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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

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THE GEOLOGY OF THE ORD RIVER REGION, WESTERN AUSTRALIA

by

D.B. Dow, I. Gemuts, K.A. Plumb, and D. Dunnet

AMENDMENTS TO THE GEOLOGY OF THE ORD RIVER REGION

WESTERN AUSTRALIA

Records 1964/104

As a result of mapping during 1964, the names of some rock units have been changed, and some boundaries have been re-defined. Details of the changes are available in:

Gellately, D.C., Derrick, G.M., and Plumb, K.A. Progress report on the geology of the Lansdowne 1:250,000 Geological Sheet and adjoining areas Bur.Min.Resour.Aust.Rec. (In preparation)

Roberts, H.G., Halligan, R. and Gemuts I. Geology of the Mount Ramsay Sheet area. Bur.Min.Resour.Aust.Rec. (In preparation)

The changes in nomenclature are given below:

Woodward Formation: discarded. Incorporated in the Biscay Formation.

Koongie Park Formation: The sandstone member is the the King Leopold Sandstone, and the volcanics are Carson Volcanics.

Mount Remarkable Member: Discarded

Speewah Group: Now includes the following formations:

Luman Siltstone

Lansdowne Arkose (old Looingnin Arkose)

Valentine Siltstone

Tunganary Formation (old Liamma Beds)

O'Donnell Formation

Boll Sandstone: Discarded. Now part of the Wade Creek Sandstone

Mount John Shale: is now a member of the Wade Creek Sandstone

Elder Formation: is now Hudson Formation

Buchanan Sandstone: is now Elder Sandstone

THE GEOLOGY OF THE ORD RIVER REGION
WESTERN AUSTRALIA

by

D.B. Dow, I. Gemuts, K.A. Plumb and D. Dunnet.

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THE GEOLOGY OF THE ORD RIVER W.A.

SUMMARY

The geology described in this report covers most of the catchment of the Ord River, in the extreme north-east of Western Australia. The north-western part of the region is mountainous and ranges up to 2600 feet above sea level, but the south-eastern corner consists mostly of rolling plains.

Most of the rocks are Precambrian, except for the plain country which consists of Cainozoic soils underlain by Palaeozoic sediments and volcanics. The geology is dominated by the Halls Creek Mobile Zone, a north-easterly trending belt of uplifted and intensely deformed rocks, which is bounded by stable blocks, the Kimberley Block on the west, and the Sturt Block on the east.

The Precambrian rocks are divided into two age groups which we have called informally the Older Proterozoic and the Younger Proterozoic. The oldest rocks are the tightly folded geosynclinal sediments and volcanics of the Halls Creek Group, and their more highly metamorphosed equivalent, the Tickalara Metamorphics. The Halls Creek Mobile Zone consists of Tickalara Metamorphics and acidic and basic plutonic rocks which have been called the Lamboo Complex. Acid volcanics (Whitewater Volcanics) and sediments and basic volcanics (Revolver Creek Formation) unconformably overlie the Halls Creek Group.

The Younger Proterozoic rocks are unmetamorphosed shallow-water sediments and minor volcanic rocks which unconformably overlie the Older Proterozoic rocks. Unconformities are common throughout the sequences and form the basis of the major rocks divisions. The Halls Creek Mobile Zone separates the Younger Proterozoic rocks of the Kimberley Block (Kimberley Basin Succession) from those of the Sturt Block (Eastern Succession). There is no overlap of the formations and correlations across the Mobile Zone are doubtful. The Younger Proterozoic rocks of the Mobile Zone are called the Carr-Boyd Succession, and these may be the equivalent to the basal parts of the flanking successions. The Eastern Succession is notable for the glacial rocks which occur near the top in the Ord Group. Widespread dolerites invade the Kimberley Basin Succession.

Cambrian rocks occupy broad structural basins in the south-eastern part of the Ord River Region. The basal unit is the very extensive Lower Cambrian Antrim Plateau Volcanics which is overlain by shale and limestone of the Negri Group. The north-eastern part of the map area is covered by the richly fossiliferous Palaeozoic rocks of the Bonaparte Basin, which are the subject of a separate report.

The Halls Creek Mobile Zone, which separates the stable Kimberley and Sturt Blocks, is a thirty to forty mile-wide belt of intensely deformed

metamorphic and plutonic igneous rocks. The Zone is characterised by sub-parallel, anastamosing faults of great magnitude, many of which have been active as recently as Upper Palaeozoic times. The amount of deformation suffered by the Older Proterozoic rocks of the stable blocks is not known, but those basement rocks exposed are tightly folded. By contrast, the overlying Younger Proterozoic rocks are in general only slightly deformed.

The Halls Creek area was a rich, but shortlived, goldfield near the end of the Century. Asbestos, chromium, platinum, copper, iron, lead, nickel, and uranium, have been found in small quantities, but none have been produced commercially. However, prospects of finding economic copper deposits in the area appear to be good, and further prospecting for base metals and chromium and platinum is warranted.

PLATE 1

GEOLOGICAL MAP OF
ORD RIVER REGION
WESTERN AUSTRALIA

Scale 1:500,000

10 0 10 20 30 MILES

Geology, 1962–64, by: D. B. Dow, K. A. Plumb, D. Dunnett, J. H. Latter, V. M. Bofinger, J. W. Smith, H. L. Davies (B.M.R.) and I. V. Gemuts, J. R. Passmore, K. J. Morgan (G.S.W.A.)

Compiled, 1964, by: D. B. Dow and A. Skoda

Drawn, 1964, by: A. Skoda

Produced and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Base map compiled from the Preliminary Editions of Cambridge Gulf, Lissadell, Dixon Range and Gordon Downs sheets, 1:250,000 Geological Series. Transverse Mercator Projection; Central Meridian 127° 30' E

Reference

CAINOZOIC

- QUATERNARY
  - Qa — Alluvium, coastal evaporites
- UNDIFFERENTIATED
  - Czs — Sand residual soil, gravel
  - Czb — Black soil
- TERTIARY
  - T — Undifferentiated

PALAEOZOIC

- UNDIFFERENTIATED
  - Pz — Undifferentiated
- DEVONIAN
  - Dr — Ragged Range Conglomerate
  - Db — Buchanan Sandstone
- MIDDLE CAMBRIAN — Negri Group
  - Ꞓm — Undifferentiated
- LOWER CAMBRIAN
  - Ꞓl — Undifferentiated
  - Ꞓla — Antrim Plateau Volcanics

PRECAMBRIAN

"YOUNGER" PROTEROZOIC

- Ꝑud — Gardiner Beds
- Albert Edward Group
  - Ꝑa — Undifferentiated
- Ord Group
  - Ꝑo — Undifferentiated
  - Ꝑom — Moonlight Valley Tillite
  - Ꝑof — Fargoo Tillite
- Ꝑse — Boll Sandstone and Helicopter Siltstone
- Ꝑsw — Wade Creek Sandstone and Mount John Shale
- Ꝑsb — Bungle Bungle Dolomite
- Ꝑsp — Mount Parker Sandstone
- Bastion Group
  - Ꝑt — Undifferentiated
- Ꝑdh — Hart Dolerite
- Kimberley Group
  - Ꝑk — Undifferentiated
- Speewah Group
  - Ꝑp — Undifferentiated
- Ꝑf — Fish Hole Dolerite
- Ꝑn — O'Donnell Formation and Liamma Beds
- Ꝑc — Undifferentiated Carr Boyd Succession
- Ꝑck — Red Rock Beds

"OLDER" PROTEROZOIC

- Ꝑr — Revolver Creek Formation
- Ꝑw — Whitewater Volcanics
- Lamboo Complex
  - Ꝑb2 — "Mixed Rock"
  - Ꝑb3 — "Biotite Granite"
  - Ꝑb4 — "Porphyritic Granite"
  - Ꝑb5 — "Porphyry"
  - Ꝑb6 — "Basics"
  - Ꝑb7 — "Ultrabasics"
  - Ꝑb8 — "Gneissic Granite"
  - Ꝑbt — Tickalara Metamorphics; Calc-silicate rocks
- Halls Creek Group
  - Ꝑh — Undifferentiated
  - Ꝑhc — Moola Bulla Formation
  - Ꝑhk — Koonjie Park Formation
  - Ꝑho — Olympio Creek Formation
  - Ꝑhr — Biscay Formation
  - Ꝑhw — Woodward Formation
  - Ꝑhs — Saunders Creek Formation
  - Ꝑhd — Ding Dong Downs Formation

Geological boundary

Fault

Anticline

Where location of boundaries and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries are dotted and faults are shown by short dashes

12 Strike and dip of strata

Horizontal strata

Vertical strata

Overturned strata

Trend line showing direction of dip

Plunge of fold axes

Battery, smelter not operating

Mine

Mine not worked

Prospect

(U) Unworked deposit

.Cu Minor mineral occurrence

Au Gold

Cu Copper

Fe Iron

U Uranium

Highway

Road

Vehicle track

Airport

Landing ground

"Nicholson" Homestead

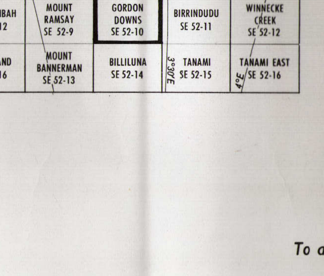
State boundary

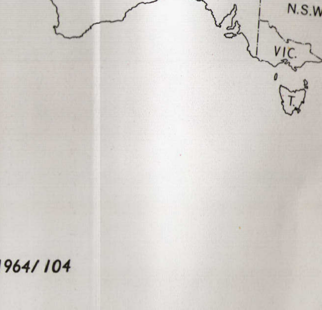
Trigonometrical station

Dry hole — abandoned

Record 1964/104

INDEX TO 1:250,000 SHEETS
Showing Magnetic Declination





To accompany Record 1964/104

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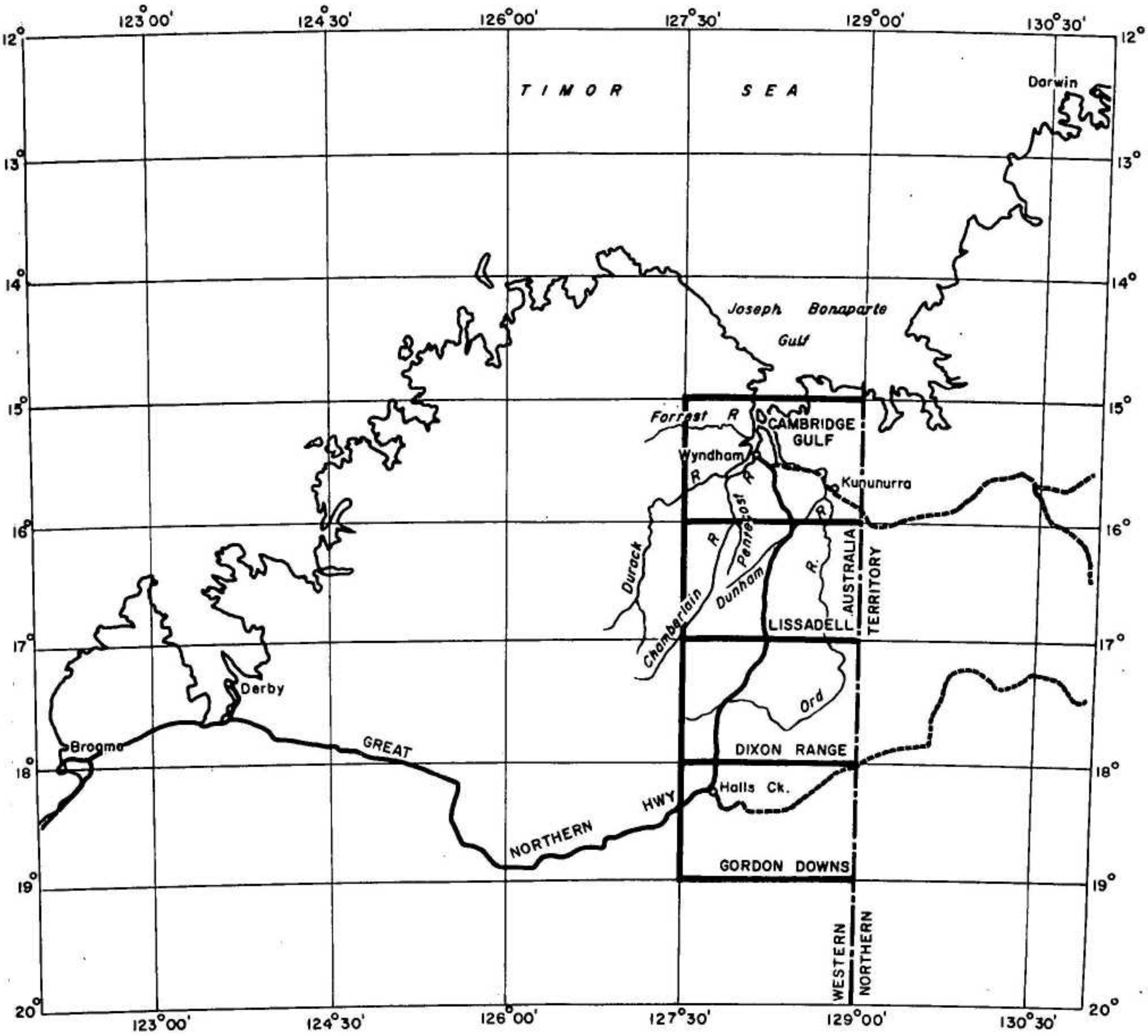

Fig I

LOCALITY MAP

ORD RIVER REGION

Bureau of Mineral Resources, Geology and Geophysics, Sept. 1964

INTRODUCTION

This report concerns the geology of almost the whole of the catchment of the Ord River, in the extreme north-eastern corner of Western Australia; its main objective is the definition of new rock units in the East Kimberley Region.

The area is part of the Kimberley Division and is a rugged mountainous region up to 2600 feet above sea level, composed mainly of Precambrian rocks. The area, shown on the accompanying geological map at a scale of 1:500,000. (Plate 1), comprises Cambridge Gulf, Lissadell, Dixon Range, and Gordon Downs 1:250,000/Sheet areas (see Figure 1). It is bounded on the east by the Northern Territory border, on the west by longitude 127° 30' E, and by latitudes 15° 00' S, and 19° 00' S in the north and south.

The mapping, part of a programme in which it is intended to map the whole Kimberley Division, was done by the Bureau of Mineral Resources in conjunction with the Geological Survey of Western Australia. The Gordon Downs Party (J.W. Smith, H.L. Davies, K. Morgan, and I. Gemuts) started the programme in 1962 and mapped the Gordon Downs 1:250,000 area and part of the Dixon Range area, and in 1963 the Dixon Range Party (D.B. Dow, J.H. Latter, I. Gemuts, and M. Bofinger), and the Lissadell Party (K.A. Plumb, D. Dunnet, and R. Passmore), mapped the Dixon Range, Lissadell, and parts of the Cambridge Gulf 1:250,000 areas.

Access

Wyndham and Kununurra are connected to Perth and Darwin by regular Fokker Friendship air services. Halls Creek and most of the stations in the area have airstrips which are regularly serviced by D.C.3 aircraft, connecting with the Fokker Friendship services. Cessna aircraft can be chartered from Wyndham and Derby.

The Great Northern Highway, which connects Derby and Wyndham, crosses the area from south to north. This road has a gravel surface and is often cut by flooded rivers in the 'wet' season. At the time of writing (1963), work on bridging and re-routing of the road was well advanced, and it should be an all-weather road within two years. Other main roads in the Ord River Region are the Duncan Highway on the east, which joins Wyndham and Nicholson Station, and a road in the south which joins Halls Creek and Nicholson and continues to the Stuart Highway in the Northern Territory. Station roads give reasonable access to much of the area : they differ greatly in standard and may be well-graded roads or barely discernible and washed-out tracks. The Central Range, the mountains north-west of Mabel Downs Homestead, the western parts of the Lissadell and Cambridge Gulf sheets and the Carr Boyd Range are not accessible by day trips from the Landrover, and here the mapping was done by means of a helicopter. There are no tracks in the belt of country west of the Halls Creek Fault (Pl. 1) between Texas Downs Homestead and Palm Springs, but it is possible to pick Landrover routes over most of the belt. 10

Climate

The region has a tropical savannah climate and a rainfall which ranges from 15 inches in the south to 35 inches in the north (Fig. 1). Most of the rain falls between December and March, locally known as the 'Wet', during which as much as six inches of rain have been recorded in one day. June to September is the dry season, but heavy winter rains have been recorded in freak seasons such as in the winter of 1956. The long periods of little rain and high evaporation (100 inches to 110 inches per year) causes dry soil conditions (Passmore, 1964), and all rivers, except the lower reachers of the Ord River and spring-fed streams in the Kimberley Plateau, stop flowing in the winter months. Large waterholes, springs and billabongs are generally only semi-permanent.

Day temperatures are very high throughout the year, and in summer may average in excess of 110°F for many consecutive days. The average daily mean temperature increases from 78°F at Halls Creek to 84°F at Wyndham, the latter figure being the highest average daily mean temperature in Australia. The average summer maximum is between 95°F to 100°F, with November the hottest month, while the average winter maximum ranges from 80°F to 90°F. Temperatures in winter can be quite low : the average minimum temperature recorded in Halls Creek for July is 45°F, and occassional frosts have been noted in the southern part of the area.

The prevailing winds are the south-east trades of the winter months and the north-west monsoons which bring the rain during the wet. The winter winds are dry since they traverse the arid interior, and relative humidity averages about 40%. Summer winds are moist and with a relative humidity of 75%. August and September are the windy months and sporadic dust storms and 'willy-willies' occur throughout the area.

Vegetation (After Teakle 1944)

The eastern part of the Ord River Region is characterized by savannah and grasslands. The most important native grasses within these areas are Mitchell (Astrebla spp.) and Flinders (Iseilema spp.) grasses and Dicanthium, but these have been replaced by a number of other species, notably Aristida. The trees of these areas are chiefly Bauhinia and rosewood (Terminalia sp.).

The rivers and small streams are fringed by grassy woodland in which a variety of trees occur. Some of the more important ones are the chestnuts (Terminalia spp.), the Leichhardt tree (Sarcocephalus sp.), various figs (Ficus spp.), cajuput (Melaleuca leucadendron), native apple (Owenia spp.), baobab (Andansonia Gregorii), and various eucalypts, including grey box (Eucalyptus Spenceriana), river gum (E. camaldulensis), bloodwood (E. pyrophora) and cabbage gum (E. clavigera). Species of Acacia also occur. Most of the trees, even the eucalpyts, are deciduous and shed their leaves in the winter but bud again after a few weeks.

Where the rivers have cut deep gorges, small areas of dense tropical forests grow in the bottoms on continually moist soils. A large variety of plants occur here, including pandanus palms and varieties of ferns.

The dry rocky areas are spinifex-covered and two species have been recognised - Triodia sp. and Plectraclina sp.

Population and Industry

The Ord River Region has a very sparse population : aborigines out number Europeans and most are employed as station hands in the principal industry of the region, cattle-raising. Because the soils are generally poor and the climate unfavourable, holdings are very large and the homesteads are up to 60 miles apart. There are only three towns in the map area : Wyndham (population 958 at June 1961), a small port on the west arm of Cambridge Gulf which has a meatworks and provides an outlet for the pastoral industry; Kununurra (population 337), about 60 miles by road from Wyndham, which is a centre for the Ord Irrigation Scheme; and Halls Creek (population 160), originally a gold mining town but now a small supply centre for local cattle stations and a Government administration centre.

A dam has been constructed at a cost of £4,000,000 on the Ord River at Kununurra to provide water for the irrigation of alluvial plains in the area. The scheme is in its early stages, and a larger dam will be built at a cost of about £30,000,000.

Gold-mining, both alluvial and lode, was an important industry before the turn of the century, but now the only gold won is produced by aborigines who work small alluvial deposits during the wet season. Since 1950 there have been spasmodic attempts to re-open some of the larger lode mines, but these have not met with success.

PREVIOUS INVESTIGATIONS

The first geological work in the Ord River Region was done in 1883 and 1884 by Hardman (1885), who was government geologist attached to the Kimberley Survey Expedition. His map is remarkably accurate, and his main rocks groups are approximately the same as the broader divisions in this report. Hardman discovered gold in the region and by 1890, considerable mining, both alluvial and lode, was taking place. Woodward (1891) & Smith (1898) reported on the geology of the goldfields.

Little was added to the knowledge of the geology of the region until the discovery of a bituminous substance in the Ord and Negri Rivers in 1921 sparked interest in the possibility of finding petroleum in the area. This bituminous occurrence was described by Blatchford (1921), and later Wade (1924) made a reconnaissance of the East Kimberley region, and reported on the prospects of finding commercial quantities of petroleum in the area. Blatchford (1927 a & b) reported briefly on gold mining at the Grants Patch centre, and the occurrence of galena on Speewah Station, and Finucane (1938 & 1939 22nd b, Finucane & Sullivan 1939), reported on the various gold mining areas of the Halls Creek Goldfields for the Aerial Geological and Geophysical Survey of Northern Australia.

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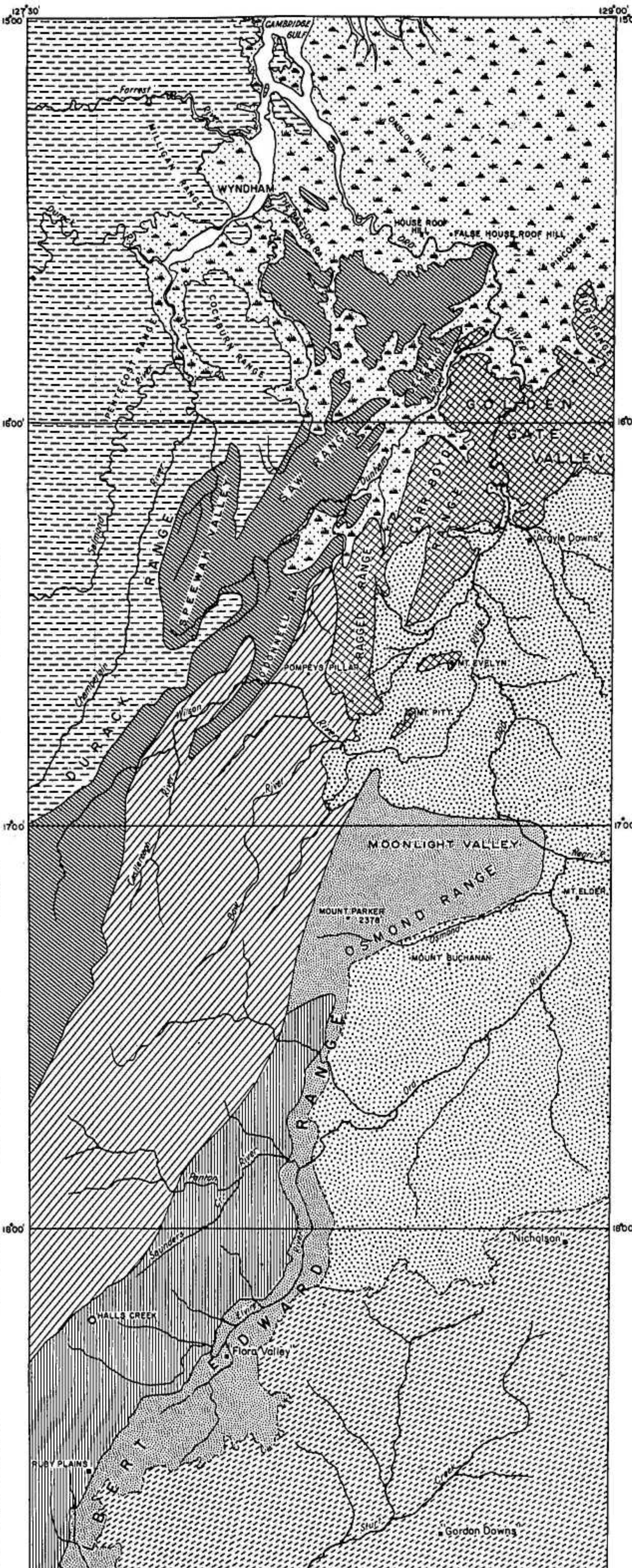
PLATE 2

PHYSIOGRAPHIC SKETCH MAP

ORD RIVER REGION

WESTERN AUSTRALIA



Scale

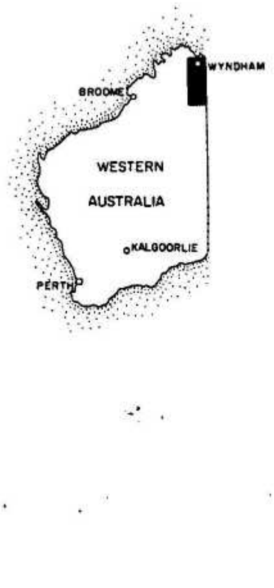
10 0 10 20 30 40 50 60 MILES

Reference

- Kimberley Plateau
- Kimberley Foothills
- Cambridge Gulf Lowlands
- Carr Boyd Ranges
- Ord Plains
- Osmond and Albert Edward Ranges
- Halls Creek Ridges
- Bow River Hills
- Sturt Plateau

"Nicholson" Homestead

Marsh, swamp



Bureau of Mineral Resources, Geology and Geophysics
Canberra, A.C.T. – August, 1964

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In 1945, Matheson & Teichert (1948) made a geological reconnaissance of the Cambrian rocks in the East Kimberley region, and in 1948 the Precambrian rocks near Halls Creek were mapped by Matheson & Guppy (1949).

Probably the greatest contribution to geological knowledge of the region since Hardman was made by Traves (1955), who as a member of a CSIRO Land Research and Regional Survey team in 1949 and 1952 mapped the Ord-Victoria Region. His map includes all the area covered by this report. The latest work has been done by Harms (1959), who made an appraisal of the whole Kimberley District, Ruker (1961), who mapped an area near Saunders Creek in the Gordon Downs sheet, and Smith (1963), who reported on work done by the Bureau of Mineral Resources party in 1962.

PHYSIOGRAPHY

The catchment of the Ord River covers the whole of the map area, with the exception of the south-eastern corner, which is drained by the inland flowing Sturt Creek, and the north-western corner, which is drained by rivers flowing into the West Arm of Cambridge Gulf. The main tributaries of the Ord River are the Dunham, Bow, Panton, and Elvire Rivers, all of which rise of the western margin of the region and follow easterly or north-easterly coarses across the regional structure, to join the Ord River on the east. Mountain barriers encountered by these tributaries are generally breached by way of deep gorges.

The Ord River Region has been divided into nine physiographic regions, based on Traves (1955), which are discussed below : their distribution is shown on Plate 2.

(1) Kimberley Plateau
(2) Kimberley Foothills
(3) Cambridge Gulf Lowlands
(4) Carr Boyd Ranges
(5) Ord Plains
(6) Osmond and Albert Edward Ranges
(7) Halls Creek Ridges
(8) Bow River Hills
(9) Sturt Plateau

(i) Kimberley Plateau

The Kimberley Plateau is the main physiographic feature in the Kimberley Region, but in the Ord River Region is confined to the western parts of Lissadell and Cambridge Gulf 1:250,000 Sheet areas. It extends north-westward from here to the coastline of the Indian Ocean and Timor Sea.

The bedrock of the Plateau is flat-lying Kimberley Group and Bastian Group rocks. In the south the margin of the Plateau is a prominent cliff along the eastern edge of the Durack Ranges, controlled by the contact of the Kimberley Group with the underlying Speewah Group rocks. The margin is not as marked in the north, where the surface slopes eastwards to merge into the Cambridge Gulf Lowlands.

Figure 2 : Salmond River Gorge.

Incised meanders of the Salmond River dissect horizontal Pentecost Sandstone in the Kimberley Plateau. Relief up to 1000 feet. G/6508

Figure 3 : Elgee Clifs

Elgee Siltstone crops out poorly in scarp beneath Pentecost Sandstone. Warton Sandstone caps dip-slope in foreground and Chamberlain River flows along contact between Warton Sandstone and Elgee Siltstone. G/6536

The Plateau consists of extensive structural benches and shallow dipping cuestas bounded by scarps up to 250 feet high. These benches are controlled by resistant sandstone beds from which overlying soft beds are being stripped by scarp retreat. The elevation of the plateau ranges between 1500 feet and 1700 feet in the south, decreasing gradually to about 100 feet in the north; a maximum of 2250 feet elevation is found in the southern Durack Ranges. The dominantly sandstone bedrock crops out very boldly throughout the Plateau and soil cover is limited. Vegetation is sparse except in isolated valleys and pockets.

Extensive dissection of the Plateau is taking place. The major streams such as the Salmond, Durack, Pentecost, and Forrest Rivers are superimposed streams incised into meandering gorges up to 750 feet deep and transgress the geological structure. The Chamberlain River, however, follows the contact of the Elgee Siltstone and Warton Sandstone for eighty miles in an asymmetrical valley 750 feet deep bounded by the Elgee Cliffs on the western side and a large cuesta of resistant Warton Sandstone on the eastern side.

The minor streams are subsequent streams with dendritic drainage, controlled by jointing, in the areas of flat-lying rocks, or a rectilinear pattern in the Durack Range area controlled by bedding and jointing of the dipping rocks. A noticeably large proportion of the streams are perennial spring-fed streams flowing in narrow gorges containing many small waterfalls.

In the Durack Range area the bedrock dips westwards and broad cuestas, 500 feet high, are formed by erosion of the Elgee Siltstone and Carson Volcanics into long, narrow, consistent valleys. The Cockburn Range, in the north, is a large mass standing well above the general plateau surface in the area; elevations range up to 2000 feet. The Bastian Range, House Roof Hill, and False House Roof Hill are small erosional remnants of a previously more extensive Kimberley Plateau preserved within the Cambridge Gulf Lowlands.

Although the Plateau is well watered, pastoral activity is limited by poor access and vegetation; it is confined to small isolated valleys and pockets.

(ii) Kimberley Foothills

The Kimberley Foothills border the Kimberley Plateau in the east, where the Younger Proterozoic rocks have been folded and faulted adjacent to the strongly deformed central zone of the map area. Differential erosion of the interbedded resistant and non-resistant rocks has produced rugged topography with a complex system of high hog-backs and cuestas; relief ranges up to 1000 feet. Small plateau are developed locally where the bedrock is flat-lying. Elevations of the ridges range from about 1750 feet to 1500 feet in the south-west, decreasing gradually to about 1000 feet in the north-east; the Foothills are erosional remnants of a previously more extensive Kimberley Plateau surface.

Figure 4 : Saw Ranges

Typical Kimberley Foothills at northern end of Saw Ranges. Three ridges, from left to right are Pentecost Sandstone, Warton Sandstone and King Leopold Sandstone. Elgee Siltstone and Carson Volcanics in valleys. Bidding dips 70° west. Relief up to 1000 feet above the Cambridge Gulf Lowlands (in background). G/6548

Figure 5 : Speewah Valley

Typical topography of Kimberley Foothills : Sill (black) of dolerite intrudes Speewah Group. Plateau of King Leopold Sandstone in background. G/6514

Most of the drainage is subsequent and is controlled by bedding, joints and faults in the bed-rock; a rectilinear drainage pattern is generally developed. Major streams such as the Dunham and Wilson Rivers are superimposed consequent streams subsequently modified by the geological structure of the bed-rock. Perennial spring-fed streams are common within the Foothills, especially adjacent to the margins of the Kimberley Plateau. The Kimberley Group rocks provide good aquifers. Fault planes also give rise to many springs.

The Saw Ranges are a most striking example of the Foothills : a simple set of parallel hog-backs, with slopes up to 70°, rising 100 feet above the surrounding Cambridge Gulf Lowlands. The O'Donnel Range area in comparison has a much more complex pattern of strike ridges which is due to folding and faulting in the bed-rock.

Large valleys occur within the Foothills along outcrops of dolerite. The Speewah Valley is an example of this : a large dolerite laccolith crops out in the core of a large dome structure, 20 miles long by up to eight miles wide, and is eroded into a valley with relatively low rounded hills surrounded by prominent cuestas of the overlying rocks.

Rather extensive pastoral activity is carried on within the larger valleys in the Foothills, especially dolerite valleys such as the Speewah, which support reasonable vegetation. Subsurface water supplies have to be used in places.

(iii) Cambridge Gulf Lowlands

Surrounding the lower reaches and estuaries of the Pentecost and Ord Rivers, in the northern part of the map area, are extensive low-lying plains, the Cambridge Gulf Lowlands. Elevations increase gradually from sea-level on the west to about 300 feet in the south. Erosional remnants of flat-lying Palaeozoic rocks, such as in the Onslow Hills and Eaber Range, and dipping Precambrian rocks (the Pincombe Range), occur as isolated ranges and hills scattered throughout the north-eastern sector of the Lowlands. Up to 500 feet of relief is present.

The plains are generally covered by Cainozoic sand and soil cover. Around the Ord River very extensive alluvial black soil plains (Carroll, 1947) are being cultivated as part of the Ord River Scheme. Black Soil plains also occur in the Dunham Valley, a large river plain surrounded by the Carr Boyd Ranges and Kimberley Foothills.

Around the tidal estuaries extensive salt and mud flats, subject to seasonal and tidal iinundation, have formed; these grade into emerged ancient salt plains further inland.

Cattle are grazed throughout the lowlands. Sub-surface water supplies are relied on, however, because surface water is very limited to the main rivers and small rock-holes around the bases of some of the hills.

Figure 6 : Carr Boyd Ranges.

Looking north-east from 'Pompeys Pillar Iron Ore Deposit'. Ridge in foreground and left-hand edge of photo is the Ivanhoe Fault zone. Low rounded hills in centre are Ragged Range Conglomerate. Carr Boyd Ranges on the skyline rise up to 1500 feet above the surrounding Ord Plains. G/6503

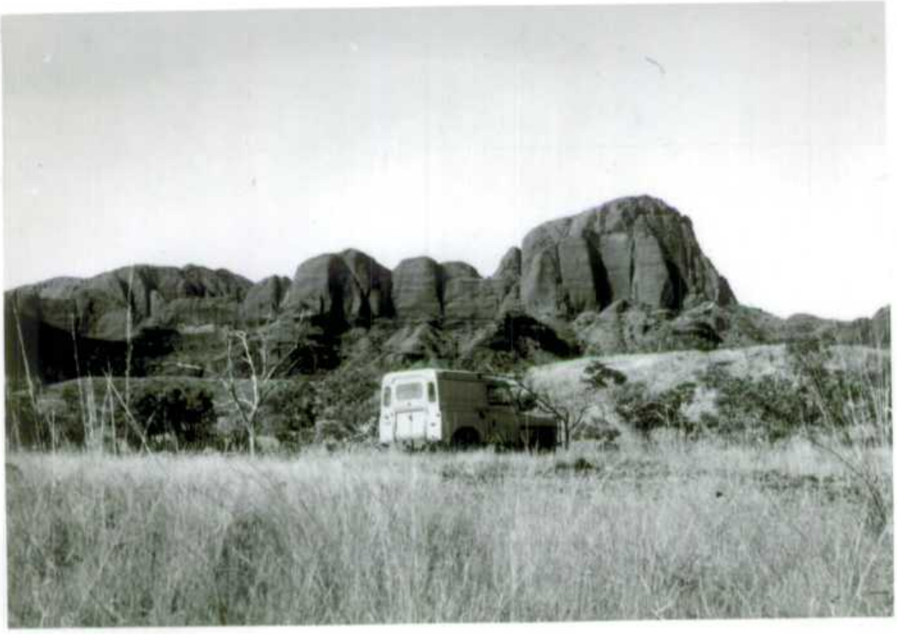

Figure 7 : Ragged Range

Typical skyline of western scarp. Antrim Plateau Volcanics in foreground. G/6504

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(iv) Carr Boyd Ranges

Some of the most rugged country in the area, the Carr Boyd Ranges, is found to the east of the Dunham River. Elevations range from about 2000 feet in the south to 1000 feet in the north. Up to 1500 feet relief is developed. The bed-rock is dominantly interbedded sandstone and siltstone, generally with low dips. These rocks have been deeply dissected into very narrow valleys and gorges making much of the area impenetrable except on foot.

Most of the drainage within the Ranges is superimposed, with the minor streams modified by the structure of the bed-rock. An irregular, dendritic pattern has formed. Superimposed drainage is well illustrated where the Ord River cuts through the Carlton Gorge. Springs are plentiful in the Ranges, especially along the large border faults. Waterfalls are common in the extremely narrow water-courses and discordant or 'handing' stream junctions have formed in places.

The Ranges are generally bounded by high, steep, fault scarps, such as the Ivanhoe and Carr Boyd Faults. In places erosion has removed the sandstones and exposed the Older Proterozoic rocks in large valleys such as around Revolver Creek and the Golden Gate Country.

The south-western border of the Ranges, near Pompeys Pillar, is a high scarp of sandstone, rising to over 2000 feet, in contrast to the faulted boundaries of the Ranges farther north. This range slopes eastwards in a series of sandstone cuestas to about 750 feet, six miles to the east in the valley around Glenhill Station. Between this range and the Ivanhoe Fault Scarp to the east a prominent, extremely dissected cuesta, about twenty miles long by three miles wide, is situated. This is called the Ragged Range because of its ragged skyline along the prominent western scarp. The elevation of the scarp is about 1500 feet and the Range slopes gradually eastwards. The bedrock is flat-lying, poorly lithified, Palaeozoic conlomerate and sandstone which is highly dissected into a dendritic insequent drainage pattern.

Mount Pitt and Mount Evelyn are erosional remnants of the Carr Boyd Ranges within the Ord Plains. They rise about 750 feet above the plain.

Pastoral activity in the Ranges is limited to the valley around Glenhill Station; the rugged topography makes the rest of the area unsuitable.

(v) Ord Plains

In its middle and lower reaches the Ord River drains open rolling plains, called here the Ord Plains, which extend from the southern margin of the Dixon Range Sheet area northwards for 130 miles to Argyle Downs. They are about 250 feet above sea-level in the north and rise gradually to 750 feet in the south. In their natural state the Plains are clothed in a heavy growth of native grasses, and provide much of the best grazing in the region. However, grazing and fires have removed the protective grasses, and seasonal torrential rains and strong winds have swept vast areas clear of soil and vegetation. The resultant sediment loads carried by the Ord River during floods have been recorded as high as 250 tons of mud per second.

A large part of the Ord Plains is underlain by Antrim Plateau Volcanics, and the country is more rugged, consisting of boulder-strewn hills up to 300 feet high. The drainage is dense, the valley walls are steep and generally broken by structural benches, and travel by vehicle is arduous. Mesas and buttes of resistant sandstone stand between 200 feet and 600 feet above the Plains (Fig. 6), and near Mount Buchanan erosion along joints has carved spectacular vertical-sided ravines and left spires of silicified sandstone.

On the southern margin of the map area, gently-dipping Headleys Limestone is cut by many narrow vertical-sided ravines formed by the enlargement of joints, and the area, in places, is almost impenetrable. Near the boundary between the Ord Plains and the Osmond and Albert Edward Ranges, Headleys Limestone is nearly vertical, and stands out from the surrounding country as straight walls up to 50 feet high and 100 feet across.

(vi) Osmond and Albert Edward Ranges

The Osmond and Albert Edward ranges are characterized by cuestas and hog-backs of Younger Proterozoic sediments.

The Osmond Range is a broad massif which juts eastwards into the Ord Plains from near the head of Bow River. It is dominated by a broad plateau of massive sandstone cut by mazes of deep ravines eroded along joints and faults. The highest point of the range, Mount Parker, 2378 feet, is the culmination of one of these plateaux. Broad cuestas flank most of the range. They dip gently away from the range, and are drained by radial, spring-fed creeks which flow down the dip slopes to the margin of the range. Osmond Creek is the largest stream : it rises in a large ampitheatre on the western end of the range and breaks through the range to the south-east in a deeply incised gorge (Fig. 12).

The Albert Edward Range extends from south of Ruby Plains Homestead north-north-westwards to the Osmond Range. It has a maximum elevation of 1600 feet, but it rarely rises more than 500 feet above the surrounding country. It is characterized by prominent cuestas and hog-backs of sandstone which have smooth, curved dip slopes to the east, and near-vertical scarps up to 400 feet high on the west. The regional drainage is west to east, and large streams break through the range in deep gorges.

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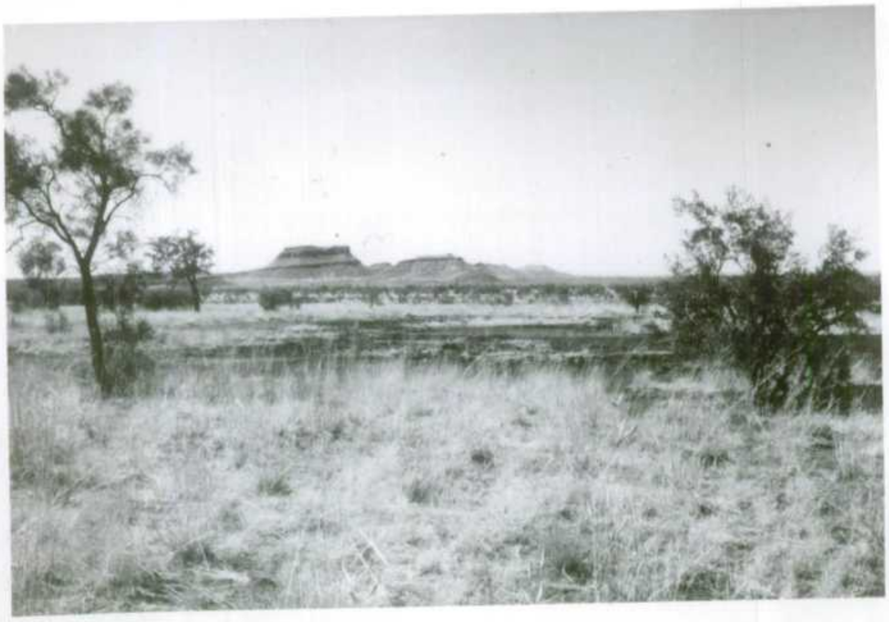


Figure 8 : Mount Elder photographed from the north. Resistant Buchanan Sandstone forms mesas up to 500 feet above the Ord Plains.

Figure 9 : Bay of Biscay Hills, photographed from near Mount Coghlan, looking north. Rocks are Olympic Creek Formation and Biscay Formation.

(vii) Halls Creek Ridges

The Halls Creek Ridges is a region of tightly folded Older Proterozoic rocks, with rough, hilly relief up to 300 feet. The Ord River is the lowest point, at about 900 feet, but the Ridges rise to over 2000 feet in the Saunders Creek area. The drainage is structurally controlled, but is extremely close-textured and best described as dense trellised drainage. The intervening ridges follow the regional north-north-easterly strike of the underlying rocks, and have steep flanks cut by steep gullies. They are closely-spaced and are generally breached every few hundred yards by cross-cutting streams (Fig. 7), and travel by vehicle, though possible in most places, is difficult. The run-off is fast, and there is little soil cover : consequently the main vegetation consists of spinifex and stunted eucalypts.

(viii) Bow River Hills

The western part of the Dixon Range Sheet consists of a north-north-east-trending belt of crystalline rocks which has an open-textured drainage moulding low rounded boulder-strewn hills, subdued strike ridges, and granite horsts. The area ranges in elevation between 1000 feet and 2000 feet and has a maximum relief of about 600 feet. The soil cover is poor, and most grazing lands are restricted to black soil plains overlying basic rocks, or alluvial deposits following the present river channels. Areas of intense shearing have eroded into wide valleys providing narrow pastoral belts and access to the north of the map area. The hilly areas are clothed in dense spinifex and sparse scattered eucalypts.

(ix) Sturt Plateau

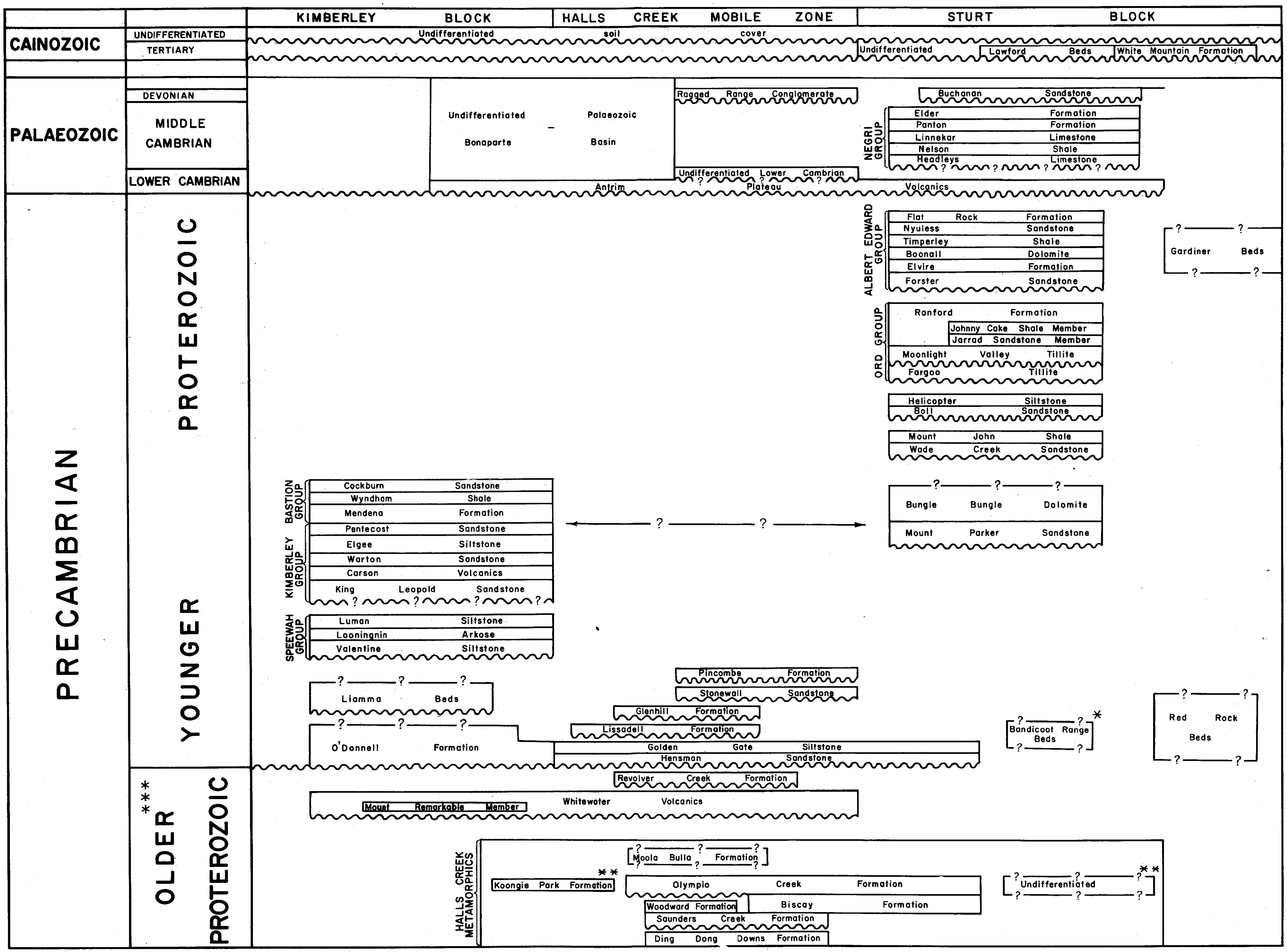
The Sturt Plateau is a high plain between 1000 feet and 1300 feet above sea-level, drained inland by Sturt Creek. On the north and west it is bounded by an erosion scarp up to 200 feet high, formed by down-cutting of the headwaters of the Ord River. South of the map area, the Plateau merges with the Canning Desert.

The Plateau is an almost flat land surface - a remnant of a lateritized peneplaned surface - covered by a thin veneer of blacksoil in the south. Sturt Creek and its tributaries are senile and poorly defined and salt water pools are common along its lower reaches.

Table 1.

STRATIGRAPHIC CORRELATION CHART

ORD RIVER REGION



NOTES:

* The Bandicoot Range Beds crop out on the western side of the Halls Creek Mobile Zone but cannot be shown in their place on the Table.

** The Koongie Park Formation is confined to the Mobile Zone. No outcrops of Metamorphics occur within the Kimberley Block. Undifferentiated Metamorphics are most extensive within the Mobile Zone.

*** The Older Proterozoic rocks are all intruded by igneous rocks of the Lamboo Complex.

STRATIGRAPHY

The stratigraphy of the region is summarized in Table. 1 [redacted]. The rocks fall into three broad divisions : tightly folded basement rocks intruded by gabbro and granite (here called Older Proterozoic rocks), faulted and generally broadly folded shallow-water sediments and volcanics (Younger Proterozoic), and a Cambrian sequence comprising plateau basalt and overlying shale and limestone. There is a considerable thickness of Upper Palaeozoic sediments in the northern part of the map area (Veevers, in preparation), but of these, only the southernmost Devonian sediments will be described in this report. Probable Tertiary sediments (chert and shale) and laterite occur in the southern part of the region.

Procambrian

OLDER PROTEROZOIC

The Older Proterozoic rocks crop out as a narrow belt between the south-western and north-eastern corners of the map area. Major faults delineate the eastern and western margins of most of this belt, and appear to have had a long history of movement during which they possibly influenced the younger Precambrian sedimentation.

Matheson & Guppy (1949) divided the Older Precambrian rocks into three units : the Halls Creek Group (metasediments and volcanics), the Mc Clintock Greenstones (mainly basic lavas), and the Lamboo Complex, which they defined as an essentially granitic complex containing sedimentary relicts. They regarded these rocks as Archaean. Traves (1955) could not differentiate between the Halls Creek Group and the Mc Clintock Greenstones, and he included both units in the Halls Creek Metamorphics, which he defined as including all the metamorphics in the vicinity of Halls Creek, and in isolated areas to the north-north-east. He regarded the Metamorphics as Lower Proterozoic. Most of the sediments are little altered, and the term Metamorphics is therefore misleading. The Lamboo Complex is discussed in detail under a separate heading.

Halls Creek Group

The rocks of the Halls Creek Group are the oldest known in the map area, and they are possibly the unmetamorphosed equivalents of the Tickalara Metamorphics. They are intruded by granite and are overlain unconformably by the Younger Proterozoic rocks.

The crop out as a north-north-easterly belt from near Ruby Plains Homestead to the Frank River, and as small inliers northwards to the limit of the map area. The rocks in the Frank River area are very little altered, but to the south they are metamorphosed, and reach low greenschist facies in the Gordon Downs 1:250,000 sheet. They are more highly metamorphosed near granitic intrusions and along large faults.

Seven formations are recognised. within the Halls Creek Group :

(top)
Moola Bulla Formation
Koongie Formation
Olympio Creek Formation
Biscay Formation
Woodward Formation
Saunders Creek Formation
Ding Dong Downs Formation
(bottom)

Ding Dong Downs Formation

The Ding Dong Downs Formation was named by Smith (1963). It is the oldest unit in the area and crops out in the cores of two domes about 20 miles north-east of Halls Creek. The base of the Formation is not exposed, and it underlies, possibly unconformably, the Saunders Creek Formation. We know little about the Formation because it is poorly exposed and is strongly faulted and folded. It consists of epidotized basalt and dolerite, quartz-muscovite and quartz-biotite schist, albitized porphyritic rhyolite, and some phyllite and slate.

The basalt is fine-grained, a distinctive light-green colour, and in places has abundant near-spherical amygdales filled with quartz, calcite, and possibly zeolite. Native copper was found near Saunders Creek Uranium Prospect as small crystals and aggregates in these amygdales, and thin veins of quartz and native copper have been reported from this locality (J. Carruthers, pers. comm.). In thin-section the rock is seen to have a granoblastic texture, and is composed mostly of pale yellow epidote and lesser amounts of randomly oriented actinolite, and cavity-filling calcite. Magnetite occurs as scattered crystals larger than the matrix and small crystals of pyrite are present in accessory amounts.

The rhyolite consists of phenocrysts of microcline partly or wholly replaced by albite, in a fine-grained matrix of quartz, sericite, feldspar, biotite, and chlorite. Calcite, iron-oxide, epidote, and zircon are accessory. Re-crystallization of quartz and biotite has impressed a slight foliation on the rock.

Banded quartz biotite schist, epidotized quartz muscovite schist, and quartz sericite schist are common in the Formation. These rocks appear to have suffered retrogressive metamorphism, which has formed randomly-oriented biotite, thus weakening the original schistosity of the rock. The Formation is considerably metamorphosed and the occurrence of 'phyllite' and 'slate' within it appears anomalous. However, no thin-sections of these rocks have been examined, and they may be fine-grained sericite schists.

The basic rocks have been mapped as part of the Ding Dong Downs Formation, but it is possible that they intrude the metasediments and the rhyolites, and are correlatives of the much younger Fish Hole Dolerite, with which they are almost identical in appearance (see later).

Saunders Creek Formation

Saunders Creek Formation was named by Ruker (1961) after Saunders Creek, 20 miles north-east of Halls Creek : the type section is 1½ miles south-west of Bulman Waterhole. The upper half of the Formation as defined by Ruker included greywacke and quartz greywacke which Smith (op. cit) put in the overlying Biscay Formation. The unit is now defined as indurated quartz sandstone, quartz conglomerate, and feldspathic sandstone which overlies the Ding Dong Downs Formation and is conformably overlain by the Biscay Formation. The Saunders Creek Formation crops out in the two domes in the Saunders Creek area and on the northern margin of the Sophie Downs Granite.

Quartz conglomerate occurs near the base of the unit as beds between twelve inches and five feet thick : it crops out only west and south-west of Bulman Waterhole and consists of rounded to sub-angular fragments of quartz and rhyolite in a quartz matrix containing a high proportion of heavy minerals which are radioactive (see Economic Geology). The sandstone is medium to coarse-grained, almost invariably cross-bedded, and consists of quartz which has been mostly recrystallized to a fine-grained mosaic, minor feldspar, calcite, rock fragments, and accessory magnetite, biotite, glauconite, muscovite, and zircon. The glauconite, which was identified by X-ray powder photography, occurs as rounded grains, some partly replacing feldspar. With increasing feldspar content the quartz sandstone grades into feldspathic sandstone.

The Formation is 600 feet thick at the type section, but thins rapidly to its eastern and western limits, where it is between 50 feet and 100 feet thick. The rapid lateral changes in lithology and thickness and the ubitiquous cross-bedding show that the Formation was laid down in shallow water.

Rhyolite pebbles in the Saunders Creek Formation could have come from the Ding Dong Downs Formation, and discordance, seen on the air photos, between structures in the Ding Dong Downs Formation and the overlying Saunders Creek Formation, suggest that the contact is unconformable. However, exposures are poor near the contact, and the field relationships are uncertain.

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Biscay Formation

The Biscay Formation was named by Smith (op. cit.) after the Bay of Biscay Hills in the middle reaches of the Panton River. The Formation crops out north and south of the Saunders Creek area in the core of a domed anticlinorium, and south of Halls Creek in the core of what is probably the same anticlinorium displaced southwards by the Halls Creek Fault. The area to the north-east of Halls Creek is a large fault wedge composed largely of these rocks.

The Formation conformably overlies the Saunders Creek Formation and is overlain, apparently conformably, by the Olympio Creek Formation. North of the Sophie Downs Granite the Woodward Formation (see below) overlies the Saunders Creek Formation, and it is probably the lateral equivalent of the Biscay Formation.

The Biscay Formation has been metamorphosed to the low greenschist facies, and consists mainly of basic volcanics and intrusives, acid and intermediate igneous rocks, muscovite and biotite schist, and calc-silicates. Basalt and dolerite predominate. It is generally impossible to tell whether the fine-grained basic rocks are extrusive or intrusive : pillow lavas have been seen in Woodward Creek, but undoubted intrusions have also been seen.

The least metamorphosed basic volcanics in the Formation are dark green, fine-grained, and in some cases, porphyritic. They show very few primary features, and in thin-section they are recrystallized. Plagioclase is pseudomorphed by sericite, kaolin, and clinozoisite or epidote and ferromagnesian minerals by small tremolite laths or chlorite and epidote. Quartz is a minor constituent and iron oxides are replaced by leucoxene. The basic intrusives have retained more of their primary features and relict sub-ophitic or allotriomorphic granular texture can be discerned. Lath-like andesine is replaced by a fine-grained aggregate of an epidote mineral. Secondary hornblende is idioblastic to xenoblastic, and the grains are fractured and replaced by biotite. In the sub-ophitic rocks the groundmass consists of fine-grained quartz and ragged feldspar.

Acid volcanics are common in the Formation. They are mostly rhyolite, which is commonly porphyritic, consisting of fine-grained granular quartz and orthoclase, minor plagioclase, and rare biotite. Phenocrysts, if present, are quartz and feldspar. Similar rocks containing dominant plagioclase are classed as dacite. Microgranite and microgranodiorite are commonly associated with the acid volcanics. They consist of quartz, soda and potash feldspar in varying proportions, and accessory iron oxides, sphene, and epidote. Ferromagnesian minerals are rare, but one thin-section contained riebeckite as phenocrysts and in the groundmass.

Grey to dark brown incipiently crenulated schists are intercalated with the volcanic rocks. They are metamorphosed to slightly higher degree than the Olympio Creek Formation and mineral assemblages found are :

quartz-biotite-chlorite;
quartz-muscovite-biotite; and
quartz-plagioclase-biotite-muscovite.

The rocks have a well developed preferred orientation, defined by small needles of muscovite and red-brown biotite. Quartz has lost its sedimentary form and occurs as polygenal, sutured grains. Plagioclase and orthoclase occur in minor amounts, and the dominant accessories are sphene, tourmaline, and apatite.

Large marble lenses are common in the lower part of the Formation. The marble is medium-grained to coarse-grained, and consists of twinned and distorted calcite crystals, minor poorly sorted and sutured grains of quartz, and prismatic crystals and rosettes of tremolite. The marble grades into rocks composed of equal proportion of calcite and tremolite. With increasing metamorphism they grade into hornblende-epidote rocks.

The rocks are tightly folded and highly sheared, and the thickness of the Formation is not known.

Woodward Formation (New Name)

Woodward Formation is the name given to interbedded, low-grade calc-silicates, subordinate quartz muscovite schist, and minor amphibolite, and graphitic schist. The Formation overlies, apparently conformably, the Saunders Creek Formation, and is overlain by the Olympio Creek Formation. It is known only north of the Sophie Downs Granite, where it crops out as a triangular fault wedge. Marble, which crops out near Mount Angelo is possibly a correlative of this Formation.

The rocks are metamorphosed to the greenschist facies. Calc-silicates consisting of quartz-calcite-chlorite schist, intercalated with tremolite-rich and epidote-rich, calc-silicates are the predominant rocks. In thin-section, the tremolite-rich rocks are seen to consist of tremolite, either as prismatic crystals or rosettes, calcite, and smaller grains of chlorite and muscovite. In the more massive rocks, detrital quartz grains can still be discerned. The epidote-rich rocks consist of decussate aggregates of chlorite and zoisite, irregular sphene, and scapolite containing tiny green poikiloblastic spinel.

Marble is common and in places is coloured black by manganese or red by limonite and hematite. Mostly it is brown to white, and in thin section it is seen to consist of a mosaic of calcite enclosing tiny grains of graphite, quartz, tremolite, and muscovite. In some thin-sections coarse-grained aggregates are surrounded by fine-grained calcite, possibly an indication of tectonic brecciation. In the type area copper, lead, and zinc mineralization is associated with the calcareous rocks (see Economic Geology).

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About 30 percent of the Formation consists of medium-grained quartz-muscovite and quartz-biotite schist, which grades into dark-green chlorite schist and a massive tremolite-rich rock. This gradation probably represents a change in the original rock from shale and greywacke to marl and calcareous sandstone. Thin bands of black graphite schist were noted but are rare.

The succession is given below, but the beds are isoclinally folded and the thicknesses given, particularly of the upper part of the succession, are probably greater than the true thickness.

<u>Olympio Creek Formation</u>

Woodward Formation	1600 feet	Mostly marble and calc. schist. Some dolomite and dolomitic shale to the west.
	800 feet	Interbedded quartz-muscovite, and quartz - biotite schist, and interbedded tremolite-rich rock.
	2000 feet	Predominantly quartz muscovite schist, chlorite schist, and tremolite-rich rock. Carbonaceous schist, marble, dolomitic ?shale, and calc. schist throughout.
	1000 feet	Mostly dark amphibolite.
	200 feet	Mostly biotite schist containing amphibolite.
Total thickness	5600 feet	
Saunders Creek Formation	400 feet	Quartz conglomerate, quartzite, and quartz sandstone.

Sophie Downs Granite (probably intrusive).

The Woodward Formation is overlain by the Olympio Creek Formation, but the nature of the contact is not known. Exposures in critical localities are poor, but apparent discordances in the structure of the two units suggest that the contact may be unconformable. The contacts between the Woodward Formation and the Biscay Formation are faulted, but the units are in the same stratigraphic position and it seems probable that the Biscay Formation is the lateral equivalent of the Woodward Formation.

Three base-metal prospects have been found in the Woodward Formation : a copper lode at Mount Angelo 30 miles south-west of Halls Creek, and two promising copper-lead-zinc prospects near Duffers Mine (see Economic Geology).

Figure 10 : Vertical quartz greywacke and fine-grained quartz jasper conglomerate of the Olympio Creek Formation. Load casts at the base of the conglomerate can be seen on the right. Photograph taken in the bed of the Ord River near the Frank River junction.

Olympio Creek Formation

The Olympio Creek Formation was named by Ruker (1961) after Olympio Creek, which is 22 miles east-north-east of Halls Creek. It overlies, apparently conformably, the Biscay Formation, and is unconformably overlain by younger Precambrian rocks.

The Formation is best developed east of the Halls Creek Fault, where it crops out as a wide belt which parallels the fault between Ruby Plains Homestead and the Osmond Range. West of the Halls Creek Fault Olympio Creek Formation is found only south of Halls Creek Township, where it crops out on the flanks of a north-east-trending anticlinorium. A small inlier in the headwaters of the Osmond River consists of almost unaltered Olympio Creek sub-greywacke on the east which grades by increasing contact metamorphism into high grade schists on the west.

The Olympio Formation consists of greywacke, feldspathic greywacke, and arkose, interbedded with siltstone and shale. Subordinate pebble conglomerate and rare limestone occur in the bottom part of the formation.

The greywacke and arkose generally occur as beds between one foot and eight feet thick, alternating with thinner beds of siltstone and shale. The relative amounts of greywacke and siltstone vary considerably, and in the upper part of the Formation north of the Ord River, shale beds up to 300 feet thick contain only rare greywacke. The coarse-grained greywacke, which grades into pebble conglomerate, crops out as beds up to 20 feet thick, separated by thin beds of shale. The shale and siltstone are generally laminated or thinly bedded, and the greywacke is massive. Graded bedding can sometimes be seen in the greywacke and load casts are common at the base of the coarser varieties (Fig. 4). Cross-bedding and ripple marks were seen but are rare.

The greywacke is dark-green or blue when fresh, fine-grained to coarse-grained, and grades into feldspathic greywacke and arkose. In thin section it is seen to be composed of subangular to subrounded grains of quartz (generally about 30 percent of the rock), feldspar, fine-grained volcanic rock fragments, and chert, chaotically distributed in a fine-grained matrix of sericite, chlorite, and quartz. Very little sorting is evident except in lighter-coloured quartz-rich varieties, which have better rounded grains and less matrix, and are classed as sub-greywacke. Many of the rocks are arkose and sub-arkose, consisting of quartz, plagioclase, minor potash feldspar, and rare rock fragments, in a matrix of sericite and chlorite. They are poorly sorted and those having abundant matrix are classed as feldspathic greywacke. Tourmaline, zircon, sphene, and iron oxide are accessory minerals in most of these rocks.

Fine-grained pebble conglomerate is common towards the middle of the succession south of the Ord River (Fig. 11). It consists of poorly sorted rounded to subrounded pebbles of quartz (generally abundant), jasper, chert, fine-grained dolerite, feldspar, and shale, in an arkose or greywacke matrix. The shale and siltstone are grey, blue-green, or dark-blue, and are commonly phyllitic. The beds of shale in the upper part of the Formation are purple or red.

There are rare pink and white marble beds near the bottom of the Formation. They are up to 300 feet thick, and some can be traced for several miles. Impure varieties are green and contain tremolite and epidote. In the Frank River area, several large masses of dolomite appear to be interbedded with the Olympio Creek Formation : they are massive and contain many chert nodules and rolls in the weathering profile.

Almost all the finer-grained beds are impressed with an axial-plane cleavage, which may not be obvious in fresh exposures, but which causes the rock to weather into blade-shaped fragments. East of the Frank River, the shale has a marked lineation parallel to the steeply dipping fold axes, and outcrops consist of tightly packed angular rods of a shale.

North of Saunders Creek the rocks of the Olympio Creek Formation are recrystallized only to a minor degree : the matrix is generally reconstituted to sericite and chlorite, but the larger detrital grains are unaltered except for slight marginal corrosion. The amount of reconstitution of the matrix could have been caused by diagenetic processes alone.

In the Gordon Downs 1:250,000 sheet area the rocks have suffered low-grade regional metamorphism to a low greenschist facies. The matrix has a slight foliation, and much of it has recrystallized to muscovite. The larger grains are considerably corroded, or sutured where they are in contact, and commonly contain flakes of chlorite near their margins. Two thin-sections examined are biotite grade in which the matrix is completely reconstituted to muscovite and biotite.

An inlier of Older Proterozoic rocks in the head of Osmond Creek is composed of rocks referred to the Olympio Creek Formation. The rocks on the east of the inlier are slightly recrystallized greywacke, sericite schist, and marble which have been intruded on the west by granite and metamorphosed to muscovite-sillimanite schist.

The rocks on the western side dip almost vertically to the south and west and it was originally thought that they were folded into an anticline which plunged south at nearly 90°. However, graded bedding found in the less metamorphosed rocks to the east indicate that the top of the succession is to the north. The thickness of the sequence described below was estimated from air photographs :

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Thickness	Lithology
	Red Rock Beds
3000 feet	Green or cream (rarely pink) marble as beds between six feet and twelve feet thick, interbedded with roughly the same amount of sericite schist. Marble is fine-grained and is invariably laminated; the laminae are rarely replaced by dolomite or chert. The sericite schist is massive and contains rare thin-bedded or laminated quartz greywacke beds up to two feet thick.
800 feet	Fine-grained quartz sericite schist containing rare graded beds of quartz greywacke up to four feet thick.
2000 feet	Thick-bedded, medium to coarse-grained quartz greywacke consisting of rounded grains of quartz and minor feldspar in a recrystallized chloritic or sericitic matrix. Rare graded bedding was seen. Interbedded phyllite and fine-grained sericite schist constitutes up to 20 percent of the sequence and crops out as massive beds up to three feet thick.
1800 feet	Laminated and thin-bedded green greywacke composed of sub-angular quartz and muscovite grains in a fine-grained chloritic matrix. Many large dykes of uralitized gabbro.
	Osmond Fault.

The rocks are metamorphosed to the low greenschist facies and are extensively intruded by gabbro, nevertheless they can confidently be referred to the Olympio Creek Formation which crops out twelve miles to the south.

The formation is tightly and much faulted, and no estimate of its thickness apart from the incomplete section noted above can be made. North-west of Mount Kinahan there appears to be not less than 10,000 feet of section exposed but the Formation is almost certainly much thicker.

Koongie Park Formation

Quartz sandstone exposed in a fault-block immediately east of Halls Creek was named Koongie Formation by Smith (1963). The Formation is bounded on all sides by faults, except to the south, where it appears to grade laterally into greywacke of the Olympio Creek Formation.

The Koongie Formation consists of fine-grained to medium-grained quartz sandstone, feldspathic sandstone, and rare ferruginous sandstone. The rocks are commonly silicified and are generally thinly-bedded, though cross-bedding does occur. Valleys containing no outcrop separate the sandstone strike-ridges, and they are probably underlain by siltstone and shale.

Poorly exposed basic rocks which crop out as low rounded hills have been included in the Koongie Formation. They are amygdaloidal, highly epidotized basalt or dolerite which may be lavas and therefore part of the succession, or they may be intrusive and correlatives of the Fish Hole Dolerite.

The rocks appear to be folded into a tight syncline containing the basic rocks in the core. If this structural interpretation is correct, the Formation is about 3200 feet thick.

Moola Bulla Formation

Arkose and feldspathic sandstone cropping out as fault-blocks east of Halls Creek and west of Duffers Mine were named by Smith (op. cit.) the Moola Bulla Formation.

The rocks are medium to coarse-grained, and generally contain scattered pebbles of quartz and quartzite. They are commonly cross-bedded, and in many places heavy minerals form layers in the cross-beds. The sandstone grades into pebble to boulder conglomerate consisting of components up to three feet across of quartz, quartzite, banded greywacke, and minor slate, in an arkose or sandstone matrix. Grey slate is interbedded with the arenaceous rocks in some parts of the sequence, but is not common.

The Formation, as measured on the air photographs, appears to be at least 12,000 feet thick. It has been included in the Halls Creek Group, but as all its contacts with other units are faulted or poorly exposed, its true stratigraphic position is not known. South of Halls Creek the Formation overlies Olympio Creek rocks, but the nature of the contact is not known. The Formation is similar to the Red Rock Beds, and it may be a correlative.

Undifferentiated

Schist and quartzite crop out in the south-eastern corner of the map area. The rocks are overlain unconfomably by the Younger Proterozoic Gardiner Formation, and have been mapped as undifferentiated Halls Creek Metamorphics. The following assemblages have been noted :

quartz-muscovite-chlorite;
quartz-muscovite-hematite; and
quartz-diopside-cordierite-microcline.

The first assemblage is from a schistose rock in which lepidoblastic flakes of muscovite are interfoliated with polygonal. xenoblastic quartz grains. Patches of sericite and muscovite are accessories and may represent retrogressed aluminium silicates.

The last two assemblages are from granular quartzites. In the first idioblastic hematite is interbanded with xenoblastic quartz and rare ragged muscovite flakes. In the other, idioblastic diopside is set in a xenoblastic granular quartz-rich base. Moderate amounts of cordierite and potash feldspar are set in sericite-rich cavities and may represent original argillaceous matrix. Minor clinozoisite, amphibole, and sphene are the dominant accessories.

Four miles north-west of the junction of the Ord and Negri Rivers an inlier of tightly folded greywacke, shale, and minor dolomite has been called 'Undifferentiated Halls Creek Group'. The rocks are mostly greywacke and quartz greywacke similar to those of the Olympio Creek Formation exposed in the Ord River 50 miles to the south-west. The greywacke is green to dark-grey, medium to coarse-grained, and consists of rounded to subangular quartz and feldspar grains in a green chloritic matrix. It grades into quartz pebble conglomerate. It occurs mostly as regular beds between two feet and six feet thick, in which cross-bedding can sometimes be distinguished in good exposures, interbedded with siltstone and shale beds between one and two feet thick. The siltstone and shale are black, or rarely green and red, and are generally laminated. Dolomite crops out in the south-western part of the inlier as beds up to 20 feet thick.

Altered gabbro dykes commonly intrude these rocks, especially along a shear zone south of the Ord River. Close to the dykes the greywacke is recrystallized, either to a weathered brown mica-rich rock, or to a hard fine-grained hornfels. The finer-grained rocks are changed to phyllite.

To the north on Lissadell and Cambridge Gulf Sheet areas inliers of undifferentiated Halls Creek Group crop out in the Carr Boyd Ranges and Golden Gate Country, unconformably overlain by the Carr Boyd Succession and Revolver Creek Formation. They cannot be directly correlated with the formations in the south.

Six miles north-north-east of Mount Nyulasy interbedded khaki slates and grey medium-grained feldspathic greywacke are tightly folded. Fold axes have very shallow plunges, and vertical slaty cleavage strikes about 210°. The rocks are overlain by the Revolver Creek Formation with marked angular unconformity. 'Porphyritic granite' intrudes them with very minor contact thermal metamorphism; recrystallization occurs only over a width of three or four inches.

Low-grade metamorphics in the upper Revolver Creek area consist of quartz greywacke, fine-grained feldspathic greywacke, green, grey and red slates, sericite schist, and minor acid (?) tuffs. These rocks dip steeply with drag folds plunging south. The original axial plane cleavage has been folded into an open antiform plunging 85° north. They are unconformably overlain by the Revolver Creek Formation.

To the east and north of Mount Hensman red slate and mica phyllite dip between 50° and 80° west and are overlain by green quartzite, in beds up to six feet thick, interbedded with quartz greywacke, mica schist, and minor red slates. Small uralitized dolerite dykes intrude them.

Near the 'Ord Damsite Road' vertically dipping quartz greywacke and minor thin beds of mica phyllite have bedding transposed into lenticular wedges paralleling cleavage. They are intruded by 'porphyritic granite', producing a superimposed contact thermal metamorphism; spotted poikiloblastic cordierite-biotite schists are present. The contact aureole is up to 1000 feet wide.

Farther north, near Fine Spring, red slate, mica phyllite, minor quartz greywacke, and a persistent chert pebble and cobble conglomerate bed, 25 feet thick, dip about 25° north. The conglomerate has a black ferruginous grit at the base. These rocks are intruded by 'porphyry', or its hornblende granodiorite phase, 'porphyritic granite', and late stage dolerite dykes. They are overlain, probably unconformably, by the Whitewater Volcanics.

Whitewater Volcanics (New Name)

Smith (1963) named acid volcanics in the western part of the Dixon Range Sheet area the Whitewater Formation after Whitewater Well on the Dixon Range Sheet area. The Formation consists predominantly of rhyolite volcanic rocks, and we prefer the name Whitewater Volcanics. The type area is Mount Remarkable near Greenvale Homestead, where the full section is exposed. The Volcanics crop out in the map area as discontinuous exposures from Whitewater Well northwards along the western side of the Lamboo Complex, to the Carr Boyd Range. They are known to extend to the west of the map area. They rest with strong angular unconformity on the Halls Creek Group and are intruded by porphyry, porphyritic granite, and biotite granite of the Lamboo Complex. They are overlain unconformably by the O'Donnell Formation in the west, and the Revolver Creek Formation in the east.

The Volcanics consist of red, green, and black rhyolite lavas, and minor rhyolite agglomerate and welded tuff. Conglomerate and other sedimentary rocks within the formation are called the Mount Remarkable Member. Intrusive acid porphyry of the Lamboo Complex is similar in composition and fabric to the Volcanics and is probably co-magmatic and the lower part of the Volcanics probably contains a considerable proportion of intrusive porphyries which cannot be distinguished from the extrusive rocks.

The lava flows are porphyritic rhyolite and consist of phenocrysts of white and blue quartz, and pink feldspar, set in a dark cryptocrystalline siliceous groundmass speckled with tiny phenocrysts of quartz and feldspar. Chlorite blebs are present, and probably represent altered mafic minerals, possibly biotite. Flow layers are prominent on the weathered surfaces, and the dip of these layers is independent of the regional structure of the rock. In thin section, euhedral to subhedral, commonly bipyramidal quartz phenocrysts, and euhedral, twinned and zoned plagioclase phenocrysts are set randomly in an almost cryptocrystalline groundmass of ragged feldspar, quartz, chlorite and devitrified glass. The plagioclase is in the albite-oligoclase range and is invariably sericitized, and embayed; it is commonly replaced by granular epidote. Potash feldspar is generally present as aggregates of feldspar and quartz in the coarser rocks, which appear to be partly intrusive, chlorite commonly pseudomorphs amphibole and in one specimen, pyroxene. They are similar in composition to the lavas. 36

Traves (1955) noted welded tuffs within the formation but they appear to be present in minor quantities only. One thin-section examined consists of dark lenticular shards and angular fragments set in a fine-grained siliceous matrix. Fractured quartz, albite, and potash feldspar are distributed randomly throughout the rock, and flow layers or compaction bands are defined by the shards and by recrystallized bands. Trendall (1962) has described other aphanitic rocks from the region : "Variations of grainsize within this mosaic define the outlines and internal structure of bands, and contorted fragments vary in size from about 2 mm down to the smallest. Subhedral feldspars are enclosed within this matrix. The shapes and stratified arrangements of the fragments strongly suggest volcanic detritus, and there is little doubt that these rocks are thoroughly welded tuffs.

The lower half of the Whitewater Volcanics is generally coarser than the upper part, flow banding is rare, and quartz phenocrysts are less common. Rare sedimentary inclusions are seen and it is thought that this lower part may be a high level intrusive, and not extrusive. The Volcanics overlying the Mount Remarkable Member are obvious flows, and exhibit considerable changes across the strike. At least three flows can be distinguished.

The formation has not been measured, but it appears to be between 1500 feet and 2000 feet thick.

Mount Remarkable Member (New Name)

We have given the name Mount Remarkable Member to volcanic conglomerate, agglomerate, arenites, and minor siltstone and chert which are 600 to 800 feet stratigraphically below the top of the Whitewater Volcanics. It is named after the type area at Mount Remarkable. It crops out along the eastern side of the Lamboo Complex in the Dixon Range Sheet area, and in the O'Donnell Range. The Member rests on the lower Whitewater Volcanics with slight erosional unconformity and is conformably overlain by the upper volcanics.

It crops out as prominent strike ridges, recognisable on airphotos by the denser growth of stunted eucalypts.

The section in the type area is :

	Rhyolite lavas
30 feet	Green to white banded chert.
10 feet	Green, poorly-sorted chert breccia or agglomerate, consisting of chert pebbles and quartz and feldspar fragments in a siliceous matrix.
400 feet +	Grey coarse-grained poorly sorted volcanic greywacke containing angular to rounded volcanic chert and jasper fragments, euhedral feldspar, quartz, and unidentified ferromagnesian minerals. The matrix is chloritic and commonly highly sheared. To the west the greywacke grades into dark boulder conglomerate consisting of rounded and angular boulders of rhyolite in a greywacke matrix.
	erosional unconformity
	acid volcanics.

North of Mount Remarkable in the southern part of the Lissadell Sheet area the member consists of thin conglomerate bands, but in the O'Donnell Range it is 700 feet to 800 feet thick. To the north-east in the Carr Boyd Range it appears to be absent. This rapid lateral variation of the Member appears to be due to the relief of the erosion surface on which the member was laid down as a valley-fill deposit.

Revolver Creek Formation (New Name)

The Revolver Creek Formation is the name given to a sequence of sandstones, siltstones, and basic volcanics which underlie the Hensman Sandstone with angular unconformity. It overlies the Whitewater Volcanics with erosional unconformity, the Halls Creek Metamorphics with marked angular unconformity, and the base of the Formation is intruded by 'Muscovite Granite' from the Lamboo Complex. The Formation is taken as being the youngest Older Proterozoic sedimentary sequence in the region and it post-dates the intense regional folding and low-grade regional metamorphism of the Halls Creek Metamorphics.

It crops out in only three areas within the Carr Boyd Ranges, namely along the northern side of Revolver Creek (Lat. 16° 15' S. Long. 128° 36' E.) from where the name is derived ; in the south-west (Lat. 16° 20' S. Long. 128° 28' E.); and on the south-western tip of the Ranges (Lat. 16° 43' S. long. 128° 20' E.) six miles north-east of Mount Nyulasy. The latter outcrop is the reference section for the Formation. It is a moderately resistant unit occurring in the scarps beneath a prominent cliff-line of Hensman Sandstone. Within the unit volcanics and siltstones form small scarps beneath prominent erosional terraces of sandstone.

The lower part of the Formation consists of massive amygdaloidal basalt with interbeds of pink arkose. Above this block white quartz sandstone alternates with interbedded flaggy fine-grained sandstone, purple-brown micaceous shale, and massive chocolate-brown siltstone. The sandstone is cross-bedded and contains abundant shale bedding partings and shale pellets. The volcanics vary rapidly in thickness along strike; an increase from about 1000 feet to 2500 feet in a mile strike distance has been observed.

The following generalized section occurs in the reference area. Thicknesses are based only on visual estimates in the field.

Hensman Sandstone

Angular Unconformity

400 feet	Blocky cream-white, friable fine-grained quartz sandstone. Strongly cross-bedded; abundant clay pellets.
200 feet	Interbedded flaggy fine-grained sandstone and fissile purple-brown micaceous shale. Blocky sandstone interbeds near base.
200 feet	Blocky white friable quartz sandstone. Strongly cross-bedded. Abundant clay pellets.

150 feet	Flaggy fine-grained sandstone and thinly flaggy micaceous siltstone. Blocky quartz sandstone interbeds near base.
50 feet	Blocky medium-grained quartz sandstone. Purple shale partings. Shale pellets. Cross-bedding.
250 feet	Flaggy fine-grained sandstone and thinly flaggy micaceous siltstone at base grades up into massive choclate-brown siltstone.
50 feet	Flaggy fine-grained purple micaceous quartz sandstone.
1000 to 2500 feet	Massive dark green altered amygdaloidal basalt with two consistant interbeds (100 feet thick) of cross-bedded pink arkose (containing ? glauconite). Basalt contains flows about 100 feet thick, defined by erosion benches and concentration of quartz amygdules at the top.
50 feet	Massive quartz sandstone.
Total 4000 feet	Angular Unconformity
	Halls Creek Group hi or Lamboo Complex intrudes basal sandstone.

The basalts in thin-section are highly altered. The ferromagnesian minerals, probably pyroxene, are altered to chlorite, and the feldspar to albite with release of calcite; epidote is absent. Spinel is common. Amygdules contain dark green chlorite and minor albite and zeolite. Quartz is concentrated at the tops of flows.

Only the basal sandstone and about 200 feet of volcanics is preserved as a small plateau capping in the outcrop around Lat. 16° 20' S. Long. 128° 25' E.

In the Revolver Creek area a thick section of sediments at the top of the Formation is preserved. The basal sandstone is missing and the volcanics are thinner than in the reference area. The Formation overlies the Whitewater Volcanics and the 'Porphyritic Granite' of the Lamboo Complex with apparent erosional unconformity. The unit has been strongly folded prior to deposition of the Hensman Sandstone. Siltstone beds have a strong subvertical cleavage and low-grade metamorphic rocks are developed in the Carry Boyd - Halls Creek Fault Zone.

Younger Proterozoic

The Younger Proterozoic rocks of the Ord River Region are defined as those rocks which unconformably overlie the Lamboo Complex. They overlie theHalls Creek Group with marked angular unconformity. The base of the Younger Proterozoic sequence is taken at the base of the Hensman Sandstone or the base of the O'Donnell Formation.

The Younger Proterozoic rocks consist of interbedded arenites and lutites with minor carbonate and volcanic rocks. Some basic intrusives occur also. The rocks are generally undeformed, apart from faulting and broad folding, except near major fault lines. This contrasts with the deformation and metamorphism of the Lower Proterozoic rocks, except the Whitewater Volcanics and Revolver Creek Formation at the top.

Three distinct successions are exposed in different areas within the Region. They are separated by major faults and little overlap is present between them. The successions are apparently of different ages but correlations are doubtful. Unconformities are common throughout.

The Carr Boyd succession is exposed throughout the Carr Boyd and Pincombe Ranges in the northern part of the Halls Creek Mobile Zone, unconformably overlying, in various places, the Revolver Creek Formation, Lamboo Complex, or Halls Creek Group. It is an alternating succession of sandstone and siltstone and consists of six formations :

Pincombe Formation
Stonewall Sandstone
Glenhill Formation
Lissadell Formation
Golden Gate Siltstone
Hensman Sandstone
(bottom)

A seventh unit, the Bandicoot Range Beds, is a stratigraphic equivalent of an unknown part of the succession.

Unconformities occur at the base of all the formations except the Golden Gate Siltstone.

The Kimberley Basin succession was deposited in the Kimberley Basin in the west of the map area. Outcrops of the succession are practically all confined to the Kimberley Block, i.e. to the area west of the Greenvale Fault. In the north outcrops extend east to the Ivanhoe Fault, the absolute easterly limit of known outcrop. The succession unconformably overlies the Whitewater Volcanics.

Sandstones and shales, with minor volcanics and some carbonate rocks, make up the succession, which consists of the following units :

Bastian Group
Kimberley Group
Speewah Group
Liamma Beds
O'Donnell Formation
(bottom)

40

Unconformities occur at the base of the O'Donnell Formation, Liamma Beds, and Speewah Group, and probably at the base of the Kimberley Group.

The eastern succession crops out only to the east of the Halls Creek Fault and is best exposed in the Osmond and Albert Edward Ranges. It is a sequence of sandstones, siltstones, and carbonate rocks, unconformably overlying the Halls Creek Group. It consists of:

Albert Edward Group

Ord Group

Helicopter Siltstone

Boll Sandstone

Mount John Shale

Wade Creek Sandstone

Bungle Bungle Dolomite

Mount Parker Sandstone

Red Rock Beds

(bottom)

Unconformities are found at the base of the Red Rock Beds, Mount Parker Sandstone, Wade Creek Sandstone, Boll Sandstone, Ord Group, and Albert Edward Group.

Very little overlap occurs between the three successions therefore any correlations between them must be based largely on lithological similarities. In general ths Carr Boyd succession is the oldest of the three, with thinner stratigraphic equivalents at the base of the other two successions; the bulk of the Kimberley Basin succession follows, and the Eastern Succession is the youngest.

A programme of radiometric dating of rocks from the Region is in progress at the Australian National University and the preliminary results obtained to date (V.M. Bofinger and I. McDougal, pers. comm.) support the proposed correlations.

The inferred stratigraphic relationships of the Younger Proterozoic rocks of the Ord River Region are shown in Table 1.

Carr Boyd Succession

The oldest succession of Younger Proterozoic rocks in the map area is exposed in the Carr Boyd and Pincombe Ranges. Outcrops are bounded in the west by the Dunham-Ivanhoe Fault System; in the east, only minor outcrops are found east of the Halls Creek Fault. The rocks unconformably overlie the Older Proterozoic rocks. East of the Halls Creek Fault rocks of the succession are unconformably overlain by both the Mount Parker Sandstone and the Ord Group, of the Eastern succession. Within the Halls Creek Mobile Zone they are unconformably overlain only by Palaeozoic rocks. Near the Cave Range, in the north, the succession may be overlain unconformably by an isolated outcrop of Kimberley Group rocks, but a fault of unknown magnitude between the two sequences makes the relationship uncertain.

The rocks throughout the succession consist of a series of rhythmically alternating sandstones and siltstones or shales. The usual cycle has an unconformity at the base overlain by a thick sandstone unit which grades upwards into siltstone and shale, over which, after another unconformity, the cycle is repeated. An overall gradation in the lithology of the lutites occurs through the succession as a whole. The silts of the older formations are poorly sorted and contain abundant unstable minerals such as mica and chlorite. The silts near the top of the succession are highly siliceous, well sorted, and contain very minor mica and chlorite.

The succession consists of the following formations:

Pincombe Formation

Stonewall Sandstone

Glenhill Formation

Lissadell Formation

Golden Gate Siltstone

Hensman Sandstone

(bottom)

Regional unconformities occur at the base of all the units except the Golden Gate Siltstone.

Although the rocks of the succession are closely related, they cannot be combined into a Group because unconformities are present. The informal name 'Carr Boyd succession' is used. Before the present survey very little geological work had been done in the Carr Boyd Ranges. Both Traves (1955) and Harms (1959) mapped the rocks as 'Undifferentiated Upper Proterozoic'.

The major faults of the Halls Creek Mobile Zone were active throughout sedimentation and their movements are responsible for many of the observed unconformable relationships. The unconformities however can be recognised at consistent stratigraphic levels throughout the area. Over large areas erosion at the unconformities is apparently minor, but locally up to 1000 feet of sediment has been removed. Elsewhere up to 4000 feet of section is transgressed by overlying units, but this could be partly the result of simple overlap of original depositional basins. The unconformities are best developed near the apparent margins of depositional basins; these margins were influenced by faults.

Many of the units are thicker in the east, near the Carr Boyd Fault, than in the west, near the Durham - Ivanhoe Fault System. Shallow-water sedimentary features are more common in the west. The Lissadell and Glenhill Formations do not crop out east of the Carr Boyd Fault and it is not known whether they were not deposited here or were eroded after deposition. The Lissadell Formation shows marked (?) depositional thinning adjacent to the Fault and the Glenhill Formation shows an apparent direction of sedimentation from across the Fault Zone to the east. The other units, which cross the Fault, are thicker, if anything, to the east of the Fault.

The Red Rock Beds at the base of the Eastern succession are considered to be stratigraphically equivalent to the Carr Boyd succession as are the O'Donnell Formation and Liamma Beds, at the base of the Kimberley Basin succession. The Speewah Group is inferred to be younger.

No stratigraphic sections were measured within the Carr Boyd succession owing to lack of suitable exposures. All thicknesses quoted are based on estimates from maps and air photographs or visual estimates in the field. The maximum thickness of the Carr Boyd succession is about 30,000 feet.

Hensman Sandstone (New Name)

The basal unit of the Younger Proterozoic rocks in the Carr Boyd succession has been named the Hensman Sandstone from its reference section at Mount Hensman (Lat. 16°00' S, Long. 128° 56' E), in the Golden Gate Country. It crops out in a prominent cliff throughout the southern and central Carr Boyd Ranges, from Mount Hensman in the north-east to near Durham Hill in the west; it only occurs east of the Durham Fault. It sits on a variety of Older Proterozoic rocks including the Revolver Creek

Formation, Whitewater Volcanics, Halls Creek Group, and Lamboo Complex, with angular unconformity, and is conformably overlain by the Golden Gate Siltstone. Its excellent outcrop and stratigraphical position make the Sandstone a valuable stratigraphical marker.

The unit consists entirely of massive, white, fine to medium-grained quartz sandstone. It is generally very clean and well sorted and contains very minor amounts of feldspar. Some cross-bedding and ripple marks are present.

The Hensman Sandstone is a stratigraphic equivalent of the lower arenite member of the O'Donnell Formation, in the west. The two meet at the Durham Fault.

No section has been measured, but the thickness of the Sandstone increases gradually from about 100 feet in the extreme west to about 800 feet in the reference area.

Golden Gate Siltstone (New Name)

Golden Gate Siltstone is the name given to a succession of black siltstone and shale, and minor interbedded sandstone, which conformably overlies the Hensman Sandstone and is unconformably overlain by the Lissadell Formation. The name is derived from the Golden Gate Country (about Lat. 16° 05' S, Long. 128° 50' E) in the north-east corner of the Lissadell Sheet area, where the thickest section is present. Outcrops extend south-west from here through the central and southern Carr Boyd Ranges and the westerly limit of outcrop is the Durham Fault, near Durham Hill. The Siltstone is poorly resistant and crops out in valleys between the underlying and overlying resistant sandstones. The topography varies from low rounded hills in areas of poor relief to deeply dissected areas of dendritic drainage in the more rugged parts of the Carr Boyd Ranges.

The facies changes from west to east. In the south-west fine-grained quartz greywacke and micaceous siltstone and shale, with minor interbeds of blocky quartz sandstone, overlie massive sandy hematite and ferruginous shale, indicating an oxidizing environment, of the Pompoys Pillar Iron Ore Deposit which occurs at the base. These grade eastwards into interbedded black siltstone and laminated fine-grained sandstone with minor interbeds of blocky blue-grey to white sandstone. The base contains chert-quartz sandstone and siltstone. Farther east black shale and pyritic shale, indicating reducing conditions, and minor blue-grey quartz greywacke interbeds overlie red-brown mudstone and chert.

This facies change is accompanied by a gradual increase in thickness from 800 feet in the west to about 7000 feet in the Golden Gate Country. This increase is depositional rather than erosional.

Three distinct 'members' can be recognized in the formation although the contacts between them are gradational. They all reflect the regional facies change. The basal member (A) contains abundant sandstone interbeds and is transitional from the underlying Hensman Sandstone. The middle member (B) is mainly siltstone and shale; minor sandstone interbeds become 44 more common towards the base. The upper member (C) has regularly interbedded shale and fine-grained sandstone with increasing blocky sandstone interbeds towards the top.

The regional transition in the Golden Gate Siltstone can be seen in the following generalized stratigraphic sections. Thicknesses are approximate, based on estimates from maps and air-photographs.

Section I

South-West Carr Boyd Ranges

Six Miles North-East Mount Myulasy

(Lat. 16°40'S. Long. 128°18'E).

Lissadell Formation

Unconformity

C	200 feet	Flaggy micaceous siltstone at base grades up into interbedded purple micaceous siltstone and green siltstone. Minor quartz-greywacke grit interbeds. Mud cracks.
	60 feet	Massive, coarse-grained, purple, friable quartz greywacke (Large rounded (2 mm.) quartz grains in purple clay matrix).
B	400 feet	Flaggy dark green to purple-brown micaceous siltstone and green shale. Minor blocky quartz interbeds increase towards base. Shale more prevalent at top. Mud cracks, lenticular bedding, ripple marks.
A	500 feet	Transitional sequence. Flaggy grey to purple lithic-greywacke siltstone and fine-grained lithic-quartz greywacke and blocky cross-bedded ferruginous quartz sandstone and sandstone.
	35 feet	Massive sandy hematite.
	50 feet	Flaggy micaceous siltstone and ferruginous siltstone interbedded with flaggy sandy ironstone.

Total 800 feet

Hensman Sandstone

Section II

West Carr Boyd Ranges

(Lat. 16°17'S. Long. 128°27'E.)

Lissadell Formation

Unconformity

C	250 feet	Flaggy to massive purple and black siltstone alternates with flaggy to fissile micaceous siltstone, grading up into shale. Minor white fine grained sandstone. Grades downwards into
B	500 feet	Interbedded flaggy black micaceous siltstone and laminated black to grey ferruginous quartz siltstone or very fine-grained sandstone. Occasional blocky blue quartz sandstone interbeds. Some massive quartz-sericite-siltstone (?tuffaceous). Wavy and lenticular bedding, micro-cross-bedding, slumping. Silt and shale dominant in upper part; laminated fine-grained sandstone increases towards base.
C	100 feet	Alternating blocky medium-grained quartz sandstone and flaggy fine-grained feldspathic sandstone and purple siltstone. Sandstone increases towards base.
	50 feet	Blocky medium-grained, poorly sorted blue-grey chert fragment sandstone and purple siltstone. Clay pellets in sandstone. Ferruginous patches.
TOTAL	900 feet	

Hensman Sandstone

Section III

Revolver Creek Area

(Lat. 16°15'S. Long. 128°33'E.)

Lissadell Formation

Unconformity

C	1200 feet	Thinly interbedded black shale and grey fine-grained sandstone. Weathers to red and white banded rock. Blocky quartz sandstone interbeds towards top.
B	1000 feet	Monotonous thinly bedded black siltstone and shale. Some scattered mica. Slaty cleavage. Minor interbeds blue-grey fine-grained quartz sandstone.
C	400 feet	Interbedded flaggy black and grey siltstone and fine-grained micaceous sandstone. Grades upwards into overlying sequence.

TOTAL 2600 feet

Hensman Sandstone

Section IV

Golden Gate Country

(Lat. 16°09'S. Long. 128°49'E.)

No top to formation exposed

C	1500 feet	Flaggy siliceous siltstone and fine-grained quartz sandstone. Minor pyritic shale. Interbeds of blocky quartz greywacke towards top.
B	5000 feet	Regularly, thinly bedded black and grey shales. Abundant pyrite. Minor interbeds, 20 feet thick, of blue-grey quartz greywacke.
A	500 feet	Thinly bedded fine-grained silty quartz sandstone interbedded with grey shale and mudstone. Grades up into shales.
		Red, brown, and grey mudstone and cherty mudstone. Well-bedded towards top

TOTAL 7000 feet

Hensman Sandstone

In the south-west (Section I) mud cracks, flow casts, and ripple marks, indicative of shallow water, are common. Flaggy fine-grained sandstone interbeds are lenticular and bedding is 'wavy'. In thin-section rocks from the basal transition zone range from fine-grained lithic quartz greywacke to feldspathic greywacke. They are poorly sorted. They have an open framework of subrounded fine sand grains (0.01 mm. to 0.1 mm.) set in abundant chlorite matrix. Rock fragments are pelletic and feldspar is either potassic or sodic. Tourmaline, zircon, and apatite are accessories.

In the middle silt 'member' of the western area (Section II) the flaggy black micaceous siltstone contains about 60% of poorly sorted angular quartz grains (about 0.02 mm.) and 10% subrounded felspar. These form an open framwork in a chloritic matrix. Scattered laths of white mica lie in the bedding and quartz grains tend to be bimodal. These siltstones are thinly interbedded with laminated ferruginous quartz siltstone and fine-grained sandstone which generally contain greater than 80% subangular quartz grains (up to 0.03 mm.) and up to 50% feldspar. Detrital muscovite lies in the bedding and up to 10% of iron oxides gives a black colour to the rock and defines the laminations. Bedding is lenticular on a small scale and is 'wavy'. Some slumping and micro-cross-bedding is present.

Some beds, about five feet thick, of massive dark green quartz-sericite siltstone occur within the 'member'. Large irregular blebs of chloritic clay of mica (perhaps after feldspar) and occasional large quartz grains, sometimes resembling shards in shape, are set in a fine-grained quartz-sericite matrix. Bedding is absent and in outcrop the rock resembles an ashstone or tuff; the evidence in thin-section is inconclusive.

East of Revolver Creek sedimentary structures are rare; some slumping is found in places. Pyrite occurs as disseminated grains within black shales, and constitutes as much as 30% of the rock; it tends to concentrate into lenticular bodies about twelve inches long and six inches thick. Interbeds of massive blue quartz greywacke, about ten to twenty feet thick, are consistent laterally and form useful marker beds. To the west they grade into blue quartz sandstone. A sub-vertical slaty cleavage is impressed on the shale by the Carr Boyd and Halls Creek Fault movements, and in the Golden Gate Country the rocks are very tightly folded.

The dominantly black colour of the rocks in the unit changes in weathered outcrop.

The Golden Gate Siltstone is unconformably overlain by the Lissadell Formation. Over large parts of the central area no angular or erosional relationship can be detected, but in the west the unconformity can be detected :

(a) Large parts of the section have been eroded locally prior to deposition of the Lissadell Formation.

(b) Pre-Lissadell faulting and subsequent erosion is present in the Golden Siltstone.

(c) An angular unconformity is found in places and the Lissadell Formation sits on stratigraphic levels as low as the Hensman Sandstone.

Between the Carr Boyd and Halls Creek Faults any overlying units present have been eroded from the top of the Siltstone. East of the Halls Creek Fault it is unconformably overlain by both the Mount Parker Sandstone and the Ord Group.

can't be correct

To the west, the lower siltstone 'member' of the O'Donnell Formation is stratigraphically equivalent to the Golden Gate Siltstone. The change between the two is gradual and marked thickening of the Golden Gate Siltstone does not begin until east of the Ivanhoe Fault. The Golden Gate Siltstone rocks which crop out to the north of Dunham Hill are typical of both the western Golden Gate Siltstone and the O'Donnell Formation and is overlain, with angular unconformity, by a sandstone resembling the basal Lissadell Formation. The change from Golden Gate Siltstone to O'Donnell Formation is arbitrarily taken as occurring at the Dunham Fault.

Lissadell Formation (New Name)

The Lissadell Formation lies unconformably between the Golden Gate Siltstone and the Glenhill Formation. The name is derived from Lissadell Station, which encompasses outcrops of the Formation. Outcrops extend throughout the central and southern Carr Boyd Ranges from the Carr Boyd Fault, near Carlton Gorge, in the north-east, to the Dunham Fault, near Dunham Hill, in the west. The sandstone in the lower part of the Formation crops out boldly as prominent cuestas which slope down into lower highly dissected areas occupied by siltstone of the upper part of the Formation.

The lower part of the Formation consists of blocky to massive fine to medium-grained white quartz sandstone. This grades up through alternating sandstone and siltstone into the upper part of the Formation which consists of interbedded flaggy green and grey siltstone and micaceous siltstone, and flaggy laminated green and white fine-grained sandstone. The green colour of fresh rocks changes to purple in weathered outcrop.

A generalized section of the Formation from the reference area (Lat. 16°08' S, Long. 128° 37' E), in the northern Carr Boyd Ranges, is given below. Thicknesses are estimated from air photographs.

Glenhill Formation

Unconformity

1000 feet	Interbedded flaggy to fissile, green grey and purple siltstone and micaceous siltstone and flaggy fine-grained sandstone and laminated fine-grained sandstone. Micaceous shale partings. Fine-grained sandstone becomes dominant towards base.
1500 feet	Flaggy purple to green siltstone and fine-grained sandstone alternates with blocky, white, medium-grained quartz sandstone. Some cross-bedding. Sandstone in beds 50 to 100 feet thick. Grades into overlying sequence.
2500 feet	Uniform blocky to massive, white, medium-grained quartz sandstone.
TOTAL 5000 feet	

Unconformity

Golden Gate Sandstone

Next to the northerly extension of the Revolver Creek Fault in the reference area, and to the Ivanhoe Fault, farther west, a local angular unconformity has been observed at the top of the basal sandstone 'member'. This is purely the product of local fault movement and is not considered significant. The horizon is difficult to map regionally and therefore the Formation has not been further subdivided.

In the reference area the massive sandstone of the lower part of the Formation is uniform in lithology and lacks sedimentary structures except bedding. Within the siltstone 'member' at the top of the Formation the fine-grained sandstone occurs as regular but lenticular beds one to two inches thick, and sometimes up to six inches. In thin section they are well sorted and contain many well rounded quartz grains (0.03 to 0.05 mm.); thin micaceous and chloritic laminae contain mica flakes up to 0.1 mm. The interbedded siltstone has well sorted and rounded quartz grains (0.01 to 0.03 mm.) in a brown chloritic-clay matrix. Mica up to 0.06 mm. lies in the bedding. Bedding partings of purple micaceous shale are common and abundant mud-cracks. About 500 feet from the top of the Formation a consistent bed, eighteen inches thick, of pink fine-grained sandstone contains large pyrite pseudomorphs.

To the south of Revolver Creek the lower sandstone has many interbeds, 200 to 300 feet thick, of flaggy interbedded fine-grained white sandstone and purple micaceous siltstone : these increase towards the base. The transition zone into the upper siltstone member is less well defined; scattered blocky sandstone interbeds, a few feet thick, occur in the lower part where laminated fine-grained sandstone is dominant. Higher in the section siltstone and shale are the commonest rocks. One bed, twenty to thirty feet thick, is a massive black siltstone similar to the possible 80 'tuff' in the Golden Gate Siltstone. The pyritic sandstone bed is still present about 400 feet from the top of the unit. Micro-cross-bedding is found in the laminated fine-grained sandstone. The section here is about 4000 feet thick.

In the far south-western corner of the Carr Boyd Range a marked north-south facies-change occurs in the middle transitional 'member'. This is traceable by interfingering sandstone and siltstone over a strike length of about eight miles and is shown by the following generalized sections :

North (Lat. 16° 30' S, Long. 128° 17' E) Thickness			South (Lat. 16° 38' S, Long 128° 17' E) Thickness
1500 feet +	Interbedded thinly flaggy purple to pale green micaceous siltstone and one inch beds of green to white flaggy fine-grained sandstone. Lenticular and wavy bedding, mud cracks. Blocky medium-grained quartz sandstone beds near base.		2000 feet +
900 feet	Interbedded laminated green to purple fine-grained sandstone and flaggy green siltstone with minor blocky sandstone. 100 feet beds of massive white sandstone. Mud cracks and micaceous shale partings.	Massive, poorly bedded, white, well sorted, clean fine-grained quartz sandstone. Grades into overlying siltstones.	1000 feet
200 feet	Bed of flaggy medium-grained purple-brown sandstone with abundant clay pellets grades up into flaggy fine-grained sandstone and siltstone. Good marker bed.		200 feet
800 feet	Massive white medium-grained quartz sandstone with grit beds near the base		900 feet
			TOTAL 4000 feet

Unconformity

Golden Gate Siltstone

The southerly section, with no transition zone, is similar to the section south of Revolver Creek and may indicate a general increase in sand content of the Formation southwards.

The Lissadell Formation overlies the Golden Gate Siltstone with angular and erosional unconformity, the evidence for which is discussed in the Golden Gate Siltstone. The contact between the Lissadell Formation and the overlying Glenhill Formation has a consistent angular unconformity with differences in dip up to 30°. The surface appears to have been little eroded before the Glenhill Formation was laid down except along the Ivanhoe Fault, in the south-west, where up to 1000 feet of section has been removed. Strong pre-Glenhill faulting occurs in the Lissadell Formation and one strong reverse fault in the Lissadell Formation shows normal fault displacement of the Glenhill Formation.

East of Dunham River Homestead the Lissadell Formation is unconformably overlain by the Lower Cambrian Antrim Plateau Volcanics.

In the north-east, between the reference section and Carlton Gorge, the Lissadell Formation shows marked thinning on to the Carr Boyd Fault Zone : the thickness decreases from about 5000 feet to 500 feet in a distance of ten miles. The thinning is almost certainly depositional. All the 'members' of the Formation appear to thin eastwards although they are difficult to trace laterally because of faulting. A marked angular unconformity occurs at the base of the Glenhill Formation in this area and no outcrops of the Lissadell Formation are found east of the Carr Boyd Fault.

Stratigraphic equivalents of the Lissadell Formation are not precisely known; it is equivalent to an unknown part of the O'Donnell Formation - Liamma Beds sequence.

<u>Glenhill Formation</u> (New Name)

The name Glenhill Formation is derived from Glenhill Station (Lat. 16° 33' S, Long. 128° 21' E) and is applied to a sequence of sandstone and shale which unconformably overlies the Lissadell Formation and is in turn overlain unconformably by the Stonewall Sandstone. The Formation crops out in two areas only, around the Glenhill Station valley in the south-west Carr Boyd Ranges and the Carlton Gorge area in the north Carr Boyd Ranges, extending westwards to the Ivanhoe Fault and southwards to the Ord Dam Site. No outcrops of the Formation occur east of the Carr Boyd Fault. The reference section for the Formation (Lat. 16° 03' S, Long. 128° 40' E) is two miles west of Carlton Gorge. Sandstone beds crop out as prominent cuestas, and the shales form areas of poor relief and poor outcrop.

A consistent bed of massive to blocky, white, clean quartz sandstone occurs at the base of the Glenhill Formation. This is overlain by flaggy green to red siltstone and shale (micaceous in part), laminated fine-grained sandstone (glauconitic in part), and blocky quartz sandstone.

A generalized stratigraphic section, from the reference area, is given below. Thickness estimates are based on both visual estimates in the field and estimates from air photographs.

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Stonewall Sandstone

Unconformity

A	1500 feet	Mauve slightly micaceous lustrous shale, red shale, and flaggy interbeds (1 inch thick) of fine-grained sandstone. Minor blocky quartz sandstone.
B	300 feet	Blocky to massive, white, medium-grained quartz sandstone.
	300 feet	Flaggy to fissile, pale green to purple, slightly micaceous shale and siltstone.
	200 feet	Interbedded blocky and flaggy, white medium-grained quartz sandstone. Some grit bed.
	700 feet	Flaggy to fissile purple-brown shale and siltstone with scattered flaggy fine-grained sandstone interbeds.
C	200 feet	Interbedded blocky medium-grained quartz sandstone; purple ferruginous sandstone; grit with fragments of chert and quartz; and flaggy laminated purple fine-grained sandstone and siltstone.
	200 feet	Flaggy to fissile red siltstone and shale. Minor mica.
	50 feet	Blocky white medium-grained quartz sandstone.
	1000 feet	Flaggy to fissile, grey and chocolate-brown siltstone and shale with ½ to 1 inch interbeds red-brown fine-grained micaceous sandstone.
D	200 feet	"Ribbon-Stone" - regularly interbedded red siltstone and white fine-grained quartz sandstone. Halite pseudomorphs. Micaceous laminae. Interbeds of laminated fine-grained sandstone and blocky medium-grained quartz sandstone.
E	700 feet	Massive white quartz sandstone. Cross-bedded.
Total	5000 feet	

Unconformity

Lissadell Formation

A facies change occurs between the reference section and Carlton Gorge, a distance of only two miles, with marked increase in sandstone content of the Formation to the east. This is partly the result of beds thickening or thinning and partly due to interfingering of sandstones and shales. To the east of Carlton Gorge sandstones become even more prominent. The overall thickness of the Formation remains about the same.

The upper siltstone member (A) of the reference section thins eastwards from about 1500 feet to 600 feet. The underlying sandstone (B) thickens markedly from 300 to 3000 feet in the east. This takes place partly by interfingering of sandstone and shale at the top of the 'member' but mainly by simple increase in deposition of sand in the east. Numerous sandstone beds within the member lens out rapidly westwards like giant foreset beds, apparently deposited from the east.

The underlying alternating sequence (C) thins from 1600 feet in the west to 550 feet in the east. The sandstone beds retain their thickness but the siltstone beds thin or are replaced by interfingering sandstones. Individual beds cannot be traced with certainty. East of Carlton Gorge the siltstones almost disappear from the section and the thickness of sandstone is increased. The large number of sandstone beds which lens out westwards, and are then overlapped by younger beds, gives the appearance, on air-photographs, of an area of giant foreset bedding, deposited from the east.

The lower shale (D) shows simple thinning from 1200 feet to 700 feet in the east and the basal sandstone (E) retains its thickness of about 700 feet.

Sedimentary structures are not common; massive sandstones show some cross-bedding, ripple marks, and micaceous shale bedding partings. The shales and fine-grained sandstones are deficient in mica, except for micaceous laminae, and the laminated fine-grained sandstones show small-scale cross-bedding. Halite pseudomorphs in the red and white banded 'ribbon-stone' indicate shallow water evaporite conditions.

In the Glenhill area the basal sandstone member is only 200 feet thick. This is immediately overlain by laminated green and white fine-grained glauconitic sandstone which grades up into interbedded laminated dark green fine-grained sandstone (chlorite rich in some beds) and thinly flaggy green to purple micaceous siltstone. Blocky sandstone interbeds occur near the base. Higher in the sequence the rocks grade into a uniform sequence of regularly bedded, laminated, grey to black micaceous shale. The Formation here is only about 2000 feet thick and is unconformably overlain by the Cambrian Antrim Plateau Volcanics.

The glauconitic sandstone in this area has well packed subrounded quartz grains (0.02 to 0.1 mm.) and laminae containing lenticular aggregates (0.2 to 0.05 mm. in size) of weathered glauconite. Flaggy green micaceous siltstone is poorly sorted and shows a very open framework of irregular and angular quartz grains (up to 0.03 mm.), and minor silica pellets, mica, feldspar, and altered ferromagnesian mineral, in abundant chloritic-clay matrix. The flaggy micaceous shale higher in the section is finer grained, poorly sorted, and similar in composition.

About six miles south of the Bandicoot Range, along the western edge of the Carr Boyd Range, about 1500 feet of blocky and flaggy quartz sandstone, and minor red shale, unconformably underlie the Stonewall Sandstone. The Pincombe Formation also sits directly on them, unconformably.. Some sandstone beds contain abundant red shale fragments lying in the bedding and red shale bedding partings are common. These outcrops are tentatively assigned to the Glenhill Formation, but cannot be directly related to any part of the known section. They are probably stratigraphically higher than the rocks in the reference section, but could just as easily be a lateral equivalent.

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Stonewall Sandstone (New Name)

The massive sandstones which unconformably overlie the Glenhill Formation, and are in turn unconformably overlain by the Pincombe Formation, are called the Stonewall Sandstone, from Stonewall Creek which cuts them at Lat. 15° 58' S. Long. 128° 47' S. The Sandstone occurs along the northern part of the Carr Boyd Ranges and Golden Gate Country, and forms the Cave Range further north. The reference section is in the Carr Boyd Ranges about Lat. 15° 58' S. Long. 128° 40' E. The Sandstone crops out boldly as widespread plateau and shallow-dipping cuesta cappings.

The formation consists of blocky to massive, purple, red and white, medium to coarse-grained quartz sandstone, clayey sandstone and feldspathic sandstone. Minor beds of grit and red shale are found in places. The sandstones are commonly quite friable. Over large areas within the sandstone no bedding can be detected. Other areas have highly variable bedding trends on air photographs, giving the impression of giant-scale foreset bedding.

Along the north-western side of the Carr Boyd Ranges the basal sandstone of the reference section overlies, with slight angular unconformity, a succession of sandstones and minor shales which have been tentatively mapped as (?) Glenhill Formation. It is possible that these beds could be a locally developed basal member of the Stonewall Sandstone.

The Stonewall Sandstone overlies the Glenhill Formation with angular unconformity while the overlying Pincombe Formation transgresses the Sandstone to sit on beds as low as the (?) Glenhill Formation. Near the Cave Range. the Stonewall Sandstone has a regional easterly dip while rocks of the Kimberley Group, half a mile to the west, show a regional north-westerly dip. From this, and other reasons (see Age Relationships of the Younger Proterozoic Successions), it is inferred that the Kimberley Group is strongly unconformable on the Stonewall Sandstone. The two outcrops however are separated by a fault of unknown magnitude.

The thickness of the Stonewall Sandstone in the Carr Boyd Ranges has been estimated from air photographs to vary between 4000 and 6000 feet.

Pincombe Formation (New Name)

The Pincombe Formation is the name given to a series of quartz sandstones and siliceous siltstones which crop out typically in the Pincombe Ranges (Lat. 15° 33' S, Long. 128° 53' E), in the north-eastern part of the map area. They also crop out in the extreme northern part of the Carr Boyd Ranges, where they overlie the Stonewall Sandstone with angular unconformity. No top is present to the unit; it is unconformably overlain by either Palaeozoic rocks or Cainozoic soil cover. Sandstone beds within the unit crop out as prominent strike ridges bordering valleys of softer siltstone. The Pincombe Formation consists of interbedded siliceous siltstone and fine-grained sandstone with minor micaceous shale. Interbeds of massive quartz sandstone occur throughout the section ranging from 10 feet to 1500 feet thick. The Pincombe Formation is characterized by the overall clean nature of the sediments and highly lenticular bedding.

The stratigraphic section in the reference area is complicated by strong strike faulting and correlations across them are difficult. The section in the Carr Boyd Ranges is not as complete so the inferred generalized section from the reference area is given below :

Soil Cover

3500 feet +	Regularly bedded, thinly flaggy, red to white siliceous siltstone and fine-grained sandstone with purple micaceous shale laminae. 'Wavy' bedding. Lenticular interbeds, 5' to 10' thick, of blocky quartz sandstone. 200' beds of massive white quartz sandstone at intervals.
1500 feet	Blocky to massive, pale grey to white, medium-grained quartz sandstone.
* 800 feet	Flaggy to fissile, purple and grey siliceous siltstone with blocky quartz sandstone interbeds.
800 feet	Blocky to massive white clean quartz sandstone with some purple ferruginous laminae. Cross-bedded, ripple-marked. Some beds friable.
2000 feet	Interbedded laminated green and white fine-grained sandstone and flaggy purple micaceous shales with scattered 20' to 30' beds of blocky quartz sandstone increasing towards top of sequence.
Total 8500 feet	Unconformity

Stonewall Sandstone

The section in the Carr Boyd Ranges cannot be directly correlated with the reference section and is briefly given below. The difference is probably due to the absence of the lower sandstone member (*) in the south while the rest of the Formation shows a general southerly thinning.

Soil Cover

2000 feet +	Thinly flaggy grey to red fine-grained sandstone and micaceous sandstone and red shale.
3000 feet	Massive to blocky, medium to coarse-grained, quartz sandstone minor with interbeds fine-grained sandstone. Some conglomerate.
2000 feet	Interbedded fine-grained sandstone and purple siltstone or fine-grained sandstone. Micaceous shale-bedding partings.
Total 4000 feet +	Unconformity

Stonewall Sandstone

The red siliceous siltstone and fine-grained sandstones of the upper 'member' are uniform in lithology and have regular but 'wavy' bedding due to oscillation ripples. Micaceous laminae have fine mica lying in the bedding producing a bedding surface lustre. Blocky sandstone interbeds are cross-bedded and highly lenticular.

In the Carr Boyd Ranges the main sandstone 'member' has highly lenticular foreset bedding on all scales. Ripple marks and cross-bedding are common. The finer-grained beds have large oscillation ripples, and bedding surfaces are often micaceous.

The lower 'member', of flaggy fine-grained sandstone and purple shale, has very lenticular bedding on all scales. Oscillation ripples are common, producing wavy bedding. Massive sandstone interbeds increase towards the top and the siltstones weather into small caves.

In the Pincombe Ranges the unconformity between the Pincombe Formation and Stonewall Sandstone cannot be detected, but in the Carr Boyd Ranges the Pincombe Formation completely transgresses the Stonewall Sandstone. It is unconformably overlain by Palaeozoic rocks.

The Formation crops out both to the east and west of the Carr Boyd Fault; the thickest section is preserved east of the Fault, where it is about 7500 feet thick. The reference section in the Pincombe Range is about 8500 feet thick.

<u>Bandicoot Range Beds</u> (New Name)

The Bandicoot Range (Lat. 15° 48' S, Long. 128° 39' E), lying about six miles west of the township of Kununurra and two miles east of the Ivanhoe Fault, is a fault-bounded block containing rocks which cannot be correlated with any specific formation of the Carr Boyd Succession. However the lithological characters allow correlation with the Succession as a whole. Six miles south of the Range, and outside the fault block, small outcrops of ferruginous sandstone and siltstone, of unknown stratigraphic position, unconformably underlie possible (?) Glenhill Formation rocks; these have been assigned to the Bandicoot Range Beds also. The Beds crop out boldly as strike ridges controlled by resistent sandstones.

The striking feature of the Beds is the presence of six beds each about ten to fifteen feet thick, of massive highly ferruginous sandstone. These, however, are only a minor fraction of the overall sequence of medium-grained quartz sandstone, clayey sandstone, and conglomerate, which contains quartzite pebbles up to one and a half inches in diameter. Minor interbedded thinly flaggy red siltstone, ferruginous shale, and fine-grained sandstone are micaceous in part.

The sandstones are cross-bedded, ripple-marked, and generally friable. They frequently have abundant white mica on bedding surfaces and are commonly purple due to ferruginous cement. The fine-grained rocks have lenticular bedding and are sometimes slumped. Much of the iron material is redistributed as secondary joint filling and staining and some beds consist of botryoidal iron oxides.

The 'ironstone' beds generally have associated ferruginous siltstones and shales with shallow water structure, very similar to rocks overlying the Pompeys Pillar Iron Ore Deposit in the lower Golden Gate Siltstone.

The Beds cannot be directly correlated with any known units in the Carr Boyd succession. The iron suggests correlation with the Golden Gate Siltstone, but the abundance of sand does not support this. It is considered more likely that the presence of iron is simply controlled by proximity to the Ivanhoe Fault. In other units of the Carr Boyd succession the fault has apparently controlled the development of shallow water conditions in the west.

The Bandicoot Range Beds are estimated from air photographs to be 3400 feet thick.

Kimberley Basin Succession

The Kimberley Basin is a large structural basin covering the whole of the Kimberley Plateau area. It contains Younger Proterozoic sedimentary rocks and is bounded in the east and west by belts of Older Proterozoic metamorphic and igenous rocks, extending north-north-east (Halls Creek Mobile Zone) and north-west respectively from the township of Halls Creek. In the north and west outcrops of rocks from the Basin are bounded by the Timor Sea and the Indian Ocean. The rocks of the Basin are only slightly disturbed, except along the margins, and probably reflect the attitude of the original depositional basin. The limits of this depositional basin are not known. Within the area covered by this report rocks of the Kimberley Basin crop out only in the west; their eastern margin is the Greenvale - Dunham - Ivanhoe Fault System.

The Kimberley Basin succession unconformably overlies the Older Proterozoic rocks and is unconformably overlain by Palaeozoic rocks. The age relationships of the succession to the Carr Boyd succession and Eastern succession is obscure and is discussed in the introduction to this Younger Proterozoic section. In general, most of the succession is younger than the Carr Boyd succession and older than most of Eastern succession (see Figure 10).

The succession consists mostly of quartz sandstone with minor siltstone, shale, feldspathic sandstone, volcanics, and carbonate rocks. The sediments in the lower part of the succession are generally 'dirtier' than those higher in the section; they have been deposited in a more unstable tectonic environment. The upper part of the succession is dominated by thick sequences of quartz sandstone.

The succession has been divided into the following units :

Bastion Group	Cookburn Sandstone
	Wyndham Shale
	Mendena Formation
	Pentecost Sandstone
	Elgee Siltstone

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Kimberley Group	Warton Sandstone
	Carson Volcanics
	King Leopold Sandstone
Speewah Group	Luman Siltstone
	Loomingnin Arkose
	Valentine Siltstone
	Liamma Beds
	O'Donnell Formation
	bottom

An erosional unconformity occurs at the base of the O'Donnell Formation and major angular unconformities occur at the base of the Liamma Beds and Speewah Group. A probable unconformity occurs at the base of the Kimberley Group but further work is required to establish it. In the West Kimberleys the Kimberley Group is unconformably overlain by the Walsh Tillite and Mount House Beds (Guppy et al.,1958).

Rocks of the succession, especially the Speewah Group, are extensively intruded by sills of Hart Dolerite. In the map area they extend as high as the Carson Volcanics, but Harms (1959) describes them intruding much younger units.

Full definition and description of, and selection of type sectionsfor, the units in the Kimberley Basin succession must await the completion of mapping of the whole Basin. The purpose of this Report is to present the revised stratigraphic nomenclature for the area and to describe briefly the main features of the Kimberley Basin succession observed to date. The stratigraphy will be more fully described in a later publication embracing the whole of the Basin.

Within the map area the Kimberley Basin succession has been measured as 19,000 feet thick.

Derivation of Stratigraphic Names

The rocks of the Kimberley Basin were first subdivided by Guppy et al.,(1958). Harms (1959) subdivided their units further and extended them throughout the Kimberley Plateau. During the current survey considerable modification was necessary to the previous nomenclature as a result of more detailed work. The development of our names is illustrated in the Table 1.

DERIVATION OF NOMENCLATURE - KIMBERLEY BASIN SUCCESSION

Guppy et al., (19[illegible])	Harms 1959	B.M.R. 1964	
Mount House Beds			
Walsh Tillite			
- - unconformity - -		Bastion Group	Cockburn Sandstone
	Mount House Beds		Wyndham Shale
			Mendena Formation
	Pentecost Sandstone	Kimberley Group	Pentecost Sandstone
	Elgee Shale		Elgee Siltstone
Warton Beds	Warton Sandstone		Warton Sandstone
Mornington Volcanics	Mornington Volcanics		Carson Volcanics
King Leopold Beds	King Leopold Sandstone		King Leopold Sandstone
			- - unconformity - -
		Speewah Group	Luman Siltstone
			Loomingnin Arkose
			Valentine Siltstone
			- - angular unconformity - -
			Liamma Beds
			- - angular unconformity - -
			O'Donnell Formation

- - Regional Unconformity - -

Lamboo Complex and Halls Creek Metamorphics

Harms correlated the rocks now mapped as Bastion Group with the Mount House Beds of Guppy et al.; in this regard he followed the ideas of Traves (1955). The current survey failed to find any evidence of an unconformity at the base of the Bastion Group and, in fact, the Mendena Formation is transitional between the Pentecost Sandstone and Wyndham Shale. No tillite has been found. The Walsh Tillite and Mount House Beds are almost certainly equivalent to the Ord Group, which is shown by radiometric dating to be about 1000 m.y. younger than the Pentecost Sandstone (V.M. Bofinger & I. Mc Dougall, pers. comm.). A time-break of this order between the Bastion and Kimberley Groups would certainly produce an unconformity adjacent to a tectonically active belt such as the Halls Creek Mobile Zone, so the Bastion Group is considered to be much older than the Mount House Beds.

Harms (1959) subdivided the Warton Beds of Guppy et al. (1958) as shown in the table. His Elgee Shale is modified to Elgee Siltstone on lithological grounds. The name Mornington Volcanics is invalid under the Code of Stratigraphic Nomenclature because of prior usage; the name Carson Volcanics is proposed in its place.

Guppy et al. (1958) defined the base of the Upper Proterozoic sequence as being the King Leopold Beds. In their type area, in the Lennard River Sheet area, they sit on the Lamboo Complex rocks unconformably and the lower part is extensively intruded by Hart Dolerite. Harms (1959) modified their name to King Leopold Sandstone. He retained the original definition and included all the rocks lying stratigraphically between the Mornington Volcanics and Lamboo Complex in his King Leopold Sandstone. In the East Kimberleys he noted the presence of shales and minor acid volcanics in the lower parts of the succession and mentioned that they may be older than the base of the King Leopold Beds in the type area.

During the current survey in the East Kimberleys strong angular unconformities were found at the base of the Liamma Beds and the Speewah Group. The rock types in the Speewah Group are distinctly different to those of our King Leopold Sandstone and an unconformity is thought to occur at the base of the Sandstone.

Reconnaissance indicates that the King Leopold Beds in the type area is the same formation as our King Leopold Sandstone. The base of the type area is still in doubt, however, owing to extensive dolerite intrusion, and must await further mapping.

<u>O'Donnell Formation</u> (New Name)

The O'Donnell Formation is named from the O'Donnell Range (Lat. 16° 24' S, Long. 128° 12' E). Outcrops extend south-west from here as discontinuous blocks along the western side of the Greenvale Fault to the Mount Remarkable area : outcrops extend westwards from there into the Lansdowne Sheet area. The Formation overlies the Whitewater Volcanics with erosional unconformity and is overlain by the Liamma Beds with angular unconformity. Resistant strike ridges of sandstone border valleys of softer siltstone. 61

The Formation contains prominent members of blocky, fine to coarse-grained sandstone with minor siltstone, shale, and conglomerate interbeds. These alternate with members containing thinly interbedded (2 to 8 inches) shale, siltstone, fine-grained sandstone, and quartz greywacke. Three sandstone and two siltstone members can be recognised in the O'Donnell Range. The base of the section has a ferruginous volcanic greywacke and conglomerate derived from the underlying Whitewater Volcanics : most of this material is transported, but bedding is poor and some of it may represent a fossil soil. Along the Bedford Stock Route, in the north, the Formation is intruded by a thick sill, up to 5000 feet thick, of altered dolerite.

The following generalized composite section (Lat. 16° 31' 48" S, Long. 128° 2' 18" S, and Lat. 16° 29' 58" S, Long. 128° 4' E) was measured near Bedford Stock Route and O'Donnell Range.

Liamma Beds

Angular Unconformity

290 feet	White to purple, blocky, medium-grained quartz sandstone, feldspathic sandstone, and friable silty sandstone. Cross-bedded, ripple-marked.
210 feet	Grey, brown and purple shale, siltstone and sandy siltstone (in part micaceous). Minor reworked ash.
155 feet	Flaggy, feldspathic, clayey quartz sandstone. Minor siltstone and thinly bedded silty sandstone.

Up to 5000 feet Dolerite sill

260 feet	Medium to coarse-grained, in part granular, blocky quartz sandstone, arkose and feldspathic sandstone. Cross-bedded, ripple marks, scour and fill structures.
170 feet	Pale green, and brown, regularly bedded (1 to 2 inches) siltstone and fine-grained sandstone.

50 feet Dolerite sill

90 feet	Green and brown, thinly bedded, fine-grained sandstone and siltstone. Micaceous laminae. Khaki shale near base.
275 feet	Blocky to flaggy, medium-grained quartz sandstone and feldspathic quartz sandstone.

B	400 feet	Black and grey shales thinly-interbedded with grey fine-grained silty quartz sandstone, quartz greywacke and minor (?) greywacke. Micaceous in part. Some siltstone.
	30 feet	Resistant coarse-grained quartz sandstone and granular sandstone.
	35 feet	Poor outcrop of red shales.
A	400 feet	Black, purple, and brown, coarse to fine-grained, poorly sorted quartz greywacke, quartz sandstone, silty sandstone, minor siltstone. Pyrite bearing beds common. Bedding 1 inch to 18 inches thick. Red chert fragments near base.
	110 feet	Chert fragment conglomerate; ferruginous volcanic greywacke, pebble conglomerate. Derived from underlying Whitewater Volcanics.

Total 2400 feet

Erosional Unconformity

Whitewater Volcanics

The alternating sandstone-siltstone sequence is diagnostic of the formation. The unit is distinguished from the overlying Liamma Beds by slightly 'dirtier' arenites, thicker bedding, and a dominantly red to khaki colour in the siltstones. Sedimentary structures are lacking.

In the Wilson River area a locally developed hematite-sandstone, 20 feet thick, and lithologically similar to the Pompeys Pillar Iron Ore Deposit, occurs in the basal arenite 'member' (A), the only part of the Formation preserved. Farther south, in the Mount Remarkable area, the thickness of the O'Donnell Formation has been estimated on air photographs to be 4500 feet.

Adjacent to the Greenvale Fault the siltstone beds in the Formation are strongly sheared, producing low-grade metamorphics, strong cleavage folds, and transposed bedding.

The basal arenite 'member' (A) in the measured section is a stratigraphic equivalent of the Hensman Sandstone in the Carr Boyd succession; the overlying siltstone 'member' (B) is equivalent to the Golden Gate Siltstone, as exposed near Dunham Hill. The change in nomenclature is taken arbitrarily at the Dunham Fault; a change in the nature of the sediments does occur here. Precise correlations cannot be made with the 'members' higher in the Formation.

<u>Liamma Beds</u> (New Name)

The name is derived from Liamma Spring (Lat. 16° 22' 43" S, Long. 128° 7' 38" E), twelve miles south-west of Dunham River Homestead. The Beds crop out in the Liamma Spring in O'Donnell Range area and extend south-west from here as discontinuous fault blocks along the western side of the Greenvale Fault. In the Mount Remarkable area the rocks are not faulted and crop out over a wider area due to flatter dips. They extend westwards into the Lansdowne Sheet area. The Beds overlie the O'Donnell Formation with marked angular unconformity and are in turn overlain with angular unconformity by the Speewah Group; in places the Speewah Group sits directly on the O'Donnell Formation. They crop out well as discontinuous, fault bounded, sandstone strike ridges and valleys of siltstone. Sections observed to date are incomplete because of the unconformity at the top and because of structural complications.

The Liamma Beds are characterized by an alternating succession of blocky quartz sandstone and thinly interbedded (less than 6 inches) green, and minor grey or black, siltstone, shale, and fine-grained quartz greywacke. The sandstones have cross-bedding, ripple marks, and clay pellets indicative of stable shallow-water conditions of sedimentation. Detrital tourmaline is common. The siltstones on the other hand have slumping laminated bedding and graded bedding. In thin-section they have a very open framework of angular poorly sorted quartz grains in a chlorite-sericite-chert matrix. These features are all indicative of unstable deeper water conditions. The fine-grained rocks weather to blade-shaped fragments in outcrop owing to bedding and cleavage partings.

The following incomplete generalized section was measured near the Bedford Stock Route (Lat. 16° 22' 43" S, Long. 128° 7' 38" E).

Valentine Siltstone

Angular Unconformity

190 feet	Blocky, fine to medium-grained, white clean quartz sandstone; minor coarse to very coarse-grained sandstone and poorly sorted clayey quartz sandstone. Tourmaline common.
30 feet	Fine-grained, cross-bedded, flaggy, clayey quartz sandstone.
285 feet	Massive green and grey chlorite siltstone, quartz siltstone, and fine-grained quartz greywacke grade down into interbedded siltstone and thinly bedded quartz greywacke in lower 150 feet. Basal 50 feet has very regularly bedded black, grey, and green siltstones and 1 to 6 inches interbeds of fine-grained quartz greywacke. Mica and chlorite on bedding surfaces. Slumping and auto-injection structures common.
250 feet	Thin bedded to blocky, white to brown, quartz sandstone, micaceous sandstone, and some feldspathic sandstone. Ripple marks and some clay pellets. Occasional 6-inch interbeds of siltstone.
65 feet	Poorly outcropping, yellow to green greywacke, probably derived from volcanics.
Total 780 feet	

Angular Unconformity

O'Donnell Formation

Elsewhere in the map area a second thick siltstone member is preserved at the top of the section.

In the Wilson River area, adjacent to the Green vale Fault, the Beds are tightly folded into simple concentric folds. Small scale folds show both a bedding-slip cleavage and an axial plane cleavage.

The Liamma Beds are distinguished from the underlying O'Donnell Formation by the thinly interbedded (always less than six inches thick) quartz greywacke and siltstone, the well developed sedimentary structures, and green to grey chloritic siltstones are dominant rather than shales. The quartz greywacke interbeds show thin laminar bedding.

Speewah Group (New Name)

The Speewah Group, a sequence of feldspathic sandstone, chloritic and micaceous siltstone, and minor acid volcanics, overlies the Liamma Beds with angular unconformity and is overlain by the Kimberley Group with a probable erosional unconformity. Preliminary reconnaissance indicates an angular unconformity in the Lansdowne Sheet area, to the west; this area will be mapped during 1964. Outcrops extend from the Ivanhoe Fault, near Valentine Creek in the north-east, southwards along the Bedford Stock Route, to the north-west corner of Dixon Range Sheet area. No outcrops occur east of the Ivanhoe Fault and most outcrops are west of the Greenvale Fault. The name is derived from the Speewah Valley (about Lat. 16° 25' S, Long. 127° 55' E), in the western part of the Lissadell Sheet area, which is surrounded by typical exposures of the Group.

The Group consists of three formations, the Valentine Siltstone, Looningnin Arkose and Luman Siltstone.

Rocks of the Group are extensively intruded by sills of Hart Dolerite. These frequently enclose large blocks, up to two miles in length, of sedimentary rocks rafted along joint or fault planes. At times the stratigraphy is complicated by repetition of sequences on either side of sills.

The thickness of the Group has been measured as 2000 feet in the Speewah Bedford Stock Route area. It appears to thicken in the south-west.

No known stratigraphic equivalents of the Group occur anywhere else in the Ord River Region.

Valentine Siltstone (New Name)

The basal unit of the Speewah Group has been named the Valentine Siltstone from Valentine Creek, in the north, which cuts the Siltstone at Lat. 15° 45' S, Long. 128° 35' E. It extends south-westwards from here along the Bedford Stock Route to the north-west corner of the Dixon Range Sheet area, and also into the Speewah Valley. It crops out poorly, generally in a scarp beneath the overlying Looningnin Arkose. The combined outcrop of the Siltstone and a sill of Hart Dolerite controls a narrow but consistent valley along the base of the Saw and Durack Ranges which the Bedford Stock Route now follows.

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The Siltstone overlies the Liamma Beds with angular unconformity and is overlain conformably by the Looningnin Arkose. A dolerite sill, up to 6000 feet thick in the Speewah Valley, is always present along, or just above, the unconformable contact between the Siltstone and the Liamma Beds. This dolerite has frequently incorporated considerable amounts of the Siltstone and a granophyre is developed at the contact. The only complete sections of the Siltstone occur in the rare places where the granophyre is absent.

The formation consists of thinly bedded green chlorite siltstone and siliceous siltstone and minor interbeds of fine to medium-grained quartz sandstone, feldspathic sandstone, and quartz greywacke. Two thin bands, rarely exceeding forty feet total thickness, of rhyolitic ashstone and rhyolitic tuff are present.

The following generalized section (Lat. 16° 28' 34" S, Long. 128° 3' 12" E) was measured adjacent to the Bedford Stock Route, in the Liamma Spring area.

Looningnin Arkose

35 feet	Dark green to black siliceous siltstone. White mica and chlorite lies in bedding.
3 feet	Massive black rhyolitic tuff.
70 feet	Interbedded fine-grained green micaceous and chloritic quartz sandstone, green siliceous chloritic siltstone and purple micaceous shale.
25 feet	Massive rhyolitic ash. In part (?) reworked.
70 feet	Very thinly bedded green fine-grained chloritic silty sandstone and green chloritic siltstone. Micro-cross-bedding.
60 feet	Green chloritic siltstone and purple-brown micaceous siltstone with 3 inch interbeds of very thinly bedded fine-grained silty sandstone.
75 feet	Interbedded pink fine-grained quartz sandstone, feldspathic sandstone, feldspathic quartz greywacke and feldspathic siltstone.
Total 340 feet	

Angular Unconformity

Liamma Beds

The volcanic bands are sometimes discontinuous. In most of the Speewah area only one volcanic is present, and in places a massive ashstone occurs at the top of the unit : this grades laterally into a thin rhyolitic tuff overlain by a few feet of siltstone. In the southwest no volcanics could be found in some sections.

In thin section the ash contains phenocrysts of quartz and feldspar, up to 2 mm. in size, in a siliceous groundmass or a groundmass of sericite, chlorite, and fine quartz and feldspar. The rhyolitic tuffs show occasional shattered and devitrified small (0.1 to 0.8 mm.) quartz phenocrysts in a crypto-crystalline felsic or quartz-sericite matrix. Some fine acid rock fragments are present.

The siltstone have an open framework of small angular quartz grains in a sericite-chlorite matrix. They may contain reworked tuff matdrial, but the evidence in thin section is inconclusive.

In the Wilson River area the section contains considerable quantities of medium-grained feldspathic sandstone, alternating with green siltstones, in beds 75 to 100 feet thick.

Looningnin Arkose (New Name)

Looningnin Creek, in the Lansdowne Sheet area, cuts the Arkose at about Lat. 17° 40' S. Long. 126° 50' E. The Arkose lies conformably between the underlying Valentine Siltstone and the overlying Luman Siltstone. It crops out throughout the Valentine Creek - Bedford Stock Route - Speewah areas, in the western part of the map area, and is the main marker unit of the Speewah Group because of its excellent outcrop : well-defined cuestas and hog-backs lie slightly below the level of the Kimberley Plateau. It has a very distinctive thinly banded pattern on air photographs, controlled by thin persistent siltstone beds and varying degrees of erosion of the arenite beds.

The formation is characterized by pink and pale purple-brown blocky medium-grained feldspathic sandstone, arkose, and clayey (after (?) feldspar) sandstone. Shale partings and pellets, large cross-beds, and ripple marks are common. Some slumping is present in places. Minor quartz sandstone occurs throughout and, in particular, a prominent white, jointed, silicified sandstone caps the upper dip-slope of the Arkose throughout the area. The formation contains minor, but persistent beds of purple micaceous siltstone and yellow-brown siltstone. Some fine-grained glauconitic arkose and green micaceous feldspathic siltstone is present.

The following generalized composite section Lat. 16° 28' 34" S, Long. 128° 3' 12" (base) and Lat. 16° 32' 24" S, Long. 127° 59' E was measured adjacent to the Bedford Stock Route in the Liamma Springs area.

Luman Siltstone

15 feet	Clean, brown to white, resistant, blocky, cross-bedded silicified quartz sandstone.
280 feet	Thinly bedded to massive, fine to medium-grained, pale purple-brown or pink feldspathic and clayey quartz sandstone. Cross-bedding, red shale partings, and red shale pellets common. Muscovite on bedding surfaces.

20 feet	Thinly bedded purple siltstone and minor fine-grained quartz sandstone.
135 feet	Thin to medium bedded, fine to medium-grained, slightly friable clayey quartz sandstone.
50 feet	Slightly friable, medium to thinly bedded, medium-grained quartz sandstone.
145 feet	Massive, medium to coarse-grained, pale purple-brown to pink feldspathic sandstone.
135 feet	Purple and grey micaceous siltstone and shale and siltstone poor in mica. Minor thinly bedded fine-grained friable silty (feldspathic) sandstone.
200 feet	Interbedded blocky to massive, fine to medium-grained pink feldspathic sandstone and arkose. Minor silty quartz sandstone and micaceous feldspathic sandstone. Lenses of black and grey shale. Shale partings and pellets common. Lowest 10 feet has increasing siltstone gradational into underlying unit.
Total 980 feet	

Valentine Siltstone

Throughout most of the area the prominent siltstone member (A) divides the unit into three distinct members. In the Wilson River area the thickness of the Arkose is estimated on air photographs to be 2000 feet. The upper siltstone (B) is more prominent there and consists of a bed of flaggy greenish-grey micaceous feldspathic siltstone, 100 feet thick, containing, in thin section, about ten percent plagioclase, five percent muscovite, and some tourmaline, in a sericite and quartz matrix. The basal arkose 'member' has abundant green siltstone interbeds : the contact with the overlying siltstone (A) and the underlying Valentine Siltstone is gradational.

In thin sections, arenites from the formation contain mostly potassic feldspar, although soda feldspar is dominant in a few. Feldspar generally constitutes ten to fifteen percent, and sometimes more than twenty percent, of the rocks, which are commonly bimodal with respect to sand grainsize. The rocks are in general more clayey towards the top of the unit and small grains of glauconite and sericite occur in places. Although highly feldspathic, the detrital material of the rocks has been subjected to considerable transport and reworking.

The formation is intruded by Hart Dolerite and in parts of the Speewah area large portions of the unit are missing, apparently digested by the dolerite. Blocks of sediment are completely enclosed by dolerite.

One mile north-east of Liamma Spring (Lat. 16° 22' S, Long. 128° 8' E) an erosional break is visible at the top of the lower siltstone 'member' (A); about 100 feet of siltstone has been eroded. This has not been observed anywhere else in the region and is probably due to local movement on the nearby Greenvale Fault.

Luman Siltstone (New Name)

The name is derived from the Luman Land Division of the East Kimberleys and is applied to a sequence of siltstone and minor sandstone which conformably overlies the Looningnin Arkose and is overlain by the King Leopold Sandstone with probable erosional unconformity. The Siltstone crops out poorly in the scarp and valley beneath the resistant King Leopold Sandstone from Valentine Creek in the north, extending southwards along the base of the Saw Ranges to the base of the Durack Ranges in the Speewah and Bedford Stock Route areas.

The Siltstone is usually divisible into three distinct 'members'. A lower 'member' of thinly flaggy purple and green chloritic-micaceous shale, siltstone, and fine-grained sandstone is overlain by friable feldspathic and clayey sandstone. The upper 'member' contains green and brown siltstone and grey shale.

The following generalized section (Lat. 16° 32' 24" S, Long. 127° 51' 00" E) was measured near the Bedford Stock Route, in the Liamma Spring area.

King Leopold Sandstone

Unconformity

285 feet	Poor outcrop of green and brown siltstone; yellow, brown, and grey shale and siliceous shale. Minor fine-grained sandstone. Scattered mica throughout.
30 feet	Thinly interbedded fine to medium-grained quartz sandstone and brown shale overlain by 13 feet of blocky fine-grained quartz sandstone.
515 feet	Dolerite sill
175 feet	Interbedded, flaggy, friable, fine-grained feldspathic sandstone, clayey sandstone and micaceous clayey sandstone, and claystone. Minor glauconitic quartz sandstone.
170 feet	Thinly flaggy to fissile, purple and green, chloritic micaceous shale and siltstone and flaggy fine-grained sandstone interbeds. Abundant ripple marks, mud cracks and flow casts. Some slumping.
Total 660 feet	

Looningnin Arkose

In the Valentine Creek area the middle sandstone member is absent : it becomes prominent southwards. In thin section a siltstone from the basal 'member' has a compact framework of rounded quartz grains (0.01 to 0.03 mm) and about five percent each of chlorite and muscovite lying in the bedding.

Extensive sills of Hart Dolerite intrude the siltstone and dolerite commonly occurs along the contact with the overlying King Leopold Sandstone. Elsewhere the contact is obscured by poor outcrop, the Siltstone being covered with sandstone scree. As a result a contact relationship between the 69

Luman Siltstone and King Leopold Sandstone was not satisfactorily determined in the map area. Over most of the area they appear to be conformable. Possible unconformities in some areas are inconclusive owing to poor outcrop and structural complications.

At the base of the Durack Ranges in the Wilson River area (about Lat. 16°52'S, Long. 127°37'E) the upper siltstone member is only about 40 feet thick, in comparison to 285 feet in the measured section farther north. This is apparently due to erosion as the other 'members' retain their thickness. A few miles to the south-west photo-interpretation (to be checked in the field) shows the King Leopold Sandstone sitting directly on Looningnin Arkose while preliminary reconnaissance in the Lansdowne Sheet area (to be mapped during 1964) indicates an angular unconformity. It is tentatively considered that the King Leopold Sandstone overlies the Luman Siltstone with a probable erosional unconformity.

<u>Kimberley Group</u> (New Name)

Most of the rocks which crop out in the north -western part of the Ord River Region belong to the Kimberley Group. They are bounded on the east by the Greenvale - Dunham - Ivanhoe Fault System and extend to the west of the map area to form the bed-rock of most of the Kimberley Plateau, from where the name is derived. Many of the units show appreciable thinning eastwards, adjacent to the bounding faults. The Group consists of sandstone, subordinate siltstone and minor volcanic and carbonate interbeds. It has been divided into five formations : (1) King Leopold Sandstone (2) Carson Volcanics (3) Warton Sandstone (4) Elgee Siltstone (5) Pentecost Sandstone.

The group is conformably overlain by the Bastion Group and overlies the Speewah Group with probable unconformity (see Luman Siltstone). The sandstones crop out boldly as rugged plateaux and strike ridges, and valleys are formed on outcrop of siltstone and volcanic units (Fig. 5). The close relationship between rock types and topography makes the Group amenable to accurate mapping by airphoto interpretation.

Stratigraphic equivalents of the Group are not precisely known elsewhere in the Region. The probable relationship is shown in Figure 10.

Within the map area the Group is 9000 feet thick.

<u>King Leopold Sandstone</u> (Old name redefined)

The name King Leopold Beds was first used by Guppy et al. (1958) to describe the beds lying stratigraphically between the Lamboo Complex and Mornington Volcanics, in the King Leopold Ranges of the West Kimberleys. Harms (1959) modified the name to King Leopold Sandstone and extended its usage throughout the Kimberleys. The name is now restricted to the sandstone overlying the Speewah Group, with probable unconformity, and

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conformably underlying the Carson Volcanics; this definition includes the rocks of the King Leopold Ranges.

The highly resistant Sandstone forms the main ridges of the Durack and Saw Ranges within the map area and also the ranges bordering the Valentine Creek Valley further north. Smaller outcrops occur around the Dunham Valley. A small isolated outcrop, about two miles west of the Cave Range, in the north-east, apparently unconformably overlies rocks of the Carr Boyd Succession.

The formation consists mainly of blocky to massive quartz sandstone containing scattered feldspar (generally less than five percent). Scattered small quartz pebbles are present throughout the rocks, which generally have a silica cement and scattered clay matrix. Cross-bedding is ubiquitous and ripple marks and slumping are common.

The middle part of the section has irregular thick lenses of grit and pebble or cobble conglomerate. Outcrops are massive and large cross-bedding is very common. Pebbles consist of quartz, sandstone, and acid igneous rocks. The sandstone pebbles appear to be almost identical to the enclosing matrix. Outcrops are highly jointed on air photographs.

In general the upper and and lower parts of the unit contain cleaner and better-sorted rocks than the middle.

No section has been measured in the unit. It has been consistently estimated from air photographs to be 3000 feet thick in the Saw Ranges and Dunham Valley area. Farther north, near Valentine Creek, it has been estimated to be greater than 4000 feet thick; faulting in the Durack Ranges makes it difficult to obtain a reliable estimate.

Carson Volcanics (New name)

Guppy et al. (1958) and Harms (1959) named the basic volcanics which crop out extensively around Mornington Homestead, in the West Kimberleys, the Mornington Volcanics. This name is invalid owing to prior usage; we have renamed them the Carson Volcanics from extensive outcrops around the Carson River (Lat. 14°30'S, Long. 126°45'E) in the north Kimberley Plateau (Harms, 1959).

The Volcanics crop out poorly in the scarp below the conformably overlying Warton Sandstone. The base level of the valley below is commonly controlled by the conformably underlying King Leopold Sandstone; streams flow along the contact between the Sandstone and Volcanics. The distribution of the Volcanics is similar to that of the King Leopold Sandstone.

The formation consists of massive saussuritized and chloritized basalt, interbedded feldspathic sandstone and chloritic siltstone, and minor green chert. The sandstones are commonly cross-bedded and contain clay pellets. The formation shows marked lateral changes in thickness and lithology.

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Two sections of the Volcanics have been measured in the map area. They are given in generalized form below:

Durack Ranges - Lat. 16°17'25"S, Long. 127°52'8"E

Warton Sandstone

170 feet	Poor outcrop of flaggy, white, feldspathic-micaceous sandstone and clayey sandstone. Fairly friable.
120 feet	Massive pink, medium-grained, feldspathic sandstone. Cross-bedded.
250 feet	Massive altered basalt. Amygdaloidal near the top of flows.
100 feet	Massive purple-brown, medium-grained feldspathic sandstone. Large cross-beds.
110 feet	Massive altered basalt.
Total 750 feet	

King Leopold Sandstone

Section II

2 Miles east of Saw Ranges - Lat. 16°7'4"S. Long. 128°20'42"E

Warton Sandstone

85 feet	Poor outcrop of flaggy green-grey micaceous feldspathic sandstone.
155 feet	Poor outcrop of flaggy green chloritic quartz siltstone and fine-grained sandstone.
2 feet	Green (?)tuffaceous chert
210 feet	Massive altered basalt. Amygdaloidal.
130 feet	Blocky purple-brown feldspathic sandstone. Cross-bedding, ripple marks and clay pellets common.
185 feet	Massive, altered, amygdaloidal basalt.
Total 865 feet	

King Leopold Sandstone

In thin-section of the basalt, the feldspar is generally altered to epidote and albite and is set in a chloritized and sericitized groundmass. Minor pyroxene occurs in some specimens. The massive feldspathic sandstones of 'member' B have silica cement and secondary enlargement of quartz grains. The feldspar is mostly andesine, with some potassic feldspar, and minor pyroxene is present. All the sedimentary rocks of the formation contain basic rock fragments.

The green chert above the second basalt of Section II has fine detrital mica, feldspar, pyroxene, and olivine in an amorphous silica matrix. The chloritic siltstone contains poorly sorted quartz grains and is highly chloritic. Minor mica occurs, large flat rock fragments lie in the bedding, and some beds contain anhedral grains of carbonate.

In the southern Durack Ranges at least five distinct basalt flows are present, separated by beds of sandstone. A dolerite sill, 25 feet thick, intrudes the basalt.

Farther north along the Ranges the proportion of basalt in the formation decreases (only two bands are present) and the sequence becomes similar to the measured section: the sandstone members thicken. The upper basalt (C) is discontinuous and lenses, up to a few hundred yards long, of massive red feldspathic sandstone, replace it. These lenses each consist of a single set of large foreset beds, up to 250 feet thick. Foreset dips are about 30° north.

In the Pentecost River area the upper basalt disappears and the unit thins. The following section was observed (Lat. 16°03'S, Long. 127° 55'E).

Warton Sandstone

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2000 feet	Soft blocky yellow-brown sandstone.
70 feet	Basalt.

- -

King Leopold Sandstone

Five miles east of here basalt is absent from the section altogether. Around the upper King River Valley only the lower basalt is present as small discontinuous flows; it is absent in the Saw Ranges.

In the Valentine Creek area, to the north-east, three basalts occur, separated by sandstones; a soft sandstone member occurs at the top of the unit.

Warton Sandstone

Guppy et al., (1958) used the term Warton Beds to describe the rocks overlying the 'Mornington' (i.e. Carson) Volcanics, perhaps unconformably, and unconformably overlain by the Walsh Tillite. Harms (1959) subdivided the beds into three formations and used Warton Sandstone for the basal unit, which forms the Warton Range (Lat. 17°24'S. Long. 126° 27'E) in the West Kimberleys. He did not support the idea of an unconformity (Guppy et al., 1958) at the base of the unit.

In the map area the Warton Sandstone is conformably overlain by the Elgee Siltstone and conformably overlies the Carson Volcanics. It crops out as prominent cuestas and hog-backs in the Durack and Saw Ranges, in ranges around the Dunham Valley and Valentine Creek farther north. It also forms the base-level of large valleys west of the Pentecost Ranges and to the north of the Forrest River. A small outcrop is found two miles west of the Cave Range.

The Sandstone is very uniform and consists of blocky to massive quartz sandstone, containing scattered feldspar and black iron oxides and grades upwards into feldspathic sandstone. The feldspar is mainly potassic. Ripple marks and cross-beds are common; clay pellets and slumping are present. The Sandstone contains minor interbeds of grit and purple shale.

Along the Durack Ranges a distinctive white silicified sandstone caps the dip-slope of the formation. The following generalized section was measured in the Ranges at Lat. 16°17'48"S, Long. 127°48'12"E.

Elgee Siltstone

	20 feet	Blocky white silicified quartz sandstone. Some feldspar
	15 feet	Flaggy purple-brown ferruginous sandstone.
	90 feet	Flaggy to blocky feldspathic sandstone.
	2 feet	Grit.
	200 feet	Massive medium-grained quartz sandstone. Scattered feldspar and black iron oxides.
	10 feet	Flaggy red-brown feldspathic sandstone.
	180 feet	Massive quartz sandstone. Some feldspar.
	10 feet	Purple shale and quartz sandstone.
	170 feet	Massive clayey quartz sandstone.
Total	700 feet	

Carson Volcanics

To the east of the Saw Range (Lat. 16°7'S, Long. 128°21'E) a measured section of the Sandstone was 430 feet thick. Adjacent to the Dunham Fault, twelve miles north of Dunham River Homestead, it is estimated to be only 200 feet thick.

Elgee Siltstone

When Harms (1959) subdivided the Warton Beds (Guppy et al.,) he named the middle formation the Elgee Shale. We have modified this to Elgee Siltstone. The name is derived from the Elgee Cliffs in the western part of the map area, where the Siltstone crops out for a distance of eighty miles.

The Siltstone crops out very poorly in the scarp beneath the conformably overlying Pentecost Sandstone (Figure 3). The top bed of the conformably underlying Warton Sandstone forms the valley floor below. Scattered outcrops occur in the Elgee Cliffs, to the west of the Pentecost Ranges, to the north of the Forrest River and along the Northern Highway about twelve miles south-east of Wyndham. Elsewhere in the area outcrops are covered by scree.

The formation consists of a distinctive massive cherry-red to purple siltstone with minor purple-brown laminated fine-grained sandstone interbeds. Minor grey and green shale and micaceous shale, micaceous fine-grained sandstone, dolomite, and blocky quartz sandstone is present within the formation.

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The following generalized section was measured in the Elgee Cliffs at Lat. 16°6'6"S, Long. 127°52'8"E.

Pentecost Sandstone

	85 feet	Interbedded flaggy to blocky, fine-grained purple-brown sandstone, flaggy purple-brown micaceous silty fine-grained sandstone, and purple siltstone. Abundant mud-cracks, cross-bedding.
	500 feet	Poor outcrop purple to red siltstone with minor interbeds of laminated purple-brown fine-grained sandstone.
	5 feet	Blocky yellow-brown medium-grained feldspathic sandstone.
	20 feet	Flaggy purple siltstone.
Total	610 feet	

Warton Sandstone

The upper part of the Siltstone grades into the Pentecost Sandstone.

Along the Karunjie Road the basal thirty feet consists of massive quartz sandstone alternating with green and purple siltstone. In the southern Elgee Cliffs the basal fifty feet of section consists of grey and green shale and micaceous shale with four beds, two to three feet thick, of flaggy grey and green dolomite and minor algal dolomite. Ripple marks and slumping are common. The dolomite does not extend to the north.

Occasional lenses of blocky, white, cross-bedded quartz sandstone, twenty feet thick and 500 feet long, crop out within the main siltstone member in the Elgee Cliffs.

Pentecost Sandstone

The upper unit of Harms' (1959) subdivision of the Warton Beds (Guppy et al., 1958) is the Pentecost Sandstone. The name is derived from the Pentecost Ranges (Lat. 15°46'S, Long. 127°45'E) in the western part of the Cambridge Gulf Sheet area. The Sandstone is the upper unit of the Kimberley Group. It conformably overlies the Elgee Siltstone and is conformably overlain by the Mendena Formation. The Sandstone is the most extensive formation of the Kimberley Group in the Ord River Region; outcrops extend from Buttons Gap, in the Valentine Creek area, to the western margin of the map area. The Sandstone, in the east, is well exposed as a series of parallel cuestas. Further west, where it forms the bed-rock for most of the Kimberley Plateau, it forms structural terraces and very shallowly dipping cuestas, controlled by soft beds within the Sandstone (Fig. 2).

The formation consists mainly of blocky to massive, fine to medium-grained, pink and pale brown quartz sandstone and flaggy fine-grained white quartz sandstone. The sand grains are well sorted and rounded and the rocks contain scattered feldspar and a white clay matrix. Purple and yellow ferruginous spots about $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter are very common. Ripple marks, cross-bedding, and clay pellets are very common throughout and armoured ferruginous mud-balls were found in the upper Salmond River area. Minor interbeds of purple siltstone and micaceous siltstone, green

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shale, glauconitic sandstone, and ferruginous feldspathic sandstone are present throughout the area.

The following generalized section (Lat. 15°59'0"S, Long. 128°5'20"E) was measured immediately south of the Cockburn Range.

Mendena Formation

50 feet	Massive, white, jointed, silicified quartz sandstone.
100 feet	No outcrop in measured section. Known from other areas to consist of flaggy purple micaceous siltstone and fine-grained sandstone.
1300 feet	Blocky medium-grained pale purple-brown quartz sandstone
200 feet	No outcrop in measured section. In adjoining areas consists of interbedded fissile grey-green to purple siltstone and laminated purple-brown to white fine-grained sandstone. Small scale cross-bedding. Lenticular bedding.
1000 feet	Blocky to massive, medium grained, well sorted pinkish-borwn quartz sandstone. Clay matrix, iron spots. Feldspar common in some beds. Clay pellets and cross-bedding.
75 feet	Poorly sorted, fine to medium-grained, grey or green slightly micaceous((?)glauconitic) sandstone.
150 feet	Thinly laminated, fine-grained ferruginous-glauconitic-micaceous sandstone.
50 feet	Poor outcrop of shale.
700 feet	Fine to medium-grained quartz sandstone. Well sorted - minor feldspar. Cross-bedded.

otal
650 feet

Elgee Siltstone

The Sandstone contains three well defined siltstone 'members' which can be traced laterally throughout most of the map area. They vary laterally in thickness and lithology.

The lowest 'member' (A) is characterized by abundant glauconite in most outcrops. East of the Saw Range it is up to 400 feet thick; to the west, near the Durack River, it thins to about 130 feet. In the southern Elgee Cliffs area it is represented by only thirty feet of quartz sandstone and minor flaggy siltstone interbeds.

The middle 'member'(B) is absent east of the Saw Ranges. In the Durack River area it contains glauconitic ferruginous sandstone and purple siltstone.

The uppermost 'member' (C) thins to the north-west of the measured section to about 50 feet near the Durack River and it is absent in the Valentine Creek area. East of the Saw Range 200 feet of flaggy, purple-brown, friable ferruginous-feldspathic sandstone underlies the top sandstone of the formation, while in the upper Salmond River area 100 feet

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of alternating yellow-brown clayey sandstone and purple ferruginous feldspathic sandstone is capped by twenty feet of massive white sandstone.

The thick sandstone members of the formation are consistent laterally, and east of the Saw Ranges the Sandstone is estimated to be only 2000 feet thick.

Bastion Group (New Name)

The Younger Proterozoic rocks which conformably overlie the Kimberley Group have been named the Bastion Group from the Bastion Range at Wyndham. The Group is unconformably overlain by the Antrim Plateau Volcanics of Cambrian age. Traves (1955) and Harms (1959) correlated the rocks of the Group with the Mount House Beds of the West Kimberleys, but the Group is now considered to be much older.

The Bastion Group crops out as scattered outliers on the more extensive Kimberley Group, throughout the north-western part of the map area. The reference area for the Group is the Cockburn Range. The rocks are characterized by dominantly green shales and minor carbonates, overlain by quartz sandstone. The Group is divided into three formations, (1) Mendena Formation (2) Wyndham Shale and (3) Cockburn Sandstone.

In the reference area it has been measured as 4600 feet thick.

Mendena Formation (New Name)

The oldest formation of the Bastion Group is named the Mendena Formation from Mendena Creek near the Forrest River Mission. The Formation conformably overlies the Pentecost Sandstone and is conformably overlain by the Wyndham Shale. It crops out poorly as low sandstone strike ridges with poorly outcropping siltstone between them in scattered outliers on Kimberley Group rocks throughout the north-western part of the map area.

The Formation consists mainly of flaggy green and purple (micaceous) shale and siltstone. There are subordinate interbeds of flaggy grey and green laminated fine-grained micaceous sandstone throughout and minor flaggy green and pink dolomitic sandstone, grey, green, and pink dolomite and oolitic dolomite, flaggy quartz sandstone. Consistent beds, about thirty to fifty feet thick, of blocky medium-grained quartz sandstone form useful marker beds. Ripple marks, cross-bedding, and clay pellets are common. The upper sandstone defines the top of the unit: no sandstone occurs in the overlying Wyndham Shale.

The following generalized reference section was measured on the Pentecost River (Lat. 15°45'55"S, Long. 127°51'28"E)

Windham Shale

- -

35 feet Blocky, white, medium-grained quartz sandstone.

M7

	60 feet	Brown and minor green shale and thin interbeds of fine-grained sandstone.
	50 feet	Blocky medium to coarse-grained slightly feldspathic quartz sandstone. Cross-bedded, ripple-marked.
	100 feet	Poor outcrop of green-brown shale and siltstone and micaceous shale and siltstone. Minor interbeds of grey dolomite or shaly dolomite. Some thin-bedded sandstone.
	55 feet	Brown and green fissile micaceous sandstone and minor interbeds of fine-grained sandstone containing abundant clay pellets.
	5 feet	Green, slightly dolomitic, thin-bedded siltstone and fine-grained sandstone. Ripple marks and gouge marks.
	65 feet	Soil cover. Probably shale.
Total	370 feet	- -

Pentecost Sandstone

Dolomitic rocks usually occur in beds about one foot thick scattered throughout the shale members of the Formation. The fine-grained flaggy sandstones are generally laminated and show small-scale cross-bedding: they become more common towards the base. The Formation is transitional between the Pentecost Sandstone and Wyndham Shale.

East of the reference area, in the Valentine Creek and Saw Ranges areas, the Formation contains three well-defined sandstone marker beds, whereas there are only two in the reference section. It is estimated to be about 500 feet thick in the east.

Wyndham Shale (New Name)

The shale which lies conformably between the overlying Cockburn Sandstone and underlying Mendena Formation has been called the Wyndham Shale from good outcrops at the township of Wyndham. It crops out very poorly in the scarp and valley below the Cockburn Sandstone, and occurs in the Cockburn - Tier Ranges area, in the Bastion Range at Wyndham, and in the scarps and valley surrounding House Roof Hill and False House Roof Hill.

The formation consists of uniform, fissile, green or grey shale and siltstone with regular, lenticular interbeds two inches to one foot thick of laminated grey fine-grained sandstone. Micaceous laminae are present and mud cracks, load casts and 'wavy' bedding are common. Elliptical concretions of black carbonate material (?siderite), up to two feet in diameter, are scattered throughout the shale.

The lower part of the Shale contains flaggy interbeds of black to grey (?)sideritic sandstone and flaggy crystalline carbonate (?siderite). Cone in cone structure has been observed. These rocks gradually disappear up the section. The top of the section consists only of shale without fine-grained laminated sandstone interbeds.

The only section of the Shale which could be measured completely crops out very poorly in the western side of the Cockburn Range. It is 2300 feet thick.

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Cockburn Sandstone (New Name)

The youngest formation of the Bastion Group is named the Cockburn Sandstone from its reference section in the Cockburn Range (Lat. 15°50'18"S, Long. 128°0'5"E). The top of the Sandstone has been eroded and it is now unconformably overlain by the Antrim Plateau Volcanics. It conformably overlies the Wyndham Shale. The Sandstone crops out boldly as plateau and mesa cappings on the Cockburn, Tier, and Bastion Ranges, and on House Roof and False House Roof Hills.

The formation consists of fine to medium-grained clean quartz sandstone. Outcrops are massive, but bedding within them is thin and regular. Ripple marks and cross-bedding are common and clay pellets are present in some beds. The Sandstone contains minor interbeds of purple-brown to grey micaceous fine-grained sandstone, thinly bedded green micaceous siltstone and shale, and silty or clayey sandstone.

The following generalized reference section was measured in the Cockburn Range.

Eroded top to unit

450 feet	Fine to medium-grained quartz sandstone. Moderate sorting and rounding of grains. White clay matrix. Pink limonitic staining. Cross-bedded and ripple marked in part.
380 feet	No outcrop. Probably sandstone.
120 feet	Interbedded buff, laminated, slightly micaceous siltstone and thin-bedded, buff, fine-grained quartz sandstone containing some feldspar. Mud pellets.
85 feet	Interbedded green-grey micaceous siltstone, fine-grained quartz sandstone, and green shale.
265 feet	Fine to medium-grained white silicified quartz sandstone. Cross-beds, ripple marks, and pellets. Shale partings near top.
90 feet	No outcrop. Probably sandstone.
250 feet	Fine to medium grained quartz sandstone. Cross-bedded, ripple marks, some clay pellets.
Total 1650 feet	

Wyndham Shale

Elsewhere in the area only thin erosional remnants of the Sandstone are preserved. In the Tier Range and House Roof Hill areas the remnants of the lower part of the section which are preserved contain abundant silty and clayey sandstones and abundant shale interbeds.

Eastern Succession

East of the Halls Creek Fault, Younger Proterozoic rocks are exposed as a narrow discontinuous belt between the Older Proterozoic basement and the upturned edge of the overlying Cambrian rocks. The most complete successions are exposed in the Osmond Range, a complexly faulted 79 anticline north of the Hardman Basin, and in the Albert Edward Range in the south-east of the map area. Minor exposures extend northwards along the Fault to Mount Brooking in the north-east. The rocks are unmetamorphosed, predominantly well-sorted shallow-water sediments which rest with a marked angular unconformity on the Halls Creek Group.

The oldest unit is the Red Rock Beds. This is overlain, unconformably, by the six formations listed below which have been called informally the Osmond Range succession.

Helicopter Siltstone
Bell Sandstone
Mount John Shale
Wade Creek Sandstone
Bungle Bungle Dolomite
Ahern Sandstone Member
Mount Parker Sandstone.
bottom

Three angular unconformities occur within this sequence, each of which represents the erosion of more than 4000 feet of sediments, but as the only known exposures of the Osmond Range succession are near the Halls Creek Mobile Zone (see Structure), the unconformities could be merely of local importance.

Two groups are recognised in the unconformably overlying sediments: the Ord Group (fine-grained marine sediments with tillites at the base), and the Albert Edward Group (sandstone, shale, and dolomite).

The only rocks that can be correlated across the Lamboo Complex are the Ord Group on the east, and the Walsh Tillite and the Mount House Beds (Guppy et al., 1958) on the west. The sediments underlying these groups are different on either side of the Lamboo Belt: they may be of different ages, or they may have been deposited contemporaneously in different environments.

Red Rock Beds (New Name)

The oldest unit in the Eastern succession has been called the Red Rock Beds from Red Rock Creek, in the Osmond Range area. The Beds consist of arenaceous sediments which crop out mainly as fault wedges in the western part of the Osmond Range. Minor outcrops extend along the Halls Creek Fault to Mount Pitt in the north. They overlie, with strong unconformity, Halls Creek Metamorphics and Lamboo 'Granite', and are separated from the overlying Mount Parker Sandstone by a strong unconformity.

Near the Halls Creek Fault the Beds are steeply-dipping white quartzite, jasper conglomerate, and minor red shale. At the head of Osmond Creek they show extreme lateral variation, and beds of quartz boulder conglomerate several hundred feet thick grade laterally into quartz sandstone and shale within distances of less than one mile. Near Bungle Bungle

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Figure 11 : Mount Parker Sandstone (foreset bedding) resting unconformably on regularly bedded conglomerate and sandstone of the Red Rock Beds. Photo taken north of the headwaters of Osmond Creek.

the Beds are folded into a tight anticline, and here 7000 feet of predominantly thin-bedded quartzite overlies 4000 feet of red and purple siltstone.

Ripple marks, cross-bedding, and foreset-bedding are common, and indicate that the formation was deposited in shallow water. The Beds are probably correlatives of the Carr-Boyd succession, which is well developed in the Lissadell Sheet area to the north.

No section has been measured in the Beds; they are estimated to be up to 11,000 feet thick.

<u>Mount Parker Sandstone</u> (New Name)

A prominent sandstone unit which overlies the Red Rock Beds has been called the Mount Parker Sandstone from the type area, Mount Parker, in the Osmond Range. The Sandstone unconformably overlies both the Red Rock Beds (Figure 11) and the Golden Gate Siltstone; it is conformably overlain by the Bungle Bungle Dolomite.

The Mount Parker Sandstone makes up a large part of the Osmond Range, and it also occurs as discontinuous exposures to the south along the Albert Edward Ranges and to the north along the Halls Creek Fault. It forms prominent escarpments, and over large areas it is seamed by numerous deep, vertical-sided gullies which have eroded along lines of weakness formed by joints and faults.

The whole of the Sandstone is pink, salmon, or white in colour, fine to medium-grained, and only moderately indurated. It consists of well-rounded and well-sorted quartz grains, and commonly has only small amounts of siliceous interstitial material. Near the bottom of the formation, the sandstone contains scattered well-rounded quartz and quartzite pebbles, and it grades into pebble conglomerate. Ferruginous quartz sandstone consisting of coarse sub-angular grains of quartz and a small amount of ferruginous matrix constitutes a small proportion of the formation.

Bedding of the lower half of the Formation consists almost entirely of cross-bedding in which the beds are between three inches and one foot thick. Current ripple marks with a wavelength of between 3 inches and 6 inches are common. Towards the top of the unit the sandstone is regularly bedded, the beds ranging in thickness from half an inch up to three feet. Rare casts of mud-pellets were seen in this part of the Formation.

The Mount Parker Sandstone appears to have been laid down in shallow water as foreset beds on a gently dipping shelf of Red Rock Beds. Because most of the bedding seen was foreset the thickness of the formation could not be measured, but from the few true dips measured, it was estimated from the air photographs to be between 500 feet and 1000 feet.

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Figure 12 : Part of anticline in Bungle Bungle Dolomite, photograph looking westwards towards the head of Osmond Creek. Mount Parker Sandstone forms the plateau on the left, northerly dipping dolomite can be seen on the left swinging to a easterly dip near the camera. On the right background Mount Parker Sandstone is repeated by a large fault. (G6211).

Bungle Bungle Dolomite (New Name)

Bungle Bungle Dolomite is the name given to a sequence of predominantly carbonate rocks which unconformably overlies the Mount Parker Sandstone, and is overlain unconformably by the Wade Creek Sandstone. The name is taken from Bungle Bungle Outstation, which is at the head of Red Rock Creek: the type section is a composite one measured in the Osmond Range between Red Rock Creek and the head of Osmond Creek (Fig.12). The Formation also crops out south of Moonlight Valley between the [illegible] Creek Fault and the Ord River, and southwards along the Albert Edward Range, where it was mapped by Smith (1963) as the Brim Creek Dolomite Member of the Mount Kinahan Formation.

The formation is mainly dolomite, dolomitic shale, and minor limestone. Near the middle of the Dolomite there is a bed of sandstone 100 feet thick, which we have called the Ahern Sandstone Member, after Ahern Creek, a tributary of the Osmond Creek.

One complete and three incomplete sections of the Bungle Bungle Dolomite were measured in the Osmond Range, [redacted]. A generalized composite section is given below.

Thickness in feet	Lithology
240	Ferruginous limestone boulder conglomerate
225	Cross-bedded quartz sandstone, minor thin-bedded dolomitic shale.
700	Medium-bedded pink and cream dolomite.
85	Thin-bedded grey dolomite and limestone.
530	Upper part: laminated and thin-bedded, silicified, medium-grained sandstone. Lower part: laminated grey dolomite and silicified shale.
385	Laminated and thin-bedded pink dolomite.
150	Massive calcareous sandstone containing lenses of dolomite.
300	Thin-bedded and laminated green shale, interbedded red and grey siliceous siltstone.
100	Thick-bedded grey limestone interbedded grey shale.
90	Grey limestone breccia.
- - - -	- - - -
100	Ahern Sandstone Member: Thin-bedded to medium-bedded fine-grained quartz shandstone containing minor interbedded shale. Ripplemarks and load casts common.
- - - -	- - - -
200	Thin-bedded dark shale and minor quartz sandstone.
240	Thin-bedded grey limestone and minor grey calcareous shale.
190	Thin-bedded pink and cream dolomite and subordinate interbedded shale.

Figure 13: Horizontal section of a stromatolite colony in Bungle Bungle Dolomite. Photo taken in the Headwaters of Osmond Creek. (G6058).

Figure 14 : Vertical section of the colony shown in Figure 13. (G6207).

Figure 15 : ?Stromatolite colony (vertical section) in Bungle Bungle Dolomite 6 miles south-west of J41 Locality. Large individuals covered by chert replacing another dolomitic colony of smaller individuals. (G.6062)

Thickness in feet.	Lithology.
420	Thick-bedded and massive cream, pink and brown dolomite.
450	Thin-bedded khaki and green shale and interbedded pink dolomite.
4585 feet	Total thickness.

Mount Parker Sandstone

There is slight lateral variation within the unit, and sandstone interbeds are less common to the east.

The northernmost exposure of the Dolomite, eight miles west of the junction of the Negri and Ord Rivers, grades northwards into thin-bedded siliceous siltstone and chert. This does not appear to be a primary sedimentary feature and it has probably resulted from secondary silicification caused by deep weathering, possibly accentuated by silicification along the fault zone which bounds the eastern side of the exposure.

Regular bedding is a feature of the Dolomite, and shallow-water features such as ripple-marks and cross-bedding are rare, indicating that the beds were laid down in moderately deep water. However, stromatolite colonies are common, especially in the upper part of the succession, and these are thought to grow largely in the intertidal zone (Black, 1933; Ginsburg, 1961; Logan, 1961).

Two types of stromatolite colony were seen. The most common, shown in Figures 13 and 14, has been found immediately below the Ahern Sandstone Member, and throughout the upper part of the Dolomite. They are generally roughly circular in cross-section, but their shape is commonly modified by the crowding of the colony as shown in Figure 13. The individuals range in size from about two inches to about three feet across, and they consist of flatly domed laminae 1/10 inch to ¼ inch thick which are convex upwards.

The second type of colony, found only in one locality eight miles west of the junction of the Negri and Ord Rivers, as shown in Figure 15. It appears to consist of two varieties of stromatolite, a later smaller variety encrusting the earlier, larger variety. The larger colony consists of individuals of circular cross-section between six and inches and one foot across, which are composed of laminae about 1/10 inch thick which are highly domed upwards. In the lower parts of the individuals the flanks of the domes are steep and smoothly curved and the apices are gently curved, but in the upper parts the apices are sharp and almost pointed. The colony is mostly dolomite, and only rarely have the laminae been replaced by chert. The encrusting colony is composed of individuals of circular cross-section about one inch across, consisting of laminae up to ¼ inch thick gently domed upwards. In contrast to the lower colony, the upper one is almost completely altered to chert.

Wade Creek Sandstone (New Name)

We have given the name Wade Creek Sandstone to quartz sandstone which unconformably overlies the Bungle Bungle Dolomite, and is conformably overlain by the Mount John Shale. The type locality is Wade Creek, which drains the western side of Mount John. The sandstone crops out extensively in the Osmond Range between Osmond Creek and Moonlight Valley.

The formation consists of 360 feet of white, medium-grained, massive and medium-bedded quartz sandstone, overlain by 140 feet of green-brown thin-bedded quartz sandstone.The lower sandstone is very pure, and is composed of well-rounded well-sorted quartz grains, and contains little or no matrix. Ripple marks and cross-bedding are common.

It was from this sandstone that Wade (1924) collected the supposed jellyfish named by Sprigg (1949) Protoniobia wadea. Wade thought the sandstone was Lower Cambrian, and Sprigg correlated the beds with the basal Cambrian of Ediacara, South Australia, but they are of course, much older. We could not find Wade's locality, but in Wade Creek there is a platform on which are exposed hundreds of small chert plates consisting of a number of concentric rings, very similar to Wade's 'jellyfish'. Many of these are single plates, between ½ inch and two inches across, but a large proportion consists of two to three individuals of various sizes fused together. In some cases, small nodules are fused to the margin of a larger one, giving the appearance of budding appendages described by Sprigg. Under these circumstances there is some doubt that Wade's 'jellyfish' is of organic origin, a doubt previously expressed by Harrington & Moore (Moore, 1956).

The only complete section of the Wade Creek Sandstone is west of Mount John, where the formation is 500 feet thick.

Mount John Shale (New Name)

Mount John Shale is known only in the Osmond Range, within 12 miles of the type locality, Mount John. It conformably overlies the Wade Creek Sandstone and is overlain unconformably by the Bell Sandstone.

The formation consists of basal shale up to 450 feet thick, overlain by sandstone about 200 feet thick. The following section was measured at Mount John:

Thickness in feet	Lithology
30	Thin-bedded highly ferruginous sandstone containing minor interbeds of siltstone. Cement of sandstone is limonite and specular haematite.
170	Thin-bedded, medium-grained, quartz sandstone containing several beds up to 20 feet thick of highly ferruginous sandstone.
270	Laminated and thin-bedded black and grey shale containing thin interbeds of cherty siltstone.

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Thickness in feet	Lithology
	Thin beds of fine-grained micaceous quartz sandstone at base.
Total 470 feet	

Wade Creek Sandstone

North of Mount John 650 feet or more of the formation is preserved and consists of 450 feet of laminated and thin-bedded khaki-green or dark olive-green shale, interbedded with white and green micaceous quartz siltstone, which is overlain by an estimated 200 feet of thin-bedded medium-grained quartz sandstone.

Boll Sandstone (New Name)

Quartz sandstone which unconformably overlies the Mount John Shale has been called Boll Sandstone; the type locality is Blackfella Creek, six miles south of Texas Downs Homestead. The formation takes its name from Boll Creek, and tributary of Osmond Creek 8 miles west of Mount Buchanan. The Sandstone crops out south of Moonlight Valley between the Halls Creek Fault and the Ord River, as a prominent dipslope which is cut by many vertical-sided ravines caused by erosion along steeply dipping joints. Sandstone and siltstone found west of Mount John probably belong to the Boll Sandstone and the Helicopter Siltstone.

The Boll Sandstone is composed of well-sorted, well-rounded quartz grains and very little matrix. It is massive or thick-bedded, mostly medium-grained, and has rare lenses of quartz pebble conglomerate. The beds of sandstone almost invariably lens out within a few hundred feet and ripple marks and sub-aqueous slump structures are common.

The thickness of the formation as measured on the airphotos, is about 600 feet. The upper part of the Sandstone consists of lensing thin-bedded quartz sandstone and laminated quartz siltstone, and it grades imperceptibly into the overlying Helicopter Siltstone. The boundary between the two has been arbitrarily put where the siltstone is predominant.

Helicopter Siltstone (New Name)

Helicopter Siltstone is the name given to thin-bedded siltstone and shale, which conformably overlie the Boll Sandstone. Its known outcrop is a narrow belt in the vicinity of the type locality, Helicopter Springs, ten miles south-west of Texas Downs Homestead. The formation is unconformably overlain by the Fargoo Tillite.

It consists mainly of green and grey micaceous quartz siltstone and some shale, which is laminated or thin-bedded and has a distinctive platy outcrop. Beds of pink or grey fine-grained quartz sandstone, generally between two inches and six inches thick, are rare in the bottom half of the formation, but constitute about 30 percent of the upper part. The Siltstone is capped by a lensing, massive quartz sandstone which has a maximum thickness of about 30 feet.

460 feet of the formation was measured near Fargoo Creek, but the section is not complete and we estimated the total thickness to be about 520 feet.

Ord Group (New Name)

Sediments consisting of tillite, shale, siltstone, and fine-grained sandstone, have been given the name Ord Group. The name is derived from the Ord River, which drains almost the whole of the region mapped, and the type area is the Moonlight Valley of the Osmond Range (Fig. 15). The Group also crops out in the Frank River, and as small remnants southwards along the Albert Edward Range, and northwards along the Halls Creek Fault.

The two basal formations are of glacial origin, and these, the Fargoo Tillite and the more extensive Moonlight Valley Tillite, unconformably overlie rocks as old as Halls Creek Group. The Ranford Formation and its two Members, the Jarrad Sandstone and the Johnny Cake Shale, complete the Group as exposed in the Ord River region. The Albert Edward Group and the Cambrian Antrim Plateau Basalt unconformably overlie the Group.

Fargoo Tillite (New Name)

We have called the tillite at the base of the Ord River Group the Fargoo Tillite. It crops out along Fargoo Creek, and along the south side of Moonlight Valley: the only other exposure known is five miles west of Dixon Range where a very small remnant has been preserved from erosion. The Formation in the type locality unconformably overlies the Helicopter Siltstone and the Blackfella Sandstone, and is overlain with slight angular unconformity by the Moonlight Valley Tillite.

Outcrops of the tillite are rare and the formation generally forms low rounded ridges covered by resistant components which have weathered out of the Tillite. Where a considerable area of tillite is exposed, it has a distinctive dendritic drainage pattern which can generally be recognized on the air photographs.

The Formation consists of basal tillite overlain by up to 200 feet of quartz sandstone. The following section was measured 4½ miles south-south-east of Texas Downs Homestead:

Moonlight Valley Tillite

------ probable angular unconformity ------

200 feet	Massive beds six feet thick of medium-grained cream to greenish-grey quartz sandstone which contains thin partings of green siltstone.
25 feet	About two thirds of massive grey stiff clay, containing beds of quartz sandstone up to 2 feet thick, with load casts at the base. Rolled and slumped dolomitic sandstone lenses.

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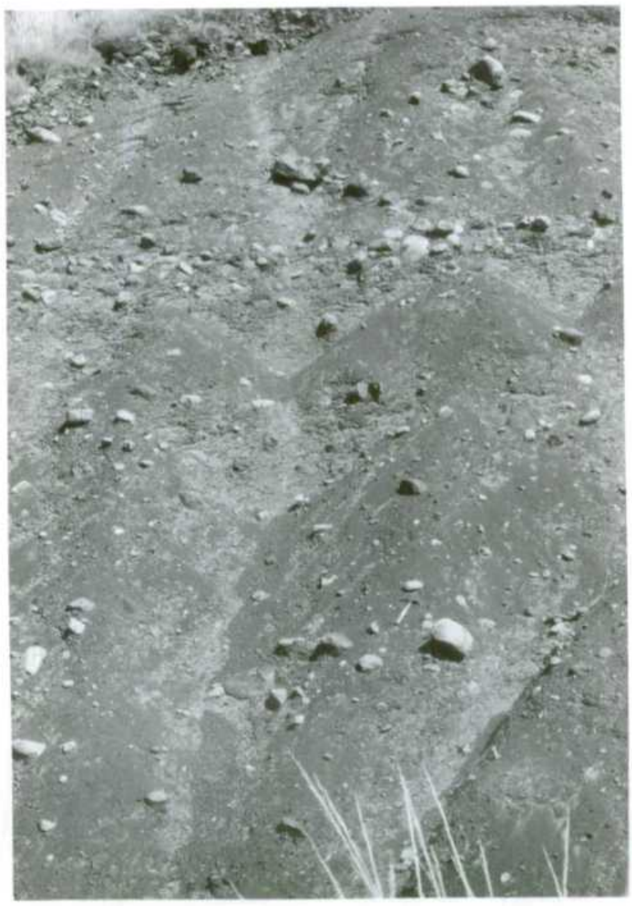

Figure 16: Fargoo Tillite exposed in far side of a steep gully 4 miles south of Texas Downs Homestead. The Hammer near the middle gives the scale. (G6073).

Figure 17 : Closeup of tillite shown in Figure 16 above. Completely unsorted nature of the deposit can be seen. (G6060)

15 feet	Thin-bedded grey shale containing rare, rounded pebbles of quartz and quartzite.
50 feet	Grey clay containing scattered, rounded, pebbles, and rolled and slumped dolomitic beds, and concretionary masses of dolomite (Fig. 16).
10 feet	Lenses of quartzite pebble conglomerate, consisting of well-rounded quartzite pebbles in a dolomitic sandstone matrix.
150 feet	Tillite, consisting of a stiff grey to green clay containing completely unsorted fragments from sandsize up to boulders several feet across (Fig. 17).

- - - - - - - Angular Unconformity - - - - - - -

Helicopter Siltstone.

The tillite ranges in thickness from 150 feet to about 450 feet. The contact with the underlying siltstone was seen only in the type section, where it is sharp and conformable with the bedding of the siltstone over a distance of about ten feet. However, on a larger scale, the siltstone beds are seen to be at an angle of about 3° to the tillite, and are progressively truncated by the tillite. Farther east, the siltstone is missing and the tillite rests on the Boll Sandstone. In this locality there is a lens of thin-bedded dolomite and cross-bedded medium-grained dolomitic sandstone over a mile long at the base of the tillite. The sandstone grades into pebble and cobble conglomerate, which consists of well-rounded fragments of grey limestone, chalcedony, quartz, agate,and a variety of material derived from the Lamboo Complex, set in a matrix of dolomitic quartz sandstone.

The tillite consists of about 90% stiff grey siltstone and clay in which are scattered completely unsorted fragments from sand size to boulders eighteen feet in diameter. The clay matrix is calcareous in some places and in this case the pebbles and boulders have a calcareous coating up to 1/16 inch thick. The deposit is invariably massive, and the only sign of possible bedding is rare concentrations of boulders in zones parallel to the bedding of the overlying sediments. Most of the larger components are well-rounded and many are roughly ovoid in shape: the flattened ovoid shape seen in Figures 16 & 17 is characteristic of the larger boulders. Polished and striated boulders are not common except in restricted localities, and though references to the faceted pebbled are common in literature on Australian tillites, no genuine faceted pebbles were seen. Fragments which have had a broken face striated by later abrasion could be mistaken for faceted pebbles, but even these are rare.

Quartzite, yellow dlomite, and grey limestone are the most common rock types found in the tillite, but almost every rock-type from the

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Lamboo Complex, the Halls Creek Group, and the Osmond Range succession is represented. Angular fragments of chert, chalcedony, and agate are seldom seen in good exposures of the Tillite, but they constitute a large proportion of the surface rubble. Judging by the great number of chips and half-formed spear heads composed of this material, Aborigines used the tillite as a source of chert for spear heads for many years.

Boulders are rare towards the top of the tillite and are succeeded by lenses, up to 30 feet long and 6 feet thick, of dolomite, dolomitic sandstone, and pebble conglomerate. Most of these lenses had slumped before consolidation and in the extreme case they consist of rolled masses of dolomite and dolomitic sandstone as shown in Figure 18. Sandstone overlying the tillite varies laterally in lithology and thickness. In the type section the sandstone is cream to greenish-grey and consists of well-rounded and well-sorted quartz sand and a small amount of argillaceous matrix. It occurs as regular six-foot thick beds separated by thin partings of greenish-grey siltstone. To the east the sandstone is cleaner and is laminated and thin-bedded, while to the west it is ferruginous and has a more argillaceous matrix. The sandstone varies greatly in thickness and in places it is absent. This irregularity could be an original sedimentary feature, but is more probably the result of warping and erosion before deposition of the Moonlight Valley Tillite.

The large proportion of rocks from the Lamboo Complex and the Osmond Range Group found in the tillite shows that the provenance was to the west and south.

Five miles west of Dixon Range, boulder conglomerate which crops out below the Moonlight Valley Tillite is probably a correlative of the Fargoo Tillite. The following sequence was measured:

Moonlight Valley Tillite
- - - - - - - - - - - - - - - - - - - -

Thickness in feet	Lithology
100 feet	Purple argillaceous quartz sandstone beds up to 2 feet thick containing thin shale and siltstone interbeds.
20 feet	Dark brown laminated and cross-bedded fine-grained dolomitic sandstone.
30-40feet	Boulder conglomerate consisting of well-rounded boulders of quartz, quartzite, dolomite and chert, rarely polished and striated, in a matrix of dolomitic sandstone. Lenses of dolomitic conglomerate.

Figure 18: Part of a large mass of rolled and slumped dolomite in upper part of Fargoo Tillite 4 miles south of Texas Downs Homestead (G6067)

Figure 19: Well-rounded and striated boulder of quartzite which has weathered from the Moonlight Valley Tillite 3 miles north-west of J41 locality. (G6054)

Flattened ellipsoidal shape is characteristic of the larger boulders in the Tillite.

Figure 20: Sunlight reflecting off a highly polished cobble from the Moonlight Valley Tillite in the J41 locality (G6206)

Figure 21: Grooved and striated bedrock of micaceous quartz sandstone one mile northwest of J41 Trig. Moonlight Valley Tillite can be seen resting on the pavement in top right hand corner of the photograph (G6217)

Figure 22: Closeup of Figure 21 (G6205)

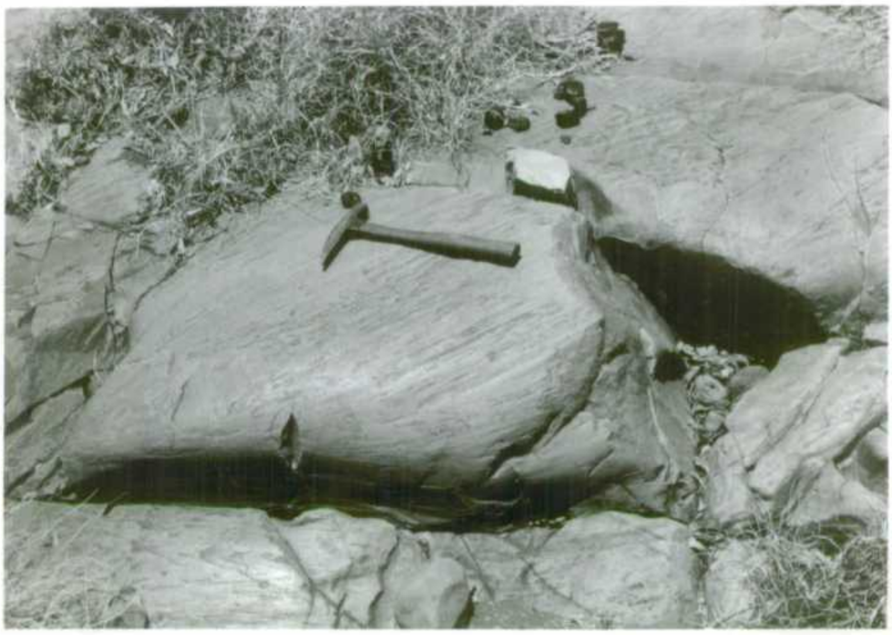

Figure 23: Polished and striated quartzite bedrock half a mile south-west of J41 Trig. The ice moved from the bottom left hand corner of the photograph towards the top right hand corner. Some of the abrupt steps in the glaciated surface have been caused by blocks breaking out recently but many are undoubtedly the result of glacial plucking. (G6218)

Thickness in feet	Lithology
10 feet	Medium-grained, well-sorted quartz sandstone, almost friable.

- - - - - - - -Angular Unconformity - - - - - -

Olympio Creek Formation

Moonlight Valley Tillite : (New Name)

Moonlight Valley Tillite is the name given to the upper tillite of the Ord River Group: in the type locality it rests unconformably on Fargoo Tillite, but farther afield it rests on rocks as old as Halls Creek Group. It is conformably overlain by the Jarrad Sandstone. The type locality is Moonlight Valley south of Texas Downs Homestead, where the formation is well exposed.

The Moonlight Valley Tillite is best developed on the northern and eastern flanks of the Osmond Range and in the Frank River. Small remnants are preserved along the Albert Edward Range at least as far south as Palm Springs, and northwards along the Halls Creek Fault to Argyle Downs Homestead. It is poorly exposed but it is a useful marker bed because it can be traced by the distinctive boulders weathering from it.

The Moonlight Valley Tillite is almost indistinguishable from the Fargoo Tillite, but it can be recognized in the field by its stratigraphical position and by a thin dolomite band which almost invariably caps it. In contrast to the Fargoo Tillite, few older Precambrian rocks are found in the Moonlight Valley Tillite; most of the components larger than pebble size are quartzite and, less commonly, dolomite. They are all well rounded and commonly striated and polished (Figs. 19,20), but in general they are not as big as those in the lower tillite: the largest seen was eight feet in diameter.

The formation is thinner than the Fargoo Tillite, but it is much more extensive. It was deposited on a surface which had a relief of at least 100 feet, and the tillite reaches its maximum thickness of about 450 feet where it was deposited in hollows. It thins or cuts out over rises in the basement, but the capping dolomite generally continues unbroken. Southwards along the Albert Edward Range these basement ridges were apparently more extensive, and the Tillite occurs as thin discontinuous lenses.

Large patches of dolomite conglomerate up to one mile across and 20 feet thick are common at the base of the Moonlight Valley Tillite in the Frank River. Similar conglomerate was also seen near the mouth of Wade Creek and in the J41 locality. The conglomerate consists of well-rounded pebbles and cobbles of dolomite and subangular pebbles of quartz 98 set in a calcareous sandstone matrix. The quartz grains of the matrix are generally angular or sub-angular. An unusual rock, in which the cobbles of dolomite are nearly spherical and roughly the same size was noted in the J41 and Wade Creek localities.

The capping dolomite, though only 6 feet to 12 feet thick, is a distinctive and very persistent indicator of the Tillite. It is pink or rarely yellow, and is invariably laminated or thin-bedded. The laminae in places are less than 1/10th of an inch thick and are very regular, and they are possibly varves.

Glaciated pavement is exposed in the J41 locality. Areas of up to 250 square feet are exposed over a distance of about one mile, where they have been recently exhumed from under the tillite. The pavement is quartzite and indurated micaceous sandstone which has been polished, grooved, striated, and plucked (Figs. 21,22,23). Some poorly preserved rounded forms up to six feet long and 2 feet high could be small roches moutonnées. These features show that the ice came from the north-east, and as no older Precambrian rocks are known closer than the Katherine-Darwin region, this probably explains the lack of metamorphic and igneous rocks in the Moonlight Valley Tillite.

Discussion:

The Fargoo and Moonlight Valley Tillites were formed as a result of widespread glaciation in late Upper Proterozoic time. The characteristic features of the tillites such as the completely unsorted nature of the deposits, the range in the size of the components from clay to boulders 15 feet across, the variety of rock types present, the polished and striated boulders, and the polished, grooved and striated quartzite bedrock, in our opinion can only be explained by glacial processes.

The large degree of rounding exhibited by most of the components of the Tillites and the apparent lack of faceted pebbles calls for comment. Von Engeln (1930) held that the end product of glacial abrasion of cobbles was a faceted flatiron shape, and Guppy et al. (1958) state that faceted boulders are common in the Walsh Tillite, which crops out in the West Kimberley region. However, recent work by Holmes (1960), who examined over 3000 pebbles and cobbles taken from Pleistocene till in New York State, has shown that faceting is rare, and that the end product of glacial abrasion of pebbles and cobbles is an ovoid shape. Our observations support his findings and it seems that many of the components of the Fargoo and Moonlight Valley Tillites were transported for considerable distances, and rounded in the process.

No trace of bedding other than the concentrations of boulders mentioned previously, nor other features indicating subaqueous deposition, were seen in either of the tillites, and they were probably laid down 99 under extensive ice caps as true till. However, the Fargoo Tillite grades upwards into massive, structureless clay which contains lenses of conglomerate and dolomite. This suggests that, despite their lack of bedding and sorting, the tillites could have been deposited under water, possibly in a quiet marine environment into which the constituents were dumped by floating ice.

Ranford Formation (New Name)

The sediments conformably overlying the Moonlight Valley Tillite have been called the Ranford Formation. The type locality is the Moonlight Valley, but the name is derived from Mount Ranford, which is in the catchment area of the Frank River. The type section was measured between Killarney Yard and Texas Downs Homestead, where it was found possible to map two members, the Jarrad Sandstone and the Johnny Cake Shale Members. The formation is best developed along the Moonlight Valley, in the Frank River, and near Lissadell and Argyle Downs Homesteads. It was mapped along the Albert Edward Range as the Duerdin Shale by Smith (1963), and its irregular thickness in this area is caused by an unconformity at the base of the overlying Albert Edward Group.

The following section was measured by Abney level near Killarney Yard:

Antrim Plateau Volcanics

------ Unconformity --------

Thickness	
1050 feet	Laminated and thin-bedded micaceous quartz siltstone, containing thin interbeds of resistant very fine-grained quartz sandstone which commonly have load castes at their base. Colour, dull khaki-green yellow and brown. Rare 2 foot-thick beds of white shale.
600 feet	Johnny Cake Shale Member: Green and reddish-purple banded shale, thin-bedded or laminated. In places gypsiferous and rarely dolomitic. Rare thin beds of fine-grained micaceous quartz sandstone and siltstone, all having load casts at their base.
210 feet	Jarrad Sandstone Member: Red-brown ferruginous quartz sandstone, medium-grained, consisting of well-rounded quartz grains in a ferruginous silty matrix. Medium-bedded.

------- conformable contact ---------

Moonlight Valley Tillite

The type locality for the Jarrad Sandstone Member is prominent cuesta between Fargoo Creek and the Moonlight Bore: the name is derived from Mount Jarrad near Texas Downs Homestead. The Member was mapped only in the Moonlight Valley and at Mount Brooking, towards north of the map area.

The only known area of outcrop of the Johnny Cake Shale Member is the Moonlight Valley, though it could be present in other localities, such as the Frank River, but not be recognized because of poor exposures.

South of the Frank River, only incomplete remnants of the Jarrad Formation are preserved beneath the Forster Sandstone. The sediments in this area are coarser-grained and consist of fine-grained micaceous quartz sandstone beds up to 2 feet thick, almost invariably with load-casts at their base, interbedded with micaceous quartz siltstone and shale.

At Mount Brooking, 70 miles south-east of Wyndham, fossil jellyfish have been found in the Ranford Formation (Dunnet, in prep.). The fossils are well preserved and very abundant in the fine-grained rocks capping Mount Brooking and the surrounding hills. Some of the forms are similar to the Ediacara fauna of South Australia (Sprigg, 1949), but some new forms are also present (A.A. Öpik, pers. comm.).

The sequence in this area differs slightly from the type section of the Ord Group and is given below:

Thickness in feet	Lithology	Formation
150	Laminated and thin-bedded siltstone and fine-grained micaceous quartz sandstone. 'Jellyfish' in upper part, 'Zebra-Stone' in lower part.	Ranford Formation
10-30	Red-brown ferruginous fine-grained quartz greywacke.	
200	White to mauve claystone, siltstone, shale, some micaceous siltstone, and fine-grained kaolinitic sandstone.	Johnny Cake Shale Member
350	Massive, red-brown ferruginous quartz greywacke which has a large amount of silt matrix containing plentiful mud pellets.	Jarrad Sandstone Member
2-10	Laminated pink dolomite	Moonlight Valley Tillite
150	Tillite	

In this area the famous 'Zebra-Stone' or 'Ribbon-Stone' of Argyle Downs is found about 100 feet below the 'jellyfish'. It consists of a white siltstone or claystone with abundant red or purple laminae, rods or ellipsoidal structures within it. Apart from their colour they are indistinguishable from the enclosing white siltstone and the coloration is probably due to some type of leaching (Hobson, 1930). The 'Zebra-Stone' has been described by Larcombe (1926), Blatchford (1927), and Hobson (1930).

V. M. Bofinger has made preliminary rubidium-strontium age determination of the Johnny Cake Shale Member from a sample taken from near the Moonlight Bore. He gives the age tentatively as 680 million years or late Upper Proterozoic, which agrees with the field relationships.

Correlatives: Harms (1959) who first found the tillite in the Ord River Region, correlated it with the Walsh Tillite. He also correlated the overlying Ranford Formation in the Moonlight Valley with the Mount House Beds of Guppy et al. (1958). We do not know whether the Walsh Tillite is a correlative of the Fargoo or Moonlight Valley Tillites, and as descriptions of the Mount House Beds by Harms and Guppy et al. are sketchy, we have given the Ord River sediments separate formation names, but we expect that detailed mapping which is projected for 1964 in the Mount House area will allow correlation of the formations.

Albert Edward Group

The Albert Edward Group was named by Smith (1963), to include all the rocks of the Albert Edward Range which unconformably overlie Lower Proterozoic Halls Creek Group. We have defined the Group to include those Upper Proterozoic sediments in the Albert Edward Range which unconformably overlie the Ord Group, and are unconformably overlain by the Antrim Plateau Volcanics. The Group crops out along the eastern side of the Albert Edward Range, and extends northwards as far as Bungle Bungle Outcamp. The only other exposure known is a thin remnant of the basal sandstone between Turkey Creek and the Bow River, but it seems likely that the Victoria River Group of Traves (1955) contains some sediments of the Albert Edward Group.

The Group comprises six formations named by Smith (op.cit): Mount Forster Sandstone, Elvire Formation, Boonall Dolomite, Timperley Shale, Nyuless Sandstone, and Flat Rock Formation.

Forster Sandstone

Forster Sandstone was named after Mount Forster, twelve miles south-west of the Hardman Range, and the type locality is the gorge of Brim Creek. The formation crops out along the Albert Edward Range and extends as far north as Bungle Bungle Outcamp: a small exposure of sandstone overlying the Ord Group south of the Camel Yard crossing of the Bow River is also referred to the Forster Sandstone.

The Sandstone overlies, probably unconformably, the Ord River Group

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and is conformably overlain by the Elvire Formation.

The Forster Sandstone is predominantly fine-grained to coarse-grained indurated quartz sandstone; it is generally cross-bedded and consists of well-rounded well-sorted quartz grains and a small amount of fine siliceous matrix. Throughout the sandstone there are lenses of fine-grained quartz conglomerate, and south of the Panton River there is a basal marker bed which consists of black and brown rounded fragments of quartz between coarse sand and pebble size, in quartz sandstone matrix. Near the top of the formation there are thin beds of siltstone and shale.

The formation was measured at Brim Creek, where it is 320 feet thick.

Elvire Formation

The type-section of the Elvire Formation is at Brim Creek, a tributary of the Elvire River. The Formation lies conformably between the Forster Sandstone and the Boonall Dolomite, and it crops out along the Albert Range as far north as the Dixon Range.

It consists of chocolate shale and green siltstone beds which are generally less than two inches thick. There are rare beds of medium-grained quartz sandstone throughout the unit. The boundary with the overlying Boonall Dolomite is gradational and the Elvire Formation generally has interbedded dolomite near the top.

The formation is 200 feet thick at Brim Creek.

Boonall Dolomite

Boonall Dolomite takes its name from Boonall Yard, 26 miles north-east of Flora Valley Homestead: the type section is at Brim Creek. The Dolomite lies conformably between the Elvire Formation and the Timperley Shale and crops out along the Albert Edward Range between Beaudesert Bore and Dixon Range.

The Dolomite is fine-grained and light grey or yellow; it is coarsely flaggy and rarely contains algal structures. In places, such as north of Beaudesert Bore, it contains dolomitic breccia, and north of the Panton River it consists mainly of dolomitic sandstone.

The Boonall Dolomite is 100 feet thick in the type section.

Timperley Shale

The Timperley Shale constitutes over half the thickness of the Albert Edward Group, and it takes its name from Mount Timperley, ten miles south of Flora Valley Homestead. The type section is immediately south-east of Mount Timperley. The formation crops out poorly, but it can be traced as scattered exposures along the Albert Edward Range as far north as

Dixon Range.

It consists of massive grey and green shale which weathers brown, and minor siltstone, fine-grained sandstone, and dolomite. The sandstone and dolomite occur near the top and bottom of the unit, and are rare in the middle. The Timperley Shale is 4150 feet thick.

Nyuless Sandstone

Nyuless Sandstone takes its name from the type locality, Nyuless Creek, ten miles east-north-east of Flora Valley Homestead. It forms a resistant strike redge east of Flora Valley Homestead between the Ten Mile Yard and the Blue Yard.

It is about 125 feet thick and consists of coarsely flaggy thin-bedded white to grey medium-grained quartz sandstone, and flaggy friable green feldspathic sandstone.

Flat Rock Formation

The Flat Rock Formation is named after Flat Rock Yard, 12 miles south-south-east Flora Valley Homestead. The unit crops out extensively south-east of Flora Valley.

The Formation consists of ferruginous dolomitic sandstone and ferruginous sandstone, interbedded with readily weathering shale and ferruginous shale. The sandstones are resistant and the formation is characterized by a surface rubble of loose flat sandstone plates.

The Formation is unconformably overlain by the Antrim Plateau Basalt, and nowhere is a complete section found. The greatest thickness measured is 1000 feet.

Gardiner Beds

Gardiner Beds were named by Casey & Wells (1960). The type locality is the Gardiner Range south of the map area, where the beds are 5000 feet thick and consist of basal boulder and pebble conglomerate overlain by quartz sandstone and shale. Cross-bedding and ripple marks are common, and laminated pink and cream dolomite is present in a few localities.

In the map area the Gardiner Beds crop out around Gordon Downs Homestead, and in the Headwaters of Sturt Creek. They unconformably overlie Tickalara Metamorphics, and consist of fine to coarse-grained, thin-bedded and cross-bedded quartz sandstone, and minor ferruginous sandstone and pebble conglomerate. The Beds are probably lateral equivalents of the younger Proterozoic rocks of the Albert Edward Range, but exposed sections are generally too small and the mapping of the beds has not been done in sufficient detail to allow correlation.

TABLE 3

SUMMARY OF PALAEOZOIC STRATIGRAPHY, ORD RIVER REGION

AGE	NAME OF UNIT: Matheson and Teichert (1945)	NAME OF UNIT: Traves (1955)		NAME OF UNIT: This Report		LITHOLOGY	FOSSILS
?DEVONIAN	ELDER SERIES	ELDER SANDSTONE		BUCHANAN SANDSTONE		White and pink cavernous sandstone, basal quartz conglomerate in places	
				Unconformity			
LOWER MIDDLE CAMBRIAN		Negri Group	Hudson Shale	Negri Group	ELDER FORMATION	Ferruginous micaceous sandstone and subordinate red siltstone. Rare flaggy limestone.	Fossil "jellyfish" *Biconuletes hardmani*
	Negri Series		Corby Limestone Negri River Shale Shady Camp Lmst. Panton Shale		PANTON FORMATION	Interbedded grey shale, siltstone, and subordinate limestone	*Girvanella* sp., *B. hardmani*, *Redlichia* sp., *Xystridura* sp. *Wimanella* sp., *Billingsella* cf. *humboldti*
			Linnekar Limestone		Linnekar Limestone	Limestone and marl.	*Redlichia forresti*, *B. hardmani*, *Girvanella* sp.
			Nelson Shale		Nelson Shale	Shale and siltstone, partly gypsiferous and calcareous rare thin limestone beds	
			Headleys Limestone		Headleys Limestone	fine-grained grey limestone	
				Possible unconformity			
PROBABLE LOWER CAMBRIAN	Basaltic Rocks	ANTRIM PLATEAU VOLCANICS		ANTRIM PLATEAU BASALT		tholeiitic basalt, minor basalt agglomerate, andesite, and some dolerite.	

PALAEOZOIC

CAMBRIAN

Antrim Plateau Volcanics

Hardman (1885) first named the large area of basaltic volcanics west of the Ord River the Great Antrim Plateau, after the Antrim Plateau of Ireland, and therefore by inference named the basalt. David (1932) first used the name Antrim Plateau Basalts, but this was changed by Traves (1955) to Antrim Plateau Volcanics, because the unit includes tuff and agglomerate.

The Volcanics crop out over much of the eastern half of the area and unconformably overlie Upper Proterozoic Albert Edward Group and are overlain, possibly unconformably, by Cambrian Headleys Limestone.

The formation consists of basalt lava flows and rare, thin, beds of basalt agglomerate. The following section of the Volcanics was measured near Bungle Bungle Outcamp:

Headleys Limestone

- - - - - - - -Apparently conformable contact - - - - - - - -

Thickness in feet	
200	fine-grained greenish basalt
200	amygdaloidal basalt
400	purple vesicular basalt breccia
280	purplish, green non-vesicular basalt
265	amygdaloidal basalt
- - - - - - - soil	profile - - - - - - - - - - - - - - -
150	olivine basalt
320	purplish-grey basalt
170	green basalt
110	very vesicular basalt
210	grey basalt
110	medium-grained purplish-green pyroxene basalt
250	purple scoriaceous basalt
30	purple basalt with chilled margins
- - - - - - -?soil	profile - - - - - - - - - - - - - -
75	purple vesicular basalt
310	purplish-green basalt
200	purplish-grey vesicular basalt containing many green zeolites
Total 3280	Bottom not seen

The Antrim Plateau Volcanics consists mainly of parallel basalt lava flows, mostly less than 100 feet thick, many of which can be traced in escarpments for several miles. Vesicular basalt makes up about 30 percent of the unit, and the vesicles are mostly lined or filled with agate,

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chalcedony, calcite, or green fibrous zeolite. Geodes up to two feet in diameter containing linings of amethyst quartz one to three inches across were found in the basalt near Bungle Bungle Outcamp, but they are rare.

Edwards & Clarke (1940) described 21 specimens of basalt of the Antrim Plateau Volcanics from widely scattered localities in the Ord River Region. They conclude that the basalts form a homogeneous petrographic province, and that they are intermediate between undersaturated olivine basalt magmas and typical oversaturated tholeiitic magmas. However, they state that the affinities of the basalts are with the tholeiitic magma type.

Thin sections of six specimens of Antrim Plateau Volcanics collected during the present survey were examined by D. Gellatly. Three of these are classed as tholeiitic basalt, one of which contains rare serpentine pseudomorphs of olivine. The clinopyroxene appears to be mostly pigeonitic, but no optic axial angles were measured to confirm this. The other three are classed as quartz andesite on the composition of the plagioclase, which is in the andesine range. However the rocks are similar in other respects to the tholeiitic basalts, and the feldspar may have been deuterically altered. In one thin section, the feldspar varies in composition, and the unaltered grains are apparently more calcic than the altered ones.

Agglomerate is a minor constituent of the succession in the map area. Only one band of agglomerate was seen in the basalt, in a creek 11 miles north-north-west of Turner Homestead. It is about 30 feet thick and consists of sub-rounded fragments of vesicular (almost scoriaceous) basalt up to eight inches across in a highly indurated basaltic matrix. The andesite breccia near the top of the measured section at Bungle Bungle Outcamp is probably a volcanic breccia, though it could possibly be a weathering feature.

Quartz grains of probable aeolian origin make up the bulk of a sandstone found at the base of the Volcanics about 300 yards north of the Horse Creek Well in the Moonlight Valley. The rock is friable, and consists of rounded spherical or ovoid grains of quartz and chert which generally have a thin ferruginous coating. The grains are remarkably well sorted, and are all about 0.08 mm in diameter: most appear to be frosted and they have probably been rounded by wind action. However, the rock is regularly bedded, and contains thin beds of finer material, and it was probably deposited in a lacustrine environment.

The thickness of the Volcanics was measured in three places: north-north-west of Turner Homestead it is 3200 feet, near Bungle Bungle Outcamp it is at least 3280 feet, and near Mount Pitt it is approximately 2800 feet. Soil profiles in the measured section near Bungle Bungle Outcamp indicate that there may have been three distinct periods of basalt outpouring, and that the formation was probably extruded over a considerable period of time. On the western side of the Hardman Basin, the basalt

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immediately beneath Headleys Limestone is in places highly ferruginous to a depth of 20 feet. Thus, though the contact between the two units appears to be conformable (Harms 1959; Traves 1955), this ferruginous layer may be the result of a long period of weathering before Headleys Limestone was deposited.

The basalt was extruded either at the end of the Proterozoic Era, or early in Cambrian times, because the basalt lies unconformably between the Albert Edward Group, which is considerably younger than 600 million years (the age of shale in the underlying Ord Group), and the basal Negri Group, which is lower Middle Cambrian.

In three separate areas Cambrian sediments have been downfolded into the Antrim Plateau Volcanics: these structural basins were called by Matheson & Teichert (1948) the Hardman, Rosewood, and Argyle Basins. The sediments are mostly shale and marl which are easily eroded, and they characteristically form open rolling country which generally has a veneer of fertile black soil. The resistant limestone and sandstone beds form prominent mesas and cuestas.

The sediments were first named by Mahony (1922), who divided them into two Series, the Negri Series and the Mount Elder Series, names which were later used by Matheson & Teichert. Traves (1955) subdivided the Negri Series into eight formations, and changed the name to Negri Group to conform to the Australian Code of Stratigraphic Nomenclature. He included in the Negri Group the lowermost part of the Elder Series of Matheson & Teichert, and named the rest of the Elder Series the Elder Sandstone (Table 3).

We have included the lower part of the Elder Sandstone in the Negri Group because we found that the upper part, now called the Buchanan Sandstone, rests unconformably on the lower part, and is probably of Devonian age.

Negri Group

The Negri Group takes its name from the Negri River, a tributary of the Ord River. The type locality is the Mount Panton - White Mountain area in the north-eastern part of the Hardman Basin. The Group occurs in the Hardman, Rosewood, and Argyle Basins, but in the latter two, only the resistant limestone units crop out, and the shale units are known only from rare, small, exposures in creek beds. Of Traves' eight formations which are the Corby and Shady Camp Limestones are thin and discontinuous and cannot be recognised away from the type area; and the Negri River and Panton Shales are alike, and in the absence of the two limestone beds cannot be distinguished. Hence we have combined the four formations into one unit, which we have called the Panton Formation.

Traves placed the transitional beds at the base of the Elder Series in the Negri Group, and called them the Hudson Shale. He renamed the overlying unit the Elder Sandstone (Table 3).

There is an unconformity within his Elder Sandstone, therefore we have called the upper part of the unit, which is probably Devonian, Buchanan Sandstone. We have combined the lower part with the Judson Shale of Traves, and have called the new unit the Elder Formation, thus following, to a large extent, the original definition of Matheson & Teichert.

Headleys Limestone

Headleys Limestone was named by Traves (1955) after Headleys Knob, 11 miles south-east of Ord River Homestead. The Formation consists of fine-grained grey limestone and is defined as the limestone which overlies the Antrim Plateau Volcanics, and is overlain conformably by the Nelson Shale.

The limestone is resistant to weathering, and where it is gently dipping, it forms cuestas which in places on the south side of the Hardman Basin have an almost impenetrable karst topography. On the western and northern sides of the Hardman and Rosewood Basins the Limestone is nearly vertical, and forms parallel-sided 'walls' up to 50 feet high.

The four sections measured on the western side of the Hardman Basin were similar and consist of 30 feet of massive, fine-grained grey limestone containing chert nodules, overlain by 120 feet of laminated and thin-bedded fine-grained grey limestone. Algal domes between two and four inches across are common in the upper parts of the Limestone, but are rare in the lower part. Beds of two-tone limestone were seen in the lower part: these are composed of fine-grained grey limestone containing blebs, lenses, and thin beds of yellow dolomitic limestone.

The Limestone varies little in thickness and lithology throughout the Ord River Region. It is between 120 feet and 180 feet thick and invariably is more massive and contains chert nodules near the base.

Contacts with the underlying Antrim Plateau Volcanics were seen only on the western and northern margins of the Hardman Basin. In most places the basalt has been ferruginized and silicified for 20 feet below the contact with the Limestone, and this is taken as evidence of a period of weathering and possibly erosion before the deposition of the Headleys Limestone. No fossils have been found in Headleys Limestone, but its stratigraphical position suggests a Lower Cambrian or early Middle Cambrian age.

Nelson Shale

The Nelson Shale, named by Traves after Nelson Creek, 26 miles west-north-west of Ord River Homestead, is the shale unit which lies conformably between Headleys Limestone and Linnekar Limestone. The formation weathers readily, and forms rolling blacksoil plains. It occurs throughout the Hardman Basin, but exposures are confined to rare isolated

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outcrops in creek beds, and no sections are completely exposed. We have assumed that the shale also occurs in the Rosewood and Argyle Basins, but we found no outcrops. Matheson & Teichert measured 525 feet of calcareous shale south of the junction of the Ord and Negri Rivers, but exposures in this area are not good. Probably the most complete section is given by the Okes-Durack Bore, drilled near White Mountain about 1923 (Hobson 1935), the log of which is quoted below:

Log of Okes-Durack Bore

Thickness	Lithology	Formation
7	Reddish brown mudstone	
27	Blue flaggy limestone, with nodular fossils (<u>Girvanella</u>)	Linnekar
24	Blue calcareous shale with thin seams of gypsum and thin bands of hard crystalline limestone and some pyrites. Fossils between 45 and 55 feet.	Limestone
8	Blue to grey limestone with nodular fossils.	
49	Grey, brown, and blue shale, with gypsum and hard streaks.	
140	Brown mudstone with patches of blue crystals of gypsum (looks like flaggy sandstone in places).	
12	Grey shale with patches of blue.	
204	Brown to reddish sandy mudstone with bands of grit, veins of crystalline gypsum and small crystals of pyrites.	Nelson
24	Blue-grey shale.	
139	Brown sandy mudstone, calcareous in places.	Shale
2	Grey limestone, water rose to within 9 feet of the surface.	
21	Brown mudstone.	
6	Thin limestone cap covering hard banded chert	
125	Grey limestone, crystalline, hard and massive. Gas noticeable in sludge. Petroliferous odour. Slightly foetid from presence of sulphur; brecciated chert in lower few feet.	Headleys Limestone
408	Light blue to grey basalt	Antrim Plateau Volcanics.

No fossils have been found in the shale, but as it conformably underlies Linnekar Limestone, it is regarded as lower Middle Cambrian.

Figure 24 : Probable algal growths exposed near the Elvire - Ord River junction in Cambrian Linnekar Limestone. (G6072)

Linnekar Limestone

Traves defined the Linnekar Limestone as the limestone which lies conformably between the Nelson Shale and the Panton Shale. The Limestone is slightly more resistant to erosion than the shales, and forms low cuestas around the southern and eastern parts of the Hardman Basin. On the western and northern margins of the Basin it dips more steeply, and is generally covered by soil or alluvium, but we found sufficient outcrop to prove that the formation continues around the Basin. It also crops out around the Rosewood and Argyle Basins, although poorly.

Linnekar Limestone consists of 10 to 20 feet of medium-bedded grey limestone overlain by 50 to 60 feet of thin-bedded grey or brown fine-grained limestone containing thin marl interbeds. Ripple marks are common near the top of the formation. Six sections of the formation have been measured in the Hardman Basin and these vary little in lithology or thickness. The maximum thickness measured was 130 feet in an excellent exposure west of the Dixon Range, but in other localities the formation is between 50 and 70 feet thick (Traves). Exposures of the Limestone in the Rosewood and Argyle Basins are poor, but the formation appears to be almost identical with that of the Hardman Basin.

The formation is richly fossiliferous in places (Pl. 1), particularly near its top. Abundant Redlichia and Biconulites are found where the road joining Ord River and Turner Homesteads crosses Linnekar Creek. The formation is also richly fossiliferous in the Nicholson River, near the mouth of the Negri River, and in the Elvire River three miles upstream from its junction with the Ord River, where algal growths are well exposed (Fig. 24). In the other localities shown on Plate 1 only fragmentary fossils have been found. The fossil assemblage comprises Redlichia forresti, Biconulites hardmani, and Girvanella, which Öpik (in Traves 1955) places in the lower Middle Cambrian.

Panton Formation

The Panton Formation of this report is defined as the shale and subordinate interbedded limestone which overlie the Linnekar Limestone and underlies sandstone of the Elder Formation. In the type locality, the Mount Panton - White Mountain area, the top of the Formation is marked by a massive, resistant limestone bed which is the uppermost limestone of the Negri Group. In the western part of the Hardman Basin, the limestone is absent, and the boundary is arbitrarily placed where regularly bedded sandstone makes its appearance.

Nowhere is a complete section exposed, but we have constructed a composite section from a sequence measured by Matheson & Teichert (1945) at Mount Panton and a section examined in the White Mountain area.

Figure 25 : Fossil "jellyfish" from the Elder Formation. (X5)

Figure 26 : Fossil "jellyfish" from the Elder Formation. (X4).

Thickness in feet	Lithology	
500 approx.	Red and brown shale containing two-feet thick beds of ferruginous fine-grained quartz sandstone	Elder Formation
10	Flaggy Limestone with B. hardmani: copper stained in places.	(Limestone C)
250 approx.	Red and brown shale and siltstone.	
10	Hard massive limestone with Girvanella and B. hardmani	(Limestone B)
16	Grey shale	Panton
12	Flaggy limestone rich in the trilobites Redlichia and Xystridura.	
6	Flaggy limestone with abundant Xystridura	
19	Grey shale with Redlichia and Xystridura	
5	Flaggy limestone	
24	Grey shale	Formation
1	Limestone with B. hardmani, and Wimanella sp.	
20	Grey shale with Redlichia sp.	
10	Massive limestone with Girvanella and B. hardmani	(Limestone A)
135	Red and grey shale	
50	No outcrop	

Linnekar Limestone

Traves correlated his Corby Limestone of the Mount Panton area with limestone B of the above section, but it appears on the air photograph to be continuous in outcrop with limestone C.

South-west of Ord River Homestead limestone beds in the Formation are masked by alluvium of the Ord River. They appear to cut out to the south-west: they were not seen in sections of the Panton Formation examined south and west of Dixon Range. South of Dixon Range a bed of algal limestone 1 foot thick underlying the Elder Sandstone is probably the lateral equivalent of Limestone C. Limestones A and B can be traced around the eastern margin of the Hardman Basin to near the junction of the Negri and Ord Rivers. They could be present on the northern margin of the Basin, but the Panton Formation there is covered by alluvium.

Little is known of the Panton Formation in the Rosewood and Argyle Basins because it is covered by thick soil, and only rare, small, outcrops of shale and siltstone were seen.

The fossil assemblage shows that the Formation is Middle Cambrian.

Elder Formation

The Elder Formation is defined as the predominantly ferruginous sandstone and subordinate siltstone overlying the Panton Formation. It is overlain unconformably by the Buchanan Sandstone. The type section is Hudson Creek on the south-western side of White Mountain.

The Formation is predominantly thin-bedded to medium-bedded brown micaceous sandstone which is commonly cross-bedded and ripple-marked, particularly towards the top of the Formation. The sandstone is mostly ferruginous, and commonly contains beds between two inches and eight inches thick, of high iron content, estimated as approaching iron ore grade. Siltstone and shale which are generally grey or red, laminated and micaceous, constitute about 20 percent of the Formation. The Formation is at least 500 feet thick.

The only fossils known in the Formation are probable jellyfish collected four miles north-north-west of the Ord-Elvire junction. Two types, are found one of which, (Fig. 25, 26) is almost identical with one of the 'jellyfish' collected from the Upper Proterozoic Ranford Formation near Mount Brooking (Dunnet, in prep.). The specimen illustrated in Figure 25 is smaller than average, and most of the individuals collected are between one and two and a half inches across.

The Elder Formation conformably overlies the Panton Formation, and is therefore probably Middle Cambrian also.

DEVONIAN

Buchanan Sandstone

Buchanan Sandstone is the name given to massive white sandstone which overlies the Elder Sandstone, the name being derived from Buchanan Creek, a tributary of Osmond Creek. The formation crops out in the north-western part of the Hardman Basin between Dixon Range and Buchanan Creek, between the Ord and Negri Rivers, and along the Hardman Range. A small outlier of quartz sandstone 22 miles east-north-east of Flora Valley Homestead is also referred to the Buchanan Sandstone.

The Sandstone forms rugged flat-topped mountain ranges which are bounded by steep cliffs (Fig. 27) closely-spaced joints in some places form deep chasms, or, more commonly, are silicified and stand out as prominent ribs. Scrub-covered plains of residual sand have been formed by erosion of the Sandstone.

Between Dixon Range and Buchanan Creek the Buchanan Sandstone rests unconformably on the Negri Group in Red Rock Creek it overlaps steeply dipping and eroded Headleys Limestone on to Antrim Plateau Volcanics, and on the western margin of the Basin, basal conglomerate rests on an irregular surface eroded on Elder Sandstone.

In the north-eastern part of the Hardman Basin, the unconformity between the Elder Formation and the Buchanan Sandstone cannot be recognized,

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and we have arbitrarily put the boundary where massive cavernous-weathering sandstone becomes predominant.

The basal conglomerate is 40 to 60 feet thick, and consists of cross-bedded quartz sandstone which contains scattered pebbles of quartz and quartzite. The sandstone is generally well-sorted, and is commonly red or pink on weathered surfaces but white when broken. It is massive or cross-bedded and weathers cavernously. Outcrops generally have a hard silicified surface, beneath which the rock is friable. Silicification along vertical or steeply dipping joints is common and can easily be mistaken for steeply-dipping thinly-bedded quartzite. An incomplete section 650 feet thick was measured near Bungle Bungle, but elsewhere the formation appears to be less than 600 feet thick.

No fossils have been found in the Buchanan Sandstone, but it is probably a correlative of the Ragged Range Conglomerate and the Cockatoo Sandstone, both of which are of Devonian age.

Ragged Range Conglomerate

800 feet of red-brown and yellow cross-bedded quartz sandstone and conglomerate with pebbles, cobbles, and boulders of quartzite crop out in the Ragged Range (Fig.7). The top is eroded. Massive conglomerate is the dominant rock in the southern part of the Range; it passes laterally into sandstone in the north. The conglomerate extends eastwards into the valley bordering the southern Carr Boyd Ranges, where it crops out poorly as rises of quartzite boulders weathered out of the conglomerate.

Traves (1955) considered the Conglomerate to be of Cambrian age on the basis of Biconulites limestone immediately below it. During 1963 pelecypods and gastropods were found near the base and 600 feet above the base. These indicate a probable Upper Devonian age (Veevers, pers. comm.) but the fauna has yet to be properly determined. The Conglomerate is probably equivalent to part of the Cockatoo Sandstone (Traves, 1955).

An unconformity has been found between the Conglomerate and the thin basal sequence of sandstone and limestone. Öpik (pers. comm.) has determined a Metaoxidid trilobite and Biconulites from these basal beds and regards their age as probably late Lower Cambrian.

UNDIFFERENTIATED

The north-eastern part of the map area contains a thick sequence of Palaeozoic rocks which were deposited in the Bonaparte Basin. Small outliers extend into the areas of Precambrian rocks. The sediments are richly fossiliferous and have been described by Traves (1955).

These rocks do not come under the scope of this Report as they are the subject of a separate investigation which is in progress (Veevers, Roberts, Kaulback, & Jones, 1964). Rocks of Cambrian, Ordovician, Devonian, Carboniferous, and Permian age have been found to date. The

Figure 27 : Cliffs of Buchanan Sandstone 8 miles south of Bungle Bungle Outcamp. Photo looking north-eastwards. (G6076)

results of the present detailed investigations will be published at a later date by Veevers et al.

CAINOZOIC

TERTIARY

Lawford Beds

The Lawford Beds crop out around Mount Timperley in the centre of the Gordon Downs Sheet area, in isolated outcrops in the Calico Creek area, and west of Douri Dam. The best outcrop is at Mount Timperley, where there is about thirty feet of white, massive, chalcedonic limestone. At the base is a poorly exposed leached, rubbly, white calcareous siltstone. No fossils have been found. Similar chalcedonic limestones occur on the Billiluna Sheet area. The name used there by Wells (1959) has been extended to the Gordon Downs Sheet area since it is probable that, though the limestone is probably freshwater, it formed a continuous deposit.

White Mountain Formation

This Formation consists of chert and subordinate shale, marl, siltstone, and minor quartz sandstone, which caps White Mountain in the north-eastern part of the Dixon Range Sheet area. The sediments have been slightly tilted and buckled, and probably owe their elevated position to post-Tertiary faulting along the faulted monocline which dislocates the Palaeozoic sediments. The Formation is over 350 feet thick in places, and appears to have been laid down in a lacustrine environment on an uneven surface on Palaeozoic rocks.

The chert is fossiliferous and Chapman (1937) has described the following assemblage: Planorbis hardmani, Planorbis cf. essingtonensis, Bullinus sp., and algae, foraminifera, sponges, ostracods, and insect remains. The Formation is probably of Tertiary age, but it could be as old as Cretaceous.

Undifferentiated

Remnants of a lateritized surface, of probable Tertiary age, crop out in the south-eastern part of the map area. Thin terrestial deposits of gravel, quartz sandstone, and siltstone overlie the laterite, and around the headwaters of the Fox River and Duerdin Creek the laterite is underlain by (?)Tertiary siltstone and shale.

UNDIFFERENTIATED

Large areas of the region, especially in the east, are covered by unconsolidated soils and alluvium. Most of these deposits are of Quaternary age, but alluvial and residual black soils may be as old as Tertiary.

Widespread residual black soils have developed on Cambrian rocks along the Ord Valley and smaller deposits occur on basic rocks within the

Lamboo Complex and on the Hart Dolerite.

The large sandstone ranges of the area are commonly flanked by sand and gravel deposits, and thin sand deposits occur on the tops of sandstone plateaux. Sand covers much of the Cambridge Gulf Lowlands in the north.

Residual soils have developed on a variety of rock-types. The most striking example is the widespread arkosic soils developed on the rocks of granitic composition in the Lamboo Complex.

Most of the streams in the area are flanked by deposits of alluvium; these are quite extensive around some of the major streams. The soils of the extensive black-soil plains surrounding the lower reaches of the Ord and Dunham Rivers near Kununurra have been shown to be of undoubted detrital origin (Carroll, 1947). Younger, less extensive deposits, of slightly more sandy alluvium, overlie them.

Evaporites and coastal silt are being deposited on the widespread tidal flats bordering the estuaries of the Pentecost and Ord Rivers.

LAMBOO COMPLEX

INTRODUCTION

The name Lamboo Complex was used by Matheson & Guppy (1949) and defined by Guppy et al. (1958), to include granite, granitic gneiss, and undigested remnants of metasediments. The name derives from Lamboo Homestead, 30 miles south-west of Halls Creek, and though the rocks in the type area are lateritized, and crop out poorly, the name is so well established in literature that we have retained it. Traves (1955) used the name to include all the granitic rocks cropping out in the East Kimberley Region, but excluded the metasediments. We prefer the original definition, and have included in the Lamboo Complex all the associated high-grade metamorphics, orthogneiss and paragneiss, and the basic and acidic plutonic rocks.

The Lamboo Complex forms a belt, nearly 200 miles long and about 30 miles wide, between Mount Dockerell off the map area to the west, and Pompey's Pillar to the north. Farther north the Complex is covered by younger sediments with the exception of inliers of granite which crop out near the Halls Creek Fault. Granite intrusions east of the Halls Creek Fault in the Osmond Range and near Saunders Creek have also been mapped as part of the Lamboo Complex.

The metamorphic rocks of the Lamboo Complex are called Tickalara Metamorphics, and the following rock-types have been recognized: schist, paragneiss, orthogneiss, calc-silicates, amphibolite, and basic granulite. "Gneissic granite" is the name given to strongly foliated granite which has probably been formed by melting of the Tickalara Metamorphics. The grade of metamorphism of the Tickalara Metamorphics increases from moderate green-schist facies in the south to granulite facies in the north.

Figure 28: Ptygmatic folding in migmatite gneiss six miles west of Mabel Downs Homestead. Intracately folded white bands are quartz, darker bands garnet biotite gneiss.

Figure 29: Migmatite gneiss in Tickalara Metamorphics. Photograph taken seven miles west of Mabel Downs Homestead. Light-coloured bands are composed of quartz and feldspar, and the darker bands are mostly biotite, sillimanite and muscovite.

We regard the Tickalara Metamorphics as the more highly metamorphosed equivalent of the Halls Creek Metamorphics.

Intrusive rocks constitute about two thirds of the outcropping Lamboo Complex and comprise the following rock types, listed in probable order of decreasing age: ultrabasic rocks, basic rocks, quartz-feldspar porphyry, and magmatic granites. These units are shown on Plate 1. As relationships between the units are not always clear in the field, the order given is only tentative, and awaits age determination for confirmation. In some areas there is an intimate mixture of granitic, basic, and metamorphic rocks which cannot be subdivided on the scale of mapping done to date. These areas are shown on the Plate 1 as 'mixed zones'.

The rocks of the Lamboo Complex vary greatly in age. The oldest are the Tickalara Metamorphics, which are probably more highly metamorphosed equivalents of the Halls Creek Metamorphics, and the youngest are the magmatic granites, which are unconformably overlain by basal Younger Proterozoic rocks.

Dyke rocks ranging in composition from basic to acid intrude the Complex, but their age is not known.

Tickalara Metamorphics

The metamorphic rocks of the Lamboo Complex are called the Tickalara Metamorphics, after Tickalara Bore in the Dixon Range Sheet area. No type area can be assigned to the unit because the constituent rocks differ greatly throughout the Complex. The Metamorphics constitute about one third of the Complex, and they crop out the length of the Complex in its eastern half. Some irregular roof pendants of metasediments in granite in the western half of the Complex are also referred to the Tickalara Metamorphics.

The formation includes a great variety of metamorphic rocks ranging in grade from low amphibolite facies in the south to granulite in the north. For convenience the rocks have been described below under the following headings: mica schist, paragneiss, orthogneiss, calc-silicates, amphibolite, and basic granulite; but the boundaries between the rock types are gradational and generally impossible to map.

Mica Schist: Medium-grade, regionally metamorphosed mica schist is found interbanded with calc-silicates and amphibolite, on the eastern flank of the Black Rock Anticline, and as a narrow belt northwards along the Halls Creek Fault. The most common rocks are quartz-muscovite schist and quartz-biotite schist, both of which commonly contain abundant porphyroblastic garnet. Chloritoid schist and kyanite schist are present, generally close to the Halls Creek Fault.

Knotted schists occur in the core of the Black Rock Anticline, as a narrow band west of the palingenetic granite between the Ord River and Turkey Creek, and around the McIntosh and Panton Sheets. These schists have a severe crenulation cleavage impressed on them, and contain staurolite

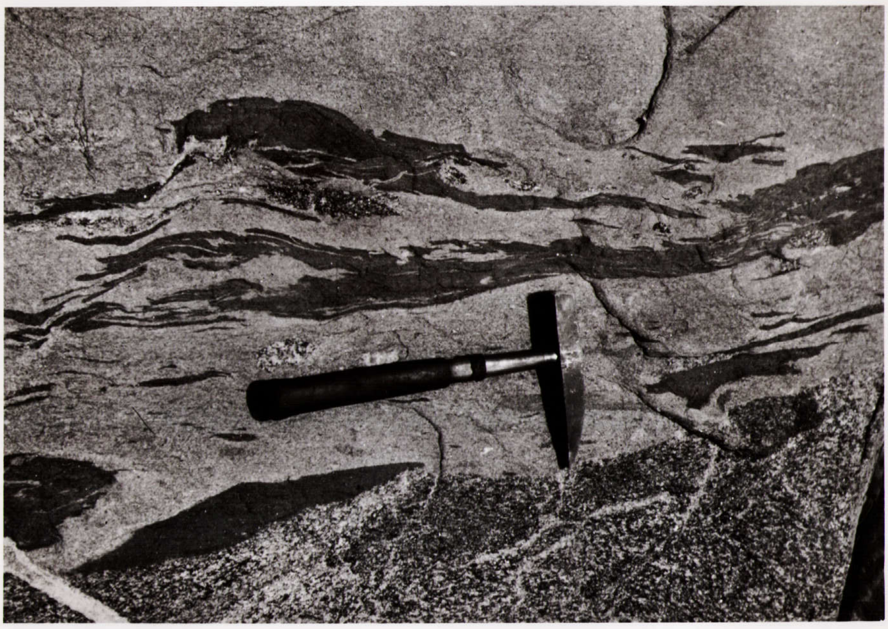

Figure 30: Stringers of basic granulite in fine-grained gneiss. Note sharp contact with coarse-grained gneiss at base.

and sillimanite in addition to the assemblages found in the lower-grade schists. Interbeds and pods of epidote-rich quartzite are present in these rocks.

Paragneiss crops out as a twenty-mile-wide belt, from the Armanda River north-north-eastwards to Bow River on the Lissadell area. Foliated quartz-feldspar-biotite gneiss is the dominant rock type in the lower-grade rocks, and is intercalated with amphibolite and calc-silicates. The gneiss consists of dark layers caused by concentrations of ferromagnesian minerals, generally biotite or hornblende, and commonly garnet. These bands are not continuous and most of them are schlieren strung out parallel to the foliation. The light-coloured layers are granitic in composition and texture, and they are very similar to the late intrusive coarse-grained granite. Thus it is probable that many of the mineral assemblages in these paragneisses have evolved during extensive granite injection into the metasediments.

Between Turkey Creek and Violet Valley the paragneiss is granulitic, and there has been lit-par-lit injection of granitic fluids to produce migmatite (Figs. 28 & 29). These rocks contain garnet, sillimanite, cordierite, and, in rare cases, graphite. The graphite is not derived from calcareous rocks, and is possibly of metasomatic origin.

Orthogneiss extends as a belt from the south-western corner of the map area to near MacKenzies Spring. The rock is leucocratic, generally strongly foliated, and consists of a mosaic of quartz, andesine, and minor amounts of biotite and hornblende. It commonly contains abundant basic xenoliths and lit-par-lit bands of porphyritic granite. It grades into paragneiss, porphyritic granite, and gneissic granite, and in some cases it is difficult to put a boundary between these rocks.

Calc-Silicate Rocks crop out in a north-north-east-trending belt on the eastern half of the Lamboo Complex, between Halls Creek and Mount Pitt in the Lissadell Sheet area. In the south, near Armanda Creek, they occur as relict sedimentary bands or sheared roof pendants within the granitic and basic rocks of the Complex, while to the north they are interfoliated with amphibolite, knotted schist and gneiss. Marble is common, but the predominant rock is composed of diopside, garnet, epidote, and wollastonite or hornblende.

Amphibolites occur throughout the Dixon Range area in association with metasediments of the Tickalara Metamorphics. Some are metamorphosed calcareous sediments and basic lava flows, possibly belonging to the Biscay Formation, but others are metamorphosed intrusives. In the Black Rock Anticline and in the vicinity of the gneissic granite, foliated amphibolite is intercalated with gneiss and calc-silicates. The most

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common assemblages are : hornblende-plagioclase-quartz-epidote-sphene, and hornblende-clino pyroxene-plagioclase-quartz. The grade of the amphibolite increases northwards and the rocks grade into basic granulites.

Basic Granulite forms dark lenses and bands in high-grade paragneiss, which range in length from inches to miles (Fig. 30). In hand specimen they are dark green to black, have a granular texture, and commonly have a rudimentary foliation. They generally consist of plagioclase, clinopyroxene, quartz, and hornblende, but they may contain, in addition, orthopyroxene, garnet, biotite, and cummingtonite.

'Gneissic Granite'

The term 'gneissic granite' embraces a wide variety of acid rocks which may have formed by melting of paragneiss of the Tickalara Metamorphics. Some of the rocks included are:

(1) Foliated, coarse-grained, porphyritic, hornblende-rich granite.
(2) Foliated, medium-grained, biotite-rich granite.
(3) Saccharoidal, medium-grained, gneissic granite containing biotite-rich schlieren.
(4) Migmatite rocks : granite injected into metasediments
(5) Well-foliated, garnet and sillimanite-rich, medium to fine-grained gneiss containing amphibolite bands.

The main body of 'gneissic granite' is lenticular and is ten miles wide and fifty miles long. It extends from the Ord River to the Bow River, parallel to the Halls Creek Fault. A stock (about eight miles by four miles) occurs on the southern side of the Ord River, and is separated from the main mass by a belt of metasediments. Both acid bodies have overall concordant contacts with the metasediments and it is difficult to tell the exact transition from paragneiss to the gneissic granite. Slight discordancy has been noted in two places: a wide marble band is truncated by the main body of granite on the eastern margin, and marble xenoliths are present in the granite. To the south amphibolites are intruded and incorporated in the smaller mass of granite.

Another variety of the 'gneissic granite' is represented by the orthopyroxene-rich granites ('charnockite') present in the northern part of the Lamboo Complex. These are best developed in the Lissadell area, but the granite body north of Mabel Downs Homestead is of this type. They are brown to dark blue, are rarely foliated and have a vitreous lustre. They are composed of andesine, microcline, orthopyroxene, minor biotite, and amphibole, and accessory apatite and zircon.

METAMORPHIC ZONES

The Hall's Creek Group and the Tickalara Metamorphics have been subdivided into five metamorphic zones (Fig.31). These zones are based on the fact that amphiboles undergoes systematic changes in colour, composition and density during progressive metamorphism from high green-

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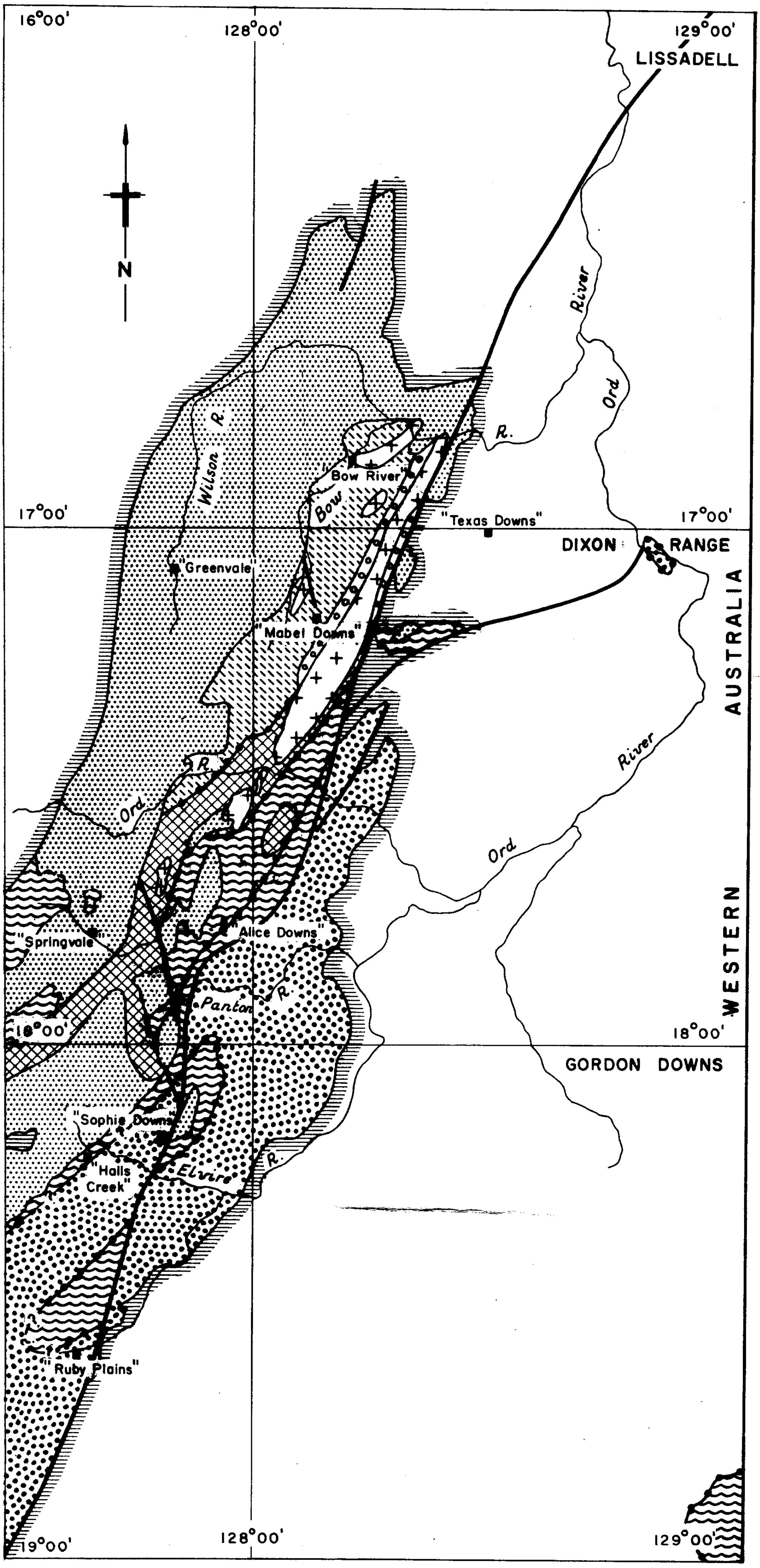

Figure 31

METAMORPHIC ZONES in the ORD RIVER REGION

SCALE

10 0 10 20 30 MILES

REFERENCE

- Younger Proterozoic sediments
- Late intrusives
- Gneissic granite
- Zone A
- Zone B
- Zone C
- Zone D
- Zone E

Bureau of Mineral Resources, Geology and Geophysics. October, 1964
Drawn by G.J.V.

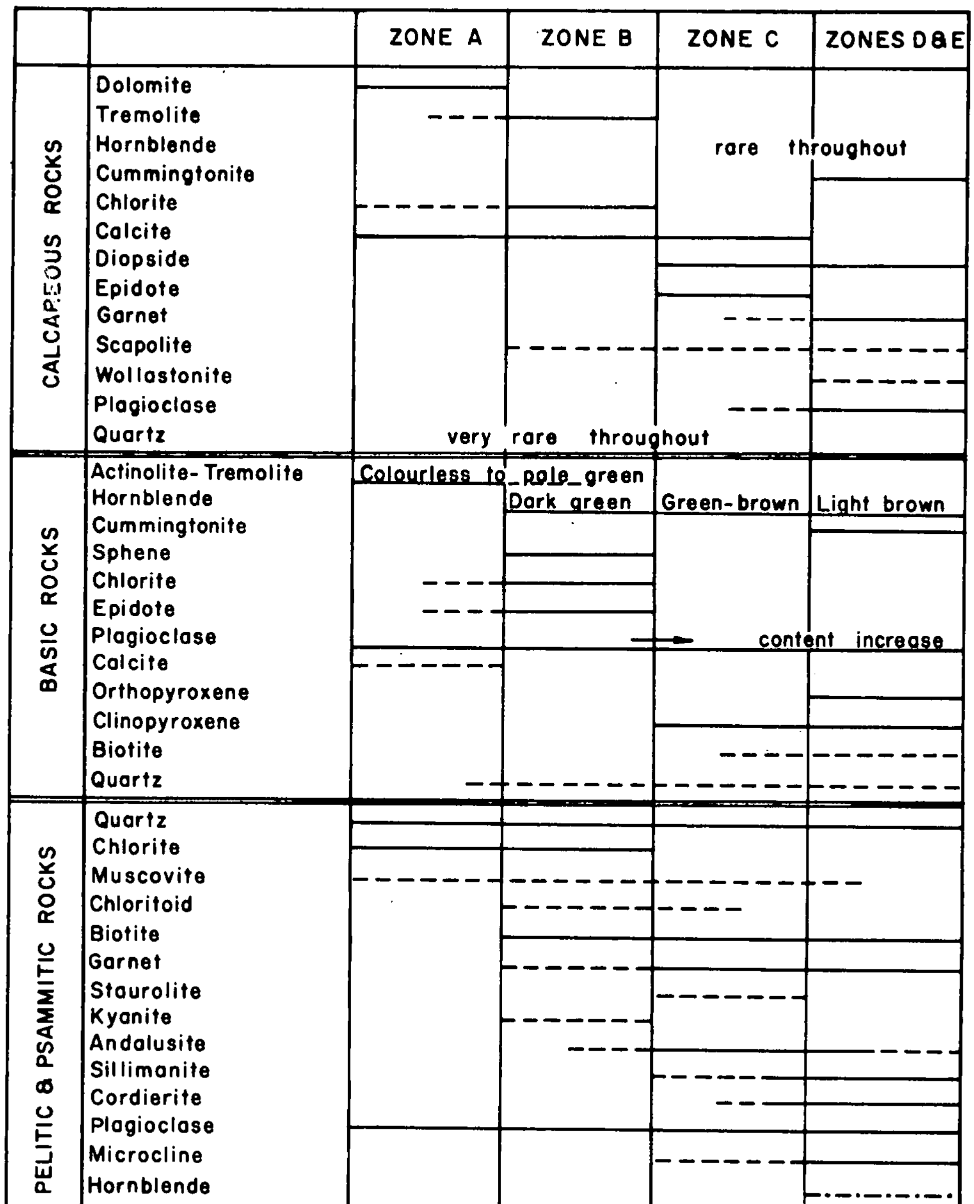

Table 4. Changes in mineral assemblages of the Tickalara Metamorphics with increasing grade of metamorphism. A full line indicates that a mineral is common and abundant, a broken line that it is common but not abundant, and a dash dot indicates that it is rare. (after Miyashiro 1958)

W/A 44

schist to hornblende-granulite facies (Engel & Engel, 1962). In the absence of chemical data, the metamorphic zones of the Lamboo Complex are based on the changes in axial colour of the calciferous amphibole present in basic rocks. This variation has proved to be consistent with mineralogical changes in other rock types: the changes in mineral assemblages with increasing grade of metamorphism, in calcareous, basic, pelitic and psammitic rocks, are shown in Table 2. Zones based on similar changes have been established in other parts of the world (see Miyashiro (1958); Shido (1958); Engel & Engel (1962); Layton (1963); Binns (1963). The zones distinguished in this report are listed below :

ZONE A: The dominant amphibole is actinolite-tremolite, forming discrete laths or replacing (primary) hornblende. The Z-axial colour varies from colourless to very pale green. This zone embraces most of the chlorite-rich shales and greywackes (chlorite 1 and 2 zones of Turner, 1938) in the Halls Creek Group. There is an incipient development of biotite in the pelites and dolomite is present in calcareous rocks.

ZONE B: Common hornblende appears in anhedral acicular laths or rosettes. Z-axial colour ranges from blue-green to dark-green. There are areas where actinolite typical of Zone A coexists with hornblende in Zone B. Epidote and sphene are common associates. Amphibolites of this zone are associated with biotite, garnet, kyanite and chloritoid schists. Calcite is the common carbonate mineral in the calcareous rocks.

ZONE C: Nematoblastic hornblende is associated with a clinopyroxene. The Z-axial colour is green brown and the disappearance of the bluish-green tinge marks the transition. Epidote and sphene cease to be present in the amphibolites. The associated calcareous rocks are rich in diopside and epidote. An indicator of grade in pelitic and psammitic rocks is the development of staurolite at the expense of chloritoid and andalusite, and fibrolitic sillimanite in place of kyanite. Knotted schists and stengel gneiss predominate.

ZONE D: Granular saccaroidal hornblende and/or cummingtonite occurs by itself or in association with an orthopyroxene. Clinopyroxene is a common constituent. The Z-axial colour of the hornblende is brown or light brown. Zone D is very difficult to trace to the south because of a lack of basic rocks and the development of orthogneiss, intercalated with coarse-grained granites. The calcareous rocks in this zone have assemblages containing wollastonite, diopside, and garnet or anorthite, and cummingtonite associated with a clinopyroxene. The pelitic and psammitic rocks have assemblages containing sillimanite replacing andalusite, microcline, and subordinate cordierite.

ZONE E: The mineralogy of the basic metamorphics is generally the same as in Zone D. Close to the palingenetic granite there is a maximum development of cordierite, biotite and microcline. Zone E has been distinguished on structural grounds, and represents a zone of permeation and injection by granitic fluids, indicated by migmatite gneisses.

High shearing stress and relatively low temperatures have been the dominant factors in production of the low-grade metamorphic rocks of X Zo zones A and B. The Olympic Creek and Biscay Formations are highly sheared and tightly folded, and the metamorphic zones parallel the regional structure. Turner (1938) has described progressive steps in low-grade regional metamorphism which apply in these zones.

'(1) Mechanical granulation, shearing out, and recrystallisation or original clastic grains

'(2) Simultaneous growth of minute crystals of new minerals with their long axes in subparallel position and subsequent increase in size of the reconstituted mineral grains'.

The higher-grade zones C to E transgress all major regional structure, and it appears that the very high-grade thermal assemblages may have been formed or modified after a regional dynamo-thermal metamorphism.

The regional metamorphism culminated in the formation of palingenetic granites.

The pelitic assemblages formed in zones D and E are similar to those described by Read (1952) from Buchan, Aberdeenshire, and Miyashiro (1958) and Shido (1958) from the Abukuma Plateau. We follow Miyashiros (1961) hypothesis: 'occurrence of andalusite and cordierite depends on the operating temperature and pressure and not upon the geological distinction between contact and regional types'. Thus, although many workers feel that the formation of andalusite and cordierite is indicative of thermal metamorphism, we think that all the assemblages investigated can be placed in the facies of regional metamorphism. The two kinds of metamorphism are so closely connected in this area that it is almost impossible to distinguish them. Following Fyfe et al., (1958) we have:

Green schist facies	ZONE A --	Quartz-albite-muscovite-chlorite subfacies
	ZONE B --	Quartz-albite-epidote-biotite to Quartz-albite-epidote-almandine subfacies
Almandine-amphibolite facies	ZONE C --	Staurolite-quartz-subfacies
Almandine-amphibolite to Granulite facies	ZONE D	Sillimanite-almandine
	ZONE E	subfacies transitional to hornblende-granulite subfacies

The minimum temperatures from mineralogical data are indicated to be between 600°C and 700°C in the hornblende-granulite subfacies. The maximum thickness of overburden to produce psammitic assemblages described in this subfacies is 30,000 feet (see Zwart, 1961).

Intrusive Rocks

The oldest known intrusive rocks of the Lamboo Complex are basic and ultrabasic bodies which were intruded into the Tickalara Metamorphics before and during regional metamorphism. Porphyry intrusions believed to be co-magmatic with the Whitewater Volcanics were intruded at a later date, and these were, in turn, intruded by the magmatic granites which comprise porphyritic granite, coarse-grained granite, biotite granite, and hornblende granite.

Ultrabasic Rocks

The Panton Sheet is a sill-like intrusion, six miles long by about one mile wide, composed of basic and subordinate ultrabasic rocks. It is a broadly layered differentiated intrusion which grades from altered ultrabasic rocks and tremolite-chlorite schist at the base to alternating bands of gabbro and leuco-gabbro towards the top of the sheet. The ultrabasic rocks were originally rich in olivine, but now they consist of relict, mostly serpentinized, olivine set in a tremolite-chlorite matrix. Chromite and magnetite are generally accessory, but in places they occur as segregated bands up to three inches thick.

The ultrabasics also occur as small lenticular bodies along the margin of, and as large xenoliths within, the McIntosh Sheet, which is a large sill-like basic body described below. These ultrabasic bodies are mostly altered olivine hypersthenite.

Basic Rocks

The Basic Rocks constitute about one third of the Lamboo Complex, and are the most extensive rocks of the Complex. The largest intrusions are sheet-like bodies, roughly circular or elliptical, which commonly have been folded into broad synclines. Notable among the more symmetrical bodies are the McIntosh and Toby Sheets, the large body near Springvale Homestead, and the elliptical stock on the Armanda River. Many small remnants of bodies such as these, and other less regular bodies, constitute the greater proportion of the basic intrusives: they occur in a belt trending north-north-east from Springvale Homestead to ten miles south of Greenvale Homestead.

The rock types found include gabbro, troctolite, norite, metagabbro, and amphibolite, most of which have been altered by regional metamorphism, shearing, or later granite intrusions. The alteration commonly takes the form of saussuritization of the feldspar and alteration of pyroxene to hornblende or actinolite. The Panton Sheet, described above, is a differentiated intrusion, grading from ultrabasic rocks at the base to leucogabbro at the top, and it is possible that the more extensive basic rocks represent in part, such later differentiates. The xenoliths noted in the McIntosh Sheet may be ruptured ultrabasic basal layers incorporated in the more basic top layers.

'Porphyry'

Quartz-feldspar porphyry crops out around Greenvale Homestead, in the north-west of the Dixon Range Sheet area, and extends northwards, along the eastern side of the Dunham Fault, to the O'Donnell Brook in the Lissadell Sheet area. Near McPhee Creek a sheet-like body of porphyry crops out along the south-western side of the Carr Boyd Ranges, from the Ivanhoe Fault in the south to near Dunham Hill to the north. Rocks occurring in the Golden Gate Country are equated to the 'porphyry' and small exposures are found near Mount Pitt.

The most common rock is dark grey, very fine-grained, and contains phenocrysts of oligoclase, quartz, and potash feldspar. The groundmass consists of quartz and potash feldspar (commonly as granophyric intergrowths), (?)oligoclase, biotite, chlorite, and secondary chlorite after (?)amphibole. Apatite, zircon, sphene are accessories. Quartz phenocrysts are commonly recorded and may be glomeroporphyritic. Oligoclase is generally more abundant than potash feldspar. Small inclusions, up to six inches long, of sedimentary and fine-grained igneous rocks are common.

The exposure near McPhee Creek appears to be a sheet-like body dipping shallowly to the east. It grades over a thickness of about 500 feet from medium-grained hornblende-biotite at the base, through fine-grained biotite to massive fine-grained black porphyry at the top. The composition of the rocks does not change.

In the Golden Gate Country even-grained hornblende-biotite granodiorite grades to fine-grained biotite microgranodiorite over a distance of several hundred yards.

The 'porphyry' here intrudes the Whitewater Volcanics and is itself intruded by a coarse even-grained phase of 'prophyritic granite'. 'Porphyritic granite' also intrudes the 'porphyry' in the O'Donnell Brook and McPhee Creek areas.

The 'porphyry' is intrusive and is almost identical with the intrusive phase of the Whitewater Volcanics. It is considered to be comagmatic with the Volcanics and represents a late, high-level intrusive phase of them.

Magmatic granites:

The magmatic granites include all the later intrusive granites of the Lamboo Complex.

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Coarse-grained and porphyritic granite are by far the most extensive and they crop out as a large batholith, and as many small irregular intrusions throughout the western half of the Complex. They intrude Tickalara Metamorphics, ultrabasic and basic rocks, porphyry, and Whitewater Volcanics. The granites are coarse-grained, and their texture ranges from even-grained to porphyritic. The coarse-grained granite consists of anhedral microcline surrounded by granular quartz and large fractured quartz grains. Biotite forms small clusters and common accessories are muscovite and magnetite. The porphyritic granite consists of large phenocrysts (up to 3 c.m. across) of microcline and subsidiary quartz, in a quartzitic groundmass which commonly contains some andesine and albite. Zircon, apatite, tourmaline, and biotite, are accessory minerals.

Biotite granite crops out north-east of Mabel Downs Homestead. It is massive and non-foliated, and appears to intrude the 'porphyritic granite', but no contacts were found, and it could be a finer-grained biotite-rich phase of the 'porphyritic granite'. No thin sections of the rock have been examined and it could be a granodiorite.

Hornblende granite (?granodiorite) bosses intrude the Olympio Creek Formation east of the Halls Creek Fault and are overlain unconformably by the Red Rock Beds. Towards the Halls Creek Fault they are highly epidotized, the feldspars have been turned salmon-red by the introduction of iron.

White muscovite granite crops out as dykes up to 300 feet wide in much of the north-eastern part of the Lamboo Complex. In most places the dykes are too small to be mapped at photo scale, but in the areas shown as muscovite granite on the geological map (Plate 1), dykes constitute over half the outcrop. The rock is fine-grained and consists of muscovite, kaolinized feldspar, and quartz: ferromagnesian minerals are absent. Associated small pegmatite dykes contain quartz, potassic feldspar, and subordinate muscovite, magnetite, tourmaline, ilmenite, and epidote. Near Mount Nyulasy, a pale green, epidotized variety of muscovite granite intrudes the base of the Revolver Creek Formation, but has little effect on the beds.

The hybrid diorite intrudes metasediments four miles north-east of Mount Nyulasy. It consists of a bewildering variety of rock-types ranging from gabbro to hornblende granodiorite, all of which may crop out within a radius of 100 feet. It may be a highly contaminated magma, or it may be a mixture of basic and acid magmas.

Late Dykes

Late-stage dykes ranging in composition from dolerite to aplite and pegmatite intrude the Lamboo Complex and post-date the porphyritic granite. Dolerite dykes are found throughout the Complex: they are up to

16 miles long and 200 feet wide, and nearly all trend between north-west and north-north-west. They consist of plagioclase, augite, and accessory biotite, hornblende, and iron oxides. Diorite dykes crop out near Springvale Homestead, and north of Armanda Stock, and cut coarse-grained granite and basic rocks. They consist of hornblende phenocrysts set in a fine groundmass of amphibole, clinopyroxene, feldspar, and quartz. Aplite dykes intrude the Tickalara Metamorphics north of Mabel Downs Homestead. They are up to two miles long and ten feet across, and consist of saccaroidal grains of feldspar, plagioclase, quartz, and minor garnet and biotite. Pegmatite dykes are distributed throughout most of the Lamboo Complex. The largest seen is 600 feet long and six to ten feet wide. The dykes are composed of graphic intergrowths of quartz and potassic feldspar, and subordinate muscovite, magnetite, tourmaline, ilmenite, and epidote.

INTRUSIVE ROCKS

Basic igneous rocks intrude Younger Proterozoic sedimentary rocks and rocks of the Lamboo Complex throughout the area. Two main groups occur. The Fish Hole Dolerite and dolerites in the O'Donnell Range area are older than the Mount Parker Sandstone and Liamma Beds respectively and are probably related to each other. The more extensive Hart Dolerite was intruded late in the Younger Proterozoic, but it may have covered a very long time span as multiple intrusion has occurred in places.

Quartz-feldspar porphyry of unknown age, possibly Palaeozoic, occurs along the Ivanhoe Fault.

Fish Hole Dolerite

Amygdaloidal dolerite and basalt associated with the Red Rock Beds are called the Fish Hole Dolerite after Fish Hole in the Osmond Range. The rocks are highly epidotized and generally contain abundant amygdales filled with zeolites and a green chloritic material. Anomalously high copper and nickel contents are characteristic of streams draining these rocks and several small showings of copper minerals have been found in the Basics.

Some of the Basic Rocks occur as sills intruding Red Rock Beds, but in the Frank River area, they could be mostly lava flows. The formation is at least 4000 feet thick in places.

Dolerite Intrusives in the O'Donnell Range

Dolerite dykes and sills crop out in the O'Donnell Range intruding the Whitewater Volcanics and O'Donnell Formation. Similar dykes occur in the Golden Gate Country and in the Lamboo Complex around Pompey's Pillar.

The O'Donnell Formation is the youngest unit known to be intruded by the dolerite. The Liamma Beds appear to overlie it unconformably. In the valley around Moonlight Valley Yard a sill, estimated about 5000 feet intrudes the upper part of the Formation.

This dolerite differs from the Hart Dolerite, and is probably older. It is uralitized, commonly sheared, and is not as rich in magnetite. Traces of copper have been found in joints. In thin section sheaths of amphibole replace pyroxene, and feldspar is saussuritized. Amygdales of dark green chlorite material occur in the dyke-rocks.

The dolerite is lithologically similar to the Fish Hole Dolerite and occurs in a similar stratigraphic position.

Hart Dolerite

The very extensive dolerite sills (Figure 5) which intrude the Younger Proterozoic rocks throughout the Kimberley Plateau and Kimberley Foothills areas have been called the Hart Dolerite from Mount Hart in the West Kimberleys. Guppy et al. (1958) referred to them as the Hart Basalt on account of their stratigraphic distribution. Harms (1959) established their intrusive nature and renamed them the Hart Dolerite.

The Dolerite extensively intrudes rocks of the Kimberley Basin succession in the western part of the Ord River Region; it does not occur east of the Greenvale - Dunham - Ivanhoe fault system. In the map area it intrudes rocks of the succession up to the Carson Volcanics: it is most extensive within the Speewah Group, and a sill up to 6000 feet thick has been noted in the Speewah Valley. Large blocks of sedimentary rocks over a mile square and at least several hundred feet thick have been 'rafted' along fault and joint planes and are completely enclosed in dolerite. Minor feeder dykes and sills intrude Kimberley Group rocks. The dolerite crops out as rounded, boulder-strewn hills, with thick grass cover, and has a characteristic 'flat', dark-grey pattern on air photographs. In many places iron staining on weathered surfaces gives very black outcrops (Fig.5).

The rocks range from dolerite and quartz dolerite to coarse-grained gabbro and diorite; Edwards (1942) shows that they are saturated with respect to quartz. Dolerites occurring in the thinner sills are generally finer-grained and have a sub-ophitic fabric. They contain andesine or labradorite and pigeonite or diopsidic augite. Magnetite is a ubiquitous accessory. Minor (altered) olivine and hypersthene is present in some specimens.

An extensive dolerite sill intrudes the base of the Speewah Group. In the Speewah area it appears to be a composite sheet. It is coarser-grained than other and thinner sills, and consists of a coarse gabbro or quartz gabbro. Hypersthene is common in some specimens but less than half the total pyroxene in others. Magnetite may make up to 15% of the rocks; the feldspar is calcic andesine or labradorite. Biotite, quartz, epidote and olivine occur as accessories.

A granophyre up to 800 feet thick forms the upper contact of this sheet throughout the Sheet area. It is reddened by iron-stained feldspar, rich in quartz and poor in mafic minerals. Potash feldspar and quartz commonly form a myrmekitic inter-growth. The granophyre contains numerous sedimentary inclusions; and in the field it is often difficult to recognise the contact between it and altered sediment. In some places sandstone is epidotized up to 200 feet from the contact. The contact effects of the smaller sills are not pronounced. Chilled margins up to 2 feet wide are found in the dolerite and the adjacent sandstones are enriched in iron; and siltstone is recrystallized to fine white mica and chlorite for several feet from the contact.

The age of the Hart Dolerite is unknown. In the map area it intrudes rocks as young as the Carson Volcanics but in the West Kimberleys Harms (1959) reports dolerite intruding rocks as young as the Walsh Tillite. In the North Kimberleys (Harms, pers. comm.) dolerite is very common within the Carson Volcanics.

Petrologically the Hart Dolerite, Carson Volcanics, and Antrim Plateau Volcanics all belong to a similar petrogenetic suite. Edwards (1940), working on specimens from these units prior to any systematic mapping, was unable to distinguish them. Petrology then is of no value in determining their age.

Harms (1959) suggests that they might be an intrusive phase of the Antrim Plateau Volcanics, and if they intrude Walsh Tillite this is probable. In the Ord River Region they are unconformably overlain by the Antrim Plateau Volcanics, however, and they show the structure of the rocks they intrude so well that it is unlikely that they are much younger than the country rocks; certainly not as young as Lower Cambrian. Their association with the Carson Volcanics suggests a likely age relationship here.

The large Speewah Sheet is a composite body, so clearly the Dolerite covers an appreciable time span. The Hart Dolerite in the East Kimberleys therefore is probably similar in age to the Kimberley Group. Younger dolerites occur in the West Kimberleys but cannot be distinguished in the field.

'Porphyry' along the Ivanhoe Fault

Small bodies of fine-grained quartz-feldspar porphyry occur within the Ivanhoe Fault Zone along the western side of the Carr Boyd Ranges. The age is unknown. Devonian rocks adjacent to the Fault are sheared, but the porphyry shows no shearing at all. It is therefore almost certainly younger than Devonian.

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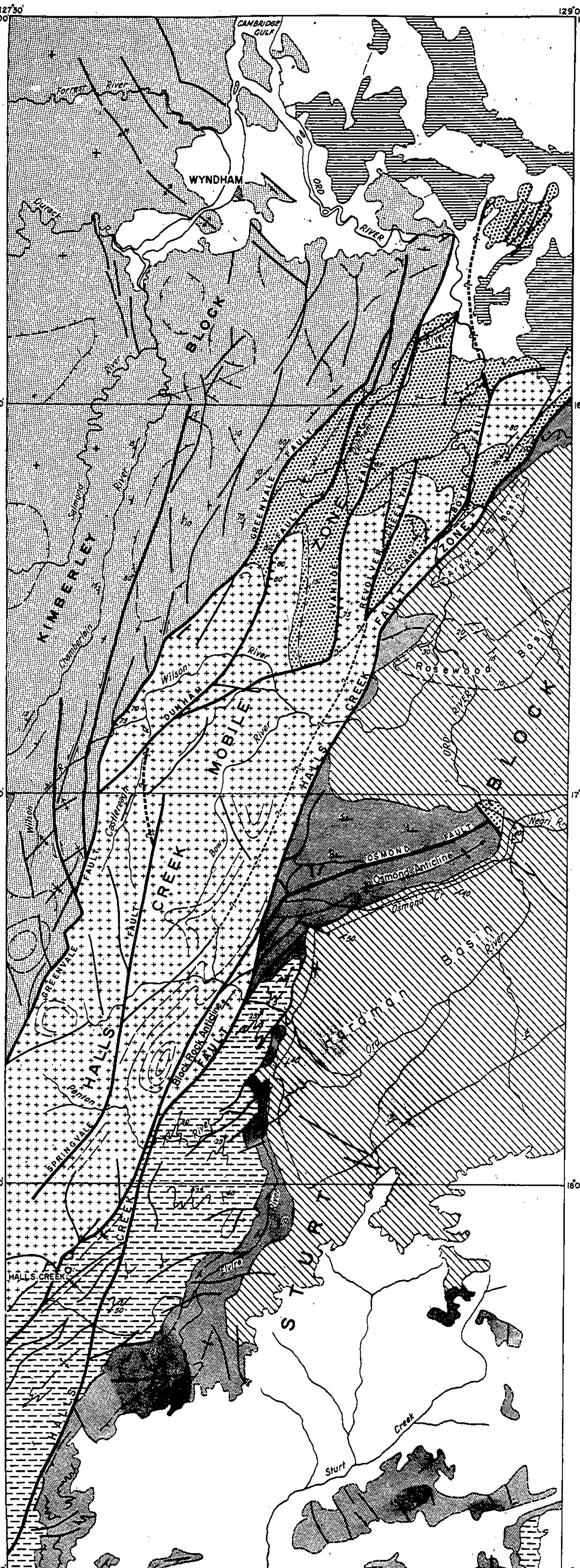
PLATE 3



STRUCTURAL SKETCH MAP

ORD RIVER REGION

WESTERN AUSTRALIA

Scale

10 0 10 20 30 40 50 60 MILES

Reference

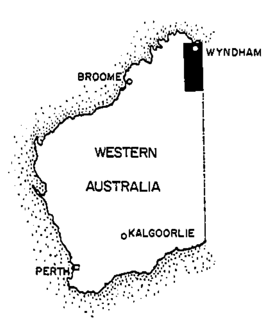
HALLS CREEK MOBILE ZONE
- Younger Proterozoic
- Lamboo Complex
- Halls Creek Metamorphics

STURT BLOCK
- Palaeozoic
- Younger Proterozoic

KIMBERLEY BLOCK
- Younger Proterozoic

- Palaeozoic rocks of Bonaparte Basin.
- Soil cover.

- Geological boundary.
- Major fault
- Minor fault
- Inferred fault
- Normal fault with dip
- Reverse fault with dip
- Transcurrent fault with movement
- Syncline showing plunge
- Anticline showing plunge
- Strike and dip of strata (generalized)
- Horizontal strata
- Trend of bedding or foliation



Bureau of Mineral Resources, Geology and Geophysics
Canberra, A.C.T. – August, 1964

STRUCTURE

INTRODUCTION

The geology of the Ord River Region is dominated by the Halls Creek Mobile Zone, a narrow belt of intensely deformed metamorphic and igneous basement rocks partly covered by strongly faulted sedimentary rocks, which extends from south of Halls Creek to Darwin in the Northern Territory. It is bounded east and west by faults of great magnitude, and is broken by a complex series of anastomosing faults, many of which appear to have throws comparable with the bounding faults.

The Mobile Zone is flanked by stable areas called the Sturt Block on the east and the Kimberley Block on the west. The Younger Proterozoic rocks covering these blocks are little deformed, except near the bounding faults, where they are strongly faulted, and in places tightly folded.

Older Proterozoic rocks are highly folded and strongly faulted; folding and faulting are probably closely related, and both are of regional significance. Within the Mobile Zone, most of the earlier folds have been obliterated by high-grade regional metamorphism and extensive invasion by igneous rocks, but at least two phases of folding can be recognized within the Zone.

By comparison, the structure of the Younger Proterozoic rocks is dominated by faulting; the rocks are broadly warped except near major faults, where they are commonly intensely deformed. The major faults are of great antiquity, and have long complex histories of movement. Some of them have been active since Devonian times, but most of their movement appears to have taken place during the Older Proterozoic deformations and all later activity has been on a steadily decreasing scale.

FOLDING

Older Proterozoic rocks near the Halls Creek Mobile Zone are very tightly folded, but very little is known of the rocks under the Younger Proterozoic rocks of the Sturt and Kimberley Blocks. Small inliers of the older rocks exposed up to 30 miles from the Mobile Zone are intensely folded and it seems probable that very large areas of Older Proterozoic rocks within these blocks reacted to stress by intense folding before the deposition of the Younger Proterozoic rocks. The structure of the Older Proterozoic rocks of the Halls Creek Mobile Zone has been largely obliterated by regional metamorphism and intrusion. Two periods of folding are known. The first produced isoclinal folds and impressed a strong axial plane cleavage over most of the area, and during the second, a strain-slip cleavage developed which cut across and deformed the earlier folds.

South of Tickalara Bore the Tickalara Metamorphics are folded into 107
tight northerly-plunging synclines and anticlines. The major fold axes

and axial planes trend north-north-east, and all minor fold axes are paralleled by steeply plunging lineations defined by oriented metamorphic minerals. The anticlines have overturned easterly limbs, and the synclines are sheared out by anastomosing faults of the Halls Creek Fault. To the west, the regional structure is disturbed by intrusive granites and numerous shear zones.

North of the Bore, near the margins of the 'gneissic granite', and in the migmatite gneiss near Mabel Downs Homestead, all logical structural patterns disappear. The structure is very complex over small areas. The folding ranges from ptygmatic to isoclinal, and the dominant processes of deformation have been transposition of folded layers and plastic flow. Flowage phenomena are especially spectacular in the marble bands, which have flowed like soft solids, whereas intercalated gneiss and amphibolite layers are shattered and dispersed.

The Halls Creek Group crops out south of Halls Creek within the Mobile Zone, and to the east of the Zone between the Frank River and Ruby Plains Homestead. They have been tightly folded into a north-north-easterly-trending anticlinorium which is domed upwards about an east-west axis near Saunders Creek: south of Saunders Creek the anticlinorium plunges to the south-south-west at about 30° to 50°, while to the north the plunge is to the north at about 20° to 25°. The basal unit of the Halls Creek Group, the Ding Dong Downs Formation, is exposed in the cores of two domes located at the culmination of the anticlinorium. The Halls Creek rocks generally dip between 60° and vertical, and the easterly limbs of the major folds are commonly overturned by as much as 20°. The degree of the folding is directly related to the competency of the rocks, and in places relatively incompetent greywacke and shale sequences have been very tightly folded and overturned against buttresses of a massive greywacke and pebble conglomerate. The Ord River marks a change in the plunge of the anticlinorium from 25° north, to a gentle southerly plunge. Eight miles north of the Ord River the plunge is again north at about 25°.

Halls Creek Group in the inlier at the head of Osmond Creek appears ro be folded into a broad syncline which plunges north nearly vertically while folds in the inlier of Halls Creek Group near the junction of the Ord and Nogri Rivers plunge very steeply south.

Folding of the competent Koongie and Moola Bulla Formations is less complex than that of the older units of the Halls Creek Group. The Koongie Formation appears to be folded into a tight syncline, and in the main area of outcrop the Moola Bulla Formation has a uniform dip to the west-north-west at about 70°.

Proterozoic rocks unconformably overlie Halls Creek Group, and away from the Mobile Zone they are only gently folded or sub-horizontal. Folding is more intense near the Mobile Zone, but as it is mainly a secondary effect of faulting, it is discussed below.

The Hardman, Rosewood, and Argyle Basins are markedly asymmetrical

Figure 32: Halls Creek Fault. View looking northwards along the Halls Creek Fault; photograph taken from five miles east of Turkey Creek. Broad rounded hills on left are Tickalara Metamorphics. The trace of the Fault is at the foot of the sandstone hills on the right. (G6065)

Figure 33: Splays of the Halls Creek Fault. The large block of Younger Proterozoic sandstone and shale is bounded right and left by splay faults of the Halls Creek Fault. The two faults join in the middle of the photograph and follow the crest of the ridge in the foreground. Photograph taken from three miles west of Moonlight Dore looking south. (G6059)

structural basins which occupy most of the eastern half of the Ord River Region. The rocks of the basins have gentle regional dips to the north-west, and the basins have been formed by upward drag along faults which form the western and north-western margins of the basins.

FAULTING

Halls Creek Mobile Zone

The Halls Creek Fault on the east, and the Greenvale Fault on the west, form the margins of the Halls Creek Mobile Zone. They are linked by a series of large anastomosing faults (Fig.33), the most important of which, the Carr-Boyd, Revolver Creek, Springvale, Dunham, and Ivanhoe Faults, have throws comparable with the boundary faults.

The faults have long complex histories of intermittent movement: the known displacements and the intensity of shearing of younger rocks are generally less than older rocks. The total displacement on these faults is not known. Proved displacements are of the order of 5000 to 10,000 feet, but though it is suspected that the faults have much larger anticlockwise horizontal displacements, there is no proof.

The Halls Creek Fault (Fig. 32) forms the eastern margin of the Mobile Belt. It generally has a shear zone up to one quarter of a mile wide which dips steeply either east or west, but in places the total displacement is distributed over several faults in a zone up to four miles wide (Fig.33).

The displacement on the Fault has a large vertical component, downthrow to the east, and near the Osmond Range it brings the Ord Group against the Lamboo Complex, a vertical throw of at least 6000 feet. In the Carr-Boyd Range to the north it brings Antrim Plateau Volcanics against the Lamboo Complex, a minimum throw of 9000 feet. These vertical throws do not take into account erosion caused by uplift on the fault before deposition of the younger rocks, and as over 30,000 feet of Younger Proterozoic sediments are missing in places, the vertical displacement could be of this order. Horizontal displacements are large but are difficult to estimate. In the south, the Halls Creek Fault appears to have displaced the Biscay Formation horizontally at least sixteen miles, west block south.

The Carr Boyd Fault is a north-trending fault up to half a mile wide, which diverges from the Halls Creek Fault near Carlton Gorge in the Carr Boyd Ranges. The vertical displacement is not known because the formations involved probably change in thickness across the Fault, but it is of the order of several thousand feet, west block down. The fault wedge between the Carr Boyd and the Halls Creek Faults has been tilted to the south, and its northern end has been upthrown several thousand feet on an easterly-striking splay of the Carr Boyd Fault. The intensity of folding and shearing of the rocks of the wedge increase markedly southwards towards the apex.

The Revolver Fault is a westerly splay of the Carr Boyd Fault and has similar splay faults diverging from it. North of Revolver Creek the Fault illustrates the pulsatory movement history of the major faults in the area. The Older Proterozoic Rocks have been strongly faulted while the overlying Hensman Sandstone shows only slight displacement; movement dies out within the Lissadell Formation.

Folded cleavage in Halls Creek Group rocks adjacent to the Fault indicates a strong horizontal component of movement.

South of Revolver Creek a fault wedge between the Carr Boyd and Revolver Creek Faults has subsided at least 6000 feet since deposition of the Glenhill Formation. The block is bounded in the north by a curved cross-fault which shows similar vertical displacement. Compression within the block has developed a strong cleavage and the rocks in the block are folded into anticlines and synclines lying at low angles to the bounding faults. They plunge about 20° south in the south and 25° north in the north.

The Greenvale Fault forms the western margin of the Halls Creek Mobile Zone and no outcrops of Lamboo Complex rocks are found to the west of it. The Fault is a composite system consisting of intersecting faults striking at about 030° to 040° and 010°. These combine to produce a 'dog-leg' trend to the Fault.

The 030° legs dip about 70° to 75° east. Drag folds adjacent to the Fault indicate high angle reverse fault movement; vertical displacements of the order of 5000 feet suggested.

Zones of shearing and tight folding, up to two miles wide, are found adjacent to the Greenvale Fault. The most intense shearing is found in rocks older than the Speewah Group: considerable movement occurred on the fault before the Group was laid down.

Numerous splay faults, subparallel to, and frequently forming extensions of, the 010° legs of the Fault, diverge westwards from it at angles up to 45°. These splays show little vertical displacement, but horizontal movements of up to 20,000 feet, west block south, are indicated. It seems probably that the Greenvale Fault has a large horizontal component of movement. These faults are expressed as narrow zones of brecciation.

The Springvale Fault is a curved zone of shearing forming zones of poor outcrop up to half a mile wide in the southern part of the map area. It crops out entirely within rocks of the Lamboo Complex and its movement is not known. It appears to displace a coarse-grained granite batholith for twenty miles horizontally, west block south, but this displacement could be illusory; the intrusion of the granite could be later than, and controlled by, the fault.

The Springvale Fault is difficult to trace in the north but appears to trend into the Dunham Fault.

An easterly splay of the fault, near the Ord River in the south, can be traced in a north-easterly direction for many miles as a belt of shearing trending into the Carr Boyd Fault.

The Dunham Fault in the north, is an easterly splay of the Greenvale Fault; the Springvale Fault, to the south, apparently trends into it. It has a shear zone up to one mile wide, commonly containing reef quartz. Throughout most of its length it bounds a prominent scarp to the west and adjacent to the O'Donnell Range and crops out as a 'knife-edge' of reef quartz 700 feet high.

The fault dips very steeply to the east. Adjacent to the O'Donnell Range vertical displacement has occurred on a high-angle reverse fault dipping 75° east. Here a zone of phyllitic rocks, half a mile wide, with drag folds paralleling the fault movement, forms the footwall. Vertical displacement of the order of 8000 feet, west block down, is indicated, but horizontal movement, of the order of 20,000 feet, west side north, could also give the observed stratigraphic displacement. The actual movement is probably somewhere between the two; the vertical and horizontal components are unknown.

Post-Devonian movement has occurred on the Fault.

The Ivanhoe Fault bifurcates from the Dunham Fault and strikes about 060°, where it transgresses the Lamboo Complex. In the south-west corner of the Carr Boyd Range it changes suddenly to about 015°, its general strike direction north of here. The fault has a shear zone up to three quarters of a mile wide and the movement is often taken up by two or more anastomosing faults.

In the north, around the Ord River, post-Devonian vertical displacement of about 3000 feet is present and the fault has had a marked effect on Palaeozoic sedimentation. It has also effected Precambrian sedimentation.

The movement pattern of the fault is difficult to determine; the the Precambrian movements are obscured by Palaeozoic sedimentation. An overall vertical displacement of west block down is apparent, and horizontal displacement of west block south is also present. Adjacent to the Ragged Range apparent vertical displacement of the order of 7000 feet is indicated; this is probably excessive due to the probably horizontal displacement of several thousand feet. In the south-west Carr Boyd Range, where the Fault strikes 060°, 10,000 feet of horizontal displacement is indicated. The horizontal displacement farther north cannot be estimated.

Near Glenhill Homestead Devonian rocks, to the east, are overturned against the Fault, which dips 75° east, indicating a high-angle reverse fault movement. Here about 3000 feet displacement is indicated as against

7000 feet six miles north: most of this movement is probably pre-Devonian, although strong post-Devonian movement has occurred. Four miles to the south Devonian rocks transgress the fault undisturbed.

In the south-west corner of the Carr Boyd Range the Lissadell Formation and underlying rocks show the full 10,000 feet lateral displacement while the overlying Glenhill Formation is displaced much less. Here the fault plane dips steeply. In the north the fault is seen to vary between 80° west and 80° east in dip.

To the north, around the Ord River, the Ivanhoe Fault is the major structure present and the Dunham and Greenvale Faults, which have decreased in intensity, trend into it. Farther north the extension of the Ivanhoe Fault, obscured by soil cover, anastomoses with the apparent extension of the Carr Boyd Fault.

Minor faulting is present throughout the Halls Creek Mobile Zone, but these minor faults are related to, and reflect the movement pattern of, the major faults just described.

East and west of the Halls Creek Mobile Zone are tectonically stable areas called respectively the Sturt Block and the Kimberley Block. Since Older Proterozoic times these areas have reacted to stress mainly by block faulting, and over large areas away from the Mobile Zone, Younger Proterozoic rocks are horizontal or gently warped. Near the Mobile Zone these rocks are strongly faulted and commonly tightly folded.

Sturt Block

Basal Younger Proterozoic rocks (Red Rock Beds) on the eastern edge of the Sturt Block are intensely faulted within four miles of the Mobile Zone. They are broken into small wedges by steeply-dipping anastomosing faults of the Halls Creek Fault and by divergent faults which trend roughly north-east. The competent rocks within these wedges are generally nearly vertical and the less competent are tighly folded and commonly overturned. The fault planes are invariably steep and though their vertical displacement is known to be of the order of several thousand feet, their horizontal displacement is not known. It could however be much larger.

Much of the faulting along the marginal zone post-dates the deposition of the Red Rock Beds, but faulting was also active during their deposition. Cliff sections in the head of Osmond Creek give ample evidence of this: a prominent bed of quartzite and quartz pebble conglomerate is downthrown by at least 500 feet, but the overlying boulder conglomerate is dislocated only 270 feet by the same fault, and the overlying Mount Parker Sandstone is not affected. The Red Rock Beds in this locality show great lateral variation which was probably caused by the contemporaneous faulting.

There was much less tectonic activity along the edge of the Sturt Block after the deposition of the Mount Parker Sandstone. The Osmond Range succession and the overlying Younger Proterozoic sediments are affected by faults on which the displacements are small and almost entirely vertical. The Osmond Fault is an exception: it dislocates the northern flank of the Osmond Anticline a vertical distance of between 8000 feet and 11,000 feet, downthrow to the south. The fault plane is vertical and Younger Proterozoic rocks are dragged vertical or overturned close to the fault. Horizontal movement appears to have been of minor importance on this fault.

Large-scale faulting continued much later along the Halls Creek Fault, and Ord Group rocks are downthrown at least 2000 feet. Cambrian rocks are also profoundly affected by movement on the Halls Creek and Osmond Faults (see folding above).

Away from the Halls Creek Mobile Zone the pattern of faulting in the Sturt Block is inferred from faults which dislocate the Cambrian sedimentary cover. These faults in the map area trend roughly north-west and it is believed that they reflect older faults in the Proterozoic basement. Evidence for this is given by the faulted monocline in the White Mountain area, which is on line with a large ancient shear zone which affects Halls Creek Metamorphics eight miles to the north-west.

Kimberley Block

The Kimberley Block contains slightly deformed Younger Proterozoic rocks and occurs to the west of the Halls Creek Mobile Zone. The rocks in the western part of the Block are flat-lying and dips increase eastwards as the edges of the Block are dragged up against the Halls Creek Mobile Zone. Most of the deformation is present within a zone twenty miles wide adjacent to the Mobile Zone.

The structure of this eastern zone is controlled by splay faults of the Greenvale Fault system, most of which strike about 010° to 015°. They generally dip between 80° east and 80° west and vertical displacements are minor while horizontal displacements up to 20,000 feet, west block south, are common. A high-angle reverse fault dipping 75° west has been found near Liamma Spring.

Drag within the fault wedges is only slight, although wedges of steeply dipping rocks are developed along the eastern margin of the Block; this is largely due to the Greenvale Fault itself rather than its smaller splays. Shearing in the rocks adjacent to the faults is minor, the rocks having yielded simply by fracture along narrow zones, which now consist of brecciated and quartz-filled zones up to twenty feet thick.

The oldest rocks in the Block, the O'Donnell Formation and Liamma Beds, are sheared where they are exposed adjacent to the Greenvale Fault.

The overlying Speewah Group and younger rocks do not have any strong shear-zones.

In the north around Cambridge Gulf north-westerly-striking faults, with relatively minor displacements, are common. Farther south this set of faults is expressed as minor splays of the larger 015° fault system.

Folding within the Kimberley Block consists of broad doming, with dips up to about 30° and no regular symmetry. The folding becomes tighter as the Greenvale Fault is approached, and is related to the faulting. In the Carr Boyd Ranges the vertical displacement is not known, because the formations involved probably change in thickness across the fault, but it is of the order of several thousand feet, west block down. The fault wedge between the Carr Boyd and the Halls Creek Faults has been tilted to the south, and its northern end has been upthrown several thousand feet on an easterly-striking splay of the Carr Boyd Fault. The intensity of folding and shearing of the rocks of the wedge increases markedly southwards towards the apex.

ECONOMIC GEOLOGY

Gold was discovered in the Ord River Region in 1884 by Hardman (1885), and a considerable amount of alluvial gold was won in the following five years. Though many small auriferous lodes were found during this period, none was of sufficient size or grade to support the industry after the alluvial gravels were worked out.

Many small deposits of various minerals are known, and these are documented by Harms (1959). Some exploration and development work has been done by companies and private individuals, but it has been spasmodic and on a small scale.

Most of the region, particularly the Older Proterozoic rocks, is a promising metalliferous province, and undoubtedly warrants large-scale exploration.

ASBESTOS

A small deposit of chrysotile occurs in serpentinized limestone overlying the Moonlight Valley Tillite north of the junction of the Ord and Negri Rivers. The chrysotile occurs as numerous lenticular seams of small extent, and has a fibre-length of up to one inch. The limestone is overlain by Antrim Plateau Volcanics, and the deposit is believed to have been formed by heat and volatiles from the volcanics acting on the limestone during extrusion.

CHROMIUM AND PLATINUM

Chromite containing platinum has been found in ultrabasic rocks of the Panton Sheet as disseminated grains, as primary segregated bands, and as secondary veins. One primary band up to 30 feet thick, consisting of alternating bands of chromite (up to one inch thick) and altered ultrabasic rocks, can be traced for over one mile. In addition, secondary chromite-rich veins up to 300 feet long and two feet wide have been found in magnesite. Grab samples from these deposits gave the following assays:

% Cr.	% Fe.	% Ni.	Pt. (dwt per ton)
Primary Band			
11.5	20.1		
12.5		0.15	0.4
Secondary veins			
19.47	22.3		
22.3		0.12	
21.7		0.2	2.0
19.5		0.09	1.5

The assay results for platinum are sufficiently high to warrant more detailed prospecting of the Panton Sheet.

COPPER

Small showings of copper minerals have been found throughout the area in rocks of many ages, but the only prospects of economic interest discovered to date occur in the Woodward Formation.

Ding Dong Downs Formation:

Amygdales of quartz and calcite containing native copper occur two miles south-south-west of Bulman Waterhole in highly epidotized basalt of the Ding Dong Downs Formation. The mineralization is near the contact with the Saunders Creek Formation and consists of scattered crystals of pyrite, and altered magnetite crystals which are surrounded by a halo of malachite staining. The known mineralized area is small, about 200 feet by 10 feet, and one sample of the basalt without amygdales assayed only 0.07 percent copper. The deposit is of no commercial significance, but thin, persistent veins of quartz and native copper (up to one inch wide), are known in the basalt in the same locality (J. Curruthers, pers. comm.), and we think that the Ding Dong Downs Formation warrants further prospecting.

Woodward Formation

Limonitic gossans in the Woodward Formation north of the Sophie Downs Granite containing secondary copper, lead, and zinc minerals were discovered during the regional mapping in 1962, and were further investigated in 1963. Two of the gossans are of sufficient size to warrant testing by diamond drilling. The mineralization was reported on by Gemuts (1963).

The two deposits, called Little Mount Isa and Ilmars Prospects, are on the western limb of a broad north-plunging anticline, the core of which is occupied by the intrusive Sophie Downs Granite. The Prospects occur near the top of the Formation in dolomite and dolomitic shale which has been isoclinally folded along axes plunging about 25° to the north. Both limbs of the folds dip steeply to the west. The area is complexly faulted, and the prospects appear to be localized along shear zones trending at a slight angle to the regional strike of the beds.

Little Mount Isa Prospect. The Little Mount Isa Prospect is a gossan about 1300 feet long and up to 75 feet wide, striking north and dipping 60° to the west. It forms a razor-backed ridge cut at about mid-point by a small westerly-flowing stream.

The gossan is composed of sheared, thin-bedded, dolomitic shale heavily impregnated with limonite, and coated and preserved by a shell of silica, manganese, and haematite. This shell in places gives the gossan the appearance of an iron-stained quartz lode. The lode contains horses up to 20 feet wide of non-gossanous mica schist, which separate gossans in the hanging-wall and footwall of the lode.

When broken open the gossan is highly leached, honeycombed, and boxworked, the main secondary mineral being limonite. Malachite and manganese oxides are present in minor quantities over most of the gossan, but two small caves at the foot of the ridge where the small creek cuts the lode are liberally coated with malachite and manganese oxide, as is a small cave on the southern end of the lode.

Ilmars Prospect. Ilmars Prospect lies about one mile to the north-east of Little Mount Isa Prospect and about 200 yards from the road to Saunders Creek Uranium Prospect. The gossan crops out near the crest and on the western face of a sharp ridge rising 50 feet above the immediate surroundings. It occurs in two bands of thin-bedded dolomitic shale separated over most of the length of the deposit by a lens of dolomite. The host rock is highly leached, and in many places heavily impregnated with limonite, cuprite, malachite, minor azurite, and rare smithsonite and cerussite.

The gossan strikes north and dips 65° west. It is 850 feet long, and averages about 60 feet wide, but over most of its length it is split by a horse, about 15 feet, wide of altered and unmineralized tremolite-bearing calc-silicate rock. In this area the footwall gossan is 25 feet wide and contains abundant secondary copper minerals in bands and small lenses. A sample assayed by the Bureau of Mineral Resources showed copper 19.1 percent, lead 0.34 percent, and zinc 1.0 percent. The hanging wall lens is up to 34 feet wide, and consists mainly of limonite-impregnated dolomitic rocks containing patches of cuprite and malachite.

The mineralization appears to follow a shear zone which trends about 5° north-west of the regional strike of the host rocks. The prospect appears to be confined to the carbonate rocks which are folded into an isoclinal syncline plunging north at about 18°, and as the keel of the syncline would be at no great depth below the prospect ridge, the copper mineralization could be shallow. Any lateral extension of the lode would be to the north in the direction of the plunge of the folds. Promise of such an extension is given by two shear zones, impregnated with limonite and stained with malachite, one 700 feet and the other 100 feet and both a few feet wide, which crop out about 1000 feet and 3000 feet north-north-east of Ilmars Prospect.

Both prospects warrant testing by diamond drilling. Limonite and manganese staining is common throughout the Woodward Formation, and although no secondary copper minerals were seen in these, detailed geochemical stream-sediment sampling of the area is warranted.

Several large iron and manganese-rich gossanous bodies were found in carbonate rocks on the northern end and western flank of the Black Rock Anticline. Despite an extensive search, no traces of base metals were found in these bodies, but as promising copper-zinc-lead prospects have been found in similar rocks in the Gordon Downs area to the south, the carbonate rocks warrant detailed prospecting.

Biscay and Olympio Creek Formations

Chalcopyrite and other base metal sulphides are minor constituents of auriferous quartz reefs in the Biscay and Olympio Creek Formation, but the occurrences have no commercial significance.

Lamboo Complex

Numerous small occurrences of secondary copper minerals are known in rocks of the Lamboo Complex (Harms 1959), but none are regarded as of economic interest. The mineralization is confined to small shear zones and rarely exceeds a length of 50 feet or a width of 2 feet: the largest seen was 100 feet long and 30 feet wide.

Whitewater Volcanics

Small amounts of copper mineralization were noted in two localities in the Whitewater Volcanics:

(1) Carbonate stains coat the surface of a waterfall in a creek five miles south of the Dunham River Jumpup.

(2) A thin isolated vein of quartz, arsenopyrite, and minor chalcopyrite crops out six miles north-east of Moonlight Valley Yard in the Lissadell Sheet area. The vein could only be traced for several inches in acid volcanics adjacent to a basic dyke.

Pyrite was also noted within the Volcanics of this area. In neither of the localities is the mineralization of commercial significance.

Fish Hole Dolerite

Showings of malachite and azurite were found in the Fish Hole Dolerite during 1963 (Plate 1), but none was greater than 50 feet long or two feet wide. The few samples taken from streams draining these rocks have high copper and nickel contents, and further prospecting of the formation may be warranted. The Dolerite is possibly a correlative of the Ding Dong Downs Formation, which contains copper mineralization in the southern part of the map area.

Older Dolerites intruding the O'Donnell Formation

Malachite and azurite coat joints in a uralitized dolerite sill intruding the O'Donnell Formation in Moonlight Valley (Lissadell Sheet area).

Carson Volcanics

Traces of secondary copper minerals were noted in amygdales of the Carson Volcanics in the Valentine Creek area.

Elgee Siltstone

Small flakes of azurite coat bedding planes of the Elgee Siltstone west of the Chamberlain River, in the south-eastern part of the Lissadell Sheet area.

Mendena Formation

Harms reports copper minerals at Plants Homestead as 'minor veinlets of copper carbonate, oxides and chalcocite in a siltstone a few chains south of the homestead. Individual veins do not exceed four feet in length and three inches in width; their origin is not apparent'. Only flakes of carbonate on joint surfaces were seen during the 1963 survey.

Hart Dolerite

Traces of copper carbonate are recorded from two localities within the Speewah Laccolith:

(1) Martins Silver-lead Prospect has azurite and malachite as scattered patches within quartz (Harms, op. cit.)

(2) Azurite was noted in a shear zone associated with epidote and quartz about five miles north of the Speewah Homestead.

Traces of copper are common throughout the Hart Dolerite in the area but the likelihood of finding economic deposits is remote.

Antrim Plateau Volcanics

Small occurrences of copper minerals have been reported from widespread localities in the Antrim Plateau Volcanics. Most consist of carbonates, chalcocite and cuprite: native copper is also found, either as vesicle fillings or as sparse disseminations. The basalt immediately underlying Headleys Limestone in the Rosewood Wall area contains no visible copper minerals, but channel samples six feet long across it assayed about 0.6 percent copper (Harms, 1959). Other samples from the same horizon farther afield showed no significant copper content, but the possibility of finding economic low-grade copper bodies in the Antrim Plateau Volcanics cannot be discounted.

Headleys Limestone

Minor copper stains are found in the Headleys Limestone in widespread localities in the map area. The largest are found in the Rosewood Wall, near Old Lissadell Homestead, and south of Bungle Bungle Outcamp, but they are of small extent and of low value.

The mineralization in the Rosewood Wall consists of disseminated and nodular chalcocite and associated secondary carbonates which are generally concentrated near the base of the Limestone. It occurs as discontinuous patches over a distance of three miles, and assays from two shallow trenches gave the following results:

Costean 1, 0.18 percent copper over 11 feet
Costean 2, 5.82 percent over six feet

The values are consistently low except for 30 inches of 11.5 percent copper in costean 2 which have unduly weighted the results.

Matheson & Teichert suggest that the copper has been leached from the volcanics by surface waters and fixed by the limestone. Alternatively, the copper may be of sedimentary origin, having been deposited from water richer in copper because of volcanic action.

Small patches of secondary copper minerals occur in the uppermost limestone of the Negri Group near Mount Elder, and minor copper carbonates occur in joints in undifferentiated Cambrian limestone underlying the Ragged Range Conglomerate on the western scarp of the Ragged Range. The occurrences are of academic interest only.

GOLD

Gold was discovered in the Kimberley Region in 1884 by Hardman (1885) during the course of a reconnaissance geological survey of the area. He reported promising alluvial prospects over a large area of metamorphic rocks, and in the ensuring rush, large quantities of gold were quickly won. However, the auriferous gravels, though mostly rich, were thin and of small extent, and the field was rapidly worked out. By 1890, when Woodward (1891) visited the field, there were very few alluvial miners still working.

Most of the alluvial gold was readily traced to its source, and by the time of Woodward's visit, all the reefs known today had been discovered, partly developed, and abandoned. The small size of the reefs, remoteness of the area, lack of water and fuel, and in some cases, the mineralogy of the ores, all contributed to the failure of the mines (Woodward, op. cit.). Since Woodward's time spasmodic attempts have been made to re-open the larger mines, but most appear to have been unprofitable.

Almost all of the mines are located in two auriferous belts, the Halls Creek-Ruby Creek area, and the Grants Creek area. These areas were mapped in 1937 and 1938 by Finucane, and his reports (1938 and 1939) provide a valuable reference.

(i) The Halls Creek - Ruby Creek area.

The gold in this area is found in small generally concordant, quartz reefs, either in basic rocks of the Biscay Formation, or in greywacke and slate of the Olympio Creek Formation. Most of the reefs appear to have been worked only in the oxidized zone, and the gold occurs free, generally in a very finely divided state, though specimen stone containing coarse gold was not rare. The reefs are rarely longer than 700 feet or wider than five feet, and as their average grade is low (between one and three penny-weights gold per ton), work has been confined to selective mining of rich shoots.

The most important mines of the area were: Ruby Queen (recorded production 8220 ounces fine gold), St. Lawrence (1533 ounces), Mount Bradley (1563 ounces), and Golden Crown (1281 ounces).

(ii) Grants Creek Area

There is no record of the gold production from the Grants Creek area which is located five miles south-east of Alice Downs Homestead, but it is believed that only a small amount of gold was won, mostly from alluvial diggings. The field was almost worked out at the time of Woodward's visit in 1890, when only three men were working in the area. Several reefs had been found, and some development had been done, including the erection of a five-head battery, but the ore had proved unsuitable for amalgamation, and lode mining had been abandoned by 1890. Finucane reported on the area in 1939, but it was deserted at the time and little work appeared to have been done in the intervening years.

There are nine mines in the field, which covers an area about three miles by one mile. The reefs are mostly small, and are generally low grade. The largest are the Perseverance Reef, about 700 feet long and up to 20 feet wide, and the Caledonian Reef, about 1000 feet by eight feet. The richest is the Star of Kimberley, which averages 7.65 dwt of gold per ton over a length of 470 feet and an average width of 40 inches (Finucane, op. cit.). The reefs are quartz containing pyrite, chalcopyrite, galena, and some calcite, and it appears that most of the gold is associated with the galena. The lodes are all within tuffaceous greywacke or basic igneous rocks of the Biscay Formation, and most trend north-east, parallel to the regional strike of the region.

The only other lode mines worthy of note are Duffers Mine, a small reef in basal Olympio Creek sediments which was worked until recently, and the Reform Mine in the head of the Mary River, which in 1894 produced 210 fine ounces of gold.

Alluvial gold is also known to have been mined north-east of Mount Coghlan, in the black Elvire River. During the present survey, a few pits on small quartz reefs were observed in the Olympio Creek Formation miles south of the Ord River.

IRON

Deposits Near Pompeys Pillar - Western and Eastern

Beds of low grade siliceous hematite crop out over a total strike length of about ten miles near the base of the Golden Gate Siltstone along the crest of a high cuestal range, situated at the south-west extremity of the Carr Boyd Ranges and lying about six miles north of Mount Nyulasy. They have been studied, and scattered samples taken for assay, by Harms (1959) and MacLeod (1963).

Only two deposits approach ore grade: the 'Western Deposit' lying about seven miles north of Mount Nyulasy; and the 'Eastern Deposit' lying aboutsix miles north-east of Mount Nyulasy. The two deposits are separated by the Ivanhoe Fault, which in this locality strikes between about 240° and 260°, and which has displaced the 'Eastern Deposit' about 10000 feet east of the 'Western Deposit'. The 'Eastern Deposit' is the larger of the two, but the overall grade is lower and access more difficult.

The deposits crop out on the dip-slope of the range and consist of beds of massive hematite with scattered sand grains and hematitic sandstone. Ferruginous shale and quartz sandstone are intimately interbedded with the iron-rich rocks and intercalate with them along strike. The massive hematite is cross-bedded, indicating a clastic origin, while associated sandstones show abundant shallow-water sedimentary features. Individual hematite beds are up to fifteen feet thick. Superficial pisolitic and botryoidal goethite occurs on the weathered dip slopes.

The 'Western Deposit' ranges between fifteen to thirty-five feet in thickness and is about 9000 feet long. The width varies up to about 400 feet (MacLeod, 1963). The deposit is accessible by means of four-wheel drive vehicle and was tested by drilling during 1962 and again more exhaustively in 1963-64. Results are not available for publication. A brief study of surface outcrops (MacLeod, 1963) indicates about six million tons of 60% Fe_2O_3 ore may be available by means of very selective mining. Silica is the main impurity.

The 'Eastern Deposit' crops out over a strike length of about four miles and is thirty-five feet thick. It caps a dip-slope, dipping 15° to 20° east, for a width of several hundred feet. Numerous small cross-faults, with throws of a few feet, cut the orebody. Individual beds range up to 60% Fe_2O_3 (Harms, 1959; MacLeod, 1963), but numerous intercalations of sand and shale make it unlikely that ore in excess of 50% Fe_2O_3 could be mined by conventional techniques. Up to twenty million tons of iron-rich material is indicated, but only a small fraction of this can be considered as possible ore (MacLeod, 1963). The deposit was not accessible by vehicle during 1963.

The overall low grade and limited extent of the Deposits make it unlikely that they could be mined economically under current market conditions to provide a direct shipping ore. However, as much of the hematite-rich zone is coarsely granular, the deposits could conceivably provide a substantial tonnage of beneficiable ore.

<u>Bandicoot Range Beds</u>

The Bandicoot Range Deposits lie two miles west of the Ord River Diversion Dam and one mile east of the Ivanhoe Fault Line in the Cambridge Gulf Sheet area. The Kununurra - '38 Mile' road passes along the northern edge of the Range. The deposits occur within the Bandicoot Range Beds of the Carr Boyd Succession.

Five widely spaced beds, up to twenty feet thick, of hematitic sandstone, and minor sandy hematite and botryoidal hematite, crop out along the crest of the Range, which has up to 750 feet relief. They dip 20° south and can be traced for up to two miles along strike.

The deposits have not been tested or assayed. Visual examination indicates that the material probably contains less than about 45% Fe_2O_3. Silica is the main impurity. The attitude of the beds would make mining difficult and the deposits cannot be considered as economic propositions at the present time.

O'Donnell Formation

Scattered beds of hematitic sandstone up to twenty feet thick, which have been traced for up to one mile along strike and small occurrences of massive hematite resulting from metasomatism adjacent to dolerite intrusions, occur within the O'Donnell Formation in the O'Donnell Range - Wilson River area. None of these deposits are of economic significance.

LEAD

Small deposits of lead are known in Halls Creek Group, granite of the Lamboo Complex, and Younger Proterozoic rocks of the Kimberley Basin Succession, but none appears to offer economic prospects.

A small patch of sparse, disseminated galena in marble of the Olympio Creek Formation crops out in the head of Osmond Creek two miles east of the Halls Creek Fault. The deposit is too small to warrant testing, and geochemical prospecting in the vicinity was undertaken by Broken Hill Pty Ltd, but no further lead mineralization was located. Galena is a minor constituent of the auriferous quartz reefs in the Grat Grants Patch goldfield, but they are of no significance as base-metal prospects.

A prospect known as Boxers Lead-barytes Show occurs in a coarse-grained granite south-west of Argyle Downs Homestead. It is adjacent to the Halls Creek Fault, and can be traced for about 20 feet (Harms, op.cit.).

Two deposits are found in the Hart Dolerite of the Speewah area.
(1) Martins Silver-lead Prospect (Blachford, 1927) is situated on the north-eastern side of the domed intrusion, on its contact with the Speewah Group. The mineralization is a flat narrow vein on top of the granophyre of the Hart Dolerite exposed where almost all of the overlying Speewah Group has been eroded.
(2) Galena and fluorite occur in a shear zone about five miles north-north-west of the old Speewah Homestead. The zone can be traced for almost ten miles, but the galena and fluorite occur in lenticular veins of quartz over a strike length of about 400 feet within the zone.

Traces of galena were noted in the Valentine Siltstone above a dolerite sill near a small fault two miles north of the Dunham River. Galena has also been reported from near Mount Lookout, and a hand specimen showed minor galena associated with quartz.

NICKEL

Nickeliferous chrysotile has been found in a small shear zone in ultrabasic rocks of the Panton Sheet, but the deposit has no commercial significance.

PETROLEUM

The possibility of the occurrence of petroleum in the East Kimberley region was first seriously considered in 1920 when Mr. Okes discovered a specimen of asphaltite near the junction of the Ord and Negri Rivers. The Okes-Durack Kimberley Oil Company was formed and a bore was sunk on an anticline north of Ord River Homestead, in sediments of the Negri Group. The bore began in Linnekar Limestone, passed through Nelson Shale and Headleys Limestone, and penetrated over 400 feet into Antrim Plateau Volcanics. No indications of the presence of oil were found, and Wade (1924) stated that it was impossible that oil was present in commercial quantities in the Ord River area.

URANIUM

Uranium has been found in two localities in the Ord River Region, (1) at Saunders Creek and (2) near Dunham River Homestead.

(1) Saunders Creek Prospect

Saunders Creek Prospect is situated about 20 miles north-east of Halls Creek on the western limb of a tight anticline in Halls Creek Group.. It was discovered in 1954 and was reported on by Walpole & Prichard (1958), and Ruker (1961). One diamond drill was put down in 1959, but only uneconomic mineralization was found (Mercer, 1961).

The radioactivity is due mostly to thorogummite, and is confined to basal quartz pebble conglomerate, quartz sandstone, and quartz greywacke of the Saunders Creek Formation. The drill hole, 734 feet long, intersected the radioactive beds between 520 feet and 618 feet, or 400 feet to 450 feet below the surface, in unoxidized material. Assay results were disappointing, and the best values were 0.16 percent eU_3O_8 from 543 feet to 543 feet 4 inches, and 0.04 percent eU_3O_8 from 538 feet to 539 feet 4 inches. The most radio-active mineral from the core was identified by its X-ray diffraction pattern as thorogummite which had thorium/uranium ratios of between 3:1 and 2:1. Indicated uranium values were thus well below economic and prospect was abandoned.

(2) Dunham River Homestead

Uranium was discovered south of Dunham River Homestead by United Uranium N.L. in 1954. It is situated close to the Dunham Fault near the Dunham Jumpup.

The northern mineral leases (M.C. 39, 42; de la Hunty, 1955) cover a basic dyke intruding sheared granite. Autunite lining joints in the dyke has been prospected by shallow costeans and a single shaft : the shaft is now inaccessible. The radioactivity of the dyke was tested for 4000 feet, but only the prospect area gave high readings.

The second prospect straddles the Great Northern Highway. North of the Highway several costeans cut the contact between sheared granite and quartz sandstone of the basal O'Donnell Formation. Torbernite occurs as a band up to four inches wide, in sheared granite close to the sandstone. During 1963 the Department of Main Roads constructed a new road which passes immediately south of the prospect, but no further minerization is visible in the road cutting.

Other claims along the Dunham Fault to the south held by United Uranium were reported on by de la Hunty (op. cit.). These were not located during the 1963 survey, but are apparently of less significance than the northern ones.

WATER

Although the Ord River Region has an annual rainfall of from twenty to thirty inches, most of this rain falls during the wet season from November to March. The rest of the year is hot and dry, resulting in evaporation of 100 to 110 inches per year. Surface waters, unless fed by groundwaters, are not permanent. Because most of the springs occur in the more rugged parts of the area where cattle grazing is impracticable, the local cattle industry relies heavily on subsurface water supplies. The hydrogeology of the region has been described by Passmore (1964).

Groundwater occurrences depend on the local rock-type and structure and on the thickness and permeability of alluvium or weathered bedrock. The thickest deposits of alluvium are found around the estuaries of the major rivers, where they are invaded by sea water and are therefore unsuitable as aquifers. Thin deposits occur along many rivers and creeks farther inland and, provided storage is adequate, these deposits can yield large quantities of water from sandy alluvium where the rivers traverse sandstone or granite.

Passmore (1964) summarizes the groundwater occurrences in the various rock types of the area as follows:

1. Of the Proterozoic rocks, the shale, slate, greywacke and low grade metamorphic rocks are poor aquifers as they have low permeability, and igneous and high grade metamorphic rocks yield water only where permeable weathered material overlies the solid rocks or where jointing or faulting allows storage and transmission of water. Jointed siliceous sandstone gives rise to many springs, and is a potential aquifer although it is hard to drill, and so far only small supplies have been obtained. The water from Proterozoic rocks is of good quality and is suitable for domestic purposes and stock.

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'In the Palaeozoic basins the basalt, limestone and sandstone are all good aquifers. The basalt and sandstone yield good quality water but the limestone, which is interbedded with shale, yields water which contains up to 1130 p.p.m. total dissolved solids and is therefore in places suitable only for stock.

'From the comparisons of the detailed analyses of eight samples from some of the aquifers it can be seen that the concentrations of the principal mineral constituents of the ground waters are controlled by the minerals present in the aquifers. The shale and limestone of the Negri Group yield calcium and sulphate to the groundwater, and the crystalline rocks yield magnesium and sodium. Siliceous sandstone is resistant to sp;ution and its water contains little dissolved matter.

'In a few areas where the water has a fairly high initial salinity, concentration of surface waters by evaporation causes salinities which are too high for domestic or stock use'.

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