# THE GEOLOGY
OF
# THE KIMBERLEY DIVISION, W.A.
AND OF AN
## ADJACENT AREA
## OF THE NORTHERN TERRITORY

DEPARTMENT OF ECONOMIC GEOLOGY
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B. Sc. (HONS.)

# THE GEOLOGY OF THE KIMBERLEY DIVISION, WESTERN AUSTRALIA

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## AN ADJACENT AREA OF THE NORTHERN TERRITORY.

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# SUMMARY.

This paper describes the geology of an area of approximately 110,000 sq. miles in the Kimberley District of northern Western Australia, and of an area of approximately 40,000 sq. miles in the adjacent portion of the Northern Territory; it presents the information gained by the author during a period of five years (1953-57) spent in field and laboratory work in the course of a survey carried out by The Broken Hill Proprietary Co. Ltd. Field work was chiefly concentrated on Lower Cambrian and Precambrian rocks, and these successions have been subdivided and described in some detail; a summary of the post-Lower Cambrian geology is also given, partly based on the author's field observations, but chiefly derived from the work of others, notably Traves, Rattigan, Guppy, Lindner, and others of the Bureau of Mineral Resources. The regional geological map with the paper is the most comprehensive so far prepared for the region.


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## C O N T E N T S.



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## M A P S.

In addition to the Maps, etc. listed and bound within each of Parts I to III, the following are bound in an envelope at the back of the paper:

1. Geological Map. Scale 1" : 10 miles.
2. Sections A-B, C-D, E-F across lines shown in geological map.
3. Transparent grid to overlay on Geological Map for rapid location of Latitude and Longitude.
4. Map showing Mineral Deposits described in Part III.

# THE GEOLOGY OF THE KIMBERLEY DIVISION, WESTERN AUSTRALIA

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### PART I.

### INDEX OF CONTENTS.



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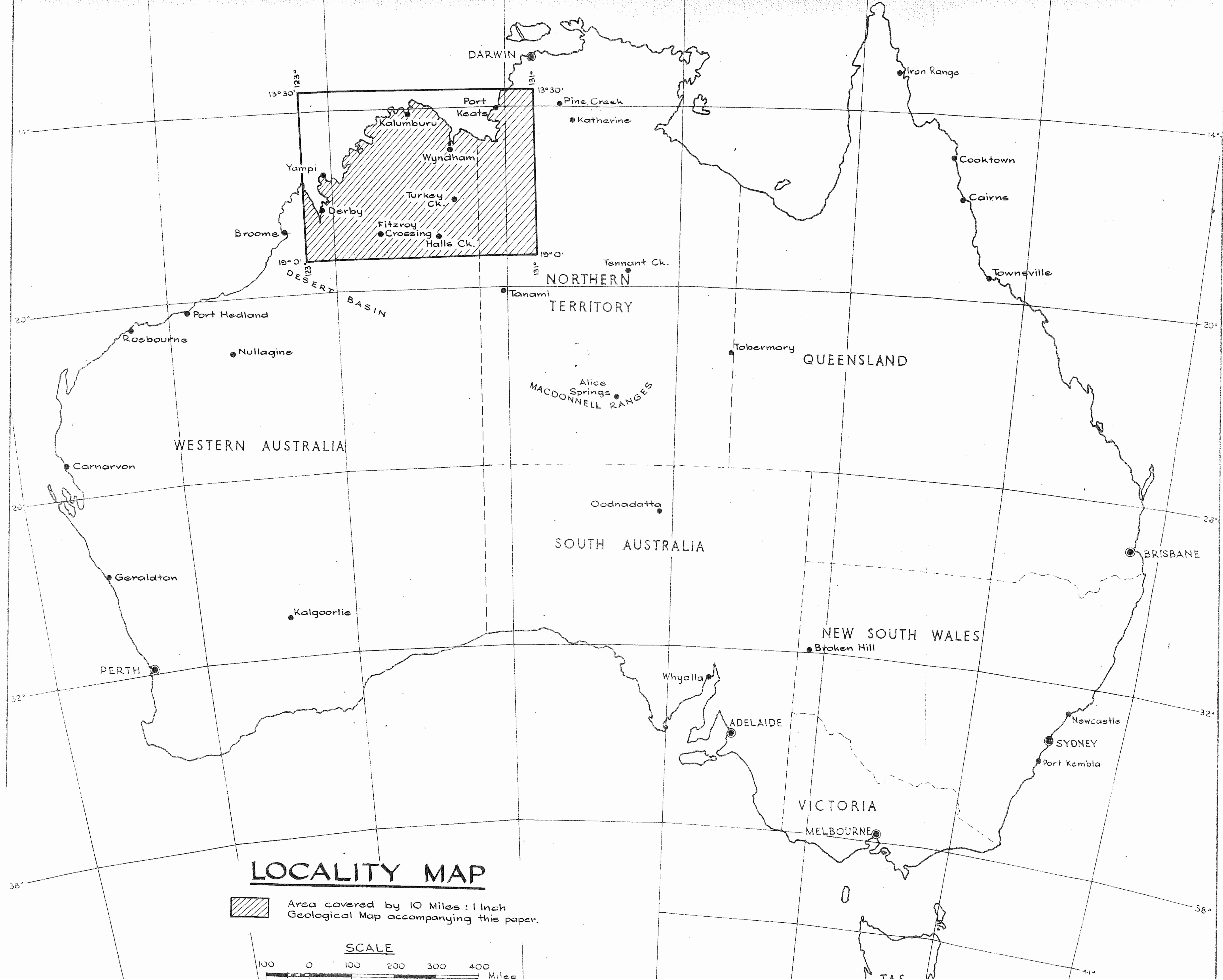

DARWIN
Iron Range
13°30'
123°
131°
Pine Creek
Port
Keats
Kalumburu
Katherine
Wyndham
Cooktown
Yampi
Cairns
Turkey
Ck.
Derby
Fitzroy
Crossing
Broome
Halls Ck.
19°0'
Tennant Ck.
Townsville
DESERT BASIN
NORTHERN
TERRITORY
Tanami
Port Hedland
Roebourne
Nullagine
Tobermory
QUEENSLAND
Alice
Springs
MACDONNELL RANGES
WESTERN AUSTRALIA
Carnarvon
Oodnadatta
SOUTH AUSTRALIA
BRISBANE
Geraldton
Kalgoorlie
NEW SOUTH WALES
Broken Hill
PERTH
Whyalla
ADELAIDE
Newcastle
SYDNEY
Port Kembla
VICTORIA
MELBOURNE
14°
20°
26°
32°
38°
41°
TAS.
LOCALITY MAP
Area covered by 10 Miles : 1 Inch
Geological Map accompanying this paper.
SCALE
100 0 100 200 300 400
Miles

LOCATION OF AREA:

The area geologically examined and mapped by the writer lies between Lat. 13°30' and 19°00' and Long. 123°00' and 131°00', as shown on the locality map. It includes the following 4 mile map sheets shown on the locality diagram at the top of the 1" = 10 mile geological map.

| | | |
|---|---|---|
| Yampi, W.A. | Mt. Elizabeth, W.A. | Waterloo, N.T. (part sheet) |
| Camden Sound, W.A. | Lansdowne, W.A. | Limbunya, N.T. ( " ) |
| Montague Sound, " | Medusa Banks, W.A. | Birrindudu " ( " ) |
| Prince Regent, W.A. | Cambridge Gulf, W.A. | Delamere, N.T. ( " ) |
| Charnley, W.A. | Lissadell, W.A. | Ferguson River, N.T. ( " ) |
| Lennard River, W.A. | Dixon Range, W.A. | Mt. Ramsay, W.A. ( " ) |
| Drysdale, W.A. | Gordon Downs, W.A. | |
| Cape Londonderry, W.A. | Port Keats, N.T. | |
| Ashton, W.A. | Auvergne, N.T. | |

In addition the geological map was extended to cover the following 4 mile sheets, for which the mapping has been mainly derived from that of the Bureau of Mineral Resources:-

| | | |
|---|---|---|
| Mt. Ramsay, W.A. | Waterloo, N.T. | (part sheet) |
| Noonkanbah, W.A. | Limbunya, N.T. | ( " " ) |
| Mt. Anderson, W.A. | Birrindudu, N.T. | ( " " ) |
| Derby, W.A. | Victoria River Downs, N.T. | ( " " ) |
| | Wave Hill, N.T. | ( " " ) |
| | Mt. Winnecke, N.T. | ( " " ) |

The area includes the towns of Derby, Cockatoo Island (Yampi), Fitzroy Crossing, Halls Creek, and Wyndham.

COMMUNICATIONS AND ACCESS:

The ports of Broome, Derby and Wyndham are served by regular calls of State ships on the Perth-Darwin run, and by various ships in the cattle and meat trade. Cockatoo Island is served by State ships and by B.H.P. ore ships, from Newcastle and Port Kembla, and is more or less dependent on the latter for supplies of fresh water. In addition State ships call at Kalumburu and Troughton Island at infrequent intervals. Port Keats Mission and the stations along the Victoria River as far as Timber Creek were formerly served by a Government ship once or twice yearly, but due to the treacherous nature of the shallow Victoria River this service has been discontinued; Port Keats Mission is still supplied entirely by sea transport except for mail and medical requirements which are carried in by air.

Broome is linked to Port Hedland by a largely natural surface road, only partly formed, which is impassable after heavy rain; Broome is linked to Fitzroy Crossing via Derby by an all weather gravelled and formed road which is, however, subject to flooding. Fitzroy Crossing is linked to Wyndham via Halls Creek by a partly formed and partly gravelled road which is impassable after heavy rain and subject to frequent flooding during the "wet" season.

A good formed and gravelled road leads from Wyndham via Ivanhoe, Rosewood, and Ord River Stations to Nicholson; this road is an all weather road but is subject to flooding of the Ord and other rivers during the "wet" season. The road from Golden Gate to Katherine via Newry, Auvergne, Timber Creek and Willeroo is mainly natural surface, partly formed, and is impassable after heavy rain or during flooding of the Victoria River. The Murranji track from Top Spring to Newcastle Waters, and the Dry River Road from Katherine to Halls Creek via Top Spring and Nicholson, are both mainly unformed natural surface graded tracks which are impassable after heavy rain.

A network of graded natural surface tracks connects various stations, and on each station is a series of ungraded natural surface windmill tracks; all of these are impassable during wet weather.

Most stations, and all mainland towns have aerodromes, and are served by bi-weekly to fortnightly air services bringing mails, passengers, and light freight; some stations in the Kimberley plateau area obtain all their supplies by air-freighter. Air services in the area are operated by MacRobertson-Miller Airways (Perth-Broome-Derby-Halls Creek-Wyndham-Darwin and mainly Western Australian inter-station services) using DC3 and Dove aircraft, and by Connellan Airways (Katherine-Wyndham-Halls Creek-Alice Springs and mainly Northern Territory Stations) using Lockheed and Dragon aircraft.

In the areas not utilised as station country, and between station tracks, cross-country travel in 4 wheel drive vehicles is usually practicable to within walking distance of points of geological interest, although it is frequently necessary to select very circuitous favourable routes from airphotos. Many coastal areas are readily accessible from the sea .

All homesteads are equipped with transceiver radio sets which are linked with the base stations for medical calls and the sending of telegrams; these stations are at Derby, Wyndham, Darwin, Alice Springs and Broome, doctors being based at each of these centres. In addition to hospitals at the main centres, the Australian Inland Mission maintains hospitals at Fitzroy Crossing and Halls Creek which are staffed by nursing sisters.

CLIMATE:

The region has a warm dry monsoonal climate with the major portion of the rain falling in the summer months December-March inclusive ("The Wet"), the remainder of the year ("The Dry" or winter) being generally cooler and dry although in freak seasons heavy winter rains have been recorded; winter rains are of greater importance in the drier inland parts. For field work the months April to September inclusive are usually ideal, but October and November are less suitable due to higher humidity and high temperatures; in the wet season, movement of vehicles is severely restricted and field work is unpleasant or impossible.

The southern inland portion of the area receives an average annual rainfall of about 15 inches, and the rainfall increases gradually toward the coast; the increase is most rapid toward the north, and the Port Keats and Kalumburu areas have an average annual rainfall of over 35 inches. The major portion of the settled area receives less than 30 inches per annum, the rainfall having a low to moderate variability and becoming increasingly unreliable as the average rainfall decreases inland. The rainfall characteristics for the area may be gauged by references to the tables for selected localities (Tables 1 - 7).

Day temperatures in the region are high especially inland, but night temperatures vary from moderate to low; in coastal areas the day and night temperatures are somewhat moderated, although humidity is generally higher. In October and November very high temperatures are experienced inland, and shade temperatures in certain areas average over 110°F for weeks.

Temperature and humidity behaviour in the area can be gauged by reference to Tables 1 to 7.

## CLIMATE - TABLE I

DERBY.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Av. 63 yrs. | Temperature. Av. Max. 44 years | Av. Min. 44 years | Humidity Av. 9 am 43 years | Av. 3 pm 43 years | No. of Wet Days Av. 30 yrs |
|---|---|---|---|---|---|---|---|---|---|
| Jan. | 551 | 440 | 446 | 744 | 94.7 | 78.9 | 70 | 58 | 12 |
| Feb. | 551 | 1665 | 514 | 566 | 94.8 | 78.6 | 71 | 57 | 9 |
| Mar. | 487 | 47 | 644 | 470 | 95.1 | 77.6 | 66 | 53 | 9 |
| Apr. | 202 | 37 | 78 | 137 | 94.8 | 72.5 | 52 | 42 | 2 |
| May | 242 | 275 | 14 | 68 | 89.7 | 66.1 | 47 | 40 | 1 |
| June | 192 | 75 | 140 | 48 | 85.2 | 60.9 | 47 | 40 | 1 |
| July | 260 | 483 | 170 | 22 | 84.5 | 58.4 | 47 | 40 | 1 |
| Aug. | 0 | 0 | 0 | 8 | 88.2 | 61.2 | 46 | 38 | 0 |
| Sept. | 0 | 0 | 0 | 1 | 92.9 | 66.4 | 47 | 39 | 0 |
| Oct. | 0 | 2 | 0 | 8 | 96.1 | 73.1 | 51 | 43 | 0 |
| Nov. | 87 | 47 | 154 | 83 | 97.1 | 78.0 | 56 | 50 | 2 |
| Dec. | 29 | 21 | 881 | 392 | 96.7 | 79.5 | 63 | 54 | 8 |
| Annual | 2601 | 3092 | 3041 | 2551 | | | | | |

# CLIMATE - TABLE 2.

## FITZROY CROSSING.

| Month | Rainfall - Pts. | | | | No. of Wet Days |
|---|---|---|---|---|---|
| | 1955 | 1956 | 1957 | Aver. 26 yrs. | Aver. 30 yrs. |
| Jan. | 558 | 408 | 342 | 619 | 13 |
| Feb. | 403 | 1378 | 325 | 531 | 10 |
| Mar. | 135 | 99 | 154 | 331 | 8 |
| Apr. | 93 | 0 | 11 | 70 | 2 |
| May | 86 | 212 | 56 | 26 | 1 |
| June | 32 | 30 | 327 | 33 | 1 |
| July | 154 | 233 | 145 | 29 | 1 |
| Aug. | 0 | 0 | 0 | 6 | 0 |
| Sept. | 0 | 0 | 0 | 6 | 0 |
| Oct. | 0 | 0 | 7 | 19 | 2 |
| Nov. | 334 | 110 | 52 | 93 | 4 |
| Dec. | 166 | 61 | 783 | 340 | 10 |
| Annual | 1961 | 2531 | 2202 | 2103 | |

## CLIMATE - TABLE 3.

### HALL'S CREEK.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Av. 11 years. | Temperature Av. Max. 42 years | Av. Min. 42 years | Humidity Av. 9 a.m. 41 years. | Av. 3 p.m. 41 years. |
|---|---|---|---|---|---|---|---|---|
| Jan. | 540 | 172 | 114 | 513 | 97.9 | 75.1 | 51 | 36 |
| Feb. | 214 | 1145 | 341 | 520 | 97.1 | 74.2 | 52 | 36 |
| Mar. | 180 | 72 | 137 | 135 | 95.1 | 71.1 | 46 | 33 |
| Apr. | 45 | 51 | 49 | 64 | 91.9 | 63.5 | 35 | 27 |
| May | 157 | 55 | 11 | 15 | 85.5 | 56.0 | 37 | 29 |
| June | 11 | 2 | 344 | 1 | 80.6 | 50.8 | 40 | 32 |
| July | 252 | 272 | 26 | 3 | 80.1 | 48.0 | 37 | 30 |
| Aug. | 16 | 0 | 0 | 15 | 85.9 | 52.0 | 33 | 26 |
| Sept. | 0 | 0 | 0 | 13 | 92.7 | 59.1 | 29 | 24 |
| Oct. | 17 | 1 | 9 | 82 | 98.2 | 69.2 | 32 | 26 |
| Nov. | 196 | 90 | 71 | 130 | 100.3 | 74.1 | 35 | 28 |
| Dec. | 38 | 68 | 304 | 259 | 99.4 | 75.3 | 43 | 32 |
| Annual | 1666 | 1928 | 1406 | 1750 | | | | |

## CLIMATE - TABLE 4.

WYNDHAM.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Av. 62 years. | Temperature Av. Max. 43 yrs. | Av. Min. 43 yrs. | Humidity Av. 9 am. 42 years. | Av. 3 p.m. 42 years. | No. of Wet Days Av. 30 years |
|---|---|---|---|---|---|---|---|---|---|
| Jan. | 534 | 461 | 1855 | 726 | 96.3 | 80.2 | 67 | 54 | 13 |
| Feb. | 1199 | 985 | 713 | 633 | 95.6 | 79.6 | 69 | 54 | 11 |
| Mar. | 672 | 475 | 252 | 488 | 95.3 | 79.2 | 64 | 49 | 9 |
| Apr. | 190 | 2 | 20 | 77 | 94.7 | 77.4 | 46 | 38 | 3 |
| May | 302 | 102 | 0 | 22 | 90.3 | 72.4 | 41 | 37 | 1 |
| June | 34 | 0 | 439 | 16 | 86.1 | 68.0 | 42 | 37 | 0 |
| July | 242 | 198 | 0 | 14 | 85.3 | 66.2 | 40 | 35 | 0 |
| Aug. | 0 | 0 | 0 | 3 | 88.7 | 69.5 | 43 | 39 | 0 |
| Sept. | 2 | 0 | 0 | 8 | 93.8 | 74.8 | 44 | 43 | 0 |
| Oct. | 0 | 0 | 3 | 47 | 97.1 | 79.6 | 51 | 47 | 2 |
| Nov. | 558 | 204 | 33 | 183 | 98.3 | 81.2 | 56 | 50 | 6 |
| Dec. | 124 | 482 | 383 | 441 | 97.5 | 81.0 | 55 | 52 | 10 |
| Annual | 3857 | 2909 | 3698 | 2658 | | | | | |

## CLIMATE - TABLE 5.

COCKATOO ISLAND.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Av. 7 years | Temperature Av. Max. 3 years. | Av. Min. 3 years. | Humidity Av. 9 a.m. for 3 years |
|---|---|---|---|---|---|---|---|
| Jan. | 462 | 392 | 330 | 344 | 91.5 | 82.1 | 73 |
| Feb. | 2066 | 3075 | | 1000 | 91.5 | 83.2 | 75 |
| Mar. | 364 | 133 | | 397 | 91.2 | 83.3 | 73 |
| Apr. | 158 | 166 | 8 | 396 | 91.5 | 82.0 | 66 |
| May | 725 | 116 | 22 | 284 | 87.5 | 78.3 | 51 |
| June | 718 | 125 | 339 | 130 | 83.1 | 74.4 | 53 |
| July | 120 | 174 | 175 | 17 | 81.6 | 72.7 | 53 |
| Aug. | 0 | 0 | 0 | 0 | 82.6 | 73.3 | 53 |
| Sept. | 0 | 0 | 0 | 1 | 85.9 | 79.7 | 66 |
| Oct. | 0 | 0 | 4 | 0 | 88.1 | 79.1 | 69 |
| Nov. | 100 | | 6 | 22 | 91.2 | 81.8 | 72 |
| Dec. | 34 | 19 | 265 | 249 | 88.2 | 83.1 | 71 |
| Annual | 4747 | | | 2840 | | | |

## CLIMATE - TABLE 6.

### GIBB RIVER.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Aver. 26 yrs. | No. of Wet Days Av. 11 yrs. |
|---|---|---|---|---|---|
| Jan. | 358 | 662 | 638 | 750 | 13 |
| Feb. | 754 | 2381 | 796 | 648 | 13 |
| Mar. | 315 | 124 | 474 | 568 | 8 |
| Apr. | 33 | 0 | 90 | 57 | 1 |
| May | 167 | 123 | 0 | 36 | 0 |
| June | 240 | 2 | 461 | 39 | 0 |
| July | 142 | 159 | 7 | 20 | 0 |
| Aug. | 25 | 0 | 0 | 2 | 1 |
| Sept. | 1 | 0 | 0 | 10 | 1 |
| Oct. | 56 | 35 | 74 | 70 | 4 |
| Nov. | 393 | 393 | 234 | 201 | 8 |
| Dec. | 335 | 170 | 330 | 473 | 11 |
| Annual | | | | 2875 | |

# CLIMATE - TABLE 7.

## KALUMBURU MISSION.

| Month | Rainfall - (Points) 1955 | 1956 | 1957 | Av. 40 years. | Temperature Av. Max. 6 years. | Av. Min. 6 years. | Humidity Av. 9 am. 7 years. | Av. 3 pm. 7 years. | No. of Wet Days Av. 9 years |
|---|---|---|---|---|---|---|---|---|---|
| Jan. | 996 | 545 | 856 | 934 | 93.5 | 76.3 | 70 | 60 | 16 |
| Feb. | 1389 | 2010 | 1741 | 862 | 91.0 | 75.7 | 73 | 65 | 17 |
| Mar. | 1488 | 381 | 803 | 753 | 93.4 | 74.8 | 70 | 58 | 14 |
| Apr. | 205 | 44 | 193 | 162 | 93.3 | 67.4 | 50 | 36 | 4 |
| May | 332 | 79 | 0 | 34 | 91.9 | 63.4 | 48 | 35 | 0 |
| June | 105 | 19 | 544 | 31 | 87.5 | 58.5 | 42 | 32 | 1 |
| July | 337 | 285 | 0 | 7 | 89.0 | 57.1 | 41 | 27 | 0 |
| Aug. | 74 | 0 | 0 | 0 | 91.3 | 59.4 | 41 | 31 | 0 |
| Sept. | 1 | 0 | 0 | 14 | 94.3 | 66.2 | 43 | 37 | 0 |
| Oct. | 6 | 0 | 66 | 64 | 97.0 | 71.9 | 47 | 42 | 3 |
| Nov. | 1988 | 230 | 192 | 263 | 97.7 | 76.2 | 52 | 48 | 8 |
| Dec. | 306 | 527 | 839 | 593 | 93.7 | 76.4 | 64 | 58 | 15 |
| Annual | | | | 3717 | | | | | |

FLORA:

Most of the area consists of grassy or spinifex covered plains and hills with (or sometimes without, especially on plains) a moderate growth of small trees in savannah type of woodland. Trees rarely exceed several feet in diameter and forty feet in height except along the watercourses; baobabs (bottle trees) are very common on some soils and formations (e.g. the Elgee Shale), and older trees attain considerable diameter at the butt, but are useless for timber. Leguminous trees are prominent and include wattle, bohemia, and ironwood. Limited areas of cypress pine occur on the Kimberley Plateau, but their geographical position prevents their extensive use for timber. Leichhardt "pine", paperbark, and other trees growing near watercourses are used for locally sawn timber for station building. Bloodwood, woollybutt, box, coolibah, river gum, and other eucalypts are widespread and are utilised for fencing and yard building; many of these gums are semi deciduous in the Kimberley climate. Deciduous trees such as baobabs, coral, "pear", cotton bush, and others are relatively prominent, and may also be caused by environment.

Other than introduced garden plants, and small scale experiments in the growing of rice, sugarcane, and other crops at Liveringa and Kimberley Research Station, no large-scale introduction of plants has occurred; new plants for pasture improvement have not been experimented with on any practical scale.

FAUNA:

In areas less suited to running cattle, and in most areas adjacent to permanent waterholes, wallabies and euros, with some kangaroos, are fairly plentiful. In addition wild turkeys, geese, ducks, and emus also occur but in general are not plentiful.

Lizards of all kinds are abundant; man-eating crocodiles ("alligators") occur in estuaries and in the rivers near the sea, and "fish" or Johnson crocodiles are plentiful throughout the larger rivers. Fish, including barramundi, bream, catfish, and jewfish, occur in pools in the rivers, and various types of fish and sharks abound in the coastal waters; dugong and turtles also occur in the coastal waters.

Snakes are not plentiful, but include pythons, brown, black, spinifex and other types, some poisonous. Pearl-oyster beds occur along parts of the western coastline but the treacherous currents have prevented their full exploitation.

Various domestic animals have been allowed to run wild, and are now assuming plague proportions in some areas; these animals include pigs, donkeys, camels, brumbies, and cattle. Dingoes are plentiful in some sections and prevent sheep breeding.

Cattle, horses, goats, donkeys, camels, and mules are raised on the various stations, and some large sheep stations have been established on the lower Fitzroy River.

Various cockatoos, parrots, finches, and other birds abound near water, and a small export trade exists in the brighter coloured types.

Except in areas containing wild cattle, and along the coast, it is difficult to obtain enough game to live on, and this necessitates the carrying of supplies of tinned food and tends to limit the time range of light vehicles on traverses.

## WATER SUPPLIES:

In station areas the sinking of bores, earth tanks, etc. has augmented the natural supplies in pools and springs, and watering points are usually not more than 10 miles apart; however, in some areas of Lower Proterozoic outcrop surface waters are scarce during the latter part of the "Dry" and this has a limiting effect on mineral exploration. Water supplies in areas of Lower Adelaidean outcrop, such as the Kimberley Plateau, are usually plentiful as pools and springs; in younger areas station bores etc. are generally plentiful and no difficulty is experienced in obtaining adequate watering points.

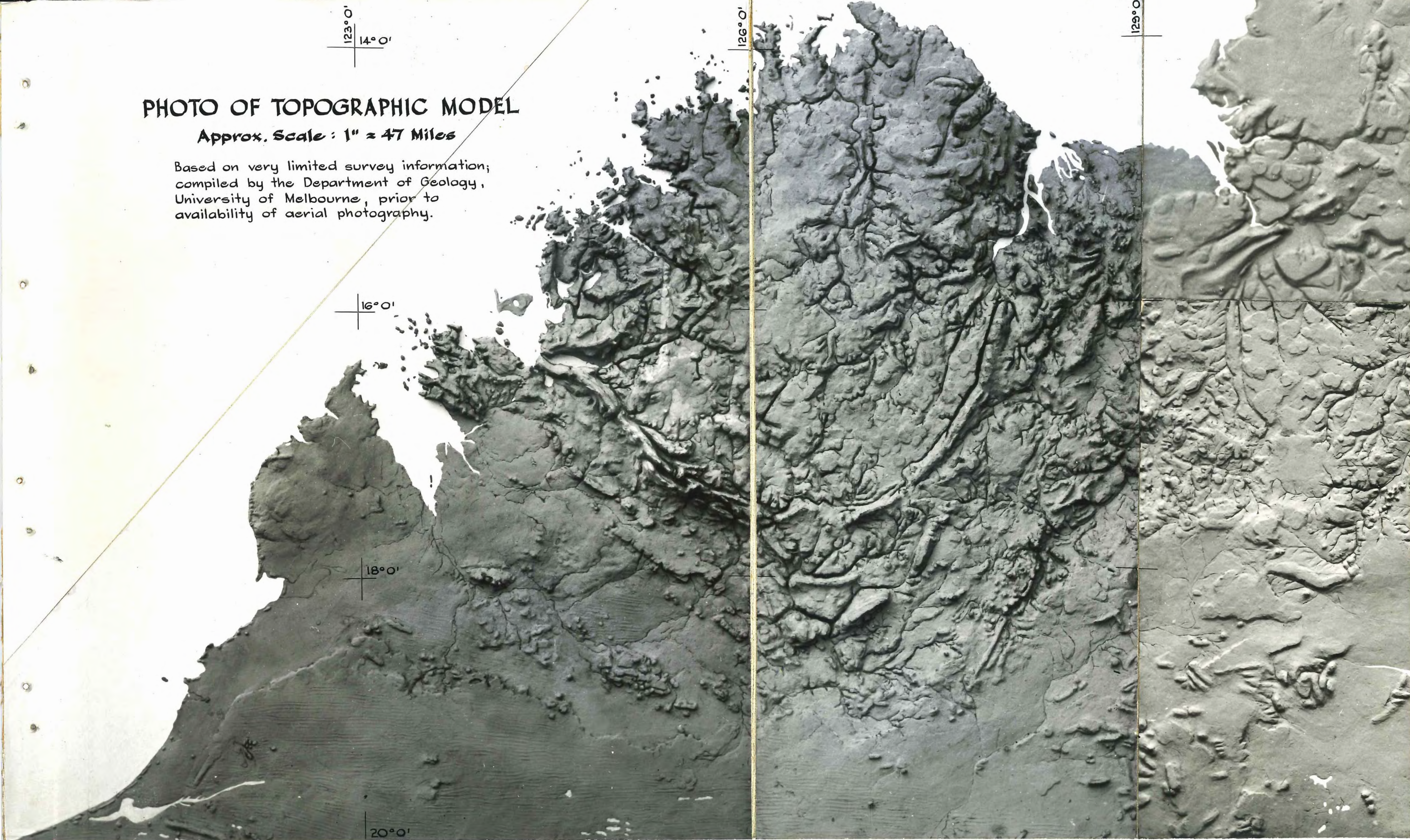
## MAP COVERAGE:

The area is predominantly poorly mapped and most of the existing maps are inaccurate and misleading. Since 1948 the area

# PHOTO OF TOPOGRAPHIC MODEL

**Approx. Scale : 1" = 47 Miles**

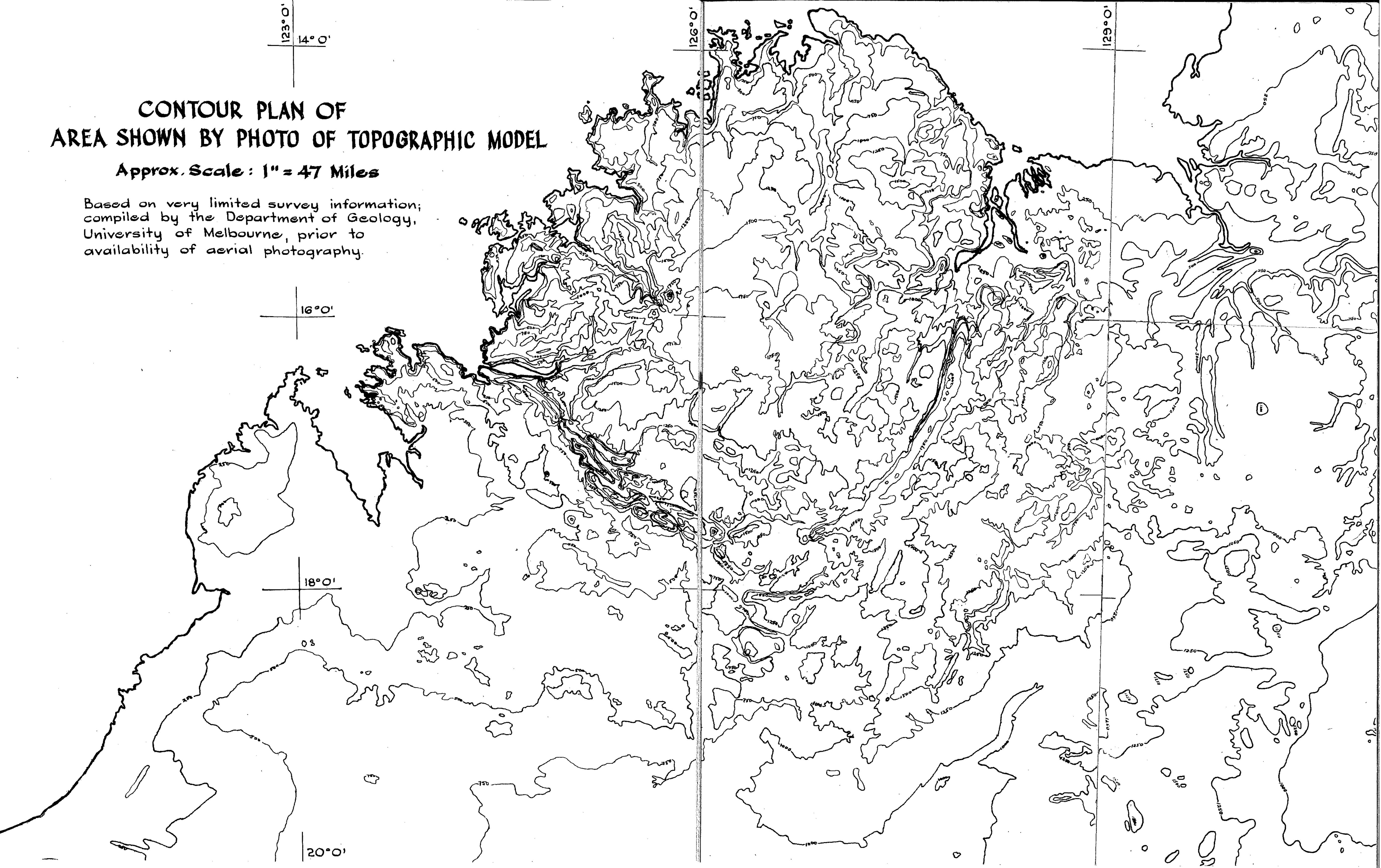
Based on very limited survey information; compiled by the Department of Geology, University of Melbourne, prior to availability of aerial photography.



# CONTOUR PLAN OF AREA SHOWN BY PHOTO OF TOPOGRAPHIC MODEL

**Approx. Scale: 1" = 47 Miles**

Based on very limited survey information; compiled by the Department of Geology, University of Melbourne, prior to availability of aerial photography.



has been completely photographed by vertical R.A.A.F. photography from 25,000 feet, the scale of the photos being of the order of 1 : 49,000; in addition parts of the coast are covered by oblique airphotos. The vertical airphotos have been assembled into roughly controlled photomaps (1" = 4 miles) by the National Mapping Department, and these photomaps and derived line-maps form the only reliable maps for most of the area; in addition the Western Australia Lands Department have prepared 1" = 1 mile mosaics for certain of the areas adjacent to the Northern Territory, and in the Lennard River area, and this project is continuing.

More recently certain areas in the Ord River Dam Site area have been re-photographed at lower levels, and the photos used to assist in preparing contoured maps of this area.

During 1955 Adastra Aerial Surveys photographed the Pompeys Pillar Iron Ore Deposit, and the Yampi Sound Iron Ore Deposits, at a scale of 600' and 1200' to the inch on behalf of the Broken Hill Pty. Co. Ltd; these photographs have been used for photo contouring and survey purposes. Small areas were photographed by the N.A.A.G.S., prior to 1938, in the vicinity of various mineral deposits.

TOPOGRAPHY:

The general nature of the topography may be seen by reference to the photo of the relief model prepared by the Melbourne University, Department of Geology, and the overall heights of the ranges may be seen by reference to the contour plan. The maximum height above sea level is 3,070 feet at Mt. Ord, in the King Leopold Range; excluding the King Leopold and Durack Ranges, and an area around Mt. Hann, the general height above sea level is less than 1600 feet. The topography is more closely dependent on the geology than is apparent from the model and contours, as these were prepared from scanty survey information and without the benefit of air photos.

Broadly speaking the area is drained by the following main groups of river systems:

The Victoria and tributaries, and the Fitzmaurice, draining chiefly the northern and eastern portion of the Northern Territory section.

The Ord and tributaries draining the southern section of the Northern Territory area, and the area in Western Australia lying east of the Durack Range; the southernmost section of the Gordon Downs Sheet is drained by the Sturt River which flows inland to Gregory's Salt Sea.

The North Kimberley Plateau is drained by a number of large north flowing rivers in the Chamberlain, Pentecost, Salmond, Durack, Berkeley, Drysdale, Carson, King Edward, and Mitchell rivers. In addition northwesterly and southerly flowing rivers drain the west and south portions; the main streams being the Prince Regent, Charnley, Calder, Isdell, Lennard, Hann-Traine-Fitzroy Rivers.

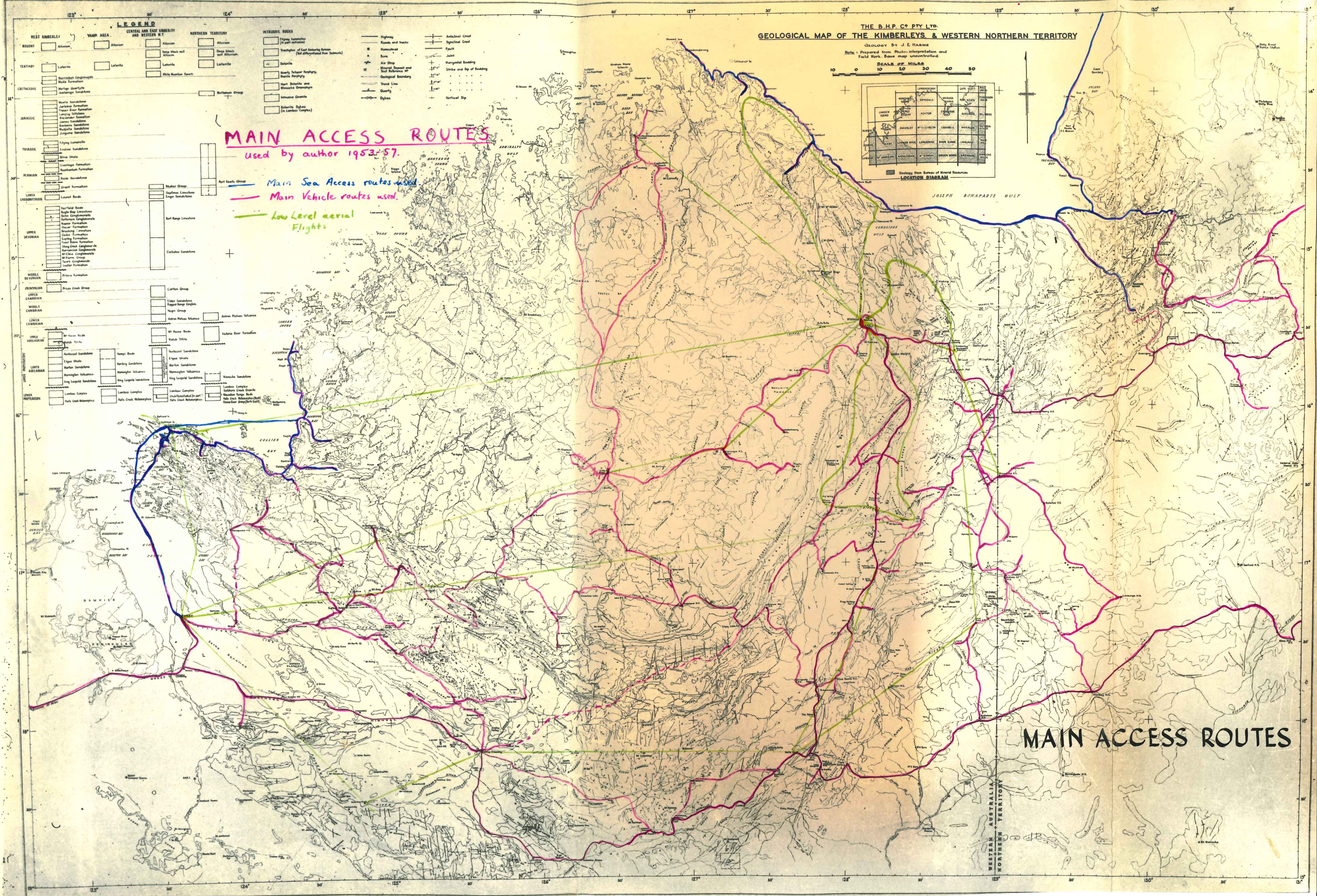
The area to the southwest of the North Kimberley Plateau is drained by the Margaret - Laura - Mary - Christmas Creek - Fitzroy and Lennard systems, with an area of internal or no defined drainage to the south of this again in the Canning Basin.

None of the above rivers are permanent as all stop flowing (at least in most places) in the latter part of the year except under exceptional conditions; most however have large waterholes, springs or billabongs which are semi-permanent and are much used as sources of stock water, and to a very limited extent for irrigation.

Various C.S.I.R.O. expeditions have surveyed the physiography and soils of the Fitzroy Basin, North Kimberley, and Ord-Victoria areas, but the results are not yet available in published form. The detailed description of physiography is partly covered by the C.S.I.R.O. work, but in other areas no systematic work has been attempted. The detailed physiography is beyond the scope of this paper, but it is recorded that the area offers excellent examples of a very wide variety of geomorphic forms, and in this respect is probably equal to any other area in Australia.

## MAPPING METHODS:

Due to the large areas involved and the lack of adequate


THE B.H.P. Co PTY LTD.
GEOLOGICAL MAP OF THE KIMBERLEYS & WESTERN NORTHERN TERRITORY
GEOLOGY BY J. E. HARMS
Note: Prepared from Photo-interpretation and Field Work. Base map uncontrolled.
SCALE OF MILES
LOCATION DIAGRAM
LEGEND
MAIN ACCESS ROUTES
used by author 1953-57.
Main Sea Access routes used
Main Vehicle routes used.
Low Level aerial Flights
JOSEPH BONAPARTE GULF
WESTERN AUSTRALIA
NORTHERN TERRITORY
MAIN ACCESS ROUTES

geological base maps, full use was made of air photos for location, planning cross-country traverses, and recording information; the excellence of the outcrops and the bold topographic expression of many beds assisted in the widespread use of photo-interpretation in preparing a geological base map.

In general the following procedure was adopted:-

1. Stereoscopic photo-interpretation of the geology of each sheet was carried out by the author or under his supervision; the geology was transferred by eye from the photos to ethulon overlays on the 4 mile to 1 inch or 1 mile to 1 inch photomaps.

2. Various doubtful areas noted during interpretation were, if possible, clarified in the field; in addition check traverses were done at convenient places, and formations of economic interest followed along the strike. In some cases of beds of characteristic colour and topographic appearance, use was made of low flying charter aircraft to follow the formation between known ground points.

3. Any indicated alterations to the initial geological plan were made, and the plan drafted.

4. The 4 mile to 1 inch plans were photographed and reduction printed to a scale of 10 miles to 1 inch, and the prints traced onto a grid-compilation. The 1 mile to 1 inch plans were reduced to 4 miles to 1 inch, assembled at 4 mile scale, and then further reduced to 10 mile scale.

5. For field use some geological plans were made at photoscale by the use of a slotted template assembly; one such area was the area of Antrim Plateau Volcanics between the Rosewood, Hardman and Argyle Basins. The practice was discontinued due to the high percentage of time required purely for preparation of the base plot without yielding any appreciable increase in the accuracy of the final geological plan.

6. In most areas field traverses were done on foot, using Landrovers to travel to and from the area of interest. Along coastal areas access was gained by sea transport, with foot traverses inland to selected points. The main access routes used are shown on the plan opposite this page.

PREVIOUS INVESTIGATIONS:

The earliest workers in the eastern part of the area were Commander Stokes (1837-1843) and Rev. Tenison Woods (1886) but the first work of significance was done by H.Y.L. Brown (1895-1909), Woolnough (1912) and Jensen (1914). Wade travelled over part of this area in 1924 and Forman (1941) collected the first assemblage of fossils from the Boneaparte Gulf Basin. Reeves examined the Boneaparte Gulf Basin (1948), and Noakes covered the fringes of the area in a geological reconnaissance between Katherine and Darwin in 1946. Isolated small areas were examined by geologists of the A.G.G.S. of N.A. between 1935 and 1940, but the outstanding regional work was carried out by D.M. Traves for the Bureau of Mineral Resources in 1949 and 1952. Subsequent to 1955 more detailed work on several areas, notably the Victoria River Area, the Boneaparte Gulf Basin, and the Port Keats area, has been initiated by Associated Australian Oilfields, the work again being under the direction of D.M. Traves.

In the Western Australian (Kimberley) section of the area Hardman carried out the first geological work in the area in 1883, and 1884, leading to the discovery of the Halls Creek Goldfield, the first in Western Australia. Woodward carried out various surveys in the area, the most notable contribution being his Report on the Halls Creek Goldfield. In 1901 A. Gibb Maitland and C.G. Gibson accompanied the Brockman and Crossland exploration team on an examination of the North and Central Kimberley; unfortunately no detailed map or report on their findings was ever published, although some references are made to the area by Maitland in reports in the following years.

In 1906 Dr. R.L. Jack reported on the prospects of artesian water in the area. Various exploratory teams contributed small amounts of geology, notably those of Easton, Fitzgerald and Basedow.

The possibility of oil occurring in the region caused surveys by Blatchford, Talbot, Wade, and Clapp. More recently Reeves, Kraus, Wade, Maddox and Smith have completed surveys for various oil companies, and the Bureau of Mineral Resources commenced a campaign of regional mapping; officers concerned in the latter campaign included Matheson, Guppy, Lindner, Thomas, Brunnschweiler, Schneeberger, Rattigan, Casey, Opik, Cuthbert, and Traves. Palaeontological contributions, (in addition to those above) have come from Crespin, Teichert, Etheridge, Chapman, Crockford, Delepine, Hill, Hinde, Hosking, Miller, Nicholson, Prendergast, Ripper and Whitehouse.

The more notable petrological works on the area have been published by Simpson, Edwards, Prider, and Farquharson, while reports on the geology of various mining fields have been made by Canavan and Edwards, Finucane, Jones, Montgomery, Macandie and Reid.

From the standpoint of regional geology the most important recent workers have been Traves, Matheson, Guppy, Lindner, Rattigan and other workers in the Bureau of Mineral Resources, the geologists of the West Australian Petroleum Coy., and the geologists of the Broken Hill Pty. Co. Ltd.

Much of the material compiled by these workers is unpublished, but the writer has had the opportunity of discussing the geology of the area with them, and has seen many of their preliminary reports and maps. This paper gives a summary of the geology of the area which is derived primarily from the writers field observations and laboratory work, but includes material gleaned from other workers; the section dealing with the post-Cambrian rocks is largely derived from the work of the Bureau of Mineral Resources, notably that presented by Traves, Guppy et al. and Rattigan. All that part of the paper dealing with the Precambrian and Cambrian geology is the work of the author and geologists of the Broken Hill Pty. working with the author, unless otherwise acknowledged; the author accepts sole responsibility for the opinions and interpretations expressed, regarding this part of the Report.

ACKNOWLEDGMENTS:

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Dr. Brian Daily has identified various fossils.

Mr. Jim Stewart, a prospector in the West Kimberleys, guided the author to various mineral occurrences in that area in 1953, and also accompanied the author as a prospector in the East Kimberleys during the year 1954.

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# THE GEOLOGY OF THE KIMBERLEY DIVISION, WESTERN AUSTRALIA, AND OF AN ADJACENT AREA OF THE NORTHERN TERRITORY.

## PART II.

## STRATIGRAPHY, TECTONICS, GEOLOGICAL HISTORY

# CONTENTS - PART II

PLANS, FIGURES ETC.



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# PART II.

## STRATIGRAPHY. TECTONICS. GEOLOGICAL HISTORY.

## STRATIGRAPHY

### 1. General.

The stratigraphy of the area embraces units of almost all periods, including Precambrian, Cambrian, Ordovician, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and Tertiary.

The Precambrian succession appears to be one of the most extensive in Northern Australia, and the subdivision of this succession may serve as a guide to correlation in areas to the east; a provisional correlation with other Precambrian successions is given, but is subject to modification.

Middle Cambrian sediments occur in three main areas in the East Kimberley, Hardman, Rosewood, and Argyle Basins; Upper Cambrian sediments occur in the Carlton Basin only. Palaeozoic sediments occur in the Boneaparte Gulf Basin, which term as used by Traves (1955) includes the Carlton and Burt Range Basins; Palaeozoic and Mesozoic sediments outcrop at various places in the Fitzroy Basin. Mesozoic sediments also form a thin veneer on some of the north-eastern portions of the Northern Territory section.

Tertiary rocks are limited to a small isolated occurrence of lacustrine beds in the White Mountain area, and to unfossiliferous laterites and some of the older deeper alluvium.

### 2. PRECAMBRIAN.

Rocks of this age outcrop over the greater portion of the mapped area, and some success was met with in subdividing the succession, especially in the North Kimberley Plateau. On parts of the "mobile zones" (see tectonic map), and to the east in the Northern Territory, the more complex structures and lack of data in critical areas, have prevented definite correlation of the units with those of the Kimberley Plateau, and such correlations must await more detailed mapping.

To prevent undue duplication and unnecessary new terms, the writer has, where possible, followed the nomenclature used by the Bureau of Mineral Resources; the Precambrian succession has been divided into three main divisions - Lower Proterozoic, and the Lower and Upper Adelaidean of the Upper Proterozoic, these age divisions being based on lithology and structural features, as no absolute age determinations are available for the area.

The Lower Proterozoic succession includes the geosynclinal metamorphics, named the Halls Creek Metamorphics, and their granitised equivalents, the Lamboo Complex.

The Lower Adelaidean (Noakes 1957) unconformably overlies the Lower Proterozoic, and has been differentiated on the Kimberley Plateau into five main units of the rank of formations; as far as possible the author has followed the nomenclature of Guppy et al. (1958), but has further subdivided and modified their units. The succession is chiefly arenaceous but includes prominent volcanics and some shales; it has been invaded by numerous and persistent basic intrusives, mainly in the form of sills.

The Upper Adelaidean is divided into two main formations, the lower of which is the Walsh Tillite (Guppy et al. 1958); the writer has extended the known occurrences of this unit in the area, and this has assisted in determining the geological history. The terms Upper and Lower Adelaidean, suggested by Noakes (1957), can only be applied in this area on the assumption that the Walsh Tillite is the approximate time-equivalent of the Sturtian Series of South Australia. In the Kimberley area the Upper Adelaidean often overlies the Lower Adelaidean with a marked erosional unconformity.

In the Northern Territory the Macadam Range Beds and the Victoria River Formation bear doubtful relationships to one another and to other units to the west, but are tentatively correlated with the Lower Proterozoic and Upper Adelaidean respectively.

The relationships and correlation of isolated units is discussed in more detail under their probable age groupings.

LOWER PROTEROZOIC.

Halls Creek Metamorphics (Traves 1955)

This is the name given to the metamorphic rocks which outcrop in the Halls Creek area (Lat. 18°15' Long. 127°48'), and in a belt trending north-north-easterly to Mount Pitt (Lat. 16°45' Long. 128°28') and south-south-westerly to south-west toward Mount Dockerell (Lat. 18°47' Long. 127°12'). Isolated exposures occur near J41 Trig Station on the Ord River (Lat. 17° 3' Long. 128°47'), north of Mt. Nyulasy (Lat. 16°42' Long. 128°17'), east of the Ragged Range (Lat. 16°20' Long. 128°28'), in the Mt. Hensman - Golden Gate (Lat. 15°56' Long. 129°00') area, and extending as far as the Keep River in the Northern Territory. Outcrops possibly of this age occur on the Fitzmaurice River near Gregory's Bar (Lat. 14°48' Long. 130°09'), and north-easterly toward Fletchers Gully; Walpole (pers. comm.) has recently discovered evidence that the Macadam Range Beds (corresponding to his Chilling Creek Sandstone) represent a facies variation of some of the upper formations of the Brocks Creek area, and it is possible that the Macadam Range Beds and certain beds in the vicinity of the Ord River Dam site may bear a similar relationship to the Halls Creek Metamorphics.

In the West Kimberley discontinuous outcrops of metamorphic rocks are probably equivalent to the Halls Creek Metamorphics, although they may in part be older. Outcrops occur (for latitude - longitude of areas see page 5 ) in the Louisa Downs area, Richenda area, Hooper Hills, near Alexander and Hawkestone Creeks, and in the Mondooma - Tarajee - Mt. Nellie areas, - and remnants of schists occur throughout the gneisses etc., of the Lamboo Complex, notably in the McSpeery's Gap and Mt. Joseph areas; in view of the semi-continuous nature of the outcrops and remnants with the Halls Creek metamorphic belt, they are taken to be of the same age, although it is possible that some of the more metamorphosed sediments are Archean. This West Kimberley belt of sediments (and associated granitised sediments) appears to have its easterly continuation in the Warramunga area, although mapping in the intervening area is as yet very sketchy.

The Halls Creek Metamorphics consist of shales, siltstones, impure limestones, basic, intermediate and acid volcanics and lavas, and impure arenaceous beds which in many places have been violently folded although elsewhere the folding is open and relatively gentle; the degree of metamorphism varies considerably, and andalusite schists, calcite-scapolite - diopside - garnet rocks and garnetiferous amphibolites are common in some areas, while others have been but little metamorphosed. The highest degree of metamorphism is attained in portions of the West Kimberley, notably near Hawkestone Creek, Clara Hills, and north of Winjana Gorge, in which areas chiastolite, staurolite, sillimanite and garnet schists outcrop; in other areas, often in the more extensive belts of sediments, phyllites, mica schists, and impure quartzites form the dominant rock types.

In the East Kimberley calc-silicate marbles sometimes form prominent marker beds on the Metamorphics; these rocks are known in the Ruby Creek - Halls Creek area, but have their main distribution in the belt trending from the Panton River north north-easterly toward Reedy Creek, and as far as Killarney Mill, east of Turkey Creek. In the northern part of this belt more or less pure marbles are associated with banded calc-silicate rocks, amphibolites, garnet amphibolites, and epidote-bearing basic rocks. Further to the north, south-west, west, and north of Mt. Pitt, bands of calc-silicate rock occur apparently as residuals of granitisation, and are associated mainly with poorly outcropping granitic rocks.

No calc-silicate rocks were noted by the author in the West Kimberleys, nor are any occurrences recorded in the published literature.

The rock types developed in various areas are summarised below from information collected mainly by the author, but also from the reports of the N.A.A.G.S.:-

| Area. | Rock Types |
|---|---|
| Tarraji River area<br>Lat. 16°14' Long. 124°12' | Mica schists, andalusite schists |
| Mondooma area.<br>Lat. 16°55' Long. 124°25' | Mica schists, quartz schist, amphibolites |
| Clara Hills - Hawkestone Ck.<br>Lat. 17°00' Long. 124°35' | Mica schist, slates Amphibolites, chiastolite schists, staurolite schists, sillimanite schists, garnet schists. |
| North of Winjana Gorge<br>Lat. 17°25' Long. 124°56' | Mica schists, garnet schists, amphibolites, ? cordierite gneiss. |
| Richenda area.<br>Lat. 17°25' Long. 125°20' | Mica schists, sandstones, quartzites, phyllites, slates, greenstones and actinolite rocks. |
| Mt. Broome area.<br>Lat. 17°19' Long. 125°17' | Sheared porphyry, acid breccias, sandstones, slates, mica schists, hornblende - chlorite schists. |
| Pigeon Creek - Hooper Hills<br>Lat. 17°52' Long. 125°35' | Slates, phyllites, mica schist sheared sandstone. |
| Louisa Downs<br>Lat. 18°42' Long. 126°42' | Quartzites and schists. |
| Mary River<br>Lat. 18°30' Long. 127°30' | Micaceous sandstones, shales, slates, foliated quartz amphibolites, massive augite-actinolite-hornblende rocks (recrystallised basic volcanics). |
| Rockhole H.S. - Ruby Ck.<br>Lat. 18°25' Long. 127°45' | Quartzite, greywacke, altered andesite, amphibolites. |
| Mt. Dockerell<br>Lat. 18°47' Long. 127°12' | Sandstones, slates, shales, recrystallised actinolite rocks, greenstone schists. |
| Halls Creek - Ruby Ck.<br>Lat. 18°13' Long. 127°40' | Quartzites, mica schists, phyllites, slates, sandstones, grits, interbedded lavas. |
| Reedy Creek area.<br>Lat. 17°30' Long. 128°2' | Marbles, garnet, amphibolite, calc-silicates, mica schists, knotted schists, epidote-bearing basic igneous or volcanic rocks, amphibolites. |

| Area | Rock Types |
| --- | --- |
| Killarney Mill<br>Lat. 17°03' Long. 128°17' | Marbles, calc-silicate rocks, garnet amphibolites, tuffs. |
| West of J41<br>Lat. 17°03' Long. 128°47' | Slates, phyllites, schists, andesites. |
| Golden Gate - Thompson's Springs.<br>Lat. 16°02' Long. 128°57' | Slates, phyllites, quartzites, altered andesite. |
| Keep River - Cockatoo Ck.<br>Lat. 15°50' Long. 129°08' | Slates, phyllites, andesites, andalusite schists. |

Very little petrology has been done on the rocks from the unit, and most of the rock types have been named on macroscopic features. The high degree of folding and faulting present in most areas renders measurement of thicknesses impossible without detailed mapping, but it is probable that the sediments attain a thickness of the order of several tens of thousands of feet.

The Metamorphics contain widespread minor mineralisation but the only economically important lodes found to date are the gold-bearing quartz veins of the greater Halls Creek area; these occurrences and others known are described in part III.

Various workers have correlated this unit with other units in Western Australia, especially those of the Pilbara area. Finucane (1938 and 1953) places the rocks in the "Mosquito Creek Series", while Forman (1936-37) suggests that they are in part comparable to the "Warrawoona Series" and Kalgoorlie Greenstones, and in part comparable to the "Mosquito Creek Series"; these correlations are based on lithological, structural, and stratigraphic resemblances to the succession developed in the Pilbara area, which is separated from the Kimberley area by some 500 miles of Palaeozoic and Mesozoic cover rocks of the Desert Basin. Matheson and Teichert (1948) attempted to differentiate the metamorphics in the "Golden Gate" area into a "Greenstone Series" and "Mosquito Creek Series"; the observations of the writer in this area do not support such a division, and certain of Matheson and Teicherts "Mosquito Creek Series - Greenstone Series" rocks are undoubtedly stratigraphically above the Halls Creek Metamorphics, and of Lower Adelaidean age (i.e. "Nullagine").

In view of the as yet poorly defined type sections of the "Mosquito Creek Series" and "Nullagine Series" in the type area, and the widespread misuse to which the terms have been put in extending them to other areas chiefly on the criteria of degree of folding and presence or absence of quartz veins without stratigraphical evidence, the writer does not agree with their use in the Kimberley area.

The correlation of the Halls Creek Metamorphics and Brocks Creek Group of the Northern Territory appears to be more valid in that discontinuous links exist between the two, but their integration will require more detailed mapping.

More detailed mapping of the Halls Creek Metamorphics will no doubt enable it to be subdivided into many formations or even groups. Matheson and Guppy (1949) attempted to differentiate two groups - the "Halls Creek Group", and the McClintock Greenstones; Traves (1955) was unable to accept these divisions, and used the term "Halls Creek Metamorphics" to embrace the two terms. The writer is in agreement with Traves in that he has been unable to differentiate the two groups on a regional scale, the boundaries between the two being very arbitrary.

<u>Macadam Range Beds (Chilling ? Creek Sandstone)</u>

In the area northwest of the main outcrop belt of the Victoria River Formation in the Auvergne - Fitzmaurice River area, a belt of moderately to highly folded sediments occurs which bears doubtful relations to other units in the area. These sediments comprise red and white massive sandstone and quartzite, and ferruginous grit, sandstone, and conglomerate, well bedded quartzites, and sandstones, and subordinate shales and siltstones; some of the massive formations outcrop strongly and are transected by prominent joints. The sediments outcrop typically in the vicinity of lower reaches of the Victoria River between Holdfast Reach and Entrance Is., on the tidal part of the Fitzmaurice River between the Goolendong Valley and the entrance, in the Macadam Range (Lat. 15°00' Long. 129°45') and southwest of this to the area south of Legune H.S. and as far as the Keep River. To the northeast, from airphotos, these beds are continuous in outcrop with all (or part) of the Chilling Sandstone as mapped by White and Walpole (Bureau of Mineral Resources).

The author has not investigated this formation in much detail in the field, and the boundary with the Victoria River Formation is largely derived from airphoto interpretation and is approximate only.

Dips in the formation vary from flat lying to over 60°, the folding being open and accompanied by a considerable amount of faulting in the incompetent beds.

In the Goolendong Valley, in the west wall below Gregory's Bar (Lat. 14°49' Long. 130°09'), the conglomerates and quartzites of this unit dip at angles of 30° to 60° west, and overlie the greenstones, sheared porphyry, slates, schists and granitic rocks of the Goolendong Valley; the contact is masked by scree, but may be in part intrusive. To the north of the Fitzmaurice River the same beds are thought to overlie schists and igneous rocks, possibly unconformably, on the basis of photointerpretation, but this area has not been examined in the field; the schists are thought to be equivalent to the Halls Creek Metamorphics, and are tentatively correlated by Walpole with the Noltenius Formation of the Finniss River Group (i.e. the upper part of the metamorphics of the Pine Creek geosyncline).

The east wall of Goolendong Valley is formed by green shales, sandstones, quartzite (underlying limestones) of the Victoria River Formation (cf. Walpole's Tolmer Gp). The relationship between the Macadam Range Beds, the Goolendong Valley igneous rocks and schists, and the Victoria River Formation is, where inspected, masked by alluvium or scree. In some areas the disposition of outcrops suggests that the Macadam Range Beds are equivalent to the Victoria River Formation, and that the Goolendong Valley forms the core of an eroded anticlinal fold. In other areas to the southwest the Victoria River Formation appears on airphotos to unconformably overlie folded sediments which may be equivalent to the Macadam Range Beds. White and Walpole, on the basis of mapping of exposures to the northeast, have concluded that the Victoria River Formation (Tolmer Group) is in fact much younger than the Macadam Range Beds (Chilling Creek Sandstone), and in the absence of definite evidence of age in the areas examined by the author, these conclusions are accepted. However Traves (1955) mapped the two units as being identical, ascribing the differences in degree of folding to variation of tectonic environment alone, and except for the lack of shales and limestones in the Macadam Range Beds, the distribution in the areas south of the Fitzmaurice River does suggest that this view is valid.

In the area southwest of the Keep River, near the Ord River and in the Carr Boyd Range, beds which contain greywacke, shales, quartzites, sandstones, and schists, and have been intruded by granite, have been described by the author under undifferentiated "Lower Adelaidean", but they may in fact be equivalent to the Macadam Range Beds and of ? Lower Proterozoic age.

If subsequent mapping proves that the Macadam Range Beds and the Chilling Creek Sandstone are in fact identical, as seems likely, it is probable that the succession provides a link (consisting of a shelf type deposit) between the main bodies of metamorphics laid down in the Halls Creek and Pine Creek troughs. This type of relationship is evident (Walpole pers. comm.) in the Northern Territory, where the Chilling Creek Sandstone is regarded as one of the top formations of the Lower Proterozoic succession of the Katherine - Darwin area, where it represents a lateral and vertical gradation of the Noltenius Formation which in turn may be regarded as a facies variation of the Burrell Creek Formation (the Chilling Creek Sandstone and Noltenius Formation forming the Finniss River Group, and the Burrell Creek and Golden Dyke Formations forming the Brocks Creek Group). In the Kimberley area the Ord Dam site - Carr Boyd Range succession may bear a similar relation to the main trough deposits of the Halls Creek Metamorphics to the south as the Finniss River Group does to the Brocks Creek Group in the Northern Territory.

Lamboo Complex (Lamboo Station Lat. 18°32' Long. 127°21')

The Lamboo Complex was the name used by Matheson and Guppy (1949) for the undifferentiated massive granite, granitic gneiss, and undigested remnants of Halls Creek Metamorphics which outcrop in the vicinity of Lamboo Station, Mt. Amherst Station and other localities west of Halls Creek; subsequently Guppy et al. (1958) applied this term to the undifferentiated outcrops of granitic and metamorphic rocks on the Lennard River four mile sheet which the author has in part differentiated into Halls Creek Metamorphics and Lamboo Complex. Traves (1955) applied the term to the igneous belt trending north-north-east from the type locality toward the Northern Territory border, and excluded the mappable belts of metamorphics, and the author has also followed this nomenclature.

The author regards the Lamboo Complex as being composed of gneisses derived from the sediments and volcanics of the Halls Creek Metamorphics, together with contemporaneous and later magmatic granite, gabbro, porphyry, and other basic and intermediate intrusive rocks; the basic, intermediate and acid, intrusive rocks such as dolerite, diorite, gabbro, and porphry, are in part at least of post-Lower Adelaidean age since they are also intrusive into the Lower Adelaidean sequence.

Remnants of undigested Halls Creek Metamorphics are common in the Complex, especially in the more gneissic parts. The granitised nature of portions of the Complex was recognised by Hardman (1884), and by R. Logan Jack (1906) and the latter wrote of the granites of the Upper Laura and Margaret Rivers west to Minnie Pool: " ........ the granite evidently represents the ultimate stage of metamorphism of the sedimentary Silurian, Cambro-Silurian, or Cambrian rocks (author's note i.e. the Halls Creek Metamorphics)". Subsequently Matheson, Guppy, Traves, and other recent workers have advanced similar hypotheses; it is emphasised that the author and all previous workers base their belief in the granitised nature of parts of the Lamboo Complex on reconnaissance field work unsupported by detailed mapping and petrology, and that alternative hypotheses may be shown to be more correct by more detailed work. During the present survey P.J. Crohn, while working with the author in the West Kimberley, considered that certain areas which the author regarded as granitised could equally well be explained by magmatic intrusion.

There is also a probability that small areas of the gneisses will be found which are older than the Halls Creek Metamorphics and of Archaean age.

The Lamboo Complex extends in a practically unbroken belt from Cone Bay on the Yampi four mile sheet, east-south-easterly to Lamboo Station, and thence north-north-easterly to the areas east of Denham Station and near Mr. Brooking; isolated outcrops continue in a north-north-easterly direction, in the Cockatoo Creek, Keep River, and Fitzmaurice River areas, and may form a link with the Northern Territory occurrences in the western part of the Pine Creek Geosyncline.

To the south of Halls Creek, granitic rocks in the headwater region of Wolf Creek, may constitute an extension of the Yampi-Lamboo Station belt toward the granitic belt in the Warramunga area; this south-eastern continuation has not been mapped, and it is not known if the two areas are semi-continuous.

The continuation, if any, of the Northern Territory - Lamboo belt in a south-south-westerly direction, is screened by later sediments.

Granitic boulders were observed in creek float 15 miles from Limbunya on the Waterloo track, but could not be traced to their source; it is probable that they were derived from Upper Adelaidean tillite and not from an isolated outcrop of the Lamboo

Complex.

Main Rock Types of the Lamboo Complex.

| Area | Main Rock Types | Comments. |
|---|---|---|
| Robinson & Tarraji Rivers (Lat. 16°42' Long.124°10') | Porphyritic gneissic granite with xenoliths and aplite veins. Granite gneiss. | Contact between gneiss and schists parallel to gneissic banding and schistosity. |
| Clara Hills (Lat. 17°03' Long.124°45') | Diorite, granite gneiss, amphibolite, dolerite, felspar porphyry. | |
| Mt. Joseph (Lat. 17°22' Long.125°06') | Massive porphyritic granite, gneisses and hybrid rocks. Abundant aplites and pegmatites. Dolerites. | Schist remnants common, with lit-par-lit structures. |
| Oscar Range (Lat. 17°53' Long.125°15') | Sheared granite. | Limited area not differentiated on map. |
| Mt. Hart Road (Lat. 17°05' Long.125°03') | Fine grained granite, coarse grained gneissic granite, granitic gneiss quartz porphyry, granite porphyry, dolerite. | Porphyry and dolerite occur extensively near the King Leopold Range. Porphyry is intrusive into Hart Dolerite and King Leopold Sandstone in bed of Duncan River. |
| Hooper Creek - Pandanus Creek (Lat. 17°50' Long.125°43') | Biotite gneiss, porphyritic gneissic granite, fine grained massive granite, granite porphyry, leucitite dyke, pegmatites. | |
| Hooper Hills (Lat. 17°52' Long.125°37') | Gneissic granite | Foliations of gneissic granite and adjacent schist dip north at angles of 60° - 80°, but the boundary between igneous and metamorphic rocks cuts across the trend of the foliation at an acute angle. |
| Palm Creek (Lat. 18°30' Long.126°25') | Granite & gneiss, granodiorite, dolerite, amphibolite. | High proportion of basic and intermediate rocks in some sections. |

| Area. | Main Rock Types | Comments |
|---|---|---|
| Mt. Amherst (Lat. 18°22' Long.127°04') | Granite, granite gneiss, amphibolite, pegmatite. | |
| Halls Creek (Lat. 18°13' Long.127°40') to Margaret River (Lat. 18°33' Long.127°07') | Granite gneiss, dolerite, granite, pegmatite. | Granite intrudes and partially digests dolerite 42 miles from Halls Creek on Highway. |
| Ord River - (Lat. 17°27' Long.127°55') Alice Downs - (Lat.17°45' Long. 127°56') Springvale (Lat. 17°46' Long.127°40') | Gneissic granites, biotite gneiss, basic gneisses, gabbro, granodiorite, diorite, dolerites, serpentine, felsite, pegmatites, amphibolites. | Large areas of basic rocks, possibly of Lower Adelaidean age, within the more granitic and probably older sections. Circular structure of unknown origin in dolerites 4 miles north-west of Alice Downs. (Noted only from air). |
| Bow River (Lat. 16°53' Long.128°11') to Ord River (Lat. 17°27' Long. 127°55') | Biotite gneiss, granodiorite, granite, gneissic granite, amphibolite, dolerite, some pegmatite. | Generally darker and more basic rocks. |
| Bow River (Lat. 16°53' Long.128°11') to south-east of Denham Stn. (Lat. 16°22' Long.128°15') | Porphyritic biotite granite, granite gneiss, porphyritic granite with corroded phenocrysts, quartz felspar porphyry. | Quartz felspar-porphyry forms elevated sheet like masses in areas adjacent to Lower Adelaidean outcrops, in the Greenvale-Denham area, and east of the main highway near Pompeys Pillar; probably a near contact zone of an intraformational sheet locally intruding the Lower Adelaidean as at Pelican Hole near C11 Trig. (Lat. 16°52' Long. 127°47') |

| Area | Main Rock Types | Comments |
| --- | --- | --- |
| Ord River Dam Site. (Lat. 15°59' Long.128°43') | Porphyritic granite | May intrude rocks of Lower Adelaidean age. |
| Fitzmaurice River (Goolendong Valley) (Lat. 14°50' Long.130°08') | Quartz felspar rock medium grained. Granite, diorites, and sheared felspar porphyry. Some small pegmatites. | |

The field relations between the various rock types composing the Complex have been only superficially studied, but the following have been observed:

(1) Schists are frequently observed to pass, along the strike, into lit-par-lit gneiss-schist rock, and thence into pure gneiss, all gradations from schist to gneiss being present. This type of "contact" appears to be due to granitisation of favourable bands and ultimately of the entire rock.

Examples of this occur in the area surrounding Mt. Joseph in the West Kimberley, and elsewhere.

(2) Schists are sometimes crosscut by intruding massive, often porphyritic, granite which contains xenoliths of the schists. In many cases little megascopic alteration of the schists is visible even a few feet from the contact. This type of contact appears to be due to intrusion of liquid or semi-liquid magma.

(3) Massive unfoliated granite has been observed to crosscut the foliations in gneiss; it is probable that many of the non-gneissic granites are of younger age than the gneisses.

(4) Dolerites are observed to intrude the gneisses and hybrid rocks and more massive granites, sometimes in large numbers as "dyke swarms" as in the Granite Range area. Some of these dolerites have been amphibolitised, while others are "fresh". Granite has been observed to crosscut and partially digest dolerite, so that it is probable that two ages of

dolerite intrusion are present and/or two ages of granite, one at least of which is post-Upper Adelaidean since the dolerites intrude the Lower Adelaidean and Upper Adelaidean sediments on the Lennard River Sheet.

(5) Quartz felspar porphyry, quartz porphyry, granophyre, diorite, dolerite, and gabbro are known to intrude Lower Adelaidean sediments where structurally favourable; similar rock types are present in the nearby and more distant portions of the Lamboo Complex, and it is probable that they are contemporaneous. Such rocks include the dolerites and gabbros of the Bedford Downs - Springvale - Alice Downs area; the quartz felspar porphyry of the Duncan River, Six-mile Gorge, Greenvale-Denham, and other areas; the dolerite dyke swarms of the Granite Range area. (Some of the latter are now amphibolites and these may be older than the unaltered dolerites).

(6) Large areas of felspar and quartz porphyry are present in the Lamboo Complex. Finucane (1939 NAAGS Report No. 33) indicates that the porphyry of the Mt. Broome area occurs as interbedded flows with the Halls Creek Metamorphics. The porphyry of the Yampi Sound and other areas intrudes Lower Adelaidean rocks. It is therefore probable that porphyries of at least two ages are present in the area.

The Lamboo Complex contains sparse mineralisation of various types, the only economically important lodes so far found being mica-bearing pegmatites; all known mineral deposits in these rocks are described in Part III.

UPPER PROTEROZOIC.

Lower Adelaidean.

The Halls Creek Metamorphics and Lamboo Complex are overlain unconformably by a succession of quartzites, conglomerates, volcanics, and shales which outcrop extensively on the Kimberley Plateau and on the "mobile belts", and also in the East Kimberley Osmond Range and elsewhere; the succession is overlain unconformably by the Walsh Tillite and Mt. House Beds of the Upper Adelaidean. Various Western Australian geologists have previously described the flat lying portion of this succession as "Nullagine Series", and the more steeply dipping and overfolded sections as "Mosquito Creek Series"; it is probable that the "Nullagine Series" may more correctly be correlated with the Upper Adelaidean sequence, although in the absence of a complete type section of the "Nullagine Series" even this is pure speculation.

The Lower Adelaidean succession in the Kimberleys was first subdivided by Guppy and Lindner working on the Lennard River Sheet (Guppy et al. 1958), and they recognised the following units:

| | |
|---|---|
| Top | Warton Beds |
| | Mornington Volcanics |
| Base | King Leopold Beds |

The writer proposes to modify the terminology from "King Leopold Beds" to "King Leopold Sandstone" since investigation has shown that this unit is predominantly arenaceous; he has also split the "Warton Beds" into three formations, for which the names "Warton Sandstone", "Elgee Shale", and "Pentecost Sandstone" are proposed. The mapped area has been extended to cover the whole of the Kimberley Plateau; in the Yampi - Charnley - Camden Sound area the Elgee Shale has not been identified, and the probable equivalents of the "Warton Beds" have been divided into the Harding Quartzite and the Yampi Beds.

In areas to the south and east of the Kimberley Plateau it has not been generally possible to recognise the individual formations of the Lower Adelaidean, but it is thought that portion of the sequence outcrops in the Albert Edward Range, the Osmond Range, the Carr Boyd Ranges, the Wesley Range, the Pincombe Range, and the Oscar Range, and possibly the Macadam Range; the Lower Adelaidean of the Mt. Ramsay 4 mile sheet is semi-continuous with that of the Kimberley Plateau but has not been mapped by the author, who has relied on mapping by the Bureau of Mineral Resources to show the trends in this area. In all these areas in which the mapping is not sufficiently advanced to differentiate formations, the sequence has been mapped as "Undifferentiated Lower Adelaidean".

On the Kimberley Plateau the distinctive patterns of the various formations on airphotos, the generally excellent outcrops, and the bold topographic expression of some of the extremely persistent horizons mapped, have enabled large areas to be mapped rapidly by photo-interpretation, with a minimum of preliminary and subsequent field work. The Lower Adelaidean succession on the Kimberley Plateau is generally flat lying or gently warped into shallow basins and domes, but near the margins, where the beds approach and transgress the "mobile belts" they are more intensely folded and faulted, and in the Yampi area they have been overfolded and exhibit marked thickening of incompetent strata at the crests and troughs of folds. In the more deformed areas the beds have been intruded by felspar porphyry, and mildly metamorphosed, and chloritoid and andalusite schists are present in the sequence; in the gently folded areas metamorphism is less obvious, and is confined to induration of shales and possibly some epidotisation of the volcanics. Many of the arenaceous rocks are quartzitic in outcrop, although it is probable that most of these rocks are sandstones below the outer "case hardened" skin, and that few true quartzites are present.

The succession has been extensively intruded by basic igneous rocks, and by porphyry, diorite, and granophyre, the major intrusions being in the form of sills and intraformational sheets in the folded areas and adjacent to the basal unconformity with the Lower Proterozoic.

<u>King Leopold Sandstone.</u>

This formation, as defined by Guppy et al. (1958) (as the King Leopold Beds) consist of beds which "crop out typically in the King Leopold and Precipice Ranges; and outcrops extend east into areas not systematically mapped....

The sediments, mainly quartzite, with shaly beds and a basal conglomerate, unconformably overlie the Lamboo Complex and are unconformably overlain by the Mornington Volcanics. The name is derived from the King Leopold Ranges (Lat. 17°21' Long. 125°25')."

The author believes that since the strata are predominantly sandstones, and the section is now well established, the term "Beds" should be replaced by "Sandstone"; he deletes the Pricipice Range from the type area as his mapping has shown that this Range is composed of Warton Sandstone and younger formations; the author also doubts that the Mornington Volcanics overlie the King Leopold Sandstone unconformably, as in all localities so far examined no discernible erosional break can be seen in the field, and the two formations are associated over a strike distance of over 1,000 miles without observable overlap; some buckling of the King Leopold Sandstone probably occurred during the extrusion of the Mornington Volcanics, and this buckling (probably with but minor erosion) may have caused slight discrepancies in dips at the contact of the formations. No significant time break appears to have occurred between the two formations.

The King Leopold Sandstone as mapped by the author, is made up of a basal sequence of bedded to massive quartzite, sandstone and pebble conglomerate alternating with shales and very subordinate volcanics, with an overlying sequence of massive resistant quartzitic sandstone and conglomerate. The lower part of the sequence is invariably exposed as a discontinous section due to intrusion by basic and intermediate sills and dykes of the Hart Dolerite; the shales in this sequence are not prominent in the type area or west of the Lansdowne 4 mile sheet, but are developed there and to the north-north-east along the foot of the Durack Range, where they consist of red, green and black shales with a high proportion of siltstone, and contain minor thin bands of amygdaloidal and tuffaceous volcanics of a doleritic and andesitic nature. The volcancs vary from a few inches in thickness in the south, to several feet in the west Liamma Spring area, and perhaps up to 400 feet in the Speewah area (Blatchford 1927 p.12). Thin lenses of sedimentary hematite are also present in the shales at at least one horizon, over a considerable distance between Bedford Downs and Dillon Springs along the stock route; they consist of massive red and black hematite up to two feet in thickness, containing small shale pellets along the bedding.

The shales and volcanics do not form a high proportion of the outcrops, and probably do not form a high proportion of the total thickness even of the basal sequence although in isolated areas they may reach 30% of this thickness; the interbedded massive and well bedded quartzites (with rare pebble conglomerate) are frequently crossbedded and often ripplemarked, and the whole sequence shows shallow water markings. The shales are frequently hidden by scree from the more resistant quartzites.

The basal quartzite - shale - volcanic succession is overlain by massive quartzite and conglomerate which are more resistant to erosion and form the main frontal bluffs of the Durack Range in the Bedford Downs - Lansdowne area. The quartzites and conglomerates are often cross-bedded, and the conglomerates consist of pebbles up to an inch (or rarely more) in size; the pebbles consist of quartz, chert, and rarely of hematite - rich material, and from their appearance are more likely to be derived from the underlying shale-quartzite sequence than from the Lower Proterozoic. The massive quartzite and conglomerates appear to be conformable with the shale-quartzite sequence, although the succession is invariably discontinuous in outcrop, and contacts masked by alluvium; the igneous intrusions in the quartzite-shale sequence and at the base of the quartzite-conglomerate have also complicated the outcrop patterns. The author initially mapped the shale-quartzite sequence as a separate formation, but found that the distinction could not be made on a regional scale by reconnaissance mapping; more detailed mapping may indicate that the King Leopold Sandstone can in fact be subdivided into two or more sections, and it is possible that the lower beds in the Lansdowne - Speewah - Dillon Springs area may prove to be slightly lower in the section than the lowest beds developed in the type area on the Lennard River Sheet.

In the West Kimberley shales are entirely absent or very subordinate, and the section (where examined by the author) is almost entirely arenaceous; in places the basal quartzites become conglomeratic, and some boulder conglomerate has been recorded.

Throughout the marginal area of the Kimberley Plateau adjacent to the unconformity with the Lower Proterozoic, the King Leopold formation has been invaded by numerous sills, intraformational sheets, and dykes of igneous material, of which dolerite forms the bulk of the outcrops. These igneous bodies (in general) weather more rapidly than the enclosing quartzites, and hence occur in valleys, and where the dip is flat, under the the basal scree of quartzite cliffs; actual exposed contacts between the igneous material and the sediments are very rare due to soil and scree cover, and certain previous workers (Rattigan, Guppy et al.) have interpreted the occurrences as valley-fills of basalt of possibly Cambrian age. Guppy et al. named the "valley fills" in the Lennard River 4 mile area "Hart Basalt"; the author proposes to modify this term to "Hart Dolerite", (although it also includes diorites and granophyres) and the unit is further discussed under that heading. The interpretation of the "Hart Dolerite" as a series of valley fills would add considerably to the total thickness of the King Leopold Sandstone throughout the area, since the dolerite would presumably be underlain by shales etc. not now exposed at the surface; in any case, interpreting the dolerite as sills, the disruption of strata by "rafting", renders thickness measurements more difficult. The thickness of exposed sediments in the King Leopold Ranges is of the order of 2,000 to 3,000 feet as measured from airphotos; in the East Kimberley the thickness appears to be somewhat less, and of the order of 1,500 - 2,000 feet.

Where flat lying the massive quartzites and conglomerates of the unit are prominently jointed, and they show a marked joint pattern on airphotos; this joint pattern has sometimes been used as a diagnostic feature of the formation in correlating during photo-interpretation, but the Harding and Warton Sandstones show equally prominent joint patterns in certain areas, as also do the quartzites in some areas of Upper Adelaidean outcrop.

The known distribution of the King Leopold Sandstone may best be seen on the 1 inch to 10 miles Geological Map accompanying this paper; outcrops are also probably present in the Osmond Range, Albert Edward Range, Wesley Range, and other areas of undifferentiated Lower Adelaidean outcrop, but are not differentiated due to the lack of diagnostic stratigraphical association; this is largely due to lack of detailed field work in the areas involved.

No economically important minerals have been found in the King Leopold Sandstone, although large quartz veins are common in certain areas, especially along the larger master joints (or faults). Some uranium mineralisation in the Denham Station area may occur in strata of this unit.

<u>Mornington Volcanics.</u>

This unit was first defined by Guppy et al. (1958) as follows, "The Mornington Volcanics are typically developed at Mornington homestead, 35 miles east-south-east of Mt. House. (Lat. 17°31' Long. 126°06'). The formation also crops out between Precipice Range and Lady Forrest Range and north of Mt. House homestead.

The Volcanics unconformably overlie the King Leopold Beds and are conformably overlain by the Warton Beds and unconformably by the Mt. House Beds".

As discussed previously, the author believes the Mornington Volcanics are essentially conformable with the King Leopold Sandstone; he has subdivided the "Warton Beds" into three formations - the Warton Sandstone, the Elgee Shale, and the Pentecost Sandstone. The author has considerably extended the area of known outcrop of the Mornington Volcanics to the north, northwest, and southwest of the type locality; the unit forms a valuable marker formation over the whole of the Kimberley Plateau (See Geological Map).

The Mornington Volcanics include fine to coarse grained doleritic basalts, amygdaloidal and vesicular basalts and andesites, tuffs, agglomerates, porphyritic dolerites, and epidosites; vesicle fillings of chert, calcite, quartz, epidote and zeolites are common in some areas, and steam holes up to three feet in diameter and lined with quartz, epidote, calcite, and other minerals are also present. Fragmental volcanics appear to be subordinate to lavas in most areas.

Certain flows of the Mornington Volcanics are indistinguishable from certain members of the Antrim Plateau Volcanics, although andesitic types are more common in the Mornington Volcanics than in the latter. The widespread association of epidote with the Mornington Volcanics as quartz-epidote dykes, epidotised lavas, vesicle fillings, and impregnations of interbedded sediments, contrasts with the virtual absence of macroscopic epidote in the Antrim Plateau Volcanics, and provides a possible distinguishing feature in areas where both could be present e.g. near Wyndham. Microscopically and chemically the two suites are similar, although Edwards (1940) has recognised differences in suites from each unit.

The unit has not been examined in detail, but is not thought to exceed 1,500 feet in total thickness; in places the unit thins to a thickness of a few hundred feet, and it may be absent in the section in the HJ11 Range north of Ivanhoe Station, and in the Saw Range.

The limited thickness of the volcanics, and their widespread occurrence, suggest their origin from a series of fissures; such fissures have been located on airphotos, but have not been checked by field observation (See Geological Map, Fissures coloured as for Hart Dolerite). A common origin between the ? fissure dykes and the Hart Dolerite seems to be indicated at first sight,but is not proven,and dolerite dykes and sills have also been observed in the beds overlying the Mornington Volcanics and in the Mt. House Beds.

In 1901 Gibb Maitland and C. Gibson spent some six months investigating the North Kimberley area, and while they published no detailed report on their findings, Maitland, in the Presidential Address to A.N.Z.A.A.S. in 1907 (also published as Misc. Rep. No. 7 G.S.W.A. Bull. 26 1907) commented as follows:

".... Our observations extended from Wyndham to Mt. Hart, near Collier Bay; the Prince Regent and Glenelg Rivers .... and as far as Admiralty Gulf. The results of our investigations indicated that the staple formation was made up of a series of quartzites, sandstones, fine conglomerates and shales disposed in a series of broad anticlinal folds. These beds extend as one continuous formation from Mt. Cockburn to Mt. Hart, a prominent summit of the King Leopold Range. Associated with the quartzites etc., are a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase. The individual characters of the different beds naturally present a large amount of variation; the rocks are sometimes amygdaloidal and contain nodules of zeolites and agates. Beds of volcanic ash and breccia are common in certain localities.

In certain isolated portions of the district excellent sections are exposed showing the intrusive nature of some of the igneous rock; the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of the igneous rock. Other sections show quite clearly that the igneous rocks have, in some cases, found an easy passage along the bedding planes of the sedimentary rocks and evidently occur in the form of sills.

The lavas are traversed by almost vertical dykes of epidosite which are traceable across country for long distances, whilst both the sedimentary and igneous rocks are intersected by numerous segregation veins of quartz, some of considerable size and horizontal extent."

There seems little doubt that Maitland's observations indicate a widespread occurrence of sills and dykes; unfortunately the lack of detailed locality references prevents most of his observations being correlated with more recent work. In a later paper (Presidential address to Royal Soc. W.A. July, 1916) Maitland records some detailed locality references:

"At Mount Hann ........the volcanic rocks can be well seen. The cliffs formed by the faces of the lavas and ashes rise perpendicularly from 100 to 300 feet in height.

....... In the vicinity of Synnot Creek is a very coarse volcanic breccia which covers a very wide area and is associated with lava flows; as a rule the ashy beds are much finer in grain and in this particular instance it seems clear that the coarse agglomerate occupies the throat of one of the volcanic vents which has not yet entirely disappeared by denudation; it is still surrounded by lava flows and fine-grained ashy beds".

The extent to which the author has checked the distribution of the Volcanics (as determined from airphotos) may be gauged by reference to the plan showing main access routes used during field investigations.

In the Durack Range area the Volcanics are much thinner than to the west, and may in places lens out entirely. Volcanics are present in the two sections examined by the author, the first along the Elgie Cliffs H.S. - Tableland H.S. track near Teroni's Gorge, and the second some 12 miles to the north; at the latter locality the volcanics are poorly exposed in the floor of Teroni's Valley, and do not appear to exceed several hundred feet in thickness. To the north of this again, (at about Lat. 15°57' Long. 128°3'), Blatchford (1927) records a volcanic bed interbedded in quartzites some two miles south of Fish Pool, which is in the horizon of the Mornington Volcanics as interpreted from airphotos. No field chekes have been made on the horizon of the unit to the east of 128°3', and it is possible that in this area the volcanics are thin or absent, although the horizon is still traceable on airphotos (possibly due to shales).

On portion of the Mt. Ramsay 4 Mile Sheet not mapped by the author, Hardman (1885) mentions amygdaloidal basalt from near J18 which may be correlated with the Mornington Volcanics, but from his description appears to be intrusive and possibly part of the Hart Dolerite.

In the Mornington, Mt. House, South Precipice Range, Mt. Barnett, and some other localities, the Volcanics include interbedded shales, siltstones, cherts, and quartzites; it is probable that many of the volcanics were deposited below the sea or that relatively shallow lakes or seas were present from time to time on some portions of the extruded lava surface. The land mass from which these sediments were derived may have consisted of Lower Proterozoic rocks, or alternatively, and implying an unconformity between the Volcanics and the King Leopold Sandstone as postulated by Guppy et al., of sediments of the King Leopold Sandstone; the detailed distribution of these intercalated sediments is as yet not sufficiently known to lend support to either of these alternatives.

An isolated area of Mornington Volcanics which includes intercalated sediments occurs in the Wesley Range north of Mt. Nyulasy in the section underlying the Pompey's Pillar iron ore deposit.

The Mornington Volcanics have many features in common with the tholeiitic or plateau basalts, but some flows tend to be more andesitic in composition; their petrology has been described by Edwards (1940). The widespread occurrence of epidote, occasional occurrence of glaucophane, the saussuratisation of felspars, and other evidences of alteration of the unstable primary basaltic minerals suggests that some of the more susceptible flows have reacted to low grade regional metamorphism or possibly to autopneumatolysis.

In the Drysdale-Gibb River area, and elsewhere, the Volcanics have been extensively lateritised, and are now partly screened by superficial cappings of laterite and laterite gravels. Red and black soils, sometimes with abundant residual ilmenite and magnetite (or hematite after magnetite) are commonly found in the more weathered sections; one such area lies on the King Edward branch track from Gibb River to Kalumburu, and occurs a few miles north of the Drysdale River Crossing.

The Volcanics contain large quartz and quartz-epidote veins, and in some areas copper minerals, barytes, and quartz-hematite and quartz-magnetite veins are also present; no large deposits of minerals are known, but various occurrences of economic minerals are described in Part III.

Warton Sandstone.

Guppy et al. (1958) used the term "Warton Beds" to describe the strata conformably overlying the Mornington Volcanics and unconformably underlying the Walsh Tillite and Mt. House Beds. Their description of the Warton Beds is as follows: "outcrops of the Warton Beds are typically developed in the Warton Range, 30 miles east of Mt. Clifton (Lat. 17°24' Long. 126°27') and the large area to the north along the Hann River, east toward Tableland Station, and the Precipice Ranges. The unit has a similar pattern on aerial photographs to the King Leopold Beds. Outcrops examined contained white to light brown well bedded medium grained to fine conglomeratic quartzite, red micaceous sandstone, and shale".

The author has subdivided the "Warton Beds" into three units, and in conformity with the Code of Stratigraphic Nomenclature, proposes the term "Warton Sandstone" for the basal of these three units; this formation occupies the greater portion of the outcrops incorporated in the original "Warton Beds", but excludes the red shale and overlying quartzites and sandstones. The Warton Sandstone is therefore defined as the unit which conformably overlies the Mornington Volcanics and is overlain conformably by the Elgee Shale. The unit outcrops in the Warton Range (Lat. 17°24' Long. 126°27'), and has been traced semi-continuously east and north into the Durack Ranges, and north and west into the Barnett, Gibb, and Carson Scarp Ranges, thence along the north coast between Long. 127° and southeast to Thurburn Bluff; the formation also occurs in the Hill Range north of Ivanhoe Station, in Menuairs Paddock south of Mt. Edith, and in the Precipice Range, and may occur in the Osmond Range and other areas of undifferentiated Lower Adelaidean rocks.

The unit attains a thickness of the order of 1,000 feet, and consists of a thin shaly (sometimes micaceous) base overlain by massive quartzite and sandstone; the quartzite and sandstone are frequently cross-bedded, usually white but sometimes purple or ferruginous, and in many areas slightly conglomeratic especially in the upper section. Where flat lying or gently dipping the formation shows an intersecting master-joint pattern on airphotos, which is similar to that shown by the King Leopold Sandstone. Due to differential erosion the formation characteristically occurs as a scarp and dipslope between the easily eroded Mornington Volcanics and Elgee Shale.

In the Synnott and Harding Ranges, in the Yampi area, in the Camden Sound area, and in the vicinity of Admiralty Gulf, the Elgee Shale has not been identified, and the quartzite unit which overlies the Mornington Volcanics and underlies the Yampi Beds, has been named the "Harding Sandstone"; the main portion of this unit is identical to the Warton Sandstone, but the Harding Sandstone may contain some horizons higher in the sequence than the base of the Elgee Shale.

Quartz veins, but no economic minerals, are known in the formation.

## Elgee Shale.

The Elgee Shale is here defined as the formation which conformably overlies the Warton Sandstone and is conformably overlain by the Pentecost Sandstone; it consists dominantly of cherry red, red-brown, and green shale, and is typically developed in the Elgee Cliffs which form the west wall of the Chamberlain River Valley between Lat. 17°15' Long. 127°15' and Lat. 16°00' Long. 127°52'. The unit has been traced continuously over approximately the same area as the Warton Sandstone, and is typically seen in the East Warton Range, Siddons Valley, upper Chapman River valley, the Seppelt, Campbell, and Maitland Ranges, Menuairs Paddock, and in the Buttons Gap area of the HJ11 Range. Outcrops may occur in the Osmond Range and elsewhere.

The dominant rock type of the Elgee Shale (in outcrop) is a red-brown to cherry red crumbling shale, which frequently contains blue-green bands and/or isolated blue-green "spheres" of presumably lower oxidation state. The red shales are invariably too crumbly to permit specimens of larger than walnut size to be taken; in places they are micaceous, and in some areas they give the appearance of being tuffaceous although no recognisable volcanic material has been found. The shales are typically interbedded with thin quartzite, sandstone, or siltstone bands a few inches in thickness, which contain cross-bedding, ripplemarks, abundant casts of mud pellets, mud cracks, and various markings of unknown origin which sometimes resemble worm burrowings and tracks.

In some areas the unit contains thin interbedded limestone lenses which exhibit algal markings; such limestones occur in the headwaters region of the Chamberlain River on the Tableland - Elgie Cliffs H.S. track, in east Siddons Valley, and in the north-east Warton Range area.

The formation has been intruded by a dolerite dyke 20 miles northeast of Tableland Station, and the dyke has baked the shales at the contact and introduced small chalcocite veins. In the Siddons Creek - Chamberlain River headwaters region, and in the area to the south of Tableland Station, extensive outcrops of dolerite occur in the formation; these dolerites may be sills or interbedded flows, but probably represent minor revivals of the volcanic activity of Mornington age. Blatchford (1927) identified similar dolerites in the area to the north at about Lat. 16° Long. 128°02', and identified the occurrence as a sill:

"..... the series has been invaded by basic igneous rocks. One occurrence was observed some seven miles south of Fish Pool where red-banded shales, which are very friable, are overlain by a dense fine grained basic igneous rock. As these red shales could be seen extending for a considerable distance to the northwest, it is more than probable that the sill also has a wide extent. Under the microscope it is .......... made up of small lath shaped plagioclase and angular augite with some black oxide of iron. The slide shows a considerable staining by red oxide of iron. The rock is a somewhat ferruginous basalt."

Edwards, in Edwards and Clarke, has described a specimen from the occurrence reported by Blatchford, as an extremely fine grained aphanitic olivine-basalt, and has analysed the rock.

The characteristic and persistent appearance and lithological character of the Elgee Shale have rendered it an ideal marker formation; its typical topographic expression has enabled it to be traced readily on airphotos and by low level reconnaissance flights from areas of known outcrop.

In the Casuarina Creek area (Lat. 14°10' Long. 127°28') outliers of the shales have been altered extensively by lateritisation (where not covered by Pentecost Sandstone during recent times) and it is possible that much of the red colour of the shales is due to surface oxidation and/or enrichment in iron, and that unweathered shale would be blue-green in colour.

Due to cover by quartzite scree the full thickness of Elgee Shale is rarely exposed, but it does not appear to exceed 500 ft. in the areas examined; the junction with the Pentecost Sandstone is gradational, and the limits of each unit arbitrary.

Pentecost Sandstone.

This unit, with the underlying Elgee Shale and Warton Sandstone, comprise the "Warton Beds" of Guppy et al.

The Pentecost Sandstone is here defined as the unit which conformably overlies the Elgee Shale and is unconformably overlain by the Walsh Tillite and Mt. House Beds; it occurs typically in the Pentecost Range (Lat. 15°46' Long. 127°45'), and in the area drained by the Durack River and its tributaries, the Salmond River and its tributaries, the upper Berkeley River and its tributaries, and the middle Drysdale River. The formation consists of a succession of thinly bedded to massive quartzites, ferruginous quartzites, sandstones, ferruginous sandstones, and subordinate shales; the latter occur in at least two prominent and fairly persistent thin horizons. The strata are frequently cross-bedded and show ripple-markings, mud pellets, casts of mudcracks, and similar evidences of shallow water deposition; minor pebble conglomerates are present in the sequence.

In the Police Creek area the formation is overlain by the Walsh Tillite and Mount House Beds with an erosional unconformity; in the Cockburn Range area the unit appears to conformably underlie the green shales and sandstones of the Cockburn and Bastion Ranges which are correlated with the Mt. House Beds on lithological grounds. In the absence of an exposed unconformity it is possible that these shales etc. form the upper portion of the Pentecost Quartzite, but more probably that the deposition of the Mt. House Beds in this area was not preceeded by a marked period of erosion. In addition to the outcrops continuous with the type area, the formation is also known in the east Warton Range, the central Precipice Range, and in the Galileo Precipice - HJ11 Ranges; doubtful occurrences are thought to outcrop in the Osmond Range, and other areas of undifferentiated Lower Adelaidean, and the Pompey's Pillar iron ore deposits may occur in this formation.

Dolerite sills or flows, often with associated copper minerals, occur intercalated in the Pentecost Sandstone in the Karunjie area, and between Blackfellow Creek and the Chapman River on the Karunjie - Gibb River track. The dolerites are associated in many areas with disseminations and segregations of copper minerals and massive calcite crystals, and may be interbedded flows which represent sporadic and isolated recurrences of the volcanic activity of Mornington age; no age relationships have been observed, and the dolerites could also be sills of ? Cambrian age.

The Yampi Beds, in the Yampi - Camden Sound area, probably represent the equivalents there of the Pentecost Sandstone, but include extensive ferruginous beds not typically developed in the latter formation; this variation may be ascribed to differences in source area rocks, and possibly also to slight differences in depositional conditions as coarse conglomerates are common in the Yampi Beds and not in the Pentecost Sandstone.

The thickness of the Pentecost Sandstone as measured approximately from air-photos is over 2,500 feet.

Harding Sandstone.

The Harding Sandstone is here defined as the formation which conformably overlies the Mornington Volcanics and is conformably overlain by the Yampi Beds; it is typically developed in the Harding Range (from Lat. 16°3' Long. 124°30' to Lat. 16°18' Long. 125°00') and has been traced westwards onto the Yampi 4 mile sheet and northwards onto the Camden Sound 4 mile sheet. It consists of a basal section of shales, micaceous siltstone, and ferruginous sandstone, overlain by massive white and red quartzites which form the bulk of the unit. Some interbedded shale bands and dolerite sills are present in the massive quartzites in the Camden Sound - Doubtful Bay area. The beds show crossbedding and ripplemarking, and are apparently of shallow water origin; minor pebble conglomerates are also rarely present. In the Deception Bay area a red shale horizon near the top of the sequence contains numerous pseudomorphs of salt crystals; this horizon may be equivalent to the Elgee Shale. A beach conglomerate is also present in the sequence in this area.

This unit is identical with the Warton Sandstone at least in the basal portion, but may include some beds stratigraphically higher, since the Elgee Shale (the upper limit of the Warton Sandstone) has not as yet been identified in the Yampi Area.

The Harding Sandstone has been intensely folded in the western part of the Yampi 4 mile sheet; the outcrops of the unit indicated on the geological map to the south of The Graveyard have been identified by photo-interpretation alone, and may be suspect. It is possible that the white quartzites occurring on the southern portion of Koolan Island, and the northern portion of the mainland opposite, are outcrops of Harding Sandstone, but the overfolding and lack of continuous outcrop have prevented its definite identification by photo-interpretation and reconnaissance field mapping. In the synclinal structure at the south-eastern end of Slug Bay (124°00' Long. - Lat. 16°23') massive coarse conglomerate and thin bedded quartzites and shales are present in the section, being overlain by massive white quartzite.

The unit typically forms high cliff faces and dip slopes where flat lying, and jagged serrated strike ridges where more steeply dipping; a considerable amount of jointing and minor faulting is evident throughout the area of outcrop.

In the Doubtful Bay area the unit attains a thickness exceeding 700 feet, but no detailed measurements of thickness have been made here or elsewhere, and it is probable that the total thickness is well in excess of 1,000 feet.

Some barytes is present in a fault zone in these rocks in Doubtful Bay, and quartz veins are common, but no other mineralisation is known. The mineralisation is adjacent to a dolerite sill at the base of the formation.

Yampi Beds.

The Yampi Beds are here defined as the unit which overlies the Harding Sandstone in the vicinity of Collier Bay, probably conformably, and in the north western portion of the Yampi 4 mile sheet (Yampi 4 mile sheet Lat. 16° to 17° Long. 123° - 124° 30'). The upper limit of the Yampi Beds has been removed by erosion.

The basal part of the unit is exposed around the southern and eastern shores of Collier Bay and consists of ferruginous sandstones and quartzites containing plates of chert, thin lenses of limonite nodules, and thinly bedded shales and quartzites.

In the synclinal structure to the north of the Grave Yard the Beds have been overfolded and slightly metamorphosed, and the following rock types are present:- baked shales, silicified siltstones, schists, andalusite schists, blue quartzites, magnetite schists, and ferruginous quartzite; the three latter rock types may be comparable to the hematite bearing rocks on

Koolan and Cockatoo Islands. In Talbot Bay the following rock types are present: chlorite schists, siltstones, hematitic schist, blue quartzite, medium to thin bedded quartzites, hematite quartzites, hematite grits, hematite conglomerates, and thin beds of crystalline, granular, hard, and micaceous hematite.

On Koolan, Cockatoo and Irvine Islands the succession includes hematite quartzites, hematite conglomerates, and hematite schists and massive hematite, interbedded with schists, slates, and quartzites low in hematite; the schists include clay schist, mica schists, and chloritoid schists. On Cockatoo Island, Reid (1956) has by detailed mapping, divided the sequence into a large number of units of the rank of formations or members, and has estimated a thickness of predominantly ferruginous beds in excess of 2,000 feet.

The Yampi Beds exhibit cross-bedding, ripplemarking, graded bedding, mudcracks, and other phenomenon associated with shallow water deposition. The widespread occurrence of what is believed to be clastic hematite (formerly magnetite), the presence of conglomerates throughout the succession, and the shallow water nature of the deposition suggest that the sediments were derived from a land mass not far removed from their present area of outcrop; they appear to have been accumulated under specialised cyclic sedimentary conditions and are not known to occur elsewhere in the Kimberley area. The unit is probably the time-equivalent of the Pentecost Sandstone, but the latter has been derived from sediments or igneous rocks less rich in iron; the relatively minor occurrence of hematite in the Pompey's Pillar area in beds which may be correlated with the Pentecost Sandstone suggests that the iron rich succession at Yampi may have been repeated elsewhere in the area where suitable source beds and basins of accumulation occurred - the Pompey's Pillar deposit however contains only a minor amount of iron rich sediment compared with the total of over 2,000 feet of iron rich sediments in the Yampi area, and no comparable thickness of iron rich sediments is known in present outcrop areas.

The Yampi Beds, in the western portion of the Yampi 4 mile sheet have been intensely folded, and frequently exhibit overfolds, recumbent folds and other evidences of over-thrusting; pitches of folds are of the order of $10^{\circ}$ - $30^{\circ}$ E.S.E. and W.N.W.; the incompetent beds show considerable thickening at the crests and troughs of folds. The strata have been invaded by thick and persistent sills, laccoliths, and bosses of quartz felspar porphyry and diorite porphyry, and show some evidence of baking and thermal metamorphism at their contact with these intrusives; the beds were also subjected to mild regional metamorphism after their injection by the igneous rocks which occurred prior to the folding or at least contemporaneously with it.

The Yampi Beds (where intensely folded) were formerly correlated with the Halls Creek Metamorphics ("Mosquito Creek") by Finucane, Hills, and others, on the assumption that younger sediments could not display the intensity of folding present in the Yampi area; the fact that these beds are situated high in the "Nullagine" succession (of these writers) suggests that similar folding may be present in comparable rocks elsewhere in Western Australia which may have been incorrectly placed in the "Mosquito Creek Series" by a similar assumption.

The Yampi Beds contain the iron ore deposits of Yampi Sound which aggregate about 80,000,000 tons of high grade hematite ore; quartz veins, and quartz hematite veins, are common, but no other economic mineralisation is known. The igneous intrusives into the beds have introduced small copper lodes, axinite, tourmaline, and other minerals, which are however mainly confined to the igneous rocks.

The numerous coarse conglomerate bands in the sequence suggest that some may be tillites; no evidence has been found to support this, but the amount of detailed stratigraphic mapping so far carried out on the base of the formation is insufficient to define the upper limit of the time of commencement of deposition.

UNDIFFERENTIATED LOWER ADELAIDEAN.

Where insufficient work has been done to differentiate the formations present in the Lower Adelaidean of the Kimberley

Plateau, the succession has been mapped as "Undifferentiated Lower Adelaidean"; the correlation, in the absence of identified marker formations, has been made on the basis of lithology and stratigraphic position, and some of the strata included may also contain younger or older beds. The chief areas are described below:

Albert Edward Range - Osmond Range. (18°32' 127°45'; 17°10' 128°30')

These ranges are more or less continuous with one another, the long, narrow Albert Edward Range outcrops broadening to the north and forming the Osmond Range. The succession is, as far as is known, entirely sedimentary, and overlies the Halls Creek Metamorphics and Lamboo Complex with marked angular unconformity; in the J41 area it is overlain with marked erosional unconformity by the Walsh Tillite, but elsewhere the Walsh Tillite has not been positively identified and the overlying rocks are the Lower Cambrian Antrim Plateau Volcanics.

In the Albert Edward Range near Flora Valley a few hundred feet of shales are overlain by a thin band of limestone, a massive quartzite, and more limestone, which is in turn overlain by a large thickness of red and green shales. The upper part of this section may be equivalent to the Mt. House Beds, but no evidence has been found to support this, and the apparent continuity of the section with the Osmond Range section indicates a Lower Adelaidean age.

Near Turner Station, in the Dixon Range area, the continuation of the Flora Valley section was noted by Traves (1956) to consist of calcareous shales overlain by massive quartzitic sandstones, in turn overlain by limestones which dip under the Antrim Plateau Volcanics.

In the Osmond Range, Wade estimated a thickness of sediments totalling about 12,000 feet, of which possibly the upper 2,000 feet are correlated by the author with the Mt. House Beds (no details are available of Wade's detailed thicknesses and possibly the whole thickness is of Lower Adelaidean rocks). In the same general area, southwest of Texas Station, Traves (1956) records a succession of well-bedded sandstones which unconformably overlie the Halls Creek Metamorphics, and are in turn conformably overlain by 1,800 feet of strongly jointed sandstone which he correlates with the King Leopold Sandstone; while it is probable that both the well-bedded sandstones and the 1,800 feet of jointed sandstone are equivalent to the King Leopold Sandstone, the correlation is based on lithology and appearance on airphotos and cannot be accepted as definite. The Mornington Volcanics, and the Elgee Shale, two persistent and distinctive marker formations on the Kimberley Plateau, have not been identified in this area, although they may be present. Traves records that the 1,800 feet of jointed sandstone are overlain by about 1,200 feet of sandstone which he correlates with the Warton Beds, and by a further 1,700 feet of sandstone and 1,000 feet of shales, calcareous shales, thinly bedded dolomites, and thinly bedded friable red sandstones, presumably correlated with the Mt. House Beds. The presence of the Walsh Tillite in this succession (see geological map) was deduced by the author from photo-interpretation but has not been checked in the field; assuming that the Tillite is present, the upper 1,000 feet of Traves section is then assigned to the Walsh Tillite and Mt. House Beds, and the remainder (totalling some + 5,000 feet) to the Lower Adelaidean.

In the area northwest of J41 Trig Station, on the Ord River east of Texas Downs (Lat. 17°3' Long. 128°48'), erosion has exposed a "window" of Halls Creek Metamorphics, more or less surrounded by outcrops of Lower Adelaidean rocks; this "window" was apparently a domal area in the latter rocks since they dip away from it in all directions except where faulted. In the eastern edge of this "window" the Halls Creek Metamorphics are overlain with marked angular unconformity by fifty to a few hundred feet of coarse conglomerate, and cross-bedded quartzites and sandstones dipping easterly at a low to moderate angle; the conglomerate contains boulders of quartzite etc., which appear identical with quartzites of the Lower Adelaidean, as well as boulders of the Halls Creek Metamorphics, and this may indicate some intraformational erosion in this area in the Lower Adelaidean.

The quartzites and conglomerate are continuous in outcrop and identical in appearance to the nearby Osmond Range exposures; they are moderately jointed and outcrop as scarps above the softer Metamorphics.

The quartzite and conglomerates are overlain with marked erosional unconformity by a tillite resting on a grooved, polished, and striated pavement of the quartzites about a mile northwest of J41; the tillite contains facetted and striated boulders of quartzite, limestone, granite, and schist. The tillite, and associated sediments, is overlain by the Antrim Plateau Volcanics of Lower Cambrian age, and is correlated with the Walsh Tillite of Upper Adelaidean age. At this locality the Tillite overlies only about 50 feet of the Lower Adelaidean rocks, indicating that some 5,000 to 10,000 feet of sediments were removed between the cessation of deposition of the Lower Adelaidean, and the deposition of the tillite; the tillite is only slightly altered since deposition, and as it contains boulders of quartzite, and the underlying quartzites are polished and striated, it is indicated that the Lower Adelaidean rocks were hardened and metamorphosed prior to the deposition of the tillite.

<u>Wesley Range (Lat. 16°43' Long. 128°41')</u>

This Range is made up of a succession of quartzites, sandstones, volcanics, shales, and siltstones, and contains the Pompey's Pillar iron ore deposit; the Range is situated to the north of Mt. Nyulasy, deriving its name from Wesley Spring, and extends northerly to the Conglomerate Range area southeast of Denham Station. In the southern portion, near Wesley Spring, the base of the succession is made up of a massive jointed quartzite which overlies the Halls Creek Metamorphics with marked angular unconformity, and is overlain conformably by a succession of volcanics with interbedded shales and quartzites; the basal quartzite is correlated with the King Leopold Sandstone, and the volcanics with the Mornington Volcanics. The Volcanics are overlain conformably by quartzite, grey shales, and a massive sandstone, which in turn is overlain by a thin bed of hematite; the hematite bed is overlain by shales, massive and bedded quartzites, and siltstones. The succession totals over 4,000 feet in thickness; the correlation of the shales, quartzites, and siltstones above the Volcanics is in doubt, but the Warton Sandstone, Elgee Shale, and Pentecost Sandstone are probably all represented. The section is overlain unconformably by Antrim Plateau Volcanics and Ragged Range Conglomerate of Cambrian age.

In the continuation of the Wesley Range to the west and north of the major fault line shown on the geological map, the lower quartzite and volcanics are absent, and the massive sandstone and overlying hematite bed, rests on porphyry; the reason for the apparent absence of the lower part of the section in this area is obscure, and may be due to igneous activity, non deposition, or erosion soon after deposition. The section above the hematite bed is normal, and is overlain unconformably by Antrim Plateau Volcanics.

Similar beds constitute the isolated ranges of Mt. Pitt, and Mt. Evelyn.

<u>O'Donnell Range (Lat. 16°24' Long. 128°10')</u>

This Range, to the south, east, and northeast of Denham Station, consists of quartzites, shales, and conglomerates, with some ferruginous beds, overlying granitic rocks of the Lamboo Complex and later porphyry(?) sills. The quartzites etc. are moderately folded and faulting is also common; they form a more or less continuous belt branching off the main outcrop of the King Leopold Sandstone in the Durack Range, and it is probable that they are made up of the lower portion of this formation. A large erosion valley in these sediments in the area west of Denham Station, has been filled with Antrim Plateau Volcanics, and in places these volcanics mask the continuity of the outcrop.

Sparse uranium mineralisation has been found in the base of these beds south of Denham Station; the beds are traversed by numerous large and small quartz veins.

<u>The Carr Boyd Ranges (Lat. 16°25' Long. 128°30'), and the area to the east of the Ord River Dam Site (Lat. 15°58' Long. 128°43')</u>

These areas consist of gently to strongly folded interbedded shales, quartzites, and minor conglomerates, and of more altered sediments such as phyllite and schist. The folding is generally rather open and pitches are of the order of 10° - 20°, (the more deformed areas have not been seen in the field). The flat lying to gently folded portions are indistinguishable from the Lower Adelaidean rocks, although the succession cannot be correlated with any of the Lower Adelaidean formations; these rocks consist of grey, green and red shales and siltstones interbedded with white and red quartzites, and show ripple-marking, cross-bedding, mudcracks, and other shallow water features.

In the area to the south of the Ord Damsite, outcrops are somewhat discontinuous, but shaly beds, which appear to be the same sequence as that in the more gently folded and better outcropping areas to the west and south-west, are intruded by porphyritic granite. The shales are not markedly altered by the granite even immediately adjacent to the contact. At the dam site similar shaly beds are markedly ripple-marked and interbedded with quartzite, and have been buckled into small pitching overfolds.

To the east of the Dam site the beds are somewhat more metamorphosed and resemble Halls Creek Metamorphics.

The southern Carr Boyd Range area consists of a strongly outcropping section of shales and quartzites, with a lower western area of rolling hills of schists, shales, and quartzites - the latter resembling Halls Creek Metamorphics and the former, although steeply dipping and conformable in dip to the western section, the Lower Adelaidean. The beds are probably all intruded by granite, and may therefore be comparable with the Ord Dam Site occurrences.

It is possible that these beds are in part a facies variation, or the upper development of, the Halls Creek Metamorphics, and they certainly resemble the MacAdam Range Beds more than the Lower Adelaidean; Walpole has recently found evidence that the MacAdam Range Beds (his Chilling Creek Sandstone) are a portion of the Finniss River Group, and they are probably comparable in part to the Upper Halls Creek Metamorphics.

The author has found no definite age relations in this area, but is inclined to the view that both Lower Adelaidean and Lower Proterozoic rocks are present.

Cave Spring and Pincombe Ranges (Lat. 15°30' Long. 128°52')

The southern end of the Pincombe Range is composed of red and white sandstones dipping gently south-easterly, but to the north the beds become more steeply dipping and the lithology is listed by Matheson and Teichert as quartzites, shales, and phyllites.

These sediments, with those of the Cave Spring Range, appear to form the easterley continuation of the Lower Adelaidean exposed in the HJ44 Range in the vicinity of Buttons Gap to the north of Ivanhoe Station H.S. (Lat. 15°37' Long. 128°40').

Oscar Range (Lat. 17°48' Long. 125°10')

Outcrops of overfolded quartzite, sheared conglomerate, and shales occur in the Oscar Range associated with sheared granite; they are correlated with the King Leopold Sandstone, but may be one of the other Lower Adelaidean formations.

UPPER ADELAIDEAN.

Rocks of this age were first mapped in the Kimberley area by Guppy et al. (1958) who discovered beds of Walsh Tillite, and overlying Mt. House Beds, on the Lennard River 4 mile sheet, and recognised the probable correlation of the Walsh Tillite with the tillites of the Adelaide System. Although recent mapping has suggested that many of the "Nullagine Series" outcrop of (?) tillite near Nullagine are probably of Permian age, the "Nullagine Series" may in fact be equivalent to the Upper Adelaidean of the Kimberley area. The Upper Adelaidean of the Kimberley Plateau consists of two units, the Walsh Tillite, and the Mt. House Beds; east of the Plateau the Victoria River Group is probably also of this age.

Walsh Tillite.

The Walsh Tillite was first named by Guppy et al. (1958) from outcrops in the headwaters of Walsh Creek (Lat. 17°12' Long. 125°35'); from a study of outcrops, and from airphotos, other outcrops of the Tillite were identified near Glenroy Homestead, and on the Traine and Hann Rivers east of Mt. House. The formation unconformably overlies the Mornington Volcanics, Warton Sandstones, Elgee Shale, and Pentecost Sandstone and is conformably overlain by the Mt. House Beds; in the type area at Walsh Creek the unit consists of completely unsorted sediments ranging in grain size from silt to boulders up to 7 feet across, the bedding being absent or very crudely developed. The matrix consists of grey-green and red siltstone and unsorted sandstone, with erratics which are predominantly quartzite, together with a few igneous rocks; the boulders are commonly facetted and striated. The thickness of the formation varies, and Guppy et al. concluded from a study of airphotos that it occurs as lenses rather than as a continuous deposit over a wide area; they discovered no evidence of the age of the Tillite, and placed it tentatively in the Upper Proterozoic.

The writer has observed tillite over a considerable area in the headwaters of the Traine River, and of Police Creek, in the region east and north of the Phillips Range. In the Police Creek area erosion has exposed glaciated bedrock of Pentecost Sandstone over an area of some acres in the vicinity of Lat. 16°52' Long. 126°25'; the quartzites have been polished, grooved, plucked and striated, and are overlain to the east by a low scarp consisting of a thin bed of tillite capped by shales, shaly banded limestone, dolomite, and ferruginous sandstone and siltstone. Further south the tillite appears to overlie the Warton Sandstone and Mornington Volcanics. To the north the tillite persists as poor outcrops above soil covered plains, and can be traced north and then east and south into the valley of the Upper Traine River; the overlying limestones, sandstone etc. forms a low plateau between the Police Creek and Traine River Valleys, with tillite exposed around the base. In the vicinity of Knapp's Yard Creek (approx. Lat. 16°40' Long. 126°28') a poorly sorted boulder conglomerate with a sandy micaceous matrix outcrops over a considerable area, and is probably glacial or fluvioglacial in origin although its relation to other units is hidden by soil cover. The occurrence of granite, basic volcanic, and quartzite boulders at the base of Mt. Sadler (Lat. 16°45' Long. 126°32'), which consists of shales and limestones with some sandstone, suggests that the soil in this area overlies or is derived from tillite.

In the Bella Creek area, south south east of Gibb River Station (Lat. 16°30' Long. 126°30') eluvial remnants of boulders form a series of low ridges north and west of the line of the scarp of the Gibb-Barnett Range, and enable the Gibb Range to be ascended by vehicle with relative ease; these remnants are believed to be derived from outcrops of tillite and although no such outcrops were seen by the author they may occur in the creek gorges in this area.

Outcrops of tillite are also present in the lower Traine River area (Lat. 17°22' Long. 126°23'), and on the lower Hann River (Lat. 17°12' Long. 126°15').

The tillite, as exposed in the Police Creek and upper Traine River area, consists typically of unsorted material, being mainly quartzite boulders up to 4 feet in diameter randomly dispersed in a non stratified, poorly consolidated, red and light green fine grained matrix; boulders of basic volcanics and granite are rare but do occur. Near Dingo Rockhole (Lat. 16°46' Long. 126°28') the upper section of the tillite consists of a poorly stratified green matrix in which boulders depress bedding at their base in a manner suggesting that they dropped from floating ice. West of Dingo Rockhole the tillite contains fewer boulders and assumes a more shaly appearance; the deep red colour of the tillite in this area suggests its derivation from the Elgee Shale. At Dingo Rockhole (Lat. 16°46' Long. 126°28') the tillite is overlain by markedly colour-banded and fissile (sometimes calcareous) shales which may be varved.

The tillite in these areas has a similar pattern on airphotos, and is similar in appearance and stratigraphic position, to the Walsh Tillite, and they are undoubtedly contemporaneous. The thickness, where determinable, varies from twenty to forty feet, but probably exceeds this in parts of the Traine River Valley.

In the West Kimberley the Walsh Tillite is overlain by the shales, limestones, dolomites and sandstones of the Mt. House Beds; no fossils (except traces of algal growths) have been found in these strata, and as they are more indurated than known Palaeozoic formations, they are assigned an Upper Proterozoic age.

In the East Kimberley the distribution of tillite is somewhat more restricted; the only proven occurrence is near J41 Trig Station at Lat. 17°02' Long. 128°49', but other occurrences are suspected. In the J41 area tillite rests on a grooved, polished and striated pavement of Lower Adelaidean quartzites, and consists of boulders of quartzite, limestone, granite, and schist, often striated and facetted, randomly dispersed in a poorly stratified green matrix; the rock is completely unsorted and the boulders vary from pebble size to three feet in diameter. The tillite is overlain, apparently conformably, by a lenticular limestone, and this in turn is overlain and in places baked, by the basalts of the Antrim Plateau Volcanics; some miles to the east these Volcanics are overlain conformably by lower Middle Cambrian fossiliferous sediments, indicating a Lower Cambrian age for the Volcanics; in other areas the Volcanics overly the Upper Adelaidean with an erosional unconformity, and this appears to indicate a significant time break - suggesting an Upper Proterozoic age for the Upper Adelaidean including the basal tillite.

A continuation of the J41 Tillite to the north is indicated by the occurrence of boulders and eluvial remnants, but exposures are rare due to masking by debris. Tillite has also been identified on airphotos in the Osmond Range to the west, but has not been checked in the field (See Albert Edward Range - Osmond Range).

In the area north of Argyle Downs (Lat. 16°14' Long. 128°49') a valley containing eluvial remnants of rounded and poorly facetted boulders is overlain by ferruginous arkosic sandstones which dip under the Cambrian sediments of the Argyle Basin. At Mt. Brooking, on the southwest side, (Lat. 16°06' Long. 128°56') numerous boulders of granite, schist, quartzite, and limestone are apparently derived from the basal beds of the strata which form the northern continuation of the Argyle Downs sandstones; some of the boulders show poor facetting and striations, but no definite evidence of glacial origin was observed. The Mt. Brooking strata appear identical to strata which dip under the Antrim Plateau Volcanics to the east.

On the road between Newry and Anvergne Stations (in the vicinity of Lat. 16°02' Long. 129°15' and northeast) isolated to numerous large boulders occur on the sandy undulating country; some of these boulders appeared to be facetted and polished, and it is possible that a more detailed examination in this area would reveal outcrops of tillite.

The occurrence of granite, quartzite and siltstone boulders in creek float 15 miles from Limbunya on the Waterloo track (Lat. 17°07' Long. 129°37') suggests the possibility of a tillite lens in this area; a limited search by the author failed to reveal any outcrops which could have formed the source of these boulders, the outcropping rocks being red and green shales of the Victoria River Group (cf. Mt. House Beds). Granite outcrops are not known within eighty miles of this area.

The J41 tillite is correlated with the Walsh Tillite of the West Kimberley, as is the probable occurrence in the Osmond Range. The remainder of the ? tillites mentioned above are tentatively thought to be Walsh Tillite, but D.M. Traves (personal communication) has suggested that some may be isolated valley remnants of Permian conglomerate; the field relationship of most occurrences does not support this view.

The nature and distribution of the outcrops of the Walsh Tillite, and the comparative abundance of glaciated bed rock, indicate that glaciation was probably limited to topographic highs and was not in the form of a large icesheet extending over the entire area. It is also probable that areas of sea existed between the exposed land masses and that Mt. House Beds were deposited contemporaneously with the terrestrial tillites in some areas, and that a subsequent extensions of these seas caused marine sediments to overlap the tillites in other areas; the tillites were probably limited to certain shore and near shore areas, and would therefore not be expected to occur everywhere in association with the Mt. House Beds (and vice versa).

The Walsh Tillite, from evidence in the J41 area, is probably of late Upper Proterzoic age; the probability of any glaciation in the Kimberley area being matched by a more widespread glaciation in areas to the south suggests that the Walsh Tillite and Sturtian Series are contemperaneous. Recent mapping in areas to the southeast in the Northern Territory (Noakes 1957 and Mawson 1957) has proved that tillite occurs at an apparently similar horizon in the Alice Springs and Tobermory (Lat. 22° - 23° Long. 137° - 138°) areas, and provides scattered extensions north of the Sturtian Series of South Australia; while these occurrences are separated from the nearest Kimberley occurrence by some 500 miles, it is probable that further outcrops will be found in the intervening largely unmapped area.

Mount House Beds (Guppy et al.)

A sequence of well bedded green and red shale, siltstone, sandstone, limestone and dolomite overlies the Walsh Tillite conformably, or the Mornington Volcanics, Warton Sandstone, Elgee Shale, or Pentecost Sandstone unconformably. The type area is in the vicinity of Mount House (Lat. 17°08' Long. 125°44') where a good section is exposed. Some of the shales show indications of incipient metamorphism and are slightly indurated; no fossils have been found, although algal growths are often present in the carbonate beds, and this, together with the "older" appearance of the beds as compared to the nearest Palaeozoic outcrops, suggests a Precambrian or Lower Cambrian age.

No detailed thicknesses have been measured, but in the Mt. House area the beds exceed 1,000 feet in thickness.

In the upper Traine River - Police Creek area the basal Mt. House Beds consist of red shales, banded limestone and dolomite, and ferruginous silty sandstone, attaining a thickness of several hundred feet; the dolomite frequently carries small nodules of chalcocite and shows numerous dendrites, and these are thought to be of syngenetic (or biogenetic) origin.

In the Mt. House area the beds are intruded by dolerite sills and dykes.

On the basis of lithology and stratigraphic position the shales, sandstones and siltstones outcropping in the Bastion Range at Wyndham (Lat. 15°27' Long. 128°06'), the House Roof Hill area (Lat. 15°32' Long. 128°27'), and the Cockburn Range area (Lat. 15°50' Long. 128°00'), have been correlated by the author with the Mt. House Beds. Except for several possible areas seen only on airphotos, these beds appear to be conformable to the underlying Pentecost Sandstone, and no outcrops of Walsh Tillite have been found in the area.

Isolated remnants of probable Mt. House Beds also occur near Forrest River Mission (Lat. 15 10' Long. 127°52'), in the area twelve miles east of the Drysdale River on the Aston 4 mile sheet (Lat. 15°15' Long. 127°10'), and possibly in the Central Bluff Face Range (Lat. 26°20' Long. 127°30').

In the Cockburn Range the Mt. House Beds consist of a basal portion of about 1,000 feet of interbedded sandstone, siltstone, and shale, which sometimes contains nodules and lenses of black calcite which appear to be of algal origin; this is overlain by about 1,000 feet of green shale and siltstone, and this in turn is overlain by some 500 feet of jointed sandstone, siltstone, and shale which forms the cappings of the Cockburn Range.

The Bastion at Wyndham is made up of about 1,000 feet of green shale with thin sandstone laminae, capped by several hundred feet of sandstone, and a similar section is exposed in the House Roof and False House Roof Hills area.

In the Osmond Range (Lat. 17°04' Long. 128°20'), photo-interpretation has indicated the probable presence of Walsh Tillite, and this is overlain by at least 1,000 feet of shale, calcareous shale, red sandstone, and dolomite which is correlated with the Mt. House Beds. In the area near J41 (Lat. 17°02'

Long. 128°49'), the Walsh Tillite is overlain by about 20-50 feet of shale and limestone which is overlain by the Antrim Plateau Volcanics; this small thickness of Mt. House Beds may be due to limited deposition in this area, or may more probably be due to erosion prior to the deposition of the Volcanics.

The strata forming Mt. John in the Osmond Range have yielded a specimen of a (?) jelly fish similar to those found in the Pound Quartzite of the Flinders Ranges in South Australia by Sprigg; the author has not inspected this locality in the field but from photo-interpretation, and the lack of unconformity between these strata and the remainder of the Osmond Range sequence ( as evidenced by Wade and others who have examined the area), the author tentatively places the Mt. John strata in the Lower Adelaidean i.e. below the Walsh Tillite.

Certain shale beds in the vicinity of Flora Valley (Lat. 18°17' Long. 128°01') station, may be equivalent to the Mt. House Beds, but are tentatively correlated with the Lower Adelaidean.

In the Argyle (Lat. 16°14' Long. 128°49'), - Mt. Brooking (Lat. 16°06' Long. 128°56'), Newry (Lat. 16°02' Long. 129°15'), and Limbunya (Lat. 17°07' Long. 129°37') areas, a possible tillite is overlain by ferruginous arkosic sandstone, or by green, white, and red shales with interbedded limestone, dolomite, and sandstone; these beds form portion of the Victoria River Formation (Traves), and overlie the Lamboo Complex, Halls Creek Metamorphics, and Lower Adelaidean unconformably, and are overlain by the Antrim Plateau Volcanics with an erosional unconformity; the carbonate rocks of the Victoria River Formation contain traces of algal growths and some bioherms of Collenia. The Victoria River Formation is believed to be equivalent to the Mt. House Beds, but in the absence of definite identification of the (?) tillite, this cannot be regarded as definite.

The Mt. House Beds are not known to be mineralised by other than small quartz veinlets, and in most areas are only gently folded, steep dips being limited to monoclinal structures which may be caused by faulting in basement rocks. A small chrysotile asbestos deposit in limestone near J41 is believed to be due to the action of heat and vapours of the Antrim Plateau Volcanic flows on the basal limestone.

<u>Victoria River Formation</u> (Victoria River (Lat. 15°15' to 15°35') (Long. 129°40' to 131°)

Traves (1955) defined this formation as "the sub-horizontal sandstone, shale, dolomite, and limestone which crop out in the vicinity of the middle and lower tracts of the Victoria River...... the unit is extended to include similar sediments which outcrop further south and at Wave Hill Police Station...... The main area of outcrops of the unit extends from east of Port Keats and west of Willeroo in the north, to Wave Hill Police Station and Limbunya in the south. This includes the rough dissected plateau country between Victoria River Downs and Auvergne".

Recent work by the author, and by White and Walpole, has suggested that Traves included an older sequence in his "Victoria River Formation, for which the author has used the name "Macadam Range Beds". If this is confirmed by more detailed mapping, the sediments outcropping at the lowest portion of the Victoria River should be excluded from the definition. Further to the northeast the section, as defined by Traves, has been sub-divided by White and Walpole into the Chilling Sandstone and Tolmer Group. The discussion of Victoria River Formation below excludes the "Macadam Range Beds" which are treated under Lower Proterozoic.

In the Willeroo - Coolibah - Fitzmaurice River - Auvergne area, the basal beds exposed are limestones, cherts, shale, and sandstone, overlain by sandstones, shales, siltstones and calcareous siltstone as exposed at the vicinity of the Coolibah Crossing of the Victoria River. The basal section, between Jasper Gorge and Timber Creek, is given by Traves (1955) as:

Top 185 feet massive grey crystalline limestone.
340 feet massive to well-bedded limestone with chert nodules.
224 feet grey and pink limestone with thin bands of sandstone.
10 feet medium grained sandstone.
30 feet pink and grey limestone.
50 feet grey fine crystalline limestone.

The overlying siltstones etc., show abundant shallow water markings which include large mudcracks, ripplemarks, and interference ripplemarks.

In the vicinity of the Saddle between Newry and Auvergne Stations, a conglomeratic sandstone contains pebbles of limestone and chert which appear to be derived from these basal limestones and cherts.

Between Coolibah and the Fitzmaurice River the sequence includes the following:

| | | |
|---|---|---|
| Top | 200 ft. (+) | thin bedded limestones, dolomites and shaly beds, with sandstone, the limestones showing traces of algal structures. |
| | 200 ft. (+) | thin bedded to massive sandstone and quartzite showing cross-bedding and mud-pellet impressions. |
| | 600 ft. (+) | grey green shale with some siltstone sandstone and limestone. Limestone at base sometimes copper stained; secondary magnesite concretions associated with basal beds in a few areas. |

The above section forms the outcrops between the Angallari River and the Fitzmaurice River, the shales usually being hidden under scree or soil cover; the entire section shows evidence of shallow water deposition and ripple marks, mudcracks, and cross-bedding are features of the various beds.

| | |
|---|---|
| + 400 ft. | Green and red shales, siltstones, and rare limestone with some sandy beds sometimes ferruginous. |
| + 400 ft. | Ripplemarked sandstone and grit overlying shale and limestone. |

The above section is exposed at intervals between Coolibah and Angallari River.

The total thickness of the Victoria River Formation in this area probably exceeds 2,500 feet; the beds are generally flat lying to gently dipping, and the soil cover between scarps renders precise measurements impossible.

North west of Auvergne Station in the Pinkerton Range, the following section is exposed:-

| | | |
|---|---|---|
| Top + 200 ft. | | Limestones and sandstones (exposed in the Afghans Gap area) |
| | 150' | Quartzite and sandstone with mud pellet impressions and ripplemarks. |
| | 150' | Limestone. |
| | 50' | Sandstone, thin-bedded, with ripplemarks and mud pellet impressions. |
| | 600' | Mainly green shales, largely scree-covered. |

This section corresponds with that between the Angallari River and the Fitzmaurice River. Broad folds occur in the Victoria River Formation, e.g. the anticlines in the area 12 miles east of the Coolibah-Timber Creek road junction, on the Victoria River Downs track. Monoclinal structures are also common e.g. west of Newry H.S. Mineralisation is absent.

The Victoria River Formation resembles in lithology, degree of folding, and apparent stratigraphic position, the Mt. House Beds at Wyndham and Mt. House. The author has tentatively identified certain conglomerate bands at the base of the section at Mt. Brooking, and the Argyle Downs area, as being probable tillite of the Walsh Tillite; the author therefore regards the Mt. Brooking etc., strata as being probably comparable with the Mt. House Beds, and while this area is not continuous in outcrop with the main outcrops of the Victoria River Formation, the strata are sufficiently similar to be regarded as identical in spite of the screening of connecting outcrops by a few miles of Antrim Plateau Volcanics and alluvium.

Traves has found several biohermal Collenia reefs in the upper part of the succession, which by analogy with other parts of Northern Australia, may indicate an Upper Proterozoic age. The Victoria River Formation, in the Sullivan Creek area between Coolibah and Willeroo (Lat. 15°30' Long. 131°18') and elsewhere, is overlain with an erosional unconformity by the Antrim Plateau Volcanics; in the area between Limbunya and Waterloo quartzites interbedded in the base of the Volcanics suggest a continuation of sedimentation, although this area was not examined in detail.

It therefore appears that in most areas at least, an erosional (and time) break separates the Victoria River Formation from the Lower Cambrian Antrim Volcanics; this again suggests an Upper Proterozoic age for the sediments of the formation.

The relationship between the Victoria River Formation (as discussed above) and the strata outcropping in the lowest reaches of the Victoria River (Entrance Island to Holdfast Reach), the Fitzmaurice River downstream from Gregory's Bar, and in the Legune area, is obscure; where examined by the author soil cover invariably obscures the contact. This contact in some areas has the appearance of a monoclinal fold, but the generally less folded nature of the Victoria River Formation suggests that it is younger in age; this is also suggested by possible unconformities in the area about 14 miles north east of Newry, where a steeply dipping zone of rocks appears to be overlain unconformably by the flat lying Victoria River Formation, - however, when traced along the strike this resembles a monocline on airphotos.

White and Walpole, in areas to the northeast, have found that the continuation of the Entrance Island - Holfast Reach beds are in fact high in the section of the Lower Proterozoic, and has named the equivalent beds the Chilling Creek Sandstone; the beds would therefore be comparable (tentatively) with the Halls Creek Metamorphics, and much older than the Victoria River Formation. Further field work in the Legune area may confirm Walpole's findings. (See Lower Proterozoic - Macadam Range Beds).

<u>Hart Dolerite.</u>

This unit is of Adelaidean or Cambrian age, and some controversy exists as to its exact nature. Guppy et al. (1958) were of the opinion that the unit was extrusive in origin, and named it the "Hart Basalt"; the author is of the opinion that the unit is of an intrusive nature, and modifies this term to "Hart Dolerite".

As defined by Guppy et al. (1958) the unit is named for Mt. Hart (lat. 16°55' Long. 125°4'), and "..... the basalt crops out at Mt. Hart as well as in the valleys in the King Leopold and Lady Forrest Ranges. The formation consists of flows of basalt and dolerite which fill old valleys in the eroded older Precambrian rocks. It unconformably overlies the Lamboo Complex and King Leopold Beds.

The age is uncertain; it may be Lower Cambrian, similar in age to the volcanics, in east Kimberley, or it may be late Proterozoic and even associated with the same phase of volcanic activity which formed the Mornington Volcanics".

As shown by the author's mapping, this unit has a considerable linear extent, but its main width is limited to a narrow zone in the King Leopold Sandstone, adjacent to the unconformity with the Lower Proterozoic and the "mobile belts" of the West and East Kimberley. This outcrop pattern is not suggestive of basalt flows. The unit extends from just west of Secure Bay (Lat. 16°32' Long. 124°15') some 250 miles in a south-easterly direction to the Lansdowne and Mt. Ramsay 4 mile sheets (not differentiated on the Mt. Ramsay sheet, but undoubtedly present and equivalent in part to Matheson & Guppy's "basalt"), and thence in a north north easterly direction for some 220 miles of semi-continuous outcrop to just south west of Ivanhoe Station at Lat. 15°47' Long. 128°32'. The rocks of the unit generally weather more rapidly than the associated quartzites, and the unit occurs in valleys; actual contacts between the rocks of the unit and the sedimentary rocks are rare due to alluvium or scree cover, and the junction normally consists of a quartzite cliff with scree at the foot, and dolerite etc. exposed at intervals along the scree slope.

The following are the observed facts about this unit:-

(1) The igneous rocks present are fine to very coarse grained dolerite, fine grained gabbro, diorite, and medium, and fine-grained granitic rocks (mainly granophyre). In the area west of Secure Bay the unit probably includes the quartz-felspar porphyry and diorite of the Yampi-Graveyard-Pt. Usborne area, although no link has been mapped in the field.

The doleritic rocks form the dominant outcrops, but in some areas such as Inglis Gap, Yampi, and mainly in the East

Kimberley at Damper Creek, Lismma Valley, and Speewah, the granitic and coarse grained dioritic rocks are believed to form a significant proportion of the total rock mass, although they form poor outcrops. The dioritic and granitic rocks are intimately associated with the dolerite and appear to be differentiates of it. It is difficult to visualise the mode of origin of the coarse grained dioritic, and granitic, types by any means other than differentiation and/or contamination of the doleritic magma with sediments; it is improbable that such differentiation could take place in a valley filling basalt, and even more improbable that the resulting rocks would have the present outcrop pattern in relation to the dolerite and quartzites.

(2) Xenoliths of quartzite in dolerite and granophyre have been intensely altered around their margins; in some cases apparently intercalated quartzite has been altered and felspathised between two (probable) sills.

(3) The spatial distribution of the igneous rocks in a relatively narrow belt northeast and northwest of the unconformity with the Lower Proterozoic, with comparable bodies rare outside this narrow zone, does not favour the extrusive origin of the unit.

(4) The lack of stratification in the field, and the lack of volcanic features such as amygdales, columnar jointing, tuffaceous material etc., does not support a volcanic origin, especially when the only known volcanics (Mornington and Antrim Plateau) in the area often exhibit these features very well.

(5) In places the dolerite appears to have "rafted" quartzite "slabs" apart, and on airphotos the angular ends can be matched jigsaw fashion.

(6) On the Yampi sheet porphyry sills have undergone regional metamorphism; in the Duncan River area similar porphyry is observed to intrude dolerite of the Hart Dolerite. The dolerites of the Hart Dolerite have also probably undergone

some low grade regional metamorphism, although insufficient detailed work has been done on these rocks to be sure that this is not autopneumatolysis.

It follows that the Hart Dolerite is probably of Adelaidean age since metamorphism appears to be limited to Precambrian rocks. The relationship of the Walsh Tillite to the unit has not been observed, but may enable more exact dating of the unit.

(7) Various workers in the East Kimberley (Blatchford, 1927, Traves 1955, Hardman 1884) have assigned portions of the Hart Dolerite (as mapped by the author) to laccoliths, sills etc. intruding the Lower Adelaidean on field evidence.

These occurrences are those in the Yampi, the Speewah, the Bedford Downs and the Ivanhoe areas. Traves assigned part of the Dolerite to the Antrim Plateau Volcanics, but as this is semi-continuous in outcrop with his "intrusive" portion, it was probably done by photo-interpretation extended from the known Antrim Plateau Volcanics near Denham Station.

(8) The outcrop pattern of the Hart Dolerite is sometimes suggestive of valley filling. In the Denham area Antrim Plateau Volcanics definitely form valley fillings in the King Leopold Sandstone, and these volcanics outcrop adjacent to the Hart Dolerite as mapped by the author in the Lianma Valley area; the author was unable to delineate a definite boundary between the two formations in the field or on airphotos, but since such a boundary would be based on grain size of dolerites, this is scarcely surprising if overlap occurred; in a distance of half a mile from the (assumed) boundary no difficulty was experienced in recognising definite volcanics such as tuffs, agglomerates, and vesicular flows in the Antrim Plateau Volcanics, whereas such features are not known to the author in the Hart Dolerite over its length of over 450 miles.

The Denham area could be interpreted to mean that the Hart Dolerite acted as a feeder for the Antrim Plateau Volcanics, in which case no definite boundary would be present in some areas.

(9) The author has observed apparent stratification and trend lines on Hart Dolerite on airphotos of the Lansdowne 4 mile sheet; similar features could be exhibited by a sill showing "bedding" inherited from an intercalated thin sheet of sediments.

"Trend-lines" have also been observed on airphotos of the formation on the Lennard River 4 mile sheet; if taken as stratification these lines indicate fairly severe folding in the Dolerite - not a feature one would expect in a valley fill of post - major folding age.

(10) The author, together with P.J. Crohn, and I.W. Reid of the Broken Hill Pty., examined the type area of the unit with some attention to the origin of the unit; no evidence for valley-filling was seen which could not equally be taken as evidence of intrusive sills with connecting dykes, and many outcrops which were difficult to explain by valley filling - involving certain stages of erosion being constant over a wide area - were found to be easily explained by an intrusive origin. No conclusive junctions were however located, and the origin in this area was therefore indicated as intrusive on circumstantial evidence only.

(11) Definite intrusions of porphyry sills, and diorite sills and bosses, are known from the Yampi area, where the field relations and microscopic evidence leave no room for doubt.

These sills etc. occur higher in the Lower Adelaidean section than the bulk of the Hart Dolerite, but they are tentatively considered to be contemporaneous or possibly slightly younger.

(12) Possible and probable sills, and transgressive dykes, of dolerite occur at isolated localities throughout the Lower Adelaidean section; more rarely dolerite sills and dykes

are also found in the Mt. House Beds. A definite sill of dolerite was seen intruding the Harding Sandstone in Deception Bay (Lat. 15°42' Long. 124°25'). If these sills are taken to be contemporaneous with each other and the Hart Dolerite, as seems reasonable in view of the lack of evidence against (other than that quoted in (6) above), they would be of Late Upper Adelaidean age or younger, and therefore probably comagmatic with the Antrim Plateau Volcanics of the Lower Cambrian. This is supported by the occurrence of the Hart Dolerite and Antrim Plateau Volcanics in "continuous" outcrop in the Denham area, but no other areas are known in which definite volcanics (of Cambrian age) occur adjacent to the Hart Dolerite, in spite of the great length of outcrop.

(13) In the Mt. Ord area the Hart Dolerite appears to end abruptly against the Mornington Volcanics - this termination may be more apparent than real, but suggests a possibility of the Hart Dolerite and Mornington Volcanics being comagmatic.

They are similar in magma type, and are both characterised by relative abundance of epidote in some sections.

The Hart Dolerite is therefore tentatively regarded by the author as a series of sills, and intraformational sheets, linked by transgressive feeders, which intrude the King Leopold Sandstone; the total thickness of the sills may be of the order of 4-5,000 feet - and they include dolerite with subordinate differentiates (or contaminates) of diorite and granophyre type rocks. The unit may include porphyry and diorite sills on the Yampi Sheet, and the dolerites intruding the section as high as the Mt. House beds, although some or all of these may be younger in age.

The unit may have been the intrusive equivalent of the Mornington or Antrim Plateau Volcanics, and may include intrusives of two ages.

The Winnecke Granophyre (Traves 1955) of the Southern part of the Northern Territory map section, is an isolated occurrence of an intrusive which may be equivalent to the Hart Dolerite.

Note on Age of Dolerites etc. in Area.

Basic rocks are intrusive into the following formations in the area:-

1. Lamboo Complex and Halls Ck. Metamorphics.
2. King Leopold Sandstone.
3. Elgee Shale, Pentecost Sandstone, Harding Sandstone, Yampi Beds.
4. Mt. House Beds.
5. Carboniferous Beds in Fraser River No. 1 Bore.
6. Possibly into Blina Shale and Erskine Sandstone. This latter is doubtful. Hardman (1884) records an outcrop of dolerite on the May River near Yarrada Hill; this area is mapped as Triassic by the B.M.R. It appears likely that the dolerite would be intrusive, and not a bed rock high, but the field relations are not mentioned by Hardman. The occurrence may tie in with the intrusive mentioned in 5. above.
7. Leucitite rocks are intrusive into the Lamboo Complex and the Triassic and older rocks of the West Kimberley.

Volcanics are known in the rocks of the following ages:-

1. Lower Proterozoic (Halls Creek Metamorphics).
2. Lower Adelaidean (King Leopold Sandstone, Mornington Volcanics and possibly Pentecost Sandstone).
3. Lower Cambrian (Antrim Plateau Volcanics of East Kimberley only).
4. Permian (Weaber Group, East Kimberley) - trachytes.
5. Post Triassic (Leucitite volcanics of West Kimberley).
6. Cretaceous: traces of volcanic material have been found in the Cretaceous of Dampierland (Brunschweiler).

It is evident that at least six, possibly seven, periods of major and minor volcanic activity have occurred, the last two in the Permian and post Triassic (the latter however not doleritic). It is equally evident that all of these volcanic periods must have left dykes and possibly sills in the underlying older rocks. Therefore, although one is tempted to correlate the various intrusive and extrusive phases as shown below, much detailed work is necessary before such a correlation can be substantiated.

| Intrusive | Extrusive equiv. ? | Age. |
|---|---|---|
| Not known (possibly some amphibolites of Lamboo Complex if portions of the latter prove to be Archean). | Acid and basic interbedded volcanics. | Lower Proterozoic |
| Basic and intermediate intrusives of Lower Proterozoic rocks in part. | Thin volcanics in basal section of King Leopold Sandstone near Durack Range (East Kimberley) | Lower Adelaidean |
| Hart Dolerite. Main Body. Fissure dykes of North Kimberley King Leopold Sandstone ? Dolerites of Lamboo Complex and Halls Creek Metamorphics (in part). | Mornington Volcanics. | Lower Adelaidean. |
| Dolerite, diorite and porphyry sills and dykes of Yampi area, also those penetrating the Harding Sandstone, Elgee Shale, and possibly Pentecost Sandstone. | ? Doubtful flows of Karungie area interbedded in Pentecost S.S. (these could also be sills) OR Antrim Plateau Volcanics. | Lower Adelaidean OR Lower Cambrian. |
| Dolerite dykes and sills of Mt. House area, penetrating Upper Adelaidean (Possibly Hart Dolerite Main Body) | Antrim Plateau Volcanics (No intrusives however known to occur adjacent to known flows). (No extrusives of Cambrian age known adjacent to West Kimberley portion of Hart Dolerite). | Lower Cambrian. |
| Trachyte of Weaber Form. East Kimberley. | Trachyte flows. | Post Permian. |
| Diorite in Fraser River No. 1 Bore. | Not known. | Post Carboniferous. |
| Dolerite at May River (Hardman) | ? Cretaceous of Dampier Lands. | ? Cretaceous |
| Leucitites of Fitzroy Valley | Leucitite flow rocks of Fitzroy Valley. | ? Tertiary |

## 3. PALAEOZOIC AND YOUNGER. - EAST KIMBERLEY AND NORTHERN TERRITORY.

### CAMBRIAN.

While no rocks of Cambrian age are known from the West Kimberley (with the possible exception of the Hart Dolerite), rocks of this age outcrop over large areas in the Northern Territory and adjacent portions of the East Kimberley. In these areas widespread out-pourings of plateau basalt and volcanics in the Lower Cambrian were followed by marine transgressions in the Lower Middle Cambrian and Upper Cambrian in which fossiliferous sediments were deposited. The following units have been recognised:

### Antrim Plateau Volcanics.

This unit takes its name from the dissected volcanic country south of the Hardman Basin, which is named the Antrim Plateau; the unit was originally named by David (1952) as the "Antrim Plateau Basalts" but has been modified to "Antrim Plateau Volcanics" by Traves (1955) because the unit includes tuffs and agglomerates.

The unit is almost continuous in outcrop from the Antrim Plateau (Lat. 18°10' Long. 128°15') to Dingo Creek (Lat. 15°55' Long. 129°5') and encloses and underlies the Hardman, Rosewood, and Argyle Basins. The volcanics outcropping southeast of Mt. Connection (Lat. 15°15' Long. 128°25') in the Carlton Basin are probably of this age, and outcrops are also found fringing the Burt Range Basin.

The unit is extended by Traves to cover the large belt of volcanics which outcrops from Hookers Creek, through Wave Hill, to Willeroo and farther north; this belt is separated from the Antrim Plateau belt by only a few miles of Proterozoic rocks from which the volcanics have been eroded. Isolated areas of volcanics are also included in the unit, notably those in the Keep River area, the Wyndham area, and in the Denham Station and Ragged Range area. Rattigan (1954) tentatively correlates the Hart Dolerite with the unit, but the author believes that the Hart Dolerite is predominately intrusive in nature, although it is possible that it may have acted as a feeder for the Antrim Plateau Volcanics.

The Antrim Plateau Volcanics are made up of numerous (about twelve are suspected in the Spring Creek - Ord River Station area) flows of fine to coarse grained basalt (and possibly andesite) with generally vesicular or amygdaloidal flow tops. Some tuffs and agglomerates occur intercalated in the flows; some of these agglomerates are persistent over a large area with a relatively constant thickness, and one such is believed to form the top horizon of the unit in the Rosewood-Lissadell - Spring Creek - Mistake Creek area, although this could also be a fragmental flow top - it consists of "boulders" and angular pieces of vesicular to massive fine-grained basalt, pieces (or crack fillings)of sandstone, and numerous vesicle and joint fillings of agate, chert, quartz crystal and calcite and zeolites, together with vesicle coatings and disseminations of blue and green chloritic minerals which generally colour the rock throughout and sometimes resemble disseminated copper carbonates.

The thickness of most flows is less than 100 feet. The thicker flows are doleritic in texture in their inner sections. In many flows the vesicles and steamholes, up to 3 feet in diameter, are filled with chert, quartz crystals, calcite, prehnite, and zeolites; some of the prehnite carries small wires and masses of native copper, and chalcopyrite and chalcocite are sometimes found in association with the chert and quartz crystal. Asphaltum (probably of secondary origin) occurs in the vesicles in several areas.

The basalts range from olivine basalt to quartz basalt, with possibly some andesitic types; only very limited petrological examination of the rocks has been carried out, and no systematic petrology has been done on the various flows.

Except on monoclinal type structures such as those at the Rosewood Limestone Wall, the Lissadell Limestone Walls, the Osmond Range area, and the Kelly Creek Anticline, the volcanics are flat-lying to gently dipping; in some areas drainage directions indicate the directions of gentle dip. The flat dips make estimates of thicknesses difficult, and estimates range from 660 feet by Jack to 4,000 feet by Mahony. The greatest thickness measured by Traves was 3,300 feet north of Turner Homestead, and he estimates the thickness at Wave Hill as about 1,000 feet, at Inverway as not much in excess of 260 feet, and at Hookers Creek as over 160 feet. In the Spring Creek - Mt. Behn area the author estimates a thickness of less than 1,000 feet, while that in the Byrnes Hill area may probably be of the order of 600 feet.

In the area south of Spring Creek, near J41 and northwest of the Ord River - Negri River junction, irregular masses of chert occur in the volcanics; the relationship of these cherts to the volcanics is not known, but they appear to be interbedded, and may represent marine sediments deposited in waters having a high content of silica derived from the volcanics. Alternatively, they may represent ridges of basement rocks which have been silicified, although they appear to occur too high in the section for this to be likely. Certain of these cherts appear to be concentrically layered, and may be of algal origin.

In general the basal flows appear to be more massive and finer grained, while the upper part of the section is characterised by vesicular and agglomeratic bands which are highly silicified and contain chloritic and other coloured minerals; in some areas the volcanics are predominately agglomeratic or vesicular.

In the area between Willeroo and Coolibah the Antrim Plateau Volcanics occupy deep erosional valleys in the Victoria River Formation. This is the only unconformable junction with the Upper Adelaidean known to the author, although the volcanics elsewhere overlie the Lower Adelaidean with marked erosional unconformity. In the J41 area the volcanics overlie the Mt. House Beds without an angular unconformity, although the small thickness (about twenty to fifty feet) of these beds in this area may indicate a considerable erosional break, and more detailed examination could reveal fossil valleys in the Mt. House Beds.

The underlying Lower and Upper Adelaidean beds have in many places been baked and silicified by the basalt flows, and the resulting rock has been utilised by the aboriginals as artifacts. Near J41 the basalt has metasomatised the limestone of the Mt. House Beds, producing chrysotile asbestos and in more intensely affected areas, calc silicate rock.

In the Limbunya-Waterloo area the author saw thin lenses of quartzite interbedded in the basalt, and these may indicate that in some areas the basalts were laid down under marine conditions, or that lakes occurred on the uneven basaltic surfaces; in view of the known erosional break between the Upper Adelaidean and the Antrim Plateau Volcanics in the Willeroo area, it is probable that a considerable time break occurred between the deposition of the Upper Adelaidean, and the initial outpouring of the volcanics; no sediments resulting from this erosional break have been recognised.

The Antrim Plateau Volcanics are overlain, apparently conformably, by the basal formation of the Negri Group, Headleys Limestone, or by the Montejinni Limestone; the latter contains abundant girvalellids, while the former is overlain by fossiliferous Lower Middle Cambrian sediments, the first known fossils occurring about 700 feet above the formation. The contact between the Antrim Plateau Volcanics and Headleys Limestone has been examined in many places; at the Rosewood Wall, where the two formations are steeply dipping, the Volcanics are overlain by a few feet of sandstone, and then by massive limestone, apparently conformably; in the lower reaches of Spring Creek, the top horizon of the volcanics, an agglomerate or fragmental flow top, is overlain conformably by a few feet of sandstone and this in turn by limestone, both the sandstone and limestone containing "bombs" of volcanic material which in one case appears to have recrystallised the enclosing limestone (this may be due to subsequent strain during compaction rather than to thermal activity); in other areas the limestone rests directly on the volcanics.

In no case has an erosional break between the Antrim Plateau Volcanics and the Negri Group been proven, and it is therefore assumed that no great time interval separated the two units.

Since the Antrim Plateau Volcanics overlie the Upper Adelaidean with an erosional unconformity, and conformably underlie Lower Middle Cambrian (or Upper Lower Cambrian) sediments, they are probably of Upper Lower Cambrian age.

Negri Group.

The term "Negri Series" was first used by Mahony, and was later used by Matheson and Teichert (1948); Traves (1955) modified the term to "Negri Group" to comply with the Australian Code of Stratigraphical Nomenclature, and extended the unit to include the lower formation of Matheson and Teicherts "Mt. Elder Series". The formations which form this unit (in ascending order) are: (Traves 1955) Headleys Limestone, Nelson Shale, Linnekar Limestone, Panton Shale, Shady Camp Limestone, Negri River Shale, Corby Limestone, and Hudson Shale. Portions of the Group are developed in three main areas - the Hardman, Rosewood, and Argyle Basins, - and in four additional minor areas.

The Hardman Basin contains the best development, and in this area the group is split into eight formations which can be readily identified in the other areas when present; the greater part of the Group consists of shale, but the limestones being harder, are more prominent in outcrop, and form useful marker beds.

Headleys Limestone.

This limestone overlies the Antrim Plateau Volcanics conformably and is overlain conformably by the Nelson Shale; the type locality is at Headleys Knob (Lat. 17°28'30" Long. 129°1'30"). The typical section of the formation is about 60 feet of thickly bedded grey crystalline limestone with abundant tuberous bodies of chert along the bedding planes, overlain by 50 to 60 feet of thinly bedded grey crystalline limestone; the chert nodules decrease in abundance from the base, and are not present in the thinly bedded limestone.

The formation is very resistant to weathering and in many places forms cappings on the Antrim Plateau Volcanics; where steeply dipping at the edges of basins the limestone forms prominent walls e.g. the Rosewood Limestone wall, the Lissadell (Mt. Pitt area) Limestone wall, and along the east limb of the Kelly Creek Anticline in the Hardman Basin.

The basal 20 feet of the formation sometimes contains lenses and disseminations of chalcocite and copper carbonates, which may be of secondary origin.

In several places (The Rosewood Wall, and near the lower reaches of Spring Creek), the limestone is underlain by 2-5 feet of sandstone which lies above the Volcanics; this sandstone sometimes contains volcanic fragments of "bombs", and in one locality a few agglomerate bombs were observed in the base of the limestone, suggesting that some minor explosive type volcanic activity was still present in some areas.

No fossils have been found in the formation but an uppermost Lower Cambrian or basal Middle Cambrian age is probable from its position in the sequence.

Nelson Shale.

The formation name of Nelson Shale is given to the lowest shale unit in the Negri Group; poor outcrops of this shale occur in the vicinity of Nelson Springs, and Nelson Yard, and exposures occur in the middle and upper tracts of Nelson Creek (vicinity of Lat. 17°25' Long. 129°19').

North of Blackfellow Rockhole on a tributary of Headleys Creek, the Nelson Shale lies conformably between Headleys Limestone and Linnekar Limestone; the dips range from 60° to 45°, and the thickness is estimated by Traves as 570 feet. The Okes Durack Bore encountered an apparent thickness of 590 feet of Nelson Shale, and Matheson and Teichert quote the thickness south of the Ord River-Negri River junction as 525 feet, and that northwest of Mt. Napier as 240 feet.

The shales are frequently gypsiferous and leaching has produced large gypsum plates on surfaces formed from the upper portion of the sequence.

No fossils have been found in the formation, but as it is conformably overlain by the fossiliferous Linnekar Limestone its age is given as Lower Middle Cambrian.

Linnekar Limestone.

This limestone forms the second limestone unit of the Negri Group; highly fossiliferous beds of this formation outcrop in the banks of Linnekar Creek at its junction with Brooks Creek

(Lat. 17°34' Long. 128°44'). The typical section is 5 - 10 feet of bedded grey to brown crystalline limestone with abundant chert nodules, overlain by 50-60 feet of thinly bedded grey limestone with intercalated thin shale beds. The upper portion contains abundant trilobites, pteropods, and girvanellids. Linnekar Limestone outcrops in the vicinity of the Okes-Durack Bore site, and the bore log reveals that 59 feet of this formation were penetrated; the sequence included flaggy blue limestone with Girvanella, blue calcareous shale, with some hard limestone, and some pyrite.

Fossils found in the formation are the trilobite Redlichia forresti, Biconulites hardmani, and Girvanella.

Teichert (1948) includes this assemblage in the Redlichia zone which he placed in the Lower Cambrian Epoch; Opik places this sequence in the Lower Middle Cambrian Epoch.

<u>Panton Shale (Mt. Panton Lat. 17°24' Long. 129°15')</u>

This shale is the second shale unit of the Negri Group; it lies conformably between the Linnekar Limestone and the Shady Camp Limestone. The approximate thickness south of Shady Camp Yard is 200 feet; on the slopes of Mt. Panton about 120 feet of red and grey shale of this unit are exposed, overlain conformably by fossiliferous beds of Shady Camp Limestone.

The exposures of the unit are generally poor, and no fossils have been recorded from it.

<u>Shady Camp Limestone (Shady Camp Yard 17°21' Long. 129°8')</u>

This is the third limestone unit of the Negri Group, and conformably overlies the Panton Shale and is conformably overlain by the Negri River Shale. The unit consists of interbedded limestones and shales; over most of the Hardman Basin, the unit consists of 10-20 feet of grey crystalline limestone which contains girvanellids, and pteropods, but in the Mt. Panton area the formation includes 145 feet of highly fossiliferous limestone and shale.

The fossil assemblage found in the formation includes the trilobites Xystridura and Redlichia, the brachippods Wimanella sp.

and Billingsella, the pteropod Biconulites hardmani, and girvanellids. Teichert assigns the unit a Lower Cambrian age, and Opik assigns the unit a Lower Middle Cambrian age.

Negri River Shale (Negri River, Lat. 17°16', Long. 129°8')

This unit is the third shale unit of the Negri Group, lying unconformably between Shady Camp Limestone and Corby Limestone; the middle tract of the Negri River is incised in this formation for many miles.

The shale forms poor outcrops; Matheson and Teichert list the thickness as 70-235 feet thick.

No fossils have been found in this unit.

Corby Limestone (Corby Creek Lat. 17°21', Long. 129°9')

This is the fourth limestone unit of the Negri Group, and takes its name from Corby Creek, a small tributary of the Negri River which flows through limestone outcrops of this unit.

The unit is about 10 feet thick, and is crystalline grey limestone with small chert nodules.

The limestone forms a good marker horizon but appears to be unfossiliferous.

Hudson Shale (Hudson Creek Lat. 17°18', Long. 128°59')

This unit conformably overlies the Corby Limestone, and at the top there is a rapid transition to the arenaceous facies of the Elder Sandstone. The unit was formerly included by Matheson and Teichert in their "Mt. Elder Series"; the transition between shale and sandstone is complete in about 20 feet of section. The Hudson Shale consists of about 650 feet of red and grey shales; it is unfossiliferous, but is assigned a Middle Cambrian age by Traves.

The eight formations of the Negri Group have been named and mapped in the Hardman Basin. In the Rosewood Basin the equivalents of Headleys Limestone, Nelson Shale, and Linnekar Limestone are present; in the Argyle Basin the correlations are not clear.

In the slopes of the western scarp of the Ragged Range a maximum of 100 feet of shale and glauconitic limestone, with Biconulites and trilobite fragments, is probably equivalent to the upper portion of the Negri Group. In all exposed contacts the Negri Group overlies Antrim Plateau Volcanics, but in the Argyle Basin there is a possibility that the Group may in some sections overlie Precambrian.

Elder Sandstone.

The term "Mt. Elder Series" originally proposed by Mahony, was used by Matheson and Teichert (1948) for the shale and sandstone which overlie the Corby Limestone in the vicinity of Mt. Elder (Lat. 17°14' Long. 128°58'). Traves (1955) modified the name to Elder Sandstone to comply with the Australian Code of Stratigraphical Nomenclature, and included the lower shale unit in the Negri Group, thus making the Elder Sandstone an essentially arenaceous unit about 1,500 feet thick.

The Elder Sandstone conformably overlies the Negri Group (the junction being gradational over about 20 feet of section), the upper limit being removed by erosion; at and near White Mountain the Elder Sandstone is overlain unconformably by up to 370 feet of fossiliferous lacustrine Tertiary beds, the White Mountain Formation. In all observed contacts the Elder Sandstone, conformably overlies the Negri Group, but on the northwest side of the Hardman Basin it appears to overlap onto the Antrim Plateau Volcanics; this apparent overlap may be due to faulting or to a slight variation in the Elder transgression.

No fossils have been found in the formation and as it is continuous in sedimentation with the Negri Group, it is assumed to be of Upper Middle Cambrian age.

The formation crops out in three areas, the largest being in the Hardman Basin west of the Ord River where the sandstones form the Dixon Range, Mt. Buchanan, and Glass Hill; between the Ord River and Mistake Creek the extension of this belt includes Mt. Elder. The third area, the Hardman Range, is a faulted remnant trending southeast from Turner Homestead.

The lower part of the formation consists of fine grained sandstone with mud pellets and shallow water markings, overlain by brown micaceous shaly sandstone, and poorly cemented reddish cross-bedded sandstone.

In the Argyle area the poorly exposed sandstones and shales occurring in the centre of the Basin may be equivalent to the Elder Sandstone or may be a facies variant of part of the Negri Group.

Ragged Range Conglomerate.

This is the formation name for the conglomerate and sandstone which form the Ragged or Conglomerate Range (Lat. 16°22', Long. 128°24'); the formation overlies the uneven surface of the Antrim Plateau Volcanics, and conformably overlies shales and limestones of the Negri Group present in fossil valleys in the Volcanics. The shales of the Negri Group rapidly grade upward into siltstone and shaly fine-grained reddish sandstone with ripple marks and shallow water markings. In the western part of the Range there are three main beds of conglomerate up to 100 feet thick, each with interbedded sandstone; the conglomerate consists of well rounded pebbles and boulders, up to three feet in diameter, which are almost entirely quartzite although Traves records some granitic boulders. No signs of glacial abrasion were seen. At Conglomerate Bluff, in the central part of the Range, the conglomerate is about 600 feet thick and contains only minor lenses of sandstone. The conglomerate boulders form rounded hills, consisting of loose boulders with little soil, adjacent to the more prominent conglomerate outcrops.

The sandstones are red, and exhibit ripple marking and cross-bedding, and frequently contain pebbles and thicker lenses of conglomerate.

The formation appears to be a local development of the Elder Sandstone. Outcrops extend southwards of the Ragged Range to the vicinity of Flying Fox Gorge (Lat. 16°33', Long. 128°23') and the area to the south and east of this Gorge; the Gorge itself is in Precambrian Quartzite, and these quartzites have no doubt been the source area for the conglomerate in the vicinity.

The formation, in view of the lack of evidence of glacial action and the rounded nature of the boulders, appears to be a fanglomerate associated with local uplift of the Middle Cambrian surface.

Carlton Group (Carlton Homestead Lat. 15°29' Long. 128°33')

This unit was first named "Carlton Series" by Reeves (1948), who described a section northwest of Carlton Homestead which contains sediments of Middle and Upper Cambrian and possibly Lower Ordovician. More recent work by Traves and others has shown that the sediments are strongly strike-faulted, and that it is impossible to obtain a complete sequence without detailed work; the strike faults, marked only by small quartz veins and some slickensides, are hard to discern, but the displacement may be over 1,000 feet. From the outcrops examined it appears that there was continuous sedimentation from Middle Cambrian to Lower Ordovician. Noakes et al. (1952) used the term Carlton Formation for the Cambrian sequence and remarked that it was apparently conformably overlain by the Pander Greensand of Lower Ordovician age. Traves (1955) includes the Pander Greensand in the Carlton Group.

From remnants in the isolated fault blocks Traves has divided the Group into five units - Hart Spring Sandstone, Skewthorpe Formation, Pretlove Sandstone, Clark Sandstone, and Pander Greensand; the sequence is determined on fossil evidence and was proposed by A.A. Opik on field determination of fossils.

Hart Spring Sandstone.

This consists of the sandstone, with some impure limestone and shale, which outcrops in the vicinity of Hart Spring, on the western side of Onslow Hills (Lat. 15°19', Long. 128°26'). The formation is the oldest unit of the Calton Group, and at Hart Spring 500 feet of reddish fine grained sandstone are exposed. Further to the northwest the sandstone contains impure limestone bands. The fossils found in the formation are brachiopods, which probably belong to the genus Billingsella, and an undescribed

Hyolithes. The fossil assemblage, and the position of the formation under the more fossiliferous Skewthorpe Formation, indicates a Middle Cambrian age for the unit; it may have its equivalent in portion of the Elder Sandstone.

Skewthorpe Formation.

This unit outcrops at Skewthorpe Ridge (Lat. 15°25' Long. 128°37') where fossiliferous oolitic limestone and white friable sandstone occur. The unit contains limestone, shale, and sandstone, and is characterised by fossiliferous oolitic limestone, and conformably overlies the Hart Spring Sandstone about 3 miles north-east of Hart Spring; its relations to other units is not seen, and the complete sequence is unknown. The total thickness is estimated at more than 600 feet. The fossils so far identified include the following:

| | | | |
|---|---|---|---|
| Trilobites: | Solenopara sp. | Damesella sp. | Blackwelderia sp. |
| Brachiopods: | Acrotreta sp. | Obolus sp. | Lingulella sp. |

Opik considers that the assemblage indicates that the formation lies at the top of the Middle Cambrian; the formation is probably younger than any in the Hardman Basin.

Pretlove Sandstone.

This unit outcrops in the Pretlove Hills (Lat. 15°23' Long. 128°39'); the sequence is interrupted by numerous faults, but at least 400 feet (and probably a much greater thickness) of reddish well-bedded sandstone are exposed. Outcrops also occur north of Pander Ridge, and at this locality a low ridge of white to iron-stained sandstone contains abundant trilobites and brachiopods. The trilobites probably belong to the genus Crepicephalus, and indicate a lower Upper Cambrian age.

Clark Sandstone (Clark Jumpup Lat. 15°27' Long. 128°38')

This sandstone outcrops on the eastern side of the fault at Clark Jump-up on the Carlton-Legune track, where 430 feet of dark greenish to reddish glauconitic sandstone and friable red sandstone dip northeast; the base of this sequence is separated by a fault from red sandstone with mud pellets, and the top of the sequence is sand covered. The section is highly fossiliferous, and contains trilobites and brachiopods.

West of the type locality, and west of Ninbing Station, other outcrops occur which are correlated with the base of the type section, and with beds below the lowest horizon at the type section; fossils found include trilobites, brachiopods, and gastropods.

The fossil assemblage indicates a middle to upper Upper Cambrian age.

## ORDOVICIAN.

### Pander Greensand.

This formation outcrops at Pander Ridge (Lat. 15°28' Long. 128°41') and 10 miles and 11 miles northeast of Carlton Homestead. At the type locality the thickest section is exposed, and consists of 401 feet of glauconitic sandstone, and sandstone, containing trilobites and brachiopods; the relation of the formation to other formations is not known due to faulting and soil cover, but the total thickness is more than 550 feet.

The formation is the topmost known formation of the Carlton Group, and was probably the final sedimentation in the Lower Palaeozoic marine transgression in the Carlton Area. Fossils in the formation include conodonts, brachiopods and trilobites which indicate a Lower Ordovician age; it may be correlated with part of the Ordovician Prices Creek Group of the West Kimberley.

## DEVONIAN.

There is no evidence of sedimentation in the Boneaparte Gulf Basin between the Pander Greensand and the Cockatoo Sandstone of Upper Devonian age. The Devonian of the East Kimberley was first mapped by Matheson and Teichert (1948), who described two Upper Devonian units, the Cockatoo "Series" and the Burt Range "Series"; Traves subsequently modified the rank of these units to present day nomenclature, and also amended the contents slightly (Traves 1955).

Cockatoo Sandstone.

This unit consists of the soft crossbedded sandstone with pebble-beds which outcrop about five miles north of Cockatoo Spring (Lat. 15°54' Long. 128°57'). The formation is extended to cover similar sandstones between Mt. Hensman and Martins Gap and the Pincombe Range; underlying the Burt Range Limestone west of Ninbing, and an area further west towards Cambridge Gulf; two probable areas east of Dillon Springs east of the Denham Station - Wyndham Road.

Northwest of Cockatoo Spring the formation overlies Antrim Plateau Volcanics, and at Mt. Cecil it probably overlies a faulted inlier of Precambrian sandstone; the upper limit is generally sand covered but the unit is thought to merge into sediments of the Burt Range Limestone. Reeves (1948) estimates a maximum thickness of 3,000 feet for the unit.

Fossils found in the unit include the following (Traves 1955) -

| | |
|---|---|
| Lepidodendron australe | |
| Paleoncilo | |
| Modiomorpha | Modiella ? sp. |
| cf. Leptodesma | Leiopteria |
| cf. Allerisma | |
| Nucula ? sp. | |

Dickens (Traves 1955) noted that the closest affinities of the fauna are with forms of upper Middle Devonian age, but the fauna could be Middle to Upper Devonian in age. From the general stratigraphic sequence an Upper Devonian age is indicated.

Burt Range Limestone (Burt Range Lat. 15°45' Long. 128°53')

This unit consists of limestone with intercalated shale and sandstone which outcrops west of the Burt Range. The formation conformably overlies the Cockatoo Sandstone and is conformably overlain by the Enga Sandstone (the latter formerly being part of Matheson and Teicherts Burt Range "Series"), or by the Weaber Group.

The formation also outcrops in a long narrow strip from the coast, through Ninbing, and south to the Ord River at Buttons Crossing.

The limestone is highly fossiliferous and contains the following:-

Syringopora sp.
Productella sp.     Chonetes. Meristella
Athyris sp.     Spirifer Atrypa
Schuchertella

Gastropods: Bellerophon
Euomphalus
Straparolus
Platyschisma
Naticopsis
Ceraumochilis
Murchisonia
Trochonema
Eunema
Meekospira

South of Ninbing large masses of biohermal limestone occur, with fossiliferous biostromal limestone, dipping away from the bioherms; the biostromal limestones contain abundant crinoid stems, brachiopods, and stromatoporoids.

Matheson and Teichert estimate the thickness of the unit as 4,000 feet. The fossil content of the formation indicates an Upper Devonian age, and the top of the unit is thought to coincide with the end of the Devonian Period. Teichert correlates the unit with his Stages IV, V and VI of the Upper Devonian sediments of the West Kimberley.

CARBONIFEROUS.

Enga Sandstone (cf. Snowie Sandstone)

This sandstone unit outcrops in Enga Ridge (Lat. 15°45' Long. 128°57'), the western ridge of the Burt Range; it overlies the Burt Range Limestone, the junction being gradational. The formation is overlain by the Septimus Limestone, but the contact is obscured by sand cover. The complete sequence of Enga Sandstone is not known, but it is approximately 1,000 feet in thickness; the section is predominantly sandstone with some sandstone containing mud pellets. Poorly preserved fossils occur including the following (Dickens) -

? Cardiopsis ? sp.

Pelecypoda, Ballerophontidae, Pleurotomariidae

If Cardiopsis is actually present it indicates a Carboniferous age. The formation lies conformably between the Upper Devonian Burt Range Limestone and the Lower Carboniferous Septimus Limestone; it probably represents the first sedimentation in the Carboniferous Period rather than the close of the sedimentation in the Devonian Period.

Septimus Limestone.

This unit includes the limestone and calcareous sandstone which outcrop on the slopes of Mt. Septimus (Lat. 15°45' Long. 128°58') and in the central Burt Range. Small outcrops are also found near Milligans Lagoon; no outcrops are known in the Carlton Area. At Mt. Septimus the formation conformably overlies Enga Sandstone and unconformably underlies the Weaber Group, both contacts being obscured. A total thickness of 355 feet of Septimus Limestone was measured by W.C. Smith, this thickness including calcareous sandstone and limestone.

Opik has recognised more than 25 genera from the fossil collection made at Mt. Septimus; he lists the following:

Syringopora Michelinia
A solitary rugose coral
Crinoids Three genera of ostracods
Fenestroellina. Chaetetes. Trepostomata
Rhipidomella, Leptaena, Productus, Reteccularia
Athyris, Composita, Camarotoechia, Euomphalus
Orthonychia, fragments of trilobites.

The indicated age is slightly younger than the base of the Lower Carboniferous.

PERMIAN.

Weaber Group.

Reeves (1948) named the sandstone and sandy shale outcropping in the Weaber Range (Lat. 15°20' Long. 128°55') the "Weaber Range Series"; this was modified by Traves to "Weaber Group" to conform to the Australian Code of Stratigraphical Nomenclature. The Group sequence consists of three formations, Nigli Gap Sandstone, Spirit Hill Limestone, and Point Spring Sandstone; a fourth formation, the Flapper Hill Sandstone, also belongs to the Group but its position in the sequence is not clear.

Nigli Gap Sandstone (Traves 1955)

This unit outcrops in Nigli Gap (Lat. 15°44' Long. 129°06') about a mile south of the southeastern end of Policeman Waterhole on the Keep River, and sediments of this formation form most of the southern portion of the Burt Range. The sediments are essentially arenaceous and most of the formation is of sandstone with numerous rafted pebbles; the unit also includes conglomerate members throughout the sequence, although the most significant conglomerate member occurs at the base, and the marginal development of this member in the southwest, northeast of Cockatoo Springs, attains a thickness of 1,000 feet of unsorted conglomerate. The conglomerate is poorly sorted, with sub-rounded pebbles and boulders ranging up to two feet in diameter; it contains some lenses of grit and brown sandstone up to a foot thick. The poorly bedded, unsorted nature of the conglomerate suggests a glacial origin. The thickness of the formation depends on the development of the basal conglomerate which may reach a thickness of 1,000 feet; the remaining sediments have an estimated thickness of 800 feet. In all observed contacts the Nigli Gap Sandstone unconformably overlies rocks of Precambrian age, or is faulted against the Middle Palaeozoic sediments of the Burt Range Basin.

Associated with the rafted-pebble sandstone at the eastern end of Nigli Gap is an old volcanic vent of vesicular and scoriaceous trachyte; the vent was probably of the explosive type with little, if any, lava flow, and occurs on an old fault line. Four miles south of this vent on the same fault line another outcrop of vesicular trachyte intrudes the rafted-pebble sandstone; thin layers of trachyte a few feet in thickness have been found in the sediments to the north-east of Spirit Hill.

The sediments in the vicinity of the ochre mine (Lat. 15°18' Long. 129°16') consist of conglomerate and sandstone, and are tentatively correlated with this formation.

Specimens of Equisetales stems have been found in the rafted-pebble sandstone at Nigli Gap, and a plant stem was found at the ochre mine.

The unit is tentatively thought to overlie the Septimus Limestone with only a minor unconformity, and is overlain conformably by the Spirit Hill Limestone.

Spirit Hill Limestone.

This unit consists of the sandy limestone and calcareous sandstone which outcrop at Spirit Hill (Lat. 15°30' Long. 129°05'); other outcrops occur to the northeast of the type locality as far as Lat. 15°23' Long. 129°11' at Sandy Creek.

At the type locality 350 feet of well-bedded sediments of this formation contain abundant poorly preserved fossils.

The unit conformably overlies Nigli Gap Sandstone. The fossil assemblage includes the following (Traves, Opik).

Syringopora Euomphalus Straparolus
A single rugose coral. Abundant crinoid stems
Chonetes Dictyoclostus Gastropods
An indeterminable nautiloid cephalopod.

Flapper Hill Sandstone.

This unit was named by Opik (1950), and consists of the fossiliferous sandstone which outcrops in the isolated Flapper Hills (Lat. 15°10' Long. 129°23'). The formation consists of white to brown friable sandstone which has been silicified in places to give hard white quartzite. About 100 feet of the formation are exposed, but the outcrops are surrounded by soil and no relations between this unit and the other units of the Weaber Group are known. The following fossils have been identified:-

Chonetes Two species of Spirifer
Syringopora Productids
Cleiothyridina Orthotetinae
Rhipidomella

These fossils suggest a possible link with the Sandy Creek outcrops of Spirit Hill Limestone.

<u>Point Spring Sandstone</u> (Opik 1950)

This unit consists of sandstones which outcrop half a mile east of Point Spring in the Weaber Range (Lat. 15°24' Long. 128° 53'), and includes other sediments which form the main bulk of Reeves "Weaber Range Series". Reeves estimated that 500 to 800 feet of sandstones, thin shales, impure sandstone, ferruginous sandstone, pebble and boulder conglomerate and gritty limestones of this formation were exposed in the Weaber Range. The unit forms the top of the Weaber Group.

Opik lists the following fossils:

Lower beds: Dictyoclostus. A productid spirifers

Upper beds: Tracks and burrowings.
Cordarites-like leaves
Calamites stems (perhaps Phyllotheca)
Stigmaria.

It appears that the Weaber Group is very low in the Permian, and it is possible that sedimentation began in the Upper Carboniferous. The cycle of sedimentation which began in the Upper Devonian was completed in the Lower Carboniferous, and was followed by an orogeny in either the Middle or Upper Carboniferous; the later cycle of sedimentation may have begun in the Upper Carboniferous or Lower Permian, and sediments of this cycle have a different distribution from sediments of the earlier cycle. G.A. Thomas, from a preliminary examination of the fossils from the Weaber Group, is inclined to assign them to the Upper Carboniferous.

<u>Port Keats Group (Noakes 1949)</u>

The unit consists of a considerable thickness of both fresh-water and marine shales and sandstones with some thin limestone beds and narrow bands of coal. The best outcrops are found along the coast south of Point Blaze as far as Fossil Head. The best sequences of the Group are provided by the records of the bores for coal which were drilled by the South Australian Government in the early part of the century (Brown 1906-1908 and later quoted by Reeves 1948). One of these bores passed into granite at 720 feet, but two bores further from the margin of the basin were sunk to 1,500 feet without reaching basement.

Fossils found in these bores include Estheria (Etheridge 1907) (now "Isaura), which Teichert regards as either Permian or Mesozoic, while Brunnschweiler (1954) regards it as Triassic. At least 40 Permian fossils have been recorded from the Group by Etheridge (1907), Crockford (1943), Crespin (1947), and Teichert (in Reeves 1948), but the identifications are not of a systematic collection and the sequence cannot be correlated with others in W.A. Noakes et al. (1952) recognised a lower stage containing Glossopteris browniana and other plant fossils, which was correlated with the Poole sandstone of the Fitzroy Basin, and an upper marine stage which was correlated with the Noonkanbah Formation and lower part of the Liveringa Formation.

The Group appears to overlie Precambrian and is overlain by Jurassic and Cretaceous with possibly some Triassic.

JURASSIC & CRETACEOUS.

In the Port Keats - Collia-Willeroo area of the Northern Territory a thin sequence of flat-lying sediments, frequently masked by laterite, has been mapped by photo-interpretation; field work by Hossfeld (1937) and Traves (1955) and others has suggested that these sediments are the equivalents of the Mullaman Group (Noakes 1949).

In the upper headwaters of Sullivan Creek west of Willeroo H.S. (Lat. 15°19' Long. 131 35'), these sediments overlie the Antrim Plateau Volcanics; in the area south-south-east of Willeroo Traves examined a similar section in which the Volcanics were overlain by 21 feet of lateritised sandstone and lateritised conglomerate containing gravel with a maximum diameter of 1 inch; the gravel consists of quartz, rock crystal, quartzite, and chert. The conglomerate is overlain by a coarse ferruginous sandstone which contains poorly preserved plant stems. This section is overlain to the east by 40 feet of "porcellanite" which is of marine origin and yielded the following fossils (I. Crespin).

| | | |
|---|---|---|
| Radiolaria: | cf. | Cenosphaera |
| | | Dictyomitra |
| Foraminifera: | cf. | Haplophragmoides |

The marine fossils examined appear to indicate a Lower Cretaceous age, while the plant fossils appear to indicate an Upper Jurassic age.

Occurrences of similar type were seen by the author in the area southwest of Wombungee, in the headwater region of the Fitzmaurice River, but were not examined in detail.

## TERTIARY.

### White Mountain Formation.

Lacustrine sediments which unconformably overlie the Elder Sandstone in the vicinity of White Mountain (Lat. 17°15' Long. 128°58') were named the "White Mountain Series" by Matheson and Teichert (1948), and the name is revised to conform to the code of Stratigraphic Nomenclature. Matheson and Teichert list the following section for the formation from a ridge southeast of J40 Trig Station:

| | | |
|---|---|---|
| 5 | feet | chert with Planorbis hardmani |
| 10 | " | siltstone |
| 30 | " | chert |
| 55 | " | siltstone |
| 215 | " | marl |
| 55 | " | siltstone with basal chert layers. |
| 370 | feet | Total |

CHAPMAN (1937) has described fossils from the top chert layer, and identified the following:

Planorbis hardmani    Planorbis cf. essingtonensis
Bullinus sp.  algae, foraminifera, sponges, ostracods, and insect remains.

The sediments appear to have been deposited on an uneven surface of tilted Elder Sandstone, and have themselves been slightly tilted and buckled. The fossil content does not indicate a definite age, and although a Tertiary age is suggested, a Pleistocene age is also possible. It is possible that the unit was formed during lateritisation of the surrounding area.

Laterite.

Evidence of the former widespread lateritisation of the East Kimberley and Northern Territory is widespread, although in many areas only isolated residuals now remain; the present distribution of the laterites suggests that rocks of the Mullaman Group, Antrim Plateau Volcanics, and Victoria River Formation were especially favourable, while on the Kimberley Plateau the Mornington Volcanics, and Elgee Shale, were similarly favourable.

In many places lateritisation has progressed to the stage where the underlying rock type can no longer be deducted; thicknesses (of the entire lateritic profile) are up to 100 feet, although generally less.

The laterites invariably have a high silica content and low ignition loss, and are not potential sources of bauxite; the iron content ranges from about 12% to 35% Fe, with selected specimens and thin layers ranging up to over 50%.

QUATERNARY.

Alluvium and Soil.

No attempt has been made to differentiate between deep soil cover and alluvium; where soil cover is thin or intermittent, and the underlying rock formation is clearly indicated, it has not been differentiated.

On parts of the Sturt Plateau (Lat. 18°30' Long. 128°30'), alluvium and soil reach a thickness of 120 feet, and Traves (1955) suggests that these deposits could be of Tertiary age and contemporaneous with the laterites.

In other areas considerable thickness of black soil are present; this black soil is in part transported, but generally appears to correspond in distribution to the distribution of certain rock types, especially volcanics.

## 4. PALAEOZOIC AND YOUNGER - WEST KIMBERLEY.

### ORDOVICIAN (Guppy & Opik 1950)

Prices Creek Group. Total known thickness 2,630 feet.

(Emanuel Formation
(
(Gap Creek Formation

### Emanuel Formation.

At the type locality along Emanuel Creek (Long. 125°55' East Lat. 18°39' South) the Emanuel Formation consists of 2,000 feet, of marine sediments, and conformably underlies the Gap Creek Formation, the base of the formation not being exposed.

The formation is poorly exposed for the greater part of the section. Apart from Emanuel Creek where it is exposed intermittently, outcrop is confined to low rises. The total thickness of definite Ordovician is about 2,000 feet, with a further possible 130 feet known from drillholes.

Fossils recorded from the Formation include the Brachiopod Obolus, and asaphids of the Lower Ordovician Trilobite Xenostegium, and the upper beds contain a rich fauna of asaphids, pliomerids gastropods, and nautiloids, with interbedded graptolite bearing horizons (dichograptids).

The lithology is made up of limestones, silty micaceous sandstones, siltstones, and calcareous siltstones. Certain siltstone beds give a foetid odour when freshly broken, and contain nodules of limonite after pyrite.

### Gap Creek Formation.

This formation conformably overlies the Emanuel Formation and underlies the Devonian Pillara Formation with a slight angular unconformity. The formation is more resistant to erosion than the Emanuel Formation, and about half the section is composed of bedded to massive crystalline dolomite; fossils are commonly silicified. The softer beds rarely outcrop but where exposed consist of dolomitic calcarenite, dolomitic sandstone, and siltstone.

The Formation consists of 630 feet of marine sediments; fossils present include a telephid genus, trilobites including Burnastus, and the brachiopod Spanodonta hoskingae.

It is now known that oil shows reported from shallow bores sunk in the Prices Creek area in 1922 originated in Ordovician rocks and not in Devonian as was previously thought; no oil shows were reported in the one hole drilled in the nearby Permian sediments.

DEVONIAN.

The Devonian sediments, together with the Ordovician, contain the most likely source rocks for oil in the Fitzroy Basin.

The Devonian outcrops are confined to a comparatively narrow belt extending for a distance of 180 miles along the north-eastern margin of the Fitzroy Basin in the marginal area of marine sedimentation during the Devonian period. Hence the outcrops will probably not be representative of Devonian sedimentation in the extensive areas to the south and west which are now covered by younger sediments but may give some idea of the type of sediments which can be expected.

The outcropping Devonian sediments are of a platform type formed under mildly unstable epeirogenic conditions, and reef masses, near shore lagoonal deposits, off reef breccias, some deep water off reef sediments, and near shore torrential fanglomerates are all represented.

The following formations have been recognised:

Pillara Formation (Guppy & Lindner)

This formation is the basal outcropping Devonian formation, consisting of marine organic limestone;. it unconformably overlies either the Precambrian or Ordovician rocks, and is overlain unconformably in their respective areas by Sadler Formation, Mt. Pierre Group, Brooking Formation, Copley Formation, Fossil Downs Formation, Oscar Formation, Geike Formation, Napier Formation, and Grant Formation.

The type section was measured at Menzous Gap in the Pillara Range (Long. 125°25' East, Lat. 18°24' South), and was named for the Pillara Range; the name replaces the "Rough Range Series" of Wade which included limestones of Upper and Middle Devonian age.

The main facies divisions of the Pillara Formation are:

Calcarenite, biostrome facies contemporaneous with reef and biohermal facies.

Calcarenite, calcilutite, biostrome facies.

Arkosic sandstone, conglomeratic facies at base.

The thickness of the formation as measured at the type locality was 1,400 feet, and a somewhat suspect thickness of 1,850 feet was measured at Wagon Pass in the Napier Range. The following fossils have been identified:

Amphipora ramosa with Presmatophyllum
Murchisonia
Hexagonaria brevillamellata
Hexagonaria hullensis
Disphyllum spp.
Temnophyllum spp.
Thamnopora spp.
Alveolites spp.

Some large thick shelled brachiopods and lamellibranchs with rare nautiloids and fish remains.

UPPER DEVONIAN

Sadler Formation.

This formation is the basal type Devonian and is not widely exposed. The type area as in the Sadler Hills along the northeast side of the Emanuel Range at Long. 125°56' E. Lat. 18°36'S. Other areas of outcrop are north of the Pillara Range, Bugle Gap, and east of Bugle Gap, Hull Range, Outcamp Billy Hills and a small area on the Oscar Plateau.

The unit unconformably overlies the Pillera Formation and is conformably overlain by one of the following units: Gogo Formation, Mt. Pierre Group, (in the area south of the Margaret River), Fossil

Downs Formation (in the area between the Margaret River and the Fitzroy River) or Napier Formation (on the Oscar Plateau). The formation interfingers with the Sparke Conglomerate, Mt. Elma Conglomerate, and Virgin Hills Formation.

The Sadler Formation is notable for the rich fossil fauna, and many of the fossils are silicified and ferruginised, giving the outcrop a very characteristic surface appearance.

The formation has two dominant lithofacies, clastic limestone, and reef (grading to biohermal), with a rare local quartz clastic lithofacies in addition.

The relationship of the lithofacies is not fully understood.

In some places a clearly identifiable time break between the Sadler Formation and the Pillara Formation can be easily demonstrated, whereas elsewhere it is practically indistinguishable; further work on the faunal assemblages may clarify the situation in the latter areas.

The thickness of the Sadler Formation has been measured in three places and ranges from 665 feet to 1230 feet; north of the Fitzroy River the unit is absent except in a small area in the Oscar Range, and it is presumed that no deposition occurred during the interval.

Fossils identified include Manticoceras sp. and corals with Upper Devonian affinities.

Mt. Pierre Group (cf. Mt. Pierre Series - Wade 1936)

In the type area between Pillara Range and Needle-eye Rocks (Long. 125°25' E. Lat. 18°17'S) the Group consists of over 1800 feet of sediments. The Group conformably overlies and interfingers with the Sadler Formation and is overlain conformably by the Fairfield Formation in the Mt. Pierre area, and by the Bugle Gap Limestone at Bugle Gap.

The Group has been divided into two formations, the lower Gogo Formation, and the Upper Virgin Hills Formation, although these have not been mapped as individual units.

125°46'E ?? 18°26'S ??

## Gogo Formation.

The type section was measured along the northern flank of the Pillara Range (Long. 125°26'E. Lat. 18°36'S.), the name being derived from Gogo Station where typical outcrops are found. The contact with the Sadler Formation is apparently conformable and usually gradational, and the upper boundary with the Virgin Hills Formation is gradational and poorly exposed. It interfingers laterally with the Sparke Conglomerate. The surface outcrop of much of the Formation is characterised by the presence of spheroidal concretions commonly with nuclei of organic remains. The lithology is siltstone, and calcarenite, with characteristic faunal assemblages consisting chiefly of necktoplanktonic organisms e.g. Tentaculites, nautiloids, and fish remains. Two zones of biohermal limestone occur in the upper part of the section on the northern side of the Pillara Range.

The one complete (but poorly exposed) section measured consisted of 1,050 feet of sediments, and partial sections have also been measured in the Old Bohemia Downs and Sadler Hills areas ranging from 180 to 460 feet in thickness. The formation is restricted to the area south of the Fitzroy River. Teichert includes the formation in his Manticoceras zone of the Upper Devonian, and it is characterised by Buchiola and other pelecypods, Tentaculites, small straight nautiloids, some ostracods, Timanites and Koenenities.

## Virgin Hills Formation.

This forms the upper unit of the Mt. Pierre Group and overlies the Gogo Formation conformably; it is overlain with probably a minor unconformity, by the Fairfield Beds or the Bugle Gap Limestone. The type area and section is in the No. 5 Bore-Needle-eye Rocks area, and the formation takes its name from the Virgin Hills (Long. 125°55'E. Lat. 18°33'S).

The beds are characteristically red in colour; the dominant rock types are red and grey, commonly mottled, thin bedded and inter-bedded calcareous siltstones, calcarenites, and fine sandstones. Sections through the formation reveal a sequence chiefly of quartz sandstone, with some recrystallised limestone bands and small bioherms. The measured sections range from 700 to 1,400 feet in thickness. Both the upper and lower parts contain the rich goniatite fauna which has permitted precise dating.

Four stages are present - Stage I (Manticoceras Zone) Stage II (Cheiloceras Zone), Stage III (Sporadoceras Zone) and Stage IV (Productella Zone)

The following corals are characteristic of the Mt. Pierre Group (Hill).

Stage I

Zaphrentoides ? excavatus
Disphyllum intertextum

Stage II

Barrendeophyllum covum

Stage III

Barrendeophyllum spp.
Phillipsastrea sp.
Caninia rudis
"Cystiphyllum" Kimberleyense
Aulopora recta

Stage IV

Catactotoechus irregularis
Catactotoechus tenuis
Zaphrentis iocosa
Phacellopyllum sp.

Sparke Conglomerate.

This conglomerate was first named the J8 beds by Wade (1936) who considered that they were Permian glacial moraines. More recent work by Teichert, Guppy, Lindner and others has shown that the formation is of Upper Devonian age and a contemporary facies of the Mt. Pierre Group. The formation unconformably overlies either Precambrian or Pillara Formation and in places either unconformably overlies or interfingers with and completely replaces the marine sediments of the Virgin Hills Formation. The type area is in the vicinity of Trig Stations J7 and J8 (Long. 126°11'E Lat. 18°35'S) in the Sparke Range.

The lithology is typical of a fanglomerate and consists of poorly exposed sections of conglomeratic coarse and medium grained greywacke, grading downwards to conglomeratic greywacke siltstone. The greywackes are commonly calcareous and strongly cross-bedded, and have the typical bimodal grain size distribution. The coarse clastic fraction ranges from pebbles to boulders as large as 12 feet in diameter, the grain size decreasing from east to west with increasing distance from the source of the material. The coarser clastics are commonly unsorted and consist of boulders, cobbles and pebbles in a pebble conglomerate or coarse greywacke groundmass. The phenoclasts are sub-rounded to angular, and include quartzites, schist, gneiss, and limestone from the Devonian. Quartzite is the main constituent and erosion leaves a thick cover of these boulders on the rounded hills.

About 1,000 feet of the unit has been preserved in the Sparke Range but no estimate of its original thickness is possible; to the west the formation becomes thinner, and is interbedded with the Mt. Pierre Group.

Wade (1936) and Reeves (1949) have suggested that the Conglomerate was derived from glacial action, but it is probable that the unit is a fanglomerate with associated marine sediments; some boulders exhibit faint striations, and crude facetting is common, but both these features may be found in fanglomerates.

The widespread occurrence of these clastic sediments suggests considerable uplift in Upper Devonian time, and hence finer grained terrigenous material may have been laid down in the deeper parts of the basin.

Bugle Gap Limestone.

This formation overlies the Virgin Hills Formation and in places is conformably overlain by the Fairfield Beds or is unconformably overlain by the Grant Formation. The type locality is situated at the southwest end of Bugle Gap (long. 126°04'E. lat. 18°42'S.). The type section is a monotonous sequence of strongly jointed, bedded and massive light brown and white calcarenite and recrystallised calcarenite, partly biohermal. Some beds are rich in fossils, mainly brachiopods, but in most places the fossils have been destroyed by diagenesis.

The lithofacies and biofacies of the formation resemble the Oscar and Geike Formations north of the Fitzroy River, and it is probably equivalent in age to the upper part of these formations. All these formations have the very characteristic steep depositional dip which is clearly revealed in Bugle Gap where Bugle Gap Limestone dipping at 25° to 40° overlies Mt. Pierre Group dipping at about 10°. The type of sediments in these units implies a source of exclusively carbonate rocks (probably Middle Devonian), a steeply shelving sea bottom, water highly charged with calcium carbonate, and comparatively turbulent conditions.

Measured thickness ranges from 950 feet to 1,233 feet, but the total thickness may be somewhat greater.

Crinoid fragments, four species of brachiopods, goniatites, and trilobites have been found in the beds, but have not been examined in detail as yet.

Fossil Downs Formation.

The complex Upper Devonian sedimentary sequence north of the Margaret River on Fossil Downs Station was given a new formation name to distinguish it from the equivalent but more simple sequence south of the River (Mt. Pierre Group).

The Fossil Downs Formation is typically developed north of Fossil Downs Homestead (Long. 125°48'E. Lat. 18°08'S.), it unconformably overlies the Precambrian and the Pillara Formation, and conformably overlies Sadler Formation, interfingers with the Geike Formation, and is overlain by the Fairfield Beds and Geike Formation. The marine sequence interfingers in a complex manner with the contemporaneous fanglomerate formations - Stony Creek Conglomerate, Barramundi Conglomerate, and Mt. Elma Conglomerate.

Calcarenites are a feature of the formation, and they persist in the outcrop sections; the section four miles north of Fossil Downs H.S. is a comparatively pure calcarenite with limestone breccia beds and lenses in the lower half of the section, with some siltstone beds appearing in the upper part.

The formation has a variable thickness up to 1700 feet. The fossil content indicates that the depositional time range is comparable with the Mt. Pierre Group, Brooking and Copley Formations, and Napier Formations.

Stony Creek Conglomerate.
Barramundi Conglomerate.
Mt. Elma Conglomerate.

These fanglomerate formations are found on the margin of the basin as facies variations of the Fossil Downs Formation; they were deposited at the same time as the Sparke Conglomerate.

Outcrops occur at Stony Creek (Long. 125°26'E. Lat. 17°57'S.) and Barramundi Range (Long. 126°14'E. Lat. 18°14'S.).

The formations unconformably overlie either Pillara Formation or Precambrian, and interfinger with the Fossil Downs Formation; the Mt. Elma Conglomerate also interfingers with the Sadler Formation. The sediments are similar to the Sparke Conglomerate, and are estimated to attain thicknesses of up to 1,000 feet.

Copley Formation.
Brooking Formation.

The Copley Formation is restricted to a small area in Copley Valley at Long. 125°42'E. Lat. 18°04'S. The formation unconformably overlies the Pillara Formation and is conformably overlain by the Geike Formation.

The Brooking Formation is comparable in stratigraphic position and lithology with the Copley Formation; the outcrop area occurs in Brooking Gap (Long. 125°35'E. Lat. 17°58'S.) where the formation unconformably overlies Pillara Formation and is overlain by the Fairfield Formation. The upper beds appear to be local lateral facies variations of the equivalent Geike and Oscar Formations.

The Brooking and Copley Formations were deposited in semi-enclosed basins flanked by the Middle Devonian, and represent material derived from the Pillara Formation. The characteristic sediment is calcarenite with minor quartzose clastics interbedded. Oolites are characteristic of the Copley Formation. Some bioherms are present, especially in the Brooking Formation.

The sections measured gave thicknesses of 2,650 feet for the Copley Formation and 3,150 feet for the Brooking Formation.

Fossils have not been identified in detail, but appear to indicate that stages I to III of the Upper Devonian are represented.

Oscar Formation
Geike Formation

The Geike Formation is a comparatively steeply dipping sequence of clastic and organic limestone which outcrops along the southern flank of the range from Brooking Gap (Long. 125°41'E Lat. 18° 06'S.) to Fossil Downs Homestead. It unconformably overlies the Pillara Formation and is equivalent in age to at least the upper beds of the Brooking and Copley Formations. The Formation is overlain by the Fairfield Beds.

The Oscar Formation has been mapped along the south-west flank of the Oscar Range from Brooking Gap to near Mt. Percy. The type locality is in the vicinity of Linesman Creek (Long. 125°23'E Lat. 17°58'S). The Oscar Formation rests unconformably on Pre-cambrian or Pillara Formation; it interfingers with the Napier and Brooking Formations and is overlain, probably conformably, by the Fairfield Beds.

The Oscar and Geike Formations are closely comparable and were deposited under the same environmental conditions; they consist only of clastic and organic limestone, and are characterised by clearly developed initial dips up to 35°.

The units consist of limestone breccias and calcarenite, much of the latter being oolitic, crinoid fragments are very conspicuous and scattered zones contain brachiopods and nautiloids. There is a tendency for biohermal reef growth, especially in the Oscar Formation.

The Geike Formation has been measured at 700 and 1350 feet in thickness, while the Oscar Formation along the Oscar Range measured 1500 to 2,300 feet in thickness.

Detailed fossil identification has not been done, but the age of the two formations is Upper Devonian, probably Stages II and III.

Napier Formation.

The Napier Range is composed mainly of the Napier Formation which also extends along the northern scarp and overlaps onto the Oscar Plateau. The type section is located at Barker Gorge (Long. 124°44'E Lat. 17°16'S) in the Napier Range.

The Formation unconformably overlies either Precambrian or the Pillara Formation; it conformably overlies the Sadler Formation, and is overlain by the Fairfield Beds, the contact not being exposed.

Lateral facies variations in the form of fanglomerates, the Patterson and Behn Conglomerates, have been mapped, and these interfinger and locally replace the normal shallow water marine facies of the Napier Formation.

The Napier Formation is primarily a calcareous and quartzose clastic interbedded with impure calcareous clastics deposited in shallow water; the development of large reef masses at the north-west end of the Oscar Plateau, near Winjana Gorge, and in the vicinity of Barnet Spring north of Old Napier H.S., is also a feature. Apart from areas of reef development the sediments consist of repeated beds of calcareous siltstone and sandstone interbedded with silty and sandy calcarenites. To the south of the northern fringe of the Oscar Range the calcarenites predominate, but near the fanglomerates of the Mt. Behn and Patterson Range areas, the quartzose clastics predominate or completely locally replace the calcarenite.

The base of the formation is in many places composed of coarse clastic material of fragments of metamorphic and granitic rocks with some fragments of Middle Devonian sediments; the beds higher in the sequence contain finer clastics from the same source. The measured sections range in thickness from 700 feet at Carpenters Gap to 3350 feet at Wagon Pass near Old Napier H.S., but most sections range between 1,000 and 1,300 feet; the upper limit is somewhat unreliable due to lack of exposures of the contact with the overlying Fairfield Beds. Detailed palaeontological investigations have not been completed, but field observations suggest that at least Stages II and III of the Upper Devonian are present.

Patterson Conglomerate.
Behn Conglomerate.

These conglomerates are local facies variations of the Napier Formation and are comparable with the Barramundi and Sparke Conglomerates. The formations outcrop in the Patterson Range (Long. 124°37'E Lat. 17°3'S) and at Mt. Behn and the vicinity (Long. 125°05' Lat. 17°29'S). The Patterson Conglomerate is overlain by younger beds of the Napier Formation, and the Behn Conglomerate may be overlain by the Fairfield Beds; both formations overlie the Precambrian unconformably. The rock types are boulder to pebble conglomerates, siltstone, and calcareous sandstone, greywacke and clastic limestone. Estimates of thickness based on assumed dips suggest that about 1,000 feet of sediments have been preserved.

Fairfield Beds.

This formation was originally named by Kraus (1942) as Fairfield Marl. Since the unit contains a number of rock types and only a portion of the sequence is known in outcrop, the name Fairfield Beds is to be preferred. The Beds are named from the Fairfield Valley (Long. 125°00'E Lat. 17°35'S) by Kraus.

In general all sections of the beds are poorly exposed and are not necessarily representative of the Beds as a whole. The Beds overlie the Upper Devonian units of the Napier and Oscar Ranges, Fossil Downs area, and Bugle Gap, and are overlain by the Carboniferous Laurel Beds and unconformably overlapped by the Grant Formation.

The depositional environment of the Fairfield Beds compared with that of the underlying Napier Formation shows a more stable shelf type environment, probably under deeper water.

The sediments exposed include sandstone, siltstone, marl, and calcareous clastic sediments; the softer marl and shaly sediments probably underlie large areas of alluvium to the west of the

Napier Range.

All sections are incomplete but 650 feet of sediments are exposed south of the Barramundi Range.

Teichert (1949) has placed the Beds in his Productella Zone, equivalent to Stage IV of the type section in Europe.

CARBONIFEROUS.

Laurel Beds.

The Laurel Beds (Thomas 1956) were originally mapped as being part of the Upper Devonian Fairfield Beds. They are named from Laurel Downs Station, 15 miles west-north-west of Fitzroy Crossing. The type locality is one mile west of Twelve Mile Bore, Springs Station.

Thomas measured about 650 feet of section. A stratigraphic bore drilled to 4,000 feet near Laurel Downs in 1956 started in Grant Formation for 80 feet and then penetrated about 1,600 feet of marine fossiliferous Laurel Beds. A ? Leptophloeum plant remnant was found at 2,500 feet, and fish remains at 2,598 feet; the bore was in Upper Devonian Mt. Pierre Group from about 2,500 feet onwards.

The lowermost part of the Laurel Beds section is poorer in fossils than the uppermost part, but both faunas are closely related. The uppermost beds consist of interbedded shelly brown calcarenite and soft grey siltstone.

The fauna includes Spirifer, Linoproductus, Athyris, Rhipidomella, Syringopora, and gastropods, pelecypods, a straight nautiloid, and sharks teeth, and indicates a lower Carboniferous age for the Beds. The Beds are unconformably overlain by the Permian Grant Formation.

PERMIAN.

The greater part of the Fitzroy Basin is covered by Permian sediments, and these are thought to extend south and to underlie the outcropping Mesozoic sediments of the Canning Basin. Most of the larger anticlinal structures of the Fitzroy Basin are developed in Permian sediments, but the sediments themselves are not considered to be probable source beds for oil, (although the structures are of interest due to the underlying sediments).

The Permian sediments are of great importance as sources of artesian and subartesian water for pastoral purposes, and the main aquifers of the area are of Permian age.

The Permian formations of the Fitzroy Basin have now been mapped and studied in some detail; the extent of the Permian south of the Fenton Fault in the Canning Basin, and in Dampier Land is hidden by overlying Mesozoic sediments, but a bore on Jurgurra Creek (B.M.R. 1955) passed through Mesozoic into the Noonkanbah Formation at about 50 feet.

The following formations have been recognised by Guppy et al. (1958).

Grant Formation.

The Grant Formation was named after the Grant Range (Long. 124°05'E Lat. 18°02'S) Guppy et al. 1952. The formation unconformably overlies Lower Carboniferous, Middle and Upper Devonian, and Precambrian rocks; the formation is overlain with a distinct unconformity by the Poole Sandstone in the Grant, Poole, and St. George Ranges.

The Grant Formation includes the "Kungangie", "Willangie", and "Grant Range Beds" of Wade, and the lower part of the "Hawkestone Sandstone" of Kraus, Findlay, and Reeves.

The formation is characterised by the large thickness of sandstones, conglomerates, tillite, siltstone and varves recorded throughout the Fitzroy Basin. About 8,800 feet was proved by the WAPET Grant Range No. 1 Bore. Outcropping sections are limited to cliffs in the Ranges, and scattered mesas, which give up to 600 feet of section; more complete information is available from outcrops and bores in the Poole Range (3500') Mt. Wynne (2650'), and Nerrima (6000'), but none of these are thought to have reached the base of the section. All the rock types of the formation are considered to be glacial and fluvioglacial in origin. Intraformational contortion and persistant cross-bedding are features of at least the upper beds of the unit.

Northeast of the Pinnacle Fault the formation wedges out rapidly against the older Palaeozoic sediments and much of it has been eroded. No evidence of the thickness or distribution south of the Fenton Fault is available, but it is probable that the formation is still an important unit in this area.

A few marine fossils, and some wood fragments are known from the Grant Formation; the age is tentatively given as Sakmarian.

Poole Sandstone (Guppy et al. 1952).

This name is revised from the "Poole Range Beds" (Talbot 1927), "Poole Range Series" or "Lower Ferruginous Series" (Wade 1936) and "Poole Range Sandstone" (Reeves 1949). The type locality is in the Poole Range (Long. 125°45'E Lat. 18°50'S) and the unit outcrops mainly on the flanks of the major folds (Poole Range, St. George Range, Mt. Wynne, and Grant Range); small areas occur along the Fenton Fault and along the north-eastern margin of the Basin.

The Poole Sandstone overlies the Grant Formation with a distinct and persistent unconformity, and is overlain by the Noonkanbah Formation with a probable disconformity.

The formation consists of thin-bedded white fine micaceous quartz sandstone, weathering to brown, with some siltstone and shale; intraformational pellets are sometimes present in the section. Plant fossils and fossil wood are commonly found in the formation. A marine fossiliferous lensing bed of friable ferruginous medium silty quartz sandstone occurs at the base of the section in some parts of the St. George and Grant Ranges, and may be correlated with the Nura Nura member in the Mt. Wynne area. The formation often shows ripplemarks, and trails of worms and molluscs.

The Poole Sandstones varies in thickness more than the other Permian units; it is unknown north-east of the Pinnacle Fault, is from 220 to 500 feet in (measured thickness) the Poole Range, 540 feet in measured sections on the north flank of the St. George Range, and over 1180 feet at Mt. Tuckwell. At the type section in the Grant Range an almost complete section measures 680 feet, and in the Nerrima No. 1 Bore it measures 1300 feet, and at Nura Nura Ridge it measures over 1600 feet. The variation in thickness may be due to local structural influence or to basin configuration.

The thin fossiliferous basal zone at the St. George Range contains the following fossils (Thomas 1954).

Neospirifer spp.
Chonetes
Pseudosyrinx sp.
Martiniopsis
"Dielasma" sp.
Pelecypods

The formation is considered to be of Lower Artinskian age.

The Nura Nura member, the base of the formation at Nura Nura Ridge, consists of sandstone and sandy limestone with rich fossil bands. The presence of the ammonites Metalegoceras clarkei and Thalassoceras wadei has enabled the formation to be correlated with the Fossil Cliff Formation of the Irwin River Basin, and the Callytharra Formation of the Carnarvon Basin. The following brachiopods have also been identified (Thomas 1954).

Aulosteges
Chonetes spp.
Taeniothaerus
Neospirifer sp.
Streptorhynchus sp.

The following bryozoa have been identified (Crockford 1956) -

Dyscritella spinigera
Fenestella horologia
Fistulipora nura
Hexagonella spp.
Stenopora hemispherica and others

These fossils indicate a Lower Artinskian age for the Nura Nura member.

<u>Noonkanbah Formation</u> (Wade 1936) cf. "Noonkanbah Shale" of Kraus and Reeves. The formation was named from the type locality near

Noonkanbah Homestead (Long. 124°48'E Lat. 18°30'S); it overlies the Poole Sandstone, probably disconformably, and is conformably overlain by the Liveringa Formation.

The common rock types of the formation are soft-weathering fine sandy siltstone and calcareous siltstone, very thin bedded and commonly containing gypsum; the siltstones are interbedded with minor amounts of shale, calcareous micaceous sandstone, and sandy limestone. The calcareous beds are more resistant to erosion and are commonly fossiliferous and contain spherical concretions and nodules which may by phosphatic. There is a pronounced change in lithofacies from east to west across the basin and the general facies indicates shallow water deposition along the eastern margin of the Basin, deepening to the west. The change in fauna also indicates changes in water depth and environment during the deposition of the formation. Most sections give a fairly constant thickness for the formation of between 1200 and 1500 feet, but a section measured on the south flank of the Grant Range gave a thickness of 2,240 feet; the latter may not be reliable because of the prevalence of strike faults in the area.

The formation contains the richest faunal assemblage known from the Permian of the Fitzroy Basin, and includes brachiopods, bryozoa, corals, crinoids, foraminifera and a few molluscs; the molluscs increase in number towards the top of the formation.

The following are a few of the fossils so far identified in the formation.

Brachiopods (G. Thomas 1954)

Aulosteges spp.
Chonetes pratti
Chonetes sp.
Cleiothyridina spp.
Dictyoclostus sp.
Marginifera sp.
Linoproductus sp.
Martiniopsid sp.
Neospirifer spp.

Pelecypods (Dickens)

Aviculopecten

Bellerophontids

Bryozoa (Crockford 1956)

| | |
|---|---|
| Fenestella (8 species) | Polypora (9 species) |
| Dyscritella (6 species) | Stenopora (3 species) |

Liveringa Formation: (Guppy et al. 1958)

This formation overlies the Noonkanbah Formation conformably and is overlain, probably unconformably, by the Blina Shale, and unconformably by the Erskine Sandstone, Mudjalla Sandstone, Barbwire Sandstone or James Sandstone. The type section for the Formation is on the south flank of Grant Range (Long. 124°04'E, Lat. 18°08'S); the formation occurs throughout the Fitzroy Basin and is very well exposed on the flanks of the anticlines. Recent work in the northeast and southeast part of the Canning Basin has shown that this formation is exposed over large areas on the eastern and southern margins.

Three lithological units may be recognised in the formation. The units of resistant sandstone normally form strike ridges, separated by a wide flat of poorly exposed siltstone and calcareous sandstones; this is exemplified in the double ridge along the south central Grant Range, the Jimberlura Ridges, Mt. Hardman and the ridge near Mt. Ibis, the low rise 2 miles east of Christmas Creek Homestead and the Mt. Talbot mesa, and the Shore Range. Plant bearing beds form the main thickness of the formation, but the marine portions form good outcrops and have been studied in more detail.

The lowest unit, the Lightjack Member, (from Lightjack Hill, Long. 125°50'E. Lat. 18°59'S) contains one of the best markers in the Permian of the Fitzroy Basin. At the base greywacke and fine, slightly micaceous, well sorted red to yellow quartz sandstone, commonly richly fossiliferous, contain lenses of limonitic oolites. These lenses contain up to 50% iron oxide and usually occur in the basal half of the fossiliferous unit. These beds are succeeded by fine thin-bedded highly micaceous olive green sandstone, and the lower unit is terminated with a friable ripplemarked sandstone, commonly with plant fragments. Some calcareous beds occur at the base of the sequence and the contact with the Noonkanbah Formation is gradational in most areas.

The plant bearing yellow sandstone forms scarps in some places, e.g. Nerrima Ridge, Shore Range.

The second unit is poorly exposed and is probably siltstone and shale, with some rare calcareous quartzose beds which form scattered lines of float. The unit forms grassy plains, best developed south of Mt. Hardman and south of Shore Range.

The uppermost unit, named the Hardman Member from Mt. Hardman (Long. 124°39'E Lat. 18°18'S) consists of dominant thin bedded friable fine to medium ripplemarked micaceous silty sandstone, commonly interbedded with massive current-bedded medium to coarse well sorted quartz sandstone. A rich assemblage of marine fossils is found at the base of and within this unit in red-brown and olive-brown micaceous sandstone very similar in lithology to the Lightjack Member.

The thickness of the formation is difficult to determine, but is very variable, probably in part owing to varying rates of deposition; although there is no clear evidence for unconformities they may exist as fossil evidence suggests a considerable time range between the Lightjack and Hardman Members.

The Lightjack Member varies from 65 feet at Lightjack Hill, to 435 feet at Grant Range. The second member is estimated at about 900 feet at Christmas Creek, 1200 feet at Mt. Hardman, and 600 feet south of Grant Range.

The Hardman Member varies from 50 to 120 feet.

The Liveringa Formation as a whole, measured in the type locality south of Grant Range, gave a thickness of 1850 feet, but the section is incomplete.

The Lightjack Member contains a rich assemblage of pelecypods, gastropods, some brachiopods, and rare ammonoids. Thomas (1954) and Dickens have identified the following (selected) fossils.

Brachiopods

Chonetes
Taeniothaerus
Neospirifer
Linoproductus

Mollusca

Atomodesma
Aviculopecten
Parallelodon
Warthia

Bryzoa

Fistulopora
Etherella
Stenodiscus
Minilya
Streblascopora

The fossils indicate an Upper Artinskian to Lower Kungarian age for this member.

The Hardman Member contains a rich assemblage of brachiopods, chiefly athyrids, which are also common in the Noonkanbah formation. The faunal list includes:

Brachiopods — Dielasma spp.
Taeniothaerus spp.
Aulosteges (four species)
Cleiothyridina spp.
Neospirifer sp.
Chonetes
Streptorhynchus
Martiniopsid

Pelecypods — 14 identified genera

Gastropods and Bryozoa

The age of the unit is Tartarian, and it is much younger than the other Permian formations of Western Australia.

## TRIASSIC.

### Blina Shale.

The formation was recognised and named by Findlay (1943) and was published by Reeves (1951). The age was formerly considered to be Permian, but Brunnschweiler (1953) recognised the Triassic age. The name is taken from Blina Homestead (124°32'E 17°46'S) and the formation is the basal Triassic unit unconformably overlying the Liveringa Formation and overlain unconformably by the Triassic Erskine Sandstone.

Areas underlain by the formation occur in the Erskine Range, Wongil Ridge, and on grassy poorly drained clay soil plains on Meda, Kimberley Downs, Blina, Liveringa, Calwynyardah, Noonkanbah, and Quanbun Stations north of the Fitzroy River, and on Luluigui and Nerrima south of the River. Generally, the formation occupies synclinal areas in the Liveringa Formation, but in addition a linear belt 6 to 8 miles wide, passing 10 miles northwest of Ellendale Station H.S. to the coast at Stokes Bay, and exposures at Wongil Ridge and between there and the Fitzroy River, are known. Outcrops are rare, and only small parts of the section are exposed in any one place. At Erskine Hill about 95 feet of the upper beds are exposed, and they consist of laminated light grey-brown and yellow-grey micaceous quartzose sandstone, shale, and siltstones. Ferruginous ochreous red and white siltstone occur at Wongil Ridge. Some conglomerates appear to be present at the base. Bone fragments under marine fossils near the base, and a probable time gap in the fossil record, suggest a disconformity between the Liveringa Formation and the Blina Shale.

Samples obtained from bores in the formation are blue-grey shale; the siltstones weather on exposure to small ferruginous chips, often fossiliferous, which occur rarely on the soil plains.

Three bores on Blina and Kimberley Downs Stations have penetrated 1,000 feet in the shale; some specimens of Isaura were seen in the drill cuttings. At 1,012 feet in Myalls Bore, Derby, (Teichert 1950) shales containing Isaura were reported. In all these the bores commenced near the top of the section, beneath the contact with the Erskine Sandstone, and did not reach the base of the formation. Bores on the northern part of Liveringa Station are believed to have bottomed in the Liveringa Formation after passing through up to 800 feet of Blina Shale.

Brunnschweiler lists the following fossils:-

Capitosaurus sp.
Isaura cf. minuta
Isaura cf. ipsviciensis
Lingula spp.

The abundance of Isaura (Estheria), together with the presence of Lingula, indicates a marine deposit of probable upper Triassic age.

Reptilian and marsupial remains from Quanbun tanks, and the pale grey clays with fossil insects and plants north of White Rocks recorded by Wade (1936) and regarded by him as Tertiary lake deposits, are now known to belong to the Blina Shale.

<u>Erskine Sandstone</u> (Wade 1936 and Reeves (1949), re-defined by Brunnschweiler 1953).

This unit consists of the sediments of Upper Triassic age bounded below by the Blina Shale and above by the Meda Conglomerate. Both contacts are poorly exposed in the field, but they are both believed to be unconformable. A sharp unconformity is seen where the Erskine Sandstone overlies the Liveringa Formation.

The best exposures of the formation occur in the Erskine Range, and the Sisters Plateau. Scattered low ridges on Kimberley Downs and Meda Stations consist of the formation, and it is exposed at Yarrada Hill and in places along the May River.

The unit consists of fine silty micaceous sandstone, massive fine sandstone and siltstone, and quartz sandstone; except for rare massive beds the bedding is thin and even, with cross-bedding; the sandstone are friable and commonly brightly coloured yellow, red, purple, brown, and thinly colour-banded. Intra-formational pellets are common.

Thicknesses up to 110 feet have been measured, but the complete thickness cannot be assessed due to discontinuous outcrops and very low dips.

Fossil wood fragments, and fossil plants are found in the formation. Two richly fossiliferous lenses on the Sisters Plateau and Yarrada Hill, have yielded well preserved plant fossils (Brunnschweiler 1953).

| | |
|---|---|
| Thinnfeldia sp. | dominant forms. |
| Gleichenites sp. | |
| Otazamites sp. | |
| Pleuromeia sp. | |
| Schizoneura sp. | |

These indicate an upper Triassic age.

## JURASSIC.

### Meda Conglomerate.

This term is proposed (Guppy et al. 1956) for the conglomeratic sediments exposed on Meda and Kimberley Downs Stations and in the vicinity of Derby. The name is taken from Meda Station (Long. 124°0'E Lat. 17°22'S) and the formation is defined as the sediments overlying the Erskine Sandstone unconformably.

The formation caps the Erskine Sandstone in the Erskine Range, Trig H.S.1, and a hillock southeast of One Tree Well, Meda Station. Gravel pits near Derby have exposed sediments of this formation.

The unit consists of medium and coarse sandstone with fine conglomeratic beds and lenses; the phenoclasts are of quartz and quartzite, and of material derived from the Erskine Sandstone. The greatest thickness observed was 30 feet at Trig H.S.1.

No fossils have been found but the regional distribution suggests that the formation is probably a marginal facies of one of the upper Jurassic formations south of the Fitzroy River.

### Jurgurra Sandstone (Brunnschweiler 1953).

This formation is named for Jurgurra Creek, and the type locality is at the base of Mt. Alexander (Long. 123°39' 06"E Lat. 18°41' 06"S). The base of the unit is not seen but the formation is disconformably overlain by the Alexander Formation. Reeves (1949) mentions the unit as "irregularly bedded sandstones with unidentified plant fragments".

The unit consists of flat bedded and current-bedded quartz sandstone with thin silty intercalations; the sandstone commonly contains large mica flakes, and silt pellet beds are common. The maximum section measured is 65 feet, but the base is not exposed. Indeterminate plant fossils and small marine pelecypods occur. The formation probably represents a marine or fluviatile transgression of post Triassic and pre Upper Jurassic age.

Mudjalla Sandstone.

This unit is named after Mudjalla Yard, Luluigui Station (125°50'E 18°03'S) (Guppy et al.). The sediments overlie the Liveringa Formation disconformably, and the upper beds have been removed by erosion. The best exposures occur in the rough "Badlands" northwest of Mudjalla Yard and northwest along the south bank of the Fitzroy River. Poor outcrops and float occur near the west bank of the Fitzroy River as far as Langey Crossing.

The formation consists of unsorted, angular medium to very coarse quartz sandstones and lensing conglomerate beds, all strongly crossbedded. Lenses of finer sediments occur in the sequence and they contain a few plant remains; the unit is regarded as being fluviatile in origin.

The maximum thickness exposed is 135 feet. The presence of conifer remains in the plant assemblage is believed to indicate a Jurassic age. The formation resembles the Jurgurra Sandstone and may be synonymous with it, or it may be the landward faces of the Tithonian Alexander and Jarlemai Formation.

Alexander Formation (Brunnschweiler 1953)

This formation is named from Mt. Alexander (Long. 123°39'E Lat. 18° 42'S); it unconformably overlies the Jurgurra Sandstone and is conformably overlain by the Jarlemai Formation. The type section at Mt. Alexander lacks 20 feet of the youngest beds, but these are exposed in mesas 5 miles to the east. Above the

Alexander Formation the siltstones of the Jarlemai Formation from the steep cliffs of the Edgar Range cuesta. The main area of outcrop of the Alexander Formation is at the base of the Edgar Ranges and the outlying mesas and buttes.

At the base of the formation is a variable thickness of strongly cross-bedded quartz sandstone with intercalated lensing beds of white siltstone. Above this is a succession of alternately bedded ripple-marked sandstone and white siltstone; towards the top of the formation these beds become more massive. The whole section is marine and fossiliferous, and the thickness is about 180 feet.

The fauna include the following (Brunnschweiler 1953)

| | |
|---|---|
| Ammonites : | Virgatosphinctes sp. |
| | Kossmatia sp. |
| | Perisphinctidae spp. |
| Pelecypods : | Inoceramus spp. |
| | Meleagrinella spp. |
| | ? Maccoyella |
| Brachiopods | Lingula sp. |
| Echinodermata | Ophiuroidea spp. |

The fauna indicates that the formation is of Kimmeridgian to early Tithonian age.

## James Sandstone.

This unit includes all the coarse conglomeratic commonly ferruginous sandstone in the vicinity of the Fenton Fault and particularly at Mt. James (Long. 124°28'E Lat. 18°41'S) from which the name is derived (Guppy et al. 1958). The formation disconformably overlies the Liveringa Formation, Noonkanbah Formation, and Poole Sandstone; the upper part of the section is eroded. Scattered outcrops occur in the vicinity of the Fenton Fault from a point 15 miles southeast of Mt. Fenton, northwest to Moulamen Hill South.

The formation includes well-bedded to thin-bedded strongly crossbedded medium to coarse porous sandstone and fine conglomerate; beds of conglomerate may be 6 inches thick but are characteristicall in single layers, the pebbles being rounded to sub-rounded and ranging up to 4 inches in diameter. The pebbles include quartz, quartzite and siliceous igneous rocks. In most places the beds are strongly ferruginous.

An incomplete section of 80 feet has been measured at Mt. James. No fossils have been found, but in lithology the unit resembles beds near the base of the Alexander Formation, and it may be equivalent and therefore of upper Jurassic age.

Jarlemai Formation. (cf. Jarlemai Siltstone - Brunschweiler 1953) (Guppy et al. 1958) The formation is exposed throughout the full length of the Edgar Ranges from Dampier Downs Homestead to south-east of Matches Springs and is named from Mt. Jarlemai (Long. 123°45'E Lat. 18°43'S). It overlies the Alexander Formation conformably, and is overlain by the Mowla Sandstone with a dis-conformity. The formation consists of poorly stratified to massive unsorted sandy siltstone and silty sandstone; near Dampier Downs H.S. and Matches Springs bedding is better developed. At the top of the formation bedded fine clean quartz sandstone occurs.

The quartz grains in the siltstone vary from fine to coarse with rare pebbles up to 4 miles in diameter. The greatest thickness measured was 300 feet, but the top portion of this section was eroded.

Fossils are rare, but the following are known:

Buchia spp.
Meleagrinella sp.
? Lima

Brunnschweiler regards the formation as Tithonian in age, slightly older than Teicherts (1949) Buchia beds from the Broome bore.

Mowla Sandstone. (Defined by Brunnschweiler(1953) as the Mowla Conglomerate). Guppy et al. 1958.

The formation disconformably overlies the Jarlemai Formation, and the upper portion has been eroded; outcrops are confined to synclinal areas near Mowla Bluff, east of Mt. Jarlemai, Matches Spring area, and east of Mt. Troy, where it occurs as isolated hills or caps the Jarlemai Formation. It is named from Mowla Bluff (Long. 123°45'E, Lat. 18°45'S).

The formation consists of strongly crossbedded, unsorted friable conglomeratic sandstone (more conglomeratic at the base), fine to coarse micaceous sandstone and interbedded siltstone near the top. The sediments are superficially silicified or ferruginised.

No fossils have been recovered, but the erosional break probably represents only a short time interval and the formation is probably of Upper Jurassic age.

Barbwire Sandstone.

About 70 feet of sediments cap the Liveringa Formation in the Barbwire Range (Long. 125°E Lat. 19°S). The contact is probably unconformable; the upper beds are eroded.

The unit consists of strongly crossbedded to massive coarse sandstone with some conglomerate and interbedded siltstone lenses.

No fossils have been found in the formation, but it is tentatively correlated with the James Sandstone on lithological grounds.

Tertiary

Pisolitic Ironstone (Guppy et al. 1958)

This is found as a shallow layer over Permian and Mesozoic formation and is a product of lateritisation. It is probably of Tertiary (? Oligocene) age.

Quaternary.

Warrimbah Conglomerate

The Warrimbah Conglomerate has been mapped in outcrop at scattered localities near the Fitzroy River, particularly near Warrimbah Homestead (Long. 125°03'E. Lat. 18°25'S) and Myroodah Homestead. The conglomerate is named from Warrimbah Homestead.

The base of the formation is not exposed but presumable unconformably overlies either Permian or Triassic.

The unit is distinct from other conglomerate formations in that it consists of massive accumulations of well-rounded waterworn pebbles and boulders which form an unconsolidated conglomerate.

No sub-surface information is available and the thickness cannot be estimated.

Fossiliferous material has not been discovered in the Conglomerate. Hardman (1884) mentions that Diprotodon australis was found in the "Lennard River just below Devils Pass"; it is of Pleistocene age, and as some high-level gravels - probably the same as the Warrimbah Conglomerate - occur in the area, the fossil is perhaps evidence of the late Tertiary or Quaternary age of the Conglomerate. The association with the Fitzroy River leaves little doubt that the formation was deposited by ancestors of the present Fitzroy River.

<u>Sand, Sand Dunes.</u> Sand is by far the most common superficial deposit in the area. The surface rocks are mostly sandy, the rainfall is low, the climate semi-arid, and the vegetation sparse; all these factors, together with the widespread lateritization, contribute towards the wide distribution of surface sand. Sand dunes are confined to areas underlain by Grant Formation and Mesozoic formations. All inland dunes are now fixed and many of them are somewhat dissected. Dunes are being formed in coastal areas such as Cape Leveque and south of Broome.

<u>Travertine.</u> This chemically precipitated carbonate rock is a superficial deposit found over calcareous sediments. It has been mapped chiefly in association with rocks of the Devonian and Noonkanbah Formation.

## <u>INTRUSIVES.</u>

### <u>FITZROY LAMPROITES:</u>

Within the Fitzroy Basin there are 19 known localities in which leucite bearing intrusives and volcanics outcrop; with the exceptions of Oscar Plug, Mt. Percy, and Mt. North, the intrusions are situated in synclines adjacent to the major anticlinal axes, and many are associated with faulting. Most of the occurrences penetrate the Permian rocks, but at White Rocks the Triassic Blina Shale has been intruded and this constitutes the only definite evidence of age; topographic considerations suggest a Tertiary age. Brunnschweiler has reported the presence of volcanic material in the Cretaceous of Dampierland, and although the mica found in the Lower Cretaceous sediments is different to that found in the lamproites, it is possible that the volcanic activity in the two areas was contemporaneous and that the Fitzroy Lamproites are of Lower Cretaceous age.

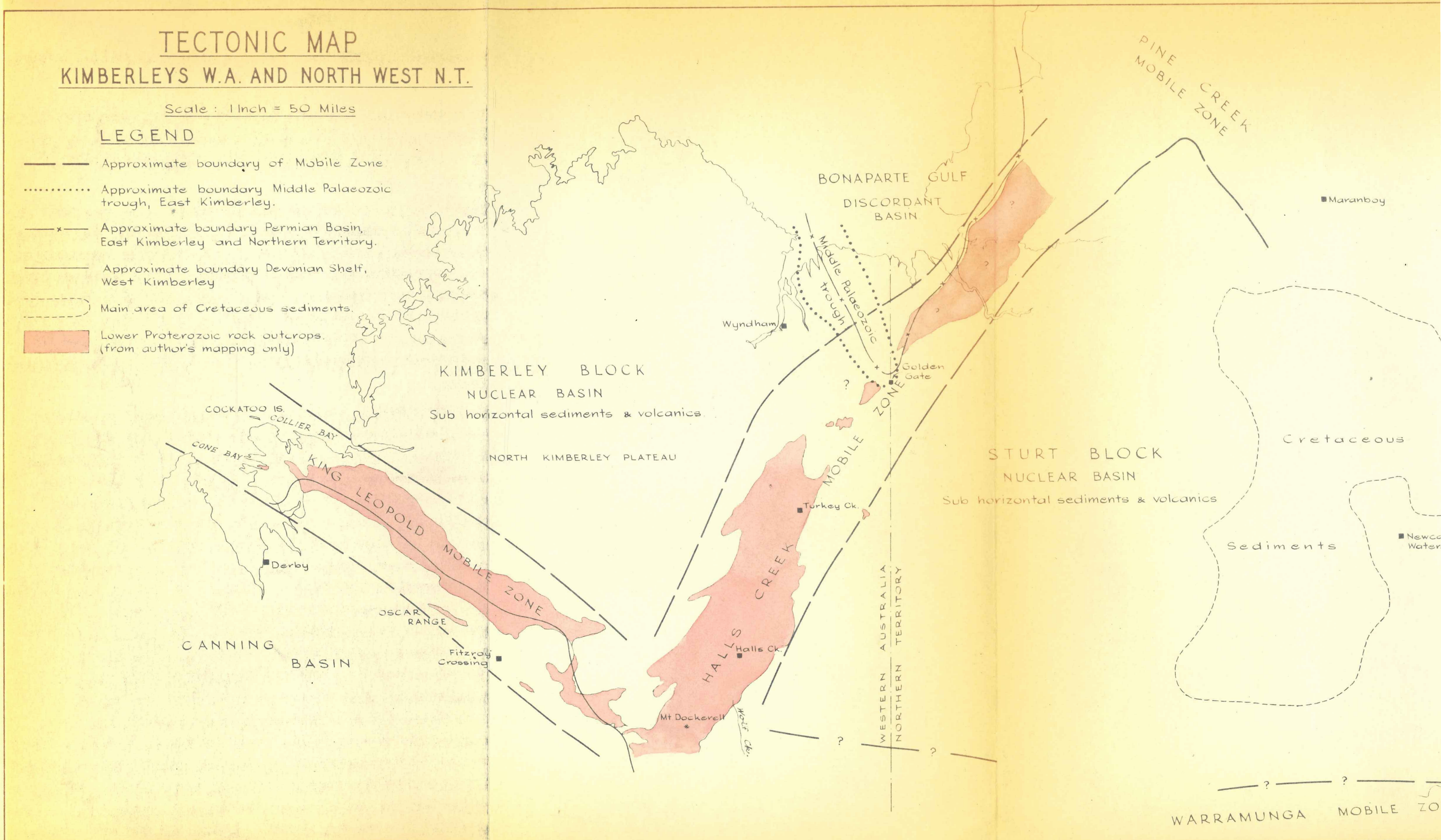
At Mt. North pyroclastics are rich in potash, magnesia and titania, and poor in alumina and soda; the occurrences have been described by Wade and Prider (1939) and Prider has described their petrology in some detail. Prider considers that the rocks were injected as a somewhat cooled magma originally derived from a potassic mica-peridotite magma by the early crystallization and removal of olivine, and rejects the limestone-assimilation hypothesis.

During the present survey a dyke of leucitite rock (similar to "Wolgidite") was found intruding the granite rocks of the Lamboo Complex in the area 1½ miles north of Old Leopold Downs; this is the first known occurrence of these rocks in the Pre-cambrian, and as no limestones are known in the Precambrian in the surrounding area, supports Prider's rejection of the limestone-assimilation hypothesis for the origin of the Fitzroy Lamproites.

OTHERS:

The Fraser River No. 1 Bore encountered a diorite body at about 10,000 feet, which was probably intrusive into the Carboniferous sediments.

A dolerite outcrop reported by Hardman (1884) in the May River near Yarrada Hill, has unknown field relations, It is unlikely that it is a basement high, and it is therefore probably intrusive into the Triassic rocks of this area. It may be


TECTONIC MAP
KIMBERLEYS W.A. AND NORTH WEST N.T.
Scale : 1 Inch = 50 Miles
LEGEND
Approximate boundary of Mobile Zone
Approximate boundary Middle Palaeozoic trough, East Kimberley.
Approximate boundary Permian Basin, East Kimberley and Northern Territory.
Approximate boundary Devonian Shelf, West Kimberley
Main area of Cretaceous sediments.
Lower Proterozoic rock outcrops. (from author's mapping only)
PINE CREEK MOBILE ZONE
BONAPARTE GULF DISCORDANT BASIN
Maranboy
Middle Palaeozoic trough
Wyndham
Golden Gate
KIMBERLEY BLOCK
NUCLEAR BASIN
Sub horizontal sediments & volcanics
COCKATOO IS.
COLLIER BAY
CONE BAY
NORTH KIMBERLEY PLATEAU
KING LEOPOLD MOBILE ZONE
HALLS CREEK MOBILE ZONE
STURT BLOCK
NUCLEAR BASIN
Sub horizontal sediments & volcanics
Cretaceous
Sediments
Turkey Ck.
Derby
OSCAR RANGE
CANNING BASIN
Fitzroy Crossing
Halls Ck.
Mt Dockerell
Wolf Ck.
WESTERN AUSTRALIA
NORTHERN TERRITORY
WARRAMUNGA MOBILE ZO

comparable to the intrusive noted in the Fraser River No. 1 Bore.

TECTONICS:

The major tectonic units of the area are the Kimberley Block, the Halls Creek Mobile Zone, the King Leopold Mobile Zone, the Sturt Block, and the Canning Basin (Hills 1946, Noakes 1953, Traves 1956)(Fig. I ).

The King Leopold Mobile Zone can be traced from the Cone Bay - Collier Bay area south-easterly toward Mt. Dockerell, and may have its continuation in the easterly trending Warramunga Mobile Zone in the as yet unmapped areas between Wolf Creek and Tennant Creek. The Lower Proterozoic sediments in this belt show more disturbance than the sediments on the adjacent Kimberley Block and the Canning Basin; the disposition of the sediments and associated granites and gneisses probably reflect the trend of a geosyncline in Lower Proterozoic time.

The Halls Creek Mobile Zone can be traced from the Mount Dockerell - Halls Creek area north north easterly to the Golden Gate area and thence into the Northern Territory toward Darwin. The mainly Lower Proterozoic sediments of this belt show more disturbance than the sediments on the adjacent Kimberley and Sturt Blocks; the disposition and trend of the sediments and associated granites and gneisses probably reflects the trend of a geosyncline in the Lower Proterozoic time. This geosynclinal belt appears to have had two main troughs, the Halls Creek trough, and the Pine Creek trough, linked by a shallower "platform" in the Carr Boyd Range - Mt. Litchfield area. The exact nature of the relations between the sediments of the Halls Creek trough, and the sediments present in the King Leopold Mobile Zone is not clear due to cover and obscuring of trends near the junction by granitisation; there is no evidence to suggest that the Lower Proterozoic sediments of the Halls Creek Mobile Zone change their trend from southwest to northwest as they approach the projection of the King Leopold Mobile Zone, but such trend changes are suggested by the trends in the Lower Adelaidean sediments, and by the apparent continuity of the granitic rocks of the two zones.

The explanation of the nature of this junction, and the relations between the King Leopold Mobile Zone (Lower Proterozoic) sediments, and the sediments of the Halls Creek trough, must await more detailed mapping in the junction area and to the south and east.

Although not folded as tightly as the Lower Proterozoic rocks, Lower Adelaidean rocks which occur as remnants in the Mobile Zones have been faulted and folded, and in some places overfolded and considerably sheared; folding has been particularly severe in the Yampi and Oscar Range areas, the East Kimberley folding being more moderate. The Lower Adelaidean rocks which were deposited in the shallow basins on the Kimberley and Sturt Blocks have been only gently folded into shallow anticlinal and synclinal flexures, except adjacent to the Mobile Zones where folding is more marked, and open structures with moderate dips are common. The folding adjacent to the Mobile Zones, and in the interiors of the Kimberley Block, has axes which are more or less parallel to the trends of the two Mobile Zones; the folding of Lower Adelaidean sediments on the western fringes of the Sturt Block is approximately parallel to the trend of the Halls creek Mobile Zone, while the east-west trends on the southern fringes are believed to indicate proximity to the projection of the Warramunga Mobile Zone. Major fault and master joint lineations in the area tend to be parallel to the trends of the Mobile Zones, and some can be traced for over a hundred miles; the master joint lineations are mentioned in more detail at the end of this section.

The Mobile Zones have remained zones of movement in the post-Proterozoic times, and where lapped by Palaeozoic and later sediments these are folded more conspicuously than where they occur on the more stable areas; this is shown by the folding present in the Fitzroy Basin and by the less folded rocks in the Canning Basin to the south, and by the folding and faulting of some of the East Kimberley Palaeozoic areas. While the main orogenies occurred between Lower and Upper Proterozoic time, and at the close of the Lower Adelaidean in middle Upper Proterozoic time, orogenies of milder type occurred as follows:-

1. In Lower Cambrian time movements formed the troughs in which the Middle Cambrian and Ordovician sediments of the East Kimberley were deposited. A mild orogeny in the East Kimberley in Upper Middle Cambrian time may have been reflected in the West Kimberley in forming the basin of deposition for the Ordovician, although the Ordovician section is incomplete and Cambrian deposition may also have occurred as in the East Kimberley.

2. In Upper Ordovician time an uplift caused the break in deposition between the Lower Ordovician and Middle Devonian sediments of both East and West Kimberley. This was probably not accompanied by major tectonic activity.

3. In Middle Devonian sinking allowed sedimentation to begin in both the Fitzroy Basin and the Bonaparte Gulf Basin. Some oscillatory movements occurred between Middle and Upper Devonian in the West Kimberley.

4. In the Middle Carboniferous uplift and erosion, and subsequent sinking, caused differences in distribution between the Devonian - Lower Carboniferous sediments and the Upper Carboniferous-Permian sequence. This break is reflected in both the East and West Kimberley, although the poor present fossil evidence apparently indicates that the break occurred somewhat later in the West than in the East.

5. In the Middle Triassic a period of folding and faulting caused the major folding in the Fitzroy Basin; this period may also have resulted in faulting and folding in the East Kimberley although no dating of the movements in this area is possible.

6. Post Upper Triassic and post Jurassic folding of minor extent is present in the West Kimberley. In the East Kimberley late Tertiary movement has caused folding in the White Mountain Formation and the warping movements associated with this time have probably caused the uplift and rejuvenation reflected in much of the topography at the present time, as well as the sinking of areas such as that part of the Boneaparte Gulf Basin which underlies the present Joseph Boneaparte Gulf.

Faulting is very prominent in the area, and the times of movement are probably comparable to the various folding periods. The majority of the faults occurred in the Lower Proterozoic and at the close of the Lower Adelaidean, and since that time movements have occurred at various times along these old fault lines, and possibly along new faults formed in post Proterozoic times. Prominent silicification is present along many fault zones in the Precambrian, and silicification is also evident on faults in Cambrian and younger Palaeozoic sediments. Monoclinal folds associated with basement faulting are common especially in the East Kimberley and Northern Territory Upper Proterozoic and Palaeozoic; the Middle Cambrian post depositional basins - the Hardman, Rosewood, and Argyle Basins, have associated with them structures which are probably due to delayed basement adjustment following the outpouring of the Antrim Plateau Volcanics during the Lower Cambrian.

The Middle Palaeozoic sediments of the Bonaparte Gulf Basin were deposited in a discordant, probably faulted, trough, normal to the Halls Creek Mobile Zone and lapping onto it in the Burt Range; faults have been formed in these sediments which are approximately parallel to the trough. The Palaeozoic sediments in the Burt Range Basin have low dips, but in the Carlton Basin the older Palaeozoic sediments dip northeast at 25° to 35° and are strongly strike faulted. (Traves 1955).

In the West Kimberley the dominant structural features of the Fitzroy Basin are the Pinnacle and Fenton "Faults", between which there are three main anticlinal belts - the Southern, Central, and Northern Anticlinal belts; axial trends of the Lower Adelaidean folds in the King Leopold Ranges are about 310°, which is approx. parallel to the direction of the Fenton and Pinnacle "Faults", whereas the Fitzroy Basin anticlinal belts trend at about 280°.

Although faulting is evident at some surface exposures of the Fenton and Pinnacle "Faults", and some movement has certainly occurred along these lines, there is a considerable amount of geophysical evidence which suggests that these are not so much major fault lines as manifestations of buried subsurface ridges.

In the case of the Fenton Fault, which represents almost the southern limit of the outcrop of the Permian sediments of the Fitzroy Basin, and the northern limit of the marine Jurassic of the Canning Basin, there is considerable stratigraphical discontinuity across some sections of the structure and practically none across others; where a fault plane has been observed it dips north at 50° - 60°.

A gravity survey across the "Fault" by Wiebenga 1953, suggested a structure with a "downthrow" to the north of 12,000 feet near Mt. James, 7,000 feet near Barnes Flow, 6,000 feet near Green Spring and Mt. Density, and no displacement at Jurgurra Creek; the gravity contours suggested a "low" appearing on the south side and a "high" on the north side of the possible northwest extension of the "Fenton Fault". Seismic work tends to confirm this picture. Airborne magnetometer traverses across the Fenton Fault suggest that a subsurface ridge runs parallel with the surface trace of the Fenton Fault, with the northern limit of the ridge almost coinciding with the position of the "Fenton Fault". The implications of this are that a thick section of sediments may have been accumulated on the south side of the Fenton "Fault" ridge, as well as on the north side in the Fitzroy Basin.

The southern anticlinal belt extends for about 120 miles from the Luck Range to the "Fenton Fault" west of Tutu Bore; the axis has five culminations; the Poole Range Structure, Mt. Hutton Structure, St. George Range Structure, Nerrima Structure, and Tutu Structure.

The central anticlinal belt can be traced for about 50 miles from east of Mt. Wyme to west of Mt. Anderson; two culminations are known, the Mt. Wynne and Grant Range Structures.

The northern anticlinal belt is rather poorly defined and the only culmination known is the Barrawadda Structure; this belt may extend to the west under Mesozoic rocks and soil cover.

Several minor structures exist in addition to those on the main structures; the most important of these is the poorly exposed Sisters Structure, which extends for about 10 miles and appears to be a terrace or monocline, or to be associated with a fault or unconformity.

MASTER JOINT LINEATIONS, NORTH KIMBERLEY PLATEAU & OTHER AREAS.

It will be noted from the geological map that the King Leopold Sandstone (and to a lesser extent the younger formation of the North Kimberley Plateau, and the Victoria River Formation), are markedly jointed, and possibly faulted. These lineations have been noted from the airphotographs, and due to the doubtful orientation in plan of any one photograph, no statistical analysis has been possible, since the inaccuracy of directions introduced by the process of plan compilation (uncontrolled airphoto mosaics) would render the results meaningless. Zones of lineation can be traced in some cases over very large distances, although the constituent lineations in each zone may be en echelon to each other, and some distance apart. Such major lineations may be seen on the map as follows:-

(a) From Prince Regent Estuary (Lat. 15°27' Long. 125°5') to near Bella Creek (Lat. 16°37' Long. 126°38') - the overall length of the zone of lineation being about 150 miles. In some places there is a suggestion of minor movement along the constituent lineations, and the relevant section has been shown as a fault. It is not thought that any major movement has occurred - and indeed it is doubtful if any significant displacement has occurred. The zone is approximately parallel to the King Leopold Mobile Zone.

(b) A weaker parallel zone of lineation occurs to the north of (a), between the Moran River (Lat. 15°20' Long. 125°40') and Maitland Range (Lat. 16°10' Long. 126°51'). The zone is about 100 miles in length.

(c) A zone of lineation extends from the Roe River (Lat. 15°20' Long. 125°34') to the Isdell River (vicinity of Lat. 16°54' Long. 125°17')

Many of the major lineaments in this zone are quartz filled, and from airphotos there is a possibility of some movement along them. The zone can be traced for about 100 miles. The zone is sub-parallel to the Halls Creek Mobile Zone, and to the main outcrop "basin" of the Pentecost Sandstone.

(d) A zone of lineation extends from Banjo Creek (Lat. 15°17' Long. 126°55') to near the Berkeley River (Lat. 14°28' Long. 127°45'), and some movement may have occurred especially in the northern sections. The zone is sub-parallel to the Halls Creek Mobile Zone.

Countless smaller lineaments are visible on the airphotos, and only the larger "joints" are shown on the geological map. Up to five main directions of lineation are present on any one airphoto, but as explained above, no statistical treatment is possible in relating these to regional structure.

Only a small number of the joint-lineaments have been seen in the field; in all cases parallel low walls of normally flatly dipping sandstone were separated by a zone of rock scree which concealed the intervening area. The minor joints in the sandstones occur in numerous directions, including sub-parallel to the joint lineament. No displacement was apparent.

In some instances the lineaments have probably been dyke filled, the most probable and extensive instance of this being in the Phillips Range (Lat. 16°37' Long. 125°27' to Lat. 16°58' Long. 126°00').

The cause of the joint lineation pattern is obscure, but the following factors are probably all involved;

(a) Regional stresses due to folding.
(b) "Silling" and uplift due to intrusion of basic igneous material.
(c) Load relief due to erosion of overlying sediments.
(d) Type of sediment - the massive sandstones of the King Leopold Sandstone appears to be the most favourable for the development of the pattern.

More detailed examination, with a statistical study of various representative areas, would be necessary to elucidate the full significance of each of the above factors.

GEOLOGICAL HISTORY.

The oldest mapped rocks in the area are the Halls Creek Metamorphics which are now exposed between the Kimberley Block, the Sturt Block and the younger sediments of the Canning Basin; these Metamorphics include arenaceous and argillaceous sediments and basic and acid volcanics which have been folded and metamorphosed, and in part granitised to form the gneisses of the Lamboo Complex. The Halls Creek Metamorphics were probably deposited in Lower Proterozoic time in geosynclinal belts corresponding to their present outcrop trends, the possible source areas being the Kimberley Block, the Sturt Block, and the present Canning Basin area. Subsequently to metamorphism and granitisation, the Lower Proterozoic rocks were intruded by magmatic granite, and most of the hydrothermal mineral deposits of the area were probably introduced at this time.

In the Upper Proterozoic, (Lower Adelaidean), after a prolonged period of erosion of the uplifted Lower Proterozoic rocks, the Kimberley Block, the Lower Proterozoic geosynclinal belts, and at least the fringes of the Sturt Block and Canning Basin area were inundated and formed a shallow basin in which the arenaceous sediments of the King Leopold Sandstone were laid down. Minor volcanic activity which occurred during the deposition of the King Leopold Sandstone increased, and the extensive basalt and andesite flows of the Mornington Volcanics were laid down probably in part from fissures in the King Leopold Sandstone; at the same time the basal portions of the King Leopold Sandstone were intruded by numerous sills, laccoliths, and dykes of the Hart Dolerite, and basic igneous rocks such as gabbro and dolerite intruded the Lower Proterozoic rocks. In some cases at least the volcanics were deposited in shallow seas, and during quiet intervals arenaceous and argillaceous sediments were laid down between the volcanic flows. As volcanic activity declined the whole area was again inundated by the shallow seas and the arenaceous Warton

Sandstone and Harding Sandstone were deposited. A probable arid period at this time resulted in the deposition of the Elgee Shale, and a return to normal conditions resulted in the deposition of the Pentecost Sandstone and Yampi Beds - the latter probably deposited under shallow water conditions near the edge of the basin of deposition, or in an adjacent barred basin, under mild orogenic conditions, and derived from iron rich sediments or igneous rocks.

The close of the King Leopold Sandstone - Pentecost Sandstone cycle of deposition was heralded by the intrusion of porphyry sills etc., into the Lower Adelaidean and Lower Proterozoic rocks, closely followed by a period of diastrophism and metamorphism during which the Lower Adelaidean succession suffered low grade regional metamorphism, and was folded and faulted; on the stable blocks the folding was restricted to gentle doming and basining of the sediments, but on and near the geosynclinal "mobile belts" the orogeny was more intense and sometimes resulted in intense folding, overturning, thrust faulting, and strong shearing as evidenced in the Yampi area and the Oscar Range, and to a lesser extent in the East Kimberleys.

Climatic changes following the uplift of the Lower Adelaidean sediments, caused the formation of local glaciers, and during and prior to the deposition of the terrestrial Walsh Tillite in the Upper Adelaidean, a considerable amount of erosion, in part at least glacial, resulted in some places in the erosion of 5,000 - 10,000 feet of sediments of the Lower Adelaidean and Lower Proterozoic.

Shallow seas which probably covered some of the area during the deposition of the Walsh Tillite, subsequently transgressed further, and the marine Mount House Beds and, in the East Kimberley and Northern Territory, the Victoria River Formation, were deposited.

At the close of Proterozoic time, a partial withdrawal of the sea, or uplift of the Upper Adelaidean sediments, caused some erosion prior to the commencement of the extensive volcanic activity in the East Kimberley and Northern Territory which resulted in the deposition of the Antrim Plateau Volcanics, mainly from fissures. This volcanic activity is not in evidence in the West Kimberley (unless the Hart Dolerite is referred to as this age and origin as postulated by Rattigan and tentatively by Guppy et al.), although the dolerite sills in the Mount House Beds, Elgee Shale, and Pentecost Quartzite probably represent contemporaneous hypabyssal igneous activity. Epeiric seas invaded the East Kimberley and Northern Territory at the close of the Antrim Plateau Volcanic activity, and the Upper Lower Cambrian to Middle Cambrian sediments of the Negri Group were deposited; minor movements caused the limestone - shale facies of the Negri Group to be succeeded by the arenaceous sediments of the Elder Sandstone, with the near shore marginal conglomerates of the Ragged Range Conglomerate.

The recession of the Middle Cambrian sea in the southern portion of the area was accompanied by deposition of Middle and Upper Cambrian and Ordovician sediments in the Carlton Basin. There is no record of deposition in the West Kimberley in Cambrian time, but during the Ordovician the area to the south of the present King Leopold Range was invaded by the sea, and the Prices Creek Group was deposited; there is at present no indication of the former extent of the Ordovician seas.

There is no record of Middle and Upper Ordovician, Silurian, or Lower Devonian sedimentation in the East and West Kimberley, and the entire area may have been a land surface at this time. During the Middle Devonian sedimentation again occurred in the West Kimberley, and the biostromal limestones with associated clastic deposits of the Pillara Formation were laid down on the uneven eroded surface of the Precambrian and Ordovician; at the close of the Middle Devonian faulting and uplift of the Middle Devonian sediments was followed by extensive erosion, and by the deposition of the Upper Devonian limestones, reef deposits, clastic rocks, and marginal conglomerates under mildly unstable epeirogenic conditions in near shore areas. Breaks in sedimentation shown by the near shore sediments may not be shown in the deeper water facies which were laid down in the off shore parts of the Fitzroy

Basin. Sedimentation was apparently continued without major interruption through the Upper Devonian into the Lower Carboniferous (Laurel Beds).

In the East Kimberley the sea transgressed the Bonaparte Gulf Basin in the Upper Devonian, and the Cockatoo Sandstone and Burt Range Limestone were deposited in the Upper Devonian, and the Enga Sandstone and Septimus Limestone were deposited in the Burt Range Basin in the Lower Carboniferous. During the Middle Carboniferous the sea recessed, and orogenic movements and perhaps dissection were followed by the deposition of the Weaber Group in Upper Carboniferous to Lower Permian time. The conglomeratic base of the Weaber Group indicates that mountain glaciers existed in this area at this time, and this glaciation may be comparable with that reflected by the Grant Formation of the West Kimberley; minor trachytic volcanic activity also occurred at this time.

In the West Kimberley there is no record of deposition during Middle and Upper Carboniferous time, deposition apparently recommencing with the glacial and fluvioglacial sediments of the Grant Formation which were laid down on the Lower Carboniferous, Devonian, and Precambrian basement rocks during the Lower Permian (or Upper Carboniferous). The source area for the Grant Formation appears to have been ice covered mountains to the northeast of the present outcrop area, and there is some evidence to indicate that during this time the Fitzroy Basin may have been a continental depositional area filled by melt waters in which the sediments were dumped. Few marine fossils have been found in the Grant Formation, although plant remains are more numerous.

As the glacial period passed, a break in deposition, and some erosion, was followed by a shallow marine transgression during which the Nura Nura Member of the Poole Sandstone was deposited. Lacustrine sedimentation followed the Nura Nura Member, with a return to deeper marine inundation during the deposition of rocks of the Noonkanbah Formation. Alternations of lacustrine and fossiliferous marine sedimentation are shown in the Liveringa Formation of Artinskian age.

In the Northern Territory the Port Keats Group was probably deposited at a somewhat later time than the Weaber Group, and contains both freshwater and marine sediments of ? Permian age; it may be comparable with parts of the Poole Sandstone - Liveringa Formation succession of the West Kimberley.

Triassic sedimentation is not recorded in the East Kimberley, although some Triassic fossils have been recorded from the Port Keats area; in the West Kimberley the deposition of the mainly marine Lower Triassic Blina Shale followed some uplift and erosion of the Permian sediments. A considerable amount of folding of the Permian and Lower Triassic sediments in the Middle Triassic, was followed by uplift and erosion, and deposition of the Upper Triassic freshwater Erskine Sandstone; the outcrops of the latter formation do not reflect the folding of the Permian sediments, suggesting that the major folds in the Permian sediments predate the formation. Marine sedimentation again occurred during the Jurassic, mainly in the southern part of the Fitzroy Basin and in the Canning Basin; Cretaceous sedimentation is recorded only in the Dampier Peninsula. The post-Lower Triassic Fitzroy Lamproite is also possibly of Mesozoic age, although some evidence points to it being of Tertiary age.

In the East Kimberley no Mesozoic sediments are known, but in the Northern Territory, in the Port Keats - Willeroo area, and to the east, remnants of these sediments are widespread. Sedimentation is thought to have begun in freshwater lakes in the Upper Jurassic, and to have been succeeded in Lower Cretaceous time by marine sedimentation in a widespread shallow epeiric sea, the Jurassic-Cretaceous succession forming the Mullaman Group. It is probable that the Cretaceous transgression extended well to the west, of the present known outcrops, and may have extended into Western Australia.

No sedimentation appears to have occurred in the early Tertiary, but possibly about Middle Tertiary time a widespread lateritization period commenced in which laterites were formed over most of the more susceptible rocks. The rate of erosion was probably slow due to a low-lying landscape with little relief, but some of the deeper alluvium, and the lacustrine lake deposits of the White Mountain Formation, were probably formed about mid-Tertiary time more or less contemporaneously with the laterites.

In the late Tertiary or Quaternary, a mild orogeny caused slight folding of the White Mountain Formation, and uplift and warping of the flat Tertiary surface over the whole area, thus initiating the present cycle of erosion. This erosion has, in many areas, cut down over 1,000 feet below what was probably the Tertiary surface, and has produced the present ranges and other topographic features. A considerable amount of soil formation has occurred, and sediments derived from its erosion are accumulating in areas such as King Sound, Walcott Inlet, Cambridge Gulf, and the lower Victoria River.

A relatively recent rise in sea level appears to be indicated by the drowned coastline in such places as Yampi, Walcott Inlet, Bonaparte Archipelago, Prince Regent River, Berkeley River, Cambridge Gulf, and the Lower Victoria and Fitzmaurice Rivers.

# PART III.

# ECONOMIC GEOLOGY.

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# PART III

# ECONOMIC GEOLOGY

## INDEX TO CONTENTS.

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PLANS AND SECTIONS INTERLEAVED.



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Locality Plan showing Main Mineral Occurrences described:

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INTRODUCTION:

Only minor quantities of minerals other than iron ore are produced from the area, and the Lower Proterozoic rocks (which outcrop over an area of about 15,000 square miles) appear to be less mineralised than comparable areas elsewhere in Australia. The area has been moderately well prospected for gold and other common minerals, but has not been well prospected for minerals such as beryl, chromite, etc.; there is some scope for detailed systematic prospecting for all minerals, as prospecting to date has been largely superficial.

The production of iron ore from the Yampi Sound deposits, which commenced in 1950, is the only significant mining enterprise in the area; the annual production is of the order of 500,000 tons of high grade hematite, and this is expected to rise to about 1,000,000 tons in the next year or so.

An intensive search for petroleum is at present in progress, and a successful outcome of this offers the best hope of increasing the value of mineral production from the area.

Numerous small mineral occurrences have been found in the area; descriptions of all those known to the author or recorded in published reports are given below:

I. GOLD:

(a) Deposits in Lower Proterozoic Rocks:

The majority of occurrences are in rocks of the Hall's Creek Metamorphics, only one being known from the Lamboo Complex.

(1) Mt. Broome (Lat. 17°21' Long. 125°19')

In the Mt. Broome Creek area, about two miles west of Mt. Broome, a large number of quartz reefs outcrop in sheared quartz porphyry, which is stated by Finucame to be interbedded with the Hall's Creek Metamorphics. Several of these reefs contain traces of gold, but the only one approaching economic grade is Turner's Reef, which is approximately 500 feet long and of the order of four to six inches wide, assaying up to 5.17 dwt. per ton over three inches; this reef produced some specimen stone.

A more detailed report on the area is given by Finucane in A.G.G.S.N.A. Report W.A. No. 32.

(2) Richenda River (Lat. 17°31'. Long. 125°21')

A number of gold prospects occurs in this area of highly folded sediments.

The main prospect consists of a quartz reef striking generally east-west and extending for a total length of some 340 feet, of which 240 feet have been fairly well tested; the width varies from six to thirtyfive inches, and two shafts of eleven feet and twentyfive feet depth have been sunk on the reef. Six samples taken at intervals within a length of 80 feet of the western section averaged 16.77 dwt/ton over an average width of twelve inches, including one assay of 67.12 dwt/ton over eleven inches. Three samples from the eastern end averaged 9.82 dwt/ton over twentyfour inches, and represent a strike length of twenty feet. Further samples over 103 feet at the eastern end averaged 1.48 dwt/ton over fourteen inches.

Further details are given in A.G.G.S.N.A. Report W.A. No. 44.

(3) Mt. Amherst (Lat. 18°22'. Long. 127°3')

Auriferous quartz reefs occur northeast of Mt. Amherst Station, associated with granite and dolerite. The largest ore-shoot is 300 feet long and the average of samples from four pits in the outcrop was 6.37 dwt/ton over twenty inches.

A representative sample from a length of 100 feet on another reef assayed 5.66 dwt/ton over an average width of twelve inches.

Further details are given on A.G.G.S.N.A. Report W.A. No.31.

(4) Mary River (Lat. 18°28'. Long. 127°35')

Many small quartz reefs occur in this area, and some shallow pits and shafts have been sunk on several of these. The main workings were at the Reform mine, and comprise an open cut seventy feet long and up to twenty feet deep, and a shaft eighteen feet deep; of six samples from these workings only two assayed over 2 dwt/ton, and these assayed 2.4 dwt/ton over fiftyfour inches and 8.5 dwt/ton over fortyeight inches, although the mine is stated to have produced 399 tons of ore yielding 210 fine ozs. of gold.

Some alluvial gold also has been won in this area.

Further details of the area are given in A.G.G.S.N.A. Report W.A. No. 41.

(5) <u>The Twelve Mile Alluvial Workings and Dredging Claims 893H and 948H (Elvira River)</u>

(Lat. 18°14'. Long. 127°52')

On Saunders Gully Island and within dredging claim 893H, gold is known to occur in small quantities in wash over an area of half a mile by up to five chains, with a depth of about fifteen feet.

On Claim 948H an area of wash four to five chains wide and a mile long occurs in an area in which some alluvial gold has been won from crevices in the bedrock.

No effective sampling of the wash on these claims has been done, but it is doubtful if they are suitable for sluicing (Ref. A.G.G.S.N.A. Report W.A. No. 42).

(6) <u>Hall's Creek - Ruby Creek Area.</u>

Most of the gold produced in the Kimberleys has been won from this area and it is the only area being worked at the present time. The following comprise the main occurrences:-

(i) <u>Ruby Queen</u> (Lat. 18°25'. Long. 127°46').

To the year 1908 this mine had produced about 9,700 tons of ore for 6,220 fine oz. of gold, the tailings assaying about 5 dwt. Subsequent production is of the order of 2,000 oz.; the mine is only working intermittently at the present time.

The reef is associated with a large drag fold on the western side of a regional anticline, and occurs in slates and sandstones; it has been developed by adits, several shafts, drives and crosscuts, and ore has been won from stopes and from an open cut. Over a total length of 330 feet the uncorrected average grade (including two high erratics of 84.5 dwt/ton over fortyseven inches and 31.6 dwt/ton over twenty inches) of samples at ten foot intervals was 8.98 dwt. over twentyseven inches; reducing the grade of the two erratics to 20 dwt/ton the corrected average grade was 5.18 dwt/ton. By selective mining the following ore shoots might be mined (A.G.G.S.N.A.):

| | |
|---|---|
| No. 1 Sheet | 60 feet averaging 13.24 dwt/ton over twentyone inches. |
| No. 2 Shoot | 20 feet averaging 9.24 dwt/ton over twenty inches. |
| No. 3 Shoot | 40 feet averaging 6.86 dwt/ton over thirtyfive inches. |

A five-stamp battery is situated about one mile east of the mine, but at certain times during the dry season difficulty is experienced in obtaining sufficient water for treatment operations.

(ii) St. Lawrence (Lat. 18°25'. Long. 127°46')

This reef occurs in a drag fold several hundred feet north-west of the Ruby Queen, and is conformable with the enclosing shales and sandstones. The most productive portion of the reef has a length of about 300 feet, and has been developed by an adit, crosscut, 105 foot shaft, and a winze, and the reef has been stoped in some places. Some ore was won from an open cut. Production is stated as 1,486 tons for 1,133 fine oz., an average of 20.57 dwt/ton.

Samples vary in assay from 0.20 dwt/ton to 89.46 dwt/ton, with widths from twelve to twentysix inches; the reef pinches in places, and has been faulted.

(iii) Other mines and reefs in the area include the Pyramid, West and Left, Goliath, Ruby Queen Extended North, Rising Sun, Sunny Corner, and Triumph; of these only the West and Left (679 tons yielding 948 oz. averaging 28.37 dwt/ton) and Rising Sun (577 tons yielding 491 fine oz. averaging 17.03 fine dwt/ton) have produced significant amounts of ore.

Further details of the field are given in the A.G.G.S.N.A. Report W.A. No. 27.

(7) Mount Bradley - Brockman Area: (Ref. A.A.G.S.N.A. Report W.A. No. 27). (Lat. 18°19'. Long. 127°50')

(i) Mount Bradley: This reef is folded, and varies in width from four to thirteen feet; the productive portion is 180 feet long and contains two shoots of ore about seventy feet apart. Development work consists of two long cross-cutting adits which intersect the northern portion of the reef about ninety feet below the outcrop, and a western adit which intersects the southern shoot about thirty feet below the outcrop. Some driving on the lode was done, and a winze was sunk from the western adit to a depth of ninetyfive feet.

The north shoot ranges in length from forty to seventy feet and has been stoped to the surface above the drive; sampling at ten foot intervals in the drive indicated a length of thirty-five feet averaging 13.79 dwt/ton over sixtythree inches, but the remaining eightyfive feet gave low results except for one assay of 11.2 dwt/ton over sixty inches. The lower workings were inaccessible and were not sampled by the A.G.G.S.N.A.

The south shoot varies from forty to sixty feet in length and has been stoped to a depth of 130 feet below the surface. Two samples cut from the northern face of the drive at thirty feet below outcrop, gave assays of 0.2 dwt/ton over thirtysix inches and 9.39 dwt/ton over sixty inches. The southern extension of the reef appears to be poor.

The total production of this mine was 2,333 tons yielding 1,563 fine oz., an average of 13.40 dwt/ton.

(ii) Brockman: The mines in this area include the Golden Crown, Lady Margaret, Faugh-a-Ballagh, Afghan, Brockman King, Mount Davis and Southern Cross, all of which are inaccessible, and were not sampled by the A.G.G.S.N.A.

Of these the Golden Crown had some very rich ore in a pocket extending to seventy feet depth, where it was worked out. Very little development was done on the Lady Margaret line, the reef as a whole being low grade, but rich ore occurred in small cross-leaders.

The remainder of the mines produced little gold.

(8) Hall's Creek (Lat. 18°13'. Long. 127°47')

The following mines existed in this area: Jacksons, Lady Broome, Black Mount, Gladstone and Jubilee; of these the only one of any consequence was the Jubilee, which was developed by three shafts, one being forty feet and another sixtyfive feet deep, and by some driving and rising. The ore contained a good deal of hematite, galena, copper and pyrite, and one crushing, presumably of picked stone, gave a return of 403 oz. from about ten tons.

A crushing of 400 tons from the Lady Broome yielded 30 oz. of gold.

Some further details are given in "Goldfields of Kimberley," by Woodward, 1891.

(9) __Grant's Creek:__ (Lat. 17°49' Long. 127°56')
(Ref. A.G.G.S.N.A. Report W.A. No. 40)

This area contains a number of auriferous quartz reefs in folded slates, shales, fine grained sandstones, re-crystallised basic rocks and tuffs, and calc-silicate rocks.

The following are the known occurrences:

(i) __Star of Kimberley:__

This reef outcrops over a length of 650 feet, dips northwesterly at 75° to 80° and consists of quartz with some pyrite, galena and chalcopyrite. It has been developed by three shafts, one seventy feet deep and two thirty feet deep, which are at present partially filled. Seven samples from shallow pits over a length of 470 feet averaged 7.65 dwt/ton over a width of forty inches, the results at either end being low. Near the centre of the outcrop a shaft was sampled to fortyfive feet in depth, at ten foot intervals, and the assays averaged 10 dwt. over fiftytwo inches. The only officially recorded production showed a yield of 0.73 fine oz. from one ton of ore; the sampling indicates that approximately 11,000 tons of fair grade ore exists per 100 foot lift.

(ii) __Perseverance:__

This reef can be traced for 700 feet and is about twenty feet wide; a shaft twentythree feet deep has been sunk on one side of the outcrop, and a crosscut extended to the opposite wall at ten feet below the surface. The reef was sampled at the outcrop opposite the shaft, three samples averaging 3.38 dwt/ton over a width of 186 inches; the crosscut was sampled over its full length and averaged 4.68 dwt/ton over 168 inches. Although the grade over the full width is low, selective mining of richer portions might be possible.

Production is stated to be five tons yielding 2.75 fine oz.

(iii) Caledonian: Four separate veins outcrop in this area, of which the most important is 150 feet long and averages six inches in width. Two shallow shafts, 110 feet apart have been sunk to depths of ten feet and eighteen feet, and a sample from the former assayed 4.29 dwt/ton over six inches, and one from the latter 4.04 dwt/ton over six inches.

(iv) The Scottish Chief: These workings consist of shallow pits on narrow veins, the highest assay recorded being 1.96 dwt/ton over twelve inches.

(v) The Comet: This consists of two main reefs, the larger of which contains only traces of gold at the surface; shallow pits have been sunk on the other vein and a sample from one of these assayed 7.96 dwt/ton over eighteen inches.

Production is stated to be 28.7 tons yielding 135.22 fine oz. gold.

(vi) Wilsons:

Wilson's reef can be traced over a length of 660 feet, and three shafts have been sunk on it to depths of twentysix, nineteen and eight feet respectively.

Three samples from the twentysix foot shaft assayed 8.62 dwt/ton over eighteen inches, 12.62 dwt/ton over thirtysix inches and 22.5 dwt/ton over twentyseven inches. The reef contains galena, pyrite and chalcopyrite. A shallow pothole fifty feet north of this shaft was sunk on a parallel vein, and a sample assayed 8.5 dwt/ton over fifteen inches. The nineteen foot shaft occurs 275 feet northeast of the twentysix foot shaft, and two samples from it assayed 9.12 dwt/ton over thirtythree inches and 0.54 dwt/ton over sixty inches; a pothole sixty feet north of this shaft was sampled but gave only a trace of gold.

(vii) Lady Kimberley: Four reefs outcrop in this area. The main vein outcrops over a length of 450 feet, and dips northwest at 70° to 80°; it has been developed by several shafts. The deepest shaft has been sunk to thirtyeight feet and three samples at ten foot intervals assayed 8.5 dwt/ton over nine inches, 6.46 dwt/ton over twelve inches and 6.96 dwt/ton over twelve inches; the other shaft occurs ninetyfive feet to the southwest and is thirteen feet deep; a sample taken at the bottom contained no gold.

(viii) Lone Hand:

This reef outcrops over a length of 500 feet; of five samples cut at intervals over a length of 300 feet the best assayed 1.21 dwt/ton over four inches. R. Neil Smith records that a sixty foot shaft was sunk and makes the following observations:

"From the surface to a depth of sixteen feet some 260 oz. of gold were obtained, but in the next fortyfour feet of the shaft not even a trace could be obtained. At this lower level the reef consists almost wholly of galena which was found to contain 26 oz. 12 dwt. silver to the ton."

(ix) Pantheon Queen:

The main vein outcrops over a length of 155 feet, and dips northwest at 80°. At the northeastern end a shaft has been sunk to thirtyseven feet and three samples taken at ten foot intervals assayed 9.70 dwt/ton over six inches, 4.12 dwt/ton over nine inches, and 38 dwt/ton over nine inches.

(10) Mt. Dockerell Centre: (Lat. 18°55' Long. 127°14')

(Ref. A.G.G.S.N.A. Rep. W.A. No. 29)

The following mines are known:

(i) Irish Lass: (or Mt. Miniard)

The main ore shoot on this vein is thirtyfive feet long, with an average grade of 8.4 dwt/ton over thirtynine inches. From 1934 to 1937 the mine produced 277 tons of ore for about 223 fine oz. of gold.

(ii) Western Lead:

Two shafts have been sunk on this reef to depths of fiftyseven and thirtysix feet; the shafts are twenty feet apart and are connected by a drive at the twenty foot level. The average of twelve samples from the shaft and drive was 5.17 dwt/ton over thirtythree inches. The reef is poor in gold at both ends.

(iii) O'Rommey's:

The main reef has been opened up by three shallow shafts and some pits, an averaged sample assaying 6.29 dwt/ton over thirteen inches.

(iv) Lady Hopetown and Victoria:

Samples from the reefs on these leases gave returns below 1 dwt/ton. Reported crushings total forty tons yielding 323 fine oz. from the Lady Hopetown, and four tons for 113 fine oz. from the Victoria.

(11) Prospect Creek: (Lat. 16°20' Long. 128°35')

Gold has been reported from Prospect Creek west of Argyle Station in the Carr-Boyd Range.

(12) Golden Gate Area: (Lat. 15°57' Lonh. 129°0')

Gold has been reported from this area but so far as is known has not been worked. The author panned several of the more promising creeks in the area, but obtained no gold.

(13) Christmas Creek: (Lat. 19°00' Long. 125°54')

Gold has been reported from the headwaters of Christmas Creek.

(b) Deposits in Lower Adelaidean Rocks:

Gold has been reported from the Carson River area. Reports of gold bearing country in this region (Lat. 14°42'; Long. 126°45') were the cause of one of A. Gibb Maitland's expeditions to the North Kimberley area. The author's mapping has indicated that no Lower Proterozoic (i.e. potentially gold-bearing) rocks outcrop on the Kimberley Plateau. It is probable that the persistent reports of gold being found in this area are due to the finding of pyrite in the basalts of the Mornington Volcanics; some of the basalts of this area were found by the author to contain segregations of pyrite up to ½" diameter.

Alternatively the quartz-epidote veins of the area could carry minor quantities of gold, although this is unlikely.

## Summary of Gold Possibilities.

The recorded production of gold from the area is shown in Tables 8 and 9.

In recent years prospecting has been carried out by only a few experienced men, and of these at least two have managed to obtain a good living from working small shallow leaders for "dollying stone." The lack of crushing facilities has discouraged many experienced prospectors, and has prevented development below any surface ore discovered. While the results to date are not encouraging, the author feels that little of the area has been prospected systematically on the scale of, say, the Coolgardie field, and that it would offer scope for experienced prospectors if treatment facilities were available.

The only mine worked in recent years is the Ruby Queen, which is equipped with a small privately owned battery; work has been desultory due to trouble between the owner and various miners hired to run the mine, and little gold has been produced. Similar reasons (in addition to the lack of return from the tailings) have prevented other miners from crushing their ore at the battery.

Of the other known mines, the known ore-showings in the Star of Kimberley and nearby reefs in the Grant's Creek area offer opportunity for small scale development. Some difficulty in the treatment of the ore from this area may be experienced due to the presence of galena and copper minerals, but encouraging results were obtained in ore dressing tests at the Kalgoorlie Metallurgical Laboratory; these tests showed that when the ore was ground to 50% minus 200 mesh, only approximately 16.1% of the gold could be recovered by amalgamation, but that a further 36.8% can be recovered by cyanidation of classified sands, and a further 39.4% by cyanidation of classified slimes, giving an overall recovery of 92.3%. The presence of copper causes high cyanide consumption and introduces difficulties in precipitation of the gold.

At the present time the high working costs (due to isolation and heavy transport costs) discourage any attempt to develop gold mining.

II. IRON ORE:

The mining of iron ore by Australian Iron and Steel Ltd., at Cockatoo Island, constitutes the major enterprise of the region; the deposit is equipped for production at the rate of 1,000,000 tons per annum, the ore being shipped to iron and steel plants in New South Wales. The ore grade as shipped is approximately Fe 64%, $SiO_2$ 3.5%, $Al_2O_3$ 3.8%, Ign. Loss 1.2%.

The hematite deposits on Cockatoo, Koolan and Irvine Islands, are the only known major deposits adjacent to tide-water, and are the only deposits from which production is likely in the foreseeable future. Transport costs to centres of consumption of ore from Yampi are high, and additional transport costs applicable to any deposit lying inland would render their exploitation uneconomic under present conditions.

The only other major deposit known in the area is that near Pompey's Pillar, which is situated 120 miles south of Wyndham, is inaccessible, presents mining problems, and the ore has a high silica content.

Low grade oolitic ferruginous lenses are known in the lower Liveringa Formation, and in the Noonkanbah Formation, and possibly some also occur in the Permian rocks of the Bonaparte Gulf Basin. These deposits have not been tested, and little is known of their thickness, grade, or distribution.

Small bodies of hematite exist adjacent to Yampi Sound in Talbot Bay, and near Koolan Island, but are too small to warrant development.

Lateritic ferruginous bodies are common in the Montague Sound-Cape Londonderry-Drysdale-Casuarina Creek area, but have not been tested; their apparent low grade and limited thickness make them poor potential sources of iron. Lateritic deposits probably also occur in the Port Keats area.

Excluding the laterites, the iron deposits all appear to be of primary origin, with only minor rearrangement of the iron content since deposition. The Precambrian ores are younger than the majority of the Western Australian iron ore deposits, and are not associated with "jaspilite;" their regional setting is described under "Yampi Beds" in the Stratigraphy of the Lower Adelaidean (Page 32 Part II).

(a) <u>Deposits in Lower Proterozoic Rocks:</u>

No iron ore deposits are known to occur in rocks of this age, and the "jaspilites" associated with similar rocks in other areas of Western Australia are also absent. Bedded deposits of hematite are reported to occur in the Richenda River area (Lat. 17°28'; Long. 125°15') but no details are known. Ilmenite and/or magnetite segregations are common in the basic rocks which intrude rocks of various ages, and occur in the area of outcrop of the Lamboo Complex, Hall's Creek Metamorphics, Hart Dolerite, and possibly the Mornington Volcanics and Antrim Plateau Volcanics. The largest segregation is reported by Hardman at Lat. 18°25'; Long. 127°30' as follows:

"South of Mt. Angelo, and near the Mary River, there is a large mass of dolerite which is interesting from the amount of magnetite it contains. It forms a series of low hills about four miles long and two wide, and Mr. Johnson found it quite impossible to take magnetic bearings from them, as the needle in some instances was reversed.....Not only is the basalt impregnated with small crystals of magnetite, but it contains large strings of that mineral, and pieces of loadstone showing strong polarity may be picked up in abundance; even specimens of the rock itself are found to be strongly polar."

Similar segregations have been noted in doleritic rocks, thirteen miles south of the Ord River on the telegraph line (See Cooper (a)(15) Page 32 ), in the Hart Dolerite near the road eleven miles on the Milliwindie Spring side of Inglis Gap (Lat.17°10' Long. 125°15') and in the area near and northeast of Bedford Downs (Lat. 17°17'; Long. 127°29').

(b) <u>Deposits in Lower Adelaidean Rocks</u>:

(1) Yampi Sound Iron Deposits (Lat. 16°6'; Long. 123°35')

(i) <u>Previous Work</u>: These deposits were discovered by pearlers about the year 1880, and the boulders of iron ore on the beaches near the deposits were used as ballast for luggers. The first official investigation of the deposits was made by W. D. Campbell of the Western Australian Geological Survey in the year 1908 following pegging of leases by a Mr. Percy Kean; Campbell's report on the area was not comprehensive and gives few details of the geology, and although he commented on the conformability of most of the "lodes" with the enclosing sediments he assumed that the ore was of hydrothermal origin because of his belief that the northern orebody on Koolan Island was a fissure vein type and cut across the bedding.

In 1919 a more detailed investigation of the area was made by A. Montgomery for the W.A. Department of Mines, and his report was published in 1920; he concluded that the deposits were primarily of sedimentary origin with the possibility of modification and enrichment by later ore-forming solutions, and was the first to suggest that all the orebodies occur at approximately the same stratigraphic horizon and consist of hematite rather than magnetite.

E. S. Simpson described chloritoid schist from Koolan Island, and also carried out some laboratory work on the ores and their gangue minerals.

Prior to mining development detailed surveys of the orebody on Cockatoo Island were made by Canavan and Macandie (1936) for Australian Iron and Steel Ltd. Canavan and Edwards (1938) subsequently published a paper on the general area, dealing with the structure, mineralogy, petrology and origin of the deposits, and giving some information on the adjacent mainland area. This paper in abridged form was later published in the "Geology of Australian Ore Deposits," (1953). In 1937 the deposits were examined by the A.G.G.S.N.A. and the results are given in their report for W.A.

No. 50 (1939); this report contains the latest published estimate of possible ore reserves, viz:

Cockatoo Island ... 18,782,000 tons
Koolan Island ... 54,096,000 tons

In addition some several millions of tons of limonitic ore occur as cappings to the orebodies on Cockatoo and Koolan Islands, although that on Cockatoo Island has now (1958) been almost entirely removed by quarrying; the northern orebodies on Koolan Island are not included in the estimates due to their doubtful economic importance. The grade of ore being quarried at Cockatoo Island is lower than that used for the calculation of ore reserves due to the winning of lower grade powder ores lying below the footwall of the high grade body, in conjunction with the high grade ore, and hence the ultimate production figures from this deposit will probably exceed the estimated tonnage.

In 1952 Canavan and Whitehead spent some time examining the mainland area checking the regional structure and rock types as determined by Whitehead by photointerpretation; this work has been further revised by photointerpretation and fieldwork by the author in 1953-55. In 1953 the author commenced a detailed survey of the orebody area of Cockatoo Island, and this was subsequently extended to cover the whole island by I. W. Reid in 1953-55 as part of a programme of detailed re-mapping of the orebearing islands. The Cockatoo Island orebody was tested by diamond drilling during 1955-57. Drilling at Koolan Island commenced in 1957 and is still proceeding. The detailed geology and structure of Cockatoo Island, based on mapping and diamond drilling to date, are given in a report to A.I.S. Ltd., by I. W. Reid (1956) and portions of this report are published in the A.I.M.M. Stilwell Anniversary Volume (1958).

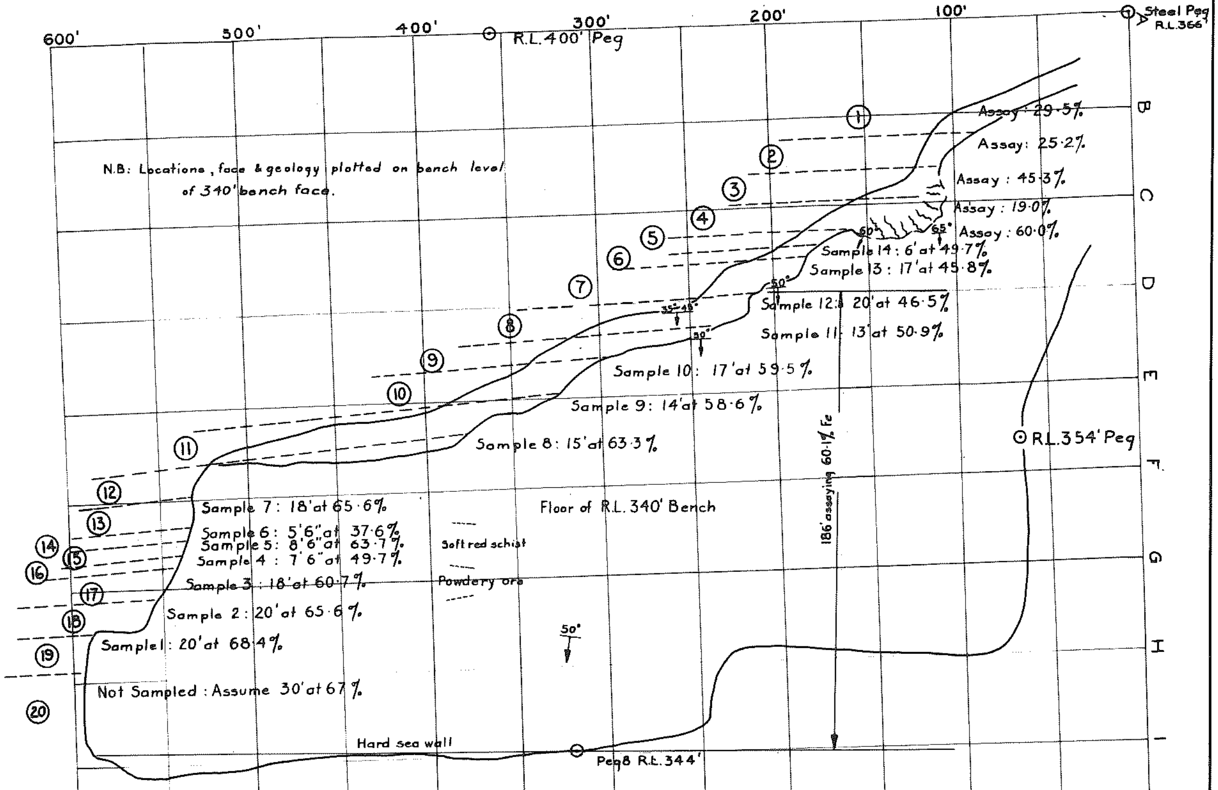
(ii) <u>The Orebodies and Associated Sediments:</u>

Known outcrops of high grade hematite are confined to Koolan Island, Cockatoo Island, Irvine Island, the Ballast Islands (just southeast of Koolan Island), and a small island in Talbot

Bay (Lat. 16°16'; Long. 123°45'); of these only Cockatoo and Koolan Islands contain large orebodies, which for the greater part can be won by open-cut methods. The orebody on Irvine Island is untested, but probably most of it lies below sea level and thus is of doubtful economic importance. Deposits on the other islands are too small to be of other than academic interest. In the vicinity of the orebodies on Cockatoo and Koolan Islands, the beds are generally overturned.

The orebodies occur as enrichments along the strike of hematite quartzites, hematite grits, hematite conglomerates, and hematite schists, and most gradations between almost hematite-free quartzites, etc., and high grade ore, occur in the various islands; the high grade sections also contain interbedded lenses of lower grade material. Except where hardened by surface exposure, most of the ore is soft, crumbly or very powdery, and requires agglomeration before charging into blast furnaces; Canavan and Edwards (1938) imply that the powdery ores are due to leaching out of silica by upward moving waters of igneous origin, but no systematic study of these ores has been done; the author is inclined to the view that the ores of all types correspond to rich portions in the original sediments, and that little subsequent alteration in their bulk contents has occurred. The ores differ from most other Australian iron ores in that the ores and associated rocks appear to have been formed by clastic sedimentary processes, rather than by chemical precipitation; although Edwards (1938) draws attention to their similarity to the Middleback Range ores and their associated jaspilites-banded hematite quartzites. Subsequently he has suggested a purely clastic origin. (Edwards, 1953).

The orebodies and ferruginous sediments occur above the horizon of the Harding Sandstone, in a succession of highly folded sediments which are intruded by quartz porphyry, granophyre, diorite and dolerite; Edwards (1938) is of the opinion that the porphyries and diorite porphyry were intruded prior to folding and metamorphism, but some degree of contemporaneity is probable. The regional




① Mottled quartz schist.

② Contorted schist with slippery feel.

③ Schist with thin hematite bands.

④ Hard quartz schist.

⑤ Blocky red hematite schist.

⑥ Hard hematite band with red & yellow schist.

⑦ Hematite bands in sandstone & yellow & red schist. Biscuit coloured slippery schist.

⑧ Powdery red & blue hematite bands in sandy schist.

⑨ Yellowish sandy schist with powdery hematite bands.

⑩ Schist with blue & red hematite bands.

⑪ Light red schist with hematite bands.

⑫ White clay schist with many blue hematite bands.

⑬ Blue hematite with two prominent white bands.

⑭ White clay schist band. Hematite & red schist.

⑮ Blue hematite.

⑯ Red schist.

⑰ Blue hematite with white clay schist bands.

⑱ Moderately hard blue hematite, fretting to powder.

⑲ Very powdery blue hematite.

⑳ Hard blocky hematite & limonite. Some outcrops of seawall hem., but mainly slumped & cemented eluvial covering powder ore.

## GEOLOGY AND SAMPLE LOCATIONS - RL. 340' BENCH
## COCKATOO ISLAND - W.A.

SCALE OF FEET

40 0 40 80 120

M.A.R. 11-3-'55

stratigraphy is described more fully under "Lower Adelaidean." (Part II, Page 32 ). Edwards' study of polished and thin sections indicates that the ores are probably metamorphosed sediments, and consist predominantly of hematite with minor amounts of magnetite and limonite, although the bulk of the hematite was formerly magnetite; much of the hematite is ferromagnetic and polarised. The hematite bearing rocks contain numerous grains of detrital tourmaline and zircon and exhibit ripplemarking and crossbedding; an occasional feature of successive bands in the hand specimen is a gradation from a sharply defined base of hematite to an upper portion rich in quartz. A generalised rythmic deposition on a larger scale is shown on Cockatoo Island, where recurring cycles of deposition frequently occur as follows:

Top: Hematite conglomerate. Quartz conglomerate.
Hematite, grit, conglomerate.
Sandstone.
Bottom: Schists.

This succession appears to be the reverse of normal sedimentary cycles, and may imply specialised sedimentary conditions; on the other hand, if the succession be taken to be normal, i.e., if the top as quoted is actually the bottom, some form of imbricate structure is necessary to account for the sequence. The rapid erosion of the schist bands, and the resistance to erosion of the hematite rich bands, cause the latter to stand out as ledges separated by scree.

The orebody on Cockatoo Island consists of a thin relatively hard almost pure hematite bed ("Hard Seawall") stratigraphically underlying powdery hematite, schistose hematite, and interbedded schists. The accompanying plan of the 340 foot level quarry shows this succession and also demonstrates the variation in grade of the beds. It will be noted that the mining "footwall" is determined by assay alone. Rapid variations of grade and thickness of individual beds occurs along the strike, and the plan shows the conditions prevailing near the widest ore zone, the mining widths decreasing rapidly to west and east. The high grade ore has a composition illustrated by the following analysis (Edwards, 1958):

Total Fe 69.4; $SiO_2$ 0.4; $Al_2O_3$ Tr.; $Fe_2O_3$ 98.9;
FeO 0.3; MgO Nil; CaO Nil; $TiO_2$ Nil; $P_2O_5$ 0.11;
MnO Nil; $H_2O$ 0.4; S Nil.

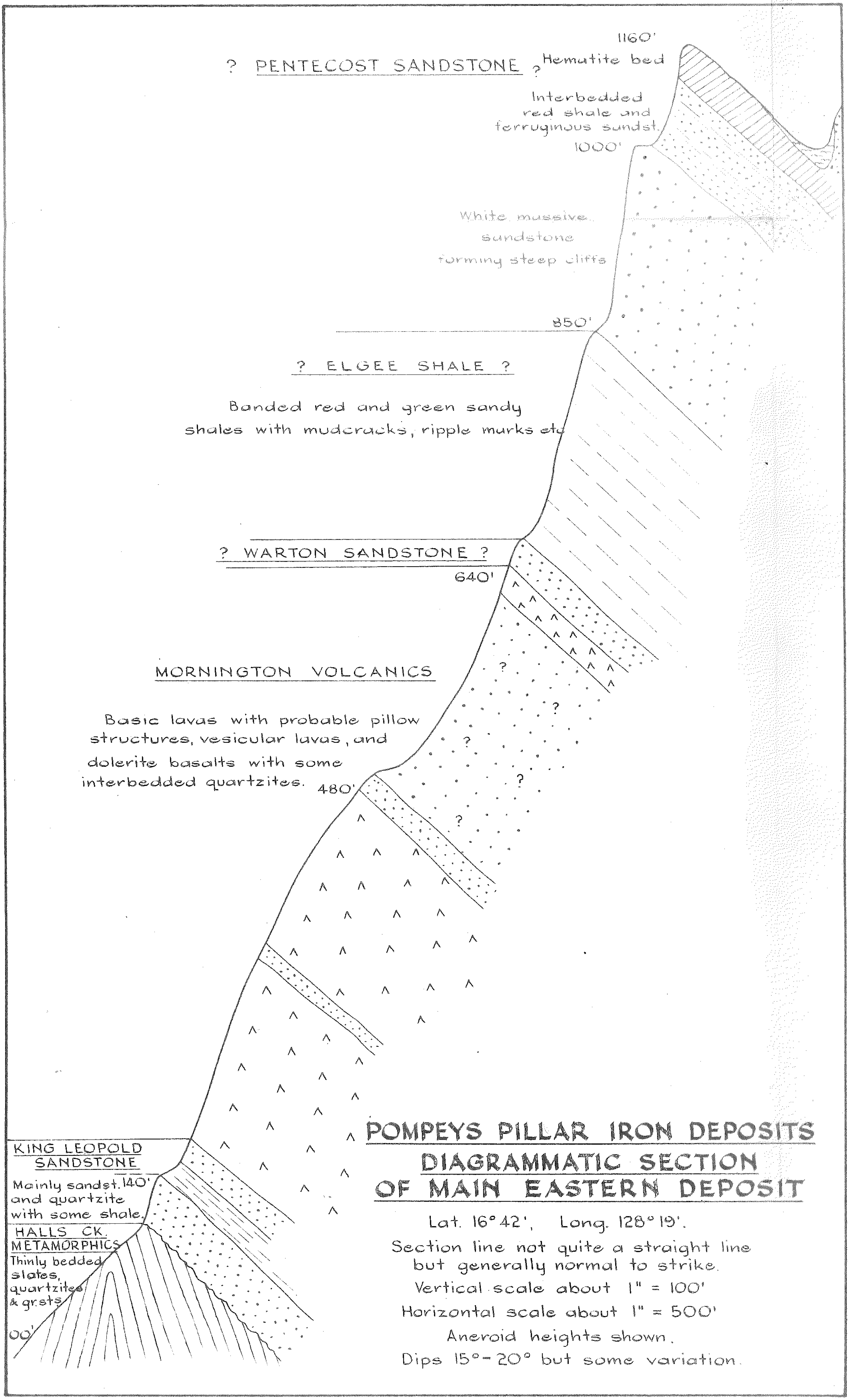
The orebodies on Koolan and Irvine Islands are similar to that on Cockatoo Island, but are more obviously conglomeratic in some sections; the hematite of the Ballast Islands is also associated with prominent hematite conglomerates, and the Talbot Bay occurrences are associated with hematite grits.

The occurrence of hematite conglomerates on Irvine, Cockatoo Koolan and the Ballast Islands suggests that the source area occurred not far from these sediments; the only logical source area appears to be that now covered by the sea to the west and/or north. No detailed study of sedimentation has been made in the islands or adjacent mainland. The source beds for the iron are unknown, although the apparent absence of sedimentary iron formations in the Lower Proterozoic (as now exposed) and the known presence of magnetite-rich basic igneous rocks possibly of that age, suggests that the latter may be the more likely source.

The alternative to a sedimentary origin for the iron is that it was introduced by hydrothermal solutions; this is considered unlikely by most geologists who have examined the deposits, although some invoke hydrothermal agencies in enriching the original sediments to ore-grade. A ready source of hydrothermal solutions may be the porphyries, etc., which are known to intrude the beds. Canavan and Edwards summarise the evidence for the various modes of origin of the ores in their paper, and Reid (1958) has also commented on this aspect.

(2) Pompey's Pillar Ore Deposits: (Lat. 16°40'; Long. 128°20')

As a result of the determination of the regional setting of the Yampi deposits, and the revision of their age by the author and his associates in the Broken Hill Pty. Co. Ltd., the search for iron ore was concentrated on the Lower Adelaidean ("Nullagine") rocks of the Kimberley area. A previously noted occurrence of




**POMPEYS PILLAR IRON DEPOSITS**
**DIAGRAMMATIC SECTION**
**OF MAIN EASTERN DEPOSIT**

Lat. 16° 42', Long. 128° 19'.

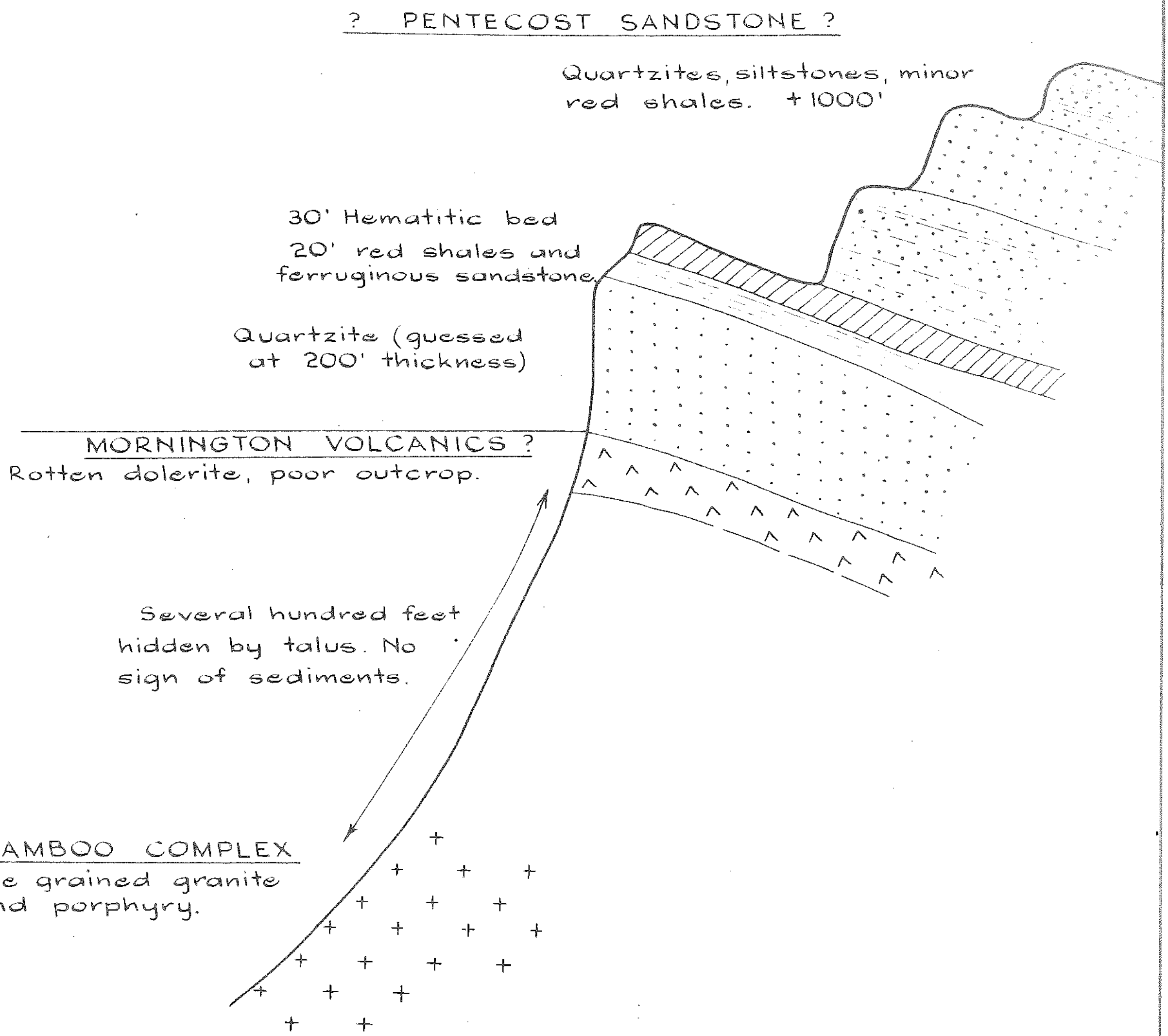
Section line not quite a straight line
but generally normal to strike.

Vertical scale about 1" = 100'

Horizontal scale about 1" = 500'

Aneroid heights shown.

Dips 15°–20° but some variation.




# POMPEYS PILLAR IRON DEPOSITS. DIAGRAMMATIC SECTION, WESTERN DEPOSIT.

Not to scale

Thicknesses estimated by eye.

hematite rich rocks in the Denham area caused this to be selected as an initial test area, and this was extended to the locality of Mt. Nyulasy from which D. M. Traves (Bureau of Mineral Resources) had reported (personal communication) a sedimentary hematite band. As a result a strike length of fifteen miles of iron formation was mapped on the Pompey's Pillar one-mile sheet, in the area bounded by -

Lat. 16°30' - 16°43'
Long. 128°15' - 128°25'

The iron formation occurs as a hematite sandstone, or hematitic quartzite, capping a prominent cliff-forming sequence of quartzitic sandstone, shales and volcanics which overlie the Hall's Creek Metamorphics with a marked angular unconformity. Typical diagrammatic sections are shown (Sections 2 and 3); it will be noted that the western section differs markedly from the southeastern section, both in thickness and variety of the beds underlying the hematite, but insufficient work has been done to explain this (See "Wesley Range" Part II, Page 37 ).

Hematite of ore grade is developed in two places in the iron formation, one in the southeastern, and the other in the southwestern section of the outcrop, the continuity of these sections being interrupted by a regional fault.

The southeastern deposit is the only one containing appreciable tonnages of high to medium grade ore, and is situated about six miles northeast of Mt. Nyulasy. In this area the basic rocks underlying the hematite bed are correlated with the Hornington Volcanics. The cliff-forming sandstone under the hematite bed may be part of the Pentecost Sandstone, or it may be correlated with the Harding and Warton Sandstones to which it is similar in appearance. In any case the iron formation occupies a generally similar stratigraphic position to the ferruginous beds at Yampi.

The ore consists of hematite grading laterally and vertically into siliceous hematite and ferruginous shale, and it varies from hard massive blue hematite to hard ore with numerous small cavities which appear to represent the positions of leached-out sand grains.

Limonite is often present as a surface cement, on or between blocks of hematite. The ore bed exhibits cross bedding, and the underlying sediments show ripplemarking, cross-bedding, mudcracks, graded bedding and other evidences of shallow water deposition. Some of the ore is highly magnetic when crushed and is probably martite. The ore-bed is approximately thirty feet thick, but at no one place is this thickness composed entirely of high grade ore, the medium to high grade sections rarely aggregating more than twenty feet. The following analyses are typical:

| | No. 1 12' Siliceous Ore: | No. 2 22' hard blue ore and "cavitous" ore with 2' shale band: | No. 3 25' hematite with ferruginous shale and sandstone: |
|---|---|---|---|
| Fe | 44.9 | 61.94 | 48.8 |
| $SiO_2$ | 29.9 | 7.2 | 18.98 |
| Mn | .01 | .04 | .02 |
| P | .028 | | .038 |
| $Al_2O_3$ | | 2.49 | |

Due to the nature of the ore bed, difficulty would be experienced in mining ore of an average grade higher than 55% Fe; the chief impurity is silica. The western part of the main outcrop ore-bed dips east-northeasterly at angles of $10^{o}$-$20^{o}$, but to the east this angle increases to $30^{o}$; the orebody is terminated to the northwest by a major fault trending ENE-WSW, while to the east it has been eroded prior to deposition of later (Cambrian) sediments. Numerous small faults (displacement two to twenty feet) are present along the strike of the orebody and would be a nuisance during mining. The shales below the orebody are slightly indurated and metamorphosed, although there is a regional suggestion that to the west these beds were invaded by a sill or intraformational sheet of quartz felspar porphyry of considerable areal extent. Veins of comb-quartz cut across the quartzite beds near faults, and the major fault to the northwest is mineralised by buck quartz. Small veinlets of white quartz occur in parts of the ore-bed.

Field evidence indicates that the ore bed has been little changed since deposition by other than surface leaching, and that the hematite-magnetite is of sedimentary origin.

(3) Liamma Stockroute Area:

Along the Bedford Downs-Liamma Spring-Dillon Spring stockroute, discontinuous lenses of hematite up to two feet thick occur in the beds underlying the quartzite and conglomerate of the Durack Range (King Leopold Sandstone). These lenses occur some hundred feet above the base of the King Leopold Sandstone, associated with shales, quartzites, and thin volcanics. Thick sills of dolerite and diorite intrude the sediments and sometimes carry a considerable proportion of coarse grained ilmenite or magnetite crystals. The hematite lenses, however, have every appearance of being primary sediments; they frequently contain small shale pellets arranged along the bedding, and show marked bedding lines.

The lenses may be seen at intervals to the east and west of the stockroute, e.g., at Lat. 16°20', Long. 128°4', just south of the Denham River; but there seems little chance of large bodies of hematite being present at this horizon.

(4) Carson River: (Lat. 15°5'; Long. 126°45')

Thin seams of magnetite are found replacing a thin sandstone lens interbedded in the Mornington Volcanics at a point about sixtyseven miles by road south of Kalumburu, half a mile east of the Carson River, and about threequarters of a mile west of the bulldozed road. The deposit can be traced for only two chains, and the total thickness of magnetite in any one section is less than two feet.

The mineralisation is probably associated with a quartz reef along a fault zone, and may be ascribed to volcanic emanations; traces of copper carbonates are also found in the quartz reef.

Traces of hematite were found replacing the Warton Sandstone to the east along the scarp; this was of academic interest only and is probably due to late volcanic activity or surface replacement during weathering.

(5) Quartz-Hematite Veins:

Quartz-hematite veins of considerable size are present in the area covered by the Yampi 4-mile sheet. The largest of these occurs one and a half miles south of the former Kotjulam Mission Station, and is in the form of a dyke-like body which forms a prominent hill; the size is masked by float, but appears to be of the order of 100 feet wide and perhaps 300 feet long. The overall grade is below 40% Fe, and the body is not of interest as a source of iron ore.

Similar veins are recorded from other areas, especially from those in which Mornington Volcanics occur. Localities include the Camden Sound, Charnley River, Humbert Creek, Mount House, Mornington, and Sunday Island areas.

(6) Sundry Occurrences of Hematite in Precambrian Sediments:

Hematite is recorded in "jaspillites" from Mt. Deception and Turkey Creek, and in metamorphosed sedimentary beds in the Richenda River area. The latter occurrence is probably in Lower Proterozoic rocks, but has not been examined by the author. The Turkey Creek occurrence could refer to the Pompey's Pillar deposit. The Mt. Deception occurrence (Hardman) is believed to be a coloured jasper bed of Cambrian age containing virtually no iron.

Ochre deposits have been reported from Mt. Amherst station, but no details on these occurrences are known.

(c) Permian Sedimentary Iron Beds:

Oolitic ferruginous beds occur in the lower Liveringa Formation, and parts of the Noonkanbah Formation. Those of the Liveringa Formation are marine in origin and consist of limonitic casts of macrofossils set in a sandstone composed of limonite oolites, and subangular to angular grains of quartz and felspar. The hand specimens and thin sections of the rock bear a close similarity to some of the Kettering-Corby oolites from England, but the Kimberley ores have been more intensely oxidised (Edwards, 1953).

Edwards has published the following analyses of specimens of the Liveringa ores with an analysis of an ore from Preston's Field, Kettering-Corby area, England, for comparison.

| | Mt. Wynne Lat.18°04' Long.124°30' | Shore Range | Shore Range Lat.19°00' Long.125°30' | English Oolite |
|---|---|---|---|---|
| $SiO_2$ | 19.10 | 28.28 | 30.79 | 7.68 |
| $Al_2O_3$ | 12.81 | 12.76 | 10.73 | 6.34 |
| $Fe_2O_3$ | 50.63 | 42.91 | 43.10 | 60.16 |
| FeO | - | - | - | - |
| MgO | .30 | .38 | .35 | .32 |
| CaO | .16 | .12 | .18 | 7.14 |
| $H_2O+$ | 11.73 | 9.98 | 9.45 | 8.72 |
| $H_2O-$ | 1.97 | 3.05 | 2.77 | 4.45 |
| $CO_2$ | | | | 4.53 |
| $TiO_2$ | .15 | .04 | .05 | .02 |
| $P_2O_5$ | .41 | .32 | .32 | .28 |
| MnO | .50 | .48 | .46 | .51 |
| | 97.76 | 98.32 | 98.20 | 100.15 |
| Fe | 35.4 | 30.0 | 30.1 | 42.1 |
| P | .18 | .14 | .14 | .12 |

These reveal that the Australian ores are high in silica and alumina, and low in carbonates, as compared to the English ore, which has a higher iron content.

Edwards suggests that below the zone of oxidation the lower Liveringa formation oolites may contain more carbonates, with the iron occurring chiefly in the ferrous state as a chamosite-like mineral.

The oolitic portions of the lower Liveringa Formation have not been mapped in the field, but are not continuous; the approximate positions in which they may occur may be gauged from the geological map by noting the trace of the Noonkanbah Formation-Liveringa Formation contact. A brief reconnaissance by Reid (unpublished report to the B.H.P. Co. Ltd., 1953) suggests that the lenses are discontinuous, too thin, and low grade to be of economic importance in the areas seen; this reconnaissance was not extensive enough to eliminate the possibility of more attractive bodies being located, and no subsurface work was carried out.

(2) Alligator Springs Ochre Mine: Ochre, probably of a sedimentary origin, occurs in arenaceous sediments of the Weaber Group of Permian age at Lat. 15°18', Long. 129°15'. The ochre is quarried in small quantities, hauled by road 120 miles to Wyndham, and shipped to Perth. Ore reserves are at least several thousand tons on surface indications, but the isolated position of the deposit renders profitable working difficult. No analyses or detailed examination of the ore horizon have been made, and it is not known if the occurrence is of value as a pointer to possible iron ore occurrences in this Group.

(d) Lateritic Deposits:

Laterites of various types occur throughout the mapped area, but are best developed in the Port Keats, N.T., Limbunya, N.T., Birrindudu, N.T., Gordon Downs and Drysdale-Montague Sound areas. Analyses of the ferruginous portions indicate a silica content of from 24% to 70%, and the highest iron content of samples taken by the author was about 30% Fe over a depth of twenty feet; certain thinner laterites in the Drysdale area may assay up to 45% Fe in the iron rich sections, and concentration might be possible. At the present time there is no possibility of using these laterites as sources of iron due to their low grade and distance from consuming centres.

(e) Deposits of Recent Age:

Forrest River (Cunningham River - Lat. 18°25'; Long. 125°15') E. T. Hardman records that on the Forrest Anabranch of the Fitzroy River there are extensive deposits of red and yellow ochre from eight to ten feet thick, and traceable for several miles in the banks. These deposits are probably of Tertiary or very recent age, but have not been seen by the author.

(f) Possibility of Further Iron Ore Deposits:

(1) Areas of outcropping Yampi Beds.

These areas have been covered by reconnaissance field mapping only, but are not thought to offer possibilities of further large orebodies, although some minor bodies may occur. The probable equivalents of the Yampi Beds to the east, the Elgee Shale and Pentecost Sandstone, could contain ferruginous horizons in any of the areas remaining uncovered by field reconnaissance; these areas are mainly well inland, and no interest in ore which might occur in such areas can be envisaged for some time to come.

(2) The Permian beds of the Bonaparte Gulf Basin (including the Port Keats area) and the Fitzroy Basin, may contain sedimentary lenses of low grade oolitic ores of the self-fluxing type, present known oolite bodies are thin, lenticular, and low grade, and are not self-fluxing at the surface.

III. CHROMIUM:

Other than fuchsite, which is recorded from Shoal Bay and Fitzroy Crossing, only one occurrence of chromium minerals is known in the area. A previously unrecorded chromite-bearing serpentine belt was located by a Broken Hill Pty. Co. Ltd. prospector in the Lamboo Complex in the Roses Yard area; this belt starts about half a mile south of the Panton River, and trends northerly for about five miles in the belt of hills just east of Roses Yard (Lat. 17°45'; Long. 127°47').

The chromite occurs as small lenses, and as a dissemination in the serpentine and associated sheared gabbro. The lenses are sometimes associated with small seams of magnesite, and are generally a few inches to six inches in width and about a chain long, although some are locally up to two feet six inches wide and up to five chains long; they dip at angles between 30° and 90° and the formation of small dip slopes on the less steeply inclined lenses sometimes gives an exaggerated impression of size.

The host rocks are commonly somewhat bleached and weathered in the vicinity of the chromite and magnesite lenses.

Assays of grab samples from the veins in three sections were as follows:

| | | | |
|---|---|---|---|
| $SiO_2$ | 4.76 | 5.40 | 8.48 |
| FeO | 30.62 | 30.24 | 26.1 |
| $Al_2O_3$ | 21.72 | 19.32 | 19.02 |
| $Cr_2O_3$ | 32.71 | 31.71 | 29.92 |

Such chromite is not of commercial use.

Extensive areas of basic igneous rocks occur in the surrounding area, and it is possible that further chromite-bearing serpentines may occur, as the area has obviously not been prospected for this mineral.

## IV. VANADIUM:

Vanadinite ($Pb_5Cl\ (VO_4)_3$) has been recorded from the Mt. Dockerell area (Lat. 18°55', Long. 127°14') but no details of its occurrence are known.

## V. COBALT:

Cobaltiferous psilomelane has been recorded from the Christmas Creek area (Lat. 19°00', Long. 125°54'), but no details are given.

## VI. MANGANESE:

No manganese has been produced from the area, and no indications of large deposits are known; the topography and/or rock types over a large part of the northern part of the area are unsuited to the occurrence of manganese "sheet" lodes of the type common in the Pilbara and Murchison areas. Some manganese may however occur associated with the Mullaman Group in the Northern Territory portion, and in the area adjacent to the Desert Basin in the southern part of the Kimberleys; so far as is known no systematic examination of these areas has been made.

although some manganese deposits have been found recently by prospectors in the Mullaman Group to the east of the geological map coverage.

Manganese minerals occur in the area to the south of Louisa Downs, where an ironstone layer from two to four feet thick shows local enrichment in manganese oxides; several occurrences were examined about twenty-three miles south of Louisa Downs (Lat. 18°42', Long. 126°43') but none of these exceeded a few feet in diameter and most were of low grade. The deposits are associated with Lower Adelaidean rocks.

Manganiferous float is known in the vicinity of Hall's Creek aerodrome, but no lodes have been found. Manganite has been recorded from Elephant Hill on Alice Downs Station, and psilomelane and pyrolusite from Brockmans, Hall's Creek, Nlarla Nlarla, Alice Downs, and Thompson Creek (Mary River), but no details are known although it is probable that only minor quantities are present. A local stockman reported that a flat-topped hill of manganese occurs west of Mt. Amherst Station, but this report has not been checked.

VII. MAGNESITE:

Small amounts of magnesite are associated with the chromite lenses of the Roses Yard area.

Scattered outcrops of magnesite are associated with greenstones in the Mt. Evelyn-Flying Fox Gorge area (Lat. 16°32', Long. 128°32'), and to a lesser extent in the Golden Gate area (Lat. 15°57', Long. 129°00').

Secondary magnesite occurs discontinuously but over a wide area at an horizon at the base of the Bradshaw shales in the Victoria River Formation.

VIII. URANIUM:

The Hall's Creek Metamorphics are probably the equivalents of the Brocks Creek Group of the Northern Territory which has proved to be uranium bearing in the Rum Jungle, Sleisbeck, and South Alligator areas. The Halls Creek Metamorphics have also been intruded by granite and are therefore potential uranium carriers.

During 1954 the Bureau of Mineral Resources conducted a reconnaissance aerial scintillometer survey between Wyndham and Christmas Creek over an area about 75 miles by 240 miles; traverses were in a general east-west direction at intervals of about four miles, using a strip camera and vertical aerial photos for location; the nominal height of the aircraft was about 500 feet above ground level.

Although this type of survey is widely regarded as being of little value in the location of uranium deposits, the publication of a list of fiftyfour well defined anomalies caused a sudden increase in uranium prospecting in the area, and all published anomalies were checked by ground parties. Without exception all anomalies proved to be due to rock/rock junctions, or to abnormally radioactive granite, and the majority of the prospectors left the area. A notable feature of the published anomalies was the virtual absence of anomalies in the belt of Halls Creek Metamorphics, the greatest number occurring in the igneous Lamboo Complex.

The only authentic occurrences of uranium minerals known to the author are those in the Denham area, which were discovered by ground prospectors of United Uranium N.L., and by J. Yorger of Western Uranium, prior to the aerial survey by the Bureau of Mineral Resources. Occurrences found by United Uranium are situated in the line of hills to the southeast of Denham Station, the main deposit being just north of the Main Northern Highway at Hearten's Jump-up, some five miles south of Denham Station (Lat. 16°22', Long. 128°13'). This has been tested by about eighteen costeans, and consists of a shear in sandstones and possibly granite, mineralized with torbernite and uranium ochres over a length of about sixty feet with widths of up to six inches; the deposit occurs near the unconformity between the Lower Adelaidean and the Lamboo Complex, the area being extensively faulted and mineralized by quartz veins. The northern deposit consisted of a dab of uranium ochres on joint planes in a dolerite dyke in granite; a 15 foot shaft sunk on the anomaly appears to have mined out the occurrence.

Some miles to the south in the same line of hills, and adjacent to the same fault system, J. Yorger has found uranium ochres in sandstones, conglomerates and porphyry, which are probably Lower Adelaidean age; the occurrence is not of economic interest. (Pers. Comm).

The general area around Denham Station has been fairly well prospected on foot, and by low flying scintillometer surveys; the remainder of the Kimberley area is virtually unprospected for uranium, the majority of the field parties having done little if any prospecting off the main roads and tracks. The West Kimberley has received little attention from uranium prospectors. Recently (1958) United Uranium have investigated an extensive uranium-bearing horizon northeast of Halls Creek towards Alice Downs. No information is available on the grade or type of occurrence, although rumours state that it is of the Blind River type.

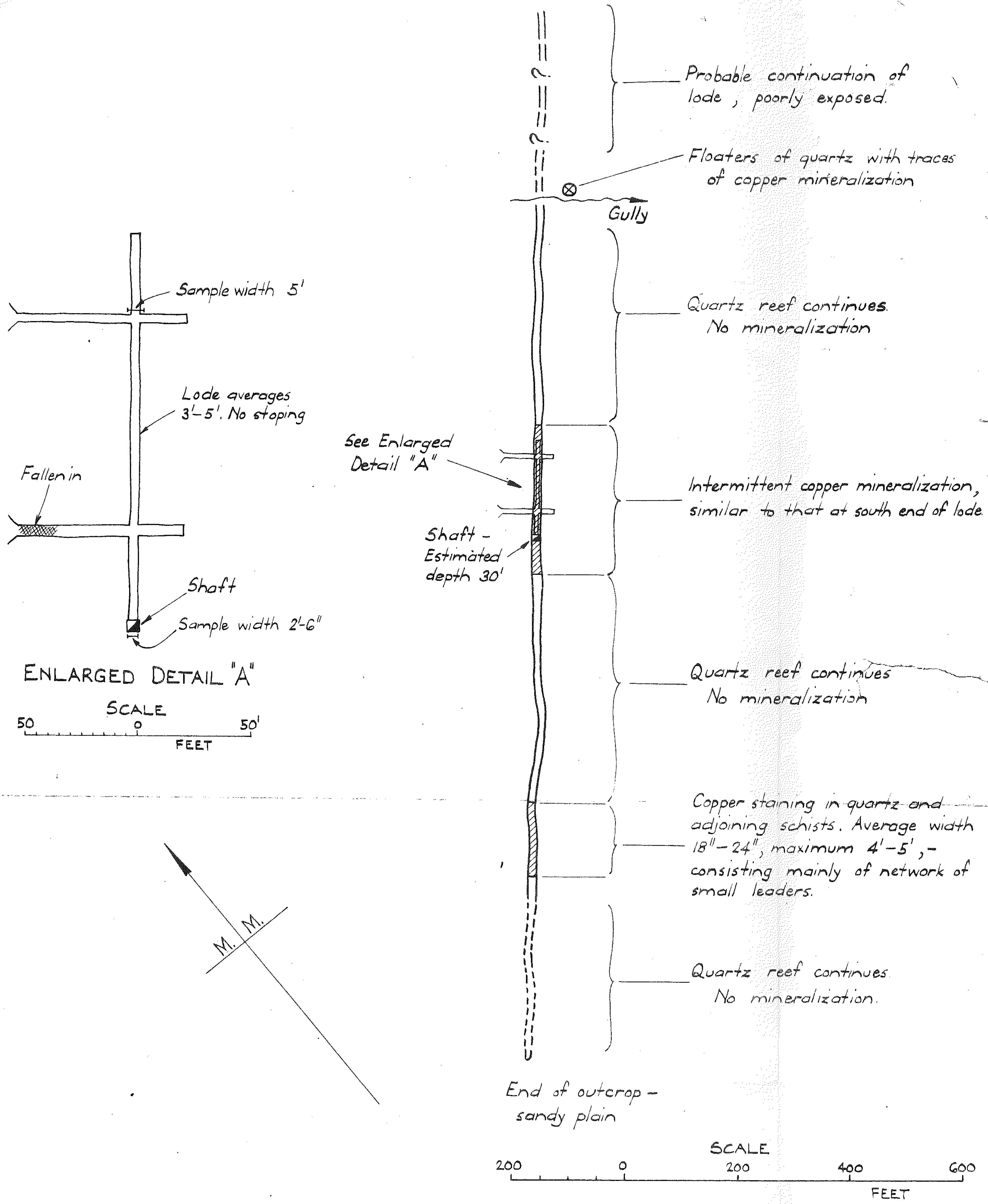
IX. COPPER:

Traces of copper minerals are widespread in the area in rocks of many ages, but there has been but little production. Copper mineralization in the Lower Adelaidean dolerites and Cambrian volcanics is apparently of similar type in part to the Keweenawan copper deposits of Michigan, but it is not known to be on an economic scale.

(a) Deposits in Halls Creek Metamorphics and Lamboo Complex:

(1) Mt. Nellie or Grants Copper Mine (Lat.16°34'';Long.124°12')

Copper lodes were discovered in the Little Tarajee River area about 1905, and some development work was done on them. Mineralization occurs in a narrow belt of schist and slate, with some amphibolites, extending from Mondooma to near Secure Bay,




# West Kimberley. W.A.
## Grant's or Mt. Nellie Copper Show

To accompany Prospecting Party Report – Kimberley Area – September 30th 1953.

which is intruded by quartz porphyry, granite and dolerite, and contains numerous prominent quartz reefs. The quartz reefs are sometimes stained by copper carbonates, and in Grants, Wilsons (Berylton?) and Mondooma prospects, contain bunches or disseminations of copper oxides and sulphides.

The Mt. Nellie (or Grants) deposit consists of three quartz veins which can be traced over a combined length of about 100 chains; the workings are scattered intermittently over a distance of about 20 chains in the central section where the reef is sub-parallel to the enclosing schists, but locally cuts across them at an acute angle. The reef is nearly vertical and strikes about 40° east of north. Copper mineralization is restricted to two shoots; the southern is approximately one chain long, usually eighteen to twentyfour inches wide, but locally ranging up to five feet, and has been worked by a small open cut; the northern shoot is about four chains long with a width of three to five feet, and has been developed by a shaft about thirty feet deep and two crosscutting adits (one of which has now fallen in), all of which are connected by a drive on the lode about 160 feet in length. (Refer plan). No stoping has been done; the orebody is two feet six inches wide at the bottom of the shaft, and five feet wide at the junction of the north crosscut and drive, and consists of disseminated copper minerals in quartz.

The remainder of the reef system shows some scattered copper staining but no consistent economic mineralization.

The Mt. Nellie ore is of moderate to low grade, and due to its disseminated character cannot be beneficiated by hand-picking; as the indicated ore reserves are insufficient to warrant provision of machinery, this prospect does not merit further development.

(2) Mt. Nellie South:

About one and a half miles south of the Mt. Nellie copper deposit, a shallow trench about fifteen feet long, has exposed a quartz reef about a foot wide which strikes west of north

40° parallel to the enclosing schists, and shows some copper staining and a little boxwork. About a chain southeast of the trench a twentyfive foot shaft sunk on the line failed to intersect a defined lode.

(3) Berylton or Wilson's Reward:

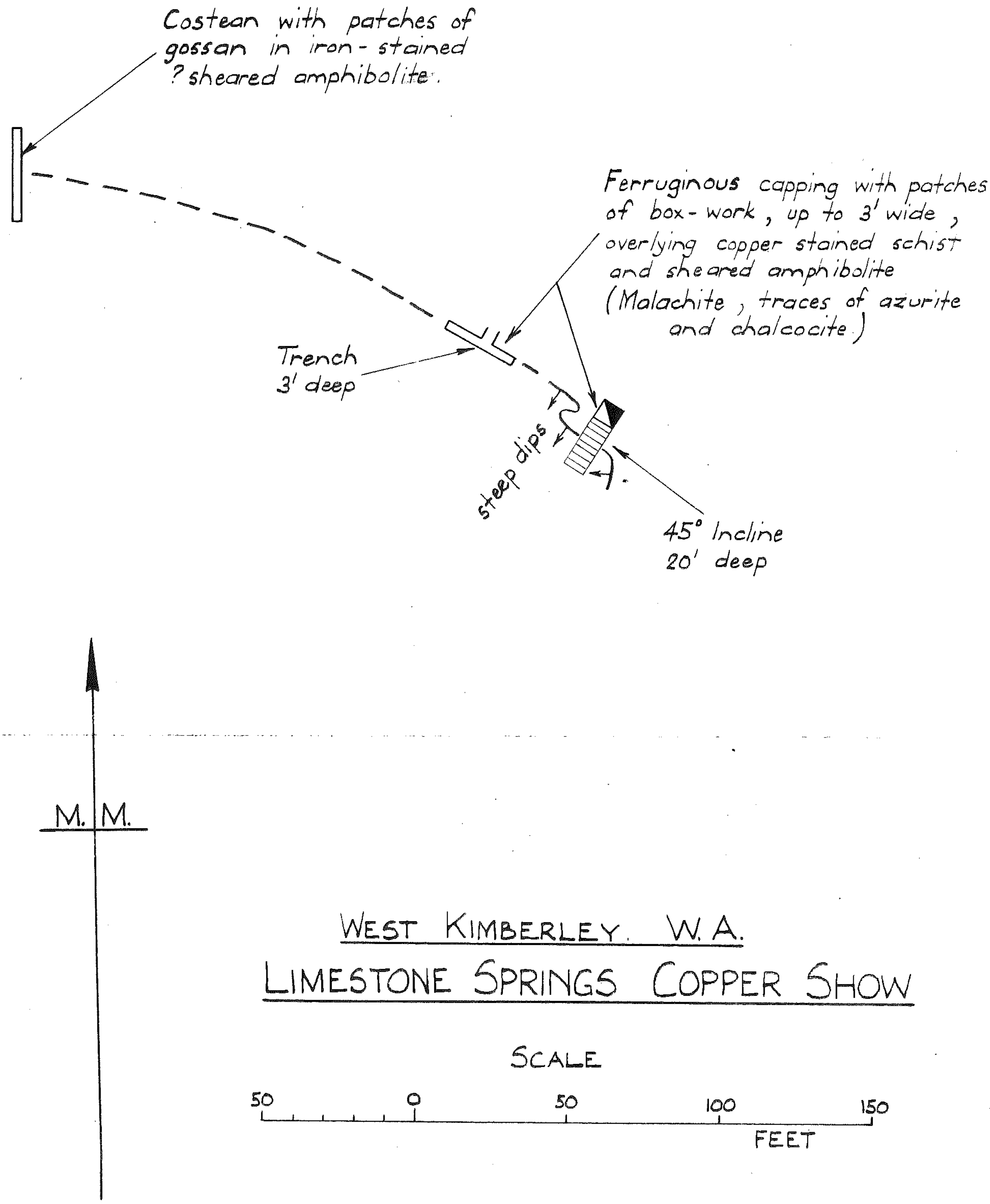
About five and a half miles south of the Mt. Nellie copper show a zone of quartz leaders outcrops on the flanks of a low ridge. These leaders strike 20°-30° west of north, sub-parallel to the enclosing schists, and have been tested by a shaft about 50 feet deep, several trenches, and pits two to three feet deep. Individual lodes are of the order of three inches wide and ten feet long, and carry only disseminated copper mineralization.

(4) Mondooma Copper Show (Lat. 16°51', Long. 124°22').

This is situated about four miles west of Mondooma Yard in a westerly trending belt of schist hills rising to 150 feet above plain level. Schist hills outcrop to the south and west, and granite gneiss some quarter mile to the north and northwest. Copper staining is visible over about half the length of a quartz reef which can be traced for about 420 yards near the summit of the ridge. The reef is sub-parallel to the surrounding schists, and the quartz is frequently idiomorphic. Over the copper stained section the reef varies from three to fifteen feet in width, but is barren over the greater portion of the width. Primary copper mineralization appears to be confined to erratically lensing, soft, iron-stained and kaolinised portions up to two feet wide, from which carbonates have been distributed as green films by the action of surface water.

The richer portions have been opened by blasting, and a shaft sunk to ten feet in depth, but these failed to expose mineralization of economic grade. No sulphides were seen, and it would be impossible to handpick the ore to a grade of 20% Cu due to its disseminated character.

None of the known occurrences in the Mondooma-Mt.Nellie area warrants further development, but it is probable that further copper-bearing quartz reefs are present in this belt.




## WEST KIMBERLEY. W.A.

## LIMESTONE SPRINGS COPPER SHOW

SCALE

50 0 50 100 150

FEET

To accompany Prospecting Party Report – Kimberley Area – September 30th 1953.

(5) Limestone Springs Copper Show (Lat. 16°56', Long. 124°28').

About two miles northwest of Limestone Spring, which is about twelve miles from Mondooma waterhole, some work has been done on traces of chalcocite and copper carbonates in a poorly defined belt of amphibolite and mica schist. An inclined shaft about twenty feet deep, a trench about twentyfive feet long, and a costean (refer plan) have all indicated slight copper mineralization and some boxwork over a length of some four chains, but the intensity of mineralization does not appear to be sufficient to warrant further testing.

(6) Ord Gap Pandanus Creek (Lat. 17°35', Long. 125°55').

Copper minerals have been reported from this locality but no details are known.

(7) Moola Bulla - Mt. Amherst (Lat. 18°20', Long. 127°17').

Guppy and Matheson reported finding a floater of copper ore of moderate grade along the telegraph line southwest of the Upper Proterozoic outlier on Moola Bulla Station; this presumably came from a lode in gneisses of the Lamboo Complex.

(8) Corkwood - Frank River (Lat. 17°18', Long. 128°11').

In the area around Corkwood yard, east of Mabel Downs Station a belt containing small quartz-pyrite-copper lodes extends over a strike length of some five miles; some copper bearing dolerite lodes are also present, and some copper-carbonate-garnet and copper carbonate-flake graphite lodes are also known. The area warrants more detailed prospecting.

(9) Frog Hollow (Lat. 17°16', Long. 128°3').

A small quartz vein, containing oxides and carbonates of copper, occurs two miles southeast of Frog Hollow; it is of no economic interest.

(10) The Palms: (Lat. 17°45', Long. 127°50')

A small copper bearing lode occurs a few chains from "The Palms" windmill, but is of no economic interest.

(11) Alice Downs (Lat. 17°45', Long. 127°50').

A small quartz-copper carbonate vein outcrops beside the Roses Yard-Alice Downs track about four miles from Roses Yard.

(12) Mt. Slencke (Lat. ? 17°42', Long. ? 128°5').

Copper ore has been produced from a lode probably about fifteen miles northeast of Alice Downs, believed to occur near the old Alice Downs-Turner pack road. The lode contains cuprite, chalcocite and carbonates of copper, but no information on its size is available, nor is its exact location known to the author.

(13) McHales Copper Show (Lat. 17°6', Long. 128°17').

Some eight miles from Turkey Creek and about two miles south of the Turkey Creek-Texas Downs track, copper mineralization occurs along shears in granite and porphyry. The mineralization consists of malachite and chalcocite in small lenticular bodies and seams in joint planes in the granite gneiss and porphyry. The mineralized sections sometimes show flat dips, but true widths are only of the order of a few inches except for small local pockets. Some thin boxwork bearing quartz veins, and some siderite veins, also occur, but costeaning failed to reveal copper mineralization in these.

No production can be expected.

(14) Mt. Evelyn Range-Smoky Creek Area (Lat. 16°37', Long. 128°28').

A prominent fault zone striking northeast which terminates the Mt. Evelyn Range on the western side, has been mineralized with quartz over a width of some hundreds of yards. The quartz is locally stained by oxides of iron and manganese, and carries traces of copper carbonates on small joint planes; copper carbonates also occur in shear planes in the granite. Some chalcopyrite and pyrite grains are present, but no defined lode gossans are known.

(15) Dougall's Well: (Approx. Lat. 17°36', Long. 127°58').

Some thirteen miles south of Dougall's Well, near the telegraph line, copper carbonates occur as surface stainings and on narrow shear planes in dolerite and actinolite rocks. The dolerites also contain large crystals of magnetite and these reach an appreciable percentage of the rock in some portions. The copper minerals probably represent a surface enrichment of disseminated copper minerals emplaced as a magnetic differentiation of the doleritic magma. The richest surface specimens assay up to 1.7% copper.

(16) Other Localities:

Copper minerals have been reported from the following localities:

Elvire River, Halls Creek, Argyle Downs, Margaret River, Ruby Creek, Panton River, Mount Dockerell.

Many of these occurrences represent minor amounts of copper minerals associated with gold-bearing quartz veins.

(b) Deposits in Lower Adelaidean Rocks.

(1) Coppermine Inlet. Copper minerals occur in quartz porphyry intrusive into the Yampi Beds on the shores of Coppermine Inlet (Lat. 16°14', Long. 123°36'). The lode is up to six feet wide and consists of quartz and sericitised and carbonated quartz porphyry, and probably occurs in a shear zone. The copper minerals are chalcocite and copper carbonates. Up to 1918, 92.86 tons of 22.8% Cu ore were produced, but no data are available on the amount or grade of ore remaining. So far as known the deposit has not been worked since 1918.

(2) Karunjie (Lat. 16°17', Long. 127°9').

Copper minerals have been discovered on Karunjie Station by the owner Mr. Dave Rust.

The copper occurs as chalcocite and copper bearing pyrite, with calcite and quartz, associated with doleritic rock interbedded with or intruding the Pentecost Sandstone. The copper bearing rock was not observed in situ, but boulders of it occur over an area of black soil about five miles west of Karunjie Homestead, and also southeast of the station; the proportion of copper bearing boulders to barren dolerite boulders is small, and the average grade of the float is not high, but specimens assay up to 15% Cu. The deposit is probably similar to other dolerite-basalt copper


CAMPBELLMERRY COPPER DEPOSIT
NEAR KARUNGIE H.S. – WEST AUST.
GEOLOGICAL MAP
Scale: 1 Inch = 100 Feet
LOCALITY
GEOLOGICAL MAP
Scale: 1 Inch = 60 Chns.
Part of BLUFF FACE RANGE
Mainly soil with some sandstone outcrop
Rough flat sandstone outcrop
Mainly sandstone outcrops
Rough SS outcrop
GORGE
Some Cu carbonate paint on joints in the sandstone in gorge 50 feet deep
Coongena Creek
SECTION AB
Scale 1" = 10'-0"
6" seam with some Cu staining.
2" Cu carbonates and oxides.
Sample 1D over 4' Cu carbonates veinlets – 6.45% Cu and stains in sandstone.
Sample 1A over 1'6" lode – 19.49%
Sample 1B over 2'3" – 4.96% Cu Cu stained sandstone.
Sample 1C over 6' – 1.02% Cu barren sandstone.
Lode
Sample 4A situated 1900' SW of EF 6.32% Cu
Specimen 5 / Specimen 6 From parallel lode 600' WSW of EF
SECTION CD
Scale 1" = 10'-0"
Soil and rubble
Barren sandstone and float.
Sample 2C over 9' Sandstone with odd veinlets of Cu carbonates. 2.43% Cu
Sample 2B over 9'3" Cu carbonate - stained sandstone with some veinlets of carbonate and oxides of Cu 3.58% Cu
Sample 2A sandstone with carbonate stains and oxides 7.37% Cu
Barren sandstone
Soil and rubble.
SECTION EF
Scale 1" = 10'-0"
Sample 3A over 2' – 6.69% Cu Lode of brecciated SS, silica, Cu, oxides and carbonates.
Soil & barren sandstone
Barren, no carbonates in costean.
Soil.
Sandstones
M.N.
Rough sandstone o/c and soil with laterite gravel.
Rough sandstone outcrops in shallow soil and laterite gravel
Soil
Scree and boulders
Some Cu stained float
Sandstone outcrops
Some sandstone outcrops
Sandstone outcrops
Siliceous lode float. No Cu.
Soil float and poor outcrop
This area mainly shallow soil and float, but some sandstone outcrops. No apparent lodes.
No further traces of Cu found along this line.
Sample 4A from best outcrop 6.32% Cu over 2'6"
40' x 2' to 6' of Cu stained quartzite with small quartz-oxide lodes.
Some flat sandstone outcrops with shallow soil.
Sandstone outcrop
Some scree
Some Cu stained sandstone close to reef
Floaters of quartz reef. No copper.
Sandstone outcrop
Poor to no outcrop
Some soil cover
Soil and float
Creek
Rough sandstone outcrop
Siliceous copper bearing lode 6" to 18" wide. Specimens of good Cu ore. 18.51% Cu
Rough sandstone outcrops with shallow soil and laterite gravel
Sandstone
Traces and thin veins of Cu on joints
5' x 6" @ about 30% Cu quartz-copper reef. – Specimen 5 comparable in grade.
Minor copper on joints.
SECTION A
SECTION C
SECTION E
1000 1100 1200 1300 1500 1600 1700 1800 1900 2000 2100

deposits in the Kimberleys, i.e., it occurs as steam-hole fillings, or as scattered lenses formed by the concentration of copper in the late magmatic fluids of the cooling lava or intrusive. The probability is therefore that the copper minerals do not occur as a defined lode, and this, combined with the difficulty of finding the float source under (apparently) deep black soil alluvium, discourages any further work.

(3) Plants (Lat. 16°23', Long. 127°40').

At Plants (Afghan's) Homestead a series of gently dipping shaly and silty beds with thin sandstone layers outcrops; the sandstones exhibit typical shallow water features.

Minor veinlets of copper carbonates, oxides and chalcocite occur in the siltstones a few chains south of the homestead in an area of several square chains. Individual veins do not exceed four feet in length and three inches in width; their origin is not apparent.

The beds may be the upper portion of the Pentecost Sandstone, or they may be Mt. House beds.

(4) Campbellmerry: (Lat. 16°11'; Long 127°36').

This deposit in Pentecost Sandstone was found by Mr. D. Rust in about 1956. It consists of narrow veins of siliceous lode carrying copper oxides and carbonates. These veins occur discontinuously and in an en echelon manner along a general shear trending northwest, and traces of copper can be found over 2,000 feet length. Leaching by rainwaters and subsequent precipitation has caused copper carbonate staining in the sandstones for widths of several yards from the "primary" veins. The main veins never exceed two feet six inches in width, and are usually less than this; the assays of samples shown on the sections, and the plan accompanying this paper, illustrate the occurrence. No single vein exceeds 50 feet in length.

The host rock is fairly pure sandstone, which is mainly flat lying although dips of up to 5° occur. In a gorge of Campbellmerry Creek forty chains south of the main deposit, copper carbonate paint occurs on joint planes in the massive to well bedded sandstone; the occurrences are rare and sporadic.

The lodes as exposed in the sandstone are not extensive or high enough in grade to warrant working on a large scale or even by gouging. It is, however, possible that they may be richer and more continuous in depth should a shale or dolerite bed underlie the unfavourable sandstone host rock. With this in view a search was made of the surrounding area for change in rock types, but without success even in the deeper gorges; sandstone will form the host rock to at least 200 feet below outcrop level. The known Elgee Shale horizon will occur at a depth of the order of a thousand feet, but it is not thought that the chances warrant drilling to this depth.

The source of the mineralization is doubtful - it is possible that it was derived from a dolerite intrusion into the sandstone at depth; no mineralization of definite granitic origin is known near this horizon, although copper mineralization associated with dolerites is widespread.

(5) <u>Tableland - Elgee Cliffs</u> (Lat. 12°15', Long.127°7')

About twenty-three miles northeast of Tableland station, just north of the head of the Chamberlain River and the Tableland-Elgee Cliffs Station track, a dolerite dyke intrudes the Elgee Shale. The dyke runs approximately north-northwest, can be traced for about eight chains, and is up to thirty feet wide. The shales at the sides and roof of the dyke have been baked at the contact, and thin veins of chalcocite up to a foot long and quarter of an inch wide have impregnated the contact zone; secondary carbonates have stained the shale for widths up to a foot.

It appears that this dolerite may be comagmatic with the dolerite of the Karunjie area; assuming that the chalcocite of the Elgee occurrence is derived from the dolerite, the inference is that the magma in this area was rich in copper minerals. Although the occurrences inspected by the writer do not appear to be economic, it is possible that further prospecting on dolerite sills (or ? flows) may reveal larger low grade concentrations of copper minerals.

(6) Speewah (Lat. 16°21', Long. 127°57').

Copper minerals, mainly carbonates and chalcocite, were identified by the writer in specimens collected from the Speewah area. The occurrences were not inspected. It is probable that the minerals occur under similar conditions as at Karunjie, and are associated with the large laccoliths of dolerite and diorite of the Speewah area, although some specimens appear to be from well defined quartz reefs.

(7) Mt. Hart (Lat. 16°55', Long. 125°3').

Thin quartz lenders carrying copper carbonates occur near Old Mt. Hart Homestead; they are associated with diorites and syenite sills of the Hart Dolerite.

(8) Copper Minerals in Mornington Volcanics:

Copper minerals have been widely reported from the Mornington Volcanics; minerals identified include bornite, chalcocite, chalcopyrite and malachite. No details of the mode of occurrences are known, but the minerals probably occur associated with the quartz and quartz-epidote reefs and as vugh fillings formed by late volatile phases of the solidifying lavas, as was observed on minor occurrences in the Carson River area (Lat. 15°5', Long. 126°45').

Copper minerals have been reported from the following localities in the area of outcrop of the Mornington Volcanics.

| | |
|---|---|
| Doubtful Bay | (Lat. 16°00', Long. 124°30') |
| Brecknock Harbour | (Lat. 15°30', Long. 124°40') |
| Cape Bougainville | (Lat. 13°54', Long. 126°07') |
| Boneaparte Archipelago | (Lat. 14°30', Long. 124°30') |
| Augustus Is. | (Lat. 15°20', Long. 124°30') |
| Camden Sound | (Lat. 15°27', Long. 124°25') |
| Glenelg River | (Lat. 15°40', Long. 124°48') |

(9) Additional Localities:

Copper minerals are also reported from Collier Bay and Water Point on the Yampi 4-mile sheet.

(c) Deposits in Upper Adelaidean Rocks.

(1) Tableland-Dingo-Rockhole-Police Creek: (Lat. 16°47', Long. 126°27').

The Walsh Tillite in the upper Traine River and Police Creek areas is overlain by banded shales which grade laterally into limestone. Near the base of the limestone a band of dolomitic limestone up to six inches thick is distinguished by the abundance of dendrites, its pink colour, and by the occurrence in it of nodules of chalcocite up to two inches by one inch. The copper appears to be confined to these nodules, and to some secondary carbonates in small joint planes adjacent to them; the nodules are erratic in distribution, but they can be found at intervals over a strike length of more than five miles near the head of Police Creek. No sign of hydrothermal mineralization or metamorphism occurs in the limestone or the underlying till, and it is probable that the chalcocite is of sedimentary or organo-sedimentary origin.

This occurrence of copper is of academic interest only as the chalcocite nodules are not present in sufficient quantity at any locality to give the dolomite an economic grade.

(2) Additional Localities:

Copper minerals have been reported from near the Carlton Crossing of the Ord River on Ivanhoe Station (Lat. 15°33', Long. 128°32'), and from Forrest River; no details of these occurrences are known, but it is thought that they occur in shales of Upper Proterozoic age.

(d) Deposits in Antrim Plateau Basalts.

(1) Native copper, Denham Station (Lat. 16°37', Long. 128°22'). Just to the east of the Northern Highway at a point about two miles north of the Denham River crossing, boulders of prehnite containing small pieces of native copper occur on several low hills of flat lying Antrim Plateau Volcanics. The boulders were not observed in situ, but are believed to have weathered out of the basalt, where they occurred as fillings of steam-holes by late magmatic volatiles during solidifcation of the lavas. The

boulders are up to several feet in maximum diameter, and are more resistant to weathering than the enclosing basalt. During 1955 most of the boulders were gathered, knapped and put into three 44-gallon drums preparatory to shipping; the author is not aware of the person who produced this ore, nor of the grade of the parcel. The small amounts of native copper present in the rock indicate that the grade would not exceed 5% Cu, and might be considerably less.

(2) Native Copper, Rosewood Station: (Lat. 16°23', Long. 129°04').

Prehnite boulders containing native copper occur on the slopes of a hill above two and a half miles east of the six-mile (or No. 6) bore which is situated north-northeast of Rosewood Station. The boulders are lighter in colour than the dark brown-grey basalt developed in the area, and show a cellular surface; they can be traced around the hill for about five chains, but do not occur at the summit. Some boulders are up to two feet in diameter, but the average is about six inches, and none were found in situ; their copper content varied from plentiful filiform pieces of native copper to rare pinhead sized pieces, and a small specimen of moderate to low grade rock assayed 0.33% Cu.

The distribution of the boulders is consistent with that which would be expected if they were formed as steam hole fillings in a flow top of the flat lying basalt, although the latter is not markedly vesicular in this area. However, a small cherty vesicle-filling, occurring in situ in grey fine-grained dense dolerite basalt, was found to contain a small piece of native copper, and this suggests that the larger prehnite boulders have a similar origin.

(3) Sundry Native Copper Occurrences: Native copper has been reported from Bluehole Yard (Limbunya Station), Turner Station and R-B Creek, but these occurrences could not be verified.

(4) <u>43-Mile Copper Deposit</u>: (Lat. 18°26', Long. 129°24').

About 43 miles south of Mistake Creek Station on the Inverway road, the author found a small chalcocite-quartz veinlet in agglomerate (or a brecciated flow top). Costeaning revealed an ill defined lode of quartz crystals, cherty quartz, and chalcocite enclosing pieces of agglomerate; the "lode", up to eighteen inches wide, could be traced for only about forty feet, and appeared to cease in depth on a more massive flow or section of flow. The agglomerate or basalt in this area is characterised by cherty quartz encrustations, and large vughs filled with quartz crystals and zeolites; the vugh fillings become separated by weathering, and occur scattered on the surface as rounded or elliptical "boulders;" they are frequently covered by a coating of green and blue chlorite minerals, which sometimes resemble copper carbonates; these blue minerals also occur disseminated in the basalt or agglomerate. Certain of the vesicles contain fillings of banded chert which sometimes show a small core of chalcopyrite.

(5) <u>Byrnes Hill - Behn Gorge</u>: (Lat. 16°27', Long. 128°52') (Lat. 16°24', Long. 129°6')

Disseminated copper carbonates were found in a shear zone, and in vesicular basalt, near Byrnes Hill and in the Behn Gorge. The copper is associated with calcite and cherty quartz; the amount of copper present is very small.

(6) <u>Denham Station</u>: (Lat. 16°15', Long. 128°20').

About ten miles north-northeast of Denham Station, just west of Conglomerate Range, traces of copper minerals occur in agglomerate and silicified agglomerate.

(7) <u>Wild Dog</u>: (Lat. 16°47', Long. 128°53').

West of Wild Dog spring on the Rosewood-Spring Creek road, chalcopyrite grains occur as the cores of banded chert fillings of vesicles; the fillings are coated with blue and green chloritic minerals.

(8) <u>Rosewood Wall</u>: (Lat. 16°29', Long. 128°58').

A sample cut across the top six feet of the Volcanics at the Rosewood Wall assayed 0.6% Cu. The material sampled contained red and blue chloritic minerals but no visible copper minerals. Samples cut from the same horizon half a mile to the south assayed 0.1% Cu over nine feet, the upper three feet of this assaying 0.53% Cu. Samples cut over twelve feet below the previously quoted top six feet contained no copper.

Assays of the top agglomeratic horizon of the Antrim Plateau Volcanics in other areas failed to show any significant copper content; from the presumed mode of origin of the copper minerals in the Volcanics, large concentrated lodes are not to be expected, and the disseminated copper mineralization appears to be too low grade and restricted to be of economic interest.

(9) Collia Volcanics (Lat. 14°22', Long. 130°55').

These volcanics are of doubtful age, being possibly younger than Cambrian.

Hossfeld quotes an assay of a sample from near Collia as 0.06% Cu.

(e) DEPOSITS IN NEGRI GROUP.

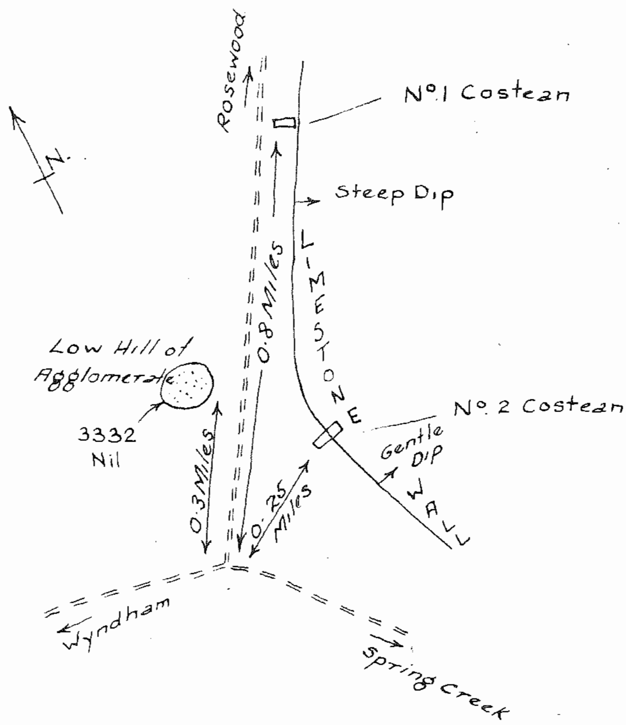
Minor copper stainings are very common in the basal limestone member of the Negri Group in the Hardman and Rosewood Basins. The richest occur in portion of the Rosewood Fall, and near Lissadell Station, but smaller and poorer occurrences were seen in the Lissadell limestone walls, near View Hill, in R-B Creek, and elsewhere. This widespread stratigraphic occurrence of copper minerals is of academic interest, and the following is a summary of the known characteristics of the mineralization.

(a) The mineralization consists of chalcocite nodules, generally elongated along the bedding; chalcocite disseminations parallel to bedding, and copper carbonate and atacamite films along the bedding or on minor joints.

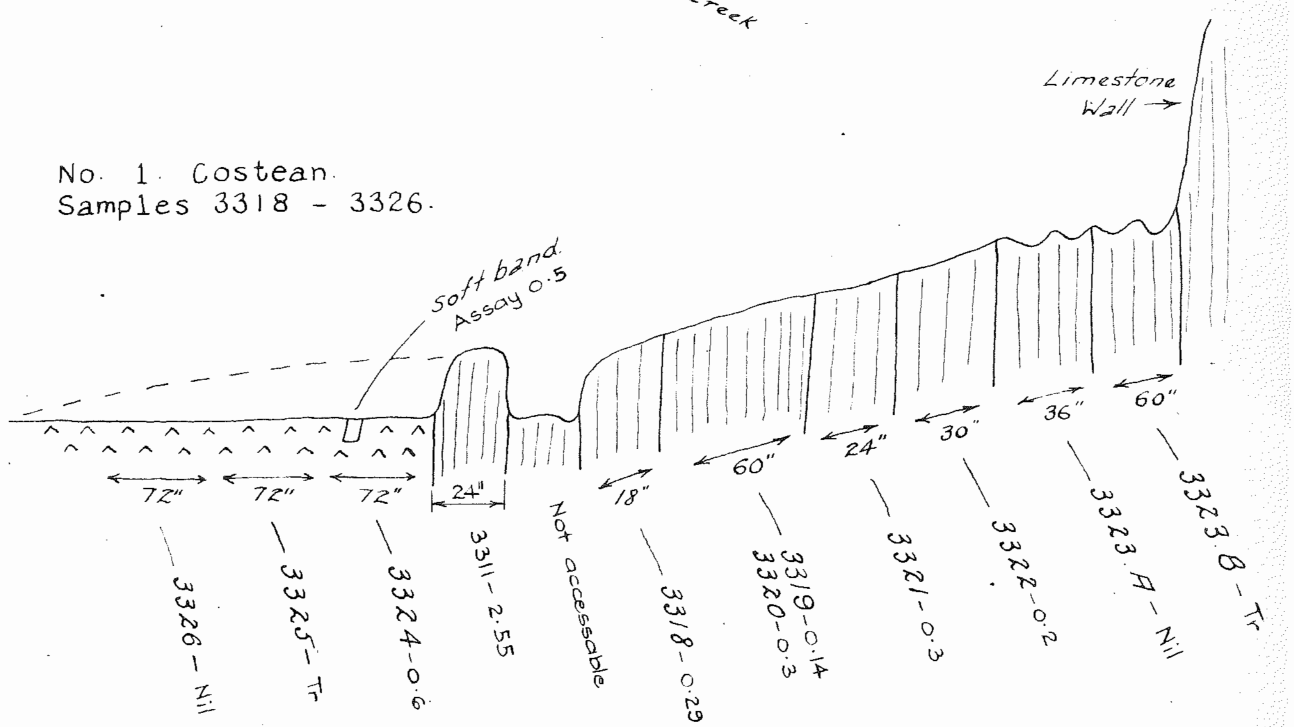
(b) The copper minerals are commonly present only in a zone six inches to four feet wide, at the base of the Headleys Limestone, i.e., immediately adjacent to the limestone-volcanics contact; however, in some areas they occur as scattered blebs over some seventy stratigraphic feet of limestone, and Matheson and Teichert (1946) reported copper minerals from a limestone bed some hundreds of feet above the base of the Negri Group.

# ROSEWOOD LIMESTONE WALL

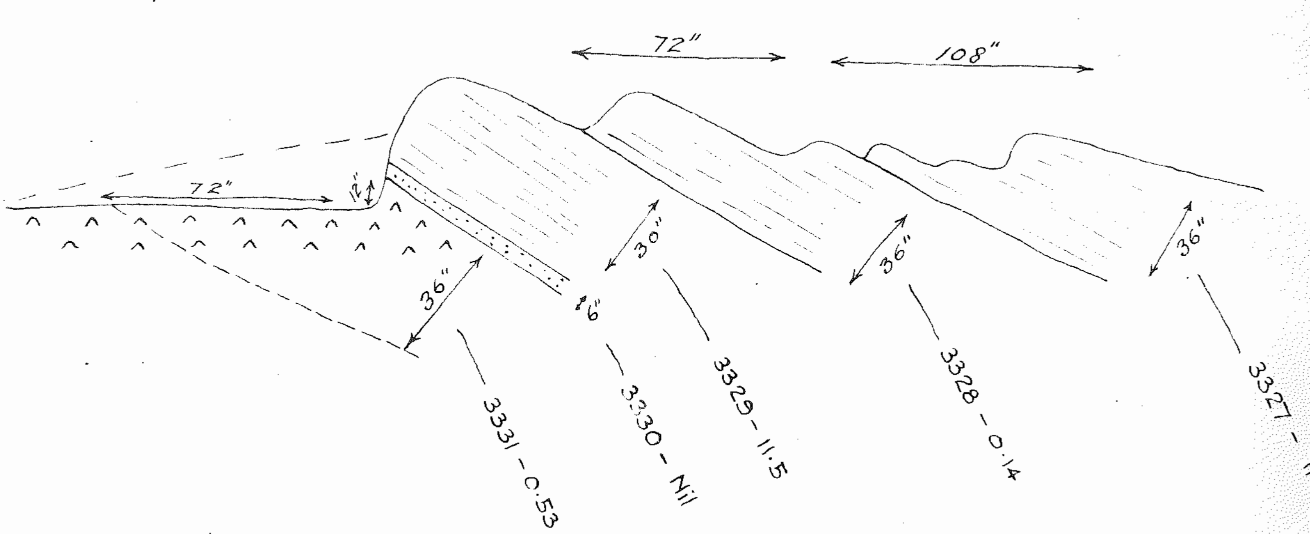
Assays % Cu




No. 1. Costean.
Samples 3318 – 3326.




No. 2. Costean.
Samples 3327 – 3331.




Sample 3332 :
Agglomerate west of Rosewood road, 0.3 miles from turn-off.
Sample from pit, 18" deep.

(c) Copper minerals have been found in the limestone where it is vertical, steeply dipping, or horizontal, i.e., the occurrences are not controlled by structure.

(d) Major joints do not appear to exert any marked influence on the distribution of the mineralization.

(e) Copper minerals occur sparsely in the underlying volcanics; the upper volcanics are relatively permeable to ground waters.

Matheson and Teichert suggest that the copper has been leached from the volcanics by surface waters and "fixed" by the relatively reactive limestone. Alternatively the copper may be of sedimentary origin, being deposited from water somewhat richer in copper due to volcanic action.

The two major occurrences are:

(1) Rosewood Limestone Wall: (Lat. 16°29', Long. 128°58').

Discontinuous copper staining is present on the northwest side of this "wall" over a distance of about three miles; the mineralization is patchy, and while assays of up to 15% copper over thirty inches were recorded from shallow pits and surface outcrops, much of the "wall" contains little if any mineralization.

Fig. shows the sampling and assay results on costeans and indicates the general distribution of values.

(2) Lissadell: (Lat. 16°32', Long. 128°42').

North of Lissadell Station and about a mile east of the road crossing of the Ord River, the basal limestones outcrop in the north bank of the Ord River. Immediately overlying the volcanics the limestone has a fair to good copper content over about six inches, and the mineralization can be traced for about ninety feet; the limestone is flat-lying.

## (f) Deposit in Devonian Rocks

Traces and thin veinlets of chalcocite and copper carbonates have been found scattered throughout the outcrop area of the Devonian limestones, notably in the Fossil Downs, Geike Range, Napier Range, and Oscar Range areas. None of the occurrences is economic.

## X. TIN, TUNGSTEN, NIOBIUM - TANTALUM:

Small deposits of tin occur in the Clara Hills, Silent Valley, Dyason's Creek, Mt. Dockerell and Bulldiva - Collis areas. Wolfram and scheelite occur associated with, and near, the tin lodes at Clara Hills (King Sound), and columbite occurs at Mt. Dockerell. The Bulldiva-Collis field, which has produced small tonnages of tin, is just outside the area examined by the writer but is included for completeness as it has a bearing on the area near Gregory's Bar on the lower Fitzmaurice River. The occurrences are all in rocks of the Lamboo Complex or Hall's Creek Metamorphics.

(1) Clara Hills (or King Sound or Wolfram Hill) Tin-Wolfram Deposit: (Lat. ? 16°59', Long. ? 124°42').

This deposit is some 120 miles from Derby, and is situated on a razor backed ridge; it consists of narrow quartz reefs bearing small crystals of wolfram and cassiterite and the hydrous ferrous arsenate scorodite; individual reefs rarely exceed a foot in width, but parallel reefs occur in a zone a chain wide and about 1,300 feet long; the reefs are sub-parallel to the enclosing schists and amphibolites, and are nearly vertical, striking about 15 degrees north of west.

The following openings have been made in the reef zone, at the crest of the ridge:

(a) No. 1 open cut near the western end of the hill. Two veins separated by twentyfour to thirty inches of slate, have been open cut over a length of 135 feet.

(b) Sixty feet east of the No. 1 open cut an attempt has been made to extend a trench across the full width of the zone, and cuts have been put into the north and south sides of the hill, but these are thirtyfive feet apart. Six small veins ranging from one to four inches in thickness are exposed in a width of twelve feet in the second open cut (No. 2 open cut) and four small veins occur in a width of twenty feet in the northern cut. The largest vein in the southern cut has been trenched along its outcrop for a length of 70 feet to a maximum depth of 15 feet, and contains wolfram and scheelite. A little wolfram occurs in the northern cut.

One hundred and eighty feet further east a narrow vein containing wolfram has been opened up over a length of eighty-five feet (No. 3 open cut).

At the eastern end of the hill a vein three inches wide and containing large pieces of wolfram, has been open cut over a length of twentyfive feet. (No. 4 open cut).

The best veins were channel sampled (by the A.G.G.S.N.A. party) at regular intervals along the exposed length and the cuttings combined to form representative samples of each vein. The results were:

(1) No. 1 Open Cut:

(a) South vein.

Seven samples were cut at ten foot intervals over a length of sixty feet and assayed 2.16% $SnO_2$ and 0.27% $WO_3$ over an average width of eight inches.

(b) North Vein.

This vein was sampled at ten foot intervals over a length of forty feet, the average assay of five samples being 2.82% $SnO_2$ and 0.26% $WO_3$ for an average width of eleven inches.

(2) No. 2 Open Cut:

The vein in this cut was sampled at five foot intervals over a length of fifteen feet and assayed 0.40% $SnO_2$ and 0.30% $WO_3$ over an average width of six inches.

(3) No. 3 Open Cut:

Eight samples were cut at intervals of ten feet over a length of seventy feet and averaged 1.26% $SnO_2$ and 2.02% $WO_3$ over a width of three inches.

After geologists of the A.G.G.S.N.A. reported on the occurrences, some exposed wolfram-tin "dollying stone" has been quarried and (when the writer visited the mine in 1953) little of these minerals was visible on the faces or dumps. The presence of scorodite probably indicates the presence of arsenopyrite in depth and this mineral would incur penalties if present in concentrates.

Opposite the eastern estremity of the ridge, J. Stewart recently loamed up to and sunk a ten foot shaft on a quartz reef patchily mineralized with arsenopyrite and scheelite. A few scheelite specimens were recovered, but no economic quantity of the mineral exists; the presence of an undiscovered scheelite bearing vein so close to the main wolfram lode suggests that little if any intensive prospecting of the surrounding area was done by the lessees of the King Sound mine.

(2) Silent Valley: (Lat.?16°53', Long. ? 124°39')

About five miles in a general northeasterly direction from the Clara Hills mine the amphibolites, schists and dolerites give way to granitic and more basic igneous rocks. In the region of the headwaters of a north flowing gully within this granite there are pockets of cassiterite-bearing wash which carry up to three pounds of cassiterite to the dish; further down the gully larger quantities of wash under some three feet of alluvium carry about an ounce of cassiterite to the dish.

The wash has been traced to small quartz leaders, one to two inches wide, which carry rich specimen cassiterite on their walls, and to a few very thin seams of cassiterite in greisen.

The richer pockets have been worked by the discoverer, J. Stewart, and about a ton of cassiterite has been recovered. Water supplies are lacking, except during storms in the wet season, and this precludes working the lower grade material.

The adjoining creeks and gullies for about five miles to the northwest have also been prospected by Stewart, and at least one of them contains amounts of cassiterite comparable with the above. This area is inaccessible except on foot, and also suffers from lack of water except immediately after rain. It has not been worked.

(3) Dyason's Creek: (Lat. 17°34', Long. 125°14').
(See A.G.G.S.N.A. Rep. W.A. No. 44)

Cassiterite occurs in this area in a small alluvial area approximately 300 yards by 80 yards, and as isolated crystals in pegmatites.

The alluvial ground has been tested by thirteen small pits, and a bulked sample from these pits yielded 0.18 ounces of concentrate from 1.25 c.ft. of wash, equivalent to 0.12 pounds of concentrate per cubic yard.

The pegmatite reef sampled by the A.G.G.S.N.A. strikes northeasterly and outcrops over a total length of 350 feet; nine samples taken at forty foot intervals averaged 0.09% $SnO_2$ over fourteen inches.

The author found an additional pegmatite lens carrying rare crystals of cassiterite some distance east of the one sampled by the A.G.G.S.N.A. It is probable that further small cassiterite bearing pegmatites are present in this area, but there is little chance of finding economic deposits.

The pegmatites occur in a belt of granite and granite gneiss with amphibolite and dolerite; to the north these rocks give way to schists, etc., the more or less linear contact trending east-west; in the areas seen by the author no junction between these rocks was observed due to cover, although just north of the main contact zone minor bodies of porphyry are intrusive into the schists. The general trend of the metamorphics in the adjacent area is sub-parallel to the contact; the dolerites etc. trend northwesterly at an angle to the contact.

(4) Mount Dockerell: (Lat. 18°55', Long. 127°14').
(See A.G.G.S.N.A. Rep. W.A. No. 30 and Blatchford (A.R.P. G.S. of W.A. 1929.

A cassiterite bearing pegmatite dyke, and several patches of alluvium containing cassiterite and columbite occur in this area, mainly in the drainage system of Columbium Creek. The area is unlikely to repay working as is shown by the following sampling results:

| Sample No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Length of Creek Sampled (ft.) | 800 | 900 | 1,100 | 500 |
| Number of pits | 16 | 10 | 12 | 6 |
| Average depth of wash (ins.) | 24 | 24 | 12 | 24 |
| Depth of wash sampled (ins.) (lower portion) | 6 | 6 | 6 | 6 |
| Calculated content of concentrate in lbs./cu/yd. | 0.93 | 0.32 | 0.10 | 0.17 |
| Assay of Concentrates | % | % | % | % |
| $SnO_2$ | 74.3 | 69.3 | 7.3 | 60.6 |
| $(TaNb)_2O_5$ | 20.0 | 22.3 | 72.4 | 27.9 |
| Present as cassiterite | 75.8 | 70.7 | 7.4 | 61.8 |
| " " columbite | 24.1 | 26.9 | 67.2 | 33.6 |

Crystals of cassiterite up to 0.75 inches in length occur in a pegmatite dyke adjacent to the creek from which No. 1 sample was obtained. Large pieces of lithiophyllite (phosphate of lithium, iron and manganese) were found in the same dyke.

Numerous pegmatite intrusions occur in slates, shales, quartzites and grits of the Hall's Creek Metamorphics.

Water is scarce except immediately after heavy rains.

(5) Buldiva - Collia: (Lat. 14°22', Long. 130°55'- (See AGGSNA. Report N.T. 18)

Production from this field is probably of the order of 100 tons of concentrates. The geology of the field is described in the above report, and the author has followed the general geology, as described, by marking it on aerial mosaics by eye and making adjustments as seemed necessary; he has not checked the area in the field or stereoscopically on airphotos.

The cassiterite occurs in pegmatites, younger (Jurassic?) conglomerates, and as alluvial, and deposits of each of these types have been worked, although the alluvial deposits are perhaps the most important.

The pegmatites occur in schists, granulites and granite. The average of thirteen samples taken from the pegmatite lodes of the Buldiva field was 0.65% Sn over thirty inches.

Most of the rich alluvial ground has been worked out but some payable ground remains. Water supplies in the area are limited except during and after heavy rains.

(6) Lower Fitzmaurice River: (Gregory's Bar) (Lat. 14°47', Long. 130°8').

It has been rumoured that cassiterite occurs near Gregory's Bar on the Fitzmaurice River; a short reconnaissance of the area to the south of the river by the author revealed granitic rocks and rare thin pegmatitic veins in a narrow valley between younger sandstone formations. Panning of creeks in this area did not show any cassiterite. The author was unable to visit the valley to the north of the Fitzmaurice, and it is possible that the cassiterite reported came from this area which, judging from airphotos, also contains granitic and schistose rocks similar to those of the Ruldiva-Collis area to the northeast.

(7) Bow River Area: (Lat. $16^{\circ}50'$, Long. $128^{\circ}20'$).

Cassiterite has been reported from the area west of Mt. Pitt and near the junction of Turkey Creek with the Bow River. The author was unable to verify these reports, and it is probable that the "cassiterite" was black iron sand which is common near some of the basic rocks in the area.

Cassiterite was also reported from Smoky Creek, to the northeast of this area, but panning of creeks in this area failed to verify the reports.

(8) Mt. Broome:

Cassiterite has also been reported from near Mt. Broome, on Leopold Downs, and in the valley of the Richenda River. No details are known as to exact locations.

Summary:

None of the cassiterite, columbite or wolfram-scheelite deposits in the area are suitable for large scale mining, and the only field of interest for production on a limited scale is the Ruldiva-Collis tin field. It is unlikely that large deposits will be found.

Scheelite may occur in the calc-silicate marbles of the Hall's Creek Metamorphics where these have been affected by igneous activity, but testing of these rocks has yielded no encouragement so far. It is unlikely that prospecting for scheelite has been thorough, and it is probable that many small scheelite bearing lodes remain to be found, especially in the West Kimberley.

XI. LEAD-ZINC-SILVER:

Minerals containing these metals are found in small quantities in many localities. The Devonian, or Narla, lead mine was one of the few working mines in the Kimberley, and produced lead-zinc ores which annually exceeded the value of any other mineral produced at that time, other than hematite. The drop in lead prices has caused a cessation of mining.

(a) Deposits in Lower Proterozoic Rocks:

(1) Mount Amherst: (Ref. AGGSNA. Rep. W.A. No. 31)
(Lat. 18°18', Long. 126°57').

Several quartz-carbonate veins containing galena and cerussite occur on Mt. Amherst Station. The largest vein is about eight miles north of the homestead, and outcrops over a length of 350 feet, the northern extension disappearing under alluvium. The outcrop has a maximum width of twelve feet; the granite on the western wall of the vein is partly kaolinised over a width of up to thirtyfive feet, and contains irregular lenses of galena. One sample of the vein at the northern end assayed 15.69% Pb and 2.34 oz. Ag per ton over a width of fifty-two inches; another from the middle of the outcrop assayed 7.27% Pb and 1.45 oz. Ag per ton over a width of twelve feet.

Since the A.G.G.S.N.A. inspection, about ten tons of 75% lead ore have been produced from this vein, and it is reported that it narrowed rapidly in depth (Pers. comm. Messrs. Black and Glidden, Mt. Amherst Station).

One mile south of the homestead lead ore has been obtained from a pit on a narrow vein of quartz and calcite, and several of the quartz reefs in this area contain small quantities of galena and chalcopyrite.

The major deposit occurs in granite of the Lamboo Complex; it is thought that some of the minor occurrences occur in sediments of the overlying/Lower Adelaidean.

The deposits may profitably yield small quantities of hand picked ore during periods of high lead prices; as they are situated 350 road miles from Derby freight costs would prevent exploitation during periods of low prices.

(2) Boxers Lead-Barytes Show, Argyle Downs:
(Lat. 16°21', Long. 128°41').

This deposit occurs in granite about six miles southwest of Argyle Downs.

The lode consists of barytes containing patches of galena, and is up to 12 inches wide. The lode strikes 20°, dips steeply, and can be traced for about twenty feet before disappearing under soil cover. The proportion of galena to barytes is about 1 : 10; minor amounts of brecciated country rock occur in the lode which is probably a filling of a minor fault.

(3) Alice Downs (Grant's Peak Area): (Lat. 17°44',
(Long. 127°56'

About six miles south of Alice Downs Station, near the telegraph line and about a mile from an old yard, a ten foot shaft and a number of small costeans and pits, sunk on an ironstone reef, have revealed cerussite and some pyromorphite.

The vein at the surface is largely made up of hard compact ironstone, but in the shaft cerussite becomes the dominant constituent of a lode twelve to eighteen inches wide. The lode is sub-parallel to the enclosing schists which strike 60° to 80° and are almost vertical; the lode dips southeast at about 45°, but portions of it have been displaced and perhaps dragged by post lode shears. Its continuation along the strike may be exposed in one of the pits twentyfive feet east of the shaft, which shows six to nine inches of ironstone with traces of lead minerals. Insufficient work has been done for evaluation.

Sections of the vein are weakly radioactive and counts of up to twice background were obtained.

The vein may prove a few tons of hi h grade oxidized ore, but is probably too small to provide any continuous production.

(4) Pandanus Creek: (Lat. 17°40', Long. 125°53').

A quartz vein containing galena occurs some ten miles north ofOld Leopold Station on the east bank of Pandanus Creek. It is thought to be similar to the vein described below.

(5) Old Leopold Downs: (Lat. 17°55', Long. 125°56').

A quartz reef with erratically distributed crystals and patches of galena occurs on the east bank of the Fitzroy River about three miles northeast of the Old Leopold Homestead site. The reef is usually about twelve to eighteen inches in width with a maximum width of three feet and can be traced with minor gaps for atotal length of about thirty chains, the strike being approximately north-south. The country rock consists of strongly sheared granite or granite porphyry with minor inclusions of schist.

(6) Margaret River: (Lat. 18°37', Long. 126°52').

Galena has been reported from Margaret River Station but no details are known; the galena may occur in Middle Precambrian rocks.

(7) Other Localities: Lead minerals have been reported from the following localities; Dixon Range, Mt. Dowera, "Mulla Mulla" Station (possibly Moola Bulla or Mulla Mulla), Osmond Creek, Turkey Creek, Ord river, Panton River, Hall's Creek, Mt. Dockerall, Grant's Creek, Barker River and Richenda River. It is possible that in many of these places minor amounts of lead minerals are associated with deposits of gold and other minerals.

(b) Deposits in Lower Adelaidean rocks.

(1) Speewah, or Martin's Silver Lead Mine: (Lat. 16°12', Long. 127°58')

(Ref. Blatchford A.P.R. G.S.W.A. 1927).

This mine lies about eighteen miles north of Speewah Station in the outcrop area of large laccoliths of gabbro, dolerite and more acidic rocks; the lead deposit, which consists mainly of quartz with a minor quantity of galena, strikes north-south and dips at a low angle to the east. The lode is practically free of overburden. The footwall is a coarse grained granitic rock which is probably a laccolith from which the roof-forming sediments have been completely denuded with the exception of a thin scale of baked sandstone and shale or tuff, fragments of which are common on the surface.

The deposit has been tested by a shallow shaft and several costeans, which show that the deposit is a remnant of a flat lying mineral segregation on top of the laccolith. The greatest thickness in any of the costeans is three feet six inches; galena, cerussite, malachite and azurite occur in scattered patches in the quartz, and some native silver is associated with the copper minerals.

Four samples taken from the costeans gave the following results:

| | Pb% | Ag oz. | Ag dwt. | Ag grs. | Cu % | Au dwt. | Au grs. |
|---|---|---|---|---|---|---|---|
| 1 Centre Costean sampled width 2 ft. at bottom | 3.87 | 23 | 4 | 6 | 3.03 | 0 | 5 |
| 2 Centre Costean sampled width 1 ft. 6 in. at top | 0.09 | 3 | 4 | 19 | 0.72 | 0 | 21 |
| 3 North Costean sampled width 2 ft. | 4.61 | 5 | 3 | 9 | Tr. | 1 | 15 |
| 4 South Costean sampled width 1 ft. 6 in. | 2.53 | 18 | 3 | 15 | 1.94 | 1 | 15 |

Two additional lead showings are recorded from this area, although the localities and geology are somewhat vaguely stated and one may be identical with the above-mentioned:

Speewah No. 1: (R. G. Horseman 1948) Lat. 16°20', Long. 128°1'.

Three parallel veins, six inches to eighteen inches wide, and fifty feet to 100 feet apart, carry quartz, fluorite and galena. The veins occupy fissures in dolerite, and can be traced for about 400 feet; they strike approximately north-south and dip 80°W.

Analyses of samples range as follows:

Pb, 3 to 11%; Ag, 4 to 37 dwt/ton; Zn, 0.02%, Cu, Nil.

Speewah No. 2: Ten miles north of Speewah No. 1.

In a quartz outcrop about 200 feet long, one pit has exposed copper staining and small pockets of galena. Selected specimens assayed up to 25% Pb and up to 70 oz/ton Ag.

(2) Mount House: (Lat. 17°03', Long. 125°42').

A quartz vein containing galena has been reported from west of Mt. House Station; it probably occurs in the Mornington Volcanics but the occurrence has not been verified by the author.

(c) Deposits in Devonian Limestone.

(1) Narla, Narlarla, Barker Gorge, or Devonian Lead Mine: (Lat. 17°15', Long. 124°43').

Two outcrops of silver-lead-zinc ore occur in the Napier Range about one mile southeast of the Barker Gorge; the deposits are tabular bodies parallel or sub-parallel to the bedding, and the smaller body has a length of 100 feet, a width of thirty-five feet, and is from five to seven feet thick. The A.G.G.S.N.A estimated the amount of ore outcropping as 1,130 tons averaging 38.67% Pb, 0.56% Cu, and 5.71 oz. Ag per ton. This orebody consisted largely of pyrite when developed below surface and is not being worked.

The larger body is 110 feet long, has a width of sixty feet, and is approximately eighteen feet thick, dipping at 24° S.E. The ore outcropping was estimated at 4,260 tons assaying 31.51% Pb, 1.51% Cu, and 4.59 oz. Ag per ton.

The surface ore consisted mainly of cerussite, but contained some hydrozincite and other zinc minerals. A composite sample from the outcrops had a zinc content of 17.24%.

The larger deposit has been mined for some years, and ore is at present being won from the sulphide zone at a depth of about thirty feet below the surface. The ore as mined contains appreciable quantities of pyrite in addition to the sulphides of Zn, Pb and Cu; the ore is crudely concentrated to recover the lead minerals on a Wilfley table, is drummed and carted by truck to Derby, a distance of about ninety miles. The concentrates are said to assay about 50% Pb and 20% Zn.

This deposit was diamond drilled about 1952 by Enterprise Exploration Ltd., but insufficient ore was found to warrant mining on a large scale.

(2) Margaret Downs J5 Trig: (Ref. Guppy and Matheson)
(Lat.18°22', Long. 125°47')

Small veinlets of galena occur in Devonian limestone two miles west of Trigonometrical Station J5. A sample of the galena contained 1 oz. 5 dwt. of Ag/ton.

(3) Other Localities:

Lead minerals have been found, presumably in Devonian rocks, at Fossil Downs and Oscar Range.

## XII. BARYTES:

### (a) Deposits in Lower Proterozoic Rocks.

(1) Boxer's Lead Deposit, Argyle Downs:
Barytes occurs with galena in granitic rocks; the deposit has been described under "Lead."

(2) Mabel Downs: (Lat. 17°11', Long. 128°7').
A fairly large barytes vein has been reported near the Northern Highway on this station.

Barytes veinlets were also found in the Corkwood area on Mabel Downs.

(3) Mt. Hensman - Golden Gate:
Barytes and witherite have been found in the metamorphic rocks of this area.

(4) Mt. Amy:
Barytes has been recorded from the Mt. Amy area, West Kimberley.

### (b) Deposits in Lower Adelaidean Rocks.

(1) Doubtful Bay: (Lat. 16°5', Long. 124°28').
On the northwestern shores of Doubtful Bay, southeast of Steep Island, a fault zone in the Harding Sandstone and an intrusive dolerite sill is mineralized by seams of barytes, some of which is of fair quality, but most of which is ironstained.

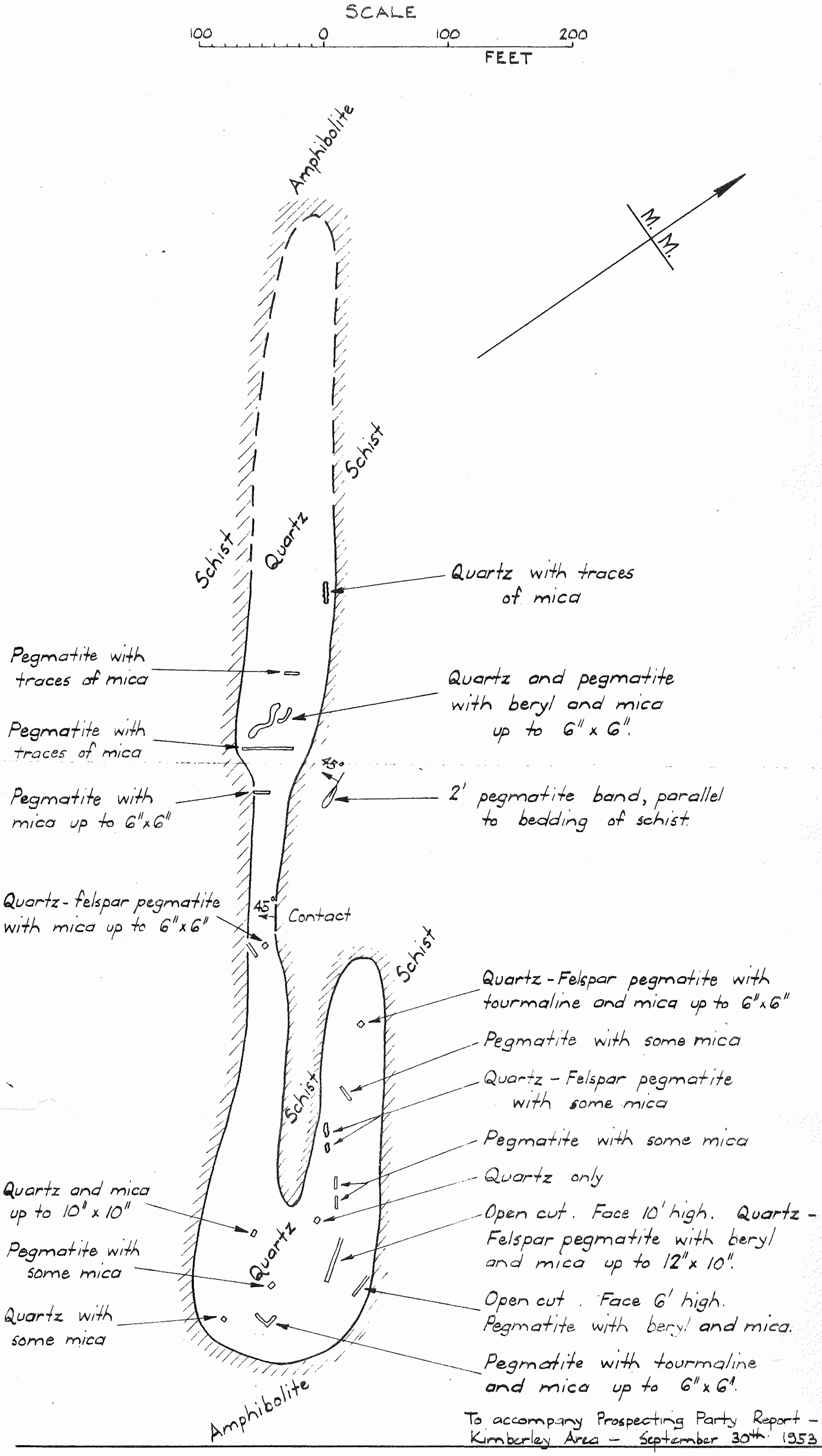
(2) Yampi Sound: Barytes has been recorded from Yampi Sound, but no details are known. Some of the schist beds on Koolan Island contain minor veinlets of barytes.

## XIII. BERYL:

Beryl crystals up to six inches in diameter have been found in the Mondooma Mica-Beryl deposit discovered by J. Stewart, Lat. 16°53', Long. 124°24'. Some of the beryl is semi-transparent, and the better crystals might yield gem quality stones. Production has totalled 3½ tons valued at £297, mainly from eluvial and further minor production should be possible in conjunction with mica production. The deposit is described under "Mica" and is shown in Plan overleaf.

WEST KIMBERLEY. W.A.

# MONDOOMA MICA-BERYL SHOW




To accompany Prospecting Party Report – Kimberley Area – September 30th 1953

No other occurrences of beryl are known, although it is probable that beryl occurs in small quantities in other areas in the pegmatites of the Lamboo Complex.

XIII. MICA (MUSCOVITE):

Two deposits have produced good quality mica from pegmatites and several other mica-bearing pegmatites are known but have not been worked; all occurrences occur in the granites or metamorphics of the Lower Proterozoic.

(1) J. Stewart's Mondooma Mica-Beryl Show:
(Lat. 16°53', Long. 124°24').
See Plan.

About five miles south of Mondooma Waterhole a composite blow of quartz and quartz-felspar pegmatite extends over an area of some fifteen chains by two chains; it contains muscovite mica "books" up to ten inches by twelve inches, which at the surface are stained but are of good quality at depth. The deposit has produced about 150 lb. of mica, but it should be possible to win larger amounts relatively easily. The mica occurs chiefly in the quartz-felspar pegmatite phase; beryl and tourmaline also occur. The deposit has been partly exposed by costeaning and present indications are encouraging for small scale production of high grade mica.

(2) Quggy's Find, Kongarrah, or Barker Gorge Mica Mine:
(Lat. 17°9', Long. 124°47').

Ref. A.G.G.S.N.A. Report W.A. No. 43.

A pegmatite dyke in granite, trending about east-southeast, can be traced over a length of some 1,000 feet. About 500 feet of the pegmatite has been tested by shallow shafts and costeans which show it to contain patches of good mica over widths of up to fifteen feet. The surface mica is clay stained, but the fresh mica is clear, free of impurities, and is wine coloured. The maximum dimension of books is eight inches, and these yield cut pieces up to six inches by six inches. The pegmatite also contains some tourmaline and garnet.

The average width of the mica bearing section appears to be about three to five feet, and the deepest shaft is said to be thirty feet deep but is now partly filled; most of the workings are only two to three feet deep. A total of half a ton of mica is reputed to have been produced from the deposit, but the value is unknown. Some quartz felspar also occurs, but no beryl was found.

The deposit should yield further quantities of easily won mica.

(3) Bow River: (Lat. 16°55', Long. 128°7').

Conspicuous muscovite-bearing pegmatite occurs some miles southeast of Bow River Station near Butler's Bow River. No details are known of the size of mica books present.

(4) Mabel Downs: (Lat. 17°10', Long. 128°07').

Moderate to large sized books of mica are reported from a pegmatite on Mabel Downs Station, but the author has not inspected the occurrence.

(5) Mt. Joseph: (Lat. 17°22', Long. 125°06').

Abundant pegmatites in this area contain muscovite up to three inches by three inches and further prospecting may reveal bodies carrying larger sheets.

(6) Other Localities: Muscovite has been recorded from Cone Bay and Sunday Is., on the Yampi 4-mile sheet, but no details are known.

XIV. ASBESTOS:

No asbestos deposits are known in the Lower Proterozoic and Lower Adelaidean other than small seams of poor quality chrysotile in the serpentine east of Roses Yard.

A small deposit of chrysotile occurs in a thin bed of serpentinised limestone about half a mile north of J41 Trig Station, Lat. 17°02', Long. 128°49'. The limestone overlies the upper Adelaidean Tillite and is overlain by basalts of the Antrim Plateau Volcanics of Lower Cambrian age. The serpentinisation is believed to be due to heat and volatiles from the basalt acting on the limestone during extrusion. The asbestos, which occurs in numerous lenticular seams, is up to an inch in fibre length, but generally averages less. It is exposed in a small pit but its full extent has not been defined; the limestone can be traced discontinuously for about a mile north of the pit, but is not well exposed and there are no signs of chrysotile. Some 44-gallon drums have been filled with hand-cobbed chrysotile, but so far as is known none of this was marketed. The sub-surface asbestos appears to be of good quality, although the fibre length is uneven.

Production of small quantities of chrysotile should be possible from the vicinity of the pit, and further work may reveal extensions.

XV. LITHIUM MINERALS:

Triphyllite ($LiFePO_4$) has been recorded in some quantity from a pegmatite in the Mt. Dockerell area. (AGGSNA Rep.W.A.No.30)

XVI. KYANITE, ANDALUSITE, STAUROLITE, SILLIMANITE:

These minerals are present in schists in the more highly metamorphosed parts of the Hall's Creek Metamorphics, and in some places form an appreciable proportion of the rock mass; such occurrences are restricted to the West Kimberley, and are known in the Hawkestone Creek area, the area northeast of Winjana Gorge, and elsewhere.

High transport costs discourage prospecting for these minerals.

XVII. EMERY:

A deposit of emery is alleged to occur in the Richenda area, some thirtytwo miles by road from McSpeery's Gap. The writer examined a claim for this mineral at the base of a prominent east-west ridge of schist and dolerite at about Lat. 17°24', Long. 125°18'; this claim bears the name of Bromby and McAlear, and is the source of all the alleged "emery" which has been produced in the Kimberley. Recent laboratory work by the author on specimens from this claim indicate that most of the "emery" is diaspore ($Al_2O_3H_2O$), and this has been confirmed by H. L. Markham who carried out several X-ray determinations; the material is non-magnetic, black, finely to coarsely crystalline, and chips pieces out of any hammer used on it. It is thought that there is no true emery in the area, although corundum occurs in portions of the material, as evidenced by the following report on it by Simpson:

"Specimens sent to Perth show that it is excellent hard sharp quality for use as an abrasive, and its commercial value has been proved by the manufacture of an emery wheel which gave good service in a metropolitan engineering workshop.

"The natural mineral forms a dense, finely crystalline, dark grey rock, with a specific gravity ranging from 3.55 to 3.76, whilst fresh splinters have a hardness of 8 to 9. This rock is extremely tough, but splits up along the fairly numerous joint planes.

"Microscopic and chemical investigation shows the chief components to be corundum and diaspore in variable proportions, corundum ranging from 23 to 48 per cent, diaspore from 36 to 61 per cent. A picked specimen of joint fillings carried 90 per cent of diaspore. In much smaller quantities, kyanite, ilmenite, rutile, grossularite and graphite are present. One specimen was analysed with the results given in Table 10. The calculated mineralogical composition from these figures is:-

| | | |
|---|---|---|
| Corundum | ... | 31.2% |
| Diaspore | ... | 53.9% |
| Kyanite | ... | 6.9% |
| Ilmenite | ... | 4.9% |
| Grossularite | ... | 2.4% |
| Graphite | ... | 5.5% |
| Rutile | ... | 0.2% |

"Other ignition losses ($H_2O$+C) determined were 5.89, 9,63 and 13.18. The graphite burns out readily on ignition leaving a greyish white residue.

"On a fresh fracture the emery rock is finely crystalline, with occasional coarse inclusions, the whole showing innumerable bright reflections off cleavage planes. Most specimens show sporadic enclosures of coarsely crystalline diaspore, which also shows as thin broad plates on the rock joints, individual crystals being from 2 to 25 mm. in length. A thin slice shows under the microscope a finely granular ground mass impregnated with minute grains of carbon, and enclosing nests of coarse diaspore and sometimes kyanite."

The diaspore rock occurs in a series of elongated areas carrying floaters which range in size from small fragments up to boulders weighing over a hundred pounds; none of the material was seen in situ. The largest area, about 200 yards by 50 yards, elongated in a northwest-southeast direction, lies within the mineral claim, but similar smaller areas not covered by claims exist a quarter of a mile south and three quarters of a mile east and southeast of the claim. Most of the ground carrying the diaspore rock is underlain by apparently normal (i.e., of relatively low metamorphic grade) schists and phyllites, sometimes intruded by "spotted dyke rocks" (rocks of doubtful origin which consist of prominent crystals or clots of felspar in a matrix resembling fine grained dolerite), and the diaspore float has probably been derived from relatively small lenses or seams connected with these dyke rocks.

Some easily won boulders are present in the various deposits, but the isolation of the area and the apparent lack of primary lodes renders other than small scale production unlikely.

XVIII. FLUORITE:

Fluorite occurs in association with quartz veins and sulphide mineralization in many places in the Kimberleys; the following examples illustrate typical occurrences. Due to high freight costs, and limited demand, fluorite is not sought by prospectors in the area.

(1) Greenvale Area: (Lat. 17°03', Long. 127°52').

Several quartz-fluorite veins up to ten feet wide, carrying minor pyrite and galena and showing some copper staining, were found in the area just northeast of Greenvale Station in the porphyry of the Lamboo Complex.

(2) Fluorite crystals occur in quartz veins in the area just north of Pompey's Pillar (Lat. 16°36', Long. 128°13'), in granite and porphyry.

(3) Quartz-fluorite-galena veins occur in the Speewah area (Lat. 16°22', Long. 127°53'), and apparently contain sufficient fluorite to form a workable source of this mineral if transport costs were not so high.

## XIX. BAUXITE:

Thousands of square miles of laterite exist in the Drysdale area, Port Keats area and areas of Antrim Volcanics. However, all of the laterites seen are too siliceous or too high in iron to be economic sources of alumina.

It is considered unlikely that large deposits of bauxite occur near the coast in the regions visited by the writer; however, the area of laterite shown on the geological map in the coastal areas of the North Kimberley warrants further examination.

## XX. QUARTZ CRYSTALS:

Quartz crystals are found in quartz veins in the Lamboo Complex, but no economic deposit is known.

Vughs up to three feet in diameter and containing small quartz crystals are very common in some of the vesicular and agglomeratic portions of the Antrim Plateau Volcanics. Quartz crystals derived from these vughs are sometimes prominent in the soils of the volcanic downs; the crystals range from clear to smoky, but are usually only an inch or two long and half an inch in diameter. Amethyst crystals are also common and some excellent specimens have been seen. The chief localities in which quartz crystals were observed were the area of basalt immediately north of the Negri Group outcrop in the Mistake Creek-Spring Creek area, and Florrie's Spring area on the Waterloo-Limbunya road, and an area near the Wave Hill Police Station.

Minor amounts of quartz crystal occur in the vesicles of the Mornington Volcanics, but they are less extensive, and the crystals are usually smaller, than those in the Antrim Plateau Volcanics.

XXI. ARSENIC:

Small amounts of arsenic minerals are known in some of the gold-quartz veins in the Ruby Creek-Hall's Creek-Mt. Dockerell areas, and scorodite (hydrated arsenate of iron) occurs extensively as an alteration product of arsenopyrite in the lode formations of the King Sound Wolfram mine.

XXII. GARNETS:

Garnets are common in sands derived from metamorphic rocks in the West Kimberleys; some fair quality small stones are present and it is probable that a few could be used as gems.

Garnets also occur in the East Kimberleys associated with the calc-silicates and amphibolites of the Hall's Creek Metamorphics.

XXIII. GRAPHITE:

Graphite, usually with some copper mineralization, occurs in the Corkwood area (Lat. 17°18', Long. 128°11') associated with doleritic, granitic, and actinolitic rocks.

It is also recorded in various rock types at Bow River, Brockman's, Mt. Broome and Ruby Creek.

XXIV. GYPSUM:

Gypsum is common in the shales of the Cambrian Negri Group on Ord River Station (Lat. 17°23', Long. 128°52').

It has also been recorded from sediments on Napier Downs Station, presumably Devonian. (Lat. 17°15', Long. 124°44').

XXV. ANHYDRITE AND EVAPORITES:

A thick bed of anhydrite was met in the Grant Range No. 1 Bore in the Liveringa area (Lat. 18°01', Long. 124°01'). It was presumably of Permian or Carboniferous age. There is a possibility that further evaporites will be encountered by drilling in the Fitzroy Basin. Saline springs, and pseudomorphs after salt crystals, have been found associated with the Cambrian sediments of the Hardman Basin, but any former salt deposits present would probably have been largely removed by artesian waters.

Pseudomorphs after salt crystals are abundant in the thin shales of the Harding Sandstone of the Deception Bay (Lat. 15°41', Long. 124°26') area, and indicate arid conditions during the formation of this section of the Precambrian rocks. No commercial accumulation of salt would be expected in this area.

XXVI. APATITE:

This minerals has been recorded from various igneous and sedimentary rocks as an accessory mineral.

On Texas Downs Station (Lat. 17°02', Long. 128°27') it occurs as nodules and impregnations in sediments, and as a petrifying agent of fossil wood of Cambrian age (Dept. of Mines W.A. Bulletin No. 1 Mineral Resources of W.A.)

XXVII. GUANO:

Guano occurs, and has been mined in some places, at the following localities:

| | |
|---|---|
| Lacepedes Islands | (30 miles west of Beagle Bay, (Lat. 16°59', Long. 122°42'). |
| Jones Island | (Lat. 13°45', Long. 126°23'). |
| Stewart Island | (Lat. 13°40', Long. 126°55'). |

XXVIII. LEUCITE:

Leucite occurs in volcanic rocks of (?) Jurassic age in the Fitzroy Valley. It is not likely to prove an economic source of potash.

XXIX. FELSPARS:

Felspars are widespread in pegmatites and igneous rocks; due to high transport costs no prospecting is done for these minerals.

XXX. COAL:

(1) Hydrous bituminous coal has been recorded from the Liveringa Station area (Lat. 18°02', Long. 124°11'), where bands of coal were found in a station bore at a depth of 50 feet. A band half an inch thick, sampled in 1909, assayed:

| | |
|---|---|
| Moisture | 11.71% |
| Volatile Matter | 37.81% |
| Fixed Carbon | 36.92% |
| Ash | 13.56% |

This band represents clean coal from a succession of shale and coal bands in a seam twelve feet thick; the bed as a whole assayed:

| | | |
|---|---|---|
| Moisture | 8.87% | |
| Volatiles | 29.73% | Calorific value 7722 B.T.U. |
| Fixed Carbon | 33.99% | |
| Ash | 27.41% | |

(2) Wyndham: (Lat. 15°27', Long. 128°6').

There is some doubt about coal occurring in this area due to insufficient precision in locating specimens or samples analysed; coal was officially reported from Wyndham about the year 1890, but in 1891, H. P. Woodward, in his "Report on the Goldfields of the Kimberley District," writes as follows:

"Some time ago a sample of black shale with thin coaly seams was brought down by the Honourable Colonial Secretary, and with these specimens a piece of steam coal had been put for comparison of which he had not been informed and so he only sent on this latter for assay and report, which caused it to be officially reported that good coal had been found at Wyndham."

Subsequently Simpson, in G.S.W.A. Bull. No. 67, 1916, Table L, Page 109, quotes an analysis of bituminous coal from a half-inch band at 115 feet in a bore at "Wyndham," sampled in 1907:

| | |
|---|---|
| Moisture | 1.74% |
| Volatile | 42.80% |
| Fixed Carbon | 51.52% |
| Ash | 3.94% |

It has not been possible to trace the exact location of this bore. The author places the Wyndham strata in the Upper Proterozoic, in which coal would not be expected.

(3) Port Keats Area: (Lat. 14°14', Long. 129°29').

The Port Keats area was studied by H.Y.L. Brown in 1895, and Etheridge identified fossils collected as being Carboniferous in age; a drilling programme was subsequently launched in search of coal, and four bores were drilled to depths of up to 1,500 ft.

Although minor carbonaceous seams were found, no economic coal seams were encountered in the drill holes; plant fossils found, in association with some marine fossils, indicate a Permian age, and the freshwater beds are correlated with the Poole Sandstone of the Liveringa area.

XXXI. PETROLEUM:

(1) East Kimberley and Northern Territory:

The only testing that has been done in the East Kimberley was one bore on the Kelly Creek Anticline (Lat. 17°17', Long. 128°58'), in the Hardman Basin directed by the Okes Durack Kimberley Oil Company in the early 1920's. The bore commenced in sediments of the Middle Cambrian Negri Group, and ceased after penetrating about 400 feet of Antrim Plateau Volcanics. No significant oil showings were obtained, and Wade (1924) stated that there was no chance of oil being found in the Hardman Basin.

Similarly, there is no chance of finding oil in the Middle Cambrian Argyle and Rosewood basins.

The origin of traces of asphaltite in the Antrim Volcanics in areas adjacent to the Negri Group outcrops, has been the subject of considerable controversy; they appear to represent petroleum residues from the underlying Upper Proterozoic or from the overlying Negri Group, but in either event are not indicative of the presence of commercial oil in these sediments at the present time.

The only other area of interest is the Bonesparte Gulf Basin. Traves indicates the following thickness of sediments in this Basin:

| | | | |
|---|---|---|---|
| Permian | Port Keats Gp. | 1500 + ft. | Sandstone, conglomerate, shale and limestone. |
| | Weaber Gp. | 2000 ft. | Sandstone, conglomerate and shale. |
| Carboniferous | Mt. Septimus Limestone | 350 + ft. | Limestone and calcareous sandstone. |
| | Enga Sandstone | 1000 ft. | Sandstone. |
| Devonian | Burt Range Limestone | 4000 ft. | Limestone, shale and calcareous sandstone. |
| | Cockatoo Sandstone | 3000 ft. | Sandstone. |
| Ordovician | Pander Greensand | 550 + ft. | Greensand |
| | Clark Sandstone | 600 + ft. | Sandstone |
| | Pretlove Sandstone | 400 + ft. | Sandstone |
| Cambrian | Skewthorpe Formation | 600 + ft. | Limestone, shale and calcareous sandstone. |
| | Hart Spring Sandstone | 600+ ft. | Sandstone, limestone and shale |

This indicates a total thickness of about 15,000 feet, but only up to one-third of this thickness is present in any one locality, e.g., in the Burt Range Basin there are no Cambrian sediments and the Devonian sediments overlie Antrim Plateau Volcanics; in the Carlton Basin Devonian sediments overlie the Cambrian and Ordovician but the Basin does not contain Carboniferous sediments.

Throughout the Bonesparte Gulf Basin the distribution of Permian sediments is independent of the distribution of the older Palaeozoic sediments, and Traves considered that in most places the Permian overlay Precambrian rocks.

Source, reservoir, and cap rocks in suitable association and in suitable structures are not known, and their occurrence under Permian rocks is not considered likely.

The numerous faults in the area may have provided suitable structural traps for any oil present in the sediments. No oil seepages or traces of oil are known from the area, even although the area is severely faulted.

The presence of Permian Volcanics (in a limited area) detracts from the oil potential of the Basin.

The possibility of better conditions occurring northward in offshore areas appears to have been discounted by the discovery of granite boulders near the littoral north-northeast of Cleanskin Bore (Lat. 15°00', Long. 128°50'), (although these may be derived from tillite or conglomerate and not from basement) and by the narrowing and even disappearance of units between Knob Peak (Lat. 15°03', Long. 128°42') and Cape Domett (Lat. 14°50', Long. 128°25').

Traves sums up his opinion (1955) as follows:

"..... on present knowledge of stratigraphical units and their distribution in the Bonaparte Gulf Basin, the possibility of finding an oil-field is slight, but the Keep River area warrants further investigation."

Subsequent and more detailed geological mapping has shown some anticlinal structures in the Spirit Hill (Lat. 15°30', Long. 129°05') area which may warrant testing.

(2) West Kimberley:

Traces of oil have been found in several bores in this area, but no productive wells have been completed. Traces of oil were first found in 1919-1922 in the Prices Creek area (Lat.18°40' Long. 125°52') by bores sunk in the Ordovician rocks; the bores were shallow and not located on defined structures. Traces of oil were also found in bores at Mt. Wynne, Poole Range and Nerrima; up to 1956 the following bores have been drilled specifically for oil, on reasonably well defined structures:

Poole Range (Max. depth 3,264 feet in No. 3 Bore)
Mt. Wynne (Max. depth 2,154 feet in No. 3 Bore)

Nerrima (Max. depth 9,072 feet in Associated Freney No. 1)

Deep Well (Max. depth 6,001 feet in Assoc. Freney Myroodah No. 1)

Grant Range (Max. depth 12,915 feet in W.A.P.E.T. No.1 Bore)

Fraser River (Max. depth 10,000 feet in W.A.P.E.T. No.1 Bore)

With the possible exception of Fraser River No. 1 Bore (on which no information is yet available beyond the fact that the hole was probably in Permian rocks at 6,000 feet, and was abandoned in diorite, possibly intrusive into Carboniferous rocks) none of these deeper holes have penetrated the Permian and Carboniferous to reach the underlying Devonian or Ordovician.

Regional mapping suggests that source rocks occur in the following:

(1) Ordovician:

Prices Creek Group - this group contains a rich marine fauna in 2,650 feet of known section, and the beds were deposited under reducing conditions. Sandy beds are present towards the top of the section which would be suitable as reservoir rocks, and shales which could act as cap rocks are also present.

(2) Devonian:

The exposed beds of this age, whilst often highly fossiliferous, are mainly reef limestones or clastic beds deposited under oxidising conditions, and not therefore likely to be source rocks, although they may act as reservoir rocks. The Devonian as known from outcrops, is almost entirely of shore and near-shore facies, and favourable source rocks may be present in the equivalent deeper water facies away from the edge of the Basin.

(3) Permian:

No good source rocks are known from the outcropping Permian, nor is their presence known in bores; doubtful source rocks exist in parts of the Noonkanbah Formation, and more favourable facies may exist in other parts of the basin such as Dampier Land.

Cap rocks are numerous in the Ordovician, Upper Devonian, Noonkanbah Formation (shales), and Blina Shale, and suitable reservoir rocks are common in the Permian, Ordovician, Devonian and Carboniferous.

The chances of finding oil therefore largely depend on locating the Ordovician or Devonian formations in a suitable structure within reach of the surface. So far all wells have failed to reach the depth necessary to penetrate the overlying Permian and Carboniferous rocks, in which no oil is expected; all wells so far completed show a greater thickness of these overlying sediments than was expected from surface mapping; the faulting etc. present in the Permian rocks has not necessarily extended to the reservoir rocks below, and no surface seepages of oil are known on anticlinal structures in Permian rocks.

The known anticlinal structures, on geophysical evidence, do not necessarily persist at depth, and the position of the axes at the surface do not correspond with their position at depth; structures that have been drilled have not contained the target beds within accessable distance of the surface. The most likely areas in which the Ordovician and Devonian rocks (if present) may be within reach are to the south of the Fenton "Fault" (or subsurface ridge) or near the northwestern extension of the Oscar Range "ridge" of Precambrian. Structures in these areas are masked by sand and later sediments, and drill site selection would have to be based largely on results of geophysics and structure drilling. At the present time (up to the beginning of 1957) no Ordovician or Devonian rocks are known to occur in these areas, and any further work depends on the supposition (supported by some geophysical results) that such beds do occur, or that the younger rocks may contain more favourable facies.

Stratigraphic drilling and geophysical work is at present being actively pursued by the Bureau of Mineral Resources and by West Australian Petroleum prior to selection of further deep test sites.

XXXII. WATER:

The cattle industry was initially dependent on surface waters, but with the gradual eating out of pastures and subsequent erosion in the vicinity of natural waters, maintenance of present production is dependent in many areas on the development of underground waters in pastures remote from surface water. In general the latter are adequate only in the Kimberley Plateau area where naturally watered areas have not been excessively overstocked, and where permanent waters are more widespread in springs, rivers and creeks. Some increase in cattle production in most areas should be possible by development of underground waters if accompanied by adequate fencing and better management.

The selection of bore sites in Lower Proterozoic rocks is usually dependent on finding areas of deep alluvium which may contain adequate supplies of ground water; this is especially true of areas in the Lamboo Complex, in which all producing bores are situated in alluvial areas or fractured zones. The Hall's Creek Metamorphics, due to their low stock carrying potential in most places, have not been extensively drilled, but have yielded small supplies of water in wells near mining centres, and should yield adequate supplies from deeper bores in favourable localities. If suitable soil be available, greater use of surface run-off by storage in earth tanks appears to be the most economical way of watering stock in these areas; such tanks may be augmented by small supplies of ground water which in themselves would probably not be adequate for watering large numbers of stock.

Pastures overlying Upper Proterozoic rocks usually have low stock carrying capacity, and frequently large pools and springs occur near or in such areas. Greater use of these natural waters could be made by piping them from inaccessible and rocky areas to the often waterless adjacent soil covered areas. This applies especially to areas of good pasture on the Hart Dolerite which are usually poorly watered but are often adjacent to springs in sediments, inaccessible to stock.

In upper Adelaidean rocks, and in the Elgee Shale, pastures of poor to medium quality occur on shales and limestones which have been tested for underground water. The shales, etc., in the Mt. House-Glenroy area have yielded useful supplies of water, probably from sandy lenses or from fractured zones, at shallow depths; supplies in such rocks may be improved by exploding a gelignite charge in the bore. The Victoria River Formation sometimes underlies fair pastures, and rocks of this formation have yielded good supplies of water in the Wave Hill and Inverway area. In some areas such as Auvergne Station, difficulty has been experienced in obtaining water in the sub-horizontal shales and limestones, etc., of this formation, but it is probable that a careful study of the structure and lithology of outcrops would enable porous formations and suitable structures to be predicted in the soil covered areas, although bores may have to be deeper than is general in the East Kimberley.

Water supplies in Antrim Plateau Volcanics, which underlie excellent pastures over much of the East Kimberley and Northern Territory area, are generally obtained from depths of 300 feet or less, and range up to 2,400 g.p.h., averaging somewhat below 1,000 g.p.h. So far as is known no definite aquifer is present, and the supply is derived from ground water in joints, fractures and other openings. Fault zones provide suitable sites for bores in many places.

Cambrian sediments in the Hardman, Rosewood and Argyle Basins provide good supplies from depths ranging from 40 to 300 feet; quantities obtained vary from 500 to 3,000 g.p.h. Selection of bore sites in this area is relatively simple for the structure is fairly well known, and permeable horizons occur in the shales and limestones at various horizons.

The Palaeozoic sediments of the East Kimberley and Northern Territory, in the Bonaparte Gulf Basin, underlie poor pastures which are fairly well watered by surface pools, springs, etc.; suitable structures and aquifers are probably present, and could be tapped should the need for underground water arise.

In the West Kimberley a considerable amount of drilling for water has been carried out in Palaeozoic and younger strata especially during the development of the large sheep stations, and experience in these areas combined with regional mapping by the Bureau of Mineral Resources, enable bore sites to be selected with some precision. Bores are in general deeper than those sunk in the East Kimberley and Northern Territory areas, ranging up to 1,600 feet in depth.

The following table, after Guppy et al. (1958) summarises the results of most of the bores:

| | Post-Triassic | Triassic | Liveringa Form. | Noonkanbah Form. | Poole S.S. | Grant Form. | Devonian |
|---|---|---|---|---|---|---|---|
| Sub-Artesian | 15 | 17 | 125 | 37 | 23 | 24 | 17 |
| Artesian | 2 | - | 1 | 4 | 5 | 3 | - |
| Dry | - | 3 | 6 | 21 | 2 | - | 8 |
| % Successful Bores | 100% | 85% | 95% | 66% | 93% | 100% | 68% |

The most reliable parts of the sequence are therefore the Post-Triassic, Grant Formation, Liveringa Formation, and Poole Sandstone; these units are primarily arenaceous with numerous horizons from which sub-artesian water can be expected. The water is potable in all bores except those tapping Noonkanbah Formation and some in the Liveringa Formation and Jurassic.

The Triassic Blina Shale contains over 1,000 feet of shale which is impermeable and unsuited as a source of underground water; the overlying Triassic Erskine Sandstone is a favourable aquifer from which nearly all the Triassic supplies are derived. In areas in which Blina Shale outcrops there is a possibility that the underlying formation may be Noonkanbah Formation, and that a bore of over 2,000 feet may be required before a suitable supply of water is obtained; the Noonkanbah Formation is for the most part unreliable as a source of water, and only the uppermost and lowest beds are likely to be aquifers.

In the Devonian suitable aquifers occur in the Fossil Downs and Napier Formations, the Fairfield Beds, and in the various conglomerates which interfinger with the more impermeable beds, although care is needed in the selection of bore sites (Guppy et al. 1958)).

* * * * * * * * * *

TABLE 8 MINERAL PRODUCTION - KIMBERLEY GOLDFIELD.

DATA FROM W.A. DEPT. OF MINES.

GOLD.

| | |
|---|---|
| 1957 | 69 fine oz. |
| 1956 | 172 " " |
| 1955 | 179 " " |
| 1954 | 72 " " |
| Prior to 1954 | 39,025 " " |
| Total to 1957 | 39,518 " " |

SILVER. (Contained in lead, zinc and gold ores)

| | |
|---|---|
| Total to 1957 | 129 oz. |

LEAD.

| | |
|---|---|
| Prior to 1954 | 9.2 tons |
| Total to 1957 | 9.2 tons |

TIN.

| | |
|---|---|
| Prior to 1954 | .83 tons |
| Total to 1957 | .83 tons |

OCHRE. (Probably produced in N.T. but shipped ex Wyndham).

| | |
|---|---|
| Prior to 1954 | 20.6 tons |
| Total to 1957 | 20.6 tons |

. . . . . . . . . . .

# TABLE 9 MINERAL PRODUCTION WEST KIMBERLEY GOLDFIELD

## DATA FROM W.A. MINES DEPT.

**IRON ORE.**

| | |
|---|---|
| 1957 | 389,686 tons |
| 1956 | 327,815 " |
| 1955 | 496,882 " |
| 1954 | 634,514 " |
| Prior to 1954 | 903,224 " |
| Total to 1957 | 2,752,121 tons |

**SILVER LEAD CONCENTRATES.**

| | | |
|---|---|---|
| 1954 | 279 tons | |
| Prior to 1954 | 1,565 " | |
| Total to 1957 | 1,834 tons | containing 13,375 oz. silver. |

**ZINC.**

| | |
|---|---|
| 1954 | 74 tons |
| Prior to 1954 | 110 " |
| Total to 1957 | 184 tons |

**COPPER ORE.**

| | |
|---|---|
| Prior to 1954 | 109.5 tons |
| Total to 1957 | 109.5 tons |

**TIN.**

| | |
|---|---|
| 1955 | .13 tons |
| Prior to 1954 | .30 " |
| Total to 1957 | .43 tons |

**WOLFRAM.**

| | |
|---|---|
| Prior to 1954 | 28.5 tons |
| Total to 1957 | 28.5 tons |

**MICA.**

| | |
|---|---|
| Prior to 1954 | 31 lbs. |
| Total to 1957 | 31 lbs. |

cont.

EMERY.

| | |
|---|---|
| 1955 | 8.15 tons |
| Rrior to 1954 | 13 " |
| Total to 1957 | 21.15 tons |

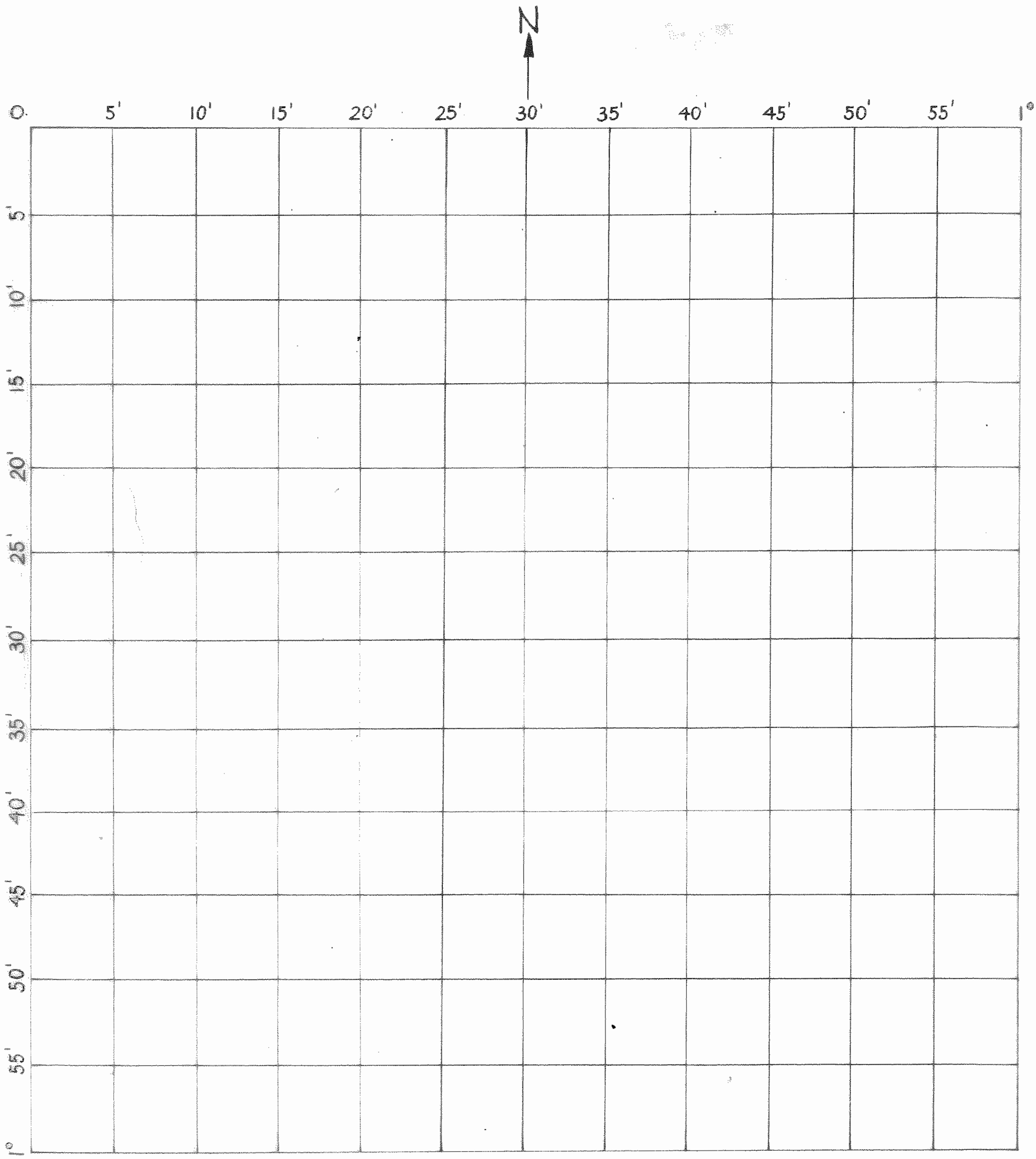
BERYL.

| | |
|---|---|
| Prior to 1954 | 3.5 tons |
| Total to 1957 | 3.5 tons |

GOLD.

| | |
|---|---|
| Prior to 1954 | 28.5 oz. |
| Total to 1957 | 28.5 oz. |

. . . . . . . . . . .




GRID FOR OVERLAYING ON
KIMBERLEY 10 MILE GEOLOGICAL PLAN

# THE GEOLOGY OF THE KIMBERLEY DIVISION, WESTERN AUSTRALIA, AND OF AN ADJACENT AREA OF THE NORTHERN TERRITORY.

## PART IV.

## BIBLIOGRAPHY.

# PART IV. - BIBLIOGRAPHY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