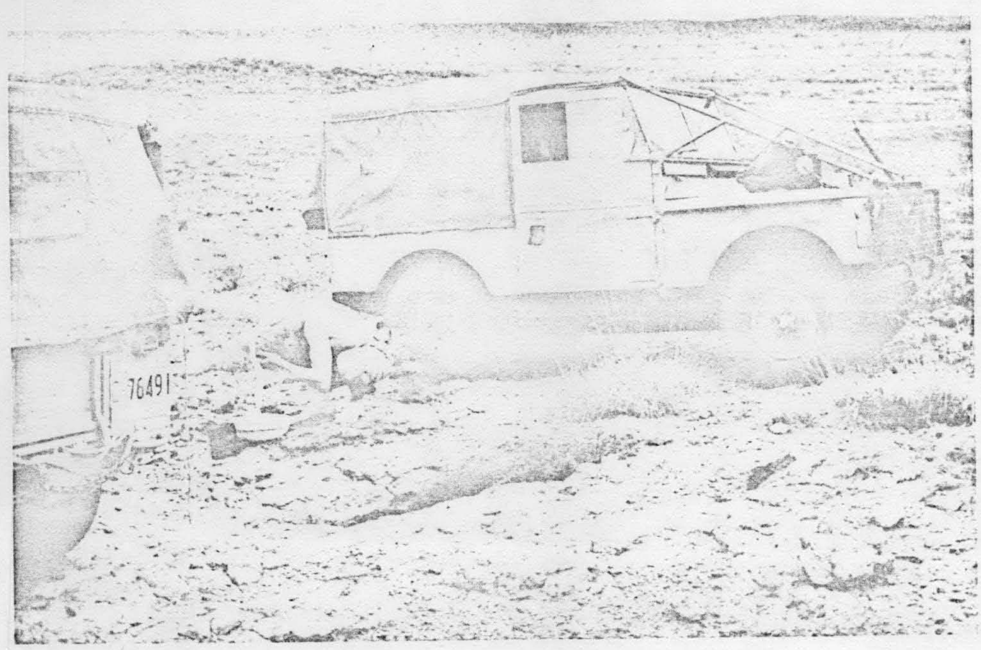


Fig. 21. Rockhole on top of a Mesozoic flat-topped hill, 30 miles east of Lake Waukarlycarly.

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 Blanch

Dunn Soak, Fig 22, three miles east of the northern portion of Lake Dora, yield 60 g.p.h. of good water; this was an old native soak (evidence of oil spears, coolamens, chippings, etc., in the debris) which was cleared out and cased with a 44 gal. drum.

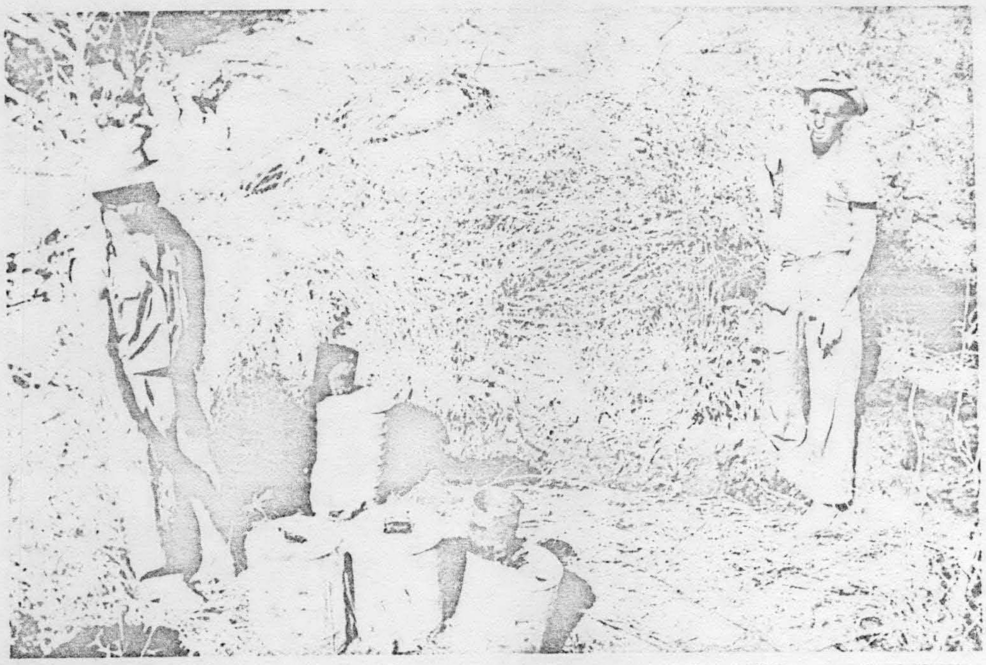


Fig. 22. Dunn Soak.

A large soak producing a permanent spring exists three miles north of Scotts Bluff on Lake Blanche, and a second soak occurs five miles east of Scotts 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 Auld 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 would not be far removed from some water supply. The dense groves of vegetation at soaks are conspicuous on the photos.

(b) 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') and yield large supplies of "hard" stock water.

The water level of most Warrawagine Wells in this Precambrian complex is about 40 ft below the surface. Trouble was experienced at Simpsons Wells where driven sheep, and those new to the paddock, quickly died from the water; this water is dark green with algae, and is being treated with copper sulphate, but the cause of death is the high proportion of soda in the water producing 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 bore failures; (i) along Callawa Creek, 4 miles south of the rabbit proof fence, where shallow bores in metamorphics and granite yield salt water. In selecting bore sites here, 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 8 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 of which are low and dissected (2 ft. exposed) 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 could easily be penetrated. 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 fences.

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

TABLE III.

SUMMARY OF MINERAL PRODUCTION.

Metal	Locality	Ore treated (tons)	Metal Extracted	Silver f. oz.	Ore Reserves	Production Period	Value of Materials Extracted.
LEAD	Rugged Hills	292.11	206.39 tons	2,315.51	31.500 tons (1938)	Total for 1951	£A25,480.35
GOLD	Bamboo Creek	1614.0	1108.44 f. oz	69.40	-	Total for 1951	Average unofficial price £15.9.10 per fine oz in Aust 1950-51.
	Talga Talga	3,774.90	3,260.54 f. oz	0.70		Total production. (Not producing at present)	
MANGANESE.	Woody Woody	8,932	about 52% Mn	-	93,000 tons (1953)	Two shipments to the U.S.A.	95 cents per unit for 48% Mn ore, c.i.f. in New York Nov. 1954.

c.i.f. - cost insurance and freight.

f.o.b. - free on board.

Unit - 1% of a ton of metal.

METALLIC DEPOSITS.

General.

The main metallogenetic epoch was earlier than the deposition of the Upper Proterozoic rocks. Large masses of granite intrude the Lower Proterozoic rocks, and the mineral deposits are most probably derived from this granite or from the Lower Proterozoic greenstones. The tin deposits are undoubtedly related to the granite, but the mode of introduction of the copper, gold, lead, zinc and other minor minerals is uncertain. No epigenetic deposits are associated with Upper Proterozoic rocks. Alluvial gold and sedimentary manganese deposits are present, but only the latter was visited.

Gold

The only producer of gold within the area is at Bamboo Creek, situated about 40 miles by road north-east of Marble Bar, in the Marble Bar district of the Pilbara Goldfield.

The Bamboo Creek mining centre has been described by Maitland (1904), Finucane (1936) and Blazey, Rayner and Nye (1938). An ore specimen from the mine owned by N. Gibson at the north-western end of the field consists of native gold associated with pyrite and galena in quartz. The ore is intimately associated with the sheared greenstones. The lode has been emplaced along lines of shears and the ore breaks away clearly from between the sheared greenstone walls. No structural interpretation of the field was attempted. The ore obtained by the underground workings is treated by amalgamation and cyaniding at the State Battery at Bamboo Creek. The deepest mine on the field is 250 feet.

Production from the field (Finucane, 1936) totalled 33,207.2 tons of ore for 54,689 fine oz. up to 1936, giving an average of 33 dwt per ton. The residues give about 1 dwt per ton. Hence the average grade crude ore has 34 dwt per ton. The Kitchener, Mt. Prophesy, and Bulletin Mines have produced 20,244.7 tons for 35,194 oz, or more than 3/5 of the total production. The main production in 1954 came from the Queen Mine, which is 230 feet deep and yielded about 20 dwt per.ton.

The production figures given in the Report of the Department of Mines, W.A. for 1951, p 116, are as follows:-

Registered Name of Co. or Lease.	Total for 1951 (fine oz) Ore Treated (tons)	Gold Therefrom	Alluvial	Dollied & Specimens	Total Production Ore Treated (tons)	Gold Therefrom.	Silver Fine oz.
Bulletin	406.00	132.97		-	457.50	172.07	-
Federation	155.00	99.62		8.22	2,589.00	1,948.06	0.10
Kitchener	168.00	412.16		-	10,262.00	14,157.21	0.75
Mickey	20.00	4.72		-	1,761.00	472.31	1.42
Mt. Prophesy	615.00	379.37		-	1,058.00	535.34	9.95
Prince Charlie	202.00	64.59		3.68	3,732.00	3,552.35	52.29
Princess May	48.00	15.01		-	48.00	15.01	-
True Blue					2,093.25	85.22	-
Voided Leases			13.54	560.19	34,160.35	38,855.26	-
Sundry Claims			8.97	307.83	5,095.85	2,999.42	4.89

The total production is recorded to 31st December, 1951.

Simpson (1902) gives the following analyses of gold from Talga and Bamboo Creek, Pilbara.

		SG	Au	Ag
Talga:	gold from quartz boulders	16.20	84.46%	15.54%
Bamboo Creek:	gold from quartz reef	-	94.00%	6.00%

The total production of the Bamboo Creek field is small when compared with the figures for other field in the Pilbara Goldfield, but it is one of the more important producers in the Marble Bar district.

Gold has been won from the Talga Talga field, 15 miles north of Marble Bar, 3 miles from the Talga river (Maitland 1904). Total production figures are:

	Alluvial fine oz.	Dollied & specimens fine oz.	Ore treated tons	Gold Therefrom fine oz.	Silver fine oz.
Voided leases	-	93.15	1,799.00	1,760.68	-
Sundry Claims	76.17	85.18	1,975.90	1,499.86	0.70

This field is probably very similar in genesis to the Bamboo Creek lodes, as it occurs in the Lower Proterozoic in rocks of similar lithology.

Manganese.

The deposits occur outside the areas mapped but were visited during the course of the field season. The mining centre is located at Woody Woody, which is about 260 miles by road east-south-east of Port Hedland. The deposit has been described previously by Owen (1953) and de la Hunty (1953).

The deposits are associated with the Upper Proterozoic dolomite and breccia, and consist mostly of amorphous manganese oxides, chiefly pyrolusite with some braunite, hausmannite and manganite. Some crystalline acicular pyrolusite forms veins and coatings in joints and vugs, and there are veins rich in barytes, calcite and siderite through the deposit. Some masses are composed almost entirely of botryoidal, concentrically laminated, irridescent hematite.

The origin of these deposits is controversial and it must be stated from the outset that the area was not studied sufficiently to give any substantial opinions.

The relationship of the breccia to the dolomite has been described in the discussion under "stratigraphy". The breccia has been derived directly from an accumulation of chert lenses and nodules left as a residual deposit from the weathering of the dolomite. It is thickest where it has accumulated in crevices, widened joints, and spaces between the remaining pinnacles of dolomite. It is apparent from the shape of the manganese deposits that they formed a similarly shaped deposit to the non-manganese-bearing breccia outcropping in other areas. It crops out as cappings on small rounded hills overlying the dolomite and it often forms bodies filling joints and large crevices in the dolomite.

It seems certain that the manganese deposition was contemporaneous with the breccia, and thin section analysis by W.M. Roberts, Bureau of Mineral Resources, has established that the chert and quartz have been replaced by the manganese, replacement beginning along fractures in the chert, and gradually completly replacing the original breccia.

Owen (1953) postulated that the manganese "accumulated into workable deposits by replacement of silicified beds in the limestone and by the infilling of joints and solution cavities which may have had silicified margins." However, the "silicified beds" or chert appears to be primary in origin. Owen reports that "the manganese deposits occur at much the same general level, which suggests that they formed on a land surface of low relief with sluggish drainage which prevented the rapid dispersal of manganese bearing solutions."

In the hand specimen there is a complete gradation between specimens of breccia with a siliceous cement to those with angular chert fragments cemented by amorphous manganese minerals and finally to pure manganese ore. Quite commonly, a breccia with a hematitic cement was found, and all types appear to grade into one another.

Several of the Upper Proterozoic dolomites were analysed by Reynolds (B.M.R.) to ascertain if these rocks could be a possible source of the manganese. The results of the analyses are as follows:-

Specimen	Acid Insol.%	SiO_2 %	$FeCO_3$ %	$CaCO_3$ %	$MgCO_3$ %	$MnCO_3$ %	(Mn)
Y62	1.20		5.56	52.00	40.22	1.45	0.69
Y63	20.78	(18.99)	1.00	42.70	36.12	0.43	0.21
CG (Carawine Gorge).	16.78		4.70	43.70	33.53	0.90	0.43
Y	15.20		2.32	67.80	14.65	0.35	0.17
Y46	42.15		10.11	47.00	2.74	0.26	0.12

Several specimens of the Lower and Upper Proterozoic basic volcanics were analysed for manganese also -

Specimen No.	Location	% Mn.
Y47 (U. Prot)	9 miles N.E. of Bamboo Ck.	0.03
Y65 (U. Prot.)	10 miles S of Warrawagine on Nullagine River.	0.08
Y52A (L. Prot.)	2 miles E. of Bamboo Ck.	0.16
Y1 (L. Prot. hematite jasper)	2 miles E of Yarrie homestead -	-
5405 (L. Prot.)	Bamboo Creek.	0.67 (Geol. Surv. W.A.)

De la Hunty (unpublished report, Mines Dept, W.A.) gives an analysis of the dolomite at the manganese workings.-

		%
No. 17395	Mn	0.06
GS/M/17 taken	Fe	0.53
from below GS/M/10	CaO	25.17
	MgO	17.46

These figures indicate that the dolomite contains slightly more manganese than the basic volcanics. The low manganese content of the dolomite below the manganese deposits may indicate greater leaching effets. The manganese, possibly in the form of the carbonate, would probably be in a more accessible form in the dolomite. However, in Twenhofel (1932, p. 562) Hewitt says "there is little to indicate that the chemical character of the rocks in a basin of sedimentation is an important factor in determining the degree of concentration of manganese in nearby sediments. --- The average igneous rock contains ---- 0.125 per cent manganese --- . In most (igneous) rocks, the percentage ranges from 0.05 to 0.15. In general the percentage is highest in the basic rocks rich in iron -----. Pure non-magnesian limestones rarely contain more than 0.1 per cent manganese oxide and similar quantities are present in fresh water marls, travertines and tufas. On the other hand, the magnesian limestones commonly contain more manganese and the quantity tends to increase with the content of ferrous carbonate." Hewitt also says that manganese carbonates are fairly common in fine-grained marine sediments and it is possible that they may be deposited by algae. He considers that "as the higher manganese oxides are very stable near the surface, they tend to accumulate on surfaces of planation. Consequently, in many parts of the world, workable bodies of oxides are found on peneplains."

The mechanisms and processes by which the manganese is deposited are somewhat obscure.

Owen (1953) calculated the reserves as 93,000 tons from 37 separate orebodies contained in 13 groups, small bodies with less than 200 tons being included. He gives the range in composition of the ore as -

	%
Mn	47.54 - 57.79
Fe	0.71 - 7.35
SiO_2	0.81 - 17.82
P	tr. - 0.15

Analysis by Reynolds (BMR) of a specimen of massive pyrolusite was:-

	%
Mn	67.50
Fe	0.78
SiO_2	4.18
P	0.32

Open cut mining operations were commenced at Woody Woody in April, 1953. The ore is loaded from a face by a 5/8 cub. yd. diesel shovel into diesel trucks of 12-24 ton capacity. The ore is trucked 260 miles to Port Hedland, where it is then loaded into 25 cwt. tubs for transportation by ship. The first shipment of 4,750 tons (Aust. Min. Ind. 1953 Review) assayed Mn 53.84%, Fe 1.40%, SiO_2 4.84%, P 0.03%; 4,182 tons were shipped to the U.S.A. in March 1954.

In 1953 the Broken Hill Pty. Co. Ltd offered about £12 per ton f.o.b. Western Australian ports for a 44-46% manganese ore. Overseas prices are higher.

The age of the deposits at Woody Woody is uncertain. The breccia was derived from the disintegration of the uplifted blocks soon after the folding of the Upper Proterozoic dolomite and its age would be Upper Proterozoic or Cambrian.

Conditions that prevailed after the deposition of the Upper Proterozoic dolomite in this area are unknown, as there are no associated younger deposits, and the conditions after deposition may be inferred only from neighbouring areas.

Lead

Lead deposits occur in the Isabella and Gregory Range area between Barramine and Ragged Hills: they are at present only worked at Ragged Hills, about 230 miles by road east-south-east from Port Hedland. The deposits have been described by Finucane (1938) and by Blatchford in the report of the Department of Mines 1924, Appendix No. 22, p. 79. J. Shepperd of the Western Australian Mines Department is producing a detailed report on the Ragged Hills area. At Ragged Hills the deposits occur in the Lower

Proterozoic greenstones and appear to be confined to, or concentrated in, the vesicular sections of the flow. The galena-bearing reefs are generally thicker in these sections. The mineralization is associated with a prominent quartz shear which dips 75° to the east and has been traced for considerable distances to the north-west; to the south-east the main shear is cut by several cross-faults which produce a displacement of only a few feet in the original shear. Proved mineralization extends 1000 yards along this shear. Farther to the north-east, from this shear, similar parallel quartz reefs are reported to be barren.

Galena, sphalerite, and cuprite, with secondary cerussite and malachite, are present. Finucane (1938) gives the average analysis for samples from the area as -

27.12% lead

3.56 oz silver per ton.

Lead ore reserves (Finucane, 1938) were estimated at 31,500 tons. Silver is confined chiefly to the main orebody where it forms $<$ 10% of the ore, with 47% lead, and 1% zinc. At the workings, the depth of the main shaft is 50 feet. The ore being mined at present has 50-50 lead and zinc, but this can be concentrated on riffle tables to give 75% lead. Water for processing is pumped from the mine at the rate of about 1000 gallons per hour; washing water is pumped from 20-foot wells in the stream valleys nearby and rain water is used for drinking. The mine was not in production when visited but approximately 2,000 tons of lead metal has been won over a period of four to fi[illegible] years. Diamond drilling has indicated good ore to a depth of 220 feet with poorer results to 400 feet.

Production figures for 1951 for M.C. 189 (R.O. Moore, Ragged Hills) were:

		Value
Ore.	292.11 tons	
Lead	206.39 tons	£24,856.15
Silver	2,315.51 fine oz	£ 624.20

After April, 1953, the price of lead was decontrolled and and was sold at the f.o.b. equivalent of the London Metal Exchange.

Tin

Tin occurs both as alluvial and residual deposits at workings near Talga-Talga and Moolyella. Both areas are near the south-western corner of the Yarrie four-mile sheet. The Moolyella Tinfield has been described by Maitland (1904).

Lode tin is also known to occur at Moolyella, but owing to the low grade it has not been worked. The tin occurs as a residual deposit mantling the granite and as alluvial deposits in creek beds; the latter is the more important source. The granite commonly has ramifying quartz veins and pegmatite dykes. No large deposits occur and workings here are now very small.

There are several unofficial reports of tin deposits from Yandagooge Creek at the southern end of the Throssel Range.

Vanadium

Vanadium ores, in the form of lead vanadates, occur at Vanadium Creek near Ragged Hills; bulk samples assayed from 7.1-16.9% V_2O_5. The commercial possibilities of these deposits are unknown.

Copper

No copper deposits are known to be worked at present, but various prospects occur between Barramine and Ragged Hills. These have been assayed by the Mines Department of Western Australia. (Report of Mines Dept. W.A., 1924, Appendix 22). Some small bodies assay up to 25% copper and 8 oz. silver per ton. In the vicinity of Moxon's Camp, 6 miles E.N.E. of Braeside, a sample is reported to contain 16% V_2O_5, 11% Cu and 34% Pb.

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APENDIX A.

Jurassic Plant Fossils from the Callawa Formation, with determinations and Correlations by R. O. Brunnschweiler.

Introduction.

Jurassic beds have previously been reported from this area by Reeves (1949). He assigns 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.

Description of Material.

Y25 - About 23½ miles north-north-west of Callawa Homestead on the Yarrie Wallae track - Yarrie four mile sheet.

The section here consists of 70 feet of conglomerate with interbedded cross-bedded coarse sandstone, and shale with ferruginous concretions overlain by 40 feet of micaceous well-bedded shale with a thin lateritic capping.

The shales are lithologically similar to the white, pink and yellowish shales that are interbedded with friable sandstones of the Alexander Formation of U. Jurassic age. However this lithological similarity has very little age significance. No foraminifera were discovered in this specimen.

A8 - About 94 miles east-south-east of Catchment tank on telegraph line. Anketell four mile sheet.

The 30 foot section consists of siliceous claystone overlying fine white micaceous sandstone.

The white, pink, and yellow shales appear to be identical with those of Y25. The softish, white, micaceous fine sandstone is similar to those rocks of the Jarlemai siltstone or the finely worm-riddled micaceous sandstone along the west coast of Dampier Peninsula (Broome Sandstone) This has little significance with regard to correlation.

Y23 - About 14 miles north-west of Callawa Homestead. Yarrie Sheet

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

Tentative identification of the plants is as follows:-

Ditcyophyllum 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)

? Pagisphyllum sp.

Cone scales, probably Araucarites.

These forms indicate that the flora is younger than Permian, but older than Cretaceous. The more exact age determination must be based on the absence of certain characteristic species First it is interesting to note the absence of the genus Thinnfeldia which is a prominent member of the flora of the Erskine Sandstone (Upper Triassic) in the same general region. The flora seems to have nothing in common with that of the Erskine Sandstone and hence is probably younger than Triassic. However the forms present are of Triassic type particularly if the determinations of Johnstonia and Cladophlebis are correct. Johnstonia is an exclusively Australian genus known only from the late Triassic of Tasmania and Queensland.

Taking everything into account, and considering the absence of the common Jurassic species Otozamites - it may be approximately of Triassic age (Lower Jurassic). It may be somewhat younger (rather than older) and tie in with the Edgar Range formations. There is great lithological similarity with the Jarlemai siltstone.

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

The section here consists of -

60' conglomerate

20' ferruginous coarse sandstone with plant remains

40' micaceous shale with chert fragments

10' ferruginous material.

This section overlies the Lower Proterozoic hematite-jasper Despite lithological similarity it is basically different from Y23. The few forms present are:-

Pagiophyllum cf. P. peregrinum (Lindley and Hutton)

? Brachiphyllum sp. (Voltzia-like, but may also be Araucarites).

Sphenopteris sp.

Seeds of ? Samaropsis type.

Wood ind.

The Pagiophyllum sp. mentioned under Y23 seems to have little to do with 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 (L. Cretaceous)

Brachyphyllum (or Araucarites), is common in the Mesozoic plant sandstones of the N.T. The presence of such a prominent Pagiophyllum species with very short and fleshy leaves makes a Triassic or even early Jurassic age rather unlikely. Y34 may possibly be rather younger than Y23, but it should be kept in mind that the sample is really too unique and may, after all, only represent a very local deviation from the standard flora of the Y23 type. However it is still possible that the two samples have nothing whatsoever in common. The fauna shows no similarity to the plant-bearing sandstone horizons in the Alexander Formation (which contains Otozamites cf. O. Bengalensis Feistm.)

CONCLUSIONS

These specimens do not indicate floral correlations with assemblages described in neighbouring areas although they are often lithologically similar to formations described from Dampier Land. The plant fossils, particularly those from Y23, are almost certainly Jurassic in age, and considering the proximity of the other sections containing fossils, these are almost certainly Jurassic also. The dissimilarity between Y23 and Y34 may indicate a slightly different environment of deposition as from its structural position and lithology they appear to be contemporaneous in origin.

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PERMIAN FOSSILIFEROUS ROCKS FROM NEAR THE SOUTH-WEST MARGIN OF THE CANNING BASIN, WESTERN AUSTRALIA

by

J.M. Dickins and G.A. Thomas

APPENDIX B.

INTRODUCTION

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 I - 4 miles east of the Central Portion of Lake Dora, 1 mile east-south-east of Dunn's Soak (Photo 5218, Run 1, Tabletop 4 mile sheet) - 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, predominantly 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 beds. 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 beds.

P 1 - 9 miles east-south-east of Cuncudgerie Hill (Photo 5231, Run 1, Paterson Range 4 mile sheet) 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 ft. 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 30ft. 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 bryzoa, 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 Fm. 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 MS from Lyons Group of the Carnarvon Basin.

Parallelodon sp. indet.

Astartila cf. A. danai (de Koninck) from the "Upper Marine" of N.S.W.

Stutchburia? sp.nov. cf. S. sp.nov. from Marine Horizon near the base of Poole Sandstone in the St. Georges Range.

Astartella? sp.nov. (this may be a new genus) cf. Astartella? sp.nov. from marine horizon near the base of the Poole Sandstone in the St. Georges Range and Nura Nura Member.

Streblochondria sp.nov.

Aviculopecten? sp. indet (non-specialized ribbing of two orders with filae).

Gastropoda

Bellerophon sp. indet.

Bellerophontidae gen. indet.

Warthia? sp. indet.

Ptychomphalina sp.nov.

Platyceras sp.

Pleurotomariidae gen. indet.

Conulariidae:

Conularia 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. Georges 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.219).

CONCLUSIONS

These samples prove the occurrence of marine Permian beds near the south-west 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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<u>Microfossils from the Southern Portion of</u>

<u>the Canning Basin, Western Australia</u>

by

I. Crespin

APPENDIX 6

During the 1954 field season, J. N. Casey and D. M. Traves collected rock samples from the southern portion of the Canning Basin, Northwest Australia, with the hope that microfossils may be present to assist in the determination of age of these beds. Permian foraminifera were found in a sample from 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 of the Canning Basin. <u>Ammodiscus nitidus</u> was recorded in material collected by Dr. Reeves from the cliffs of Scott's Bluff on the eastern edge of Lake Blanche in 1949.

Samples of hard white sandy siltstone were examined in thin section from Patterson Range, Table Top and Yarrie 4 mile sheets for radiolaria. Rounded bodies 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.

<u>Northern end of Lake Dora - Dora Shale</u>

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

Purplish, micaceous sandy shale with angular quartz grains and arenaceous froaminifera.

<u>Foraminifera;</u>

<u>Ammodiscus nitidus</u> Parr (f)

<u>Ammobaculites</u> cf. <u>woolnoughi</u> Crespin and Parr (r)

<u>Hyperamminoides acicula</u> Parr (f)

<u>Hyperamminoides</u> cf. <u>expansus</u> Plummer

This assemblage of Permian species of arenaceous foraminifera is characteristic of the beds in the Wandagee horizon of the Carnarvon Basin and of the Noonkanbah horizon of the Kimberley area. <u>Hyperamminoides acicula</u> is very common in the ferruginous rocks of both Basins and, as it can usually be seen in hand specimen, it is a useful species for the determination of a Permian age.

<u>Anketell 4 miles sheet. Photo Run 5/5026</u>

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.

<u>Foraminifera</u>

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 Cadjeput 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 RANGES	Originally Named Rawlinson Ranges by F.T. Gregory 1861 after Sir Henry Rawlinson President of the Royal Geographic Society.
ISABELLA RANGE	Named by Col. Warburton, 1873.
TARWAH SOAK	Native name collected by R.J. Anketell, 1906.
DEGREY RIVER	Named by F.T.Gregory 1861, after Lord De Grey, Marquis of Ripon, Pres. of Royal Geographic Soc.
OAKOVER RIVER	Named by F.G.Gregory, 1961.
NULLAGINE RIVER	Native name by F.S.Brockman, 1878.
COPPIN'S GAP	The Coppin family have for long been pastoralists in this area.

APENDIX D. CONTINUED.

BLACK HILL	Probably named by F.S.Brockman who established a trigonometrical station on it.
BAMBOO OR CHUGAMRI 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.
CARDOLA ROCK HOLE	Native name given by Land Inspector W.Grant, 1925.
PINJIAN POOL	Native name, F.S.Brockman 1884.
COORACOORAWINE POOL	Native word "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 FS.Brockman 1884
TOOMBINGIDGEE POOL	" " " " " "
YULADING POOL (not Yalading)	" " " " " "
NGUMBERAMURING POOL	" " " " " "
WONGAWOBBIN POOL	" " " " " "
NGARNIN CREEK	" " " " " "
MININGARRA CREEK	" " " " " "
DALUBUNING POOL	" " " " " "
EEL CREEK	Most probably named by F.T.Gregory 1861, as it is shown on the map of his explorations.
KOCKENYA CREEK	Native word for "hawk".
CARLUBORONG POOL	Native name collected by F.S.Brockman, 1884.
BALLANTINE SPRING	" " " " "
MUCCANOO POOL (not Muccanu)	Native name by Alec Forrest, 1878.
COONIEENA CREEK	" " " " " "
COONIENA KER	This is an error for Coonieena Creek.

APPENDIX D CONTINUED

COOLCOOLINNAMARINER	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, 1897.
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 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.
MUNDAMUDDA (CHRISTMAS) POOL	By W.F.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.
TABLE TOP SHEET	
LAKE AULD	Named by L.A.Wells, 1896, after W.P. Auld, of Adelaide, a member of John McDouall 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.
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.
LAKE WINIFRED	By W.F.Rudall, 1897.
NANGABBITTAJARRA	Native name collected by A.W.Canning 1906-7.
DUNDA JANDA 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, Mrs. 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	" " " " "
NUMBRAGUARRA POOL	" " " " "
POONEMERLARRA SOAK	" " " " "
MATRARA POOL	" " " " "
CURRUNCURRUN ROCK HOLE	" " " " "
CHOOMUN WATER HOLE	" " " " "
NOOLOO SOAK	" " " " "
GARGOONYA WATER HOLE	" " " " "
MOONGOONGUNYAH ROCK	Native name collected by W.F.Rudall 1897.
BOORABEE HILL	" " " " " "
YIRRAMANYAH ROCK HOLE	" " " " " "
MARLOO MARLOO ROCK HOLE	" " " " " "
YANDANUNYAH ROCK HOLE	" " " " " "
PINDINYAH ROCK HOLE	" " " " " "

<u>MISCELLANEOUS</u>

MILGALONG POOL	Native name by F.S.Brockman, 1884.
MEJAJAGEN POOL	Native name by F.S.Brockman, 1884.
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 Stations

Callawa

Nimingarra

Warrawagine

Wallal

Yarrie

CALLAWA H.S. Alt. 445 ft.

	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 Larrie road; mill on W. of Wattle Creek			25 ft.		Bad, but clear with taste of H_2S	Spoils of green schist, shale and quartzite.
Wonga Wadua 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	1 ml. N.N.W. of Donison Bore, ¼ ml. S. of E.W. fence		40 ft.			Salty water in 1942 after floods of 1941	? Metamorphicsl 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, boulder of vesicular basalt.
Dud Bore	3½ ml. N. of "The Bore"		150 ft.		Dry		Spoils of granite and grey schist.

NIMINGARRA STATION Alt. 285 ft. (10[illegible],000 acres, 4,000 sheep in 1955)

	Situation	Altitude	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-sodery	Well.
Blue Hills Mill	4 ml. N. of Chooks						Well.
Duffs Mill	2 ml. N.E. of H.S.			20 ft.		Fair-sodery, 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.						

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
Sears Well	14 ml. N. of H.S.			40 ft.		Fair, slightly sodery. 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 sodery - little worse than Sears Well. Sheep flock on it	(No. 3 Well). Faintly alkaline, 259 grains per gallon total soluble salts.
Little Tiringadgee 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.
Toominbidgee 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.

	Situation	Alti-tude	Total Depth	Water Level	Yield	Analysis	Strata
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 Boanhume 2 ml. S. of Simpsons is a dud well in granodiorite on a N-S fence. Depth is 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.
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 Mg.	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	

	Situation	Altitude	Total Depth	Water Level	Yield	Analysis	Strata
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 Timingadgee Well	1 ml. S. of Little Timingadgee Well			40 ft.		Good	Well now fallen in. Probably in river alluvium.
Oakover Bore	4 ml. N. 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 Rivers junction. First well in district	375 ft.	40 ft.	25 ft.	Unlimited supply	Good	Spoils of gneissic granite and quartzite.
Bonnhams	2 ml. S. of Oakover, Nullagine Rivers 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	

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. N. of No. 2. At junction of N-S and 75° fences	285 ft.		150 ft.		Excellent	Well. Spoils of fine conglomerat and coarse sandstone with white fine sandstone with plant remain
Lungera Mill	Intersection of two fences. Has two palm trees	190 ft.		60 ft.		Fairly good, slightly sodery	Well
Tank Mill	On edge of grey clayey soil with Ti trees.			20 ft.		Salty	
Chirrup Bore	¼ ml. W. from main north highway	160 ft.		15 ft.		Good	

YARRIE H.S. Alt. 3[illegible]5 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		310 ft.			Good water (not pumping in 1954)	Bore; probably in Mesozoic.

STRATIGRAPHY OF THE SOUTHERN PART OF THE CANNING BASIN, 1954

TABLE I.

AGE		FORMATION	THICKNESS.	LITHOLOGY	TOPOGRAPHY	CORRELATION
QUATERNARY	RECENT		50'±	Alluvial clays, gravels and boulder beds	Confined to valley floors & river systems	
			2'±	Evaporites	Playa lakes	
			130'±	Aeolian sand	Forms parallel long seif dunes and covers principally the Palaeozoic and Mesozoic sediments.	
			10'±	Caliche and travertine	Confined mostly to inland areas around salt lakes.	
TERTIARY		LATERITE	10'±	Pisolitic ironstone	Caps flat topped dissected hills of Palaeozoic and Mesozoic sediments. Breakaway topography.	
		OAKOVER BEDS	100'±	Marls and limestone with chalcedonic capping. Lacustrine.	Mesas and buttes	
MESOZOIC	CRETACEOUS	ANKETELL SANDSTONE.	100'±	Marine sandstones and shales containing <u>Rhizocorallium</u>.	Low small flat topped outcrops.	Jarlemai Formation, Meda & Mowla Congl.
	JURASSIC	CALLAWA FORMATION	250'±	Current bedded coarse sandstone, alternating with coarse conglomerate. Freshwater plants probably passing into marine basinwards.	Mesas and buttes, low rises.	Alexander Formation?
				---------- U N C O N F O R M I T Y ----------		
		TRIWHITE SANDSTONE	50-400'±	Marine, fossiliferous ferruginous sandstone and greywacke	Small 50-100' hills	Liveringa Group
		DORA SHALE	50'±	Marine fine sandy shales with foraminifera. Probably decalcified.	Forms beds of playa lakes and 40' cliffs.	Noonkanbah Formation.
		CUNCUDGERIE [redacted]	130'±	Ferruginous coarse to fine sandstone, [redacted]	Some small peaks, coarse [redacted]	Nura Nura [redacted]

PALAEOZOIC	PERMIAN	DOL. SHALE	50'±	Marine fine sandy shales with foraminifera. Probably decalcified.	Forms beds of playa lakes and 40' cliffs.	Noonkanbah Formation.
		CUNCUDGERIE SANDSTONE	130'±	Ferruginous coarse to fine sandstone, richly fossiliferous in restricted bands. Marine	Some small peaks, coarse sandstone. Rather resistant. Small outliers	Nura Nura member
		(PATERSON FORMATION (BRAESIDE (TILLITE	100'±) 400'±)	Unsorted sandstone and shale with striated boulders. Normally massive. Some varves. Fluvioglacial. Shows slumping and contortion.	50' hills overlying Pre-Cambrian	Grant Formation or Lyons Group
				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'±	Altered basaltic lavas, probably of different ages.	Valley flows producing undulating country.	
		QUARTZ FELDSPAR PORPHYRY.	1000'±	Intruded into base of Upper Proterozoic succession Porphyry sills invade sandstones.	Undulating hills and small plateaux	
		DOLOMITE & LIMESTONE	1000'±	Contain ? algal colonies, and slump structures. Very sandy in some sections.	Linear low ridges, rugged topography due to differential hardness.	Nullagine beds? or Kimberley System.
		SANDSTONE	1200'±	Arkosic, well jointed, medium to coarse grained.	Sharp ridges, high elevation due to surface silicification.	
				U N C O N F O R M I T Y		
	LOWER	LOWER METAMORPHICS	Thousands of feet	Greenstones, quartz mica schists, talc chlorite carbonate schists, dolomitic marbles, banded haematite jasper, slates and possibly pillow lavas. Whole intruded by subsequent bathyliths 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.	Mosquito Ck beds? Warrawoona beds? or Lamboo Complex.

TABLE 2.

STRATIGRAPHIC CORRELATION.

		CARNARVON BASIN (after Condon 1954)		CANNING BASIN		FITZROY BASIN. (after Guppy 1953)	
QUARTERNARY	Qp-Qr	40'±	Alluvium, limestone, conglomerate, etc.	60'±	Alluvium, travertine, caliche, sand, evaporites, etc.	150'±	Alluvium, etc.
TERTIARY	Te-Tp	20'±	Laterite, etc.	0-10'±	Laterite	6'±	Pisolitic Ironstone
		200-1700'±	Yardie Group Cape Range Group	100'± 0-8'±	Oakover Beds Conglomerate (at A.11)	15'±	Meda conglomerate, etc.
MESOZOIC	CRETACEOUS	400'± 745'± 100'±	Cardabia Group Winning Group Birdrong Formation	50-100'±	Anketell Sandstone		Dampier Group, etc.
	JURASSIC	25'±	Curdamudia Sandstone	250'±	Callawa Formation	230'± 180'± 20'+ 60-110'±	Jarlemai Formation Alexander Formation Jurjurra Sandstone Erskine Sandstone
	TRIASSIC					1000'±	Blina Shale
PALAEOZOIC	PERMIAN	2735'±	Kennedy Group	50-300'±	Triwhite Sandstone	2420'±	Liveringa Group
		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	4500'	Grant Formation
	C	[illegible]10'	Sandstone, lime-stone, greywacke			[illegible]	Recognised by [illegible]

	TRI-ASS.					1000'±	Blina Shale
PALAEOZOIC	PERMIAN	2735'±	Kennedy Group	50-300'±	Triwhite Sandstone	2420'±	Liveringa Group
		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	4500'	Grant Formation
	C	2510'±	Sandstone, limestone, greywacke			100'±	Recognised by Thomas (1955)
	DEVONIAN	5120'±	Sandstone, limestone, siltstone			4120'± 2000'±	Upper Devonian Limestone, congl. Pillara Formation
	O					2450'±	Prices Creek Group
	Є					?	Hart dolerite
PRE-CAMBRIAN	PROTEROZOIC Upper			20'± 500'± 1000'± 1000'± 1200'± 0-300'	Breccia Volcanics Porphyry Dolomitic Limestone Sandstone Basal Conglomerate		Mt. House Beds) Walsh Tillite) Warton Beds) Mornington Volcanics) King Leopold Sandstone)
	PROTEROZOIC Lower		) Basic dykes,) quartzite, limestone, slate,) schist, granite,) gneiss		Basic Dykes Granite Lower Metamorphics		Lamboo Complex

- - - - - - - Unconformity .... Disconformity

(Not to Scale)