Copy 3

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1953, No. 146

PRELIMINARY REPORT ON

THE GEOLOGY OF THE FITZROY BASIN

KIMBERLEY DIVISION,
WESTERN AUSTRALIA

JUNE, 1953

by

D. J. GUPPY

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1953, No. 146

PRELIMINARY REPORT ON

THE GEOLOGY OF THE FITZROY BASIN

KIMBERLEY DIVISION,
WESTERN AUSTRALIA

JUNE, 1953

by

D. J. GUPPY

CONTENTS.

PAGE.

PAGE.

Enclosures have not been supplied in the hardcopy of record 1953/146.

ENCLOSURES.

INTRODUCTION.

PURPOSE AND SCOPE OF SURVEY:

The investigation of the Fitzroy Basin and adjacent areas was commenced in 1948 when a detailed survey was made of the Nerrima Structure and a widespread reconnaissance by land, sea and air was completed.

The investigation was in the charge of D. J. GUPPY, assisted by A.W. LINDNER, J. H. RATTIGAN (1949-1952), J. N. CASEY (1950-1952), J. O. CUTHBERT (1948-1949) and A. B. Clarke (1952).

The Fitzroy Basin survey was completed in 1952 and during this period 24 months were spent in the field and the remainder in office preparation. Approximately 40,000 square miles were examined during the survey and detailed maps covering an area of 28,000 square miles have been prepared at 1 inch = 1 mile, 1 inch = 2 miles and 1 inch = 10 miles.

The area has been examined in the past in varying detail by three geological parties on behalf of local and overseas oil companies. The purpose of this survey was to examine the complete sedimentary sequence in sufficient detail to solve the problems encountered by previous surveys and eventually to be in a position to assess to a reliable degree the petroleum prospects of the area based on the examination of surface outcrop.

The assessmentof the petroleum prospects of the area has very definite limitations in that the potential source rocks (Devonian & Ordovician) are limited to the extreme eastern margin of the basin and nothing is known about their distribution or facies elsewhere under the cover of Permian and Mesozoic sediments.

For m preparation controlled template plots, divided into 1 mile sheets of the Army Series, were prepared by the Lands and Surveys Branch, Western Australia and the Army Survey Corps. During the field work information was plotted directly on the photographic prints and transferred at a later date to the photo-scale sheets. The aerial photography of the area, which was conducted by the Survey Squadron of the Royal Australian Air Force, has been the basis of all mapping, as reliable topgraphic maps of the area were not available.

CLIMATE:

The climate of the area is monsoonal with normally sharply defined wet and dry periods. The annual rainfall ranges from about 18 inches in the southern part of the Basin to 31 inches in the Oobagooma area in the north. With rare exceptions the annual rainfall is received during the period December to March, During abnormal climatic conditions over 10 inches have been recorded in a brief period during the dry months from May to September. Provision should always be made for such a possibility when planning operations in the area.

VEGETATION AND SOIL (Christian & Stewart 1952)

The vegetation of the area is controlled to a large extent by the nature of the soil which in turn is specific for the particular formation over which it has formed.

Five main soil and vegetation types are recognisable. These are broadly comparable throughout the area but vary in detail in both soil quality and vegetation population from one area to another.

In order of importance from an agricultural aspect they are:- Levee Lands, Black Soil Plains, Alluvial Plains, Pindan and Stony Lands.

LEVEE LANDS. These areas are found adjacent to the main stream courses such as Barker River, Lennard River, Fitzroy River, Margaret River and Christmas Creek. The Levee Soils support a woodland of Eucalyptus tectifica, Eucalyptus microtheca, Eucaplyptus Papuana, Eucalyptus camaldulensis and a ground flora including Chrysopogon, Aristida and Schima nervosum. These areas contain the highest quality soils known in the area and with sufficient water supply would probably be suitable for wide variety of crops.

BLACK SOIL PLAINS.- These plains, which are notable for the development of shrinkage cracks, which produce an extremely rough surface, are found scattered throughout the area. To a large extent they are related to the underlying formation and are typically developed over calcareous formations such as Mt. Pierre Group, Fairfield Formation and Blina Shale. The plant population is restricted to grasses, including Chrysopogon sp., Dichanthium fecundum and Astrebla sp. The soil is heavy and clayey and usually water logged after rain. Development for agricultural purposes would be limited.

ALLUVIAL PLAINS (Flood Plains).- These areas are adjacent to the main rivers and marginal to the Levee Lands and in some areas are subject to annual flooding. The vegetation is more varied and form a medium to tall woodland including Eucalyptus tectifica. Eucalyptus microtheca with a ground flora including Chrysopogon sp., Schima nervosum, Aristida spp., Eriachne sp., Heteronogon contortus, Isoilena spp., Xerochloa spp., Sorghum spp., Dichanthium fecundum and Astrebla squarrosa. The soils are of varying quality and in places suitable forirrigation and crop growth.

PINDAN.- Areas of undulating sandy soil, with or without fixed sand dunes, and supporting a vegetation ranging from sparse woodland to low thick scrub, are known locally as Pindan. Sparse Eucalyptus spp. a dense layer of Acacia spp., and grasses including Chrysopogon, Aristida, Plectrachne spp., Eriachne spp. and Triodia spp. are typical.

Generally speaking the Pindan is not suitable for irrigation but in places where heavy textured subsoils are present, limited agricultural development may be practicable.

STONY LANDS.-These are gently to steeply sloping areas with a thin cover of soil over country rock. Soil cover has frequently been completely removed. The vegetation is a hardy population including a large proportion of Triodia spp. and Plectrachne spp. with low trees and shrubs sparsely distributed.

In this large area only a comparatively small proportion is suitable for large scale agriculture due to the limiting factors of climate, water supply and the low quality of the soil. Very large areas are, however, suitable for stock utilization and much developmental work is required to bring the area to its potential productivity.

INDUSTRIAL DEVELOPMENT:

Industry with rare exceptions is limited to, primary production and in particular wool and beef. Pearl shell, mining and pig production are other industries of lesser importance. Secondary industry is restricted to meat-works at Broome and Glenroy, where beef cattle are killed and processed for home consumption and export as chilled carcasses.

The development and modernisation of the area has been slow and uninspiring with the exception of the sheep stations, where modern technique and intensive development has been found a paying propo... In general the modernisation of the cattle industry has not been attempted and in some areas the standard has shown a tendency to fall. Strong positive measures are required to lift the industry to a level where a reasonable degree of productivity is attained and legislation is required to prevent the misuse of the land and the consequent problems it produces in soil erosion and extinction of natural grasses.

In comparatively recent years a first class inter-station air service has been provided and this, together with the frequent air services from Perth, the coastal shipping service and an adequate road haulage system, provides (at a reasonable cost), mail and freight services comparable with more closely settled areas.

PREVIOUS INVESTIGATION.

The original geological investigations in the area were under the leadership of Hardman (1884, 1885), the Government Geologist of Western Australia.

Foord, Nicholson and Hinde (1890) described fossils from Hardman's collections.

Etheridge (1889) recorded Stenopora and Evactinopora from Mt. Marmion and Basedow (1918) described polyzoal remains from Balmaningarra Station near Mt. Marmion.

In 1915, Etheridge described Calceolispongia from the Noonkanbah Formation at Mt. Marmion; this genus has since been recorded from the Bitauni and Baslec Beds in Timor, from the Umaria Stage of Peninsula India, from Tasmania and the Carnarvon Basin of Western Australia.

Wade (1924, 1936 and 1953) initiated systematic stratigraphical studies of the Permian sediments together with a rapid reconnaissance of the Devonian sediments. Wade's published results have, to a large extent, been the basis of all later work in the Permian. Wade (1932) collected ammonites from the Nura Nura Member of the Poole Sandstone. These were determined by Miller (1936) as Metalegoceras clarkei and Thallassoceras wadei. Teichert (1924) has recorded Metalegoceras striatum from the same locality.

Chapman and Pass (1937) described fusulinids collected by Wade from the Upper marine beds of the Liveringa Group and suggested a late Artinkian age. Information obtained during the present survey has shown that the beds indentified as Artinskian by Chapman and Pass were of Triassic age and it is believed that the fusulinids were actually bone fragments.

A more detailed examination of a large part of the Fitzroy Basin was made by Kraus (1942), Findlay (1942 and Teichert (1949). This survey was based on the study of selected sections with fossil collections. The programme was interrupted by the Pacific War but had established a sound basis for later work, particularly in the Devonian sequence.

More recently the area has been traversed by Reeves (1949). His published results created several problems to which particular attention was directed by the writer.

Geological investigations of a more limited nature have been published by Jack (1906) and Blatchford (1927).

A paper published by Chapman (1924) described fossils collected by Wade and records 15 species of hydrozoa, corals, crinoids and cephalopods of Devonian age.

Hosking (1933) examined the fossils collected by Blatchford and Talbot in 1929, Wells in 1922 and a collection from near Mt. Pierre Gorge.

The goniatites collected by Clarke and Talbot from the Mt. Pierre area were described by Delepine (1935) who concluded they indicated Famennian age and were equivalent to Stage III of the Upper Devonian of Europe.

Hill (1936) examined earlier collections of corals from the Devonian and concluded that Middle and Lower Upper Devonian forms were represented.

Contributions to the Devonian palaeontology of the area were prepared by Teichert (1939, 1940, 1941, 1943, 1947, and 1949).

More recent papers have been published by Fenton (1943) on stromatolitic algae, Fletcher (1943) Conocardium. and Howell (1944) prepared a short paper on sponges.

PHYSIOGRAPHY.

The Fitzroy Basin and adjacent areas are divided into the following physiographic provinces;-

- King Leopold Ranges
- Limestone Ranges
- Fitzroy Valley
- Desert Plateau
- Dampier Land Peninsula

KING LEOPOLD RANGES:

The ranges constitute a natural boundary to the area in the east and consist of rugged strike ranges with incised valleys with a local relief of up to 500 feet. the topography is closely controlled by structure and lithology and whereas the ranges consist of doleritic rocks with a significant accumulation of alluvia. With the exception of the Fitzroy and Barker Rivers, the streams are controlled by structure and are actively down-cutting. The Fitzroy and Barker Rivers differ from the other river courses in this area in that they disregard all natural barriers and flow almost in a straight line through the ranges. The streams are probably of the superposed type. On the Kimberley Plateau, the comparatively flat area of considerable extent to the north of the Glenroy-Tableland region, flatly-bedded Upper Proterozoic sediments unconformably cap the more strongly folded quartzite section and have created a distinct physiographical province in which the major streams of the Fitzroy Valley originate. These flatly bedded sediments were probably much more extensive than their present outcrop would indicate.

Owing to the high percentage run-off, created by the combination of rock types and restricted amount of soil and alluvia, large quantities of water move down the King Leopold Ranges' drainage system after falls of heavy rain during the monsoonal season. This water is the main source of flooding in the lower reaches of the major rivers in the Fitzroy Valley.

LIMESTONE RANGES:

The ranges form an orderly feature from Bugle Gap (near Christmas Creek Homestead), north-west to Limestone Spring, a distance of 180 miles. The area south of the Fitzroy River contains a system of broken limestone ranges over a width of 12 miles with gently undulating areas between, underlain by softer sediments. North of the Fitzroy River, except for narrow passes, the Ranges are unbroken to Limestone Spring with a width of about 10 miles on the Oscar Plateau, narrowing to a few hundred yards to the north in sections of the Napier Range.

The limestone masses have developed a typical, very rough, often impenetrable, karrenfeld which represents an advanced stage in the karst cycle, Soil is restricted to surrounding areas of more easily eroded sediments and scattered depressions in the ranges. Underground solution is largely restricted to surface steams which have taken underground courses and emerge again at the surface. Notable examples are Tunnel Creek in the Napier Range, which passes through the Napier Range over a distance of almost a mile, and the stream which emerges at Cave Spring in Bugle Gap after a similar distance underground. Caves of various sizes, at ground level, have been formed through the ranges. The underground streams are of particular importance as they are an unfailing perennial source of water in what may be a waterless area in adverse seasons.

Springs of varying flow are found throughout the ranges but are normally nor permanent and appear to be controlled by annual rainfall.

The region between the Limestone Ranges and the King Leopold Ranges is underlain by the basement rocks of the area - schist, gneiss, porphyry, etc. The topography is subdued although the surface is frequently very rugged. This area represents the former undulating surface on which the sediments of the King Leopold Ranges and the Limestone Ranges were deposited. There is reason to believe that this surface is of considerable antiquity, at least epi-Devonian, with some comparatively recent dissection.

FITZROY VALLEY:

This area, which includes the valleys of the Fitzroy, Lennard, Barker and Margaret Rivers and Christmas and Jurgurra Creeks, covers an area of approximately 10,000 square miles. The entire area is comparatively flat and underlain by sediments of Permain and Mesozoic age. Areas with notable relief are confined to areas of structural relief such as Poole Range, St. George Range, Mt. Mynne and Grant Range. Scattered small hills, or mesas, relics of a former land surface, are scattered sporadically through the area.

The major streams and subsequents have steep banks and appear to be actively down-cutting in inland areas into the alluvial filled valleys.

The soil cover is variable and a large portion, apart from areas of outcrop, is covered by poor grade sandy soil or simply by sand.

DESERT PLATEAU:

The Desert Plateau (and the Great Sandy Desert) froms a natural limit to the Fitzroy Valley to the south and south-west and extends to the south to the vicinity of the Tropic of Capricorn. This large flat desert area is characterised by numerous fixed parallel sief sand dunes, trending east to east-north east and extending with minor breaks for over 100 miles with an average altitude of 80 feet and an average amplitude of ½ mile. The monotony of the area is broken only by the scattered and small outcrops, e.g., McLartys Hills and the claypans which frequently form between the dunes and in areas of interior drainage, e.g. Gregory Slat Sea.

From the west, the desert surface rises gradually from sea level to approximately 1000 feet, the general level of the Desert Plateau. From the north the grade is again gradual from the Fitzroy Valley. In the Edgar Ranges, however, erosion has formed a break-away on the northern edge of the Plateau at the headquaters of Jurgurra. Creek.

There is practically no drainage system within the area, although after heavy rain there is a limited movement of surface water in areas of interior drainage such as Sturt Creek.

As far as is known, outcrops in the area are confined to sediments of Permain and, more commonly, Mesozoic age.

DAMPIER LAND PENINSULA:

The province is restricted to the area between the Indian Ocean and King Sound and is actually a tongue of the Desert Plateau which extends to the north over Mesozoic sediments. This area also has the remnants of a former plateau, relics of which remain near the headwaters of the Frazer River. Partly eroded fixed sief dunes are found throughout this area which now supports a dense pinden vegetation in a 20-30 inch rainfall area.

Outcrops are restricted to coastal cliffs and scattered mesas, particularly surrounding the upper reaches of Frazer River.

The maximum relief of the area is 3,0700 feet from sealevel to Mt. Ord in the King Leopold Ranges. The Kimberley Plateau has an average altitude of 1000 feet with higher points such as Tableland Homestead at 2,300 feet.

South-west of the Limestone Ranges the altitude drops rapidly to 400 feet at Fitzroy Crossing and then gradually to sea-level at the coast,

The area between the western scarp of the King Leopold Ranges and the Fitzroy Valley - including the Limestone Ranges has an average height of between 800 and 1,100 feet.

The 1000 feet level is a well expressed surface over a large area and is apparently the relic of a former land surface.

The grading of the primary streams is strongly affected by the rock types over which they flow during their long courses. In the upper reaches of the Fitzroy River from Tableland Homestead to Fitzroy Crossing the grade is 2000 feet in 100 miles while in the lower course from Fitzroy Crossing to King Sound the grade is 400 feet in 160 miles. As a result there is and has been aggradation taking place in the Fitzroy Valley for some considerable period and the river courses are entrenched in deeply filled alluvial valleys. In the upper reaches, active degradation is continuing.

In the Fitzroy Valley the land surface has a gradual slope towards the coast broken by the areas of high country mentioned previously, where an upper level of approximately 1000 feet is again common.

The Dampier Land Peninsula rises to approximately 800 feet in the central part of the Peninsula with a regular slop seawards.

STRATIGRAPHY.

PRE-CAMBRIAN (Table I)

Although these rocks were not directly involved in the investigations it was considered necessary to spend a reasonable length of time studying them to obtain a knowledge of the types of sediments and the structure. With this information available the effect of these sediments on the lithology and structure of younger deposits can be assessed with considerable more reliability.

LAMBOO COMPLEX.- The Complex is composed of a variety of igneous and metamorphic rocks which outcrop chiefly in a belt between the Devonian sediments and the outer scarp of the King Leopold Ranges. Rock types indentified during widely spaced traverses over these rocks include granitic rocks, acid porphyry, diorite, dolerite, aplite, basic and acid igneous lavas, schist, gneiss, quartzite with numerous quartz reefs. Practically nothing is known of the complex structure of these rocks and the age has been tentatively considered Lower Proterozoic and may include rocks of Archaeozoic age.

Small areas of the Complex have been mapped where they outcrop amongst Devonian sediments adjacent to Pillara Range and the southern Outcamp Range. Schists associated with sharp folding in the quartzites of the Oscar Range are probably rocks of the Lamboo Complex.

Mineralisation has been known in rocks of the Lamboo Complex for many years as the original gold discovery in Western Australia was in rocks of this age near Halls Creek. Subsequently, small qualtities of lead, tin, mica, beryl, wolfram and scheelite have been mined intermittently.

KING LEOPOLD FORMATION. Definition. - The unit outcrops typically in the King Leopold and Precipice Ranges but has a much more extensive area of outcrop east of the present map coverage in areas which have not been systematically mapped during this survey. The sediments which are mainly quartzites in outcrop, unconformably overlie the Lamboo Complex and are unconformable over lain by the Mornington Volcanics.

Lithology.- Although no detailed work has been attempted it is considered probably that the greater part of the section will be quartzite although the possibility exists that some shaly beds are interbedded. In places the basal beds are conglomeratic and contain well rounded cobbles and pebbles. Conglomeratic quartzites are a feature of the strongly folded beds forming the Oscar Range and which it is considered are probably portion of this Formation.

Thickness.- No reliable estimate of thickness can be given without further study of the Formation.

Age.- No fossils have been observed in the Formation and an Upper Proterozoic age has been tentatively assigned.

MORNINGTON VOLCANICS. Definition.- The formation is typically developed in the vininity of Mornington Homestead (Long. 126° 06' E., Lat. 17° 31' S.). The formation also outcrops between Precipice Range and Lady Forrest Range and north of Mt. House Homestead. Further areas of outcrop have been observed north and east of the accompanying map coverage.

The Volcanics unconformably overlie the King Leopold Formation and are conformably overlain by the Warton Beds.

Lithology.- The formation has not been examined in detail but during rapid reconnaissance traverses the following rock types were observed: grey-green, dense, fine-grained andesite, in places amygdaloidal, medium-grained dolerite. Indurated shale and quartzite occur interbedded in the sequence and intrusions of basalt and quartz in the form of dykes and veins were noted.

Thickness and Age.- No estimate of the thickness of the formation can be given and the age has been tentatively assigned to Upper Proterozoic.

WARTON BEDS. Definition.- Outcrops of the formation are typically developed in the Warton Range (Long. 126° 27' E., Lat. 17° 24' S.) and a large area to the north along the Hann River, east towards Tableland Homestead, and the Precipice Range. The unit has a similar pattern on aerial photographs to the King Leopold Formation. Outcrops examined contained well bedded, medium grained to fine conglomeratice, white to light brown quartzite, red micaceous sandstone and shale.

The unit is apparently conformable with the underlying Mornington Volcanics and is overlain unconformably both by Walsh Tillite and Mt. House Beds.

Thickness and Age.- No estimate of thickness can be given and tentatively an Upper Protorozoic age has been assigned to the Warton Beds.

WALSH TILLITE. Definition.- The formation was originally examined and named in outcrop on the headwaters of Walsh Creek (Long. 125° 35' E. Lat. 17° 12' S.). From a study of outcrop and aerial photographs further outcrops of the Tillite are presumed to occur near Glenroy Homestead and along the Hann River. (Fig.).

The formation unconformably overlies the Warton Beds and is conformably overlain by the Mt. House Beds.

Lithology.- In the type area on Walsh Creek the formation consists of an extremely unsorted sediment ranging in size from silt to boulders (up to 7 feet across) and in which bedding is absent or very crudely developed. The matrix consists of grey-green and red siltstone and unsorted sandstone. Erratics are predominantly quartzite of types occurring in the Warton Beds, together with rare igneous rock types. Boulders are commonly faceted and show striations.

Thickness and Age.- The formation is a lensing unit with variable thickness. No estimate of thickness is possible without more detailed work. No evidence of the age of the Tillite has been discovered and it is tentatively placed in the Upper proterozoic.

MT. HOUSE BEDS. Definition.- The unit has an extensive distribution on the Kimberley Plateau (Fig.) and beyond the accompanying map coverage. The type area was examined in the vicinity of Mt. House (Long. 125° 44' E., Lat. 17° 08' S.) Where the Beds unconformably overlie the Warton Beds and conformably overlie the Walsh Tillite. No younger sediments were observed to directly overlie the Mt. House Beds.

Lithology.- The section in the Mt. House area consists of interbedded siltstone, sandstone and quartzite with bands of limestone and dolomite. The sediments are intruded by sills of dolerite.

Thickness and Age.- No estimate of thickness is available at this stage. Fossils have not been observed in the formation but a diligent search in the calcareous bands may eventually reveal the presence of recognisable fossil remains. For the present the unit is placed in the Upper Proterozoic but there is a possibility that both the Walsh Tillite and Mt. House Beds are of Lower Cambrian age.

PRE-CAMBRIAN CORRELATION.- From time to time various authors have attempted correlations between the Proterozoic sediments from the several basins on the Australian Continent, and in particular the Proterozoic sequences in Western Australia (Nullagine and King Leopold Ranges - Kimberley Plateau), Northern Territory (Katherine-Darwin area) and South Australia, (Mt. Lofty Ranges, Flinders Ranges). Although the available stratigraphic information on these sequences is improving rapidly, it is now apparent that much of the previous correlation was based on both meagre and unsound evidence (often entirely on similarities in lithology), The stage is now approaching when more reliable correlation may be possible. It is apparent that more detailed stratigraphic studies are required on the Proterozoic sections of Western Australia and the Northern Territory before reliable correlations can be made with one another and the now well-known sections in South Australia.

At present all thatcan be said is that the Nullagine Series the Upper Proterozoic of the King Leopold Ranges and the Buldiva Quartzite of the Northern Territory are probably in part equivalent. The discovery of what are probably Upper Proterozoic tillites on the Kimberley Plateau is of importance and immediately suggests a close, though not necessarily contemporary, relationship with the tillite of the South Australian Upper Proterozoic. This discovery also indicates that glacial horizons may be found elsewhere in little known Proterozoic sequences in Northern Australia and if found may provide reliable horizons for correlation purposes.

Correlation of the Lower Proterozoic and Archaeozoic has not reached the stage where reliable comparisons can be attempted.

ORDOVICIAN (Guppy and Öpik, 1950) Table I.

The Ordovician beds of the Prices Creek area are the first fossiliferous rocks of Ordovician age to be discovered in Western Australia. They are of particular importance both for their rich faunal content and their association with the Fitzroy Basin.

This discovery has now shown that the oil shows, reported from shallow bores sunk in this area in 1922, originated in Ordovician rocks and not in Devonian rocks as was though at the time of drilling. It is also of interest to recall that the one bore in which no oil shows were reported was drilled in Permian sediments.

PRICES CREEK GROUP (New Group). Definition.- The type area of the Ordovician is adjacent to Prices Creek, (Long. 125° 57' E., Lat. 18o 39' S.) from which the Group name has been derived. The outcrops cover an area of approximately 12 square miles along the south-west scarp of the Emanuel Range. The major part of the outcrop is in the form of low rises with outcrops confined mainly to the few creeks; the upper dolomitic formation forms sharp ridges and bold outcrop which contrasts sharply with the underlying shale and limestone.

The Prices Creek Group contains two formations, the Gap Creek Formation and the Emanuel Formation, and underlies the Middle Devonian Pillara Formation are obscured by faulting and the overlap of Permian sediments.

Although it appears likely that the rocks underlying the Ordovicinn sediments will be of Pre-Cambrian age, the possibility exists of overlap over older Palaeozoic sediments.

Thickness.- The Prices Creek Group has an outcropping thickness of 2,450 feet. This thickness may be appreciably increased if future boring should penetrate the remaining subsurface section.

EMANUAL FORMATION (New Formation). Definition. At the type locality along Emanuel Creek (Long. 125o 55' E., Lat. 18° 39' S.) the Formation consists of 1,670+feet of marine sediments. The dip of the Formation is low and varies between 10° and 15° to the north-east with a reversal of dip towards the base of the section. The Formation conformably underlies the Gap Creek Formation and the base is not exposed.

Emanuel Creek was named during the survey after the owner of Christmas Creek Station.

Lithology.- The Formation consists of outcrops of weathered shale or marl with interbedded harder bands of limestone. Except along Emanuel Creek, where a reasonable section is exposed, outcrops are poor and consist of low rises with loese fragments and are barely visible on aerial photographs.

The Formation is richly fossiliferous throughout the section.

Thickness.- The section in Emanuel Creek is the only surface section available for study. The measured thickness was 1,670 feet.

Palaeontology and Age.- The lowest fossiliferous bed in the Emanuel Formation contains the brachiopod Obulus which indicates Tremadocian (Europe) or Ozarkian (U.S.A.) age (Table 2). There is no indication of any break at the base of the outcroppping sequence and therefore lower beds of Ozarkian and Possibily Cambrian can be expected. The Obolus-bearing limestone is overlain by limestone with asaphids of the genus Xenostegium Walcott, a Lower Ordovician

(Canadian) trilobite. The upper beds of the Emanuel Formation contain a rich fauna of asaphids, pliomerids, gastropods and nautiloids with interbedded graptolite-bearing horizons (dichograptids). A new asaphid genus which can be compared with Ogygites (Ogygia of older text-books) is represented by several species. The highest beds of the Formation are composed of limestone and marl containing a telephid genus which continues into the lower beds of the Gap Creek Formation.

GAP CREEK FORMATION (New Formation). Definition.- The Formation is named from the type locality near Gap Creek (Long. 125° 55' E., Lat. 18° 38' S.) and consists of 780 feet of marine sediments. The Formation conformably overlies the Emanuel Formation and underlies the Devonian (Pillara Formation) with a slight angular unconformity. The dip is low and ranges from 13° to 15° to the north-east.

Lithology.- The change in lithology between the two Ordovician Formations is well marked. The Gap Creek Formation is resistant to erosion and crops out as strik ridges with well-marked bedding and a distinctive brown colour. The sequence consists of silty dolomite and dolomiticsandstone with bands of sandstone becoming more common towards the top of the unit.

Thickness.- Evidence of repetition of section was obtained adjacent to Gap Spring. The section measured contained 780 feet of sediments.

Palaeontology and Age.-The Formation contains an illaenid, possibly Bumastus, together with other trilobites. A plectambonoid brachiopod, Spanodonta hoskingiae Prendergast, is present in abundance and was originally described as an Upper Palaeozoic fossil (Prendergast, 1935). The Gap Creek Fromation may be correlated with the Lower Trention of the United States of America (Table 2).

DEVONIAN (Table 3.)

The sediments of Devonian age are of considerable importance as they constitute, together with the Ordovician sequence, the most likely source rocks for petroleum in the area.

The outcrops are confined to a comparatively narrow belt extending for a distance of 180 miles along the eastern margin of the basin in a position which represents the marginal area of marine sedimentation during the Devonian Period.

As a result it is clear that the outcrops of Devonian sediments will not necessarily be representative of Devonian sedimentation in the extensive area now covered by younger sediments. These outcrops do provide the information from which can be deduced, in a general way, the type of sediments that can be expected elsewhere in the Fitzroy Basin under varying environmental conditions.

For these reasons particular attention has been directed towards the study of the outcropping Devonian sediments. The conclusions reached in this paper should be modified from time to time as further information becomes available during future boring projects.

PILLARA FORMATION (New Formation). Definition. - The Formation is the basal Devonian Formation and unconformably overlies either Pre-Cambrian or Ordovician rocks, The Formation is unconformably overlain either by Saddler Beds, Mt. Pierre Group, Brooking formation Sheep Camp Formation, Fossil Downs Group, Oscar Formation, Springs Formation or Napier Formation. (See Plate).

The type section was examined in the Pillara Range at Menjous Gap (Long. 125° 52' E., Lat. 18° 24' S.) where 2,000 feet of section was meansured.

TABLE 2: STRATIGRAPHICAL UNITS. FAUNAL STAGES.

AND

TIME CORRELATION OF THE ORDOVICIAN IN PRICES CREEK AREA, W.A.

Stratigraphic Units.		Faunal Stages	Faunal Sequence		Tentative time Correlation with Ordovician of U.S.A.
			Zone Fossils	Faunal Assemblage	
Upper Middle Devonian Pillara Limestone					
Unconformity					
Prices Creek Group. Lower & Middle Ordovician)	Gap Creek Formation	V.	Spanedonta	Illaenus (Bumastas) pliomerids (Ectenontus) Isetolus, several genera of gastropods, Ostracoda etc.	Lower Trenton
	Emanuel Formation	IV.	Telephide	Asaphides, Asaphellinae, Pliomeridae, Agnostidae, Clitambonitidae.	Chasian
		III.	Dichograptids, nautiloids and new genus of asaphids	Ostracoda, Conodents, Bellerophostacea, several general of Gastropoda including Plethospira.	Canadian
		II.	Kasostegium		
		I.	Obolus		Upper Ozarkian
Base not seen					

The Formation is widely distributed through the outcropping belt of Devonian rocks. Details of the distribution are recorded in the accompanying Table 3.

Lithology;- Although the Formation has such a widespread development the lithology is comparable throughout and indicates stable environmental conditions over the exposed area of deposition.

In the Oscar and Napier Ranges outcrops are restricted to thin erosional relics, whereas in the Geikie Range and to the south as far as Old Bohemia area thick sections of the Formation are preserved.

Two main units within the Formation are recognisable in all outcrops where sufficient section has been preserved. These consist of a basal elastic section overlain by a thick section of biostromal limestone tending towards a biohermal limestone in some areas.

In the area south of the Fitzroy River the basal clastic section is thin with a measured thickness of 125 feet at the type section, Farther to the north along the eastern margin of the Oscar Plateau, and at Windjana Gorge in the Napier Range, the basal clastics are up to 300 feet thick.

Overlying the basal unit is a thick section of biostromal limestone consisting of bedded to massively bedded limestone with some lenses of clastic limestone derived from contemporaneous erosion.

The beds become more massive towards the top of the section and biohermal and reef growths have been observed in Bugle Gap and near Geikie Gorge.

Type Section - Pillara Formation - Menious Gap

	Thickness (feet) 1.	2.
Limestone, brown, massive with brachiopods and corals	105	2015
Limestone, light-brown, rich fauna of brachiopods	173	1910
Limestone, grey, massive with corals and brachiopods. Bed with brachiopods at base	74	1737
Limestone, light-brown, massive with corals and stromatoporoids, brachiopod bands.	567	1663
Limestone, light-brown, massive with corals and gastropods with bands of grey-brown limestone with crinoids, etc.	387	1096
Limestone, light-brown, massive, cavernous with corals and brachiopods near base.	387	709
Limestone, light-brown, massive with corals.	67	322
Limestone, light-brown, massive with corals and brachiopods.	45	255
Limestone, light-brown with gastropods overlying massive grey limestone with larger pelecypods and brachiopods. Grey shelly limestone with brachiopods at base.	85	210
Limestone, light-brown, sandy with thin beds of calcareous sandstone.	25	125
Limestone, grey, sandy with brachiopods and gastropods	20	100
Limestone, grey, sandy with interbedded siltstones	50	80

Limestone, brown, arkesic with pebbles of fine conglomerate including grantic fragments.	30	30

The figures in column 1. are the thicknesses of the individual units described and the figures in Column 2. are the cumulative thicknesses of the units.

Thickness.- The thickest outcropping section of Pillara Formation is 2,015 feet measured at Menjous Gap. Elsewhere, owing chiefly to erosion and overlap of Upper Devonian, the outcropping thickness is variable from a few feet up to hundreds of feet.

Palaeontology.- Massive stromatopordid biostromes with localised bioherms constitute at large portion of the Pillara Formation. Although the organic structures have been fequently destroyed by recrystallization, many forms should be distinguishable from detailed collecting. The well-bedded biostromes of Amphipora ramosa and associated Prismatophyllum dominate, in general, only at the base of the stromatoporoid biostromes; higher in section they are replaced by more massive forms. In the Emanuel Ranges, Amphipora persists throughout the section. Brachiopods and Gastropods are associated with the atromatoporoids at the base but are unusual in the upper beds. The stromatoporoid biostomes are replaced in even higher beds by coral and brachiopod biostromes with local bioherms.

Large thick-shelled brachiopods and lamellibranches (up to 2 and 3 inches across) are associated withthe basal assemblage of Amphipora ramosa, Prismatophyllum brevilamellatum, and Murchisonia, in practically all localities in which the basal beds of the Pillara Formation are found.

The fauna identified from the Formation is listed by Teichert (1949, p 10). Recent work by Hill has added to and amended the corals listed. (Palaeontological work on the large quantity of Devonian material collected during the present survey has not been studied fully and as several years will elapse before publication the present status of palaeontological knowledge will be indicated under each Formation or Group).

SADDLER BEDS. (New Unit) Definition.- The Saddler Beds, which is the basal Upper Devonian unit, has a comparatively limited distribution. The type area is in the Saddler Hills along the north-east side of the Emanuel Range at Long. 125° 56' E. Lat. 180 36' S. Further areas of outcrop are know from north of the Pillara Range, Bugle Gap, Hull Range and a small area on the Oscar Plateau.

The unit unconformably overlies the Pillara Formation and is conformably overlain by one of the following units:- Mt. Pierra Group (in the area south of the Margaret River), Fossil Downs Group (in the area between the Margaret River and the Fitzroy River) and the Napier Group (on the Oscar Plateau).

Lithology.- The Saddler Beds are notable for the rich fossil fauna they contain. The fossils are frequently silicified and ferruginised giving the outcrop a very characteristic surface appearance.

A section though the unit is given below from the outcrops north of the Pillara Range.

Section, Saddler Beds, Pillara Range.

	Thickness (feet) 1	2
Limestone, sandy with calcareous sandstone and dark and light grey limestone	85	850
Limestone, grey-brown clastic with brachiopods and corals	169	775
Limestone, brown, sandy.	72	606
Limestone, clastic with corals and bands of sandy limestone	154	534

Section, Saddler Beds, Pillara Range.

	Thickness (feet) 1.	2.
Limestone, grey-brown sandy with corals, brachiopods, gastropods.	116	380
Limestone, grey-brown with brachiopods	14	264
Outcrops poor, gentle folding	40	250
Limestone, light brown, sandly limestone with corals and brachiopods	60	210
Limestone, light brown with geniatites, nautiloids, brachiopods, corals. Fossils replaced by limonite.	40	150
Limestone, grey-brown, with shelly limestone at base. Corals, stromatoporoids, brachiopods, trilobites	110	110

Thickness.- The thickness of the unit varies from one area to another. Measured sections indicate a range from 500 to almost 1000 feet.

Palaeontology and Age.- The Saddler Beds are equivalent to the Atrypa Beds of Teichert (1949) and the list of fossils on page 11 indicates the comparative richness of the fauna preserved.

The presence of immature Manticoceras and corals with Upper Devonian affinities indicates a Frasnian age for these Beds. It is considered that further palaeontological studies will prove conclusively the Upper Devonian age of the Saddler Beds.

MT. PIERRE GROUP. (Redefined). Definition.- The term Mt. Pierre Series was originally applied by Wade (1936) to the limestones in the vicinity of Mt. Pierre, Bugle Gap and Old Bohemia, etc. The Mt. Pierre Group, as redefined, includes the Mt. Pierre Series and the Gogo Stage, which Wade considered was Carboniferous.

In the type area between the Pillara Range and Needleeye Rocks (Long. 125° 52' E., Lat. 18° 17' S.) the Group consists of over 2000 feet of marine sediments.

The Group conformably overlies the Saddler Beds and is overlain by both Fairfield Formation (in the Mt. Pierre area) and Bugle Gap limestone (at Bugle Gap).

In the accompanying stratigraphic table the Group has been divided into two units, a lower No.10 Formation and an upper No.5 Formation. These units are distinct morphological and lithological units. Owing to the limited time available in the field they have not been mapped individually and are included in the Mt. Pierre Group on the accompanying Maps.

No.10 FORMATION (New Formation). Definition.- The Formation is the development of concretions of various sizes, a feature which is restricted to this Formation. The lithology of the Formation is illustrated by the following section which was measured in the area north of the Pillara Range.

Section No.10 Formation. Pillara Range

	Thickness (feet) 1.	2.
Siltstone, calcareous, thinly bedded with light-brown limestone at top containing scaphopods, nautiloids, brachiopods and gastropods.	70	990

Section No.10 Formation. Pillara Range. Contd.

	Thickness (feet) 1.	2.
Limestone, light-brown, with abundant small spheroidal concretions.	10	920
Limestone, light-brown, sandy, with concretions containing small brachiopods.	165	910
No outcrops, probably mainly sandy or silty limestone and siltstone.	485	745
Limestone, grey-brown, sandy with brachiopods, scaphopods, nautiloids, coccostean remains in concretions.	260	260

Thickness.- The only complete section available in the area is the section described above. Elsewhere the sections are either incomplete or poorly exposed, The 990 feet in the section described probably represents the maximum thickness of the Formation in the area. A similar but poorly exposed section has been examined in the area north of the Emanuel Range, adjacent to Longs Well.

Palaeontology and Age.- The Formation has been included by Teichert in his Manticoceras Zone (or Stage I of the type section in Germany). The Formation is characterised by Buchiola and other lamellibranchs associated with numerous Tentaculites, small straight nautiloids, some ostracods and coccostean remains in grey shale, platy limestone, silty limestone concretions and siltstone. Timanites and Koenenities, restricted to the lower part of Stage I, occur in these beds. Although geniatites were observed in the underlying Saddler Beds and in the overlying No.5 Formation, they are not known from the No.10 Formation and apparently indicate unfavourable environmental conditions during the deposition of this Formation.

The age indicated by the fauna is Frasnian.

NO.5 FORMATION (New Formation). Definition.- The Formation forms the upper unit of the Mt. Pierre Group and overlies the No.5 Formation conformably and is overlain by the Fairfield Formation and the Bugle Gap Limestone. Although conclusive evidence has not been obtained there is a possibility of a minor unconformity at the top of the No.5 Formation.

The type area and section is in the No.5 Bore - Needle-eye Rocks area (Long. 125° 52' E., Lat. 18° 17' S.)

Lithology.- The Formation consists almost entirely of siltstone, limestone and combinations of these rock types in varying proportions. A distinctive feature of the Formation is the red colour which is consistently found. The colour, together with thin beeding and fossil content, has resulted in a rock type which is readily recognisable throughout the area of distribution south of the Margaret River.

The type section which was examined and compiled in the area between the Pillara Range and Needle-eye Rocks is featured below:-

Section No.5 Formation.

	Thickness (feet) 1.	2.
Limestone, red-brown with geniatites	15	970
Limestone, light-brown to white.	10	955
Limestone, light-brown to white, clastic	10	945

Section No.5 Formation. (Contd.)	Thickness (feet) 1.	2
Limestone, brown, silty	20	935
Limestone, light-brown, crinoid fragments	5	915
Limestone, red-brown and grey w ith goniatites, nautiloids and crinoids.	105	910
Limestone, red-brown, silty, goniatites	60	805
Limestone, red-brown, silty, unfossiliferous	35	745
Limestone, red-brown, silty goniatites, nautiloids, corals crinoids.	125	710
Limestone, red-brown and light-brown with goniatites and crinoids	140	585
Outcrops rare, probably mainly thinly bedded, red and light brown marls, calcareous shale, silty limestone	-	-
Limestone, sandy and siltstone	270	445
Limestone, fine grained, white with corals	15	175
Siltstone, calcareous and calcareous sandstone with corals at base.	160	160

Thickness.- The section described is the most complete sequence of beds available. The 970 feet recorded does not include the section in which no outcrops are avilable. The total thickness therefore probably exceeds 1000 feet. The Formation probably varies in thickness from place to place but as far as could be seen does not exceed 1000 feet elsewhere in the outcrop area.

Palaeontology and Age.- The Mt. Pierre Group contains a faunal assemblage unique in the Devonian of Australia. As mentioned previously, Teichert (1949) has established that the succession of ammonoid forms in the Mt. Pierre Group is similar to the type succession in Germany and he has recognised four palaeontological zones which correspond closely with the lower four stages in Europe.

All four stages, viz: Stage 1 (Manticoceras Zone), Stage 2 (Cheiloceras Zone), Stage 3 (Sporadoceras Zone) and Stage 4 (P roductella Zone), are represented in the No.5 Formation.

The fauna representative, of the For mation, is listed by Teichert on pages 17-21.

The age of the unit is mainly Famennian but the presence of Manticoceras indicates a Frasnian age for the lower most beds.

J8 CONGLOMERATE (Re-defined). Definition.- The formation was originally named J8 Beds by Wade (1936) who consider they were Permian glacial moraines. More recent work by Teichert and the writer has shown conclusively that the formation is of Upper Devonian age and a contemporary facies of the No.10 Formation. The formation unconformably overlies either Pre-Cambrian or Pillara Formation and in places also unconformably overlies Mt. Pierre Group. The Formation interfingers with and completely replaces the marine sediments of the No.10 Formation in localities in the Virgin Hills and Sparks Range.

The type area was examined in the vicinity of Trig. Stations J7 and J8 (Long. 126° 11' E., Lat. 18° 35' S.). in the Sparke Range.

Lithology.- Although the formation is mainly conglomerate, the sediments range from boulder conglomerate, with boulders as large as 12 feet across, to fine greywacke and rarely **siltstone.**

The grain-size varies from east to west away from the source of the material with coarse clastics in the Sparks Range to medium and coarse, cross-bedded, greywacke and silty sandstone with conglomerate lenses, in the Virgin Hills.

The coarser clastics are commonly unsorted and consist of accumulations of boulders, cobbles and pebbles in a pebble conglomerate, fine conglome rate or coarse greywacke ground mass. The phenoclasts are subrounded to sub-angular (a few show polishing, faceting and abrasion marks), and consist of quartzite, schist, gneiss, granitic and basic rocks. Quartzite has provided a large proportion of the phenoclasts. The basal portion of the section at some localities (R21, 39 and NH26) consist entirely of angular fragments of limestone derived from nearby outcrops. The calcareous cementing material in the finer grades of the Conglomerate was also derived from the Devonian limestone.

Bedding is rarely visible in the coarser clastics and where present is defined by lenses of finer material and a tendency towards grading of the conglomerate. Cross-bedding is characteristic throughout the formation, particularly in the greywacke of the Virgin Hills where dips to the west of between 15° and 20° are frequent.

Thickness.- Approximately 1000 feet of sediments of the formation have been preserved at R203 and R239 in the Sparke Range. Prior to erosion the formation was thicker but no estimate of the original thickness can be given. The formation becomes thinner westward where it becomes interbedded with the Mt. Pierre Group.

Palaeontology and Age.- The formation is typically unfossiliferous but thin beds and lenses of limestone (R1) are present and contain Upper Devonian fossils. Fossils are common the clastic limestone found in the conglomerate and the faunal assemblage may be either contemporaneous with or older than the deposition of the conglomerate.

Origin.- Previous reports by Wade (1936) and Reeves (1949) have suggested that the J8 Conglomerate resulted from glacial action. It is now clear that the formation has a torrential origin and may be described as a fan-conglomerate (Teichert (1949)). Although some boulders exhibit faint striations and crude faceting is common, both these features may be found in fan-conglomerates. Boulder clays are not represented in the formation and the gradual change from coarse to fine clastics from east to west is a normal result of deposition by swift flowing streams.

Whether represnetatives of J8 Conglomerate (and the other conglomerate formations) will be found farther to the west under the cover of Permian sediments is not known. If they do occur it is likely that they will be confined to relatively narrow channels for some distance to the west from the outcrops.

South of Trig. Station J9 interbedded conglomerate, sandstone, siltstone abut against the hills formed by the J8 Conglomerate, Although these sediment s are similar in some respects to the J8 Conglomerate the higher degree of grading and the presence of layers of siltstone and probably shale indicates they are part of the Grant Formation of Permain age.

BUGLE GAP LIMESTONE (New Formation). Definition.- This for mation, which was previously included in the Mt. Pierre Series by Wade, overlies the No.5 Formation and is unconformably overlain by

Lithology.- The type section is a monotoneous sequence of highly jointed, bedded and massive tending towards biohermal, light-brown and white limestone. Although some beds are rich in brachiopods, many of the fossils have been destroyed by diagenesis.

Palaeontology and Age.- This formation includes Stage 4 and the Productella Zone of Teichert. Fossil remains are comparatively rare but a more detailed search will probably reveal the presence of more species. Crinoid fragments, four species of brachiopods, goniatites and trilobites have been observed but no detailed determinations have been attempted.

FOSSIL DOWNS GROUP (New Group.) Definition.- The complex Upper Devonian sedimentary sequence north of the Margaret River on Fossil Downs Station has been given a new group name to distinguish it from the equivalent but more simple sequence south of the river (Mt. Pierre Group). The Group is typically developed north of Fossil Down Homestead (see accompanying maps). at Long. 125° 47' E., Lat. 18° 08' S. The Group unconformably overlies Pillara Formation and is overlain by the Fairfield Formation. The marine sequence interfingers in a complex manner with the contemporaneous conglomerate formations - Stony Creek Conglomerate, Burramundi Conglomerate and Mt. Elma Conglomerate.

Lithology.- The marine sequence of the Group consists of beds of calcarenite, clastic limestone, sandy and silty limestone and typical small and scattered biohermal growths. Beeding is thin and well-bedded and the colour is characteristically red and red and white mottled. The sequence is essentially a shallow water clastic sediment with a persistent tendency towards reff formation.

Palaeontology and Age.- The fossil content indicates the presence of Stages 1 - 3 of the Upper Devonian and a depositional time range closely comparable with the Mt. Pierre Group (see column section Plate).

STONY CREEK CONGLOMERATE
BURRAMUNDI CONGLOMERATE. (New Formations)
MT. ELMA CONGLOMERATE. (Definition).- These fanconglomerate formations are found on the margin of the basin as facies variations of the Fossil Downs Group and are the approximate time equivalents of the J8 Conglomerate, south of the Margaret River. Outcrops of the formations occur at Long. 125° 56' E., Lat. 17° 57' S. (Stony Creek Conglomerate), Long. 126° 11' E., Lat. 18° 02' S. (Burramundi Conglomerate), Long 126o 14' E., Lat. 18o 14' S. (Mt. Elma Conglomerate).

The formations unconformably overlie either Pillara Formation or Pre-Cambrian.

Lithology -. The sediments are essentially the same as those described from the J8 Conglomerate on page 29.

Thickness.- The sections exposed are again limited to approximately 200 feet or less. On the basis of observed dip values the formations are estimated to be 1000 feet thick.

Age.- The formations are confined to the Upper Devonian and were deposited approximately during the same time range as the J8 Conglomerate but with more restricted areas of deposition.

SHEEP CAMP FORMATION. (New Formation). Definition.- The Formation is restricted to a comparatively small basin of marine sediments immediately north of Geikie Gorge at Long. 125° 44' E., Lat. 18° 00' S. The formation unconformably overlies the Pillara Formation and is conformably overlain by the Sprlngs Formation.

Lithology.- The Formation is essentially a clastic Formation consisting of a well bedded to massively bedded sequence of grey, light brown, red, and mottled clastic limestone, biohermal limestone, oolitic limestone, sandy and silty limestone and probably calcerenite. The Formation has a typical red colour similar to that of the Mt. Pierre Group and Napier Group.

The clastic material is partially derived from erosion of the underlying Pillara Formation and partly from contemporaneous erosion during sedimentation.

Small and scattered biohermal growths were observed throughout the sequence but were inhibited by the adverse invironmental conditions and did not reach major development.

Thickness.- The section measured indicated a thickness of 2,600 feet, It is possible that the section may be slightly thicker in other sections.

Palaeontology and Age.- The fauna of the Formation has not been examined. By comparison with the better known Mt. Pierre Group it is suggested that probably Stages 1 to 3 of the Upper Devonian may be represented. The virtual absence of the goniatite fauna in the area north of the Fitzroy River creates problems in rapid field correlations and requires more detailed analysis of the few goniatites and nautiloids available together with the impoverished fauna of other orders.

SPRINGS FORMATION (New Formation). Definition.- The Springs Formation is a comparatively steeply dipping Formation along the southern flank of the range from Brooking Gap (Long. 125° 40' E., Lat. 18° 06' S.) to Fossil Downs Homestead. The Formation overlies Pillara Formation unconformably and is a facies variation of at least the upper beds of the Brooking and Sheep Camp Formations. It is comparable but not continuous with the Oscar Formation which flanks the Oscar Range.

The Formation is overlain by the Fairfield Fromation but the contact is not exposed.

Lithology.-The Formation consists of thin bedded, medium bedded and some massive beds of chiefly calcaronite with fine to coarse limestone breccia, oolitic limestone and rarely sandy limestone. The massive beds are restricted to the coarse clastic limestone which occurs as lenses in the Formation. Bioherm masses are also sporadically developed but are not an important feature of the Formation.

Thickness.- The section measured through the Formation has a thickness of 1,140 feet. As outcrops of the upper part are not well exposed the thickness of the complete Formation may exceed this figure.

Palaeontology and Age.- The fauna of the unit has not been examined but the fossils observed, together with the position of the Formation in the Upper Devonian sequence, suggests the presence of Stages 2 and 3. Further palaeontological work will be required to determine whether Stage 1 is present in the sequence.

BROOKING FORMATION. (New Formation). Definition.- The Formation is closely comparable with the Sheep Camp Formation and is confined to a semi-enclosed basin in Middel Devonian sediments.
The area of outcrops occurs in Brooking Gap (Long. 125° 35' E., Lat. 17° 58' S.) where the Formation unconformably overlies Pillara Formation and is overlain by the Fairfield Formation. The upper beds appear to be lateral facies variations of the Oscar and Springs Formations.

Lithology.- The sedimentary sequence is similar to that of the Sheep Camp Formation and the two Formations were formed under essentially the same environmental conditions in limited areas. The Formation is usually thinly bedded with mottled, red, light brown and white clastic limestone, sandy and silty limestone, oolitic limestone and sandstone. The beds are frequently cross-bedded with a scattered devleopment of bioherms, tending towards reef formation.

Thickness.- A complete section was measured through the Formation at Brooking Gap and resulted in the recording of 3,750 feet of sediments.

Palaeontology and Age.- See under Sheep Camp Formation.

OSCAR FORMATION (New Formation). Definition.- The Oscar formation is confined to the south-west flank of the Oscar Range from Brooking Gap, where the For mation is replaced by the Brooking Formation, to the vicinity of Mt. Percy. The type locality is in the vicinity of Linesman Creek, (Long 125° 23' E., Lat. 17° 58' S.).

The Formation unconformably overlies both Pre-Cambrian and Middle Devonian (Pillara Formation) and is overlain by Fairfield Formation.

Lithology.- The sediments form a comparativ ely uniform linear outcrop flanking the Oscar Range. In localities where they directly overlie an eroded surface or scarp of the Pillara Formation, the basal beds consist of massive accumulations, in situ, from the coastal cliff formed by the Middle Devonian limestone. The basal beds are overlain by medium bedded calcaronite and clastic limestone with the normal steep dip (25°-30°) of the Formation. Higher beds consist of medium to thinly bedded calcarenites together with lensing masses of contemporaneous clastic limestone and some small biohermal growths. Penecontemporaneous slumping is a feature of some horizons.

The Oscar Formation is notable for the almost complete absence of siliceous clastic material (so common in other Upper Devonian formations except for Springs Formation).

Examination of this sections have revealed the presence of small quantities of quartz grains in the rocks but, for the most part, the rock can be considered a carbonate rock devoid of siliceous contamination.

Towards the north-west the growth of biohermal masses becomes more pronounced and although the bedded nature of the Formation is still apparent, there is undoubtedly a strong tencency towards reef growth. Further observations are obscured by the overlap of Permian sandstones.

Palaeontology and Age.- No palaeontological work has been completed on the fauna of the Formation. By analogy with the Springs Formation, it is tentatively assumed that Stages 2 and 3 of the Upper Devonian are represented.

NAPIER GROUP (New Group) Definition.- The Group outcrops in, and to a large extent forms, the Napier Range. The unit forms the northern scarp of the Oscar Plateau and the bas. overlapping beds have been preserved on portions of the Plateau. Two type sections have been measured to adequately define the group and those are located near Wire Spring on the northern flank of the Oscar Plateau (Long. 125° 03' E., Lat. 17° 40' S.) and at Barker Gorge (Long. 124° 44' E., Lat. 17° 16' S.) in the Napier Range.

The Group unconformably overlies either Pre-Cambrian rocks or Middle Devonian Pillara Formation and is overlain by the Fairfield Formation. The contact with the latter Formation is not exposed.

The Patterson and Behn Conglomerates are formations within the Group representing facies variations. These fan-conglomerates are restricted in distribution and interfinger with the normal shallow water marine facies of the Group.

Lithology.- The environmental conditions, under which the marine portion of the Group was deposited, are essentially the same throughout the area of deposition. The main feature of interest is the development of biohermal and reef masses along the strike. The section is essentially a clastic section throughout the outcrop area. Although conditions in this marginal area were undoubtedly to a large extent unfavourable for the growth of biohermal masses, the reef forming fauna was able to establish itself from time to time and form scattered biohermal masses. In more favourable localities at Windjana Gorge north to Barker Gorge and in the vicinity of Elimberrie Spring, favourable environmental conditions existed for reef development and thick reef growths have flourished in these areas indicating that a suitable faunal assemblage for the growth of reefs and bioherms was in existence. The development was inhibited in some areas and supported in others

Apart from the occurrence of the reef masses the group consists of a reasonably consistent section of thinly bedded to medium bedded clastic sediments consisting of calcareous siltstone and sandstone with conglomerate beds towards the base of the section. Clastic limestone, consistingof beds of anguar fragments of limestone together with fragments of the contemporaneous deposits in a calcareous silty and sandy base, are a recurring feature of the section.

The basal beds of the Group, particularly in the Pandanus Spring area, consist of limestone conglomerate and breccia in a quartzitic sandy base which it is believed marks the transgressive overlap of the Upper Devonian over the surface of Middle Devonian rocks.

The overlying section, which frequently has the red-brown colour typical of the Upper Devonian south of the Fitzroy River, has been described above and contains scattered biohermal masses which eventually form large reef masses at the top of the section .

Thickness.- The outcropping section has a variable thickness and measured sedtions range from 2,800 feet in the vicinity of Elmiberrie Spring to 385 feet immediately south of Barker Gorge. Although there is a possibility that the sectionis not completely exposed in some localities the variation in thickness of the measured section is considere to indicate changes in thickness of the Group along the strike.

Palaeontology and Age.- No detailed examination of the Group has been completed. Field observations indicate the presence of Stages 2 and 3 of the Upper Devonian. Further work will be required to establish the presence of Stage 1.

PATERSON CONGLOMERATE.
BEHN CONGLOMERATE. (New Formations). Definition.- These fan-conglomerate formations are marginal facies variations of the Napier Group and contain both terrestrial and marine deposited sediments. The interfingering with the marine sequence of the Napier Group is complex and as mapped indicates the distribution of clearly defined sediments of the formations. The formations outcrop in the Patterson Range (Long. 124° 37' E., Lat. 17o 03' S.) and at Mt. Behn (Long. 125° 05' E., Lat. 17° 29' S.).

Both formations unconformably overlie Pre-Cambrian, interfinger with and, in the case of the Behn Conglomerate, replace the normal marine sequence of the Napier Group. The Patterson Conglomerate is overlain by younger beds of the Napier Group and the Behn Conglomerate is presumably overlain by the Fair field Formation. The latter Formation does not outcrop in the Mt. Behn locality and the contact is therefore not exposed.

Thickness. - No accurate figures are available due to limited exposures. The Formations have similar outcrop thicknesses and over 1000 feet of sediments are estimated.

FAIRFIELD FORMATION (Re-named). Definition. - The unit was originally named Fairfield Marl by Kraus (1942). Recent work has indicated that Marl is an invalid designation. The Formation was named from the Fairfield Valley (Long. 125° 00' E., Lat. 17° 35' S.) by Kraus on the basis of the limited outcrop in that area. Sections were measured during the present survey near 12 Mile Bore (Oscar Station) and at Old Napier Homestead. These sections are poorly exposed and probably are not representative of the Formation as a whole. The Formation overlies the Upper Devonian formations of the Napier Range, Oscar Range, etc. and is unconformably overlapped by Permian sandstone of the Grant Formation.

Lithology.- The exposed section consists of inter-bedded, grey-brown, yellow-brown, fine, limestone breccia, calcarenite, sandy and silty limestone, marl and sandstone. The sandstone bands differ from clastics found in older beds in that they are relatively clean and the grains well-rounded and sorted.

Paleontology and Age.- Teichert (1949) has placed the Formation in his Productella Zone which corresponds with Stage 4 of the German type section. The small section exposed has a rich fauna mainly of brachiopods.

PERMIAN. (Table 4)

Permian rocks cover a large proportion of the Fitzroy Basin and extend farther to the south-east to the vicinity of Billiluna on the Canning Stock Route. They also presumably underlie the Mesozoic sediments outcropping to the south in the Great Sandy Desert and in Dampier Land Peninsula.

The importance of these rocks lies not so much in their petroleum potentialities as the fact that all the important anticlinal structures are closed in Permian rocks. They also serve as a vital part in the industry of the area as aquifers for the good supplies of sub-artesian water.

GRANT FORMATION, (Re-defined). Definition.- The Formation derives its name from the Grant Range (Long. 124° 10' E., Lat. 18° 00' S.). Woolnough (1933) used the term Grant Range Beds for the glacial beds and Wade (1936), applied the term Grant Range Beds to that portion of his Glacial Series exposed in the "basins of the Fitzroy and Lennard Rivers". These are equivalent to his Willanyie Beds of the Poole Range area. Beneath the Willanyie Beds, Wade distinguished the Kungangie Beds (in the Poole Range area) and the J8 Conglomerate (in the Sparke Range), as units of the Glacial Series. The J8 Conglomerate has since been proved Upper Devonian (Teicher, 1949). Kraus (1942) and Findlay (1942) recognised the Hawkestone Sandstone as a distinct formation north of the Fitzroy River and considered it equivalent to the Grant Range Beds and Poole Sandstone found outcropping between the Poole Range and Grant Range.

After a study of outcrops and taking into consideration the logs of bores which have penetrated the Formation, it has been decided to rename the Formation the Grant Formation. The Formation is re-defined to include all the glacial sediments exposed. Although nothing is known of the basal beds of the Formation it is possible that the Grant Formation will include all Permian sediments below the Poole Sandstone. The Grant Formation will include the Kunganyie, Willanyie and Grant Range Beds of Wade and the basal glacial portion of the Hawkestone Sandstone of Kraus, Findlay and Reeves.

The Formation unconformably overlies Middle and Upper Devonian sediments along the eastern margin of the basin and also overlaps on Pre-Cambrian rocks in isolated localities. The unconformity is well displayed along the southern side of Bugle Gap where the Grant Formation unconformably overlies the Bugle Gap Limestone. The Poole Sandstone overlies the Grant Formation with a distinct unconformity in the Poole Range and in parts of St. George Range.

The unconformity is of minor importance but provides a mapping horizon which is usually readily identified.

The Formation is best exposed in the cores of the anticlines - Poole Range, St. George Range, Mt. Wynne and Grant Range. Scattered outcrops persist along the eatern margin where overlap on Devonian sediments was frequently observed. The Formation is also wxposed in shattered outcrops along the Pinnacle and Fenton Fault lines.

Lithology.- The Grant Formation contains a number of different types of glacial and squeolglacial sediments including sandstone, conglomerate, tillite, varves, siltstone and shale. Intraformational contortions are a characteristic feature of the glacial sediments.

Most of the exposed section is sandstone; it is typically massive, poorly beded, white, silty with grains generally sub- angular, but sometimes sub-rounded to rounded. Pebbly lenses with scattered boulders are present and also cherty silstone.

Tillites and associated deposits have been examined at Mt. Millard, on the south-west flank of the Poole Range, south of Donkey Gorge, and in the central part of St. George Range. The deposits consist of unbedded, blue-grey, sandy siltstones containing glaciated boulders of many rock types, including granite, metamorphic quartzites and limestone. The sediments associated with the tillites comprise blue siltstone, shale, calcareous sandstone and thin, hard, grey limestone beds.

Sediments which can be classified as varves form the to of the mass at Hill 'O' (2½ miles west of Fitzroy Crossing). These thinly bedded deposits consist of alternating, graded, fine white siltstone and fine, silty sandstone with layers approximately ⅛" in thickness. The varves overlie massive and irregularly beded conglomeratic beds which have the appearance of morainic deposits.

The following section from Mt. Millard (Poole Range) is representative of the tillitic beds in the Grant Formation.

	Thickness (feet)
Sandstone, white, weathering to brown, massive, current bedded	40
Claystone, yellow, white, blue, grey, thinly bedded, often sandy with thin beds of clayey sandstone.	82
Claystone, blue-grey, finely bedded with coarse sandstone bands, Contains limestone concretions and glacial pebbles	21
Sandstone, light-grey with scattered glacial pebbles and boulders	4
Tillite, massive grey, sandy clay with lenses of coarse sandstone with boulders distributes throughout	70

Thciknoss.- Although no complete section of the Formation is exposed in the Fitzroy Basin, the No.3 Bore, Poole Range, penetrated 3,264 feet of Grant Formation. Approximately 200 feet of the Formation outcrops above the bore site indicating a minimum thickness of 3,460 feet for the Formation at this locality. It is considered likely that this order of thickness will be maintained throughout the region bounded by the Pinnacle and Fenton Faults. North-east of the Pinnacle Faoult the Formation wedges out rapidly against the older Palaeozoic sedimets and a large percentage has been eroded.

The Formation does not outcrop south of the Fention Fault and no other evidence is available to indicate the thickness or distribution south of the Fault.

POOLE SANDSTONE. (Re-defined). Definition.- The formation name was firse used by Tabot for the type area in the Poole Range (Long. 125° 45' E., Lat. 18° 05' S.). The oringinal name used for the formation by Talbot was Poole Range Beds. The formation was later named Poole Range Series (or Lower Ferruginous Series) by Wade (1936) and Poole Range Sandstone by Reeves (1949). In this report the name is reduced to Poole Sandstone.

The formation is overlain by the Noonkanbah Formation. Outcrops at Mt. Synnott and the persistent conglomerate bed at the junction of the two formations in the Poole Range-St. George Range areas suggests the probability of an erosional unconformity between the Poole Sandstones and the Noonkanbah Formation at least in the areas mentioned.

The Poole Sandstone overlies the Grant Formation with a minor erosional unconformity.

The distribution is chiefly confined to the flanks of the major anticlinal folds - Poole Range, St. George Range, Mt. Wynne and Grant Range. Small areas of outcrop have been mapped along the Fenton Fault and along the eastern margin of the basin.

The Nura Nura Member is a fossiliferous marine section which occurs at the base of the Poole Sandstone in the Mt. Wynne area.

Lithology.- The formation consists mainly of thinly bedded white, weathering to brown, fine micaceous sandstone with plant remains. Outcrops of low elevation are frequently highly ferruginised (hence Wade's term Lower Ferruginous). Cross-bedding, ripple marks and worm tracks are characteristic and indicate shallow water, perhaps estuarine, deposition.

A thin, massive bed of sandstone, with well-rounded quartze grains, forms a reliable marker bed at the base of the formation in the south-west Poole Range. In the north-east Poole Range a single layer of quartz pebbles is commonly found at the base of the formation.

A lenticular fossiliferous bed has been examined at localities NJ27, NJ27, NJ91, NJ107, NJ132 and NH108 along the southern and eastern flanks of the St. George Range. The bed outcrops approximatdy 40 feet above the Grant Formation and consists of ferruginous sandstone. brown, friable, porous, medium grained, containing 40% rounded quartz grains in an argillaceous, non-calcareous ground mass. The sediment is well bedded, richly fossiliferous and in some parts colitic.

Thickness.- The thickness of the formation increses from approximately 200 feet in the Poole Range area to 600 feet in the Western St. George Range and 1200 feet on the Nerrima Bore and Grant Range.

Palaeontology and Age.- Detailed fossil examinations of the fauna are at present in progress and the following is a brief general description.

The lensing, fossiliferous bed, referred to previously, contains a poorly preserved fauna of chiefly brachiopods including productids and molluses. (Ostracods, bryozoans and Foraminifera (*Ammodiscus* and *Calcitornella* also occur in small numbers).

Fossil plant remains have been collected over a large portion of the formation.

Althgether approximately 6[illegible] species of fossils have been collected from the Poole Sandstone.

During the field work it was thought that this bed was probably the equivalent of the Nura Nura Member. Owing mainly to different environment conditions it has not been possible to equate the two horizons precisely. Further fossil collections will be made to endeavour to satisfactorily solve this problem.

NURA NURA MEMBER. (re-named). Definition.- The Member forms the base of the Poole Sandstone at Nura Nura Ridge (Long. 124° 30' E., Lat. 18° 06' S.). This lensing marine unit was originally named Nura Nura Limestone by Wade (1936).

Lithology.- The Member consists of a well-bedded section of calcareous sandstone, sandy limestone and limestone with bands of unsorted, coarser clastics.

Thickness.- The thickness of the mapped unit varies rapidly. Measured sections indicate a range from 25-50 feet.

Palaeontology and Age.- The presence of the ammonites Metalegoceras clarkei and Thalassoceras wadei was permitted correlation with the Fossil Cliff Formation of the Irwin River Basin and the Callytharra Formation of the Carnarvon Basin.

The age of the Member is basal Artinskian.

NOONKANBAH FORMATION (Re-named). Definition.- The Formation was originally named by Wade (1936) from the type locality near Noonkanbah Homestead (Long.124° 50' E., Lat. 18° 30' S.) Later observers (Kraus (1942) and Reeves (1949)).have all referred to the Formation as the Noonkanbah Shale. As a result of the observations made during the present survey it is clear that the rock types in the Formation towards the eastern margin of the basin, are not predominantly shale. It is equally clear that the Formation consists mainly of shale in the Nerrima area and this section has been studied in details in the cores from the Nerrima Bore.

The Formation is conformably overlain by the Liveringa Group and is underlain (unconformably in some areas) by the Poole Sandstone.

The Formation is widely distributed in the Fitzroy Basin. The rock types do not usually produce good outcrops where they are predominantly shaly and are then identified by photographic pattern, topography and soil type. The non-shaly rock types in the Christmas Creek area, however, have resulted in more continuous outcrop and palaeontological studies are limited to this area. The main structures, Poole Range, St. George Range, etc., are entirely surrounded by gently deipping beds of the Formation.

Lithology.- The type section was examined near Brutens Yard (Long. 125° 52' E., Lat. 18° 50' S.), where it consists of interbedded siltstone, sandstone, limestone and shale. The limestones are richly fossiliferous and form low ridges; the sandstones, siltstones, and shales rarely outcrop.

Outcrops have been observed as far east as Pinnacle Fault where they are noticeably coarser and sandy and include conglomeratic lenses and beds.

The Formation, where penetrated by the Nerrima Bore, is primarily shale but some thin siltstone and sandstone bands occur.

Thickness.- The Formation has a thickness of 1,260 feet at Brutens Yard and approximately 1,200 feet north and south of Great Range, 1,320 feet at Jimberlurah, 1,320 feet at Duchess Ridge and 1,200 feet at Kimberley Downs. The evidence points to a sustained thickness of 1,200 - 1,300 feet for the Formation throughout the Fitzroy Basin.

The shoreline of the Formation appears to be located in the vicinity of the Pinnacle Fault as Outcrops are not known east of the Fault. There are scattered outcrops of the Formation south of the Fenton Fault which suggests that overlap to the south of this Fault was established. The extent and thickness of the sediments in this area is unknown owing to lack of outcrop and the cover of Mesozoic sediments.

Palaeontology and Age.- The Noonkanbah Formation contains the richest marine fauna in the Permian sequence and approximately 170 species have been recognised. In the Christmas Creek area the lower half of the Formation is poorly fossiliferous and the upper 700 feet contains a rich and varied fauna of bryozoans (at least 32 species), brachiopods. Calceolispongia first appears 800 feet above the base of the section in the area west of Christmas Creek Homestead. Foraminifera and corals are present together with pelecypods. The pelecypods increase in number towards the top of the section and in the overlying Liveringa Group they outnumber all other types.

The age of the Formation is Artinskian.

LIVERINGA GROUP- (Re-defined). Definition.- The Liveringa Group is named from Liveringa Ridge (Long. 124° 06' E., Lat. 17° 56' S.). Wade (1936) first used the term "Liveringa Series" for a sequence of ferruginous sandstone above the Noonkanbah Series and below the plant-bearing beds which he called the Erskine Series. Kraus (1942) and Findlay (1942) recognised three Permian formations above the Noonkanbah "Shale" and which they names Liveringa Iron Sandstone, Blina Shale, and Erskine Sandstone. Reeves (1949) used the term "Liveringa Beds" for all the strata between the Noonkanbah Shale and the beds of Mesozoic age and sub-divided them into two units, the Liveringa Sandstone and the Blina Shale.

The terminology of Reeves was closely followed by the writer in a previous publication (Guppy et alia, 1952).

This particular problem was examined in detail in 1952 and as a result it has been shown that both the Blina Shale and the Erskine Sandstone are Triassic formations.

The Liveringa Group is now formally defined as the beds of Permian age overlying the Noonkanbah Formation and unconformably overlain by either Blina Shale or Erskine Sandstone or Triassic age. The type section for the Group has been examined on the south flank of the Grant Range.

The Group is found throughout the Fitzroy Basin and is particularly well exposed on the flanks of the anticlines.

Lithology.- The outcrops of the Group have usually been highly ferruginised to a dark brown to almost black platy and concretionary hardcap which masks the original lithology of the rocks, and explains the term "Upper Ferruginous" which Wade applied to the Group. The effect is probably caused by leaching of the original iron oxides of the sediments.

The change from Noonkanbah Formation to Liveringa Group is transitional wherever exposed, e.g. Shore Range and Nerrima.

In the Shore Range the transitional beds have a stratigraphic thickness of approximately 40 feet and comprise alternating calcareous sandy sediments with intra-formational pebbles, fragmental fossils and grey-green sandstone. These beds are richly fossiliferous. The transitional beds are succeeded by fine, thinly bedded, highly micaceous, olive-green sandstone with intercalated red-brown, fine, oolitic limonite containing up to 50% Fe_2O_3.

A similar section is exposed in the vicinity of Brutens Hill. The type section south of the Grant Range and a similar section between Mt. Hardman and the Fitzroy River consist of four units: a thin basal unit of limonitic sandstone with marine fossils, a higher unit with plant fossils, a thick unit of clean sandstone overlain by calcareous siltstone and sandstone and impure limestone with abundant marine fossils. This unit is the youngest Permian known in the area and is well exposed at Mt. Hardman.

Thickness.- Owing to the unconformity below the overlying Triassic it is doubtful whether a complete section of the Group has been preserved in the Fitzroy Basin. The section south of the Grant Range has a measured thickness of 2,420 feet and is the thickestt surface section preserved.

To the north in the vicinity of Mt. Marmion the belt of Liveringa Group has a much thinner outcropping section but whether this is due to erosion or thinning is not clear. It is suspected however that convergence of the Group has taken place together with epi-Triassic erosion.

Palaeontology and Age.- The lower part of the section contains a marine fauna with mainly pelecypods and brachiopods. These beds are succeeded by horizons with abundant plant remains. The top of the section at Mt. Hardman contains a particularly interesting and rich fauna which is being studied at the time of writing. Preliminary determinations indicate an age high in the Permian and probably approximately equivalent to the Upper Productus Beds of the Salt Range.

TRIASSIC: (Table 4)

BLINA SHALE. (Re-defined). Definition.- The Blina Shale was originally named by Kraus (1942) who considered it was the top of the Permian sequence. The Shale is now re-defined as the basal Triassic unit overlying unconformably the Liveringa Group of Permian age. Areas underlain by the formation have been mapped in the Erskine Range, Wongil Ridge and areas covered by black soil on Meda, Kimberley Downs, Blina, Liveringa, Calwynyardah, Noonkanbah, Quanbun, Lulugui and Nerrim Stations.

Lithology.- Outcrops of the formation are notoriously rare but where examined consisted of light-grey-brown and yellow-grey shale, siltstone and fine sandy shale. Concretions are common in these outcropping beds. Bore samples consist almost entirely of grey-blue shale. Gypsum crystals have been noted on the surface over the formation and probably contribute to the poor quality of water found on rare occasions in the formation.

Conglomerate beds, probably of a lensing nature, have been mapped at Dry Corner (north-west of Nerruma Structure), Willumbah Ridge and north of Le-lievres Bore. Although proof is lacking, it is believed that this bed represents the base of the Triassic in these areas.

Thickness.- Surface sections never exceed 130 feet. Bore information indicates a thickness of at least 1000 feet in the Blina-Yeeda area. Owing to the unconformable relation with the underlying Liveringa Group, variations in thickness of the formation can be expected as further sub-surface information becomes available.

Palaeontology and Age.- Previously this formation has been considered unfossiliferous. Collections by the author over the past three years have now clearly proved a Triassic (Probably Middle) age. Included in the fauna are the following (Brunnschweiler, 1952):-

Lingula rattigani n. sp.
Lingula caseyi n sp.
Palaeolimnadia coghlani Cox
Pseudestheria insuiciensis Mitchell
Fish scales of *Palaeoniscidae*.

ERSKINE SANDSTONE (re-defined). Definition.- The formation has been previously considered Jurassic in age. The examination of collections made by the author has indicated an Upper Triassic age. The formation is re-defined as the Upper Triassic formation conformably overlying the Blina Shale and unconformably overlain by the Meda Conglomerate. The formation has alimited distribution and has been mapped on the top of Erskine Hill and Range, Sisters Plateau, as low ridges on Kimberley Downs and Meda Stations. Small outcrops have been identified in the bed of the May River and form the adjacent Yarada Hill.

Lithology.- The Sandstone consists of thin-bedded, evenly bedded and finely bedded, friable medium and fine grained, silty sandstone. Beds of massive, fine sandstone and siltstone occur rarely. Cross-bedding has been well developed at some horizons. The outcropping rock is commonly highly coloured and low outcrops are usually strongly ferruginised.

Thickness.- The maximum section measured was 110 feet.

Palaeontology and Age.- The examination of the abundant flora of the formation has not been completed. Current evidence suggests an Upper (Keuper) Triassic age for the formation.

JURASSIC: (Table 4).

JURGURRA SANDSTONE (New Formation). Definition.- The formation is probably the basal Jurassic unit and is unconformably overlain by the Alexander Formation. The base is not exposed and the relationship with underlying formations is therefore unknown.

The formation name has been derived from Jurgurra Creek (Long. 123° 35' E., Lat. 18° 27' S.) in which it outcrops.

The outcrop distribution is confined to Jurgurra Creek and tributaries, upstream from Clanmeyer Pool.

Lithology.- The formation consists of current bedded, medium and coarse, friable, quartz sandstone with large mica flakes and thin silty beds. Scattered through the formation are what appear to be clay pellets.

Thickness.- The maximum section available has a thickness of 20 feet. As the base of the unit has not been seen the true thickness will be in excess of this figure.

Palaeontology and Age.- Fragments of fossil wood are a feature of the unit. Pelecypods are also believed to be present in the formation but are so poorly preserved that no identifiable specimens have been collected.

The precise age of the formation has yet to be established It is tentatively considered of Jurassic age with a slight possibility of Triassic.

BARBWIRE BEDS. (New Unit) Definition.- These beds are restricted to a small area of outcrop in the western Barbwire Range (Approx. Long. 124° 53' E. Lat. 18° 47' S.) The beds cap the Liveringa Group and presumably overlie the Permian unconformably.

Lithology.- The beds contain friable fine sandstone, silty sandstone, siltstone and conglomerate lenses in coarse sandstone

Thickness.- Sections up to 55 feet have been measured in the Barbwire Range. As the upper part of the section has been removed by erosion the measured section can be considered a minimum value.

Palaeontology and Age.- The age is uncertain since no fossiliferous material has been collected. On a purely lithological basis it is correlated with the Alexander Formation, and a tentative Upper Jurassic age has been assigned to the unit.

JAMES BEDS. (New Unit). Definition.- The James Beds are confined to the vicinity of the Fenton Fault and particularly at Mt. James (Long.124° 28' E., Lat. 18° 40' S.) from which the unit name has been derived. The James Beds unconformably overlie either Liveringa Group, Noonkanbah Formation or Poole Sandstone.

Lithology.- The section is primarly sandstone which is normally strongly cross-bedded or well-bedded weathering to massive and well-graded. The grain-size is variable, ranging from medium to conglomeratic.

Thickness.- An incomplete section of 80 feet has been measured at Mt. James.

Palaeontology and Age.- The unit has not yet yielded fossils but on stratigraphic grounds is tentatively considered to be Jurassic and possibly equivalent to the basal part of the Alexander Formation on the basis of lithological similarities.

MUDJALLA SANDSTONE (New Formation). Definition.- The formation has a limited area of distribution in the vicinity of Mudjalla Yard (Long.123° 51' E, Lat. 18° C5' S.). Discontinuous outcrops have also been identified farther to the north-west along the west bank of the Fitzroy River towards Mangel Creek. The Mudjalla Sandstone unconformably overlies the Liveringa Group; the upper beds have been removed by erosion.

Lithology.- The formation consists of cross-bedded, unsorted, ~~angular~~ medium and coarse grained sandstone with lensing conglomerate beds.

Thickness.- A maximum section of 120 feet has been preserved.

Palaeontology and Age.- Preliminary determinations of the rare plants remains in the unit indicate a tentative Upper Jurassic age.

ALEXANDER FORMATION. (New Formation). Definition.- The Formation was included by Reeves (1949) in his Edgar Range Beds. Subsequent work has indicated a precise age for the unit. The distribution is confined to the Edgar Range area where it has been mapped between Mt. Jarlemai and Jurgurra Creek, near Wilson Creek, Camelgooda Hill and as low scattered outcrops between sand dunes to the north-east of the Edgar Ranges. The Formation unconformably overlies the Jurgurra Sandstone and is overlain conformably by the Jarlemai Formation.

The Formation has been named from Mt. Alexander (Long.123° 40' E., Lat. 18° 41' S.).

Lithology.- The Formation consists of alternating beds of fine to coarse grained, impure, quartz sandstone and siltstone with silty shales. The sandstone tends to be friable and the colour varies from brick-red to yellowish-brown. The shales consist of white, pink or purple kaolinitic silt with small mica flakes and small lenses of coarse quartz sand.

Cross-bedding is a feature of the sequence and the bedding ranges from massive to well bedded.

Thickness.- The Formation thickness ranges within the limits of 150-180 feet.

Palaeontology and Age.- A preliminary examination of the marine fauna by R.O. Brunnschweiler has indicated the presence of the following forms:-

Ammonoidea : Virgatosphinctes c.f. V. communis Spath and other Perisphinctidae

Pelecypods : Inoceramus c.f. I.everesti Holdhaus
Meleagrinella n. ssp.
Maccoyella n. ssp.
Maccoyella c.f. M. Corbiensis Eth. jun.
Modiola n. sp.

Echinoderms ?Ophiura ssp.
Asteroidea ssp.

The fauna in the lower part of the unit is less varied and consists of

Pelecypods: Maccoyella n. sp.
Inoceramus n. sp.
Quenstedtia sp.

Brachiopods: Lingula n. sp.

Echinoderms: Ophiuriidae ssp.

The faunal assemblage is indicative of a Jurassic (Portlandian) age.

JARLEMAI FORMATION. (New Formation). Definition.- The Formation conformably overlies the Alexander Formation and is overlain by the Mowla Conglomerate. There is some doubt whether the junction with the Mowla Conglomerate is unconformable or transitional and in fact the relationship may vary from one to the other from one locality to another. Generally speaking, it is considered to represent a time break.

The Formation was included by Reeves (1949) in his Edgar Range Beds.

The Formation has been mapped in the Edgar Range, west of the western tributary of Jurgurra Creek, south-east of Mt. Jarlemai and elsewhere capping the Alexander Formation.

The unit name has been derived from Mt. Jarlemai (Long. 123° 47' E., Lat. 18° 43' S.).

Lithology.- The Formation consists of poorly stratified to massive, unsorted sandy siltstone and silty sandstone. The siltstone ranges from sandy to very fine and could be described as a kaolinitic claystone containing ochre. The weathered surface tends to exfoliate and forms abrupt, frequently perpendicular, scraps, a spectacular feature of the Edgar Range topography.

Thickness.- Sections were measured ranging from 230-300 feet representing the maximum thickness of the Formation in the outcrop area.

Palaeontology and Age.- The marine fauna is relatively impoverished and consists of two genera with five species:-

Buchia ("Aucella") c.f. B. spitienais Holdhaus
Buchia ssp.
Meleagrinella n sp.

It is considered that the fauna differs from those of the underlying Alexander Formation and the presumably overlying Langey Siltstone of Dampier Land Peninsula. (Brunnschweiler, Personal Communication).

The former is Portlandian (or possibly early Tithonian), and the latter is late Tithonian. It has been concluded that the Jarlemai Formation is of early or middle Tithonian.

The Formation is the youngest Jurassic of the area under review.

CRETACEOUS OR TERTIARY? (Table 5)

MEDA CONGLOMERATE (New Formation). Definition.- The Formation unconformably overlies the Erskine Sandstone and has been mapped as a capping on Erskine Hill and Range, at Trig. HS 1 and as scattered outcrops in the pindan north and west of One Tree Bore (Meda). The gravel pits in the Derby town area are considered to be in the formation.

The formation has been named from Meda Station (Long. 124° 00' E., Lat. 17° 22' S.), where the more important outcrops are situated.

Lithology.-The formation is essentially a mixed lithological type consisting of medium and coarse grained quartz sandstone with, commonly, beds and lenses of sorted and unsorted conglomerate. The coarser phenoclasts include quartz, quartzite and angular fragments of rock material derived from the Erskine Sandstone. The outcrops are frequently highly ferruginised.

Thickness.- Up to 30 feet of the Conglomerate has been preserved but no complete section is available.

Palaeontology and Age.- No fossils have been collected from the unit and the age cannot be exactly established. It is tentatively assigned to the Cretaceous-Tertiary interval.

MOWLA CONGLOMERATE. (New Formation). Definition.- The formation is limited to two areas, one south-east of Mt. Jarlemai and the other adjacent to Mowla Bluff (Long. 123° 43' E., Lat. 18° 46' S.). The Conglomerate unconformably overlies the Jarlemai Formation and the upper part has been removed by erosion.

Lithology.- The Conglomerate consists of strongly cross-bedded, unsorted conglomerate, conglomeratic sandstone and coarse sandstone. The surface outcrop is highly ferruginised but a friable condition can be expected at depth. The variable nature, and related characteristics, indicate a shallow water deposit of variable thickness and lithology.

Thickness.- A complete surface section has not been preserved. Up to 15 feet have been measured in outcrop and it is anticipated that the unit may be considerably thicker in suitable localities.

Palaeontology and Age.- The apparent absence of fossils has prevented accurate dating of the formation. Although the age could range from Cretaceous to Tertiary, the latter is considered to be a more likely age for the unit.

TERTIARY: (Table 5)

WARRIMBAH CONGLOMERATE. (New Formation). Definition.- The formation has been mapped in outcrop at scattered localities in the vicinity of the Fitzroy River, particularly near Warrimbah Homestead (Long. 124° 58' E., Lat. 18° 24' S.) and Myroodah Homestead. The base of the formation is not exposed but presumably unconformably overlies either Permian or Mesozoic.

Lithology.- The unit is distinct from other conglomerate formations in that it consists of massive accumulations of well-rounded water-worn pebble and boulder conglomerate. The conglomerate is invariably unconsolidated.

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

Palaeontology and Age.- Fossiliferous material has not been discovered in the Conglomerate. The association with the Fitzroy River leaves little doubt that the formation was deposited by ancestors of the present Fitzroy River. The age is tentatively placed in the Tertiary.

PISOLITIC IRONSTONE.

The Ironstone is found as a shallow layer over Permian and Mesozoic formations and is a product of lateritization. The rock consists of a hard mass of ferruginous pisolites and nodules with rock fragments cemented in a sandy ferruginous matrix.

It has been generally accepted that the late Tertiary was an active period of lateritization throughout northern Australia and it is probably that most, if not all, of the pisolitic ironstone of the Fitzroy Basin is related to this period of active lateritization.

During the survey by the author, no detailed work was attempted on the laterite profiles exposed in the area.

QUATERNARY: (Table5)

Sand, Sand Dunes.- Sand is by far the most common superficial deposit in the area. The predominantly sandy rock formations, low rainfall and climate, and the sparse vegetation collectively contribute towards the wide distribution of surface sand. Sand dunes on the other hand are more specific and are confined to areas underlain by Grant Formation and, particularly, Mesozoic formations. All inland dunes are now fixed and frequently show signs of dessection. Active dune formation is taking place in coastal areas such as Cape Leveque and south of Broome. The desert dunes have been discussed previously under Physiography.

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

The remaining units listed in the accompanying stratigraphical table, viz: alluvium, residual soils and black soils have been discussed in the section on Vegetation and Soils.

STRUCTURE.

REGIONAL STRUCTURE

The study of the development of the broad structural elements of the Fitzroy Basin and adjacent areas since Pre-Cambrian times is of vital importance at this stage of the investigation. As a result of this study it is possible to predict (within obvious limits) the type and disposition of deposits which may be expected in deeper parts of the Fitzroy Basin by analogy with outcropping sediments of the same or similar age.

Owing to the limited amount of information available predictions must necessarily be subject to variations as geophysical and drilling information becomes available.

The geological history of the area suggests that the Fitzroy Basin is located, partly at least, in an ancient mobile belt which has possibly persisted from Proterozoic time. To the north-east and to the south the sediments overlap on to the more stable blocks of the Kimberley Plateau and the Pilbara area.

The Proterozoic geological record of the area is restricted to the margin of the Fitzroy Basin on the north-east and ranges from strongly folded and granitized rocks of the Lamboo Complex has a complex orogenic history; The Kimberley System was deposited in mainly shallow water in a mild orogenic to epeirogenic environment.

The Kimberley System is represented in the Fitzroy Basin by outcrops in the Oscar Range where quartzites and conglomeratic quartzites, probably of Upper Proterozoic age, occur. These rocks differ from similar rocks in the Leopold Ranges in that they are intricately folded, overturned and probably involved in thrust faulting. The conglomeratic beds are also strongly sheared.

Thus it is indicated that during the Upper Proterozoic there was a more intensive erogenic environment in areas adjacent to the Fitzroy Basin than farther east in the Kimberley Plateau, where folding in the lower Formations of the System is well developed but not intense.

Recent mapping in the Kimberley Plateau has shown that a diastrophism pre-dated the deposition of the upper beds of the Kimberley System. The gently dipping and sub-horizontal sediments of the Walsh Tillite and Mt. House Beds overlie the eroded, folded structures in the Warton Beds, Mornington Volcanics and King Leopold Formation.

The isolated occurrence of Ordovician rocks in the Prices Creek area prohibits any convincing conclusion being reached on the configuration of the Ordovician basin. It is presumed that the Fitzroy Basin area was already a negative element and deposition was taking place together with erosion of the shield areas (or positive elements) to the north-east and south.

Deposition in the north-east marginal area then continued with intermittent breaks throughout the Palaeozoic. The process was also continuous throughout the Fitzroy Basin, but whether or not the breaks in sedimentation observed along the margin will also be repeated throughout the Basin is purely conjectural. There is a strong possibility that sedimentation in deeper parts may be more continuous than in marginal areas as shorelines are sensitive to even minor erogenic movements.

The two major structural features of the Fitzroy Basin are the Pinnacle Fault and its extension to the north-west and the Fenton Fault. In effect these two fault lines, or zones, form the margins of the present concept of the Fitzroy Basin. The area to the north-east of the Pinnacle Fault was a shelf area in Devonian and was not transgressed by later seas. The area to the south of the Fenton Fault is unknown geologically owing to the cover of Mesozoic sediments and the total lack of sub-surface information. It does seem probable that Permian transgression took place across the Fenton Fault but it is suggested that this transgression was of very limited extent.

The Pinnacle Fault is the western limit of both Ordovician and Devonian outcrop. Examination has revealed that considerable movement has taken place along this line since the deposition of the Grant Formation. Along the north-east side of the Fault are outcrops of shattered Grant Formation and Devonian limestone. On the south-west side outcrop virtually unaffected beds of the Noonkanbah Formation.

These facts suggest that the negative element was to the south-west of the Pinnacle Fault during the deposition of the Noonkanbah Formation and Liveringa Group and disposition of these latter units more or less kept pace with the subsidence. At the same time older formations of Grant Formation, Devonian and Ordovician, which were deposited over this tectonic line, were subjected to crushing as the downward movement progressed.

It is also possible that the negative element bounded by the Pinnacle Fault was already active during the Devonian, Ordovician and earlier. Owing to lack of surface and sub-surface information this question cannot be answered. Such a tectonic line would probably have a profound effect on environmental conditions during the Devonian Period and may well have delineated the seaward extent of the shelf deposits represented in the outcrop area.

The history of the Fenton Fault could conceivably be similar to the Pinnacle Fault with a consequent important effect on environmental conditions and disposition of sedimentation during the Palaeozoic. Outcrops along the Fault are restricted to the Permian and Mesozoic. There has undoubtedly been considerable movement along some sections of the Fault and practically no movement in others. For example, between Nerrima Creek and Mt. Fenton the fault plane has been studied at a number of localities and dips to the north at 50° to 60° with considerable displacement.

In general it can be stated that the fault has a throw to the north, with a variable displacement, in Permian rocks. Geophysical evidence has indicated the possibility of a reversal of throw towards Nerrima Creek.

Mesozoic beds have also been faulted along the Fenton Fault and where observed have a displacement of 140 feet to the south-west.

A comparison of the information available on the Fenton and Pinnacel Faults indicates that movement along the Fenton Fault has persisted after movement along the Pinnacle Fault has ceased. It is also possible that movement along the Pinnacle Fault may have been significant before movement along the Fenton Fault had commenced.

Apart from the boundary faults the outstanding structural features are the three main anticlinal axes which will be referred to as the Southern Anticline, Central Anticline and Northern Anticline.

All three anticlinal axes have a trend of approximately 280°. By comparison, the axial trend of the structures in the King Leopold Range have a trend of approximately 310°, and this compares closely withthe strike of the Fenton and Pinnacle Faults.

The Southern Anticline extends for a distance of about 120 miles from the Luck Range (east of Christmas Creek Homestead) to the Fenton Fault (west of Tutu Bore). The axis has five distinct culminations, viz: Poole Range Structure, Mt. Hutton Structure, St. George Range Structure, Nerrima Structure and Tutu Structure.

The Central Anticline can be traced for about 50 miles from east of Mt. Wynne to the Fitzroy River (west of Mt. Anderson). Two culminations are known along the axis of this anticline, viz., Mt. Wynne Structure and Grant Range Structure.

The Northern Anticline is, by comparison, poorly defined and only one culmination, the Warrawadda Structure (8 miles south of Blina Homestead), has been identified.

The Northern Anticline may extend farther to the north-west but the lack of outcrop and the overlap of Mesozoic sediments effectively conceal any extension that may exist.

In addition to the structures associated with the major anticlines there are a number of subsidiary folds which will be discussed in more detail in the following section.

FOLDING AND FAULTING IN THE FITZROY BASIN.

Poole Range - Mt. Hutton Structure.- The structure has a major culmination in the Poole Range and a minor culmination at Mt. Hutton. The westerly plunge is terminated by the faulted zone near Roxona Bore and to the east the fold passes into the gently dipping beds of the Luck Range. Flank dips are low (between 3° and 5°) and regular and the structure can be classed as symmetrical.

Mapping of the structure is complicated by a system of northerly trending high angle normal faults which cut across the structure at intervals of ½ to 1 mile. The result has been the formation of a series of fault defined blocks which have modified surface plunge of the axis. The faults are clearly defined on the surface and the average displacement is in the vicinity of 80 feet with a limit of 150 feet. The dip of the fault plane is normally about 80°.

All Permian formations outcrop on the structure with Grant Formation and Poole Sandstone forming the core of the structure and the Noonkanbah Formation and Liveringa Group outcropping on the grassy flats surrounding the resistant core. The Poole Range-Mt. Hutton structure has a surface closure in the Noonkanbah Formation.

Owing to the complicated structural pattern on the western plunge it has not been possible to accurately assess vertical closure either on this structure or St. George Range Structure. With the assistance of a detailed stereocomparagraph study, based on the geological information obtained during the survey, a satisfactory estimate of vertical closure will be possible.

St. George Range Structure.- The structure has a length of 35 miles and a width of about 30 miles and covers an area of approximately 1000 square miles.

The core of the structure consists of resistant beds of Grant Formation with scattered outliers of Poole Sandstone. The flanks consist mainly of beds of the Poole Sandstone fringed by grassy plains underlain by the Noonkanbah Formation. The Liveringa Group occurs as low strike ridges of the Shore Range, low on the southern flank as discontinuous rises on the northern flank.

The structure is closed in the Noonkanbah Formation.

Flank dips along the northern side of the structure reach a maximum of 5°. Dips along the southern flank vary between 3° and 14° and are affected locally by the development of a secondary anticlinal structure covering an area of approximately 600 square miles. Variations in dip and strike have resulted from the movements of the blocks between the numerous trancverse faults which intersect the structure.

The system of northerly trending faults is similar to those described from the Poole Range-Mt. Hutton Structure. Twentyfive of the larger faults were examined and it has been concluded that, in general, these faults can be traced across the structure and well down the flanks. The displacement reaches a maximum on the flanks and appears to reach a minimum in the crestal area. All faults which can be traced across the axis are of the normal high angle pivotal type.

As a result the dip and displacement direction reverses from one to the other side of the axis with a double reversal where the faults cross the double axis on the southern central flank.

The average vertical displacement of the faults is 200 feet with a maximum displacement of approximately 600 feet in the major fault east of Mt. Tuckfield.

Norrima Structure.- The Nerrima Structure is a low, faulted, domal structure 16 miles in length and 8 miles in width. The vertical closure is of the order of 250 feet over an area of approximately 30 square miles with a drainage area of approximately 300 square miles. (Guppy ét alia, 1950).

Mapping of the structure encountered similar problems to those previously discussed as a result of the transverse faulting; confirmation of westerly closure was also complicated by complex faulting.

Outcrops of the formations involved are poorly developed throughout and as a result it was necessary to interpret structure in areas where no evidence was available. As a result the interpretation presented may be questionable in some areas but overall it is believed that the structural contour map presents a reasonably accurate picture of the surface geology.

Seismic and gravity investigations carried out in the Norrima area in 1952 tend to suggest that the structure does not persist in depth. Owing to the difficulties encountered by the seismic crew working in this highly faulted area the writer prefers to reserve judgement on the geophysical interpretation until broader regional work has been completed.

Tutu Structure.- The structure is the most westerly culmination on the Southern Anticline. The structure has a length of 10 miles and a width of 6 miles. The western plunge and closure is well defined although containing a number of faulted wedges of Grant Formation and Poole Sandstone in the vicinity of the Fenton Fault.

The southern flank and the eastern plunge have not been satisfactorily revealed during mapping and will require further detailed study before the structure can be adequately defined.

Deep Well Anticline.- The axis of the structure is 18 miles north-west of the Norrima Bore and is separated from the Norrima-Tutu anticline by a very well defined synclinal axis, the Dry Corner Syncline. On the northern flank of the anticline is a small, but also well defined, synclinal structure, the Myroodah Syncline.

Both flanks of the Anticline are clearly revealed on aerial photographs but faulting, together with lack of outcrop, has effectively concealed the plunge to both the west and east. By comparison with the adjacent, plunging synclines, it can be reasonably expected that the Deep Well Anticline has a surface closure in sediments of the Liveringa Group.

Flank dips cannot be measured on the synclinal and anticlinal structures described above owing to lack of outcrop. Experience in nearby areas suggests that the dips will be less than 3°.

McLarty Syncline.- South of the Norrima Structure a synclinal axis parallel to the Fenton Fault can be traced for 28 miles from north-west of Barnes Flow to the vicinity of Andys Bore, north-east of Mt. Fenton. The axis of this structure is in the Liveringa Group and the flanks consist of the Noonkanbah Formation.

The syncline is highly asymmetrical with northern flank dips of 2° - 3° and southern flank dips adjacent to the Fenton Fault as high as 8°.

The structure has similar characteristics to the Talbot Syncline which is adjacent and parallel to the Pinnacle Fault.

Mt. Wynne Structure.- Both the Mt. Wynne and Grant Grange Structures are characterised by longitudinal faults together with normal transverse faults. As a result the dips of the beds in the axial areas are frequently very variable and contradictory. Low on the flanks the plunging anticlinal pattern becomes more obvious.

The core of the Structure is composed of strongly faulted Grant Formation and Poole Sandstone with dips ranging from 4° to 14°. The Structure is roughly symmetrical with dips up to 8° - 10° on both north and south flanks.

Two culminations have been mapped on the structure, one in the vicinity of Mt. Wynne and the other west of Paradise Outcamp. Low folding and strike faulting in the Poole Sandstone and Grant Formation occur between the two culminations.

Faults trending north and slightly west of north are most common but probably do not exceed 100 feet displacement. More important are strike faults. A major strike fault passes between Jimberlura Hill and the Jimberlura Ridges and has a displacement of 1500 - 2000 feet north of Jimberlura Hill with decreasing displacement to the north-west. Similar strike faults of unknown displacement occur through Mt. Wynne, terminating the local set of north trending faults, and probable strike faults between the Mt. Wynne and Jimberlura folds.

Grant Range Structure.- The Structure is a large faulted plunging anticline comparable in size to the St. George Range Structure. The stratigraphy is essentially the same as the St. George Range Structure but differs in the strong development of strike faults with subordinate transverse faulting. The accompanying maps show the extent of the faulting. Mapping of the area has indicated that the larger faults have a displacement exceeding 1000 feet.

The structure is closed in the Noonkanbah Formation.

Warrawadda Structure.- The structure has been mapped mainly on aerial photographs in an area of gentle folding adjacent to the Derby-Fitzroy Crossing Highway. Associated with the anticline are at least two synclinal structures.

The structure is closed in the Liveringa Group and possibly contains a core of the Noonkanbah Formation. Surface outcrop is absent and stratigraphic interpretation is based on loose surface rubble, soil types and water bore information.

Flank dips are very low (probably less than 3°) and no faulting has been observed.

Talbot Syncline.- The Syncline is a small structure parallel and closely related to the Pinnacle Fault. It has been identified between 6 Mile Bore and Mt. Talbot where dip readings indicate a plunging asymmetrical syncline. Beds of the Liveringa Group form the axial region of the fold and are underlain to the south-west by beds of the Noonkanbah Formation. To the south-east the Liveringa Group outcrops against the Pinnacle Fault and the underlying Noonkanbah Formation does not reappear in the vicinity.

North-west of the Talbot Syncline there are indications of further gentle folds, but outcrops are poor and scattered and detailed mapping was impracticable.

The age of the surface folding, though not precise, post-dates the deposition of the Liveringa Group.

The surface fold is apparently the result of mainly vertical movement of the Pinnacle Fault after the deposition of the Liveringa sediments. As indicated earlier the structure is comparable with the McLarty Syncline adjacent to the Fenton Fault.

LEUCITE-BEARING INTRUSIONS:

Twenty leucite rich intrusions are known from the Fitzroy Basin and have been described in detail by Wade and Prider (1940). The intrusions are described as plugs and craters by Wade, and Prider has shown that these rare rock types may be described as lamproites. Apart from the rock italite they are the richest leucite-bearing rocks known.

With the possible exception of Oscar Plug, Mt. Percy and Mt. North, the intrusions are situated in the synclines adjacent to the major anticlinal axes.

Kalaida Hills, consisting of two plugs, are intrusive into sediments of the Liveringa Group in the syncline immediately south of the Southern Anticline. These are the only intrusions known from this synclinal axis.

The greatest concentration occurs intruding beds in the syncline between the Southern and Central Anticlines (Plate).

Altogether 15 intrusions are known from this syncline, viz: Brutens Hill, "P" Hill, Mt. Ibis, Machells Pyramid, Mt. Abbott, White Rocks, Howes Hill, Fishery Hill, Mamilu Hill and Mt. Cythe.

With the exception of White Rocks, these intrusions have penetrated the section as high as either the Noonkanbah Formation or Liveringa Group. At White Rocks, the lamproite is intrusive into Triassic sediments of the Blina Shale.

Moulamen Hill is comparable with the Kalaida Hills in that it is the only intrusion known from the syncline between the Central and Northern Anticlines.

The intrusions of Mt. Percy and Mt. North have no obvious connection with structure in Permian rocks and outcrop as intrusives in Grant Formation. They are both adjacent to the syncline of the Fairfield Valley where depositional dips of the Upper Devonian sediments form a distinct synclinal area with flanks forming the Napier Range and the northern Oscar Plateau.

Oscar Plug is an intrusion distinct from the other concentrations and with no known structure affiliations.

The presence of volcanic material in the Lower Cretaceous sediments of Dampier Land indicates a Lower Cretaceous age for the Fitzroy Volcanics. Owing to lack of information they have previously been considered Tertiary intrusions.

SEDIMENTARY TECTONICS

In relation to Devonian and Ordovician sedimentation in areas buried under later sediments.

ORDOVICIAN.

The Ordovician section, and in particular the lower part of the outcropping section (Emanuel Formation), is characterised by a particularly rich marine fauna in shales and limestones. Glauconite and limonite (after pyrite) have been observed in these beds.

The lithology and fauna indicates that the Formation was deposited on a sinking shelf in a relatively stable, reducing environment under cool water conditions.

The overlying Gap Creek Formation differs from the Emanuel Formation in the presence of primary dolomite throughout the section and the occurrence of beds of well-sorted sandstone in the upper beds. Fossils are again present but are usually silicified.

The Gap Creek Formation was probably deposited under similar conditions to the Emanuel Formation but in warmer water and under mildly unstable conditions.

It appears likely that the Ordovician shore line was adjacent to the present outcrop and probably in a similar position to the shore line in Devonian time. Thus it is not surprising that erosion has removed all but a small part of the Ordovician from areas which were later transgressed by both Middle and Upper Devonian seas.

The Ordovician basin was probably extensive and may well have covered a large part of the Fitzroy Basin. If this is so it is also possible that large areas of Ordovician sediments within the basin may be preserved.

It is impossible to predict the type of sediments that may be expected but in zones where a similar environment existed to that described from the Prices Creek area rich fossil faunas may again be expected. Areas of deeper water environment can also be expected with a consequent variation in fauna and lithology.

DEVONIAN.

Middle Devonian.- The Pillara Formation is notable for the widespread and consistent nature of the rock types developed in the outcrop area. The outcrops are restricted to sediments, both organic and inorganic, developed on the shelf area in what Krumbein and Sloss (1951) term an epineritic biostromal environment. In this environment sediments are formed in shallow clear water with open circulation and little land derived sediment. The controlling factors are temperature, salinity, oxygen content and depth.

Upper Devonian.- The Upper Devonian is represented broadly by three types of deposits:- the quartzose clastic group (Mt. Pierre Group, Fossil Downs Group, Sheep Camp Formation, Brooking Formation and Napier Group), the calcarenite - reef group (Springs Formation, Oscar Formation, Bugle Gap Limestone) and the clastic - shale group (Fairfield Formation). All three types were developed on a mildly unstable shelf in an environment ranging from epineritic to epineritic biostromal. Although, to a large extent contemporaneous, the marked difference in sediments between the quartzose clastic group and the calcarenite- reef group, was due to the effect of the Oscar Range which acted as a barrier to the deposition of land-derived sediment and provided lime sand and clastic limestone from the erosion of the Middle Devonian.

The clastic - shale group, the youngest Devonian outcropping, was deposited under different conditions, possibly in deeper water.

Summarising, it can be stated that the Upper Devonian of the outcrop area was deposited under shallow water conditions on a sinking shelf in an environment in which a potential biohermal and reef building fauna existed. Under suitable conditions biohermal growths thrived whereas in other zones the growth was inhibited by adverse conditions, related to local shore line environments.

The absence of sediments of Silurian age in Western Australia suggests that there was a regression of the sea at the close of the Ordovician and it is possible that this regression may have retreated beyond the present continental margin.

At least as early as Middle Devonian there was a major transgression which eventually formed a shore line a short distance east of the present outcrop area. The outcrops have revealed the presence of a reef and biostromal building fauna and under suitable conditions (e.g. along tectonic lines such as Pinnacle Fault and Fenton Fault and topographic highs) organic limestone would probably be developed.

In areas of deeper water or in areas where the sea floor was sinking at a rate which prevented the continued development of biohermal or biostromal growths, corresponding calcareous sediment would be deposited under primarily reducing conditions.

At the end of the Middle Devonian there was a further regression from the shelf area. The actual extent of the regression cannot be determined owing to lack of outcrop and sub-surface information west of the outcrop area. The fauna of Middle and Upper Devonian suggests that this withdrawal was of comparatively short duration and was followed by a further transgression in epi-Upper Devonian. It is therefore possible that the unconformity between Middle and Upper Devonian, revealed in the outcrop area, may be restricted to marginal areas and continuous deposition proceeded in other areas throughout the Middle and Upper Devonian.

The study of the Upper Devonian outcrop has revealed that a potential reef building fauna existed and reef growth would be established in suitable environments and corresponding deeper water sediments, both organic and inorganic, would be developed elsewhere.

In the Fitzroy Basin approximately one half of the Devonian shore line has been revealed by erosion - the remainder is concealed under subsequent sediments. Numerous opportunities for reef and biostromal growth would be expected along the shore line, and around off-shore islands, in a basin as large as the Fitzroy Basin. In addition zones of deeper water, in which sediments would be deposited under reducing conditions, could be expected.

PETROLEUM PROSPECTS.

SOURCE ROCKS.

Ordovician. - The Prices Creek Group contains the highest grade source rocks for petroleum known in the area. Shallow drilling in the period 1919-1922 produced several showings of oil in these rocks, (at the time the rocks were considered to be of Devonian age.)

The rich marine fauna found throughout the 2,450 feet sequence, the evidence of reducing conditions during deposition and the possibility of a much wider development of the Group in the Fitzroy Basin, gives a high source rock potential to the Group. Potential reservoir rocks exist in the sandy beds towards the top of the Group.

Devonian.- The outcropping section in the Middle and Upper Devonian of the Fitzroy Basin is not of great significance as a source rock.

Comparatively recent exploration in North America and particularly in central Alberta has resulted in the discovery of rich oil fields in Devonian reef and associated formations. In general, however, the organic material required for the production of petroleum will not be preserved in the oxidising environment inherent in reef growths. The deeper water limestone and other sediments deposited during the time of reef growth may be highly favourable source rocks and as a result of migration can eventually accumulate in porous zones of reefs in adjacent areas. Generally speaking it appears that bioherms and reef complexes are valuable primarily as reservoir rocks together with other porous and jointed sediments which may occur in favourable areas.

As pointed out previously, possibilities do exist for the presence of reef growths and associated marine limestones and clastic sediments which could act as both source rocks and reservoir rocks in structurally favourable situations.

Formation.- The outcropping sequence in the Fitzroy Basin contains no marine sediments which could be classed as source rocks. The section does contain numerous beds which would be favourable as reservoir rocks.

There is a slight possibility that more favourable facies could be encountered in the sub-surface section under the Dampier Land Peninsula. The possibility is comparatively remote and can be ignored for the present.

CAP ROCKS:

Ordovician.- The Emanuel Formation consists of interbedded limestone and shale. The shale beds would act as suitable cap rocks wherever they are found.

The upper Cap Creek Dolomite contains no beds which could be considered reliable cap rocks.

Devonian.- Generally, the Middle Devonian contains no suitable cap rock beds. The Upper Devonian, however, contains numerous horizons with low permeability, a feature which would improve in deeper water equivalents.

The Fairfield Formation, the uppermost Devonian Formation, is not well known but it is suspected that it contains shale horizons which would be ideal as cap rocks.

Permian.- Both the Noonkanbah Formation and the Blina Shale contain shale horizons which act as impermeable layers, a feature consistently illustrated by water-boring. The Noonkanbah Formation could act as cap rock on structures such as the Norrima

Structure, Tutu Structure, Deep Well Anticline and Warrawadda Structure.

The Blina Shale could be of value only if a structure is proved in Dampier Land Peninsula. Elsewhere the Shale has been eroded from anticlinal structures.

GENERAL STATEMENT:

Throughout the foregoing remarks it has been emphasized that surface outcrop and structure are the only factors upon which the conclusions expressed are based. As this information is to a large extent superficial, the interpretation of the sub-surface geology is a highly controversial subject open to various interpretations and subject to a number of complicating factors which are not apparent from the surface geology.

If subsequent work should indicate that Ordovician and Devonian sediments have a significant sub-surface development it would be reasonable to rate the petroleum prospects as high and good opportunities would exist for obtaining petroleum in suitable structural or stratigraphic traps. A similar situation would exist if it could be proved (as seems likely) that the Devonian sediments alone have a significant sub-surface distribution.

For comparison it is relevant to compare the geology of the Fitzroy Basin with the Williston Basin (Burg 1952, Barnes, 1953) which extends from northern U.S.A. into southern Canada. In this area a similar stratigraphic section to that in the Fitzroy Basin is known. The main differences are the occurrence of Silurian and Carboniferous which are unknown in outcrop in the Fitzroy Basin.

Few successful bores had been sunk in the Williston Basin until recent exploration proved the existence of accumulations in Ordovician, Devonian and Permian.

In the Fitzroy Basin the presence of petroliferous horizons in the Palaeozoic (particularly in the Ordovician) has been known for over 30 years. Although attempts have been made throughout this period no bore has been drilled on a suitable structure to horizon below the Permian. Apart from bores in the Prices Creek area, which were shallow and were not located on defined structure, four bores have been drilled specifically for oil exploration. These were located. on information from geological surveys, on the Poole Range, Mt. Wynne and Nerrima Structures. For various technical reasons all bores have ceased drilling the Grant Formation even though traces of oil were reported from two of the four bores.

Consequently it can be stated that no structures have been adequately tested during drilling operations in an area where the surface geological surveys have indicated a reasonable possibility of finding oil in economic accumulations.

RECOMMENDATIONS.

The seismic and gravity surveys which have been planned for the 1953 field season should be continued to obtain a good coverage of the Fitzroy Basin. The seismic traverses should be used for detailed investigations over the known anticlinal structures. Earlier work at Nerrima has indicated that faulting in the structures will provide problems which are not readily overcome. Various techniques should be applied in an endeavour to obtain as clear an interpretation of the sub-surface structure as possible.

Further work appears to be warranted in the vicinity of the Pinnacle Fault Zone. Although Ordovician sediments outcrop east of the Fault, west of the Fault Ordovician sediments, which it is presumed survived the epi-Middle Devonian period of erosion, are now buried under a section of Permian and Devonian sediments. By means of detailed geological mapping, assisted by seismic shooting, it should be possible to indicate the type of drag structures produced by the Fault movements and estimate the displacement. With this information it would be possible to locate a test hole on either side of the Fault. The object of such a test would be to penetrate the Ordovician section in a structurally favourable locality.

Although bores in the localities would not necessarily be conclusive, they have the advantage of being comparatively shallow together with the probability that both bores will penetrate Ordovician sediments.

Whether or not the sub-surface section near the Pinnacle Fault is tested, steps should be taken to locate drilling sites on the anticlinal structures described previously. In order of preference, these structures are listed below:-

Grant Range
St. George Range
Poole Range
Deep Well
Nerrima
Warrawadda
Mt. Wynne

In order to select the most suitable site on each structure it will be necessary to prepare a structural contour map of each by either the normal surveying methods or by the use of a stereocomparagraph with adequate ground control. The latter method is to be preferred as the first three structures listed are located in difficult and very rugged terrain. In addition a seismic programme may obtain sufficient information to indicate the most suitable location for a drilling site in relation to deep structure.

Rotary drilling in the Fitzroy Basin should encounter no difficulties beyond the highly abrasive nature of the Grant Formation.

The study of the surface sections has indicated that the following drilling depths may be anticipated:-

STRUCTURE	Depth to top of Devonian	Depth to top of Ordovician	Depth to Pre-Cambrian
Grant Range	3000 + feet	10,000 - feet	12,000 - feet
St. George Range	3000 + feet	10,000 - feet	12,000 - feet
Poole Range	3000 + feet	10,000 - feet	12,000 - feet
Deep Well	6000 + feet	13,000 - feet	15,000 - feet
Nerrima	6000 + feet	13,000 ± feet	15,000 - feet
Warrawadda	6000 + feet	13,000 ± feet	15,000 - feet
Mt. Wynne	3000 + feet	10,000 ± feet	12,000 - feet

The depths quoted to the top of the Ordovician and Pre-Cambrian can probably be treated as extreme values and could be considerably less if erosion and variations in thickness were significant factors.

The order of preference listed earlier is presented after taking into account factors such as structure, exposed stratigraphical horizons and accessibility. An alternate preference would reverse the order of the first three structures listed.

The relative proximity of the outcropping Ordovician and Devonian sections would be the main argument in the selection of the Poole Range Structure as the first preference. However, with current knowledge there is no reason to believe that the sub-surface section below the various structures should be substantially different.

In the suggested list of preferences the Grant Range Structure is chosen in advance of St. George and Poole Range Structures mainly on account of accessibility.

WATER SUPPLY

During the survey the position of all known bores was plotted on the geological maps and the relevant drillers logs were obtained from the station managers. Altogether 323 logs were obtained and have been plotted on the accompanying table (Table). The logs of shallow bores sunk during the early days of settlement in the area are not available. The stratigraphic position of the bores in Table are an interpretation based on the surface geological knowledge and the drillers logs. In cases where the bore has been completed near a sub-surface boundary between two formations it is not always possible to decidd whether the main source of water has been derived from the base of the upper formation or the top of the lower formation. In these cases the most likely interpretation has been plotted.

In the following table, the ratio between sub-artesian bores, artesian bores and dud bores has been tabulated.

TABLE 7.

	Post Triassic	Triassic	Liveringa Group	Noonkanbah Formation	Poole Sandstone	Grant Formation	Devonian
Sub-Artesian	15	17	125	37	23	24	17
Artesian	2	-	1	4	5	3	-
Dud	-	3	6	21	2	-	8
% Successful Bores	100%	85%	95%	66%	93%	100%	68%

The number of bores drilled in the various stratigraphic units is not a true reflection of the availability of underground water. The two major sheep stations, Liveringa and Noonkanbah, are so situated that a large number of the bores have been drilled in the Liveringa Group. The percentage of successful bores to dud bores does provide a reliable guide.

From table 7 it is evident that the most reliable parts of the sequence in which to drill for water are the Post Triassic (Jurassic, Cretaceous and more recent deposits), Grant Formation, Liveringa Group and Poole Sandstone, These units are primarily standstone sequences with numerous horizons from which a supply of sub-artesian water can be expected. With the exception of the Jurassic, Cretaceous and sometimes the Liveringa Group the water is invariably of potable quality. Water horizons with a significant mineral content have been penetrated in the Mesozoic sediments but with rare exceptions water suitable for stock purposes can be found.

The Triassic sequence contains over 1000 feet of shale (Blina Shale) which is impermeable and can be considered unsuited for the production of underground water. The overlying sandstone (Erskine Sandstone) is afavourable water-bearing sequence from which practically all the Triassic supply is derived. In areas where it has been necessary to locate bores on the Blina Shale there is the risk that the underlying formation may be Noonkanbah Formation. In such a case a bore of 2000 feet may be required before a suitable supply of water is obtained.

The Noonkanbah Formation, for the most part, is an unreliable source of water. Apart from marginal areas of the basin the Formation is mainly a shale section with low permeability. The main opportunities for a supply of water are restricted to the upper and basal beds. Water, including artesian water, has apparently been obtained from bores which have been unwittingly drilled on one of the transverse faults.

The Devonian formations differ from the Permian and younger formations in the rapidly changing facies and the rough topography which limits the area suitable for bore locations. The restricted number of bores which have been drilled in the Devonian does not permit an adequate assessment to be made of the ground water supplies that may be available. The following remarks are therefore subject to modification as more data becomes available.

The Pillara Formation, Saddler Beds and Bugle Gap limestone are not usually suited for drilling locations, due to rough topography. It would be possible to select sites in valleys such as Menjous Gap, Gap Spring, etc., if water supply was needed in those areas. Although no bores have been drilled in the formations it is considered that the task would be a difficult one and a supply of water would be limited to joints and the sandy beds at the base of the Pillara Formation.

Experience has shown that the Mt. Pierre Group is a particularly poor source of shallow water and should be avoided unless the operator is prepared to drill through the Group in the hope of finding an equifer at a lower horizon.

The Fossil Downs Group and Napier Group are untested but contain a sufficient proportion of sandy layers to provide good supplies of water.

The Oscar Formation, Springs Formation, Brooking Formation and Sheep Camp Formation are unsuited topographically for bore sites.

The Fairfield Formation has been tested at two bore sites and provided the bore site is located carefully the Formation should provide supplies of water from the sandy beds which are interbedded in the section.

Of particular importance are the conglomeratic formations (Patterson Conglomerate, Bohn Conglomerate, Stony Creek Conglomerate, Burramandi Conglomerate, Mt. Alma Conglomerate and J8 Conglomerate). These sediments are obvious sources of underground water and when found interfingering with the otherwise impervious Mt. Pierre Group and Fossil Downs Group are a drilling target. Successful results have been achieved on Fossil Downs and Margaret Downs stations by drilling in areas where conglomeratic beds have been predicted.

The underground water resources of the Fitzroy Basin are unusually good and with geological supervision it would be possible to obtain a very high percentage of successful bores in Permian and younger sediments. A similar situation exists in areas of Devonian sediments but here more caution is needed and experimental bores will be required to test sequences which have not been tested previously.

R E F E R E N C E S.

Barnes, T. B., 1953 - Williston Basin, New Province for Oil Exploration. Bull. Amer.Ass. Petrol.Geolog., Vol.37, 2.

Basedow, H., 1918- Narrative of an Expedition of Exploration in North-Western Australia. Proc.Roy. Geog. Sec. Aust. S.A. Branch, 18, pp. 102-295

Blatchford, T., 1927- The Geology of Portions of the Kimberley Division, with special reference to the Fitzroy Basin and the possibilities of the Occurrence of Mineral Oil.Geol.Surv. W.Aust.Bull. 93.

Burg. K. E., 1952- Exploration Problems of the Williston Basin. Geophysics Vol 17 No.3

Brunnschweiler, R., 1952- Geology of Dampier Peninsula. Unpub. report. Bur. Min. Resour. Aust.

Chapman, F., 1924- The Wade Collection of Fossils. By Authority. Commonwealth of Aust.

Chapman F., and Parr., W. J., 1937- On the Discovery of Fusulinid Foraminifera in the Upper Palaeozoic of North West Australia with a note on a new bivalve. Vic. Nat. 53, p.175.

Christian, C.S. & Stewart, G.A., 1952- Report on Preliminary Examination of Several Areas in the West Kimberley Division of Western Australia. Sci. Ind. Res. Org. Canberra. Unpublished Records, No.52/1.

Delepino. G., 1935- Upper Devonian Goniatites from Mt. Pierre, Kimberley District, Western Australia. Quart. J. Geol. S c. Lond. 91, 208.

Etheridge, T., 1918- Observations on Carboniferous and other fossils. Proc.Rev.Geog. Soc.Aust. (S.Aust. Branch). 18, (1916-17), p.250.

Fenton, C.L., 1943- A New Devonian Algae from Western Australia. Amer. Midl. Nat. 30,112

Findlay, W.A., 1942- Geologic Report, Northwestern Fitzroy Basin, Kimberley Division, Western Australia. Unpublished report to Caltex Aust. Oil Develop. Pty. Ltd.

Fletcher, H.O., 1943- The Genus Conocardium from Australian Palaeozoic Rocks. Aust.Mus.Rec. 21. p.231.

Foord, A.H., 1890- Description of Fossils from the Kimberley District, Western Australia. Geol. Mag., 111, 7 p.2

Guppy, et. alia., 1950- Geology of the Norrima Dome. Bur. Min. Resources. Aust. Rep No.4.

Guppy, D. J. & Opik, A.A. 1950- Discovery of Ordovician Rocks, Kimberley Division, Western Australia Aust. Jour. Sci. Vol. 12, No.6. p.205.

Guppy, D.J., et alia., 1952- The stratigraphy of the Mesozoic and Permian Sediments of the Desert Basin, Western Australia. Congres Geologique International (Gondwana Symposium Alger 1952.

Hardman, E.T. 1884 - Report on the Geology of the Kimberley District, Western Aust. Parliamentary Pap ers. W. Aust. No.30

1885 - Report on the Geology of the Kimberley District, Western Aust. Parliamentary Papers.W.Aust. No.34

Hill, D., 1936 - Upper Devonian Corals from Western Australia. Roy. Soc. W.Aust. 22,p.25

Hinde, C.J., 1890 - Notes on the Palaeontology of Western Australia, Part 2. corals & Polyzoa. Geol. Mag. 111. 7 p.194

Hosking, L.F.V., 1933 - Distribution of Devonian Rocks in the Kimberley Division, and Description of a recent Collection of Devonian Fossils from the Kimberley Division. Roy. Soc. W. Aust. Jour. 19,p.67

Howell, B. G., 1944 - Calcareous Sponges in Devonian of Australia. Bull. Geol. Soc.Amer., 55, p.1469.

Jack, R.L. 1906 - The Prospects of Obtaining Artesian Water in the Kimberley District. Geol. Surv. W. Aust. Bull, 25, p.1

Kraus, P.S. 1942 - Geologic and Stratigraphic Reconnaissance, North-West Portion Caltex Concession 7-H, Kimberley Division, Western Australia. Unpub. Report Caltex (Aust).Oil Development. Pty. Ltd.

Krumbein & Sloss. 1951 -

Maitland, A.G. & Montgom ery, A., 1924 - The Geology and Mineral Industry of Western Australia. Geol. Surv. of W. Aust. Bull, 89.

Miller, A.K. 1938 - Devonian Ammonoidea of America. Geol. Soc. Amer. Special Papers. No. 14.

Nicholson, H.A., 1890 - Notes on the Palaeontology of Western Australia 1. Stromatoporoidea. Geol. Mag. 111, p.193.

Prendergast, K.L., 1935 - Some Western Australian Upper Palaeozoic Fossils. Roy.Soc.W.Aust. Jour. 21, p.9

Reeves, F., 1949 - Geology and Oil Prospects of Desert Basin, Western Australia. Unpublished Report to Vacuum Oil Co. Pty.Ltd.

1951 - Australian Oil Possibilities. Bull. Amer. Assoc. Petrol. Geol., 35, 12 p.2479

Teichert, C., 1939 - Nautiloid Cephalopods from the Devonian of Western Australia. Roy. Soc. W.Aust. Jour. 25. p.102

1940 - Actinosiphonate Cephalopods from the Devonian of Australia. Roy. Soc. W. Aust. Jour. 26, p.59

1941 - Upper Devonian in the Neighbourhood of Mt. Pierre. Aust.Jour.Sci. (2) p.148.

1941 - Upper Devonian Gonistite Succession of Western Austral'a. Amer.Jour.Sci., 239, p.148.

1943 - The Devonian of Western Australia. A preliminary Review. Amer.Jour.Sci., 241, pp.69 & 167.

1947 - The Stratigraphy of Western Australia. Bull.Amer. Ass. Petrol Geol., 31, p.1 and Jour. Roy. Soc. N.S.W., 80, p.81.

1949 - Observations on Stratigraphy and Palaeontology of Devonian, Western Portion of Kimberley Division, Western Australia. Bur. Min. Resour., Report No. 2.

Wade, A., 1924 - Petroleum Prospects, Kimberley District of Western Australia and Northern Territory. By Authority, Melbourne.

1936 - The Geology of the West Kimberley District of Western Australia. Final Report on Concessions held by Freney Kimberley Oil Co., Perth.

1938 - The Geological Succession in the West Kimberley District of Western Aust. Aust. N.Z. Assoc. Adv. Sci., Rep. 23, p.93.

Wade, A. & Prider R., 1940 - The leucite-bearing Rocks of the West Kimberley Area, Western Australia. Quart. J. Geol.Soc.Lond., Vol.XCVI p.39.

Woonough, W.G., 1933 - Report on Aerial Survey Operations in Australia during 1932. By Authority. Canberra.

APPENDIX 1.

Resume of Reported Oil Shows in the Fitzroy Basin.

Prices Creek:- The original report was made during water boring by a hand-plant. As a result the Western Australian Government supervised the drilling of a hole to 90 feet. This bore was situated in Ordovician and traces of oil were collected. The Government Analyst (E.S.Simpson) examined seven samples from this bore and reported the presence of mineral oil in all. The oil was described as an unsaponified oil with paraffinic odour and apparently of mineral origin.

The Freney Kimberley Oil Co. Ltd., in 1922-1923 drilled four holes in the Prices Creek area to depths ranging from 1008 feet to 340 feet. Nos. 1-3 were situated in Ordovician sediments and No.4 was probably west of the Pinnacle Fault in Permian sediments. Good showings of oil were sampled in Bores 1-3 and were submitted to the Government Analyst. The samples were described by the Analyst as pale yellow with a petroliferous odour and evidently of mineral origin.

Concurrent with the Prices Creek tests a deep bore was drilling at Mt. Wynne.

No.1 bore reached a depth of 896 feet in Permian Grant Formation and was then abandoned for technical reasons. Asphaltum was reported in the bore at depths of 109 feet and 120 feet and bitumen at 225 feet. A section of core was submitted to the Government Analyst who reported - "This asphaltum was plastic at 20°C and melted completely below 100°C. On dry distillation it yielded a large volume of dark brown oil.

The chemical and physical properties of the substance agree in all respects with a true petroleum of the 'soft asphaltum type'. This is usually looked upon as an indication of the comparatively recent presence of asphaltic oil in the near vicinity."

During the period 1923-1925, No.3 Bore was drilled with a percussion plant to a depth of 2,154 feet. Throughout the drilling of this hole water stood within 80 feet of the surface owing to cementing failures andthe hole was eventually abandoned. Oil showings were reported from several horizons, the lowest at 1,650 feet.

Samples were again submitted to the Government Analyst who reported:- "This unsaponified matter consists of a pale yellow coloured hydrocarbon oil which is semi-solid at ordinary temperature and mobile at 60°C. It is undoubtedly a petroleum carrying a large proportion of the lubricating fractions."

During the period 1927-1930, the No.3 Bore Poole Range was drilled to a depth of 3,264 feet before the tools stuck and the hole was abandoned in the Permian Grant Formation. Cementing failures were a consistent feature of this bore and water was standing within 150 feet of the surface throughout the drilling. Oil seepage of a convincing nature was reported from 2085 feet. A sample was submitted to the Government Analyst who reported as follows:- "The sample submitted contained about an ounce of a crude brownish black petroleum of viscous consistency and holding a mixed paraffin and asphalt base. On direct distillation, it yielded only traces of distillate utilizable as motor fuel, and only a very small proportion (4.3%) of illuminating oil.

Approximately three quarters of the oil was recovered in the form of a medium lubricating oil whilst other valuable products would be asphalt and wax..."

APPENDIX II

Comments on Reports by Reeves (1949 and 1951)

The report by Reeves (1949) was of particular value in that it raised problems which had not been previously mentioned. The most important of those is the rather definite conclusion reached by Reeves concerning the age of the Grant Formation. He considered the Grant Formation was of Devonian age for the following reasons:-

1. There is no fossil evidence that the Grant Range beds are Permian in age. The fossil wood occasionaly found in them may just as well be Devonian as Permian.

2. The Grant Range Beds, like the Devonian, are overlain unconformably by Permian sandstone. The Grant Range beds are overlain by the Poole Range sandstone, and the Devonian by the Hawkestone sandstone. These two overlapping sandstones appear to be equivalent.

3. The Grant Range beds are similar to the Devonian in being highly jointed and more folded than the overlying Permian sandstone.

4. The Devonian limestones end abruptly south-east of their outcrops in the Rough Range and appear to be replaced by sandstone further to the south-east showing the normal high Devonian dips.

5. The Grant Range beds in the Nerrima Bore and Poole Range No.3 show a change towards the limestone ranges from apure sandstone to a series of sandstone interbedded with calcareous shale.

6. The possibility exists that the limestone and shale overlying massive sandstone encountered in water bores in the Mt. Wynne area are Devonian in age.

7. The Grant Range beds contain glacial erratics in their upper part and entirely similar boulders occur in great numbers in the limestone ranges and are interbedded with fossiliferous beds of Stage III of theUpper Devonian.

8. No erratics of Devonian limestone have been found in the Grant Range beds, although the glaciers, if Permian in age, moved across wide belts occupied by Devonian limestone. The boulders of limestone mentioned by Wade and Talbot in the glacial beds in Poole Range and elsewhere are concretionary limestone boulders occurring in calcareous clay.

During the survey by the writer particular attention was devoted to this problem. As a result the points raised by Reeves are answered below;-

1. The plant remains in the Grant Formation have not been examined in detail owing to the lack of good material. They do appear to be Permian general rather than Pre-Permian. By analogy with the glacial section in the Carnarvon Basin there is no doubtthat the Grant Formation is of Permian age.

2. The Grant Formation is overlain unconformably by the Poole Sandstone. The unconformity is frequently unrecognisable while the unconformity between Devonian and Permian is a major break and readily recognisable at all times. In addition sandstone of the Grant Formation unconformably overlies all formations in the Devonian sequence from Pillara Formation to Bugle Gap Limestone.

3. The Grant Formation is strongly jointed by the Grant

Formation and higher Permian units were folded together along the anticlinal axes.

4. The Devonian limestones are simply overlapped in the southern Emanuel Range (formerly Rough Range) by sandstone etc. of the Grant Formation and actually reappear farther to the south near Old Bohemia Homestead.

5. This statement is of doubtful value as it is based on the percussion bore logs. Even if the lithological changes were as stated they could not be used as a valid argument.

6. There is no possibility that the limestone and shale is Devonian as 2154 feet of Grant Formation was penetrated in Mt. Wynne No. 3 bore without reaching proven Devonian sediments.

7. The Grant Formation contains proven glacial horizons and is probably entirely derived from glacial activity. An exhaustive examination was made of the conglomerate formations referred to by Reeves in the limestone ranges. No evidence of glacial action was observed and the writer is convinced that these conglomerates are fan-conglomerates of local significance and in no way related to the Grant Formation.

8. Limestone boulders from Devonian rocks have been identified from the Grant Formation. These boulders are abundant along the margin of the Oscar Range where the Permian overlaps the Fairfield Formation. Boulders of probable Devonian age have been collected from the Grant Formation in St. George Range and Grant Range.

Summarising, it can be stated that surface outcrops of the Grant Formation are of post-Devonian age and are considered to be Permian in age. There is no evidence to indicate that the deep bores at Mt. Wynne, Poole Range and Nerrima have reached the base of the Permian Grant Formation.

It is therefore concluded that none of the bores mentioned have penetrated pre-Grant Formation and in addition the objective, Devonian limestone, has not been reached.

In a later paper Reeves (1951) has stated that the prospects of finding oil south of the Fenton Fault are "practically nil". Although this presumption may in fact be true the writer believes there is insufficient evidence to substantiate such a claim. If, for example, conditions during Devonian sedimentation were favourable the vicinity of the Fenton Fault, and possibly areas to the south, could have been areas of reef growth. Proof is lacking of Reeve's suggestion that the area to the south of the Fenton Fault consists of a thin cover of Permian over Pre-Cambrian in the central part of the Great Sandy Desert.

The following statement is quoted from Reeves (1951):- "The conclusion was also reached that only coastal parts of the Fitzroy Basin merited further investigation. The basis for this opinion rests on the following observations. Only slight traces of oil were obtained in Freney's tests, at least half of which were located on pronounced folds and drilled to sufficient depths to have encountered good showings of oil, if the formations penetrated or those at greater depths were petroliferous. The absence of surface indication of oil, despite the highly fractured nature of the formations, also indicates that the sub-surface formations are not oil-bearing. This conclusion is further supported by the fact that warm springs issue along faults. These flows of warm water are attributable to the underground movement of meteoric water at considerable depth, and some of them should show traces of oil if the formations through which the water circulates are petroliferous. The minor igneous intrusives in the area, which in places have brought up fragments of rock from great depths, do nw show the slightest trace of odour of oil."

The foregoing statement is based on the assumption that the Grant Formation is of Devonian age, although this is not specifically stated. The suggestion that the deep tests by Freney's penetrated to sufficient depth to prove or deny the presence of oil accumulations is not a valid conclusion. In the writer's opinion (and this is supported by experience in other areas), a test will not be of value until the complete section to basement has been sampled and the stratigraphy substantiated by fossil evidence. Although distinct oil showings were encountered during drilling at Mt. Wynne and Poole Range, the shows were logged in holes almost full of water with a high hydrostatic pressure.

Observations of fractured strata are confined to surface outcrop in the Permian sediments and it does not follow that the fracturing will persist, in the surface form, to basement. In any event the fracturing will not necessarily permit the escape of any pertroleum which exists in the lower beds.

Warm springs are a common feature of the major fault zones. The water probably originates in the porous intake beds of the Grant Formation and Poole Sandstone along the north-eastern margin of the basin. There is no reason to suspect that the Permian sediments are petroliferous and contamination of underground water would not be expected.

The leucite intrusions are for the most part intrusive into the major synclinal areas and signs of petroleum contamination would be surprising. It is most unlikely that the intrusives would bring up fragments of rock from a great depth, as suggested by Reeves. Plugs such as Mt. Percy and Mt. North almost certainly were intruded through Devonian sediments but no fragments have been identified on the surface. Sandstones of the Permian sequence when baked by the intrusions are similar to the typical quartzites of the Proterozoic and appear to have been mistakenly identified by Reeves.

Reeves suggests in conclusion that the Ordovician has a very limited distribution and supports this belief by referring to the absence of both Middle Devonian and Ordovician in 67 Mile Bore (12 miles north-west of Oscar Range). Unfortunately, it is impossible to predict the distribution of the Ordovician sediments in the Fitzroy Basin. The 67 Mile Bore does not provide reliable evidence in support of Reeves' hypothesis. In the writer's opinion, the 67 Mile Bore is situated on, or near, the axis of the Oscar Range. The section exposed on the Oscar range has shown that this area has been a positive element for a considerable time and on the western flank practically all the Middle Devonian has been eroded prior to deposition of Upper Devonian. Any Ordovician that may have existed in this area has also been completely removed by erosion. Similar conditions were apparently proved by the 67 Mile Bore. The area from the Oscar Range to the 67 Mile Bore was a marginal area throughout the Devonian and the preserved section will not necessarily be a true indication of the section to be expected elsewhere in the Fitzroy Basin.