COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

BULLETIN No. 36.

THE GEOLOGY OF THE FITZROY BASIN, WESTERN AUSTRALIA

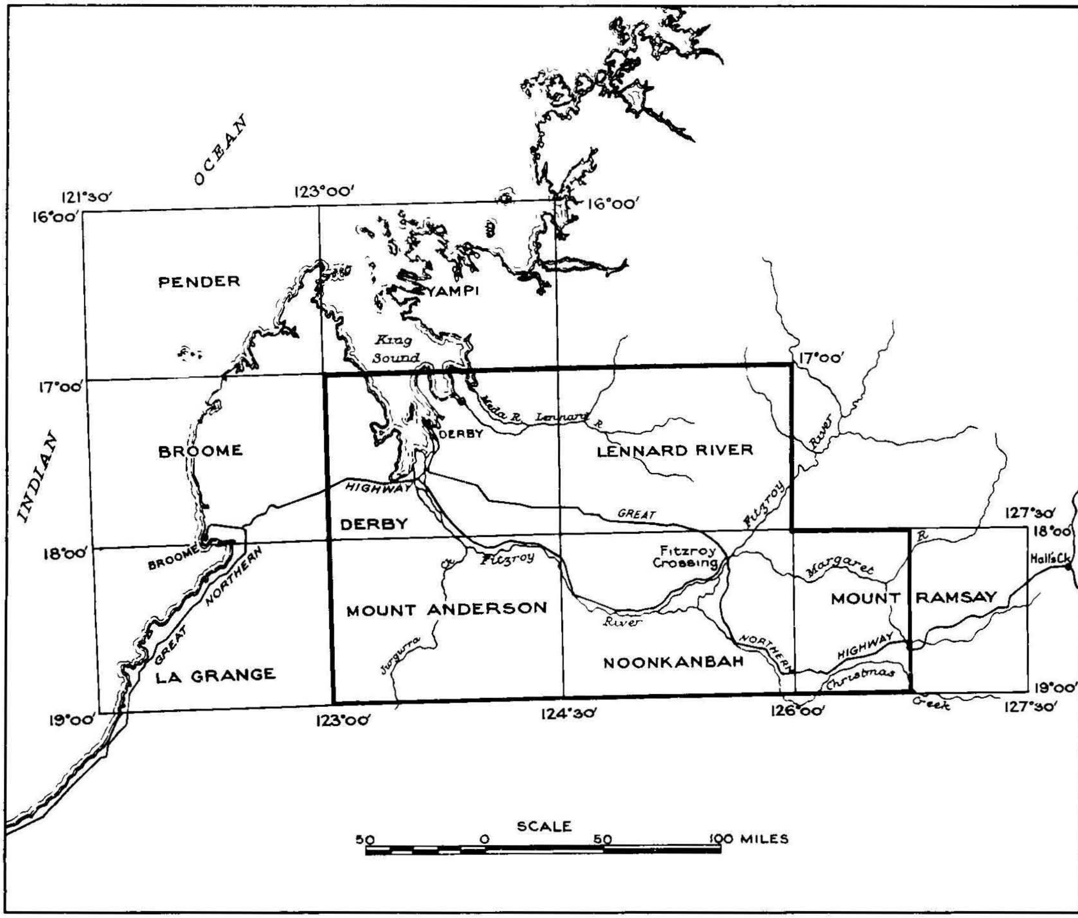
BY

D. J. GUPPY, A. W. LINDNER, J. H. RATTIGAN, and J. N. CASEY.

Issued under the authority of Senator the Hon. W. H. Spooner,
Minister for National Development.
1958.

By Authority:
A. J ARTHUR, Commonwealth Government Printer, Canberra.
(Printed in Australia.)

3336/57.



MAP SHOWING AREA DEALT WITH IN BULLETIN AND REFERENCE TO AUSTRALIAN FOUR-MILE MAP SERIES

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS · AUG. 1956

WA3E-23

WJB

COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

Minister : SENATOR THE HON. W. H. SPOONER, M.M.
Secretary : H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

Director : P. B. NYE, O.B.E.
Deputy Director : J. M. RAYNER.

This Bulletin was prepared in the Geological Section.

Chief Geologist : N. H. FISHER.

CONTENTS.

APPENDICES.

ILLUSTRATIONS.

TABLES.

SUMMARY.

The stratigraphy, structure, sedimentary environments, petroleum prospects, and water supply of the Fitzroy Basin are described and the more important structural and petroleum accumulation problems are discussed.

The Fitzroy Basin forms the inhabited northern part of the large Canning Basin, and contains a cumulative total of about 35,000 feet of Palaeozoic and Mesozoic sediments; geophysical results suggest a thickness of 20,000 feet of sediments in the Poole Range area, and about 13,000 feet of sediments were penetrated by drilling in the Grant Range. The sediments overlie a Precambrian basement which consists of Lower Proterozoic granite, gneiss, schist and quartzite, and Upper Proterozoic conglomerate, sandstone, shale, dolomite, tillite, and basic volcanics.

The Palaeozoic sediments consist of about 3,000 feet of Ordovician marine limestone, dolomite, sandy shale, and shale; 9,000 feet of Devonian marine clastic oolitic and silty limestone, limestone, limestone breccia, calcarenites, calcilutites, calcareous siltstone, calcareous sandstone, sandstone, biostromes and bioherms, with interbedded fanglomerates; 6,000 feet of Carboniferous marine calcarenites, oolitic calcarenites, sandstone, and siltstone; and 14,000 feet of Permian marine siltstone, greywacke, sandstone, limestone, sandy limestone, and freshwater conglomerate, sandstone, and shale (this includes 9,000 feet of glacial and fluvioglacial sediments at the base).

The Mesozoic sediments consist of about 1,000 feet of Triassic brackish-water shale and siltstone and freshwater sandstone, 600+ feet of Jurassic marine conglomerate, sandstone, siltstone and glauconitic siltstone, and 1,000 feet of Cretaceous marine and possible freshwater sandstone and some conglomerate.

Cainozoic sediments consist of river gravels, travertine, pisolitic ironstone, sand, dunes, black soil and alluvium, which covers much of the Fitzroy Basin.

Post-Triassic leucite-lamproites intrude Permian and Triassic sediments and crop out mainly in synclinal areas.

The Fitzroy Basin is a graben-like thick sequence of sediments controlled on the north by the Pinnacle Fault and on the south by the Fenton Fault; both these features trend north-west. Whether these features are major faults or whether they represent the edge of buried ridges is one of the major tectonic problems not completely solved. The sediments between them are folded into three parallel westerly-trending anticlinal lines along which are domal culminations.

Devonian reefs fringe the Precambrian rocks on the northern side of the basin; Jurassic sediments and sand cover the southern side. Possible petroleum source rocks occur in the Ordovician, Devonian, Carboniferous, and Permian sequences; reservoir rocks occur at least in the Devonian and Permian sediments. If Devonian or Ordovician reefs are present in the central part of the basin, particularly fringing basement highs which may underlie the large surface anticlinal structures, the oil potential in the Fitzroy basin is encouraging.

INTRODUCTION.

The Fitzroy Basin in this bulletin refers to that part of the Canning Basin which lies between the Precambrian of the Kimberley Plateau in the north and the Fenton Fault in the south; the bulletin also considers some formations cropping out south of the Fenton Fault. The Canning Basin is the area of Palaeozoic and Mesozoic rocks bounded by the Precambrian of the Kimberley Plateau on the north, and the Pilbara area in the south, and extending westward on to the continental shelf. Downwarps within the Canning Basin may warrant separate names; the first to be named is the Fitzroy Basin.

Purpose and Scope of Survey.

The geological investigation of the Fitzroy Basin was carried out by D. J. Guppy, A. W. Lindner, J. H. Rattigan (1949-1952), J. N. Casey (1950-1952), J. O. Cuthbert (1948-1949) and A. B. Clarke (1952).

This reconnaissance survey was completed in 1952, and during the period from 1948 to 1952, 24 months were spent in the field and the remainder in office preparation and studies. About 40,000 square miles were examined during the survey, and detailed and regional maps covering an area of 28,000 square miles have been prepared at scales of 1 inch to 2 miles, 1 inch to 4 miles and 1 inch to 8 miles. Maps at scales of 1 inch to 4 miles and 1 inch to 8 miles are included in this bulletin.

As a result of a fire at the Bureau of Mineral Resources in Canberra early in 1953, part of the records of the Fitzroy Basin survey was destroyed. This information was replaced during 1953 by the two senior authors, who were then on the staff of West Australian Petroleum Pty. Ltd., Perth, and who assembled the stratigraphical columns and the Derby 4-mile geological sheet included in this bulletin.

The area has been examined in the past in varying detail by three geological parties on behalf of oil companies, local (Freney Kimberley Oil Co.), and overseas (Caltex (Aust.) Oil Development Pty. Ltd. and Vacuum Oil Co.). The purpose of the survey by the Bureau of Mineral Resources was to examine the complete sedimentary sequence in sufficient detail to elucidate the problems encountered by previous surveys and eventually to be in a position to assess the petroleum prospects of the area as far as surface information would allow.

This assessment has definite limitations because the potential source rocks (Ordovician, Devonian, Carboniferous and Permian) crop out only over a small area, and practically nothing is known about their distribution or lithology under cover of younger sediments and in the large areas in which there is no outcrop.

For map preparation, controlled template plots, divided into 1-mile sheets of the Army Series, were prepared by Lands and Surveys Branch, Western

Australia, and the Army Survey Corps, from the aerial photographs covering the area. During the field operations points were plotted directly on the photographic prints, transferred to the photo-scale compilations, and photographically reduced to the various map scales. The aerial photographs of the area, produced by the Survey Squadron of the Royal Australian Air Force, have been the basis of all mapping, as reliable planimetric maps of the area were not available.

CLIMATE.

The climate of the area is monsoonal, with sharply defined wet and dry periods. The annual rainfall ranges from about 18 inches in the southern part of the Fitzroy Basin to 31 inches in the Oobagooma area (60 miles west-north-west of Napier Downs) in the north. Normally, all but a small fraction of the annual rainfall is precipitated between December and March.

During abnormal climatic cycles very heavy falls have been recorded in brief periods, particularly in May, during the normal dry season, and road and air communications have been consequently disrupted. Provision should always be made for such a possibility when operations in the area are planned.

VEGETATION AND SOIL (Christian and Stewart, 1952).

The vegetation of the area is largely controlled by the nature of the soil, which is specific for the particular rock formation over which it has formed. Five main soil and vegetation types are recognizable; each varies in detail in both soil quality and density of vegetation from one area to another. In order of importance, from an agricultural aspect, they are:—Levée Lands, Black Soil Plains, Alluvial Plains, Pindan, and Stony Lands.

Levée 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 levée soils support a woodland of *Eucalyptus tectifica, Eucalyptus microtheca, Eucalyptus papuana, Eucalyptus camaldulensis,* and a ground flora including *Chrysopogon, Aristida,* and *Sehima nervosum.* The levée lands contain the highest quality soils known in the area, and with sufficient water supply would probably be suitable for a wide variety of crops.

Black Soil Plains.—These plains are scattered throughout the Basin and are notable for the development of shrinkage cracks, which produce an extremely rough surface. They are generally related to the underlying rock formation, and are typically developed over calcareous formations such as Mount Pierre Group, Fairfield Beds 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. It is not suitable for most types of crop.

Alluvial Plains (Flood Plains).—Soils of this type are close to the main rivers and marginal to the levée lands, and in some areas are subject to annual flooding. The vegetation is more varied, and forms a medium to tall woodland including *Eucalyptus tectifica* and *Eucalyptus microtheca,* with a ground flora including *Chrysopogon* sp., *Sehima nervosum, Aristida* spp., *Eriachne* sp., *Heteropogon contortus, Isailena* spp., *Xerochloa* sp., *Sorghum* spp., *Dichanthium fecundum,* and *Astrebla squarrosa.* The soils are of varying quality and in places are suitable for irrigation 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, some selected crops may be grown.

Stony Lands.—These are gently to steeply sloping areas with a thin cover of soil over country rock: in many places the soil cover has been completely removed. The vegetation is a hardy population including a large proportion of *Triodia* spp. and *Plectrachne* spp., with sparsely distributed low trees and shrubs.

Only a comparatively small proportion of the Basin is suitable for large-scale agriculture because of the limiting factors of climate, water supply, and the low quality of the soil. Very large areas are suitable for stock, but much developmental work will be required to bring the area to the maximum potential level of productivity.

PREVIOUS INVESTIGATIONS.

The original geological investigations in the area were under the leadership of Hardman (1884), the Government Geologist of Western Australia. Foord (1890), Nicholson (1890), and Hinde (1890) described fossils from Hardman's collections.

Etheridge (1889) recorded *Stenopora* and *Evactinopora* from Mount Marmion, and Basedow (1918) described polyzoal remains from the old Balmaningarra Station near Mount Marmion.

In 1915, Etheridge described *Calceolispongia* from the Noonkanbah Formation at Mount Marmion; this genus has since been recorded from the Bitaœni and Basleo Beds in Timor, from the Umaria Stage of Peninsular India, from Tasmania, and from the Carnarvon Basin of Western Australia.

Wade (1924, 1936, and 1938) made the first systematic stratigraphical studies of the Permian sediments together with a rapid reconnaissance of the Devonian sediments. Wade's published results have been the basis of all later work in the Permian.

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

Wade in 1932 collected ammonites from the Nura Nura Member of the Poole Sandstone. These were determined by Miller (1936) as *Metalegoceras clarkei* and *Thalassoceras wadei*: Teichert (1942) has recorded *Metalegoceras striatum* from the same locality. Chapman and Parr (1937) described "fusulinids" collected by Wade from the upper marine beds of the Liveringa Formation and suggested a late Artinskian age. Information obtained during the present survey has shown that the beds identified as Artinskian by Chapman and Parr were of Triassic age, and the "fusulinids" were actually bone fragments (Brunnschweiler, 1953).

More detailed examinations of a large part of the Fitzroy Basin were made by Kraus (1941), Findlay (1942), and Teichert (1949). These surveys were 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. More recently the area has been traversed by Reeves (1949). His published results indicated several problems to which particular attention was directed by the writers. In 1948 a detailed survey of the Nerrima Structure was made by geologists of the Bureau of Mineral Resources (Guppy et al., 1950) and a widespread reconnaissance by land, sea, and air was undertaken. The results of more limited geological investigations have been published by Jack (1906) and Blatchford (1927).

Hosking (1933) examined the fossils collected by Blatchford and Talbot in 1929, and Wells in 1922, and a collection from near Mount Pierre Gorge. The goniatites collected by Clarke and Talbot from the Mount Pierre area were described by Delepine (1935), who concluded that 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) on *Conocardium,* Howell (1944) on sponges, Hill (1954) on corals, Crockford (1957) on bryozoa, Coleman (1957) on productaceans, and Glenister (1958) on ammonoids. Bureau Bulletins on Devonian brachiopods and Permian Orthotetacea are now in press.

Miss Crespin in 1940-41 analysed the core from Nerrima No. 1 bore and determined fossils from the upper part of the bore (*see* Appendix B).

PHYSIOGRAPHY.

The Fitzroy Basin and adjacent areas are divided into the following physiographic provinces (Fig. 1)—

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

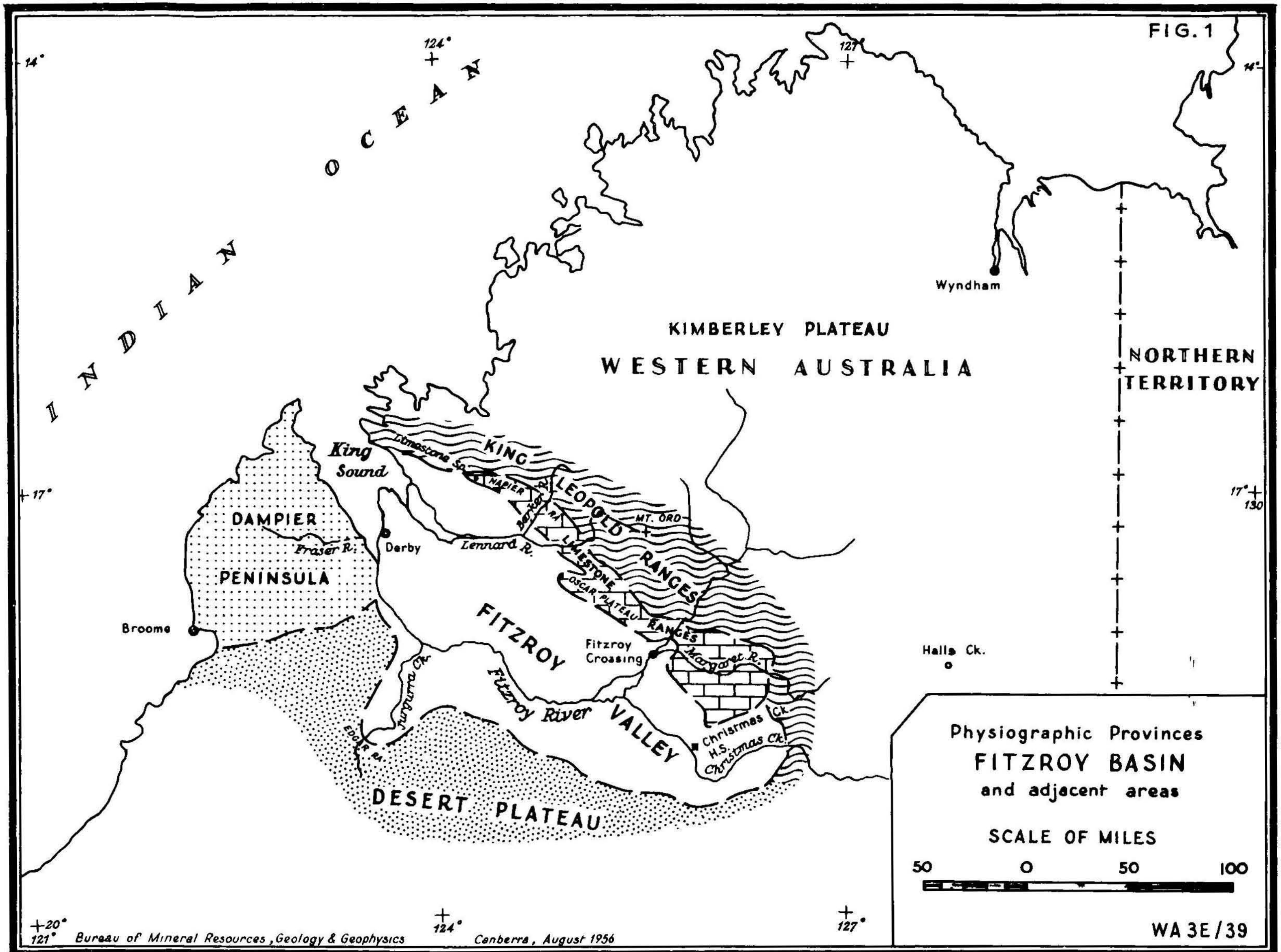


FIG. 1
INDIAN OCEAN
KIMBERLEY PLATEAU
WESTERN AUSTRALIA
NORTHERN TERRITORY
Wyndham
King Sound
Limestone Sp.
KING LEOPOLD RANGES
NAPIER
Barker R.
MT. ORD
DAMPIER PENINSULA
Fraser R.
Derby
Lennard R.
LIMESTONE
OSCAR PLATEAU RANGES
Broome
FITZROY
Fitzroy Crossing
Margaret R.
Halls Ck.
Fitzroy River VALLEY
EDGAR RA.
Christmas H.S.
Christmas Ck.
DESERT PLATEAU
Physiographic Provinces
FITZROY BASIN
and adjacent areas
SCALE OF MILES
50 0 50 100
WA 3E/39
Bureau of Mineral Resources, Geology & Geophysics
Canberra, August 1956

King Leopold Ranges.

The ranges forming the boundary to the Basin in the north-east consist of rugged strike ranges and deeply incised valleys; the relief locally is about 1,000 feet. The maximum altitude of the area is 3,070 feet at Mount Ord, in the King Leopold Ranges. The Kimberley Plateau has an average altitude of 1,500 feet.

The topography is closely controlled by structure and lithology; the ranges consist of folded beds of hard quartzite; many of the valleys consist of doleritic rocks with a considerable accumulation of alluvium. With the exception of the Fitzroy and Barker Rivers, the streams are controlled by the geological structure, and mostly they are actively down-cutting. The major channels of the Fitzroy and Barker Rivers differ from others in that they cut across all natural barriers and flow almost in a straight line through the ranges; they are almost certainly superimposed. The Kimberley Plateau, which lies north-east of the King Leopold Ranges, is a comparatively flat area of considerable extent in which flatly-bedded Upper Proterozoic sediments unconformably cap more strongly folded quartzite; these younger sediments form a distinct physiographical province in which the major streams of the Fitzroy Valley originate.

Run-off is high, partly because of the types of rock and partly because of the scanty soil cover. Consequently, large quantities of water move down the King Leopold Ranges drainage system during and after the monsoonal rainy season. This influx of water into the lower reaches of the major rivers is the main source of flooding in the Fitzroy Valley.

Limestone Ranges.

The Limestone Ranges are a distinctive feature of the landscape from Bugle Gap (near Christmas Creek Homestead) north-west to Limestone Spring, a distance of 180 miles. The area south-east of the Fitzroy River contains a system of dissected limestone ranges twelve miles wide, interspersed with gently undulating areas underlain by softer sediments. North of the Fitzroy River, the Ranges are unbroken, except for narrow passes, to Limestone Spring (30 miles north-west of Napier Downs) with a width of about 10 miles on the Oscar Plateau, narrowing to a few hundred yards in parts of the Napier Range.

The limestone masses have developed a typical, very rough and often impenetrable, " karren-feld " which represents an advanced stage in the karst cycle. Soil is found only in surrounding areas of more easily eroded sediments and scattered depressions in the ranges. Underground solution is mainly due to surface streams which have taken underground courses and emerge again at the surface. Notable examples are Tunnel Creek, which passes under the Napier Range for almost a mile, and the stream which emerges at Cave Spring in Bugle Gap after a similar distance underground. Caves of various sizes, at the level of the plains on either side, have been formed throughout the ranges. The underground streams are of particular importance as they are an unfailing perennial source of water in what may, in adverse seasons, be a waterless area.

Springs of varying flow are found throughout the ranges; they have been recorded on the accompanying maps. Normally they are not permanent and appear to be dependent on 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, &c. The topography is subdued although much of the surface is very rugged, particularly where schistose rocks crop out. Part of this area possibly represents a wave-cut platform on which sediments of the Limestone Ranges were deposited. Probably this surface is very old, at least Devonian, with some comparatively recent dissection.

Fitzroy Valley.

The Fitzroy Valley, which includes the valleys of the Fitzroy, Lennard, Barker, and Margaret Rivers and Christmas and Jurgurra Creeks, covers an area of about 10,000 square miles. The entire area is relatively flat and underlain by sediments of Permian and Mesozoic age. Notable relief is confined to structural highs such as Poole Range, St. George Range, Mount Wynne and Grant Range. Scattered small hills, buttes or mesas, relics of a former land surface, are scattered through the area. Typical examples are Erskine Hill, The Sisters, Mount Marmion, Moulamen Hill, and Mount Arthur.

The major streams and their main tributaries have steep banks and appear to be cutting down into the alluvium-filled valleys.

Desert Plateau.

The area between the south-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 800-foot level is a well expressed surface over a large area and is apparently the relic of a former land surface.

The grading of the long primary streams is strongly affected by the rock types over which they flow. In the upper reaches of the Fitzroy River from Tableland Homestead to Fitzroy Crossing the fall is 2,000 feet in 100 miles; in the lower course from Fitzroy Crossing to King Sound the fall is 400 feet in 160 miles. As a result the stream is aggrading in the Fitzroy Valley and has done so for a long time; and the river courses are entrenched in deeply filled alluvial valleys. In the upper reaches, degradation is continuing.

In the Fitzroy Valley the gradual slope of the land surface towards the coast is broken by areas of high country which rise to 800 or 1,000 feet. The highest point of the Dampier Peninsula is over 600 feet, in the west central part, with a regular slope seawards.

Only the northern edge of the Desert Plateau (the Canning Basin) is represented in the area described here. A description of the South-west Canning Basin is given by Traves, Casey, and Wells (1956).

TABLE 1. FITZROY BASIN.—ORDOVICIAN AND PRECAMBRIAN STRATIGRAPHY, STRUCTURE, TOPOGRAPHY AND WATER SUPPLY.

Period or Epoch.	—	Stratigraphic Unit.	Distribution.	Lithology.	Thickness (feet).	Structure.	Topography.	Correlation.	Water Supply.	General Remarks.
LOWER ORDOVICIAN	Lower Trenton ..	Prices Creek Group: Gap Creek Formation (Og)	Emanuel Creek to Prices Creek	Dolomite, silty dolomitic limestone, sandy bands common. Marine	630 +	Low regional dip	Low strike ridges		No boring attempted. Probably a favourable formation	Conformably overlies Emanuel Formation and unconformably overlain by Pillara Formation
LOWER ORDOVICIAN	Chazian, Canadian, Upper Ozarkian	Prices Creek Group: Emanuel Formation (Oe)..	Emanuel Creek to Prices Creek	Limestone and shale. Marine ..	2000 +	Low regional dip. Base of section down-faulted and not exposed	Featureless plains with very low strike ridges. Outcrop confined to Emanuel Creek and near vicinity		No boring attempted. Doubtful possibilities	Presumably overlies either Precambrian or older Palaeozoic sediments. Conformably overlain by Gap Creek Formation
?CAMBRIAN		Hart Basalt (?Ch)	Strike valleys in King Leopold and Lady Forrest Ranges	Dolerite, mainly flows ..	N.D. (Not Determined)	Flatly bedded flows partly filling erosional valleys in ranges	Gently undulating with occasional ridges with sparse vegetation cover	Probably comparable with Cambrian basalts of Antrim Plateau of East Kimberley Division	Unfavourable for underground water	Unconformably overlies Upper Proterozoic. May be genetically related to the Mornington Volcanics
UPPER PROTEROZOIC		Mount House Beds (Puh) ..	Mount House H.S. to Mount Clifton area and eastwards beyond map coverage	Red, green, grey-green splintery shale and siltstone, red and light-grey dolomite, red quartzite, siliceous siltstone and red micaceous sandstone	N.D.	Sub-horizontal and low dips up to 4°	Scrub-covered plains and residual mesas		No information. Water probably obtainable in sandy lenses	Overlies the Walsh Tillite conformably and the Warton Beds and Mornington Volcanics unconformably
UPPER PROTEROZOIC		Walsh Tillite (Puw)	Headwaters of Walsh Creek and east of map coverage	Tillite consisting of unsorted fragments up to 7 feet across in a matrix of grey, grey-green and red siltstone and unsorted sandstone. Erratics mainly quartzite and rarely acid and basic volcanics. Boulders faceted and striated. Glacial terrestrial	N.D.	Gently dipping fold structures which appear to be depositional over topographic highs in the underlying Warton Beds. Lensing of the Formation indicated from surface mapping	Rounded hills and boulder strewn plains	May be compared tentatively with Sturtian Tillite of South Australia	No boring attempted. Favourable in suitable localities	Unconformably overlies Warton Beds. Conformably overlain by Mount House Beds
UPPER PROTEROZOIC		Warton Beds (Pur)	Extensive development east of map coverage in Warton Range and east of Hann River. Outcrops in Precipice Range on Lennard River sheet	White and grey, fine conglomeratic quartzite, red micaceous sandstone and red micaceous shale	N.D.	Gently folded with some faulting	Rough, rocky hills and ranges ..		No boring attempted	Unconformably underlies Walsh Tillite and Mount House Beds. Conformably overlies Mornington Volcanics
UPPER PROTEROZOIC		Mornington Volcanics (Pum) ..	Outcrops in folded structures between Precipice Range and Lady Forrest Range, vicinity of Mount House H.S. and east of map coverage in vicinity of Mornington H.S.	Grey-green dense fine-grained andesitic, in places amygdaloidal and medium grained doleritic rock. Interbedded indurated shale and quartzite. Slight mineralization	N.D.	Folded and faulted. Details lacking	Rugged hills and black soil plains		No boring attempted. Limited possibilities in favourable localities	Galena and specular iron is associated with quartz veining. Unconformably overlies King Leopold Beds
UPPER PROTEROZOIC		King Leopold Beds (Puk) ..	King Leopold Range and possibly Oscar Range. Extensive distribution to east of map coverage	Quartzite, sandstone, conglomeratic quartzite and sandstone. Possibly some silty or shaly beds	N.D.	Folded into large anticlines and synclines. Some faulting particularly in Oscar Range and east of map area	Rugged deeply dissected strike ranges		No boring attempted	Unconformably overlies metamorphics, &c., of Lamboo Complex. Unconformably overlain by Mornington Volcanics
LOWER PROTEROZOIC and/or ARCHAEOZOIC		Lamboo Complex (PCl) ..	Wide belt between limestone ranges and King Leopold Range extending to east beyond map coverage. Small inliers between Virgin Hills and Pillara Range	Schists, acid porphyritic gneiss, basic lavas and dykes, acid gneiss, quartzites, acid lavas, &c.	N.D.	Complex system of metamorphic and igneous rock	Low rounded hills and very rugged dissected areas		No information available. Water probably available at selected sites in alluvium covered areas	Basement complex of area. Mineralization including galena, copper, wolfram, scheelite, mica, gold

[To face page 13.]
3336/57.

It is characterised by numerous fixed parallel seif dunes, trending west to west-north-west, and broken only by scattered small outcrops and by claypans. The dunes vary in height; they average about 40 feet.

The Edgar Range, at the northern edge of the plateau, is a scarp formed by wind erosion and the cutting back of the head-waters of Jurgurra Creek.

Dampier Peninsula (Brunnschweiler, 1957).

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. The Fraser River heads in the central part of the Peninsula, where remnants of a former plateau surface exist. Partly eroded fixed seif dunes are found throughout the area, which now grows a dense " pindan " vegetation in a 20 to 30 inch rainfall belt.

Outcrops of Mesozoic rocks are restricted to coastal cliffs along both coastlines and to scattered mesas in the upper reaches of the Fraser River System, at Mount Clarkson, and near Stony Ridge on the Broome-Derby road.

STRATIGRAPHY.

Precambrian, Ordovician, Devonian, Carboniferous, Permian, Triassic, Jurassic and younger formations have been mapped. The known sedimentary section amounts to about 35,000 feet; it contains several possible source beds for oil.

Existing formation names have been retained where possible; otherwise the name has been re-defined or a new name defined. All rock unit names have been approved by the Western Australian Committee on Stratigraphical Nomenclature.

PRECAMBRIAN (Table I.).

Although Precambrian rocks were not directly involved in the investigations, it was considered necessary to spend some time studying them to obtain a knowledge of their lithology and structure. With this information available the influence of these rocks on the lithology and structure of younger sediments can be assessed more reliably.

Lamboo Complex.

The name Lamboo Complex was first used but not defined by Matheson and Guppy (1949) as consisting of " undifferentiated massive granite, granite gneiss and undigested remnants of both the McClintock Greenstones and Halls Creek Group ". The type locality is near Lamboo Station (Long. 127° 21′ E., Lat. 18° 32′ S.) and the rock types include granitic rocks, acid porphyry, diorite, dolerite, aplite, basic and acid igneous lavas, schist, gneiss, quartzite, numerous quartz reefs and at least one pegmatite dyke in the Mondooma area, north-west of the Napier Range. The Complex crops out chiefly in a belt between the Devonian sediments and the outer scarp of the King Leopold Ranges. Little is known of the complex structure of these rocks and they have been tentatively considered as Lower Proterozoic, and may include rocks of Archaeozoic age.

Small areas of the Complex have been mapped where the Devonian sediments lie directly on them in the Pillara Range.

Mineralization has been known in rocks of the Lamboo Complex for many years; the original gold discovery in Western Australia was made in rocks of this age near Halls Creek in 1882. Subsequently, small quantities of lead, tin, mica, beryl, wolfram, and scheelite have been mined intermittently.

King Leopold Beds (New Name).

The King Leopold Beds crop out typically in the King Leopold and Precipice Ranges; and outcrops extend east into areas not systematically mapped during this survey. The sediments, mainly quartzite, with shaly beds and a basal conglomerate, unconformably overlie the Lamboo Complex and are unconformably overlain by the Mornington Volcanics. The name is derived from the King Leopold Ranges (Long. 125° 25′ E., Lat. 17° 21′ S.).

No detailed analysis has been attempted, but most of the section is probably quartzite; some shales may be interbedded. In places the basal beds are conglomeratic (e.g. near the Fletcher River where it passes through the western scarp of the King Leopold Ranges) and contain well-rounded cobbles and pebbles. Sheared conglomeratic quartzites are a feature of the strongly folded beds forming the core of the Oscar Range. These quartzites are considered to be equivalent to the King Leopold Beds.

Without further studies no reliable estimate of thickness can be given for any of the Precambrian formations described. No fossils have been observed in any of the formations described and an Upper Proterozoic age has been tentatively assigned to them.

Mornington Volcanics (New Name).

The Mornington Volcanics are typically developed at Mornington Homestead, 35 miles east-south-east of Mount House (Long. 126° 06′ E., Lat. 17° 31′ S.). The formation also crops out between Precipice Range and Lady Forrest Range and north of Mount House Homestead.

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

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

Warton Beds (New Name).

Outcrops of the Warton Beds are typically developed in the Warton Range, 30 miles east of Mount Clifton (Long. 126° 27′ E., Lat. 17° 24′ S.) and the large area to the north along the Hann River, east towards Tableland Homestead (75 miles east of Mount House), and the Precipice Ranges. The unit has a similar pattern on aerial photographs to the King Leopold Beds. Outcrops examined contained white to light-brown well-bedded medium-grained to fine conglomeratic quartzite, red micaceous sandstone, and shale.

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

Walsh Tillite (New Name).

The Walsh Tillite is named from outcrops in the headwaters of Walsh Creek (Long. 125° 35′ E., Lat. 17° 12′ S.). A study of outcrops and aerial photographs shows that other outcrops of the Tillite occur near Glenroy Homestead (25 miles east-south-east of Mount House) and along the Traine River (tributary of the Hann River and 45 miles east of Mount House) and Hann River (20 miles east of Mount House).

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

In the type area at Walsh Creek the formation consists of a completely unsorted sediment ranging in grain-size from silt to boulders up to 7 feet across; the 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 Warton Beds, together with a few igneous rocks. Boulders are commonly faceted and striated.

The thickness of the formation varies. A study of the outcrop pattern on aerial photographs indicates that it occurs as lenses rather than a continuous deposit over a large area. No evidence of the age of the Tillite has been discovered, and it is tentatively placed in the Upper Proterozoic.

Mount House Beds (New Name).

The Mount House Beds are extensively distributed on the Kimberley Plateau and beyond the present map coverage. The type area was examined near Mount House (Long. 125° 44′ E., Lat. 17° 08′ S.), where the Beds unconformably overlie the Warton Beds and the Mornington Volcanics, and conformably overlie the Walsh Tillite. No younger sediments were observed to overlie the Mount House Beds directly.

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

No estimate of thickness is available at this stage. Fossils have not been found in the formation, but a diligent search in the calcareous bands may eventually reveal the presence of recognizable fossil remains. For the present the unit is placed in the Upper Proterozoic, but both the Walsh Tillite and the Mount House Beds may be of Lower Cambrian age.

Hart Basalt (New Name).

The Hart Basalt derives its name from Mount Hart (Long. 125° 04′ E., Lat. 16° 55′ S.), and the basalt crops out at Mount Hart as well as in the valleys in the King Leopold and Lady Forrest Ranges.

The formation consists of flows of basalt and dolerite which fill old valleys in the eroded older Precambrian rocks. It unconformably overlies the Lamboo Complex and King Leopold Beds.

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

Precambrian Correlation.

Various authors have attempted correlations between the Precambrian sediments from the several basins on the Australian Continent, and particularly the Proterozoic sequences in Western Australia (Nullagine and East and West Kimberley districts), Northern Territory (Katherine-Darwin area), and South Australia (Mount Lofty and Flinders Ranges). As more information on the stratigraphy of these sequences becomes available it is 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. At present all that can be said is that the "Nullagine Beds" (Maitland, 1904), the Upper Proterozoic of the King Leopold Ranges and Kimberley Plateau, and Upper Proterozoic quartzitic sandstones of the Northern Territory are probably in part equivalent. The whole Upper Proterozoic section is closely comparable with that of the Adelaidean System in South Australia because of their stratigraphic position and lithological similarity. The discovery of tillites on the Kimberley Plateau is of importance and immediately suggests a close, though not necessarily contemporary, relationship with the tillites of the South Australian and Tasmanian 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.

ORDOVICIAN (Table I.).

The Ordovician beds of the Prices Creek area were the first fossiliferous rocks of Ordovician age to be discovered in Western Australia (Guppy and Öpik, 1950). They are of particular importance for their rich faunal content, their palaeogeographical significance, and as a potential oil source within the Fitzroy Basin.

It is now known that the oil shows reported from shallow bores sunk in this area in 1922 originated in Ordovician rocks and not in Devonian as was previously thought. It is also of interest to recall that the one bore in which no oil shows were reported was drilled in Permian sediments nearby.

Prices Creek Group.

The type area of the Ordovician of the Fitzroy Basin is adjacent to Prices Creek (Long. 125° 47′ E., Lat. 18° 39′ S.), from which the group's name has been taken. The outcrops cover an area of about 12 square miles along the south-west scarp of the Emanuel Range. Most good exposures are confined to the few creeks, but the surface outcrop takes the form of low rises; the upper dolomitic formation forms sharp ridges and bold outcrops, which contrast sharply with the underlying shale and limestone.

The Prices Creek Group consists of two formations, the younger Gap Creek Formation and the older Emanuel Formation, and underlies the Middle Devonian Pillara Formation with a slight angular unconformity. The basal beds of the Emanuel Formation are obscured by faulting and the overlap of Permian sediments.

Smith (1955), in a refraction traverse along the strike of the Ordovician rocks, showed that a northerly trending erosion scarp or fault, with a " downthrow " of 250 feet to the north-west, occurred 1 mile north-west of Prices Creek No. 2 Bore. On the north-west side of this feature the refractor dips slightly north-east; on the other side it dips 1½° to the south-east.

The rocks underlying the Ordovician sediments in the outcrop area are presumed to be of Precambrian age; but if the distribution of the Ordovician sediments is wider than the outcrop area they may overlap older Palaeozoic sediments.

The Prices Creek Group has a total known thickness of 2,630 feet from surface outcrop and test bores.

Emanuel Formation.

At the type locality along Emanuel Creek (Long. 125° 55′ E., Lat. 18° 39′ S.) the Emanuel Formation consists of 2,000 feet of marine sediments. The dip of the formation ranges between 10 and 15 degrees to the north-east, with a reversal of dip at 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, and the name has been accepted by the Lands and Survey Department of Western Australia.

The formation is poorly exposed for the greater part of the section. Apart from Emanuel Creek, where it is exposed intermittently, outcrop is confined

3336/57.—2

to low rises. Bedding trends are visible on the aerial photographs for short distances. The type section is given in detail in Appendix II, p 86.

A general section from top to bottom is as follows:—

Total	Interval.	——
1,950	..	Highest exposed outcrop
..	10	Grey limestone and silty micaceous sandstone
..	240	No section
1,700	1,150	Creek section shows that the soft weathered sediments are siltstone and calcareous siltstone. Rich fossiliferous limestone lenses occur at intervals from 550 to 1,200 feet from the base. Between 1,200 and 1,400 feet fossiliferous limestone beds are more abundant in a siltstone section with large discoidal nodules; the siltstone gives a foetid odour when freshly fractured. Near 1,300 feet from the base, nodules of limonite after pyrite are common on the surface; such nodules were reported from many seismic shot holes drilled near this horizon in 1953
550	170	Occasional beds of crystalline limestone in soft weathering sediments
380	80	No section
300	100	Interbedded silty sandstone and siltstone
200	40	Crystalline glauconitic limestone
160	60	No section
100	100	Scattered outcrops of dense, massive, light-brown, crystalline limestone. Flat gastropods in the upper part
0	0	Base not exposed
55*	55	Crystalline limestone
70*	15	Interbedded limestone and sandstone
182*	112	Sandstone which becomes coarser in lowest 10 feet. Some cuttings show presence of limestone beds and pyrite nodules in this section. This section cannot be confidently assigned to the Ordovician, but for the present it is placed in the Ordovician
2,130		

* From seismic drill hole by Smith (1955).

Surface exposures of the formation contain 1,950 feet of sediments; 50 feet of the drill hole is regarded as definitely Emanuel Formation, giving a total thickness of 2,000 feet. Smith (1955, p. 6) in a seismic refraction survey, recorded a high velocity refractor (19,500 feet per second) at a depth of about 1,600 feet from shot holes near the top of the Emanuel Formation but about 2 miles north of the hole drilled through the basal part of the section as set out above.

Gap Creek Formation

The Gap Creek Formation is named from Gap Creek, which is near the type locality (Long. 125° 55′ E., Lat. 18° 38′ S.). The formation conformably overlies the Emanuel Formation and underlies the Devonian (Pillara Formation) with a slight angular unconformity. The dip ranges from 13 to 15 degrees to the north-east.

The change in lithology between the two Ordovician formations is well marked. The Gap Creek Formation is resistant to erosion and crops out as strike ridges showing well-marked bedding and a distinctive brown colour. The resistant beds are bedded to massive crystalline dolomite, weathering characteristically light brown with a granular surface due to the rhomb faces of the carbonate crystals. Fossils are commonly silicified. The softer beds rarely crop out even though they represent half the formation. Where visible they are sparkling dolomitic calcarenite, dolomitic sandstone, and siltstone. Medium to coarse calcareous quartz sandstone beds occur from 600 to 630 feet above base. From 500 to 550 feet, the outcrop is restricted to silicified dolomite and thinly colour-laminated quartzite derived from the silicification of silty dolomite. The type section is detailed in Appendix II., p. 88.

A typical specimen has been described by Glover (1956) as—

"a dense, granular rock, grey on fresh surfaces, with irregularly distributed pink patches about 1 mm. in diameter, weathering brown. Under the microscope the rock is a mosaic of anhedral and subhedral grains of dolomite of average diameter 0.25 mm a few grains are rhombic. Red iron oxide thinly impregnates the rock and is locally concentrated to give the red spots visible in the hand specimens. Small quartz and plagioclase grains (average length 0.05 mm.) constitute 10 per cent. by weight of the rock. Many apparently anhedral quartz grains show development of minute crystal edges, and probably 90 per cent. of the quartz can be demonstrated to have undergone authigenic growth. Most plagioclase is perfectly euhedral, and is authigenic: there are also a few rare grains of authigenic tourmaline.

Minute black granules are scattered through the rock. Mineragraphic examination indicated a manganese mineral, possibly pyrolusite."

The Gap Creek Formation consists of 630 feet of marine sediments.

Palaeontology—Prices Creek Group.

The lowest fossiliferous bed in the Prices Creek Group contains the brachiopod *Obolus,* which indicates Tremadocian (Ozarkian) age (Table 2). There is no indication of any break at the base of the outcropping sequence and therefore lower beds of Ozarkian or possibly 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. The Gap Creek Formation has a more restricted fauna. *Bumastus* and other, undetermined, trilobites have been collected. A plectambonoid brachiopod, *Spanodonta hoskingae* Prendergast, is present in abundance; it was originally described as an Upper Palaeozoic fossil (Prendergast, 1935). The Gap Creek Formation may be correlated with the Lower Trenton of the United States of America (Table 2).

TABLE 2.—STRATIGRAPHIC 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 Formation.				
Unconformity.					
LOWER AND MIDDLE ORDOVICIAN Prices Creek Group	Gap Creek Formation.	V.	*Spanodonta*	*Illaenus* (*Bumastus*) Pliomerids (*Ectenonotus* ?), *Isotelus*, several genera of gastropods, ostracods, &c.	Lower Trenton
	Emanuel Formation.	IV.	Telephids	Asaphidae, Asaphellinae, Pliomeridae, Agnostidae, Clitambonitidae.	Chazian
		III.	Dichograptids; New genus of asaphids; Nautiloids	Ostracoda, conodonts, Bellerophontacea, several genera of gastropods including *Plethospira*.	Canadian
		II.	*Xenostegium*		
		I.	*Obolus*		Upper Ozarkian
Base not seen					

Unconformity between Devonian and Ordovician.

An angular unconformity separates the two systems in the outcrop area along the south-west scarp of the Emanuel Range. The Pillara Formation overlies both the Gap Creek Formation and the Emanuel Formation. The unconformity is clearly shown at the entrance to the linear valley through the range, half a mile north-west of Gap Spring. Elsewhere the contact between the two formations is difficult to trace, owing partly to similarities in lithology, since the basal beds of the Devonian in this area were doubtless derived from local ridges of the Gap Creek Formation. At locality O.G.1, beneath the lowest biostromes and calcarenites of Devonian age, are 47 feet of unfossiliferous sediments, similar in appearance to the Gap Creek Formation. A massive bed of dolomite conglomerate, with pebbles of dolomite up to 2½ inches in diameter in a dolomitic matrix, occurs in the basal 6 feet of this unit. It is overlain by 11 feet of bedded and cross-bedded fine dolomite conglomerate and sandy dolomite containing coarse quartz grains. These sediments are overlain by 30 feet of interbedded thin-bedded calcilutite and silty dolomite with friable fine silty sandstone, and immediately beneath the first Devonian biostrome is a thick bed of calcilutite with half-inch pellets of dolomite. At the head of Emanuel Creek, and the top of O.E.1, 84 feet of sediments are exposed between the top of the soft siltstone at the top of the Emanuel Formation and a dense crystallin unfossiliferous limestone, which is considered to be the base of the Pillara Formation in this area. The lowest 16 feet of the interval consist of interbedded silicified fine to coarse quartz sandstone, thinly cross-bedded fine sandy

TABLE 3. FITZROY BASIN—DEVONIAN STRATIGRAPHY, STRUCTURE, TOPOGRAPHY AND WATER SUPPLY.

Period or Epoch.	——	Stratigraphic Unit.	Distribution.	Lithology.	Thickness (feet).	Structure.	Topography.	Correlation.	Water Supply.	General Remarks.
UPPER DEVONIAN		Fairfield Beds (Duf)	Belt along western flank of Oscar and Napier Ranges and scattered outcrops north and south of Margaret River	Includes interbedded grey-brown and yellow-brown fine limestone breccia, calcarenite, sandy and silty limestone, marl and sandstone	650 +	Gently folded with some small scale faulting	Low hills and ridges and underlies featureless grass plains	Probably equivalent in age to Bugle Gap Limestone	Insufficient information but generally unfavourable	Overlies Mount Pierre Group, Fossil Downs Formation, Geikie Formation, Oscar Formation, Napier Formation. Possibility of unconformity at base of formation
UPPER DEVONIAN	Famennian and Frasnian ?	Napier Formation (Dun) ..	Napier Range	Calcareous siltstone, sandstone and conglomerate with combinations. Clastic limestone, biohermal and reef limestone, calcarenite. Marine, shallow water	700–3,350	General homoclinal dip considered to be primarily depositional	Rugged forming Napier Range. Karst topography in limestone masses	Probable time equivalent of Oscar, Geikie, Brooking, Copley, Fossil Downs Formations, and Mount Pierre Group	No boring attempted but considered very favourable	Uncomformably overlies Pillara Formation and Precambrian. Overlain possibly unconformably by Fairfield Beds
UPPER DEVONIAN	Famennian and Frasnian ?	Van Emmerick Conglomerate (Dug)	Van Emmerick Range	Boulder, cobble, pebble conglomerate, impure sandstone, thick bedded, strongly cross-bedded. Torrential fan-conglomerate	Exceeds 1,000	Regional dip to south-west ..	Rounded hills and range with complex drainage pattern from high points	Approximately equivalent in time and formed under similar conditions to other conglomerate formations	No boring attempted. Probably good aquifers	Unconformably overlies Precambrian and interfingers seaward with sediments of Napier Formation
UPPER DEVONIAN	Famennian and Frasnian ?	Behn Conglomerate (Duc) ..	Mount Behn	Boulder, cobble, pebble conglomerate, impure sandstone and siltstone, clastic limestone. Torrential fan-conglomerate	Exceeds 1,000	Regional dip to south-west ..	Rounded hills and range with complex drainage pattern from highest points	as above	No boring attempted. Probably good aquifers	as above
UPPER DEVONIAN	Famennian and Frasnian ?	Oscar Formation (Duo) ..	South-west flank of Oscar Range	Clastic and organic limestone. Contains significant proportion of calcarenite and limestone breccia. Usually thinly bedded becoming massive and reef forming. Marine	1,500–2,300	Homoclinal dip between 25° and 30°. Dip considered primarily depositional	Rugged and broken limestone range — dissected by Pre-Permian and Epi-Permian erosion. Karst topography	Equivalent in time to Geikie Formation and at least to upper beds of Napier Formation and Brocking Formation	No boring attempted	Passes laterally into Napier and Brooking Formations. Unconformably overlies Pillara Formation and Precambrian and overlain by Fairfield Beds
UPPER DEVONIAN	Famennian and Frasnian ?	Brooking Formation (Duk) ..	Brooking Gap area, south-east Oscar Range	Interbedded red, grey and mottled clastic limestone, sandy, silty limestone, oolitic limestone, sandstone. Beds lensing and cross-bedded in upper part with scattered bioherms. Marine	3,150	Gently folded. Dips essentially depositional	Forms flat or gently undulating surface with flaggy outcrops	At least upper beds are a lithofacies of the Geikie and Oscar Formations	No boring attempted. Probably good aquifers	Unconformably overlies Pillara Formation and overlain by Fairfield Beds
UPPER DEVONIAN	Famennian and Frasnian ?	Geikie Formation (Dus) ..	Forms southern flank of range from Brooking Gap to Fossil Downs H.S.	Bedded grey calcarenite, fine limestone breccia, oolitic limestone and rarely sandy limestone. Small bioherms and massive beds of organic and clastic limestone. Marine	1,350 max.	Some compaction over buried ridges. Present dips primarily depositional	Forms rugged and sometimes cavernous flank on the south and south-east side of Geikie Range. Karst topography	Equivalent to Oscar Formation and at least in part to Brooking Formation and Copley Formation	No boring attempted	Unconformably overlies Pillara Formation and passes laterally into Brooking and Copley Formations
UPPER DEVONIAN	Famennian and Frasnian ?	Copley Formation (Duh) ..	Area north of Geikie Gorge ..	Interbedded grey, red, mottled clastic limestone, oolitic limestone, sand and silty limestone, limestone breccia. Marine	2,650	Gentle folding, dips essentially depositional, small scale faulting	Flat or gently undulating surface with flaggy outcrops	Upper beds a lithofacies of Geikie Formation	No boring attempted. Probably good aquifers	Unconformably overlies Pillara Formation
UPPER DEVONIAN	Famennian and Frasnian	Fossil Downs Formation (Dul) ..	Area north and east of Fossil Downs H.S.	Calcarenite, clastic limestone, biohermal limestone, limestone, sandy and silty limestone. Marine	1,500–1,700	Gentle folding and variable dips. Steep dips primarily depositional	Ranges, hills and plains with scattered outcrop	Approximate time equivalent of Mount Pierre Group and Napier Formation, &c.	Insufficient information. Good aquifers probably available	Unconformably overlies Pillara Formation and Precambrian. Overlain by Fairfield Beds
UPPER DEVONIAN	Famennian and Frasnian	Stony Creek Conglomerate (Dut) ..	Stony Creek vicinity	Boulder to pebble conglomerate, greywacke and sandstone. Torrential fanglomerate	unknown	No information	Low rounded hills	Lithofacies of Fossil Downs Formation. Marginal to marine facies	No information available. Good aquifers	Unconformably overlies Pillara Formation
UPPER DEVONIAN	Famennian and Frasnian	Burramundi Conglomerate (Dua)	Burramundi Range	as above	1,000 estimated 450 exposed	Generally flatly bedded, outcrops rare	Rounded hills with radial dendritic drainage pattern	Lithofacies of Fossil Downs Formation	No information available. Probably good aquifers	Unconformably overlies Precambrian
UPPER DEVONIAN	Famennian and Frasnian	Mount Elma Conglomerate (Due)	Mount Elma and vicinity ..	as above	1,000 estimated 200 + exposed	Generally flatly bedded, outcrops rare	as above	as above	as above	Unconformably overlies Pillara Formation and Precambrian
UPPER DEVONIAN	Famennian and Frasnian	Bugle Gap Limestone (Dub) ..	Belt from southern entrance to Bugle Gap towards Old Bohemia H.S.	Light grey-brown bedded and massively bedded limestone, calcarenite. Biohermal limestone, clastic limestone	1,230 +	Regional south and south-east dip	Dissected limestone ridges, karst topography	Probably partly time equivalent of Fairfield Beds, and may extend into Carboniferous	No information available. Probably unfavourable	Overlies Mount Pierre Group and is unconformably overlain by Permian Grant Formation
UPPER DEVONIAN	Famennian and Frasnian	Sparke Conglomerate (Duj) ..	Sparke Range, Virgin Hills ..	Boulder to pebble conglomerate, calcareous sandstone. Strongly crossbedded sandstone. Torrential fan-conglomerate	1,000	Usually sub-horizontal but irregular	Rounded hills with radial dendritic drainage pattern	Marginal lithofacies of Mount Pierre Group and approximate time equivalent of conglomerate facies elsewhere	No boring attempted. Probably good aquifer, but would be difficult to bore	Unconformably overlies Pillara Formation and Precambrian and interfingers with normal marine facies of Mount Pierre Group
UPPER DEVONIAN	Famennian and Frasnian	Mt. Pierre Group (Dup): Virgin Hills Formation (Dup)	No. 5 Bore area, Mount Pierre, Needle-eye Rocks, Old Bohemia, No. 10 Bore, Virgin Hills, Bugle Gap, &c.	Red-brown, grey and mottled, silty limestone and calcareous siltstone, shale. Small bioherms. Sandy and conglomeratic adjacent to conglomeratic facies. Marine	1,400 approx. (Probably not maximum thickness)	Some gentle folding. Gently dipping or sub-horizontal	Chiefly grass plains with shrinkage cracks. Low ridges with flaggy outcrops	Probable time equivalent of Fossil Downs and Napier Formations	Bores usually unsuccessful except in sandy and conglomeratic facies	Conformably overlies Gogo Formation and unconformably overlies Pillara Formation. Overlain by Bugle Gap Limestone and Fairfield Beds
UPPER DEVONIAN	Frasnian	Mt. Pierre Group (Dup): Gogo Formation (Dup) ..	Northern flank of Pillara and Emanuel Ranges, Old Bohemia area and Bugle Gap	Grey-brown bedded limestone, siltstone and shale with concretions. Marine	1,050 max.	Sub-horizontal bedding ..	Grassed and lightly timbered plains. Outcrop rare		Bores usually unsuccessful ..	Conformably overlies Sadler Formation. Conformably overlain by Virgin Hills Formation
UPPER DEVONIAN	Frasnian	Sadler Formation (Dud) ..	Northern scarp of Pillara and Emanuel Ranges, Bugle Gap, Hull Range area, Oscar Plateau	Clastic limestone, bioherms and massive reefs, sandy and silty limestone, siltstone. Fossil remains commonly silicified and ferruginized. Marine	665–1,200 app. 1,230 max.	Gently folded; some faulting. Dip generally low	Low ridges and gently undulating with flaggy outcrops		No boring attempted. Probably unfavourable	Unconformably overlies Pillara Formation. Conformably overlain by Mount Pierre Group, Napier Formation, Fossil Downs Formation
MIDDLE DEVONIAN	Givetian	Pillara Formation (Dmp) ..	Bugle Gap, Emanuel Range, Pillara Range, Minnie Pool, Hull Range, Geikie Range, Oscar Range, Oscar Plateau, Napier Range	Biostromal limestone, bedded limestone, calcareous sandstones, siltstone, marl. Marine	1,850 max.	Pronounced regional dip in area south of Margaret River and Hull Range. Elsewhere dips low. Faulting common	Rugged deeply dissected karst. Epi-Permian surface recognisable		No boring attempted. Probably generally unfavourable	Unconformably overlies Prices Creek Group and Precambrian

[*To face page* 21.]

3336/57.

dolomite, and fine dolomite conglomerate with pebbles of dolomite (up to 1 inch) and scattered quartz grains ($\frac{1}{2}$ inch). This is overlain by 52 feet of interbedded dense fine dolomite and friable sandy dolomite with fine quartz grains. The uppermost 16 feet consist of interbedded granulated thin-bedded silty dolomite and friable fine crystalline dolomite capped by fine sandy siltstone with pebbles of dolomite.

The base of the Gap Creek Formation is not seen at O.G.1 and there is no indication at O.G.1 that the base of the formation is similar to the 84 feet of sediments described at the top of O.E.1. From their position these 84 feet could be regarded as the basal beds of the Gap Creek Formation; but there is a similarity between the upper parts of the two sections that could indicate basal Devonian rather than Ordovician.

DEVONIAN (Table 3).

The Devonian sediments are of considerable importance as they contain, together with the Ordovician sequence, the most likely potential oil-source rocks known in the Fitzroy Basin.

The Devonian outcrops are confined to a comparatively narrow belt extending for a distance of 180 miles along the north-eastern margin of the Fitzroy Basin in the marginal area of marine sedimentation during the Devonian Period. Consequently the outcrops of Devonian sediments will probably not be representative of Devonian sedimentation in the extensive areas to the south and west which are now covered by younger sediments, but they provide the only information from which can be deduced, in a general way, the type of sediments that can be expected elsewhere in the Fitzroy Basin.

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

Recent geophysical work (Smith, 1955) has given an approximate " depth to basement " of 20,000 feet in the Poole Range area, but more detailed work must be done before a contour of the basin floor is known. How the basement contour in the deeper parts of the basin changes the type of Devonian sediment is not known; it may be predicted that the platform type of sediment will give place to a pelagic deposit towards the south and west of the known Devonian outcrops.

Pillara Formation.

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

The type section was measured at Menyous Gap (Long. 125° 25′ East, Lat. 18° 24′ South) in the Pillara Range (*see* Appendix II., p. 89); the Formation was named from the Pillara Range, and the name replaces the " Rough Range Series " of Wade, which included limestones of Upper and Middle Devonian age.

The formation is widely distributed through the belt of outcropping Devonian Rocks; localities are briefly recorded in Table 3.

Although the formation is exposed over a large area it retains its essential characteristics throughout, and with few exceptions is readily recognizable in its several lithofacies.

The main facies divisions of the Pillara Formation are as follows:—

Calcarenite, biostrome facies contemporaneous with reef and biohermal facies;

Calcarenite, calcilutite, biostrome facies;

Arkosic sandstone, conglomerate facies at base.

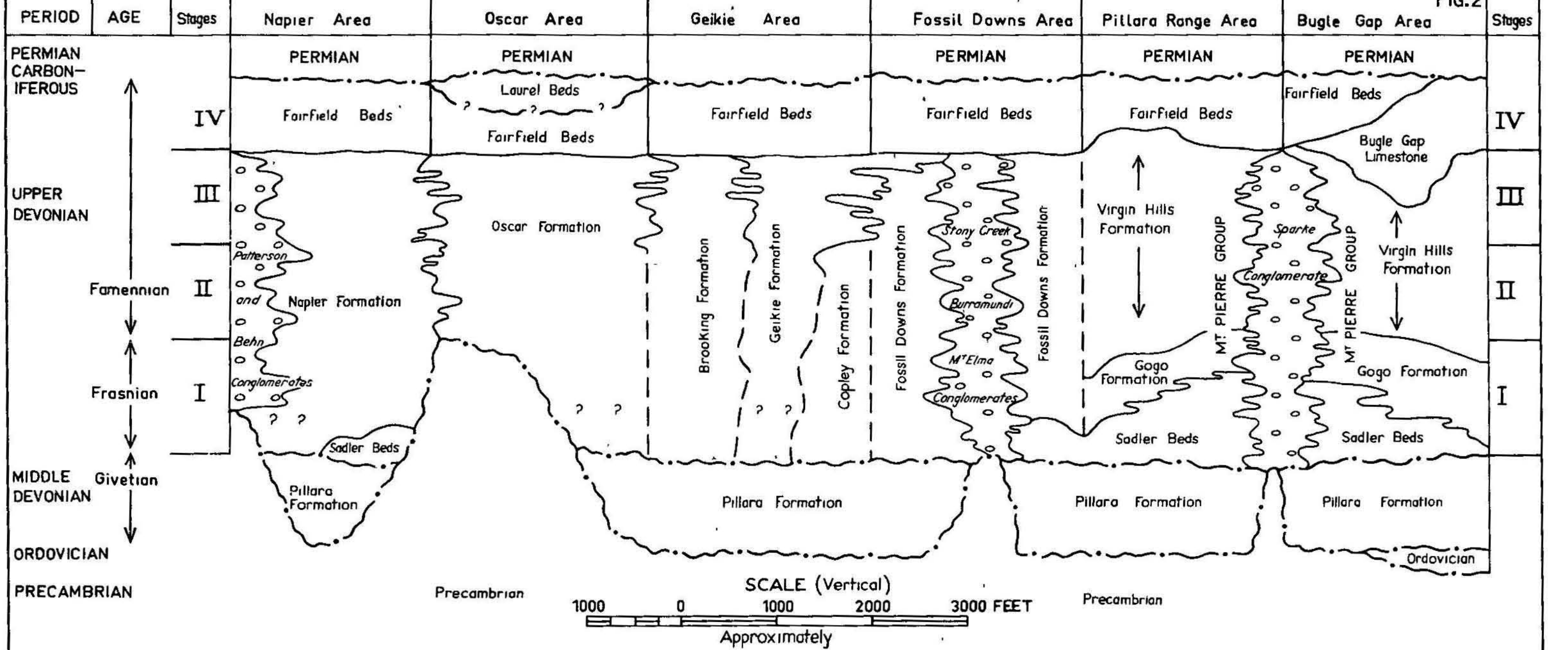
Arkosic sandstone facies.—This characteristic basal facies was derived from a former transgression when the Devonian shoreline transgressed north-eastwards across an undulating surface of Precambrian granitic rocks and Ordovician dolomitic rocks in the Prices Creek area. The clastic facies is a characteristic but by no means universal feature, and in some sections south of the Margaret River in the Pillara Range it is absent. The lensing of this facies is apparently due to the irregular surface of the basement, which resulted in accumulation of quartzose clastic material in large areas and the deposition of calcarenite and biostromal limestone directly on basement in others. Fossil shell banks are a feature of the basal beds of the Pillara Formation in the Pillara and Home Ranges where these beds rest on basement rises or islands.

In the Emanuel Range, the dolomitic beds of the Gap Creek Formation have contributed material for the basal Pillara and the junction between the two formations can be selected with confidence only where the unconformity is clearly revealed.

North of the Margaret River, particularly in the Oscar Plateau, Oscar Range, and Napier Range, the basal quartzose clastic facies is strongly developed. The outcrop forms part of the northern wall of Windjana Gorge in the Napier Range, and here quartzose clastic material is conspicuous 500 feet above the base of the section. This section differs from the thinner sections of this facies studied elsewhere in the occurrence, throughout the section, of beds of stromatoporoid biostrome, indicating a type of cyclic sedimentation varying from pure clastic to pure organic growth.

Calcarenite, calcilutite, biostrome facies.—This facies overlies the basal quartzose clastic facies throughout the area as a general type. In detail numerous variations occur both in lithofacies and thickness of the division. The facies

FIG.2



Upper Devonian formations arranged according to their stages.

No true vertical scale of thickness, but apart from conglomerates is approximately of the order of 1000 feet = 1 inch.

Reference

Interfingering formation

Formation boundaries

Unconformity

DEVONIAN FORMATION RELATIONSHIPS

FITZROY BASIN W.A.

Compiled by J.N.Casey

Bureau of Mineral Resources Geology & Geophysics. 1956

WA3. 25

PB

is widespread, and with genetically related lithofacies 1,200 feet of sediment are found over an area of 160 miles by 40 miles; so the environment must have been favorable for organic growth over a very wide area.

Glover (1956) described typical examples chosen from the section at Windjana Gorge and Pillara Range—

"Calcarenites at Windjana Gorge vary from grey through brown to red, and weather grey and brown. Mineralogically they grade from almost pure carbonate through sandy and micaceous calcarenite to calcareous sandstone. In many places calcarenites grade vertically in a few inches to biostromal limestone. A typical sandy micaceous calcarenite contains irregularly shaped to subrounded, moderately to poorly sorted clastic grains of grey calcilutite, angular quartz, a few ooliths and mica flakes and clean crystalline calcite cement. The diameter of grains varies between 0.1 mm. and 2.0 mm. Calcilutite fragments are finely divided grey calcite containing a few minute angular granules of quartz (0.05 mm.) and some recrystallized fossil fragments. The raggedness of quartz grains in the calcarenite, and of quartz granules in calcilutite fragments strongly suggests diagenetic solution. Some quartz grains and a few calcilutite fragments have a narrow rim of calcilutite as though they had rolled in lime mud before incorporation in the rock. The clean crystalline calcite cement is considered precipitated and not recrystallized lime mud."

Two calcarenites are described below from the type section at Menyous Gap (*see* page 89).

"Specimen F 77 is pale brown, medium to coarse grained and is made up of grey poorly sorted fragments up to 2 mm. long in a pale brown matrix that is indistinct under the hand lens and varies between aphanitic and finely granular. Microscopy emphasizes the poor sorting. Crinoid and ostracod remains, other organic fragments and calcilutite grains are set in a matrix mainly of brown, finely divided calcite (lime mud) and partly of clear crystalline calcite. Association of lime mud with very poorly sorted fragments is typical of calcarenites.

Specimen F 71A as seen under the hand lens is a very well-sorted, fine-grained, light grey calcarenite flecked with irregularly shaped patches and streaks of clear crystalline calcite. Some streaks are 5 mm. long and 1 mm. wide. Microscopic examination shows that the rock is made up of rounded cloudy grey grains between 0.1 and 0.2 mm. diameter, and clear calcite cement. Lime mud was probably winnowed out of the rock before lithification and clear calcite was precipitated in the porous, even-grained limestone. The drusy outer fringe of crystals in clear crystalline aggregates points to growth inwards from borders of a void. Where precipitation was excessive clastic grains have been pushed apart by crystal growth until they no longer touch; clear calcite masses so formed are the calcite flecks observed in hand specimens.

A specimen of *calcilutite* (F 72B) consists of small fossil fragments and minute recrystallised ooliths set in a fine calcite paste consisting over 90 per cent. of the rock. The hand specimen is light grey and aphanitic.

Specimen F 239 is considered a typical biostromal limestone. The hand specimen has a pink finely granular matrix that weathers tan to buff, and on weathered surfaces the small rhombs making up much of the matrix are visible with a hand lens. The remainder of the rock (about 30 per cent.) consists of white branching stromatoporoids. Microscopy, etching and staining reveals the texture and mineralogy. The pink matrix consists of dolomite rhombs whose average length along the greatest diagonal is 0.25 mm., set in finely divided interstitial calcite the rhombs are coated with a film of red iron oxide that imparts pinkness to the matrix in hand specimens and one index (ω) was determined as 1.682 ± .001. Stromatoporoids are composed of calcite (ω = 1.658 ± .001) and are not dolomitised but their edges are penetrated by rhombs growing from the adjoining matrix. Where the matrix is only slightly dolomitised its angular texture is evident. The matrix is calcilutite and consists of minute recrystallized oolites, ostracods and other organic fragments in a finely-divided slightly iron stained calcite base. A few dolomite rhombs are scattered throughout the calcilutite and rarely in stromatoporoids. The calcilutite is probably lithified lime mud.

In some biostromal limestones complete recrystallization prevents identification or even recognition of reef building organisms, but their nature is assumed from comparison with less recrystallized fossils nearby. The calcilutite matrix appears unaltered in such rocks."

Calcarenite, biostromal facies, contemporaneous with reef and biohermal facies: This uppermost division of the Pillara Formation is the most complex portion of the section and would require considerable detailed studies to elucidate completely the changing environment which controlled deposition. The studies already completed are sufficient to indicate in a general way the changes that have occurred in the outcrop area; such changes presumably could be repeated in areas where a similar environment existed, but which are now covered by younger formations.

This facies division is restricted to the area surrounding Geikie Gorge, on the Fitzroy River, and farther south-east in the Pillara and Emanuel Ranges. The equivalent portion of the section in the Napier Range has been eroded.

In the area south-east of the Fitzroy River the division clearly shows a lateral change in lithofacies from interbedded calcarenites and biostromes to bioherms and reefs. (The term " reef " is used to distinguish the large complex areas of many organic or biohermal masses, welded together with clastic limestone and calcarenite, with steep off-dipping marginal sediments, from isolated and clearly defined organic mounds which are referred to simply as bioherms.)

On the north side of the Pillara Range, south-east of Menyous Gap, the typical biostrome-calcarenite of the upper part of the Pillara Formation can be traced laterally along the strike to a sequence of thinly bedded calcarenites. The biostrome-calcarenite lithofacies contains compound corals, whereas the bedded calcarenites are characterized by solitary corals and brachiopods. A similar facies change has been studied on the north side of the Hull Range in a comparable environment. The several exposed beds of calcarenite with massive and branching stromatoporoids, rugose corals, and brachiopods may be traced laterally into the range, where they merge into the continuous sequence of interbedded calcarenites and biostromes of the Pillara Formation. A similar lateral facies change has been observed on the northern side of the Emanuel Range near Paddys Spring, in a similar environment. In the field these changes in lithofacies and biofacies are clearly outlined and reveal the results of what were probably comparatively minor and essentially local changes in environment, which would continually occur on a platform adjacent to a shore-line.

Reef and biohermal masses are a feature of the upper beds of the Pillara Formation at widely spaced localities. A section revealed by Geikie Gorge has shown that bedded dolomitized biostromes dipping gently south-west flatten out or reverse slightly before passing into massive, flat, and crudely bedded reef limestone. The reef extends 400 feet in the direction of the dip before the appearance of the crude off-reef bedding, dipping steeply south-west. Typical Pillara fossils are found in the dolomitized biostromes, but the lateral equivalents of these in the reef zone are recrystallized brachiopods. The off-reef zone contains sponges, rugose corals, branching stromatoporoids, algae and rare brachiopods. Milky calcite encloses fossil and breccia fragments and has been chemically precipitated in vugs.

A similar biohermal facies has been examined north-west of Paddys Spring in the Emanuel Range. Poorly exposed beds of calcarenite of the upper part of the Pillara Formation can be traced along the strike to a northerly extension of the main range, where they pass laterally into thick stromatoporoid biostromes which merge with the reef mass that forms the core of this portion of the range. The massive core has caused local arching of the flanking biostromes on the south-east flank.

A biostromal sequence, being organic and chemical in origin, will be more subject to abrupt lateral and vertical termination due to change in environment than a clastic sequence. Also, once the environment has changed, the unique conditions favorable for growth of biostromes may never return. In such a way a biostrome sequence may terminate laterally or vertically in a clastic (calcarenite) sequence or reef in the manner described above.

Thickness: The Pillara Formation is overlain unconformably by the Upper Devonian in the outcrop area and the complete section is not preserved. The maximum thickness measured was 1,850 feet at Wagon Pass in the Napier Range. Since the outcrops are poor the dip values were irregular and questionable. The thickness may have been exaggerated by 400 feet. A reliable section of 1,400 feet of sediments has been measured at the type section. Elsewhere partial sections were measured and can be utilized for comparative purposes.

The outcropping section deposited in the platform environment was probably uniformly thick and possibly reached 2,000 feet if the section at Wagon Pass is a reliable indication of the thickness towards the northern part of the area.

Changes in thickness can be expected over such a length of deposition in the same way as changes in facies occur, but have not been demonstrated from surface outcrop.

Palaeontology: The large mass of fossil material collected from the Devonian Formations is still being analysed and the results are not yet available for publication, but the age is given as Givetian. Consequently, the remarks on palaeontology presented with this report are preliminary and will be supplemented as further data become available.

Massive stromatoporoid biostromes with local bioherms constitute a large portion of the formation and are considered typical. The well-bedded biostromes of *Amphipora ramosa* and associated *Hexagonaria* dominate, in general, at the base of the stromatoporoid biostromes; higher in the unit they are replaced by more massive forms. In the reduced section of the Emanuel Range *Amphipora* persists throughout the section. Brachiopods and gastropods are associated with the stromatoporoids at the base, but are absent or rare in the upper beds. The stromatoporoid biostromes are replaced in the higher beds by coral and brachiopod biostromes and calcarenites with local bioherms and reef complexes.

Large thick-shelled brachiopods and lamellibranchs together with rare nautiloids and fish remains are associated with the basal assemblage of *Amphipora ramosa, Hexagonaria brevilamellata,* and *Murchisonia,* particularly in the Home Range.

A preliminary list of fauna of the formation is given by Teichert (1949, p. 10) and recent work by Hill (1954, p. 7) has amended and added to the corals listed.

The following corals have now been identified from the Pillara Formation :—

Hexagonaria brevilamellata (Hill).
H. hullensis Hill.
Disphyllum goldfussi (Geinitz).
D. virgatum (Hinde).
D. virgatum var. *densum* Hill.
D. depressum (Hinde).
D. curtum Hill.
Temnophyllum sp?
T. turbinatum (Hill).
Temnophyllum? floriforme (Hill).
Spongophyllum? sp.
Thamnopora augusta Lecompte.
T. boloniensis (Gosselet).
Alveolites tumidus (Hinde).
A. suborbicularis Lamarck.
Aulopora sp. cf. *foordi* (Etheridge).

Sadler Formation.

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

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

The formation interfingers with the Sparke Conglomerate and Mount Elma Conglomerate.

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

The two dominant lithofacies in the formation are clastic limestone and reef (grading to biohermal). A local quartz clastic lithofacies has been examined at the base of the reef facies in the Castle Rock area, north of the Hull Range. The relationship of the lithofacies is not fully understood and considerably more detailed work is required. However, the lateral variation has been established in the field and the use of " formation " to define the unit is justified.

Clastic Limestone Lithofacies: This facies is typically developed in the Sadler Ridge and has been examined in detail in two sections, spaced at a distance of 1 mile along the strike at Sadler Hills. They reveal the rapid changes which may occur in thickness and biofacies, while the gross lithofacies remains essentially comparable. The thicker of the two sections can be studied on p. 90. The thinner section is unique in that it commences with a local reef mass containing corals and brachiopods. This local reef mass is associated with local near-shore conditions and formed near low cliffs of Pillara-age biostromes.

Younger beds in the two sections are then comparable and consist of calcarenites with the very typical silicified fossils forming a coquinoid limestone in some beds. In the thinner section the richly fossiliferous beds, with scattered bioherms, persist to the top of the section, whereas the thicker section, which contains more silt, is less rich. The higher beds in both sections contain limestone breccia.

These features indicate near-shore conditions with comparatively rapid and local changes in environment, probably associated with the configuration of the adjacent coastline, ocean currents, and the contemporaneous growth of reefs and bioherms. Further detailed studies of the lithology and fauna of the beds along the northern flanks of the Emanuel and Pillara Ranges would provide a wealth of information of the effects of local changes in conditions.

Reef Lithofacies: The greatest development occurs in the upper portion of the Sadler Formation at Castle Rock. The reef extends for a mile along the strike and consists of a complicated and heterogeneous mass of limestone breccia, calcarenite, and biostromal limestone with rugose corals and massive and branching stromatoporoids.

The presence of corals and stromatoporoids throughout the exposed section of the Sadler Formation reveals that the fauna suitable for reef growth was present. In most of the exposed outcrop the environment must have been unfavorable for reef growth; but reefs developed, for instance, at Castle Rock, and they could be expected in other areas, covered by younger sediments.

Contact between Pillara Formation and Sadler Formation: Considerable attention has been given to this contact and it is believed that a significant break in sedimentation occurred at the contact between the two units. This unconformity is placed between the Middle and Upper Devonian. The precise time range of the two formations will not be known until studies of the faunas have been completed.

In some places the time break between the Pillara Formation and the Upper Devonian units (other than the Sadler Formation) may be clearly identifiable, whereas in other places it is practically indistinguishable. The presence in the Sadler Formation of biostromes and fossiliferous calcarenites with a similar faunal content to the Pillara Formation makes the division between these units extremely difficult.

An area of particular interest and one in which further detailed work is warranted lies in Bugle Gap at the south-east end of the Emanuel Range. The east wall of the Gap has the appearance of a barrier reef over 9 miles long and 1 mile at the greatest width. For about 4 miles it has a core of flat-bedded biostromes and calcarenites of the Pillara Formation. These beds have been observed in the walls of the creek that cuts the reef near Cave Spring and elsewhere. At these localities it is not possible to locate the exact contact with the Pillara Formation, although bedded calcarenites with brachiopods of the Sadler Formation dip off the reef to the east and west. Structureless cavernous limestone with steep off-dipping clastic limestone extends both north and south of the crestal core of Pillara Formation. A section is available through the reef mass along the old road pass to old Bohemia Downs Homestead. Here the usual central core of cavernous structureless recrystallized limestone is exposed, flanked on either side by crudely bedded limestone. Brachiopods and massive and branching stromatoporoids occur in both the cavernous and bedded limestone, with a matrix of calcilutite. Flank dips as high as 48° were recorded, but the dips soon decrease to 20°.

It is clear that the core of this reef is Middle Devonian in age and the flanks and the extremities are of Upper Devonian age. It is an area where considerably more work is required before the relationship of the two formations is fully understood.

The absence of reliable palaeontological data prohibits precise dating and correlation of the separate areas of outcrop of the Sadler Formation. It is suspected that later work on the specimens may reveal variations in the interval of time represented by the Sadler Formation. Without detailed palaeontological studies it is extremely difficult to distinguish the reef facies at the top of the Pillara Formation from that of the Sadler Formation. However, as has been described in preceding pages, it is believed that fringing and barrier reef masses were formed during both Middle and Upper Devonian.

Three complete sections have been measured through the unit, indicating a range of thickness from 665 feet to 1,230 feet. North of the Fitzroy River, apart from a small area on the Oscar Plateau, the unit is missing, and it is presumed that there was no deposition during the interval.

The Sadler Formation is for the most part equivalent to the Atrypa Beds of Teichert (1949) and the list of fossils given by him indicates the richness of the fauna.

The frequence of *Manticoceras* and corals with Upper Devonian affinities indicates a Frasnian age, Upper Devonian Stage I. Further palaeontological studies are likely to prove conclusively the Upper Devonian age of the Sadler Formation.

Mount Pierre Group.

The term Mount Pierre Series was originally applied by Wade (1936) to the limestones in the vicinity of Mount Pierre, Bugle Gap, and Old Bohemia (Table 3). In the type area between Pillara Range and Needle-eye Rocks (Long. 125° 25′ E., Lat. 18° 17′ S.) the group consists of over 1,800 feet of sediments. Interfingering of facies and the absence of units has resulted in considerable variation in the thickness of the group.

The group conformably overlies and interfingers with the Sadler Formation and is overlain probably conformably by the Fairfield Formation (in the Mount Pierre area) and Bugle Gap Limestone (at Bugle Gap).

In the accompanying stratigraphical table (Table 3), the Group has been divided into two formations, a lower Gogo Formation and an upper Virgin Hills 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 Mount Pierre Group on the accompanying geological maps.

Gogo Formation.—The type section was measured along the northern flank of the Pillara Range (Long. 125° 26′ E., Lat. 118° 36′ S.). The formation name was derived from Gogo Station, where typical outcrops of the formation are found. It replaces the lower part of the " Gogo Stage " of Wade (1936) ; the " Gogo Stage " actually included the Gogo Formation and the lower unfossiliferous part of the Virgin Hills Formation. Wade regarded his " Stage " as Carboniferous. The contact with the Sadler Formation is apparently conformable and usually gradational. The upper boundary with the Virgin Hills Formation is gradational and poorly exposed. It interfingers laterally with the Sparke Conglomerate. Other outcrops of the formation are in Bugle Gap-Old Bohemia area, and north of the Emanuel Range.

The most characteristic feature of the surface outcrop is the presence of spheroidal concretions, commonly with nuclei of organic remains. The concretions are presumed to be epigenetic and not necessarily a feature of the formation in depth.

The section on page 91 shows clearly the increase in quartz clastic material as compared with the limestone clastics of the Sadler Formation. The lithology changes rapidly through siltstone, sandstone, and calcarenite, together with a very characteristic faunal assemblage consisting chiefly of nektoplanktonic organisms—*Tentaculites,* nautiloids, fish remains. Small molluscs and brachiopods are present and the overall aspect is one of shallow marine environment with continuous but slow sedimentation. Benthonic organisms were inhibited by the existing conditions and the fauna is typically impoverished.

The recording of two zones of biohermal limestone in the upper part of the section on the northern side of the Pillara Range indicates that reef-forming organisms were present but were inhibited by an unfavorable environment in the outcrop area.

In one complete but poorly exposed section 1,050 feet of sediments have been described. Partial sections have been examined in the Old Bohemia Downs area and north of Sadler Hills, with thicknesses ranging from 180 feet to 460 feet.

The formation is restricted to the area south of the Fitzroy River and has not been recognized throughout the Oscar and Napier Range areas.

The Formation has been included by Teichert in his *Manticoceras* Zone of the Upper Devonian (Frasnian, Stage I). The Formation is characterized by *Buchiola* and other pelecypods, associated with numerous *Tentaculites,* small straight nautiloids, some ostracods, and coccostean and crustacean remains, in grey siltstone, platy limestone, and silty limestone concretions. *Timanites* and *Koenenites,* restricted to the lower part of the *Manticoceras* Zone, occur in these beds.

The age indicated by the fauna is Frasnian.

Virgin Hills Formation.—The Virgin Hills Formation forms the upper unit of the Mount Pierre Group and overlies the Gogo Formation conformably; it is overlain by the Fairfield Beds or the Bugle Gap Limestone. Although conclusive evidence is lacking, there is probably a minor unconformity at the top of the Virgin Hills Formation.

The type area and section (*see* page 92) is in the No. 5 Bore/Needle-eye Rocks area and the formation takes its name from the Virgin Hills (Long. 125° 55′ E., Lat. 18° 33′ S.).

The name replaces Wade's (1936) Mount Pierre Series, which included the Napier, Brooking and Copley Formations.

The most characteristic feature of the formation is the red colour. Red and greenish-grey, commonly mottled, thin-bedded and interbedded calcareous siltstones, calcarenites and fine sandstones are the dominant rock types. Both the lower and upper parts of the formation contain the rich goniatite fauna which has permitted precise dating of this facies of the Upper Devonian.

The formation contains abrupt facies changes which can be directly related to outwash and extension of the marginal accumulations of polymictic conglomerate (Sparke Conglomerate), which are a feature of the Upper Devonian along the margin of the basin.

Sections through the formation reveal a sequence chiefly of quartz sandstone; the grain-size is variable, but it becomes finer westward. Recrystallized limestone bands and small bioherms have been described from the formation, but although the sediment was deposited in a marine environment the material was derived mainly from the adjacent land mass and conditions generally were not favorable towards marine life.

The only complete sections available in the area are the type section from the No. 5 Bore/Needle-eye Rocks area and a section at Old Bohemia. About 700 feet of section has been examined at the type area. The central part of the section is either poorly exposed or covered by soil, and a total thickness of 1,000 feet could be present in this area. A similar section could be expected in the area between the Emanuel Range and Virgin Hills, with the additional thickness of sandstone and conglomerate in the upper part of the section. The section at Old Bohemia is essentially the same as the type section; it is poorly exposed with an estimated thickness of 1,400 feet. Elsewhere, thin sections of the unit are exposed where they interfinger with other units in the Upper Devonian. Kraus (1941, p. 24) records gas from black sand at 700 feet in No. 5 Bore, drilled for water.

The Mount Pierre Group contains a faunal assemblage unique in the Devonian of Australia. Teichert (1949) established that the succession of ammonoid forms in the Mount Pierre Group is similar to the type section in Germany, and recognized four palaeontological zones which correspond closely with the lower four stages in Europe.

Stages I (*Manticoceras* Zone), II (*Cheiloceras* Zone), and III (*Sporadoceras* Zone) are represented in the Virgin Hills Formation.

Recent study (Hill, 1954) of the material collected by the writers has indicated that the following corals are characteristic of the Mount Pierre Group:—

Stage I.—*Zaphrentoides? excavatus* Hill.
Disphyllum intertextum Hill.
Stage II.—*Barrendeophyllum cavum* Hill.
Stage III.—*Barrendeophyllum* spp.
Phillipsastrea sp.
Caninia rudis Hill.
"*Cystiphyllum*" *kimberleyense* Hill.
Aulopora recta Hill.

The additional fauna representative of the Group is listed by Teichert (1949).

The age is mainly Famennian, but the presence of *Manticoceras* indicates a Frasnian age for the lowermost beds.

Sparke Conglomerate.

The Sparke Conglomerate was originally named "J8 beds" by Wade (1936), who considered they were Permian glacial moraines. More recent work by Teichert and the writers has shown conclusively that the formation is of

Upper Devonian age and a contemporary facies of the Mount Pierre Group. The formation unconformably overlies either Precambrian or Pillara Formation and in places either unconformably overlies or interfingers with and completely replaces the marine sediments of the Virgin Hills Formation, in localities in the Virgin Hills and Sparke Range.

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

The lithology is typical of a fanglomerate (or polymictic conglomerate) and consists of poorly exposed sections of conglomeratic coarse and medium grained greywacke, grading downwards to conglomeratic greywacke-siltstone. The greywackes are commonly calcareous and strongly cross-bedded and have the typical bimodal grain-size distribution. The coarse clastic fraction ranges from pebbles to boulders with boulders as large as 12 feet across.

Grain-size decreases from east to west away from the source of the material, coarse clastics in the Sparke Range gradually merge into medium and coarse cross-bedded greywacke with conglomerate lenses and scattered pebbles in the Virgin Hills.

The coarser clastics are commonly unsorted and consist of accumulations of boulders, cobbles, and pebbles, in a pebble conglomerate, fine conglomerate, or coarse greywacke groundmass. The phenoclasts are subrounded to subangular, depending to some extent on their composition; they include quartzite, schist, gneiss, granitic and basic rocks, and limestone from the Devonian. Quartzite is the major constituent and erosion leaves the rounded hills strewn with a thick cover of quartzite cobbles and boulders. The basal part of the formation at some localities in the eastern Sparke Range consists entirely of angular fragments of limestone derived from adjacent outcrop.

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.

Approximately 1,000 feet of the unit has been preserved in the Sparke Range; no estimate of the original thickness is possible. The formation becomes thinner westward, where it is interbedded with the Mount Pierre Group.

The unit is typically unfossiliferous, but thin interfingering beds of limestone and calcareous siltstone contain Upper Devonian fossils in the Virgin Hills. Fossils are common in the clastic limestone found in the conglomerate and the faunal assemblage may be either contemporaneous with or older than the conglomerate.

Previous reports by Wade (1936) and Reeves (1949) have suggested that the Sparke Conglomerate was derived from glacial action. It is now clear that the unit is a fanglomerate with associated marine sediments. Although some boulders exhibit faint striations and crude facetting is common, both these features may be found in fanglomerates. Boulder clays are not represented in the formation and the gradual change from coarse to fine clastic from east to west is a normal result of deposition by water.

The widespread occurrence of these clastic sediments suggests considerable uplift in Upper Devonian time; and hence finer-grained terrigenous material such as silt and perhaps fine quartz and limestone clastics have probably been laid down in the deeper parts of the basin throughout Stages I to III of the Upper Devonian.

South of Trig. Station J9, interbedded conglomerate, sandstone, and siltstone abut against the hills formed by the Sparke Conglomerate. Although these sediments are similar in some respects to the Sparke Conglomerate, the better grading and the presence of layers of siltstone and probably shale indicate that they are part of the Grant Formation of Permian age.

Bugle Gap Limestone.

The Bugle Gap Limestone, which was included in the Mount Pierre Series by Wade, overlies the Virgin Hills Formation and in places is conformably overlain by the Fairfield Beds or is unconformably overlain by Permian sandstone of the Grant Formation. The type locality is situated at the south-west end of Bugle Gap (Long. 126° 04′ E., Lat. 18° 42′ S.).

The type section is a monotonous sequence of strongly jointed, bedded and massive, light brown and white calcarenite and recrystallized calcarenite, partly biohermal. Some beds are rich in fossils, mainly brachiopods, but in most places the fossils have been destroyed by diagenesis.

The lithofacies and biofacies of the formation resemble the Oscar and Geikie Formations north of the Fitzroy River; and in part it is probably equivalent in age to the upper part of these formations. All these formations have the very characteristic steep depositional dip which is clearly revealed in Bugle Gap, where Bugle Gap Limestone dipping at 25° to 40° overlies Mount Pierre Group dipping at about 10°.

The type of sediments in these units implies a highly specialized environment, including a source of exclusively carbonate rocks (probably Middle Devonian biostromes, calcarenites, and reef masses), a steeply shelving sea bottom, water highly charged with calcium carbonate, and comparatively turbulent conditions.

Fine to coarse calcarenite forms the major part of the sediment and the only conceivable source is the underlying Pillara Formation. A study of the Bugle Gap Limestone suggests that there is a persistent tendency towards reef development which nowhere reached significant proportions in the outcrop area.

Two sections have been measured in the formation and one of these is given on p. 93.

The two sections measured have thicknesses of 1,230 feet and 950 feet. The former section is unconformably overlapped by Permian sandstone and the latter is overlain by the uppermost Devonian unit, the Fairfield Beds.

3336/57.—3

Consequently the thickness at 1,230 feet is not a complete section as the topmost beds are concealed. The section of 950 feet may represent a complete section, although a minor unconformity is suspected at the base of the Fairfield Beds.

The formation includes Stage III and the *Productella* Zone (Stage IV) of Teichert, and it may well range into the Carboniferous. 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 await specific determination. Hill (1954) identified *Catactotoechus irregularis* Hill, *C. tenuis* Hill, *Zaphrentis iocosa* Hill, and *Phacellophyllum* sp., which are Stage IV corals, in the Bugle Gap Limestone.

Fossil Downs Formation.

The complex Upper Devonian sedimentary sequence north of the Margaret River on Fossil Downs Station has been given a new formation name to distinguish it from the equivalent but more simple sequence south of the river (Mount Pierre Group). The Fossil Downs Formation is typically developed north of Fossil Downs Homestead (at Long. 125° 48′ E., Lat. 18° 08′ S.). The formation unconformably overlies Precambrian and the Pillara Formation, and conformably overlies Sadler Formation, and is overlain by the Fairfield Beds and Geikie Formation; and it interfingers with the Geikie Formation. The marine sequence interfingers in a complex manner with the contemporaneous fanglomerate formations—Stony Creek Conglomerate, Burramundi Conglomerate and Mount Elma Conglomerate.

Calcarenites are a feature of the formation, and, unlike those of the Mount Pierre Group, they persist in the outcrop section. The section 4 miles north of Fossil Downs Homestead is a comparatively pure calcarenite with limestone breccia beds and lenses for the lower half of the section with some siltstone beds appearing in the upper part. Scattered biohermal masses occur through the central part of the section and are conspicuously absent from the sections mentioned below.

In the sections measured south of Mount Elma and in the Burramundi Range the basal part of the Fossil Downs Formation has been replaced by the fanglomerates of Mount Elma and Burramundi Range, and the influence of this influx of rudites is seen to a lesser extent through most of the higher portions of the unit.

The formation has a variable thickness: 1,700 feet was the maximum recorded.

A change to dolomite is a common feature of the calcarenite beds. The dolomite is characterized by a pink and brown colour and a sandy weathering surface, due to the etching of dolomite rhombs.

The fossil content indicates the presence of Stages I to III of the Upper Devonian and a depositional time range closely comparable with the Mount Pierre Group, Brooking and Copley Formations, and Napier Formation.

Stony Creek Conglomerate.
Burramundi Conglomerate.
Mount Elma Conglomerate.

These fanglomerate formations are found on the margin of the basin as facies variations of the Fossil Downs Formation; they were deposited at the same time as the Sparke Conglomerate, south of the Margaret River. Outcrops of the formations occur at Stony Creek, Long. 125° 26′ E., Lat. 17° 57′ S.; Burramundi Range, Long. 126° 14′ E., Lat. 18° 14′ S.; and Mount Elma, Long. 126° 11′ E., Lat. 18° 02′ S.

The formations unconformably overlie either Pillara Formation or Precambrian and interfinger with the Fossil Downs Formation; the Mount Elma Conglomerate also interfingers with the Sadler Formation.

The sediments are essentially the same as those of the Sparke Conglomerate and consist of conglomerates, with some greywacke and sandstone which is often calcareous.

The sections exposed in these units are 200 feet or less thick, although the formations are estimated to be about 1,000 feet thick on the evidence of a few observed dips.

Since the units are lateral facies variants of the Fossil Downs Formation they were deposited during the Upper Devonian and during a similar time range to the Sparke Conglomerate.

Copley Formation.

The Copley Formation is found only in a small area in Copley Valley immediately north of Geikie Gorge at Long. 125° 42′ E., Lat. 18° 04′ S. The formation unconformably overlies the Pillara Formation and is conformably overlain by the Geikie Formation. The Copley Formation, together with the Brooking Formation, represents a local lithofacies of what might be considered the normal lithofacies of Stages I to III of the Upper Devonian in the Mount Pierre Group and the Napier Formation.

The Copley Formation was deposited in a small marine basin flanked by the Pillara Formation and represents a facies between the quartzose clastics of the Napier Formation and the calcarenite reef of the Geikie and Oscar Formations.

This distinct variation in lithofacies can be attributed to the environmental factors controlling deposition. The transgressing shore-line provided abundant calcareous clastics, throughout the full range of grain-size, from the erosion of the calcarenites, biostromes, and reef masses of the Middle Devonian. The introduction of quartzose clastics was restricted by the barrier of Middle Devonian which would deflect the flow of terrigenous material to the north-west and south-east. Consequently the section measured (*see* page 95) contains a minor amount of calcareous siltstone interbedded in the section, and coarser quartzose clastics are conspicuously absent. The characteristic sediment is grey-brown and reddish calcarenite, often silty and rarely sandy. Limestone breccias occur throughout the section, starting with a very characteristic coarse 200-foot breccia at the base. Oolites are a characteristic feature of the formation, and a typical example is described by Glover (1956)—

"The specimen, No. 155, is a grey to pink, bedded oolitic limestone that weathers grey. It is stylolitic and locally fossiliferous, and evenly-sorted concentrically-ringed ooliths set in clear cement are visible with the hand lens. The rock is an oolite. Under the microscope it comprises grey and grey-brown concentrically-ringed ooliths of average diameter 0.5 mm. in a clear crystalline carbonate matrix. A few angular to subrounded grains of quartz and calcilutite and rare fossil fragments are also present. Quartz is the core of a few ooliths but brown carbonate is far more common. . . An analysis gave: $CaCO_3$ 93.3 per cent., $MgCO_3$ 1.8 per cent., Fe_2O_3 0.1 per cent., insolubles 4.2 per cent. . .

Specimen 159B is light grey and well-bedded, and under the hand lens appears to be composed of very well-sorted rounded fragments and ooliths. Under the microscope, ooliths, quartz (a little of which is authigenic), calcilutite fragments, and crystalline calcite cement are seen. A microstylolite is present and the two parts of the rock on either side of it have been forced together with simultaneous solution and removal of calcite. The concentration of quartz, compared with its relatively sparse distribution in the rock, indicates movement of the order of 1 mm. Dark material delineating the stylolite is most likely an insoluble residue of clay minerals and iron oxide."

A zone of small isolated bioherms occurs down dip from the basal limestone breccia, where the formation overlies the Pillara Formation. Bioherms have not grown elsewhere except for isolated cases near the top of the formation. The Geikie Formation inter-tongues on the seaward side with this reef mass, which contributed to the isolation and separation of the Copley Basin.

In the Copley Formation is the section measured north-east of Springs Homestead, 2,650 feet thick. (*See* Appendix II, p. 95.)

Since the fauna in the formation has not been examined, apart from field observations, precise correlation is not advisable. By comparison with the better known Mount Pierre Group it is suggested that probably Stages I to III of the Upper Devonian are represented. Rapid field correlation is made difficult by the impoverished fauna and virtual absence of the goniatite fauna in the area north of the Fitzroy River, but the siltstones and calcarenites resemble the "red beds" of the Mount Pierre Group.

Brooking Formation.

The Brooking Formation is comparable in stratigraphical position and lithology with the Copley Formation, and is also restricted to a semi-enclosed basin in Middle Devonian limestones. The outcrop area occurs in Brooking Gap (Long. 125° 35′ E., Lat. 17° 58′ S.), where the formation unconformably overlies Pillara Formation and is overlain by the Fairfield Beds. The upper beds in the section appear to be local lateral facies variations of the equivalent Geikie and Oscar Formations.

The section from Brooking Gap (page 95) indicates the similarity in the lithology of the Copley and Brooking Formations. The lithofacies is again primarily calcareous clastic with minor amounts of quartzose clastic interbedded. More bioherms are found than in the Copley Formation.

The measured section is 3,150 feet thick. Some variation in the thickness of the unit can be expected in other parts of the basin.

The fossils collected have not yet been determined in detail, but probably Stages I to III of the Upper Devonian are represented.

Geikie Formation.

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

The formation is overlain by the Fairfield Beds, but the contact is not exposed.

The Geikie and Oscar Formations differ from all other lithological units in the Basin in that they consist only of clastic and organic limestone. Clearly developed initial dips are also characteristic; dips up to 35° have been recorded. The Geikie Formation was deposited on the western side of a large mass of the Pillara Formation which supplied the material for the calcareous clastics of the Geikie Formation, and acted as a barrier so that the quartzose clastics were not swept into the sea from the mainland.

The significance of the initial dips is not fully understood, but they are presumably related to a steeply shelving sea-bottom.

Calcarenite, much of it oolitic, forms the larger part of the unit, with scattered beds and masses of limestone breccia throughout the section.

Two sections have been measured through the formation in the vicinity of Springs Homestead; 770 feet and 1,350 feet were recorded in these sections, and it is considered that 1,350 feet is a representative thickness for the formation.

Both the Geikie and Oscar Formations are rich in crinoid fragments, and scattered zones contain brachiopods and nautiloids. Precise correlation must await detailed palaeontological analysis and in the meantime the formations are tentatively assigned to Stages II and III of the Upper Devonian.

Oscar Formation.

The Oscar Formation has been mapped along the south-west flank of the Oscar Range from Brooking Gap to near Mount Percy. The type locality is in the vicinity of Linesman Creek (Long. 125° 23′ E., Lat. 17° 58′ S.).

The Oscar Formation rests unconformably on Precambrian or Pillara Formation; it interfingers with the Napier and Brooking Formations and is overlain, probably conformably, by the Fairfield Beds. The contact with the Fairfield Beds is not exposed and the relationship between the units is doubtful.

The Oscar Formation is closely comparable with the Geikie Formation and was deposited under the same environmental conditions. The absence of quartzose clastic is again the outstanding characteristic. In localities where the formation directly overlies the eroded remnants of the Pillara Formation the basal beds consist of unsorted accumulations of fragments of Pillara Formation which represent accumulation, practically *in situ,* from local erosion of the coastal cliffs formed by the Pillara Formation. These coarse basal clastics are replaced in higher beds by the normal calcarenites and clastic limestones with steep dips. Contemporaneous slumping and cross-bedding on a large scale have consistently been recorded from the Oscar Formation and are considered characteristic and in keeping with the type of sedimentation.

Oolitic calcarenites are found throughout the formation. Dark calcilutite fragments from an earlier limestone are scattered throughout, but most detritus is crystalline crinoid debris. Calcite cement has crystallized in optical continuity with crinoid fragments.

The examination of further thin sections has indicated that minor amounts of quartzose clastic may occur in pockets, but for the most part the sediment is a pure carbonate clastic.

North-west along the outcrop biohermal growths are found, although the unit is still bedded. Further observations to the west and north-west are obscured by the overlap of Permian sandstone of the Grant Formation.

Sections measured along the Oscar Range are 1,500 to 2,300 feet thick.

The age is Upper Devonian, probably Stage II and III. The palaeontology and age are discussed under Geikie Formation.

Napier Formation.

The Napier Range is composed mainly of the Napier Formation, which also extends along the northern scarp and overlaps on to the Oscar Plateau. The type section is located at Barker Gorge (Long. 124° 44′ E., Lat. 17° 16′ S.) in the Napier Range (*see* p. 97).

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

Lateral facies variations in the form of fanglomerates (Van Emmerick and Behn Conglomerates) have been mapped. These fanglomerates are found only in a few places, and interfinger and locally replace the normal shallow-water marine facies of the Napier Formation.

The formation is primarily a calcareous and quartzose clastic interbedded with impure calcareous clastics deposited in shallow water. The development of large reef masses at the north-west end of the Oscar Plateau, near Winjana Gorge, and in the vicinity of Barnet Spring (north of Old Napier homestead), is a feature of particular interest.

Except for areas of reef development the sediments of the Napier Formation were all laid down in the same environment, with repeated beds of calcareous siltstone and sandstone interbedded with silty and sandy calcarenites. To the south on the northern fringe of the Oscar Range the calcarenites predominate, but near the fanglomerates of the Van Emmerick Range and Mount Behn the quartzose clastics predominate or completely replace the calcarenites locally.

The base of the formation, particularly in the southern Napier Range and near Winjana Gorge, is in many places composed entirely of coarse clastic material consisting of fragments of metamorphic, granitic, and quartzitic rocks intermingled with limestone and calcareous sandy clastics. These sediments are typical basal breccias derived from the erosion of the adjacent Precambrian mainland, with contributions from the erosion of the masses of Middle Devonian sediments. Coarse clastics were only introduced into the basal beds, and younger beds contain finer quartzose clastics derived from the same source.

The persistent recurrence of limestone clastics throughout the Napier Formation is explained by contemporaneous erosion, and good examples of contemporaneous brecciation, through slumping or agitation by wave action in shallow water, have been observed.

Reefs were only developed in the localities mentioned earlier, but throughout the section and the outcrop area there is a persistent, though sporadic, development of small and large biohermal masses. These bioherms were formed under what appear to be very adverse environmental conditions. It is apparent that throughout the area organisms capable, under favorable circumstances, of building bioherms and consequently reefs persisted, and extensive reefs may have developed in areas now concealed under the younger sediments.

The sections measured through the formation vary considerably in thickness. The figures are unreliable to some extent in that the upper contact with the Fairfield Beds is not exposed. The extreme range of the measured sections is from 700 feet at Carpenters Gap to 3,350 feet at Wagon Pass (near Old Napier homestead). Most of the sections range between 1,000 feet and 1,300 feet.

A water bore drilled near Old Napier Homestead on the south side of the Napier Range penetrated 1,580 feet of probable Upper Devonian sediments before terminating in Precambrian crystalline rocks. The bore probably started in Fairfield Beds, and apparently did not penetrate any Middle Devonian.

As no detailed palaeontological investigations have been completed, the precise time range of the formation and exact correlation with other Upper Devonian units cannot be formulated. Field observations suggest that at least Stages II and III of the Upper Devonian are present.

Lead occurs in the limestone at Barker Gorge, and is being worked by Baker and sons (Narlarla Lead Mine). It was first reported by Woodward (1907); Finucane (1939) and Prider (1941) have made subsequent reports. The ore appears to follow the bedding of the limestone, which dips 25° to the south-west.

*Van Emmerick Conglomerate.**
Behn Conglomerate.

The Van Emmerick and Behn Conglomerates are local facies variations of the Napier Formation, and are comparable with the Burramundi and Sparke Conglomerates described south of the Fitzroy River. They interfinger with the marine sequence of the Napier Formation. The formations crop out in the Van Emmerick Range (Long. 124° 37′ E., Lat. 17° 03′ S.) and at Mount Behn and vicinity (Long. 125° 05′ E., Lat. 17° 29′ S.).

Both formations unconformably overlie Precambrian. The Van Emmerick Conglomerate is overlain by younger beds of the Napier Formation and the Behn Conglomerate is possibly overlain by the Fairfield Beds.

The rock types are boulder to pebble conglomerate, calcareous sandstone, siltstone, greywacke and clastic limestone.

Estimates based on assumed dip suggest that approximately 1,000 feet of sediment has been preserved.

Fairfield Beds.

Kraus (1941) originally named the Fairfield Beds the Fairfield Marl. Since the unit contains a number of rock types and only a portion of the sequence is known in outcrop, the name Fairfield Beds is to be preferred. The Beds were named from the Fairfield Valley (Long. 125° 00′ E., Lat. 17° 35′ S.) by Kraus.

Partial sections through the Beds have been measured throughout the area extending from south of Bugle Gap north to Old Napier homestead. In general, all sections are poorly exposed and are not necessarily representative of the Beds as a whole. The Beds overlie the Upper Devonian units of the Napier and Oscar Ranges, Fossil Downs area, and Bugle Gap, and are probably overlain by the Carboniferous Laurel Beds and unconformably overlapped by Permian sandstone of the Grant Formation.

Throughout the area the change in environmental conditions is clearly manifest in the lithology. Apart from the faunal change, the most distinctive and persistent feature is the appearance of well-rounded quartz grains in varying proportions throughout the section. The quartz grains are quite distinct from those in the underlying Napier and Fossil Downs Formations and Mount Pierre Group in that they reveal evidence of thorough sorting and form clean sandstone and siltstone beds, whereas the grades are mixed in the underlying units. Large areas without outcrop and presumably underlain by the basal beds of the Fairfield Beds are known from the western flank of the Napier Range. These areas are probably underlain by fine-grained clastic sediments such as marl, calcareous siltstone, or calcareous shale, and create a sharp contrast in topography, particularly along the Oscar and Napier Ranges.

* Called Patterson Conglomerate on maps; the name of the range has recently been changed by the Surveyor-General of Western Australia to avoid confusion with the Paterson Range in the South-western Canning Basin.

TABLE 4. FITZROY BASIN—PERMIAN AND MESOZOIC STRATIGRAPHY, STRUCTURE. TOPOGRAPHY AND WATER SUPPLY.

Period or Epoch.	——	Stratigraphic Unit.	Distribution.	Lithology.	Thickness (feet).	Structure.	Topography.	Correlation.	Water Supply.	General Remarks.
JURASSIC	Upper Tithonian	Jarlemai Formation (Jur) ..	Edgar Range—Dampier Downs H.S. to east of Matches Springs	Poorly stratified to massive, unsorted sandy siltstone and silty sandstone. Weathers to pastel shades	300	Generally sub-horizontal bedding but with a few gentle asymmetrical folds and small scale faulting	Mesas, buttes and tableland of the Edgar Range			Conformably underlain by Alexander Formation. Overlain unconformably by Mowla Sandstone
	Lower Tithonian Kimmeridgian	Alexander Formation (Jua) ..	Edgar Range—Jurgurra Creek to Matches Springs	Thin-bedded sandstone. Marine fossils	180	Gentle asymmetrical folds and faults with 50 feet displacement. Elsewhere sub-horizontal	Isolated buttes and low hills in the Edgar Ranges			Unconformably overlies Jurgurra Sandstone. Conformably overlain by Jarlemai Formation
		James Sandstone (Juj)	Along the Fenton Fault ..	Well-bedded, commonly ferruginized, conglomeratic sandstone, strongly cross-bedded	80 +	Sub-horizontal or tilted by numerous small scale faults with an average displacement of 150–200 feet	Capping to low scattered hills ..			Unconformably overlies sediments of the Liveringa and Noonkanbah Formations and Poole Sandstone
		Barbwire Sandstone (Jub) ..	Western Barbwire Range ..	Interbedded red and white siltstone, sandstone with conglomerate lenses	70 +	Sub-horizontal	Capping on dissected mesas forming the Barbwire Range			Unconformably overlying Liveringa Formation
		Mudjalla Sandstone (Jm) ..	Narrow belt running north from Mudjalla Yard to Manguel Creek	Unsorted, angular, medium and coarse sandstone, lensing conglomerate beds, strongly cross-bedded. Rare plant remains	135 max.	Gently dipping to sub-horizontal. Evidence of faulting	Low with some dissection in area adjacent to Fitzroy River System			Overlies Liveringa Formation unconformably
JURASSIC?		Jurgurra Sandstone (Jj) ..	Jurgurra Creek and tributaries ..	Current bedded, medium and coarse, friable, quartz sandstone with large mica flakes and thin silty beds. Rare marine fossils	65 max.	Not known	Rock bars in creek channels and low rises			Overlain unconformably by Alexander Formation
TRIASSIC	Upper (Keuper) ..	Erskine Sandstone (Rue) ..	Erskine Range, Sisters Plateau, Meda Station	Thin, evenly bedded, and finely cross-bedded friable fine, silty sandstone and massive fine sandstone and siltstone—commonly brightly coloured. Plant fossils abundant	60–110	Sub-horizontal or gentle homoclinal dip to south-west	Low mesas of the Erskine Range, dissected tableland of the Sisters Plateau			Overlies the Blina Shale unconformably and is unconformably overlain by the Meda Formation
	Middle	Blina Shale (Rb)	Scattered areas over the Noonkanbah, Mount Anderson, Derby and Lennard River Sheets	Light-grey, brown and yellow-grey siltstone, shale and sandy shale exposed. Blue-grey shales in bores. Marine fossils	1,000 app. (95 exposed)	Not known	Featureless grass plains ..		Poor aquifer, saline water obtained from lower beds	Probably overlies Liveringa Formation unconformably
PERMIAN	Upper Permian (Kazanian to Tartarian?) (Upper Productus of Salt Range) Basal Kungurian	Liveringa Formation (Pl) ..	Outcrops on all map sheets ..	Sandstone; micaceous, silty, and conglomeratic sandstone with highly ferruginized sub-greywacke in the basal beds. Marine and estuarine	1,850–3,000	Exposures are mainly associated with the gentle folded anticlinal and synclinal folds. Transverse faults with small displacement common	Low ridges and flat featureless areas	Base of formation approximately equivalent to base of Kennedy Group of Carnarvon Basin	Good aquifer with sub-artesian water of fair to good quality	Unconformably overlain by Triassic and Jurassic sediments. Conformably overlies Noonkanbah Formation
	Lower Permian (Artinskian)	Noonkanbah Formation (Pn) ..	Outcrops on all map sheets with this report	Shale, siltstone, limestone, sandstone, becoming conglomeratic towards margin of the basin. Marine	1,400–2,240?	as above	Flat grassy plains with low ridges and scattered outcrop	Probably equivalent to part of Byro Group of Carnarvon Basin	Poor aquifer with water of poor quality. Possibility of better supplies along north-eastern margin of basin in vicinity of Pinnacle Fault	Conformably overlain by Liveringa Formation. Possibility of minor unconformity with Poole Sandstone
	Lower Permian (Lower Artinskian)	Poole Sandstone (Pp) including Nura Nura Member	Narrow belt along north-eastern margin of basin and outcropping on flanks of major anticlines	Well-bedded, thinly-bedded micaceous sandstone, silty sandstone. Cross-bedding and ripple marks common. Partly marine	220–1,600	as above	Flank ridges, conical hills of major folds. Flat sandy belt along north-eastern margin of basin	Nura Nura Member equivalent to Callytharra Formation of Carnarvon Basin	Excellent quality artesian and sub-artesian water	Overlain by Noonkanbah Formation with possible unconformity. Unconformably overlies Grant Formation in some areas
	Lower Permian (Sakmarian)	Grant Formation (Pg)	Belt along north-eastern margin of basin, outliers on Devonian and Precambrian; cores of major anticlines	Glacial and aqueo-glacial sediments including sandstone, conglomerate, tillite, siltstone, shale, varves	8,800 + (Grant Range No. 1 Bore)	as above	Forms rugged hills in the cores of the major anticlines. Flat sandy country with scattered hills along north-east margin	Equivalent to at least part of Lyons Group, Carnarvon Basin	Excellent quality sub-artesian water	In some areas unconformably overlain by Poole Sandstone. Unconformably overlies Carboniferous, Devonian and Precambrian rocks
CARBONIFEROUS	Lower	Laurel Beds (Cll)	Along south-east side of Oscar Range near the 12 Mile Bore and Laurel Downs	Calcarenites and soft grey siltstone; very fossiliferous in uppermost beds	1,500 +	Gentle anticline structure, axis parallel with Oscar Range. Beds show much local complex folding, probably from slumping	Forms plains with low outcrops ..		Not expected to be a good aquifer	Junction with underlying Oscar Formation not seen but there is a time break between the two. Unconformably overlain by Grant Formation

[To face page 41.]

3336/57.

The Fairfield Beds were deposited in a more stable shelf-type environment, probably under deeper water, than the underlying Napier Formation.

A complete section is not available for examination and the thickest section known is described from south of Burramundi Range, where approximately 650 feet is exposed as intermittent outcrop.

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

CARBONIFEROUS (Table 4).

Laurel Beds.

Thomas (1955) suspected that the Fairfield Beds, as mapped in the 12-Mile Bore area, were Carboniferous in age, and in 1957 he separated them as the Laurel Beds. They are named from Laurel Downs sheep station, 15 miles west-north-west of Fitzroy Crossing. The complementary type sections lie two miles north-west, and three miles south-south-east, of Twelve Mile Bore, Springs Station.

Thomas has measured 1,000-1,500 feet of section. A stratigraphic bore drilled to 4,000 feet near Laurel Downs in 1956, for the Bureau of Mineral Resources, penetrated Grant Sandstone for the first 170 feet and then penetrated 1,400 feet of marine fossiliferous Laurel Beds. A remnant of *Leptophloeum australe* was found at 2,500 feet and fish remains at 2,598 feet. The bore was in Upper Devonian until it terminated at 4,000 feet (Henderson, 1956a, c).

The lowermost part of the section is poorer in fossils than the uppermost part, but both faunas are closely related. The uppermost beds consist of thin-bedded, medium-grained, shelly, yellowish-brown calcarenite interbedded with soft grey siltstones; the lower beds consist of pale-grey, sandy calcarenite inter-bedded with softer, non-outcropping sediments—the quartz grains are sub-angular to rounded.

The Beds show complex folding and faulting within the strata; this is in contrast to the underlying Upper Devonian, which dips south-west into the basin at 15°. The local complex folding is probably due to slumping.

The fauna (Thomas, 1957) includes—

Spirifer cf. *tornacensis* de Kon.,
Linoproductus sp.,
Cleiothyridina sp.,
cf. *Athyris* sp.,
Rhipidomella sp.,
cf. *Pustula* sp.,
Camarotoechia pleurodon var. *tripla* Prendergast,
Composita sp ,
Syringopora sp.,

as well as crinoid stems, gastropods, pelecypods, straight nautiloids, ostracods, and sharks' teeth which include bradyodont and cladodont types. The fauna indicates a Lower Carboniferous age for the sequence and a considerable time break between it and the Oscar Formation. The Laurel Beds are unconformably overlain by the Permian Grant Formation.

PERMIAN (Table 4).

Most of the Fitzroy Basin is covered by Permian sediments, which extend south into the Canning Basin under cover of Mesozoic sediments. The importance of these rocks is not so much that they are a potential source of petroleum as that most of the larger anticlinal structures are developed in Permian formations. The primary interest lies in their relation to artesian and sub-artesian water resources, because they provide the greater part of the underground water on which industry in the area is dependent.

The four Permian units (Grant Formation, Poole Sandstone, Noonkanbah Formation, and Liveringa Formation) have now been studied throughout the Fitzroy Basin, where they crop out. The extent of the Permian south of the Fenton Fault and west of Derby (Dampier Land) remains unknown, as water bores have failed to penetrate the Mesozoic into the underlying Permian sequence.

A stratigraphic bore drilled by the Bureau of Mineral Resources south of the Fenton Fault on Jurgurra Creek late in 1955 passed through sand and alluvium into Permian (Noonkanbah Formation) at shallow depth (Henderson, 1956b).

Particular attention has been directed towards the recognition of facies changes and thickness changes in these formations. Although changes in both facies and thickness have been noted, the main feature of the Permian units is widespread continuity of both facies and thickness in the Fitzroy Basin.

Grant Formation.

The Grant Formation is named after the Grant Range (Long. 124° 05′ E., Lat. 18° 02′ S.) and was defined by Guppy et al. (1952). 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 Willangie Beds of the Poole Range area. Beneath the Willangie Beds, Wade distinguished the "Kungangie Beds " (in the Poole Range area) and the " J8 Beds " (in the Sparke Range), as units of his Glacial Series. The " J8 Beds " have since been proved to be Upper Devonian (Teichert, 1949). Kraus (1941) and Findlay (1942) recognized the Hawkstone Sandstone as a distinct formation north of the Fitzroy River and considered that it was equivalent to the " Grant Range Beds " and Poole Sandstone between Poole Range and Grant Range.

As a result of further study and an investigation of the bore logs which have penetrated the formation it has been decided to rename it the Grant

Formation and include all the glacial and fluvioglacial sediments below the Poole Sandstone.

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

The Grant Formation unconformably overlies Lower Carboniferous, Middle and Upper Devonian, and Precambrian rocks. 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, St. George, and Grant Ranges.

The formation is characterized by the large thickness of sandstone, conglomerate, tillite, siltstone and varves recorded throughout the Fitzroy Basin. About 8,000 feet was proved by drilling in the Grant Range Bore drilled by West Australian Petroleum Pty. Ltd. in 1954-55. The only sections cropping out are those in cliffs in the ranges and scattered mesas which give up to 600 feet section. More complete information is available from the bore logs from exploratory drilling at Poole Range. Mount Wynne, and Nerrima. Unfortunately, none of these deeper bores in the basin penetrated to the base of the Permian section.

All the rock types of the Grant Formation are considered to be glacial or fluvioglacial in origin. Examination of outcrop has revealed that intraformational contortion and persistent cross-bedding are features of at least the upper beds of the unit.

Sediments resembling tillites, varves, and morainic beds have been examined in the Poole Range, the central St. George Range, and central Grant Range. The deposits consist of unbedded blue-grey sandy siltstone containing glaciated boulders of many rock types, including granite, metamorphic quartzites, and Devonian limestone.

A more unusual type of sediment has been examined from the top of the mesa 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 about ¼ inch in thickness. The sediment can probably be classified as a varved clastic and overlies massive and irregularly bedded morainic conglomeratic beds.

No complete section of the formation is exposed; about 3,500 feet (including 236 feet exposed) of the formation was penetrated in the No. 3 bore in the Poole Range; 2,650 feet (including 500 feet exposed) was penetrated in the No. 3 bore in the Mount Wynne area; 2,170 feet was penetrated in the No. 1 Freney-Kimberley bore at Nerrima in 1941; at least 6,000 feet was penetrated in Associated-Freney No. 1 bore at Nerrima in 1955. In the Grant Range area the West Australian Petroleum Pty. Ltd. No. 1 bore, starting 800-900 feet below the top of the outcropping section, penetrated about 8,000 feet, and reached Carboniferous sediments; it was the only bore to drill right through the Grant Formation.

North-east of the Pinnacle Fault the formation wedges out rapidly against the older Palaeozoic sediments and much of it has been eroded.

Little is known of the area south of the Fenton Fault, and although it is strongly suspected that the Grant Formation continues to the south as an important unit, no evidence is yet available to indicate the thickness or distribution south of the fault.

Few marine fossils and wood fragments are known from the Grant Formation; the age is tentatively considered to be Sakmarian. Reeves (1949) considered the formation to be Devonian, but Grant Range No. 1 Bore proved that it overlies Upper Carboniferous.

Poole Sandstone.

The name was first used by Talbot (1927) for the type area in the Poole Range (Long. 125° 45′ E., Lat. 18° 50′ S.): the original 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 revised to Poole Sandstone (Guppy et al., 1952).

The Poole Sandstone is overlain by the Noonkanbah Formation; the contact may be seen at Mount Synnott, where a sandstone and conglomerate sequence capping Mount Synnott represents the base of the Noonkanbah. The persistent conglomerate bed at the junction of the two formations in the area between Poole Range and St. George Range suggests that a disconformity separates the Poole Sandstone and the Noonkanbah Formation, at least in the area mentioned. The Poole Sandstone overlies the Grant Formation with a distinct and persistent disconformity.

The unit crops out mainly on the flanks of the major folds (Poole Range, St. George Range, Mount Wynne, and Grant Range). Small areas have been noted along the Fenton Fault and along the north-eastern margin of the Basin.

A section measured through the unit is shown on p. 99. In general the unit can be described as a thin-bedded white fine micaceous quartz sandstone, weathering to brown. Siltstone and shaly beds are found in the sequence, particularly in Nerrima No. 1 Bore.

Ripple marks and the trail of worms and molluscs, and plant remains, are common.

The formation thickens towards the north-west, where medium-bedded to massive sandstones are more prominent. These particular sandstones are commonly silty and micaceous and some may be classified as sub-greywackes. Intraformational pellets occur in the sections at Nura Nura Ridge and Mount Tuckfield. The pellet beds commonly contain porous coarse quartz sand and have been strongly ferruginized.

A marine, fossiliferous, lensing bed of ferruginous friable medium silty quartz sandstone occurs at the base of the formation along the southern and central northern flanks of St. George Range, and in the central valley of the Grant Range; the bed is oolitic in places. This marine bed may be correlated with the Nura Nura Member in the Mount Wynne area.

The Poole Sandstone varies in thickness more than the other Permian units, and surface and subsurface data have given a broad idea of these variations. The formation is unknown north-east of the Pinnacle Fault and first appears as a recognizable unit in the Poole Range, where 220 to 500 feet has been measured; 540 feet of section has been recorded on the north flank of St. George Range and 1,180 feet in an incomplete section at Mount Tuckfield. At the type section on the eastern plunge of the Grant Range 680 feet of section is preserved, and it is believed that this is practically a complete section, although the actual contact with the overlying unit is not exposed locally. The Poole Sandstone is 1,300 feet thick in the Nerrima No. 1 Bore, and 1,600 feet hs been measured at Nura Nura Ridge. At this stage it is not possible to decide whether the variations in thickness of the formation are related to local structural influence or to basin configuration.

The thin fossiliferous zone at the base of the formation in St. George Range contains the following fauna (Thomas, 1954 and pers. comm.):

Neospirifer sp. nov.
Neospirifer spp. indet.
Chonetes cf. *pratti* Davidson
Pseudosyrinx sp. nov.
Martiniopsid gen. et sp. nov. A.
Permorthotetes lindneri Thomas
"*Dielasma*" sp. nov.

The faunal assemblage has affinities with the Callytharra Formation of the Carnarvon Basin and the Lower Productus Limestone of the Salt Range, India. The Poole Sandstone is therefore considered to be of lower Artinskian age.

Fossil plants occur throughout the formation, particularly in the upper part of the section. They include (Wade, 1936; Teichert, 1943; Reeves, 1949; and determinations by present authors):

Bothrodendron sp.
? *Brachyphyllum* sp.
Cordaicarpus emaginata Walkom
cf. *Gangamopteris* sp.
Glossopteris cf. *angustifolia* Brong.
Glossopteris browniana Brong.
Glossopteris indica Brong.
Glossopteris sp.
Lepidodendron spp.
Lepidodendron sp. nov.
Noeggerathiopsis hislopi (Bunbury)

Samaropsis milleri
Stigmaria sp.
cf. *Taeniopteris spatulata* McLean.

Nura Nura Member: The Nura Nura Member (Guppy et al., 1952) forms the base of the Poole Sandstone at Nura Nura Ridge (Long. 124° 28′ E., Lat. 18° 02′ S.). This lensing unit was originally named Nura Nura Limestone by Wade (1936).

The Nura Nura Member is mapped at the southern part of Nura Nura Ridge, where 35 feet of sediments are exposed over the Grant Formation, and possible equivalents have been mapped in the Grant Range and St. George Range areas. The rocks are calcareous quartz sandstone, fine friable sandstone, and sandy limestone with rich fossil bands.

Rapid changes in thickness of the unit (between 25 and 50 feet) have been observed within the small area of outcrop.

The presence of the ammonites *Metalegoceras clarkei* and *Thalassoceras wadei* has provided valuable time markers, from which the unit may be correlated with the Fossil Cliff Formation of the Irwin River Basin and the Callytharra Formation of the Carnarvon Basin. The unit also contains a well-preserved brachiopod fauna which supports this correlation and reveals affinities with the Lower Productus Limestone of the Salt Range.

The following brachiopods have been identified from the Nura Nura Member (Thomas, 1954 and pers. comm.; Coleman, 1957):

Aulosteges cf. *spinosus* Hosking
cf. *Camerophoria* sp.
Chonetes cf. *pratti* Davidson
Chonetes sp. nov.
Dictyoclostus callytharrensis Prend. (doubtful)
D. magnus Coleman
Linoproductus cancriniformis (Tschern.)
Martiniopsid gen. et sp. nov. A.
Neospirifer sp. nov.
Streptorhynchus sp. indet.
Taeniothaerus irwinensis Coleman (doubtful)

The following bryozoa have been identified from the Member (Crockford, 1956):—

Dyscritella spinigera (Bassler)
Fenestella horologia Bretnall
Fistulipora nura Crockford
Hexagonella australis (Bretnall)
H. hudlestoni Crockford
Leioclema globosa Crockford
Lyropora joselini Crockford
Evactinostella crucialis (Hudleston)
Stenopora hemispherica Waagen and Wentzel
Streblascopora marmionensis (Eth. fil.).

Other forms found include foraminifera (*Calcitornella stephensi* (Howchin), *Hyperammina expansa* Plummer, *Glomospirella nyei* Crespin MS.), ammonoids (*Metalegoceras clarkei* Miller, *M. striatum* Teichert, *Thalassoceras wadei* Buller, and cf. *Popanoceras indo-australicum* Haniel), and molluscs (*Aviculopecten* cf. *A. subquinquelineatus* Eth. fil., *Atomodesma* cf. *A. mytiloides* Beyrich, and *?Myalina mingenewensis* Eth. fil.) (Thomas and Dickins, 1954), conodont fragments and *Nereites* (Reeves, 1949), crinoid ossicles, and ostracods (*Healdia* sp. and *Bairdia* sp.).

The age of the Nura Nura Member is lower Artinskian.

Noonkanbah Formation.

The Noonkanbah Formation (Guppy et. al., 1952) was originally named by Wade (1936) from the type locality near Noonkanbah Homestead (Long. 124° 48′ E., Lat. 18° 30′ S.). Later observers (Kraus, 1941; Reeves, 1949) referred to the formation as the Noonkanbah Shale.

More detailed mapping shows that the unit contains several rock types and also shows some changes in lithofacies across the Fitzroy Basin. Consequently the unit is referred to as a formation.

The formation is conformably overlain by the Liveringa Formation and is underlain by the Poole Sandstone. The lower contact is exposed in some places throughout the area, particularly around the Poole Range. The basal bed in this area is a fine conglomerate and the presence of a disconformity is suspected.

The common rock types in the formation are soft-weathering, fine sandy siltstone and calcareous siltstone, very thin-bedded and commonly containing gypsum; the siltstones are interbedded with minor amounts of shale, calcareous, micaceous quartz sandstone, and sandy limestone. The calcareous beds are the more resistant to erosion and are commonly fossiliferous and contain spherical concretions and nodules which may be phosphatic.

The change in lithofacies from east to west is illustrated in the section detailed on page 100, which was examined at Christmas Creek Homestead, close to the margin of Noonkanbah sedimentation. The outcropping section is primarily sandstone with minor amounts of siltstone and mudstone. Substantial portions of the section which do not crop out may be either siltstone or shaly beds.

By contrast the section from Nerrima No. 1 Bore consists of alternating mudstone and sandstone with minor amounts of siltstone. Pyrite and carbonaceous material are found in the section.

The general facies indicates shallow-water deposition along the eastern margin of the Basin, deepening to the west. The change in fauna also indicates changes in depth and environment during the deposition of the formation.

From the small number of sections measured a reasonably constant thickness of between 1,200 and 1,500 feet has been demonstrated. A section measured on the south flank of Grant Range gave a thickness of 2,240 feet; this section may not be reliable, because strike faults are common in the Grant Range, but no repetition of fossil markers was observed. If the measured thickness is correct it indicates a rapid thickening of the section in this locality, which could be related to subsidence in the Grant Range area during the deposition of the Noonkanbah.

The formation contains the richest faunal assemblage known from the Permian of the Fitzroy Basin and includes brachiopods, bryozoa, corals, crinoids, foraminifera and a few molluscs; the molluscs increase in number towards the top of the section and they outnumber all other forms in the overlying Liveringa Formation.

Calceolispongia first appears 800 feet above the base of the section west of Christmas Creek, worm tracks low in the section, and *Serpulites* 900 feet above the base, and again at the base of the Liveringa Formation, where some phosphatization has occurred.

The following brachiopods have been identified from the formation (Thomas, 1954 and pers. comm.; and Coleman, 1957):—

Aulosteges ingens Hosking
Camerophoria (*Stenoschisma*) spp. nov.
Chonetes pratti Dav.
Chonetes sp.
Cleiothyridina macleayana Eth.
Cleiothyridina sp. nov.
cf. *Composita* sp. nov.
Dictyoclostus wadei Prendergast
Dielasma sp. nov.
Etheridgina muirwoodae Prendergast
Hustedia basedowi (Eth.)
Hustedia sp.
Kiangsiella cf. *condoni* Thomas MS
Kiangsiella sp.
cf. *Krotovia* sp.
Linoproductus cancriniformis Tschern.
Marginifera gratiodentalis (Grabau)
Marliniopsid gen. et sp. nov. B
Neospirifer sp. cf. *N. byroensis* (Glauert)
N. sp. nov aff. *N. marcoui* (Waagen)
N. sp. cf. *N. hardmani* (Foord)
N. sp. cf. *N. rostalinus* (Hosking)
Permorthotetes guppyi Thomas MS
Phricidothyris spp. nov.
Spiriferid gen. et sp. nov. A. spinose
Spiriferid gen. et sp. nov. B.
Spiriferella australasica Eth. fil
Spiriferellina sp. nov.
Streptorhynchus crassimurus Thomas MS
S. costatus Thomas
Strophalosia multispinifera Prendergast
S. (*Heteralosia*) *kimberleyensis* Prendergast
S. (*H.*) *prendergastae* Coleman
Taeniothaerus miniliensis Coleman
Terebratuloid gen et. sp. nov. A. and B.

Pelecypoda (Dickins, unpubl.):

Astartila blatchfordi (Hosking)
Atomodesma cf. *mytiloides* Beyrich
Aviculopecten spp.
Pseudomyalina cf. *mingenewensis* Eth. fil.
Pseudomonotis sp. nov. A.
Steblopteria? sp. nov.
Steblochondria sp.
Undulomya sp.

Gastropoda (Dickins, unpubl.):

Baylea? sp. nov.
Bellerophontids
Ptychomphalina maitlandi Eth. fil.
Ptychomphalina sp. nov.

Bryozoa (Crockford, 1957):

Acanthocladia sp. indet.
Callocladia? ramosa Crock.
Dybowskiella arborescens Crock.
D. crescens Crock.
Dyscritella adnascens Bassl.
D. bruteni Crock.
D. macrostoma Crock.
D. spinigera (Bassl.)
D. cf. *spinulosa* Bassl.
D. tenuirama Crock.
Eridopora permiana Crock.
Etherella irregularis Crock.
E. porosa Crock.
Evactinostella crucialis (Hudleston)
Fenestella basleoensis Bassl.
F. cacuminatis Crock.
F. columnaris (Crock.)
F. disjecta (Crock.)
F. hindei (Crock.)
F. horologia Bretnall
F. valentis (Crock.)
F. sp. nov.
Fistulamina lata Crock.
Fistulipora stereos Crock.
F. vacuolata Crock.
Goniocladia indica Waagen & Pichl
G. timorensis Bassl.
Hexagonella australis (Bretnall)
H. hudlestoni Crock.
Liguloclema meridianus (Eth. fil).
L. typicalis Crock.
Megacanthopora? scalariformis Crock.
Minilya duplaris Crock.
M. princeps Crock.
Polypora fovea Crock.
P. kimberleyensis Crock.
P. megastoma de Koninck
P. multiporifera Crock.
P. natalis Crock.
P. obesa Crock.
P. wadei Crock.
P. woodsi (Eth. fil)
P. sp. nov.
Prismopora? attenuata Crock.
P. digitata Crock.
P?. triradiata Crock.
Protoretepora ampla (Lonsdale)
P. flexuosa Crock.
P. robusta (Bassl.)
Rhabdomeson bispinosum Crock.
R. bretnalli Crock.
R. grande Bassl.
R. mammillatum (Bretnall)
Rhombocladia spinulifera Crock.
Saffordotaxis castanea Crock.
S. elegans Crock.
S. multigranulata (Bretnall)
S. cf. *wanneri* (Bassl.)
Stenodiscus hardmani Crock.
S. variabilis Crock.
Stenopora bella Crock.
S. lineata Crock.
S. spicata (Bassl.)
Streblascopora marmionensis (Eth. fil)
Streblotrypa minutula Bassl.
Synocladia teicherti Crock.
Tabulipora scissa Crock.

3336/57.—4

Foraminifera (Crespin, pers. comm.):

Ammodiscus erugatus Crespin MS
A. nitidus Parr
Digitina recurvata Crespin & Parr
Hyperammina acicula (Parr)
H. coleyi Parr
H. elegans (Cushman & Waters)
H. expansa (Plummer)
Pelosina hemisphaerica Chapman & Howchin
Rectoglandulina serocoldensis (Crespin)
Rephax ellipsiformis Crespin MS
R. subasper Parr
R. tricameratus Parr
Thurammina phialaeformis Crespin MS
Thuramminoides sphaerodalis Plummer
T. teicherti (Parr)
Trochammima subobtusa Parr

Arthropoda:

Cypris sp.
Ostracoda gen. indet.

Corals (Hill, 1943):

Cladochonus nicholsoni (Eth. fil)
Thamnopora marmionensis (Eth. fil)
T. immensa Hill

The age is Artinskian.

Liveringa Formation.

The term Liveringa Group (named from Liveringa Ridge, 124° 06′ E., 17° 56′ S.) was first used by the field geologists of the Bureau of Mineral Resources (Guppy et al., 1952). Wade (1936) used the terms Liveringa Series and Upper Ferruginous Series. Subsequent workers, Kraus (1941), Findlay (1942), and Reeves (1949), retained the word Liveringa but appended "Iron sandstone", "Sandstone", "Beds". It was not until the Blina Shale was demonstrated to be Triassic and boundaries of the Noonkanbah Formation and Blina Shale defined in the field that the true nature and extent of the intervening section was known.

The sequence has been renamed "Liveringa Formation" because it does not fall within the definition of a group; and its separable units are named as members. The Liveringa Formation is therefore defined as the sequence overlying the Noonkanbah Formation conformably and overlain, probably unconformably, by the Blina Shale, and unconformably by the Erskine Sandstone, Mudjalla Sandstone, Barbwire Sandstone, or James Sandstone. The type section for the formation is on the south flank of Grant Range (at Long. 124° E., Lat. 18° 08′ S.).

The Liveringa Formation occurs throughout the Fitzroy Basin and is particularly well exposed on the flanks of the anticlines.*

Three lithological units may be recognized in the formation. The units of resistant sandstone normally form strike ridges, separated by a wide flat of poorly exposed siltstone and calcareous sandstone. The units are exemplified in the double ridge along the south central Grant Range; the Jimberlura Ridges; Mount Hardman and the ridge near Mount Ibis; the low rise 2 miles east of Christmas Creek Homestead and the Mount Talbot mesa; and the Shore Range.

The lowest unit, named here the *Lightjack Member* from Lightjack Hill (Long. 125° 50′ E., Lat. 18° 59′ S.), contains one of the best markers in the Permian of the Fitzroy Basin. At the base, greywacke and fine, slightly micaceous, well-sorted red to yellow quartz sandstone, commonly richly fossiliferous, contain lenses of limonitic oolites. These lenses contain up to 50 per cent. iron oxide, and usually occur in the basal half of the fossiliferous unit (Edwards, 1953).

These beds are succeeded by fine, thin-bedded, highly micaceous, olive-green sandstone, and this in turn by a friable ripple-marked thin-bedded light yellow-brown sandstone, commonly with plant fragments. Some calcareous beds occur at the base of the sequence and the contact with the Noonkanbah Formation is gradational in most areas; in many places the transition beds contain intraformational pellets.

The plant-bearing sandstone forms scarps in some places, for instance along Nerrima Ridge and at Shore Range, and caps Bucknell's Pinnacle and Bruten's Hill, where the thin-bedded micaceous dark-coloured sandstone weathers deeply. At these localities, a double ridge is formed in the basal unit, probably caused by faulting or monoclinal folding. Some coal seams have been reported from this sequence, but the seams are too thin and of too low grade to be commercially important (Woodward, 1915, p. 11; Blatchford, 1927, p. 26).

The second unit is poorly exposed and is probably a siltstone and shale with rare interbedded calcareous beds. The calcareous beds, which are quartzose, form scattered lines of float and range from siltstone to medium-grained sandstone. The unit forms grassy plains, best developed south of Mount Hardman and south of the Shore Range.

The uppermost unit, named the *Hardman Member* from Mount Hardman (Long. 124° 39′ E., Lat. 18° 18′ S.), consists of dominant thin-bedded friable fine to medium micaceous silty sandstone, commonly ripple-marked and interbedded with massive current-bedded, medium to coarse well-sorted quartz

* Recent work in the north-east and south-west parts of the Canning Basin has shown this formation to be exposed over large areas on the north-eastern and southern margins of the Basin.

sandstone. A rich assemblage of marine fossils is found at the base of and within this unit in red-brown and olive-brown micaceous sandstone, very similar in lithology to the Lightjack Member.

Thickness determinations are made difficult by the lack of dip control in the poorly exposed parts of the section and by a very poorly exposed contact with the Blina Shale. Sufficient data have been obtained to indicate that the thickness of the formation is very variable, probably in part owing to varying rates of deposition, and, although there is no clear evidence for unconformities, they may exist, as fossil evidence suggests a considerable time range between the Lightjack and Hardman Members.

The Lightjack Member varies in thickness from 65 feet at Lightjack Hill (east of Christmas Creek Homestead) to 250 feet in the Shore Range and Barbwire Ranges over a distance of 33 miles, and again from 200 feet at Duchess Ridge to 435 feet south of Grant Range, a distance of 30 miles. At Duchess Ridge and south of Grant Range, a very characteristic bed of partly silicified vuggy siltstone with plant remains and common opal occurs at the top of the Lightjack Member. The thickness of this plant bed itself decreases from 85 feet (Grant Range) to 10 feet (Duchess Ridge).

The second or middle unit is about 600 feet thick south of Grant Range, and although dips are few in the Mount Hardman and Christmas Creek area, this unit is estimated at 1,200 feet at Mount Hardman and 900 feet at Christmas Creek.

The Hardman Member crops out near the mouth of Manguel Creek, in the Myroodah, Blina and Kalyeeda areas, near Mount Talbot and in the Millyit Range (20 miles south of Shore Range) as well as at Mount Hardman. The thickness varies from 120 feet at Mount Hardman to 50-75 feet in the Millyit Range.

About 1,850 feet of the Liveringa Formation was measured in the type locality, south of Grant Range (p. 104), but the section is incomplete. The only complete section obtained through the formation was from Mount Ibis to Mount Hardman, where a thickness of 3,000 feet is estimated. Dip data in this area are so meagre, however, that no reliance can be placed on this thickness.

The Lightjack Member contains a rich assemblage of pelecypods, gastropods, some brachiopods, and rare ammonoids. The faunal list includes—

Brachiopoda (Thomas, 1954 and pers. comm.; brachiopods are rather rare except locally, as in the Shore Range).

Chonetes sp. nov. (present at several localities)
Cleiothyridina sp.
Dielasma sp.
Martiniopsid gen. et sp. nov. C.
Neospirifer sp. nov.
Permorthotetes guppyi Thomas MS
Spiriferid gen. et sp. nov. (2)
Streptorhynchus sp. aff. *S. perfidiabadensis* (Eth. fil.)

Other brachiopods reported as occurring in this member (Coleman, 1957) are—

Aulosteges ingens Hosking
Etheridgina muirwoodae Prend.
Linoproductus cancriniformis Tschernyschew
Strophalosia (Heteralosia) prendergastae Coleman

Mollusca (Dickins, pers. comm.):

Astartila fletcheri Dickins
Atomodesma esaraba Beyrich
Aviculopecten? hardmani Eth. fil.
Bucanopsis emerii (Eth. fil.)
Hantonia? sp. nov.
Nuculana basedowi Eth. fil.
Oriocrassatella stokesi Eth. fil.
Parallelodon subtilistriatula Wanner
Schizodus kennedyensis Dickins
Streblochondria sp.
Stutchburia muderongensis Dickins
Warthia cf. *micromphala* (Morris)
Bellerephontidae gen. et sp. nov.

Bryozoa (Crockford, 1957):

Etherella porosa Crock.
Fistulopora liveringa Crock.
Minilya duplaris Crock.
Saffordotaxis elegans Crock.
Stenodiscus variabilis Crock.
Streblascopora marmionensis Eth. fil.

Foraminifera:
Hyperamminoides spp.
Hyperammina fusta Crespin MS
Reophax subasper Parr

Anthozoa:

Conularia warthi Waagen
Serpulites sp.
Tachylasma densum Hill

Crinoid ossicles.
Worm tracks.
Nereites sp.

An upper Artinskian to lower Kungurian age is indicated for this member and it is equivalent to the lower part of the Kennedy Group of the Carnarvon Basin.

The middle sandstone member contains the following flora:—

?*Bothrodendron* sp. (Teichert, 1939).
?*Gangamopteris* sp.
Glossopteris indica Brong.

The Hardman Member contains a rich assemblage of brachiopods. The faunal list includes—

Brachiopoda (Thomas, 1954 and pers. comm.; and Coleman, 1957):

Aulosteges fairbridgei Coleman
A. ingens Hosking (fide Coleman, 1957)
A. reclinis Coleman (this species is allied to *A. dalhousi* Davidson)
Chonetes sp. nov.
Cleiothyridina penta (Prendergast)
Cleiothyridina spp. nov. (2)
Derbyia hardmani Thomas MS
Dielasma sp. aff. *D. elongata* Schlotheim.
Hustedia cf. *grandicosta* Waagen
Martiniopsid gen. et sp. nov. D
Neospirifer sp. nov.
Spiriferid gen. et sp. nov. (2)
Streptorhynchus luluigui Hosking
Streptorhynchus cf. *pelargonatus* Schlotheim
Strophalosia (*Heteralosia*) *prendergastae* Coleman
Strophalosia sp. nov.
Taeniothaerus? fletcheri Coleman
Terebratuloid gen. et sp. nov. aff. "*Dielasma*" *latouchei* Diener
Waagenoconcha imperfecta Prendergast.

Pelecypoda (Dickins, pers. comm.):

Astartila? sp. nov.
Astartella sp. nov.
Atomodesma cf. *semiplicata* Reed
Atomodesma cf. *mytiloides* Beyrich
Aviculopecten spp.
Modiola sp. nov.
Nuculanids
Pseudomonotis sp. nov. B.
Procrassatella sp.
Sanguinolitidae gen. et sp. nov.
Schizodus cf. *obscura* King
Schizodus sp. nov.
Streblochondria sp.
Stutchburia sp.

A number of unidentified genera.

Gastropoda:

Bellerophontids
Pleurotomariids
Warthia sp.

Bryozoa (Crockford, 1957):

Dyscritella liveringa Crock.
Stenodiscus hardmani Crock.

The age of this unit is Upper Permian, probably Tartarian, and it is much younger than other Permian formations in Western Australia; it has very strong affinities with the Upper Productus Limestone in the Salt Range Sequence of India.

TABLE 5. FITZROY BASIN—MESOZOIC AND CAINOZOIC STRATIGRAPHY, STRUCTURE, TOPOGRAPHY AND WATER SUPPLY.

Period or Epoch.	Stratigraphic Unit.	Distribution.	Lithology.	Thickness (feet).	Structure.	Topography.	Correlation.	Water Supply.	General Remarks.
QUATERNARY	Residual black soil (Qrb) ..	Throughout the area and particularly over Noonkanbah Formation, Blina Shale, Mount Pierre Group	Frequently heavy textured with well developed cracks when dry	Superficial		Large plains and small areas. Rough surface due to shrinkage cracks			
	Other residual soils (Qrr) ..	Throughout the area. May be preserved over all formations	Variable texture and usually sandy. Quality variable	Superficial		Confined to comparatively flat areas			
	Alluvium (Qra)	Confined to vicinity of rivers and streams, particularly Fitzroy, Margaret, Lennard, Barker Rivers and Christmas Creek	Light textured alluvia usually with high sand content. Variable	100 ±		River banks and flood plains. Gullying common in easily eroded material		Good quality water available at shallow depth along river banks in normal seasons	
	Travertine (Qrc)	Commonly overlying low outcrops of Devonian, Noonkanbah Formation	Impure chemically precipitated carbonate rock. In places nodular and pisolitic	Superficial		Flat platforms and low ridges ..			
	Sand, sand dunes (Qs)	Confined to areas underlain by Mesozoic sediments and Grant Formation	Well rounded quartz sand with noticeable content of iron oxide	50 ±		Residual sand forms areas of low topography. Aeolian sands form seif dunes		Shallow water of good quality available in favourable areas	
	Warrimbah Conglomerate (Tw) ..	Scattered outcrops north and south of Fitzroy River particularly near Warrimbah HS and Myroodah HS	Unconsolidated pebble to boulder conglomerate. Chiefly quartzite	Not known (?10+)	Bedding not exposed but deposits probably related to older river courses	Low ridges with pebbles and boulders weathering out		Good water (sub-artesian) between 50–60 feet	Unconformably overlies Permian or Mesozoic and probably post-Pisolitic Ironstone
TERTIARY	Pisolitic Ironstone (Tp) ..	Scattered and irregular areas over Permian and Mesozoic sediments	Ferruginous pisolites and nodules with rock fragments cemented in a sandy ferruginous matrix	6 (approx.)	Thin capping over a former peneplained land surface				Part of laterite profile
LOWER CRETACEOUS	Melligo Quartzite (Klm) ..	As a north to south linear belt west of Nillibucca Well	Primary silicified quartz sandstone, white and grey. Medium to coarse	40–70		As scrub covered low rocky ridge	Aptian	Not known	Overlies Jowlaenga Sandstone conformably
	Jowlaenga Sandstone (Klj) ..	Forming low hills in Dampier Land and forming Mount Clarkson	Fine to medium quartz sandstone, often ferruginized. Feldspar and mica in fine-grained beds. Well bedded, cross-bedded	250 +		Low hills and mesas	Valanginian	Good for shallow water ..	Conformably overlain by Melligo Quartzite
L. CRETACEOUS ?	Fitzroy Lamproites (fv) ..	Intrude Permian and Triassic sediments in synclinal belts north of Noonkanbah HS, &c.	Leucite rich rocks known as leucite-lamproites. Associated fractured and chemically altered country rocks	Not known	Plugs, necks and flows ..	Form small, low, rounded hills and sharp peaks resistant to erosion			Post-Triassic in age
JURASSIC	Limestone ("Fraser River Limestone") (Juf)	Lower reaches of Fraser River and South Fraser River	Hard yellowish silicified nodular limestone	Not known		Low laterite covered rises ..	Stratigraphical equivalent of "Langey Siltstone"	Not known	Overlaid by Jowlaenga Sandstone
	Glauconitic Siltstone ("Langey Siltstone") (Jul)	Near Langey Crossing	Nodular greenish to white sandy and glauconitic silicious siltstone with some micaceous shale	300 +		Rubble rises and small cliff on Fitzroy River and road cuttings	Stratigraphical equivalent of "Fraser River Limestone"; Portlandian	Not permeable	Probably overlain by Jowlaenga Sandstone. Base not seen
	Mowla Sandstone (Juo) ..	Small outcrops south-east of Mount Jarlemai and south of Mowla Bluff—overlies Jarlemai Formation	Strongly cross-bedded, unsorted, friable conglomeratic sandstone, coarse sandstone	60		Low rounded hills and capping on low hills			Unconformably overlies Jarlemai Formation
	Meda Formation (Jum) ..	Erskine Range, Meda and Kimberley Downs stations. Possibly at Willumbah Ridge	Conglomerate, consisting of phenoclasts of slates, blocks of Erskine Sandstone and rounded quartz pebbles in a matrix of unsorted fine sandstone	30 +	Outcrops small and often poorly exposed				Unconformably overlies Erskine Sandstone

[*To face page 55.*]
3336/57.

TRIASSIC (Table 4).

Blina Shale.

The Blina Shale was first recognized and named by Findlay (1942) and the name was published by Reeves (1951). Both considered the age of the formation to be Permian. Brunnschweiler (1954) recognized the Triassic age of the Blina Shale. It is the basal Triassic unit, unconformably overlying the Permian Liveringa Formation and overlain unconformably by the Triassic Erskine Sandstone The name is taken from Blina Homestead (Lat. 17° 46′ S., Long. 124° 32′ E) Areas underlain by the formation have been mapped in the Erskine Range, Wongil Ridge, and on grassy, poorly drained, clay-soil plains on Meda, Kimberley Downs, Blina, Liveringa, Calwynyardah, Noonkanbah, and Quanbun Stations north of the Fitzroy River, and Luluigui and Nerrima Stations south of the Fitzroy River. Generally, the formation occupies synclinal areas in the Liveringa Formation (Dry Corner Syncline, the syncline between the Mount Wynne and Warrawadda Structures, and the area between Mount Hardman and Widgiemoora Rock). In addition, a linear belt, 6 to 8 miles wide, passing 10 miles north-west of Ellendale Homestead to the coast at Stokes Bay, and exposures at Wongil Ridge and between Wongil Ridge and the Fitzroy River, are known.

There is no type section for the unit as outcrops are rare and very incomplete; the formation is represented on the surface largely by float material overlying black-soil plains.

Ferruginized conglomeratic sandstone occurs in an area of no other outcrop, near the contact of the formation with the Liveringa Formation near the west branch of Nerrima Creek and at Willumbah Ridge. Shed rounded quartz pebbles occur between float material of the Blina Shale and outcrops or float of the Liveringa Formation north of Lower Liveringa Ridge and north of Le Lievres Bore (Liveringa Station). This material, the presence of bone fragments below marine fossils, and a probable time gap in the fossil record between the Blina and Liveringa formations, are the only evidence of a disconformity between the Liveringa Formation and the Blina Shale. About 95 feet of the upper beds of the Blina Shale are exposed at the base of Erskine Hill; they consist of laminated light grey-brown and yellow-grey micaceous quartzose siltstone, shale, and fine sandy siltstone. Ferruginous, ochreous red and white siltstone occurs at Wongil Ridge. The surface outcrops have vertical cylindrical concentric concretions which commonly form a blister on the under-surface of a bed. Samples obtained from bores which have penetrated the formation are blue-grey shale. The formation is a poor aquifer, but small supplies have been obtained from near the base, which suggests that the basal beds may be more sandy.

The siltstone weathers on exposure to small ferruginous chips, commonly fossiliferous, which occur rarely on the soil plains. Gypsum crystals are commonly found in the surface soil.

Three bores on Blina and Kimberley Downs Station have penetrated 1,000 feet in the Shale, and it has been recorded as "puggy blue clay" in drillers logs; some specimens of *Isaura* were seen in the drill cuttings from Barker No. 2 Bore. At 1,012 feet in Myalls Bore, Derby, shales containing *Isaura* were reported (Teichert, 1950). In all instances the bores began near the top of the section, beneath the contact with the Erskine Sandstone, and did not reach the base of the formation. Bores on the northern part of Liveringa Station are believed to have bottomed in the Liveringa Formation after passing through variable thicknesses (up to 800 feet) of Blina Shale. The Blina Shale is believed to overlie the Liveringa Formation unconformably in broad shallow basins between the anticlinal folds; this may account for the variation in thickness.

The faunal list is taken from Brunnschweiler (1954):

Capitosaurus sp.
?*Acrodus* sp.
Vertebrae and small scales of small Palaeoniscidae.
Isaura cf. *I. minuta* (Goldfuss)
Isaura cf. *I. ipsviciensis* (Mitchell)
Lingula n. sp. A. (subcircular outline).
Lingula n. sp. B. (elongate oval outline).

According to Brunnschweiler, the abundance of *Isaura* (*Estheria*), which occurs in numerous thin coquinites, suggests an Upper Triassic age for the formation, and the presence of *Lingula* indicates that it is a marine deposit.*

Pale grey clays with fossil insects and plants north of White Rocks, recorded by Wade (1936), and regarded by him as Tertiary lake deposits, are now thought to belong to the Blina Shale. Pleistocene reptilian and marsupial remains from Quanbun Tanks (Glauert, 1921)—probably Alligator Tank—have been found in a depression within the Blina Shale.

Erskine Sandstone.

Wade (1936) first used the term "Erskine Series" for sandstones and conglomeratic sandstones from the Erskine Range (17° 50′ S., 124° 20′ E.) and Sisters Plateau area, as well as outcrops in the Edgar and Millyit Ranges, and he regarded these as the youngest member of the Permian sequence. Reeves (1949) separated the Erskine Sandstone from the Permian and regarded it as Mesozoic (Jurassic). The term was redefined by Brunnschweiler (1954) and is now used in a more restricted sense as the unit consisting of sediments of Upper Triassic age bounded below by the Blina Shale and above by the Meda Formation. Both contacts are poorly exposed in the field, except at Erskine Hill, but the thickness at that locality together with the relative distribution of the formation suggests that both contacts are unconformable. A sharp unconformity is seen where the Erskine Sandstone overlies Liveringa Formation.

Best exposures occur in the Erskine Range and Sisters Plateau. Scattered low ridges on Kimberley Downs, and widespread, commonly sand-covered,

* Fossils collected while this Bulletin was in press suggest a Permian age for the Blina Shale.

outcrops on Meda, consist of rocks of the formation. Yarrada Hill consists of sediments of the formation and exposures occur in places along the bed of the May River.

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

The greatest thickness measured was 110 feet on the north scarp of The Sisters Plateau. 85 feet is exposed at Yarrada Hill. Both these thicknesses are incomplete above and below. At Erskine Hill, 60 feet of the unit has been preserved between the Blina Shale and Meda Formation. The complete thickness of the formation cannot be assessed because of the discontinuity of outcrop and the very low dips.

Fossil plants collected by the authors in 1948 from the May River indicated a Mesozoic rather than Permian age. Fossil wood fragments are common in all exposures, but identifiable forms are rare. However, two richly fossiliferous lenses, on The Sisters Plateau and Yarrada Hill, have yielded well-preserved plants of Upper Triassic (?Keuper) age (Brunnschweiler, 1954).*

Forms described include:

Thinnfeldia (*Dicroidium*) sp. } dominant forms.
Gleichenites sp. }
Otozamites sp.

Schizoneura sp.
Pleuromeia sp.

JURASSIC (Tables 4 and 5).

Meda Formation.

A new term is proposed for the conglomeratic sediments exposed on Meda and Kimberley Downs Stations and in the vicinity of Derby. The name is taken from Meda Station (Long. 124° 0′ E., Lat. 17° 22′ S.) and the formation is defined as the sediments overlying the Erskine Sandstone unconformably. Wade (1936) and Findlay (1942) included the unit in the Erskine " Series ", although Findlay suspected a disconformity between the conglomerate and sandstone. Reeves (1949) included the unit in his Derby Beds, and Brunnschweiler (1954) in the Erskine Sandstone.

The formation caps the Erskine Sandstone in the Erskine Range, Trig. H 81, and a hillock south-east of One Tree Well, Meda Station. Gravel pits near Derby have exposed sediments of this formation.

The unit consists of medium and coarse sandstone with fine conglomerate beds and lenses. The phenoclasts are of quartz and quartzite (Erskine Range), and of material derived from the Erskine Sandstone.

The greatest thickness observed is 30 feet at Trig H 81.

* Plant fossils of probable Permian age have recently (late 1957) been found at Erskine Hill. This raises the possibility that the exposures at The Sisters and Yarrada Hill belong to a different, younger, formation not recognized here.

No fossils have been found, but from its regional distribution the formation is probably a marginal facies of one of the Upper Jurassic formations south of the Fitzroy River.

Jurgurra Sandstone.

The Jurgurra Sandstone was defined by Brunnschweiler (1954) and is named from Jurgurra Creek. The type area is at the base of Mount Alexander (Long. 123° 39′ 06″ E., Lat. 18° 41′ 06″ S.). The base of the unit is not seen, but the formation is disconformably overlain by the Alexander Formation. Reeves (1949) mentions the unit as " irregularly bedded sandstones with unidentifiable plant fragments ", but does not name it or include it in any of his units.

Exposures are confined to the bed of Jurgurra Creek and its tributaries upstream from Clanmeyer Pool, and to the lowest part of nearby hills such as Mount Alexander and Goorda Tower.

The unit consists of flat-bedded medium and coarse sandstone with thin silty intercalations. The sandstone is current-bedded, massive, friable, and buff to cream-coloured, and commonly contains large mica flakes. Silt pellet beds are common.

The maximum section is 65 feet thick. As the base of the unit has not been seen, the true thickness will be greater.

Indeterminate, poorly-preserved plant fossils and small marine pelecypods have been found. The unit is disconformably overlain by the Upper Jurassic Alexander Formation; the contact appears as a wavy erosion surface. As the lithology of the Jurgurra Sandstone is unlike that of any of the Permian or Triassic sediments, the formation represents a marine or fluviatile transgression, post-Triassic and pre-Upper Jurassic in age.

Mudjalla Sandstone.

The Mudjalla Sandstone is a new unit, named after Mudjalla Yard, Luluigui Station (Long. 123° 50′ E., Lat. 18° 03′ S.). The sediments overlie the Liveringa Formation disconformably; the upper beds have been removed by erosion. The best exposures occur in the rough " badlands " gully-scour north-west of Mudjalla Yard and north-west along the south bank of the Fitzroy River. Scattered outcrops occur as far north-west as the mouth of Manguel Creek. Float material and poor exposures occur near the west bank of the Minnie (Fitzroy) River, and as far north as Langey Crossing.

The formation consists of unsorted medium, coarse, and very coarse quartz sandstones, and lensing conglomerate beds, all strongly cross-bedded. Lenses of fine and medium micaceous quartz sandstone and rare siltstones occur in the sequence; they contain a few plant remains. The sandstone is clean, porous, friable, and light to yellow grey in colour, weathering red. The quartz grains are angular. The unit is regarded as being fluviatile in origin.

The maximum thickness exposed is 135 feet, near Mudjalla Yard.

The presence of conifer remains in the plant assemblage is believed to indicate a Jurassic age. The formation resembles the Jurgurra Sandstone lithologically and may be synonymous with it. It may also be the landward facies of the Tithonian Alexander and Jarlemai Formations.

Alexander Formation.

The Alexander Formation was included by Reeves (1949, 1951) in his "Fraser River Beds", but the two units have different lithology. In addition Brunnschweiler (1954) indicated that the formations are of different ages and he named the Alexander Formation from Mount Alexander (Long. 123° 39′ E., Lat. 18° 42′ S.). The formation is overlain conformably by the Jarlemai Formation and underlain unconformably by the Jurgurra Sandstone. The type section at Mount Alexander lacks 20 feet of the youngest beds, but these are exposed in mesas 5 miles to the east. Above the Alexander Formation poorly bedded saccharoidal siltstones of the Jarlemai Formation form the steep cliffs of the Edgar Range cuesta.

The main area of outcrop is at the base of the Edgar Ranges and the outlying mesas and buttes, between the west tributary of Jurgurra Creek and Matches Springs. Scattered low outcrops north-east of Matches Springs and north of Craven Ord Hill have been interpreted from aerial photographs as consisting of sediments of the Alexander Formation.

At the base of the formation is a variable thickness of strongly cross-bedded medium and coarse quartz sandstone with intercalated lensing beds of white siltstone. Above this thin-bedded medium buff ripple-marked sandstone and white siltstone occur alternately with rare thick beds. Towards the top of the formation, the bedding is commonly more massive and the sediments consist of interbedded medium sandstone and siltstone. The whole section is marine and fossiliferous.

Complete sections reveal a thickness of 180 feet.

The faunal list includes (Brunnschweiler, 1954)—

Ammonoidea: *Virgatosphinctes* cf. *V. communis* Spath
Kossmatia sp. indet.
Perisphinctidae spp.

Pelecypoda: *Inoceramus* cf. *I. everesti* Holdhaus
Meleagrinella spp. nov.
?*Maccoyella* sp.
Inoceramus sp.
Cf. *Quenstedtia* sp.

Brachiopoda: *Lingula* sp. nov.

Echinodermata: *Ophiuroidea* spp.

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

James Sandstone.

The James Sandstone includes all the coarse conglomeratic commonly ferruginous sandstone in the vicinity of the Fenton Fault and particularly at Mount James (Long. 124° 28′ E., Lat. 18° 41′ S.) from which the name has been derived. These sediments were included in the Erskine Series of Wade (1936) and were regarded as the basal beds of the Jurassic transgression by Reeves (1949). The James Sandstone disconformably overlies the Liveringa Formation, Noonkanbah Formation, and Poole Sandstone; the upper part of the James Sandstone is eroded.

Scattered outcrops occur in the vicinity of the Fenton Fault from a point 15 miles south-east of Mount Fenton north-west to Moulamen Hill South. An exposure on the top of a mesa 2 miles west of Mount Fenton, consisting of typical sediments of the Alexander Formation, is the farthest known outcrop from the Fenton Fault.

The formation includes quartz sandstone and fine conglomerate. The sandstone is well-bedded to thin-bedded, strongly cross-bedded, medium to coarse, and porous. Beds of conglomerate may be 6 inches thick, but are characteristically in single layers. Individual beds and cross beds of sandstone are well-sorted, but the grain-size commonly varies largely from bed to bed, and the beds weather massively. The pebbles are rounded to subrounded, ranging from ¼ to 4 inches in diameter, and consist of quartz, quartzite, and siliceous igneous rocks. In most places, the beds are very ferruginous.

An incomplete thickness of 80 feet has been measured at Mount James.

No fossils have been observed in the sediments, but in lithology they resemble beds near the base of the Alexander Formation, where these are ferruginous. The Alexander beds are finer grained. The James Sandstone is regarded as being possibly equivalent to the Alexander Formation and therefore of Upper Jurassic age, and to represent a marginal Jurassic transgression.

Jarlemai Formation.

The name was introduced by Brunnschweiler (1954) as "Jarlemai Siltstone" to replace the "Edgar Range Beds" of Reeves (1951). The amount of sandstone present, as well as saccharoidal siltstones, have caused the authors to rename the "Jarlemai Siltstone" Jarlemai Formation.

The formation is exposed throughout the full length of the Edgar Ranges from Dampier Downs Homestead to south-east of Matches Springs, and is named from Mount Jarlemai (Long. 123° 45′ E., Lat. 18° 43′ S.). It overlies Alexander Formation conformably and is overlain disconformably by the Mowla Sandstone.

The formation consists of poorly stratified to massive unsorted sandy (saccharoidal) siltstone and silty sandstone. Near Dampier Downs Homestead and Matches Springs, bedding is better developed. Bedded fine clean quartz sandstone occurs at the top of the formation. Quartz grains in the siltstone vary from fine to coarse with rare pebbles up to 4 inches across. The white and light coloured siltstone has pastel weathering shades of yellow, brown, purple, and grey-green. The massive beds tend to weather by exfoliation.

The greatest thickness measured is 300 feet in the Matches Springs area, with the upper part of the section removed by erosion.

Fossils are rare in the formation. The faunal list is—

Buchia ("*Aucella*") cf. *B. extensa* (Holdhaus)
Buchia cf. *B. pitiensis* (Holdhaus)
Meleagrinella sp. nov.
?*Lima* sp. indet.

Brunnschweiler says that the formation is of Tithonian (Upper Jurassic) age, and slightly older than Teichert's (1940b) *Buchia* beds from the Broome bore.

Mowla Sandstone.

The formation was defined by Brunnschweiler (1954) as Mowla Conglomerate. It overlies the Jarlemai Formation disconformably and the upper portion has been removed by erosion. The formation crops out only in synclinal areas: near Mowla Bluff, east of Mount Jarlemai, Matches Springs area, and east of Mount Troy, where it occurs as isolated hills or caps the Jarlemai Formation. It is named from Mowla Bluff (Long. 123° 45′ E., Lat. 18° 45′ S.). The formation consists of conglomeratic sandstone, which is strongly cross-bedded, friable, and unsorted, passing into micaceous sandstone, with which siltstone is inter-bedded near the top. The sediments are superficially silicified or ferruginized.

The thickest section measured was 60 feet.

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

Barbwire Sandstone.

About 70 feet of sediments cap the Liveringa Formation in the Barbwire Range (Long. 125° E., Lat. 19° S.). The Barbwire Sandstone overlies the Liveringa Formation unconformably. The contact with the older beds has only been observed in one place in the Fitzroy Basin, but south-east of the Barbwire Range the Barbwire Sandstone overlies the Liveringa Formation with a 5° unconformity (R. Elliott, personal communication).

The unit consists of fine to poorly sorted strongly cross-bedded to massive coarse sandstone, with some conglomerate and intercalated siltstone lenses; the siltstone is white, weathering to red-brown. As the upper part of the section has been removed by erosion, the beds must be more than 70 feet thick.

The age is uncertain as no fossiliferous material has been collected. The lithology suggests a correlation with the James Sandstone, and a tentative Upper Jurassic age has been assigned to it.

Glauconitic Siltstone.

This was referred to as the "Langey Crossing Marl" by Guppy et al. (1952), and then as the "Langey Siltstone" by Brunnschweiler (1954); the present usage is taken from Brunnschweiler (1957).

The formation crops out at Langey Crossing on the Fitzroy River and consists of nodular greenish to white sandy and glauconitic siliceous siltstone with thin bands of white fine sandy micaceous shale.

Information from nearby water bores suggests that the formation is a few hundred feet thick; Triassic Blina Shale crops out 14 miles east of the type locality at Langey Crossing.

The marine fossils (which include *Calpionella, Buchia, Kossmatia* and *Belemnopsis*) found in the glauconitic siltstone (Brunnschweiler, 1957) indicate a late Tithonian age; sedimentation probably took place in a neritic rather than littoral environment.

Subsurface information from water bores near Broome and Derby indicates that the glauconitic siltstone is underlain by interbedded marine sandstone (in part glauconitic) and shale containing a Kimmeridgian fauna.

Limestone.

The limestone was referred to as the "Fraser River Limestone" by Guppy et al. (1952), and by Brunnschweiler (1954); the present usage is taken from Brunnschweiler (1957).

Reeves (1949, 1951) used "Fraser River beds" for some successions found in Dampier Land; but this name now comprises two separate formations of Cretaceous age, the Jowlaenga Sandstone and the Melligo Quartzite.

The limestone crops out on the lower Fraser River, and the exposures are unfossiliferous; but it occupies the same stratigraphical position as the glauconitic siltstone at Langey Crossing—below the Neocomian Jowlaenga Sandstone—and may represent another facies of the Upper Tithonian.

CRETACEOUS.

Jowlaenga Sandstone.

The Jowlaenga Sandstone is the oldest formation in the Dampier Group (Brunnschweiler, 1957). It crops out in all mesas and buttes in the Fraser River area as well as on the east coast of Dampier Land. At the type locality of Mount Jowlaenga, the Sandstone is capped by Melligo Quartzite. The rock consists of marine quartz sandstone, fine to medium-grained, and commonly ferruginous; the grain-size decreases towards the north; the environment of deposition was that of a near-shore deposit. The maximum observed section is about 250 feet thick; estimated total thickness is 400 feet. The thickness probably increased toward the west.

The lower part of the Sandstone contains a number of fossiliferous beds, and the fossils include *Meleagrinella, Iotrigonia* and *Belemnopsis* (*see* Brunnschweiler, 1957); the age is Valanginian (part of Neocomian).

Melligo Quartzite.

Brunnschweiler (1957) first named this formation; it had previously been thought to be the silicified (lateritized) top part of the Jowlaenga Sandstone. It crops out in Dampier Land, west of Nillibubacca Well, and as a 40-70-foot capping on mesas in the Fraser River area. The rock is a tough quartz sandstone, white to grey, medium to coarse-grained, and completely silicified.

The Melligo Quartzite contains marine fossils including *Fissilunula, Cyrenopsis, Panopaea* and *Belemnites,* and the age is Aptian. It is the youngest member of the Mesozoic sequence in Dampier Land and it overlaps the Precambrian rocks exposed on islands lying off the north-east coast of Dampier Land.

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.

The ironstone is probably of the Tertiary (probably Oligocene) age ascribed to laterite throughout Northern Australia.

QUATERNARY.

Warrimbah Conglomerate.

The Warrimbah Conglomerate has been mapped in outcrop at scattered localities near the Fitzroy River, particularly near Warrimbah Homestead (Long. 125° 03′ E., Lat. 18° 25′ S.) and Myroodah Homestead. The conglomerate is named from Warrimbah Homestead. The base of the formation is not exposed but presumably unconformably overlies either Permian or Triassic.

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

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

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

Sand, Sand Dunes.

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

Travertine.

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.

Alluvium, residual soils, and black soils have been discussed at p. 8ff.

STRUCTURE.

Regional Structure.

The study of the development of the broad structure of the Fitzroy Basin and adjacent areas since Precambrian times makes it possible to predict (within certain 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. But predictions must necessarily be subject to amendment as further geophysical and drilling information becomes available.

The geological history of the area suggests that at least the northern (Fitzroy Basin) and southern parts of the Canning Basin are located in an ancient mobile belt that has possibly persisted from Proterozoic time. The Palaeozoic sediments overlap on to the more stable blocks of the Kimberley Plateau in the north-east and on the Pilbara Area in the south.

The south-western margin of the Upper Proterozoic basin of deposition lies along the north-western edge of the Fitzroy Basin, and crops out in the Oscar Range. Most of the Upper Proterozoic sandstone, shale, and basalt was laid down in shallow water, and has been subjected to mild orogenic or epeirogenic movement (as can be seen in the King Leopold Ranges). The margin of the Upper Proterozoic, however, in the Oscar Range, is intricately folded, overturned, and probably thrust-faulted. A similar change can be seen farther north-west, where the strong folding at Yampi Sound gives way north-eastwards to the more stable conditions of the Kimberley Plateau.

Recent mapping in the Kimberley Plateau has shown that a diastrophism antedated the deposition of the upper beds of the Upper Proterozoic. The gently dipping and sub-horizontal sediments of the Walsh Tillite and Mount House Beds overlie eroded fold structures in the Wharton Beds, Mornington Volcanics, and King Leopold Beds.

Although the single outcrop of Ordovician rocks in the Prices Creek area gives no indication of the configuration of the Ordovician basin or of the subsurface extent of the Ordovician sediments, the Fitzroy Basin was probably a basin during the Ordovician, and the sediments deposited there were eroded from the shield area at least in the north-east.

Deposition in the north-east marginal area continued, with intermittent breaks, throughout the Palaeozoic. Deposition probably was 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.

Sedimentation in deeper parts has very probably been more continuous than in marginal areas, as shorelines are sensitive to even minor relative movements of sea level.

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 transgressian 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. In the vicinity of The Pinnacles 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 beds of the Liveringa Formation, Noonkanbah Formation and Poole Sandstone show little evidence of fault movement. These facts suggest that the downthrow was to the south-west of the Pinnacle Fault during the deposition of the Poole Sandstone, Noonkanbah Formation, and Liveringa Formation, and deposition of these units more or less kept pace with the subsidence. At the same time older formations (Grant Formation, Devonian and Ordovician), which were deposited over this tectonic line, were subjected to crushing as the downward movement progressed.

Recent seismic work in the Prices Creek area suggests a downthrow of about 1,500 feet to the south of the fault. Such a tectonic line would probably have a profound effect on the 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 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

3336/57.—5

in others. For example, between Nerrima Creek and Mount 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 been faulted along the Fenton Fault with a down-throw of 140 feet to the south-west.

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

Within the Fitzroy Basin, bounded by the Pinnacle and Fenton structures, are three main anticlinal belts which will be referred to as the Southern, Central and Northern Anticlinal Belts. All three anticlinal axes have a trend of about 280°.

The Southern Anticlinal Belt extends for 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: Poole Range Structure, Mount Hutton Structure, St. George Range Structure, Nerrima Structure, and Tutu Structure.

The Central Anticlinal Belt can be traced for about 50 miles from east of Mount Wynne to the Fitzroy River west of Mount Anderson. Two culminations are known along the axis of this anticline: Mount Wynne Structure and Grant Range Structure.

The Northern Anticlinal Belt is, by comparison, poorly defined, and only one culmination, the Warrawadda Structure (8 miles south of Blina Homestead), has been identified; the belt may extend farther to the 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 a number of subsidiary folds are discussed in the following section.

Folding and Faulting in the Fitzroy Basin.

Seismic and gravity work has recently been done by the Geophysical Section of the Bureau of Mineral Resources on some structures in the Fitzroy Basin. Reflection and refraction shooting were employed in seismic surveys, but few reflections were obtained over the area of anticlines where the reflection method was employed. This could be due to the dispersal of energy by the faulted and jointed rocks (predominantly sandstones) which are near the surface or crop out on the anticlinal area: on the flanks of the structures and

* An alternative interpretation of the phenomena recorded on and near the Pinnacle and Fenton Faults is given by M. A. Condon and J N. Casey in Appendix IV

in the synclines these rocks would tend to be compressed and they would therefore transmit energy. Reflection techniques are best suited for structural problems; the refraction techniques are more suited to determining depths to basement and identifying stratigraphic members; both techniques can determine faults, but the refraction method is usually more definite.

Poole Range-Mount Hutton Structure.—The structure has a major culmination in the Poole Range and a minor culmination at Mount Hutton. The westerly plunge is terminated by the faulted zone near Rexona 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 is symmetrical.

A system of northerly-trending high-angle normal faults cuts across the structure at intervals of ½ to 1 mile, and forms a series of fault-defined blocks which have modified the surface plunge of the axis. The faults are clearly defined on the surface and the displacement is from 80 feet to 150 feet. The dip of the fault planes is about 80°.

All Permian formations crop out in the structure; Grant Formation and Poole Sandstone form the core of the structure and the Noonkanbah Formation and Liveringa Formation crop out on the grassy flats surrounding the anticlinal core.

Owing to the complicated structural pattern on the western plunge it has not been possible accurately to assess vertical closure either on this structure or St. George Range Structure.

Seismic reflection and refraction traverses in 1954-1955 (Smith, 1955) from the Pinnacle Fault to the Poole Range showed that the Poole Range structure probably persists in depth. An unconformity may exist in the Poole Range area and 2 miles south of Dusty Bore. Its depth is estimated as about 8,000 feet; at 5,000 feet the upper beds dip 3½° to the east-south-east and at 10,000 feet the lower beds dip 11° to the east. This unconformity may represent the Permian-Carboniferous contact. There is a second unconformity at about 13,000 feet. Reflections continued to 20,000 feet in the Talbot Syncline area.

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 1,000 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 the Noonkanbah Formation. The Liveringa Formation occurs on the southern flank as a 150-foot-high strike ridge forming the Shore Range, and only as discontinuous rises on the northern flank.

Flank dips along the northern side of the structure reach a maximum of 5°. Dips along the southern flank range between 3° and 14° and are affected locally by the development of a secondary anticlinal structure covering an area of approximately 60 square miles. Variations in dip and strike have resulted from the movements of the blocks between the numerous transverse faults which intersect the structure.

The system of northerly-trending faults is similar to that described from the Poole Range/Mount Hutton Structure. Twenty-five of the larger faults were examined, and, in general, they can be traced across the structure and well down the flanks. The displacement is greatest on the flanks and, apparently, least in the crestal area. All faults that can be traced across the axis are of the normal high-angle pivotal type: the dip and displacement directions reverse from one side of the axis to the other, with a double reversal where the faults cross the double axis on the southern central flank.

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

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

The formations are poorly exposed, and transverse faulting and in some places complex faulting, coupled with the lack of outcrop, prevent an accurate determination of closure. Seismic refraction traverses across this structure (Vale et al., 1953) suggested that the structure at depth is complex and does not conform with the domal structure at the surface. There is probably an unconformity at 2,000 feet and another at 7,000 feet, and faulting is present through the section to at least 7,000 feet; the maximum calculated throw of any of these subsurface faults was 1,700 feet. Also, the dips on the deeper beds are usually much greater than those shown at the surface. Gravity traverses (Wiebenga et al., 1953) completed before the seismic investigations gave a similar result. In fact it was suggested that a "large gravity minimum extends across the Nerrima structure". By using a density contrast of 0.22 between the Permian and underlying rocks, the base of the Permian is calculated at 7,000 to 8,000 feet. The gravity survey also indicated a "high" between the two large minima situated immediately south-east of the Nerrima surface structure; this "high" may indicate a basement high or a dome.

The oil bore drilled by Associated Freney Co. in 1955 to 9,072 feet may have terminated in Carboniferous beds; if so, the seismic and gravity unconformity at 7,000 or 8,000 feet could represent the Permian-Carboniferous contact.

Tutu Structure.—The structure is the most westerly culmination on the Southern Anticlinal belt; it is 10 miles long and 6 miles wide. The western plunge is well defined although it contains a number of faulted wedges of Grant Formation and Poole Sandstone near 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 Deep Well structure is separated from the Nerrima and Tutu anticlines by the well-defined Dry Corner syncline; its axis is 18 miles north-west of the Nerrima Bore. On the northern flank of the anticline is the small well-defined Myroodah Syncline.

Both flanks of the Anticline are clearly revealed on aerial photographs, but faulting and lack of outcrop have 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 Noonkanbah Formation, and in the lower part of Liveringa Formation.

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°.

Wiebenga et al. (1953) suggested that a small gravity anomaly may be related to the Deep Well Anticline (or "Myroodah Anticline" as he called it). A seismic reflection traverse in 1954 (Williams, 1955) confirmed that the surface anticlinal structure became more pronounced in depth and it extends to about 24,000 feet. As with all other anticlinal structures in the Fitzroy Basin, there was a lack of reflections from the axis of the anticline; the gap in reflections in the Deep Well Anticline was 2 miles; this was less than in other anticlines. About 3 miles south-west of Myroodah Homestead the seismic traverses revealed a prominent syncline, but there were no strong reflections in the syncline below 4,000 to 5,000 feet, whereas reflections continued to 24,000 feet in the Deep Well anticline; the strong reflector in the syncline may prevent further passage of energy to the deeper beds. Over the anticline the dip of the reflecting beds increases with depth. Williams suggested that a strong reflector at 1,500 feet on the anticlinal axis would be the Noonkanbah-Poole junction. However, from a recent oil bore drilled on this structure by Associated Freney Co., to 6,001 feet, Traves (1956) regards the reflector as representing the Liveringa-Noonkanbah boundary and it is expected that the base of the Permian succession would be about 12,000 feet.

McLarty Syncline.—South of the Nerrima Structure a synclinal axis parallel to the Fenton Fault can be traced for 28 miles from north-west of Barnes Flow to near Andy's Bore, north-east of Mount Fenton. The axis of this structure is in the Liveringa Formation and the flanks consist of the Noonkanbah Formation.

The syncline is 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.

Mount Wynne Structure.—Both the Mount Wynne and Grant Range Structures are characterized by longitudinal faults together with normal transverse faults. As a result the dips of the beds in the axial areas are very variable in amount and direction. On the flanks the plunging anticlinal pattern is more obvious.

The core of the Mount Wynne Structure consists 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 north and south flanks.

Two culminations have been mapped on the structure, one near Mount Wynne and the other west of Paradise Homestead. Small folds and strike faults in the Poole Sandstone and Grant Formation occur between the two culminations.

Faults trending north and slightly west of north are most common, but displacements probably do not exceed 100 feet.

East-trending strike faults are more pronounced, and a major strike fault passes between Jimberlura Hill and the Jimberlura Ridges; it has a displacement of 1,500-2,000 feet north of Jimberlura Hill, with decreasing displacement to the north-west. A similar strike fault of unknown displacement passes through Mount Wynne and terminates the local set of north-trending faults; other probable strike faults occur between the Mount Wynne and Paradise folds.

Grant Range Structure.—The Grant Range Structure is a large faulted plunging anticline comparable in size to the St. George Range Structure; it has the Noonkanbah Formation on the flanks and plunges. It is stratigraphically similar to the St. George Range Structure, but differs from it in the strong development of strike faults with subordinate transverse faulting; the larger faults have a displacement exceeding 1,000 feet.

Warrawadda Structure.—The Warrawadda Structure has been mapped mainly from aerial photographs in an area of gentle folding adjacent to the Derby/Fitzroy Crossing Highway. The anticline is flanked on each side by a syncline.

The structure has Liveringa Formation on flanks and plunges and possibly contains a core of Noonkanbah Formation. Surface outcrop is absent and stratigraphical interpretation is based on loose surface rubble, soil types, and water-bore information.

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

Talbot Syncline.—The Talbot Syncline is a small structure parallel and closely related to the Pinnacle Fault. It has been identified between 6 Mile Bore and Mount Talbot, where dip readings indicate a plunging asymmetrical syncline; the beds on the north-east side are the steeper. Beds of the Liveringa Formation form the axial region of the fold and are underlain to the south-west by beds of the Noonkanbah Formation. To the north-east the Liveringa Formation outcrops against the Pinnacle Fault and the underlying Noonkanbah Formation does not appear.

North-west of the Talbot Syncline there are indications of further gentle folds, but outcrops are poor and scattered. Seismic work by Smith (1955) indicates about 20,000 feet of sediment in the syncline, with probable unconformities at 8,000 and 13,000 feet.

The Sisters Structure.—About 10 miles north-east of Erskine Hill is a structure extending for about 10 miles north-west from Blina Homestead. Blina Shale forms the black soil plains on the north-eastern side of this structure and Erskine Sandstone overlies Liveringa and probably Noonkanbah Formation on the south-western side. About 1,000 feet of Blina Shale has been proved during water boring. The structure is probably a terrace (Wade, 1936) or monocline, a fault line or an angle-of-rest type unconformity trending north-west.*

LEUCITE-BEARING INTRUSIVES.

Twenty leucite-rich intrusives are known from the Fitzroy Basin and have been described in detail by Wade and Prider (1940). The intrusives are described as plugs and craters by Wade, and Prider has described them as lamproites. Apart from the rock italite they are the richest leucite-bearing rocks known.

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

The two plugs of the Kalyeeda Hills are intrusive into sediments of the Liveringa Formation in the syncline immediately south of the Southern Anticline. These are the only intrusives known from this synclinal axis.

Most intrusives penetrate beds in the syncline between the Southern and Central Anticlines. Sixteen are known from this syncline: Bruten's Hill, " P " Hill, Mount Ibis, Machell's Pyramid, Mount Abbott, White Rocks, Howe's Hill, Fishery Hill, Mamilu Hill, Mount Gytha, Djada Hill, Mount Cedric, Noonkanbah Hill, Hill's Cone, Wolgidee Hill and Mount Noreen.

With the exception of White Rocks, these intrusives have penetrated the section as high as either the Noonkanbah Formation or Liveringa Formation. At White Rocks, the lamproite intrudes the Triassic Blina Shale.

Moulamen Hill** is the only intrusive known from the syncline between the Central and Northern Anticlines.

The intrusives of Mount Percy and Mount North have no obvious connexion with structures 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, south of the Oscar Range, intrudes Grant Formation and it has no known structural affinities

* Detailed geophysical work has lately been done by Associated Freney, who own the lease, and has revealed that the Sisters Structure may represent the southern edge of a continental shelf (Mines Administration, 1956)

** This has been re-named Rice Hill by Dept. of Lands and Survey, W.A.

At "P" Hill fragments of fossiliferous Liveringa Formation are caught up in the intrusives.

The presence of volcanic material in the Lower Cretaceous sediments of Dampier Land may indicate a Lower Cretaceous age for the Fitzroy Lamproites, but as pointed out by Brunnschweiler (1954) the mica found in the Lower Cretaceous sediments is different from that found in the lamproites, and therefore the sediments may not be related at all to the lamproites. The lamproites intrude the Blina Shale and are therefore younger than Upper Triassic. Pyroclastic material crops out at the base of the lavas at Mount North and rests on sandstone of the Grant Formation. The base of the pyroclastic beds is about 20 feet above present ground level at the base of Mount North. This suggests that the surface in this area has been little eroded since the intrusion of the plugs. The plugs may possibly, therefore, be of Tertiary age.

SEDIMENTARY ENVIRONMENTS OF ORDOVICIAN AND DEVONIAN SEDIMENTATION.

Ordovician.

The Ordovician section, and in particular the lower part of the outcropping section (Emanuel Formation), is characterized by a particularly rich marine fauna in shale and limestone. Glauconite and limonite (after pyrite) have been observed in these beds. The lithology and fauna indicate that the formation was deposited on a slowly 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 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 more unstable conditions and in warmer water than the Emanuel Formation.

The Ordovician shoreline may have been close to the present outcrop and in a similar position to the shoreline in Devonian time. If so, 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 may well have extended south into the remainder of the Canning Basin, and certainly it covered some of the Fitzroy Basin; large areas of Ordovician sediments within the basin may therefore be preserved. As the Prices Creek area represents shelf-type conditions, areas of deeper-water environment can be expected in the Fitzroy Basin, with a consequent variation in fauna and lithology.

Devonian.

Middle Devonian.—The Pillara Formation is notable because the rock types developed are consistent over large areas. All the outcrops are of sediments, both organic and terrigenous, 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 of temperature, salinity, oxygen content, and depth play a major role in forming bioherms and biostromes that are characteristic of the Pillara Formation.

Upper Devonian.—The Upper Devonian is represented broadly by three types of deposit; the quartzose clastic group (Mount Pierre Group, Fossil Downs Formation, Copley Formation, Brooking Formation and Napier Formation), the calcarenite/reef group (Geikie Formation, Oscar Formation, Bugle Gap Limestone) and the clastic shale group (Fairfield Beds). All three types were developed on a mildly unstable shelf in an environment ranging from epineritic to epineritic biostromal. Under suitable conditions biohermal growths thrived, but in other areas biohermal growth was inhibited by adverse local shoreline environments. Although the quartzose clastic group and the calcarenite reef group were to a large extent contemporaneous, the marked difference in sediments 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 sediment exposed, was deposited under different conditions, possibly in deeper water.

The absence of sediments of Silurian age in Western Australia suggests that the sea receded at the close of the Ordovician; it may have retreated beyond the present continental margin.

At least as early as Middle Devonian there was a major transgression which eventually formed a shoreline a short distance east of the present outcrop areas. The outcrops have revealed the presence of a reef and biostromal 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 too fast for bioherms or biostromes to grow, corresponding calcareous sediment would be deposited under reducing conditions.

At the end of the Middle Devonian there was a further regression from the shelf area. How far the sea receded cannot be determined, owing to lack of outcrop and subsurface 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 early Upper Devonian. The unconformity between Middle and Upper Devonian, revealed in the outcrop area, may therefore be restricted to marginal areas, whereas deposition was continuous in other areas throughout the Middle and Upper Devonian.

PETROLEUM PROSPECTS.

Source and Reservoir Rocks.

Ordovician.—The Prices Creek Group contains the highest-grade source rocks for petroleum known in the area. Shallow drilling during 1919 to 1922 produced several showings of oil in these rocks (at that time the rocks were considered to be of Devonian age). Petroliferous shale is common in the Emanuel Formation.

The rich marine fauna found throughout the 2,630-foot sequence, the evidence of reducing conditions during deposition, and the possibility of a much wider development of the Prices Creek Group in the Fitzroy Basin, show the Group to contain promising potential source-rocks. Potential reservoir rocks exist in the sandy beds towards the top of the Group, and the development of solution or joint cavities in the dolomite at the unconformity between the Ordovician and later sediments.

Devonian.—The outcropping section in the Middle and Upper Devonian of the Fitzroy Basin reveals no source rock.

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 oxidizing environment inherent in reef growths. The deeper-water sediments deposited during the time of reef growth may be highly favorable source rocks, and as a result of migration oil 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 favorable areas.

As pointed out previously, reef growths and associated marine limestones and clastic sediments may be present; they could act as reservoir rocks and source rocks in structurally favorable situations.

Permian.—The outcropping sequence in the Fitzroy Basin contains no marine sediments which could be classed as source rocks except parts of the Noonkanbah Formation. Numerous beds would be favorable reservoir rocks. More favorable facies might possibly be encountered in the sub-surface section under the Dampier Land Peninsula.

CAP ROCKS.

Ordovician.—The Emanuel Formation consists of interbedded limestone and shale; the shale beds would act as suitable cap rocks. The upper Gap Creek Formation contains no beds which could be considered reliable cap rocks.

Devonian.—Generally, the Middle Devonian contains no suitable cap rock beds; but the Upper Devonian contains numerous horizons with low permeability; the permeability would be expected to decrease in deeper water equivalents. The Fairfield Beds, the uppermost Devonian sequence, are not well known. but are suspected to contain shale horizons which would be ideal as cap rocks.

Permian and Triassic.—Both the Noonkanbah Formation and the Blina Shale contain shale horizons which act as impermeable layers, a feature consistently confirmed by water-boring. The Noonkanbah Formation could act as cap rock on structures such as the Nerrima Structure, Tutu Structure, Deep Well Anticline and Warrawadda Structure.

The Blina Shale could be of value only where it is overlain by younger sediments, as for example in Dampier Land Peninsula. Elsewhere, the shale has been eroded from anticlinal structures.

GENERAL.

Throughout the foregoing remarks it has been emphasized that outcrop, surface structure, and limited geophysical work are the only factors upon which the conclusions expressed are based. The interpretation of the sub-surface geology is highly controversial and 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 are better developed below the surface, good opportunities would exist for obtaining petroleum in suitable structural or stratigraphical traps.

It is relevant to compare the Fitzroy Basin with the Williston Basin (Burg, 1952; Barnes, 1953) which extends from northern United States of America into southern Canada. In this area a similar stratigraphical section to that in the Fitzroy Basin is known: the main difference is the occurrence of Silurian. Few successful bores had been sunk in the Williston Basin until recent exploration proved the existence of accumulations in Ordovician, Devonian, and Permian rocks.

In the Fitzroy Basin the presence of petroliferous horizons in the Palaeozoic (particularly in the Ordovician) has been known for over 30 years. Although several bores have been put down since 1919, only the Grant Range No. 1 bore, drilled by West Australian Petroleum Pty. Ltd., in 1955, has been drilled on a suitable structure to a definite horizon (Carboniferous) below the Permian. Only five geological structures have been drilled specifically for oil. These were: Poole Range Structure (total maximum depth 3,264 feet in No. 3 Bore), Mount Wynne Structure (total depth 2,154 feet in No. 3 Bore), Nerrima Structure (9,072 feet in Associated Freney Nerrima No. 1 Bore), Deep Well Structure (6,001 feet in Associated Freney Myroodah No. 1 Bore) and Grant Range Structure (12,915 feet in Wapet No. 1 Bore). The bores in Prices Creek area were shallow holes drilled in Ordovician rocks and not located on defined structures. For various technical reasons all bores except Grant Range and probably Nerrima ceased drilling in Grant Formation; traces of oil were reported from Mount Wynne, Poole Range, and Nerrima.

Reeves (1951) stated that the prospects of finding oil south of the Fenton Fault are "practically nil". Although this presumption may in fact be true there is insufficient evidence to substantiate such a claim. If, for example, conditions during Devonian sedimentation were favorable 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 Precambrian in the central part of the Canning Basin desert.

No structures, therefore, have been adequately tested (at least to Devonian or Ordovician reservoir beds) during drilling operations in an area where the surface geological survey has indicated a reasonable possibility of finding oil in economic accumulations.

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 6). The logs of shallow bores sunk during the early days of settlement in the area are not available. The stratigraphical position of the bores in Table 7 is an interpretation based on the surface geological knowledge and the drillers' logs. If the bore has been completed near a sub-surface boundary between two formations it is not always possible to decide 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 dry bores has been tabulated.

TABLE 7.

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

The number of bores drilled in the various stratigraphical 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 Formation. The percentage of successful and unsuccessful bores provides 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 Formation, and Poole Sandstone. These units are primarily sandstone sequences with numerous horizons from which a supply of sub-artesian water can be expected. The water is potable in all bores except those tapping Noonkanbah rocks and some in the Liveringa Formation and Jurassic.

The Triassic sequence contains over 1,000 feet of shale (Blina Shale) which is impermeable and can be considered unsuited as a source of underground water. The overlying sandstone (Erskine Sandstone) is a favorable 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 2,000 feet may be required (1,200 feet Noonkanbah and 1,000 feet Blina) 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 of shale with low permeability. Only the uppermost and lowermost beds are likely to be aquifers.

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 sites. The few bores which have been drilled in the Devonian do not permit the ground-water supplies that may be available to be adequately assessed. The following remarks are therefore subject to modification as more data become available.

The Pillara Formation, Sadler Formation, and Bugle Gap Limestone are not generally suited for bore sites, owing to rough topography. It would be possible to select sites in valleys such as Menyous Gap, Gap Spring, &c., if water supply were needed in those areas; all water would probably only be found in joints and the sandy beds at the base of the Pillara Formation.

Experience has shown that the Mount Pierre Group is a 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 aquifer at a lower horizon.

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

The Oscar Formation, Geikie Formation, Brooking Formation, and Copley Formation are unsuited topographically for bore sites.

The Fairfield Beds have 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 (Van Emmerick Conglomerate, Behn Conglomerate, Stony Creek Conglomerate, Burramundi Conglomerate, Mount Elma Conglomerate and Sparke Conglomerate). These sediments are obvious sources of underground water and when found inter-fingering with the otherwise impervious Mount Pierre Group and Fossil Downs Formation 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.

STRUCTURAL AND PETROLEUM PROBLEMS.

The seismic and gravity surveys which have continued since 1953 have obtained a good reconnaissance coverage of the Fitzroy Basin. Airborne magnetometer work has extended the subsurface coverage of the basin as well as relating the structure of the Fitzroy Basin to that of the Canning Basin.

The recent activity in the Fitzroy Basin by private oil companies and the oil wells drilled as a result have elucidated many stratigraphical problems; simple anticlinal structures have been tested with negative and rather startling results. Sections which were expected to contain 1,000 feet or so of sediments have shown two to four times this thickness when drilled; formations which have been suspected from a marginal study of the basin have been proved to be of considerable thickness within the basin.

Stratigraphic holes drilled in 1955-56 yielded limited but worthwhile results.

The two major structural elements of the Fitzroy Basin are the anticlines and the Pinnacle and Fenton Faults.

Geophysical evidence has shown that the anticlines do not necessarily persist at depth and the surface axis does not correspond with the subsurface axis. Furthermore, the anticlinal structures that have been drilled have shown a large increase in the thickness of Permian and Carboniferous sediments and the drill has not penetrated to possible Ordovician or Devonian reservoir rocks. Moreover, suitable source and reservoir rocks are found in the Ordovician and Devonian formations; the Poole Range is the nearest major structure to these outcropping formations and geophysical evidence suggests that about 20,000 feet of sediments lie above " basement ", with unconformities at 8,000 and 13,000 feet; this is measured on the flanks of the structure and thicknesses are expected to be less under the surface axis of the Poole Range.

The Pinnacle and Fenton Faults have not been definitely elucidated. Geophysical evidence suggests that there is a large depression in the basement on the southern side of the Pinnacle Fault and on the northern side of the Fenton Fault, and there is some reason to regard the Fenton Fault as representing the north side of a north-west-trending ridge in basement

No matter whether the Fenton Fault is a dominant fault or merely the surface trace of the edge of a ridge it is evident that a drill-hole situated south of the Fenton Fault would encounter older strata (possibly Devonian or Ordovician reservoir rocks) at a shallower depth than in the Fitzroy Basin proper.

The possible extension of the Precambrian core of the Oscar Range to the north-west should be investigated. Not only could this core have formed islands around which grew Devonian and possibly Ordovician reefs that have been covered by Permian sediments, but the core could have formed a barrier behind which was deposited (in the Fairfield Valley area) a back-reef facies in probably stagnant water at least in middle Devonian or possibly Ordovician time.

The main structural problems which need elucidating, and problems which will have a major effect on petroleum accumulation in the basin, are—

1. The nature of the area south of the Fenton Fault; geophysical work could be continued in this area with a view to locating a suitable structural "high" to be tested by a deep stratigraphic drill-hole. The area south-west of Barnes Flow is suggested for geophysical work and it is essential to carry traverses across sand country for at least 20 miles.

2. Whether the Oscar Range Precambrian core extends to the north-west as a linear structure; geophysical as well as detailed geological work is required to determine the existence of a Precambrian high and to examine any changes in the Devonian fauna which may indicate an environmental change from marginal reef forms to those of back-reef lagoonal types.

3. What rocks underlie the Pinnacle Fault on the north-east side. Geophysical evidence suggests that the Ordovician has less than 900 feet of non-outcropping section, and that Precambrian underlies the Ordovician. A shallow stratigraphic hole should clarify the geophysical evidence of shallow basement in this area.*

4. The Pinnacle Fault continues as a major structural feature to the north-west; the structure gives such a sharp seismic profile in the Prices Creek area that further work along a possible continuation to the north-west would give positive and important results. A "roll" or subsurface structure may develop on the subsurface profile; such a structure could act as a trap for petroleum, formed in the basin proper, which may have migrated up dip.

5. What underlies the Grant Formation in Poole Range. Anticlinal structures that have been drilled in the central part of the basin have over 10,000 feet of Carboniferous and Grant Formation sediments. The Poole Range is the nearest surface structure to the outcropping Ordovician and Devonian rocks and if anticlines are to be drilled in the future within the Fitzroy Basin, the Poole Range is suggested as the logical choice; the Grant Formation here is expected to be not less than 6,000 feet thick.

* B.M.R. No. 3 Bore, Prices Creek Area, drilled in May, 1956, penetrated 200 feet of dolomitic sandstone, 390 feet of arkosic sandstone, 82 feet of basic volcanics (perhaps similar to the Hart Basalt) and terminated in granitized schist and hornfels at 694 feet.

REFERENCES.

BARNES, T. B., 1953.—Williston Basin, New Province for Oil Exploration. *Bull. Amer. Ass. Petrol. Geol.*, 37 (2), 340.

BASEDOW, H., 1918.—Narrative of an Expedition of Exploration in North-western Australia. *Proc. S. Aust. Br. geogr. Soc. Aust.*, 18, 102-295.

BLATCHFORD, T., 1922.—Petroleum Indications in the Kimberley Division. *Ann. Rep. geol. Surv. W. Aust.*, 1921, 19.

BLATCHFORD, T., 1927.—The Geology of Portions of the Kimberley Division, with special reference to the Fitzroy Basin and the possibilities of the occurrences of Mineral Oil. *Geol. Surv. W. Aust. Bull.*, 93.

BLATCHFORD, T., 1928.—Boring for Mineral Oil at Poole Range. *Ann. Rep. Dep. Min. W. Aust.*, 1928, 17.

BLATCHFORD, T., 1929.—Boring for Mineral Oil at Poole Range. *Ann. Rep. Dep Min. W. Aust.*, 1929, 86.

BREMNER, C. St. J., 1940.—Aerial Geological Reconnaissance of the Fitzroy Desert Basin, Western Australia. Unpublished report to *Caltex (Aust.) Oil Develop. Pty Ltd.*

BREMNER, C. St. J., 1942.—Aerial Reconnaissance of the South Margin of the Fitzroy Basin, Western Australia. Unpublished report to *Caltex (Aust.) Oil Develop. Pty Ltd.*

BRETNALL, R. W., 1926.—Descriptions of some Western Australian Fossil Polyzoa. *Geol. Surv. W. Aust. Bull.* 88, 7.

BURG, K E., 1952.—Exploration Problems of the Williston Basin. *Geophysics*, 17 (3).

BRUNNSCHWEILER, R., 1954.—Mesozoic Stratigraphy of the Canning Desert. *J. geol. Soc. Aust.*, 1, 35.

BRUNNSCHWEILER, R., 1957.—Geology of Dampier Peninsula. *Bur. Min. Resour. Aust. Rep.* 13.

CHAPMAN, F., 1924a.—THE WADE COLLECTION OF FOSSILS. Commonwealth of Australia.

CHAPMAN, F., 1924b.—List of Fossils from West Kimberley. *Ann Rep. geol. Surv. W. Aust.*, 1923, 35.

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, 175.

CHRISTIAN, C. S., and STEWART, G. A., 1952.—Report on Preliminary Examination of Several Areas in the West Kimberley Division of Western Australia. *Sci. ind. Res. Org. Melb., Unpub. Rec.* 52/1.

CLAPP, F. G., 1925.—A few observations on the Geology and Geography of the North-west and Desert Basins, Western Australia. *Proc. Linn. Soc. N.S.W.*, 50 (2), 47.

CLAPP, F. G., 1926.—Oil Prospects of the Desert Basin of Western Australia. *Bull. Amer. Ass. Petrol. Geol.*, 10 (11), 1118.

CLAPP, F. G., 1926.—The Oil Problem in Western Australia. *Econ. Geol.*, 21, 409.

CLARKE, E. de C., 1937.—Correlation of the Carboniferous and Permian Formations of Australia. Part 2, Western Australia. *Rep. Aust. Ass. Adv. Sci.*, 1937, 427-28.

COLEMAN, P. J., 1957.—Permian Productacea of Western Australia. *Bur. Min. Resour. Aust. Bull.*, 40.

CRESPIN, I., 1947.—Foraminifera of the Permian rocks of Australia. *Bur. Min. Resour. Aust. Bull.*, 15.

CRESPIN, I., 1955.—Micropalaeontological Examination of Fraser River Structure Hole. *Bur. Min. Res. Aust. Rec.*, 1955/86.

CRESPIN, I., 1956a.—Micropalaeontological Investigations in the Bureau of Mineral Resources 1927-52. *Bur. Min Resour. Aust. Rep.*, 20.

CRESPIN, I., 1956b.—Micropalaeontological Examination of Fraser River No. 1 Well. *Bur. Min. Resour. Aust. Rec.*, 1956/86.

CRESPIN, IRENE, 1958.—Permian Foraminifera of Australia. *Bur. Min. Resour. Aust. Bull.*, 48 (in press).

CROCKFORD, J., 1944a.—A revision of some previously described Bryozoa from the Upper Palaeozoic of Western Australia. *J. Roy. Soc. W. Aust.*, 28 (1941-2), 187.

CROCKFORD, J., 1944b.—Bryozoa from the Wandagee and Noonkanbah Series (Permian) of Western Australia (Part 1). *J. Roy. Soc. W. Aust.*, 28 (1941-2), 165-185.

CROCKFORD, J., 1944c.—Bryozoa from the Permian of Western Australia, Part 1. *Proc. Linn. Soc. N.S.W.*, 69, 139-175.

CROCKFORD, J., 1951.—The Development of Bryozoan Faunas in the Upper Palaeozoic of Australia. *Proc. Linn. Soc. N.S.W.*, 76 (3-4), 105.

CROCKFORD, J., 1957.—Permian Bryozoa from the Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.*, 34.

DAVID, T. W. E., 1924a.—Discovery of Glacial Erratics and Tillite by T. Blatchford and H. W. B. Talbot in the Kimberley area of Western Australia. *Rep. Aust. Ass. Adv. Sci.*, 17, 77-80.

DAVID, T. W. E., 1924*b*.—Notes on the Stratigraphy of the Permo-Carboniferous Beds of Kimberley. *Ibid.*, 17, 62.

DAVID, T. W. E., and BROWNE, W. R., 1950.—THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA. London, Arnold.

DAVID, T. W. E., and SUSSMILCH, C. A., 1936.—The Carboniferous and Permian Periods in Australia. *16th Int. geol. Cong.*, 1, 629-44 (Washington).

DELEPINE, G., 1935.—Upper Devonian Goniatites from Mount Pierre, Kimberley District, Western Australia. *Quart. J. geol. Soc. Lond.*, 91, 208.

EDWARDS, A. B., 1953.—An oolitic iron formation from north-western Western Australia. *Sci. ind. Res. Org. Melb., Miner. Inv. Rep.*, 540.

ETHERIDGE, R., Jnr., 1889.—Remarks on Fossils of Permo-Carboniferous Age from North West Australia, in the MacLeay Museum. *Proc. Linn. Soc. N.S.W.*, 4 (2), 199.

ETHERIDGE, R., Jnr., 1914.—Palaeontological Contributions to the Geology of Western Australia. *W. Aust. geol. Surv. Bull.*, 58.

ETHERIDGE, R. Jnr., 1918.—Observations on Carboniferous and other Fossils. *Proc. S. Aust. Br. geogr. Soc. Aust.*, 18 (1916-17), 250.

FENTON, C. L., 1943.—A New Devonian Alga from Western Australia. *Amer. Midl. Nat.*, 30, 112.

FINDLAY, W. A., 1942.—Geologic Report, North-western Basin, Kimberley Division, Western Australia. Unpub. report to *Caltex (Aust.) Oil Develop. Pty Ltd.*

FINUCANE, K. J., 1939.—The Barker River Area—West Kimberleys. *Aer. Surv. N. Aust., W. Aust. Rep.*, 43.

FITZGERALD, W. V., 1907.—Reports on Portions of the Kimberleys, 1905-6. *W. Aust. parl. Pap.* 19.

FLETCHER, H. O., 1943.—The Genus *Conocardium* from Australian Palaeozoic Rocks. *Aust. Mus. Rec.*, 21 (5), 231.

FLETCHER, H. O., 1946.—New Lamellibranchia from the Upper Permian of Western Australia. *Aust. Mus. Rec.*, 21 (7), 395.

FOORD, A. H., 1890.—Description of fossils from the Kimberley District, Western Australia. *Geol. Mag.*, 27, 2.

FORMAN, F. G., 1930.—Notes on the Geology and Petroleum Prospects of the Desert Basin of Western Australia. *Ann. Rep. Dep. Min. W. Aust.* (1929), 97.

FORMAN, F. G., 1931.—Artesian Water Possibilities on Kimberley Downs and Napier Downs Stations, West Kimberleys. *Ann. Rep. geol. Surv. W. Aust.* (1930), 31.

GLAUERT, L., 1910.—West Australian Fossil Plants. *Geol. Surv. W. Aust. Bull.*, 36, 107.

GLAUERT, L., 1921.—Pleistocene fossil vertebrates from the Fitzroy River, Western Australia. *J. Roy. Soc. W. Aust.*, 7, 85.

GLAUERT, L., 1926.—A list of Western Australian fossils. *Geol. Surv. W. Aust. Bull.*, 88, 36.

GLENISTER, B. F., 1958.—Upper Devonian ammonoids from the *Manticoceras* zone, Fitzroy Basin, Western Australia. *J. Paleont.*, 32 (1), 58-96.

GLOVER, J. E., 1956.—Petrology and Petrography of limestones from the Fitzroy Basin. *Bur. Min. Resour. Aust. Rep.*, 18.

GUPPY, D. J., CUTHBERT, J. D., and LINDNER, A. W., 1950.—Geology of the Nerrima Dome. *Bur. Min. Resour. Aust. Rep.* 4.

GUPPY, D. J., and LINDNER, A. W., 1949.—Preliminary Report on the Geology of Dampier Land. *Bur. Min. Resour. Aust. Rec.* 1949/11 (unpubl.).

GUPPY, D. J., and OPIK, A. A., 1950.—Discovery of Ordovician Rocks, Kimberley Division, Western Australia. *Aust. J. Sci.*, 12 (6), 205.

GUPPY, D. J., LINDNER, A. W., RATTIGAN, J. H., and CASEY, J. N., 1952.—The Stratigraphy of the Mesozoic and Permian Sediments of the Desert Basin, Western Australia. *XIXième Cong. géol. int.* (Gondwana Symposium), Alger, 1952.

HARDMAN, E. T., 1884.—Report on the Geology of the Kimberley District, Western Australia. *W. Aust. parl. Pap.* 31.

3336/57.—6

HARDMAN, E. T., 1885.—Report on the Geology of the Kimberley District, Western Australia. *Ibid.*, 34.

HENDERSON, S. D., 1956a.—Lithological log, bore B.M.R. 2, Laurel Downs, Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1956/49 (unpubl.).

HENDERSON, S. D., 1956b.—Stratigraphic Drilling, West Kimberley Division, Western Australia —B.M.R. 1, Jurgurra Creek. *Ibid.*, 1956/94 (unpubl.).

HENDERSON, S. D., 1956c.—Stratigraphic Drilling, West Kimberley Division—B.M.R. 2, Laurel Downs. *Ibid.*, 1956/95 (unpubl.).

HENDERSON, S. D., 1956d.—Stratigraphic Drilling, West Kimberley Division, Western Australia—B.M.R. 3, Prices Creek. *Ibid.*, 1956/96 (unpubl.).

HILL, D., 1936.—Upper Devonian Corals from Western Australia. *J. Roy. Soc. W. Aust.*, 22, 25.

HILL, D., 1937.—The Permian Corals of Western Australia. *Ibid.*, 23, 43.

HILL, D., 1943.—Further Permian Corals from Western Australia. *Ibid.* (1940-41), 27, 57.

HILL, D., 1954.—Coral Faunas from the Silurian of New South Wales and the Devonian of Western Australia. *Bur. Min. Resour. Aust. Bull.* 23.

HILL, W. G., 1955.—Nerrima No. 1 Exploration Well, Final Report for Associated Freney Oil-fields N.L. *Unpubl. report for Mines Administration Pty.*

HILL, W. G., 1956.—Myroodah No. 1 Exploration Well, Final Report. *Unpubl. report for Mines Administration Pty.*

HINDE, C. J., 1890.—Notes on the Palaeontology of Western Australia, Part 2, corals and Polyzoa. *Geo. Mag.*, III., 7, 194.

HOBSON, R. A., 1936.—Summary of Petroleum Exploration in Western Australia to January, 1935. *Ann. Rep. geol. Surv. W. Aust.*, (1935), 22.

HOSKING, L. V. F., 1931.—West Australian Orthotetinae. *J. Roy. Soc. W. Aust.*, 18, 43.

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. *J. Roy. Soc. W. Aust.*, 19, 67.

HOWELL, B. G., 1944.—Calcareous Sponges in Devonian of Australia. *Bull. geol. Soc. Amer.*, 55, 146.

JACK, R. L., 1906.—The Prospects of Obtaining Artesian Water in the Kimberley District. *Geol. Surv. W. Aust. Bull.* 25.

JUTSON, J. T., 1934.—The Physiography of Western Australia. *Geol. Surv. W. Aust. Bull.* 95.

KRAUS, P. S., 1941.—Geologic and Stratigraphic Reconnaissance, North-west Portion Caltex Concession 7-H, Kimberley Division, Western Australia. *Unpubl. Rep. to Caltex (Aust.) Oil Develop. Pty Ltd.*

KRUMBEIN, W. C., and SLOSS, E. C., 1951.—STRATIGRAPHY AND SEDIMENTATION. California, Freeman.

LARCOMBE, C. O. G., 1911.—Geology of Western Australia. *W. Aust. Sch. Min.*, 5.

MADDOX, W. H., 1941.—A geologic Reconnaissance of the North-east part of the Fitzroy Basin, Western Australia. *Unpubl. Rep. to Caltex (Aust.) Oil Develop. Pty Ltd.*

MAITLAND, A. G., 1907.—Recent Advances in the Knowledge of the Geology of Western Australia. *Rep. Aust. Ass. Adv Sci.*, 11, 131.

MAITLAND, A. G., 1919.—Coal Deposits of Western Australia. *Geol. Surv. W. Aust. Mem.* 1, ch. II., Pt. III., p. 8.

MAITLAND, A. G., 1920.—Development of Water Power for the Generation of electricity, Kimberley Division, Western Australia. *Ann. Rep. W. Aust. Dep. Min.*, (1920), 179.

MAITLAND, A. G., and MONTGOMERY, A., 1924.—The Geology and Mineral Industry of Western Australia. *Geol. Surv. W. Aust. Bull.* 89.

MATHESON, R. S., and GUPPY, D. J., 1949.—Geological Reconnaissance in the Mount Ramsay Area, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1949/48 (unpubl.).

MILLER, A. K., 1936.—A new Permian Ammonoid Fauna from Western Australia. *J. Paleont.*, 10, 684.

MILLER, A. K., 1938.—Devonian Ammonoidea of America. *Sp. Pap. geol. Soc. Amer.*, 14.

MINES ADMINISTRATION, 1956.—Geological and geophysical survey, The Sisters Permit (LP17h), West Kimberley Division, Western Australia. *Unpubl. Rep.*

NEWTON, R. B., 1892.—Occurrence of *Chonetes pratti* (Davidson) in Carboniferous of Western Australia. *Geol Mag.*, 9, 542.

NICHOLSON, H. A., 1890.—Notes on the Palaeontology of Western Australia 1. Stromatoporoidea. *Geol. Mag.*, 27, 193.

PRENDERGAST, K. L., 1935.—Some Western Australian Upper Palaeozoic Fossils. *J. Roy. Soc. W. Aust.*, 21, 9.

PRENDERGAST, K. L., 1941.—Permian Productinae and Strophalosiinae of Western Australia. *Ibid.*, 28, 1.

PRIDER, R. T., 1941.—Hydrozincite at Narlarla, West Kimberley. *Miner. Mag.*, 26 (173), 60-65.

RAGGATT, H. G., 1954.—The Search for Oil in Australia and New Guinea. *Aust. Inst. Min. Metall. Publ.*

REEVES, F., 1949.—Geology and Oil Prospects of Desert Basin, Western Australia. *Unpubl. Rep. to Vacuum Oil Co. Pty Ltd.*

REEVES, F., 1951.—Australian Oil Possibilities. *Bull. Amer. Ass. Petrol. Geol.*, 35 (12), 1479.

RIPPER, E. A., 1937.—Note on occurrence of *Amphipora ramosa* (Phillips) in Western Australia. *J. Roy. Soc. W. Aust.*, 23, 7.

SCHNEEBERGER, W. F., 1952.—A review of the petroleum prospects of the North-west and Fitzroy Basins of Western Australia, and suggestions for a future exploration programme. *Bur. Min. Resour. Aust. Rec.* 1952/59 (unpubl.).

SIMPSON, E. S., 1922.—Oil Prospecting, Mount Wynne, Kimberley, Western Australia. *Ann. Rep. Dep. Min. W. Aust.* (1922), 115.

SMITH, E. R., 1955.—Seismic Survey of the Poole Range Prices Creek Area. Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1955/35 (unpubl.).

SMITH, HAMPTON, 1951a.—Oil Possibilities, Dampier Land, Western Australia, January, 1951. *Unpubl. Rep. for Ampol.*

SMITH, HAMPTON, 1951b.—Oil Possibilities, Desert Basin and North West Basin, Western Australia, January, 1951. *Unpubl. Rep. for Ampol.*

TALBOT, W. H. B., 1927.—See Blatchford, 1927, p. 49

TEICHERT, C., 1939.—Nautiloid Cephalopods from the Devonian of Western Australia. *J. Roy. Soc. W. Aust.*, 25, 102.

TEICHERT, C., 1939a.—The Mesozoic Transgressions in Western Australia. *Aust. J. Sci.*, 2 (3), 84-86.

TEICHERT, C., 1939b.—Review of Western Australian Upper Palaeozoic Correlation, Palaeogeography and Tectonics. *Rep. Aust. Ass. Adv. Sci.*, 24, 92.

TEICHERT, C., 1940a.—Actinosyphonate Cephalopods from the Devonian of Australia. *J. Roy. Soc. W. Aust.*, 26, 59.

TEICHERT, C., 1940b.—Marine Jurassic of East Indian affinities at Broome, North-western Australia. *J. Roy. Soc. W. Aust.*, 26, 103-119.

TEICHERT, C., 1941a.—Observations on the Stratigraphy and Paleontology of the Devonian in the country between the Oscar Range and Bugle Gap, West Kimberley. *Unpubl. rep. for Caltex (Aust.) Oil Develop. Pty Ltd*, February, 1941.

TEICHERT, C., 1941b.—Upper Devonian Goniatite Succession of Western Australia. *Amer. J. Sci.*, 239, 148.

TEICHERT, C., 1941c.—Upper Palaeozoic of Western Australia, Correlation and Paleogeography. *Bull. Amer. Ass. Petrol. Geol.*, 25, 371.

TEICHERT, C., 1941d.—Upper Devonian near Mount Pierre, Western Australia. *Aust. J. Sci.*, 4 (2), 148.

TEICHERT, C., 1942a.—Permian Ammonoids from Western Australia. *J. Paleont.*, 16 (2), 221.

TEICHERT, C., 1942b.—Marine Upper Jurassic near Derby, North-western Australia. *Aust. J. Sci.*, 5 (1), 33.

TEICHERT, C., 1943a.—The Devonian of Western Australia. A preliminary Review. *Amer. J. Sci.*, 241, 69 and 167.

TEICHERT, C., 1943b.—*Gangamopteris* in the Permian of Western Australia. *Aust. J. Sci.*, 6, 79.

TEICHERT, C., 1946a.—The Stratigraphy of Western Australia. *Bull. Amer. Ass. Petrol. Geol.*, 31, 1, and *J. Roy. Soc. N.S.W.*, 80, 81.

TEICHERT, C., 1946b.—Palaeontology in Western Australia. *Rep. Cttee Marine Ecology*, 1945-46, 6, 72-78.

TEICHERT, C., 1949a —Observations on Stratigraphy and Palaeontology of Devonian, Western Portion of Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rep.* 2.

TEICHERT, C., 1949b —Permian Crinoid—*Calceolispongia*. *Geol. Surv. Amer. Mem.* 34.

TEICHERT, C., 1950.—Some recent additions to the Stratigraphy of Western Australia. *Bull. Amer. Ass. Petrol. Geol.*, 34 (9), 1787-94.

TEICHERT, C., 1951.—The Marine Permian faunas of Western Australia. *Paläont. Z.*, 24 (1-2), 76-90.

THOMAS, G. A., 1954.—Report on Permian Brachiopods from the Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1954/9 (unpubl.).

THOMAS, G. A., 1955.—Probable lower Carboniferous Deposits in the Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1955/37 (unpubl.).

THOMAS, G A., 1957.—Lower Carboniferous Deposits in the Fitzroy Basin, Western Australia. *Aust. J. Sci.*, 19 (4), 160.

THOMAS, G. A., 1958.—Permian Orthotetacea from Western Australia. *Bur. Min. Resour. Aust. Bull.* 39 (in press).

THOMAS, G. A., and DICKENS, J. M., 1954.—Correlation and Age of Marine Permian Formations in Western Australia. *Aust. J. Sci.*, 16 (6), 219.

TRAVES, D. M., CASEY, J. N., and WELLS, A. T., 1957.—The Geology of the South-Western Canning Basin. *Bur. Min. Resour. Aust. Rep.* 29.

TRAVES, D. M., 1956.—Discussion of the Bureau of Mineral Resources Seismic Traverse at Myroodah with relation to well data from Myroodah No. 1. *Unpubl. Rep. for Mines Administration Pty Ltd, Brisbane.*

VALE, K. R., SMITH, E. R., and GARRETT, M. J., 1953.—Seismic survey of the Nerrima Dome, Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1953/72 (unpubl.).

VALE, K. R., and WILLIAMS, L. W., 1955.—Preliminary Seismic Reflection Investigations, Broome Area, Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1955/112 (unpubl.).

WADE, A., 1924.—Petroleum Prospects, Kimberley District of Western Australia and Northern Territory. *By authority*, Melbourne.

WADE, A., 1936.—The Geology of the West Kimberley District of Western Australia. *Final Report on Concessions held by Freney Kimberley Oil Co.* (Unpubl.).

WADE, A., 1937.—The Geological Succession in the West Kimberley District of Western Australia. *Rep. Aust. Ass. Adv. Sci.*, 23, 93.

WADE, A., 1939.—The Permian Sequence in Australia. *Ibid.*, 24, 95.

WADE, A., and PRIDER, R., 1940.—The leucite-bearing rocks of the West Kimberley Area, Western Australia. *Quart. J. geol. Soc. Lond.*, 96, 39.

WALKOM, A. B., 1921.—On the occurrence of *Otozamites* in Australia, with descriptions of specimens from Western Australia. *Proc. Linn. Soc. N.S.W.*, 46 (1), 147.

WATERFORD, L. M., 1941 —Résumé of Oil Drilling Operations in the West Kimberley District of Western Australia by the Freney-Kimberley Oil Co. Ltd. and its successor the Freney Kimberley Oil Co. (1932) N.L.

WHITEHOUSE, F. W., 1933.—Permo-Carboniferous Plants in Queensland. *Qld Govt Min. J.*, 34, 37-8.

WIEBENGA, W. A., and VAN DER LINDEN, J., 1953.—Gravity Survey in the Fitzroy Basin, Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1953/64 (unpubl.).

WILLIAMS, L. W., 1955.—Seismic reflection survey over Deep Well Anticline, Myroodah, Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1955/110 (unpubl.)

WILLIAMS, L. W., 1956.—Seismic Reflection Survey in the Poole Range-Christmas Creek Area, Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1956/66 (unpubl.).

WOODWARD, H. P., 1907.—Mineral Discoveries at Narlarla, in the West Kimberley District. *Ann. Rep. geol. Surv. W. Aust.* (1906), 11.

WOODWARD, H. P., 1915.—Coal Resources of Western Australia. *Bull. geol. Surv. W. Aust.*, 64, 11.

WOOLNOUGH, W. G., 1933.—Report on Aerial Survey Operations in Australia during 1932. *By Authority*, Canberra.

APPENDIX I.

RÉSUMÉ OF REPORTED OIL SHOWS AND PETROLEUM DRILLING IN THE FITZROY BASIN.

The original report of oil showings was made during boring for water by hand-plant at Prices Creek in 1919. As a result the Western Australian Government supervised the drilling of a hole, in 1921, to 90 feet. This bore was situated in Ordovician (thought at the time to be Devonian) and traces of oil were collected; the bottom 10 feet contained .026 per cent. mineral oil. 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 Oil Company Limited, in 1922-23, drilled four holes in the Prices Creek area to depths ranging from 340 feet to 1008 feet. Nos. 1-3 were drilled in Ordovician sediments and No. 4 was west of the Pinnacle Fault and in Permian sediments. Showings of oil in bores 1-3 were obtained and submitted to the Government Analyst. The samples were described by the Analyst as pale yellow with a petroliferous odour and evidently of mineral origin. No oil was found in No. 4 bore.

Mount Wynne No. 1 bore was drilled in 1922-23, using core-making methods, and reached 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° 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 ".

Mount Wynne No. 2 and No. 3 bores were drilled with a percussion plant in 1923-25; No. 3 bore was drilled to a depth of 2,154 feet, and in No. 2 bore, tools stuck at 60 feet. Throughout the drilling of No. 3 bore, water stood within 80 feet of the surface owing to cementing failures, and the hole was eventually abandoned in Grant Formation. Oil showings were reported from several horizons, the lowest at 1,650 feet.

Samples were 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 1926-1930, five bores were drilled at the Poole Range, by Freney Oil Company. The No. 3 bore was drilled to a depth of 3,264 feet before the tools stuck and the hole was abandoned in the Permian Grant Formation. (No. 1 was a water bore and No. 2 a test bore to 1,000 feet.) Cementing failures were frequent in No. 3 bore and water was standing within 150 feet of the surface throughout the drilling. A convincing oil seepage was reported from 2,085 feet. A sample was submitted to the Government Analyst, who reported as follows:—" The sample submitted contained about an ounce of 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 per cent.) 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 . . .". No. 4 bore was a water bore and No. 5 was drilled to 1,545 feet and abandoned with no oil or gas showings.

The Freney Oil Company Limited went into voluntary liquidation in 1932 and was reconstructed as the Freney Kimberley Oil Company (1932) N.L.

Nerrima No. 1 bore was started in 1939, and was abandoned in 1941 at 4,271 feet. The Commonwealth and Western Australian Governments combined with Freney Kimberley to drill this hole; the Commonwealth provided the rig and petroleum technologists. The bore bottomed in Grant Formation after drilling through Noonkanbah and Poole Formations; no oil or gas showings were encountered.

A complete account of analysts' reports is given in Reeves (1949).

Associated Australian Oilfields N.L. and Freney Kimberley Oil Company combined, in 1954, to form Associated Freney Oilfields N.L., and drilled Associated Freney Nerrima No. 1 well to 9,072 feet in 1955. Small oil showings were encourtered at about 2,700 feet in the Grant Formation. The company then drilled Myroodah No. 1 to 6,001 feet in 1955-56. This bore was abandoned in Grant Formation with no showings of oil or gas.

West Australian Petroleum Proprietary Limited (WAPET), a combined company formed by Caltex (Standard Oil of California and Texas) and Ampol (Australian Motorists Petrol and Oil Limited), drilled Grant Range No. 1 Well in 1955, to 12,915 feet, penetrating Permian Grant and Carboniferous formations. There were no showings of oil or gas.

WAPET began drilling Fraser River No. 1 Well in 1956 and abandoned it at 10,000 feet in August, 1956, in diorite possibly intrusive into Carboniferous rocks.

Stratigraphical holes were drilled under contract for the Bureau of Mineral Resources in 1955-56. No. 1 hole at Jurgurra Creek, south of the Fenton Fault, penetrated Permian (?Noonkanbah Formation) to 645 feet and was abandoned at 1,680 feet in Permian (?Grant Formation). No. 2 hole, at Laurel Downs, was abandoned in Upper Devonian (?Mount Pierre Group) at 4,000 feet, after passing through 170 feet of Grant Formation and about 1,250 feet of Carboniferous Laurel Beds. No. 3 hole at Prices Creek passed through 592 feet of Ordovician, 82 feet of basalt (?Hart Basalt) and terminated in basement at 694 feet (Henderson, 1956a, b, c, d).

APPENDIX II.

DETAILS OF TYPE SECTIONS.

ORDOVICIAN.

Prices Creek Group.

Emanuel Formation (Locality OE1—Emanuel Creek).

Top of Section.

263 feet—Mainly no outcrop, but a little *Sandstone,* silty, micaceous, light yellow grey, friable and porous, interbedded with *Limestone,* grey, fine to medium crystalline ½-1½-in. beds, fossiliferous.

207 feet—*Limestone,* silty, grey, *Siltstone,* calcareous, grey; *Siltstone,* grey, rare fossils, outcrops in creek bank; *Limestone,* grey, fine, crystalline, dense—trilobites, coiled ammonoids.

57 feet—*Siltstone,* calcareous, earthy grey, weathering to mottled grey and yellow-grey discoidal nodules up to 9 inches, sometimes fine crystalline; trilobite fragments, rare graptolites; interbedded with *Siltstone,* grey, and *Limestone,* silty, foetid odour.

63 feet—*Shale* and *Siltstone,* grey, soft weathering, poorly exposed; *Limestone,* fine crystalline, grey discoidal weathering, rich in fossils; interbedded with *Limestone,* silty, foetid odour, discoidal nodules, and *Siltstone,* calcareous.

33 feet—*Limestone,* silty, grey to grey-brown, foetid, with discoidal nodules, and *Siltstone,* calcareous? asaphids and graptolites; interbedded with *Shale* and *Siltstone* poorly outcropping.

Limestone, crystalline, 2½ inches thick, with nautiloids, at base.

28 feet—*Limestone,* silty, light grey and brown, nodular, foetid odour; asaphids and graptolites; limonite-after-pyrite nodules on surface; interbedded with *Siltstone,* grey, thin-bedded, fine grained, weathering with discoidal nodules.

12 feet—*Limestone,* grey, silty, foetid odour, with gastropods, asaphids, trilobites; interbedded with *Siltstone,* blue and yellow and grey, discoidal nodules.

Limestone, grey, dense, fine to medium; ammonites, gastropods, asaphids at base.

56 feet—*Limestone,* grey to grey-brown; interbedded with *Limestone,* silty, light grey with trilobites; and *Siltstone,* light yellow-grey and blue-grey, thin-bedded, friable, porous discoidal nodules.

Limestone, grey to grey-brown, dense, fine to medium crystalline, slight foetid odour; rich trilobite (asaphid) fauna.

233 feet—*Limestone,* light grey, fine, dense, with grey-brown crystalline calcite; very fossiliferous with gastropods, brachiopods, cephalopods; interbedded with *Siltstone* and calareous *Siltstone,* blue-grey, weathering to yellow-grey, in 1-in. beds.

514 feet—*Limestone,* thinly bedded, platy weathering; interbedded with *Siltstone* (or shale), green-grey weathered, ½-in. beds, fossiliferous with brachiopods; *Limestone,* crystalline, grey-brown, dense; fossils rare and mainly gastropods.

108 feet—*Limestone,* light grey-brown and grey, medium crystalline, fine dense, weathers to light brown, slabby and slightly fluted in 1-1½-in. beds; beds occur in section with no other outcrop.

27 feet—*Limestone,* fine crystalline, light grey to some brown, ½-in. beds; richly fossiliferous; trilobites, brachiopods, gastropods.

105 feet—*Limestone,* light grey-brown in ½-in. beds; interbedded with either *Sandstone,* fine silty, or *Siltstone,* fossiliferous. Outcrop confined to creek walls.

240 feet—Rubble of *Limestone,* crystalline, mottled light brown, dark brown, rarely red, medium; scattered glauconite and quartz grains (subangular fine to coarse): rock weathers to mottled yellow and brown.

Rubble of *Limestone,* medium crystalline, grey brown and dark brown mottled, dense, rare flat gastropods; otherwise no outcrop except *Limestone,* crystalline, light brown to grey-brown, dense hard, weathering massive, at base. From here there is a 182-ft. B.M.R. Test Drill Hole.

14 feet—*Limestone* (dolomitic?) light brown mottled with red, fine, hard and brittle, with thin beds of *Sandstone,* white, fine.

7 feet—*Sandstone,* white, fine, grains angular or polished. *Limestone* sandy light brown.

19 feet—*Limestone,* sandy, light brown mottled with red, fine, hard and brittle; with thin beds of *Limestone,* blue grey to black, fine, hard shell fragments.

5 feet—No returns.

9 feet—*Dolomite,* blue-grey and fine.

18 feet—*Sandstone,* calcareous, white to light brown, slightly micaceous; *Limestone,* blue-grey, fine calcite veins.

30 feet—*Sandstone,* slightly calcareous, pale grey to white, shell fragments and calcite chips.

10 feet—*Sandstone,* slightly micaceous and silty, grey, fine and medium; pyrite, gypsum, fragments of garnet gneiss.

10 feet—*Sandstone,* with clay, grey and dense, fine, overlying *Sandstone,* white, clear angular grains.

6 feet—*Siltstone,* grey.

24 feet—*Sandstone,* fine, occasionally medium, white to pale grey, angular, calcite fragments.

23 feet—*Sandstone,* light grey to light brown, fine, with occasional beds of medium and coarse angular to sub-angular calcite and pyrite fragments, slightly friable.

7 feet—*Sandstone,* medium, poorly sorted, rounded to sub-angular, interbedded with *Sandstone,* grey-green, fine, rounded, well sorted, interbedded *Siltstone,* grey in thin beds.

Base of Section.

Gap Creek Formation (Locality OG1—Emanuel Creek).

Top of Section.

Unconformably overlain by Pillara Formation.

40 feet—*Sandstone,* calcareous, medium to coarse, well rounded to sub-rounded; lime matrix?; over

Dolomite, in thick beds amongst sequence of *dolomite,* fine, friable, light yellow brown.

Calcarenite, sandy and dolomitic, medium to coarse, light brown at base.

72 feet—*Dolomite,* repeated as thick beds, over *Quartzite,* fine silty, white to grey—probably silicified *dolomite.*

7 feet—*Quartzite,* fine silty colour-laminated to $\pm \frac{1}{16}''$, white to grey-yellow grey, concretionary; brachiopods; probably silicified dolomite.

22 feet—No outcrop, some caliche on surface.

15 feet—*Dolomite,* fine light brown, weathering to form rhombs on surface, dense, grey when fresh. Interbedded softer rock, either *siltstone* or *shale.* Ammonoids, nautiloids, gastropods.

40 feet—*Sandstone,* calcareous? interbedded bands of *dolomite,* hard, with gastropods (planispiral), in ratio of five or more sandstone to one of dolomite.

185 feet—*Dolomite* in thin beds interbedded with *sandstone,* soft, friable; silicified brachiopods and gastropods. Ratio of five or more sandstone to one of dolomite.

50 feet no exposure.

Dolomite, brown, hard red interbedded with *Siltstone* or dolomitic *sandstone*—poorly exposed.

70 feet—Twenty feet no outcrop.
Dolomite, dark grey-brown with red flecks, dense, medium, crystalline, interbedded with *sandstone,* calcareous or dolomitic, yellow brown, fine, friable.

60 feet—*Dolomite,* light grey-brown, weathering light brown. Weathered surface has "sandy" appearance due to dolomite rhombs; silicified brachiopods.

15 feet—*Dolomite,* grey brown weathering to light-brown, dense medium, interbedded with *calcarenite,* light-grey, fine and probably thin *siltstone* beds.

86 feet—*Limestone,* thin beds with calcified fossils—brachiopods and gastropods, trilobites. Overlies section with no exposure, probably representing *siltstone* or similar soft sediments.
Top of Emanuel Formation.

DEVONIAN.

Pillara Formation (Locality DMP1—Menyous Gap).
Unconformably overlain by Sadler Formation.

240 feet—*Biostromal limestone,* pale grey-brown, weathering grey and occasionally red-brown, crudely-bedded to massive, fossils mainly stromatoporoids.
Remainder of unit *biostromal limestone,* except for 6′ brown *limestone* at about 180′ above base, origin unknown.

2-5 feet—*Calcilutite,* grey-brown with powdery surface, corals, gastropods, brachiopods.

161 feet—*Biostromal limestone,* greyish-white weathering grey and occasionally red, bedded to thick-bedded, weathering massive with lumpy-surfaced cliff faces, corals, stromatoporoids, rare brachiopods.

59 feet—*Biostromal limestone,* grey to white, bedded to massive, weathering massive; corals and stromatoporoids.

6 feet—*Calcilutite* grey, bedded to massive, weathering massive.

22 feet—*Biostromal limestone* as above.

46 feet—*Calcilutite* as above.

18 feet—*Calcilutite* with stromatoporoids.

27 feet—*Calcilutite,* brown-grey, weathering massive, with calcite in clear blebs.

14 feet—*Biostromal limestone,* grey, massive, with corals, stromatoporoids, gastropods.

13 feet—*Calcilutite* as above.

9 feet—*Biostromal limestone* as above.

89 feet—*Calcilutite* is upper half of unit, grey-brown, weathering grey, thin bedded to bedded, weathering massive, fossiliferous. Underlain by one foot (lenticular) bed of *calcarenite,* grey-brown, fine, weathering to boulders. Lower half is *biostromal limestone,* massive and weathering massive, large stromatoporoid, varying laterally to about 95% calcilutite.

179 feet—*Biostromal limestone* and *calcilutite,* alternate bedded, thin-bedded, bedded, and massive, weathering massive and rarely thin-bedded, beds seem to vary in thickness laterally. Biostrome contains stromatoporoids and dominates upper part of section. Calcilutite contains corals.

232 feet—*Calcilutite,* brown-grey, weathering grey and occasionally white, dense, with "blebs" of clear calcite (up to 1/10 inch) scattered through beds, thin bedded to bedded, weathering massive with pinnacled and fluted surface, interbedded with occasional beds of *biostromal limestone,* white to grey, weathering white, two feet to three feet thick, stromatoporoids; and *limestone,* grey, two feet to three feet thick, weathering recessed.

66 feet—*Biostromal limestone* about 50% of unit, but most frequent at base, grey, hard, fine, in places with distinct foetid odour (of hydrocarbons), corals and stromatoporoids; interbedded with *calcilutite,* grey, hard, conchoidal fracture, thick bedded, unfossiliferous, and *calcarenite,* brown grey, weathering grey, fine hard, thick bedded. Whole unit weathers massive, but beds one to two feet thick.

41 feet—*Biostromal limestone,* grey, with corals, stromatoporoids, *Amphipora.*

44 feet—*Calcilutite,* pale grey, weathering grey-brown. thin-bedded, weathering massive, not more than 10% organic growth (stromatoporoid) cut in strike-direction by brown calcite-like veins.

48 feet—Alternate-bedded *calcilutite* and *biostromal limestone,* both light grey to white, weathering grey-brown, hard, thin-bedded, weathering massive. Biostromes mainly stromatoporoids.

37 feet—Alternate-bedded *calcilutite,* grey, hard, conchoidal fracture, and *calcilutite,* weathering softer to lumpy on nodular surface; some *calcarenite,* cream to grey brown, fine, hard, bedded. No quartz sand observed. Corals and rare brachiopods.

Unconformity.

Lamboo Complex, metamorphic rocks.

Sadler Formation (Locality DD1, Emanuel Range—Sadler Ridge).

162 feet—*Calcarenite,* brown, medium, thin-bedded to bedded, scattered brachiopods throughout, brachiopod bed at base—with *limestone breccia,* fine, at 54 feet and 124 feet, outcrops poor from 80 feet above base.

32 feet—*Calcarenite,* brown, medium, thin-bedded to bedded, scattered brachiopods throughout, brachiopod bed at base.

26 feet—*Calcarenite,* as above.

27 feet—*Calcarenite,* as above.

58 feet—*Calcarenite,* light brown, medium, scattered brachiopods, thin bedded to bedded.

115 feet—*Limestone breccia,* medium to fine, overlain by *calcarenite,* grey-brown, medium to fine, bedded to thin-bedded.

31 feet—*Calcarenite,* grey brown, medium, thin-bedded.

50 feet—Alternate beds of *calcarenite,* silty, thin bedded, with wider interspersed areas of no outcrop, probably representing more silty beds which weather easily; first occurrence of ferruginized fossils.

52 feet—*Calcarenite* as above, with brachiopods throughout unit.

64 feet—*Calcarenite* as above, with brachiopod band at base.

32 feet—*Calcarenite* as above, with brachiopods, *Tentaculites.*

43 feet—*Calcarenite* as above.

69 feet—*Calcarenite,* outcrop non-continuous, probably silty, brown, medium to fine, thinly bedded, fine laminae, and well-preserved brachiopods and corals near base.

283 feet—No outcrop except for single bed of *Calcarenite,* silty (?), yellow-brown, fine, thin-bedded, rare gastropods, 76 feet above base.

30 feet—*Calcarenite,* shelly, grey-brown weathering yellow-brown, medium to thick bedded, fossiliferous, alternate outcrop and soil cover.

51 feet—No outcrop; soil cover.

34 feet—*Calcarenite,* shelley, pale grey-brown, fine, bedded, rich fauna, interbedded with *calcarenite,* grey, fine, thin-bedded, impoverished fauna.

16 feet—*Calcarenite,* shelly, pale grey-brown, fine to medium, bedded to thick bedded, coral and brachiopod coquinoids.

26 feet—*Calcarenite,* shelly, pale brown-grey, fine to medium, bedded, brachiopod and coral coquinoids, gastropods.

20 feet—*Calcarenite,* shelly, light brown to grey-brown, fine to medium-grained, thin-bedded to bedded, nodules of chert common, silicified fossils.

8 feet—*Calcarenite* shelly, light brown to grey-brown, medium to fine grained thin-bedded to bedded, fossiliferous, fossils silicified. Boundary based on change from rich brachiopodal *calcarenite* (Pillara Formation) to brachiopod-coral-crinoidal *calcarenite* (Sadler Formation).

Mount Pierre Group.

Gogo Formation. (Locality DP5, S.E. of North Entrance Menyou Gap—Pillara Range.)

(Virgin Hills Formation—Siltstone, poor exposure, reddish colour, lack of concretions, slightly thicker beds, conformable over)

11 feet—*Biohermal limestone,* in sinuous line along strike with stromatoporoid colonies up to 2 feet. Interstitial *limestone breccia, limestone conglomerate, calcarenite,* light grey, medium. Dips up to 30°.

27 feet—*Siltstone* dark brown, weathering grey-brown, concretionary with fossils (at 12 feet from base), thin bedded and laminated, soft weathering.

8 feet—*Calcarenite* and *limestone breccia,* with silicified and iron-stained fossil fragments, bed to two feet thick, breccia fine, calcarenite medium to coarse.

62 feet—*Siltstone,* thin bedded and laminated, soft weathering, harder beds in lower 35 feet. Concretions rare to 35 feet, but occur in numbers from about 40 feet to 55 feet, dark brown in colour. Bed of *siltstone,* silicified, ochreous red and yellow, at 35 feet above base.

23 feet—*Siltstone,* leached and ochreous, laminated, thin-bedded, porous.

5 feet—*Biohermal limestone?* light and dark grey, irregular calcite veining and iron staining; silicified. Surface exposure measures 50 feet x 15 feet x 3 feet. No organic growth seen.

50 feet—*Siltstone,* leached and weathering white, ochreous red and yellow stained surfaces, laminated and thin bedded, porous.

9 feet—*Siltstone,* calcareous (and leached?), slightly micaceous, light yellow to light yellow-grey and cream, very thin-bedded ($\frac{1}{16}$ inch); interbedded with rare *calcarenite,* tending concretionary with spherical nodules of dark grey-brown radiating crystals, size $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches. Fossils in beds.

21 feet—As above, but incidence of thin beds of *calcarenite* increasing. Concretions decreasing in size upwards.

7 feet—*Siltstone* and *calcarenite* as above, but beds up to one inch and two inches thick.

51 feet—*Siltstone* and *calcarenite* as above. Concretions common. Up to three inches by 8 inches. Mollusc, *Tentaculites.*

2 feet—*Calcarenite,* light grey-brown, weathering brown, medium thick-bedded (8 to 10 inches), grading upwards into *limestone breccia,* fine-medium, with fragments of stromatoporoids, corals, brachiopods, commonly silicified.

47 feet—Interbedded and continuous section of *siltstone,* calcareous, and *siltstone,* sandy, fine yellow to pale-yellow-grey in colour—laminations thinner than the thin beds (⅛ inch to ½ inch); tends to weather to small chips, rare concretions with *Tentaculites.* Gypsum? present.

34 feet—*Calcarenite,* light grey brown, medium and fine, rounded, bedded (4 inches), finely cross bedded; interbedded with *siltstone* grading to *fine sandstone,* calcareous?, pink, weathering to reddish soil, slight colour banding, friable thin-bedded (½ inch to 2 inches).

406 feet—No outcrop—Concretions near base of *calcareous siltstone* shed on surface, and rare thin beds of *limestone,* concretionary, and with small iron oxide nodules—the concretions contain nautiloids, arthropods, *Tentaculites,* ostracods.

103 feet—Outcrop rare; bed of *quartz sandstone,* calcareous, light yellow-grey, medium, subrounded, soft weathering and friable; and one of *sandstone* and *siltstone,* calcareous, fine, concretionary; commonly, shed concretions only indication of outcrop. *Tentaculites.*

44 feet—Exposure poor in upper half of unit. Interbedded *limestone* (or fine, recrystallized calcarenite), *fontainebleau sandstone,* light grey-brown, medium, *siltstone,* calcareous, light grey-brown, concretionary with fossils. Siltstone weathers deeply, shedding concretions.

35 feet—*Calcarenite,* light grey-brown, fine, concretionary; interbedded with *siltstone,* calcareous, and *sandstone,* calcareous, light yellow-grey, porous, soft weathering, adhesive to tongue, thin-bedded; forms bulk of unit but poorly exposed. *Tentaculites.*

132 feet—*Calcarenite* light grey-brown to light brown, fine and fine-medium, dense; interbedded with *siltstone,* calcareous?, light pinkish-grey, weathering light yellow-brown, porous, friable, thin-bedded. Exposures rare and poor, but about 90 feet above base is six-inch bed of *sandstone,* calcareous, micaceous, pinkish-grey, medium, with quartz, felspar?, brown mica with fontainebleau base; interbedded with *sandstone,* calcareous, pink, thin bedded;

Conformable over Sadler Formation.

Virgin Hills Formation (Locality DP20—Needle-eye Rocks).

Calcarenite of Fairfield Beds, sandy grey, thin-bedded, conformable over

50 feet—*Siltstone,* calcareous, interbedded, red-brown and grey thin-bedded; occasional corals, goniatites.

38 feet—*Siltstone* calcareous, interbedded, red-brown and grey, thin-bedded, weathering nodular (rubbly).

26 feet—*Siltstone,* calcareous, red-brown, thin-bedded; interbedded with *siltstone,* calcareous, grey. Occasional goniatites, corals.

12 feet—No outcrop.

31 feet—*Siltstone,* quartz-mica, red-brown, interbedded with *siltstone,* calcareous, grey; both thin-bedded, friable.

2 feet—*Siltstone,* red-brown and grey, with *Sporadoceras.*

28 feet—*Siltstone* (poor exposure), quartz-mica, red-brown, thin-bedded, interbedded with *siltstone,* calcareous, grey.

35 feet—No outcrop.

61 feet—*Siltstone,* quartz-mica, calcareous, interbedded red-brown and grey, thin-bedded, scattered goniatites.

93 feet—*Siltstone,* quartz-mica, red-brown; interbedded with *siltstone,* calcareous, quartz-mica, grey, both medium to coarse, friable, thin-bedded, ripple marked. Unit contains first recognizable *Cheiloceras* together with nautiloids, crinoids, rare solitary corals.

117 feet—*Siltstone,* quartz-mica, calcareous, interbedded, red-brown and grey, medium-grained, friable, low-porosity, thin-bedded, crinoids and occasional coral.

37 feet—No outcrop.

13 feet—*Siltstone* quartz-mica, calcareous, red-brown with patches of grey, medium to coarse, sub-angular grains, friable, porosity low; *calcarenite,* sandy and silty, grey, thin-bedded, crinoid fragments.

An interval of unknown depth separates the base of this Section from the top of DP5, which represents the base of the formation.

(Locality DP5—1½ miles S.E. of N. entrance of Menyous Gap.)

52 feet—*Sandstone,* calcareous, grey-brown and reddish-grey, quartz, biotite and rock fragments, fine to medium, thin-bedded weathering flaggy. Exposures poor.

48 feet—*Siltstone,* calcareous, red-brown; interbedded with *siltstone,* red-brown, and sandstone, red-brown, fine thin-bedded.

84 feet—*Siltstone,* sandy, fine, to *sandstone,* silty, calcareous and non-calcareous, red-brown, rarely grey, thin-bedded, soft weathering, generally some mica present, calcareous beds thinner, but more resistant than non-calcareous beds. Rare beds of *greywacke,* calcareous, brown, medium, with mica, rock fragments, thin-bedded.

Conformable over Gogo Formation.

Bugle Gap Limestone (Locality DB1, South-East Wall of Bugle Gap).

Grant Formation (Permian) (Sandstone, uncomformable over).

88 feet—*Calcarenite,* yellow-brown, fine to medium, unsorted, friable, poor outcrops; over *calcarenite,* recrystallized, light grey-brown to grey-white, rarely reddish-grey, unsorted, fine to medium; over *calcarenite,* oolitic grey-white, at base.

51 feet—*Calcarenite,* grey to brown, medium, milky calcite—spiriferids, productids, trilobites.

Biohermal limestone in lenses 5-8 feet thick and 20-30 feet along strike, *calcarenite* matrix.

51 feet—*Limestone* (recrystallized medium *calcarenite*), medium, light grey-brown to grey-white, bedded, lensing, with crinoid fragments.

152 feet—*Limestone* (recrystallized calcarenite?), white, interbedded with *calcarenite,* cream, fine and medium. Pronounced layering of crystalline calcite and calcarenite. Nautiloids and gastropods.

434 feet—As above but more crudely bedded. Calcite crystalline, white, layered, well developed throughout. Fossils rare—nautiloids, crinoids, gastropods. Deep erosion is typical of this unit.

135 feet—As above. Spiriferids, productids, sponges, nautiloids. Bedded with tendency to massive and crude bedding. Calcite, crystalline, white in layers, probably chemical origin. Massive lenses of *limestone* near top may be biohermal.

10 feet—*Calcarenite,* silty, red, interbedded towards top with *limestone,* grey-white and white; calcite, crinoids, sponges.

43 feet—*Limestone,* thick bedded with cannon-hole weathering.
Leorhynchid, smooth brachiopod at top of unit.

10 feet—*Calcarenite,* greyish white, medium recrystallized, flaggy, lensing, cross-bedding?

145 feet—*Calcarenite,* fine and fine to medium, grey-white, thinly bedded, interbedded with *calcarenite,* medium to coarse, bedded to thick bedded. Ammonoids rare, brachiopods near base, crinoid fragments common.

30 feet—Interbedded *calcarenite,* fine *sandstone,* and *limestone.* Brachiopods at base of unit.

84 feet—*Calcarenite,* red with layers of white calcite (chemical or organic) interbedded with *limestone* and *sandstone,* fine, to *siltstone* with calcarenite matrix, light grey-brown,
Productids near base; ammonoid at top.
Conformable over Mount Pierre Group (Upper Devonian).

Fossil Downs Formation (Locality DL3, 4 miles North of Fossil Downs Homestead).

13 feet—*Limestone* breccia, coarse to fine-grained. Biohermal masses with no recognizable organic content.

10 feet—*Calcarenite,* silty, red-brown, with crinoid fragments.

11 feet—*Limestone breccia,* coarse, fragments of stromatoporoids in silty calcarenite, pink to brown.

14 feet—*Calcarenite,* light brown, medium to coarse, interbedded with red silty *calcarenite,* with crinoid fragments

19 feet—*Limestone breccia,* calcarenite fragments in a calcarenite base, light brown to pink weathering to mottled. Porosity low.

83 feet—*Calcarenite,* medium to coarse, white to light brown poorly sorted, weathering to brown, overlying interbedded
Limestone breccia, fine grained, and *calcarenite,* silty, pink coloration, thinly bedded, porosity low.

113 feet—*Calcarenite,* medium to fine grained, thin bedded to bedded, interbedded with *siltstone,* calcareous, red thin bedded. Unit constant throughout.

323 feet—Outcrop very poor, but unit probably similar to the immediately underlying and overlying units.
Biohermal limestone growth in central part of unit.

37 feet—*Calcarenite,* white, medium-grained, and *siltstone* calcareous, red.

7 feet—*Calcarenite,* white to light brown, medium.
Limestone breccia (5 feet) at base, fragments of calcarenite up to 6 inches in medium to coarse calcarenite groundmass.

174 feet—*Calcarenite,* white weathering to brown, medium crystalline cement, low porosity, cement may contain a small proportion of quartz silt. Biohermal masses with oolitic? lenses scattered through unit.

105 feet—*Calcarenite,* white weathering brown, partly recrystallized particularly near base, porosity low, medium-grained.
Fossil bed at top of unit.

222 feet—*Calcarenite,* as above.
Limestone breccia in beds and lenses.

431 feet—*Calcarenite,* as above.
Limestone breccia in beds and lenses.
Unconformably over Pillara Formation.

Burramundi Conglomerate (Locality DA2, Burramundi Range).

228 feet—*Conglomerate,* red-brown, grain-size pebble to boulder (<24 inches), unsorted, well-rounded, crudely thick-bedded. Matrix ranges from *sandstone* to fine *conglomerate,* and is angular. Beds of *sandstone* present but are typically lensing. Conglomerate "dykes" in the outcrop are probably local shatter zones.

221 feet—Uncemented mass of boulders derived by erosion from underlying conglomerate beds. Eroded to form rounded hills with slopes at approximately angle of repose.

Unconformable on Lamboo Complex (Precambrian).

Copley Formation (Locality DH1, from 8.5 to 4.5 miles N.E. of Springs Homestead).

331 feet—*Calcarenite,* oolitic, light brown, weathering to rubble, interbedded with calcareous *siltstone. Limestone breccia* occurs sporadically towards top of unit.

66 feet—*Calcarenite,* oolitic, light brown, slightly sandy, interbedded with *siltstone,* calcareous, red-brown to pink, weathers rubbly, poor outcrop.

876 feet—*Calcarenite* and *siltstone* as above.

607 feet—*Calcarenite,* oolitic, with fine *limestone breccia* at base, light brown to light grey, becoming sandy, weathers thick-bedded with good outcrop, interbedded with *calcarenite,* silty, light grey to red-brown, fine-grained, weathering to rubbly, silty soil, jointed.

174 feet—*Breccia,* fine, *calcarenite* fragments, oolitic; brachiopods, pelecypods; interbedded with soft sediment which does not outcrop (*calcareous siltstone*).

381 feet—*Calcarenite* and fine *breccia,* red-brown to light brown, calcite veins and vugs; rounded masses of calcarenite occur through the greatest part of the unit. Occasional beds of *calcarenite,* sandy, well rounded, cross-bedded, medium grained; oolitic? *limestone,* with angular fragments of fine-grained limestone, in thin beds; and *calcarenite,* silty, fragments of calcilutite. Brachiopods, corals, crinoids.

214 feet—*Limestone,* massive, reef and breccia, breccia coarse. Remnants of stromatoporoids occur but main mass is recrystallized to fine to medium grained limestone, light grey, jointed, may be oolitic in parts.

Unconformable on Pillara Formation.

Brooking Formation (Locality DK1, Brooking Gap).

Fairfield Beds unconformably on:

1,213 feet—*Calcarenite,* light brown, light grey, fine to medium grain. Upper part thin-bedded to bedded, middle part bedded to thick-bedded, weathering thick-bedded to massive, lower part thin-bedded to massive. Upper part coarser in grain and partly oolitic. Calcite veins near base of unit.

1,503 feet—*Calcarenite,* top 300 feet partly oolitic, pale grey medium-grained thin-bedded occasionally massive. Some shows pseudo-brecciation due to interfingering and stylolites. Below this, *bioherms* scattered through 330 feet of section, in pale-grey medium-grained poorly sorted thin-bedded calcarenite which continues downward, becoming oolitic. 120-175 feet above base of unit calcarenite is slightly sandy and interbedded with *calcarenite breccia,* medium to coarse matrix, with fragments of recrystallized fossils. Base of unit is *oolitic calcarenite,* light brown to light grey, medium to coarse grained, with small bioherms scattered throughout. Occasional recrystallized fossils. Sporadic thin beds of *calcarenite breccia.*

431 feet—*Limestone,* oolitic light brown to red-brown, bedded to thick bedded, with *calcarenite,* medium-grained often oolitic, few thin beds, and *limestone breccia,* fine, occasional thin bed. Fossil fragments, mostly recrystallized.

Calcarenite at base of unit, light brown, massive, medium-grained, fossiliferous, rare stylolite markings and occasional calcite vein.

Unconformably on *Limestone,* light grey-white, recrystallized, dense.

Geikie Formation (Locality DS1, 3.5 miles N. of Springs Homestead).

11 feet—*Limestone breccia,* fine to medium, grey-brown, and red to blue-grey.

51 feet—*Calcarenite,* medium to coarse grained, interbedded with *calcarenite,* oolitic, medium to coarse with large crinoid fragments.

147 feet—*Calcarenite,* rare oolites, light grey-brown, fine to medium interbedded with *calcarenite,* oolitic.

Limestone breccia (near base) greyish white, fine to medium, oolitic, interbedded with *calcarenite,* light grey-brown, with crinoid fragments.

69 feet—*Calcarenite,* oolitic, interbedded with limestone breccia, fine, milky calcite veins common.

23 feet—*Limestone breccia,* light grey-brown and grey, some oolites in matrix.

71 feet—*Calcarenite* strongly oolitic, interbedded with *calcarenite*, oolitic, light grey-brown, small patches of siliceous material.

131 feet—*Calcarenite,* oolitic, light grey, fine to medium, subrounded to rounded, matrix commonly clear calcite. Some beds very rich in oolites.

129 feet—*Calcarenite* fine to medium, unsorted, with lenses of *Limestone breccia,* oolites common.

69 feet—As above, oolites less common.

310 feet—*Calcarenite,* medium to fine and rarely coarse, well rounded grains, interbedded with *limestone breccia* uniform composition with calcite encrusting the fragments.

Structureless *limestone* masses may be bioherms.

185 feet—*Calcarenite,* medium to coarse with rare oolites, stylolitic weathering along bedding planes, interbedded with a few *limestone breccia* beds with milky calcite encrusting fragments, fossiliferous.

31 feet—*Limestone breccia,* coarse, rarely very coarse, grey-brown to greyish white fragments encrusted in milky calcite veining.

35 feet—*Calcarenite,* light grey-brown, fine and medium with some coarse, unsorted; calcite veining. Brachiopods and crinoids.

76 feet—*Calcarenite,* light grey-brown, greyish white, and pink-brown, milky calcite encrusting fossil fragments, unsorted. Nautiloids, goniatites, pelecypods, brachiopods (*Spirifer,* rhynchonellids).

Unconformable over Pillara Formation (Middle Devonian).

Oscar Formation (Locality DO1—Linesman's Creek).

203 feet—*Calcarenite* crinoidal, brown, weathering to brown and light grey. Crinoids abundant with scattered nautiloids.

387 feet—*Calcarenite,* calcareous cement, oolitic in places, light brown weathering to grey, grains angular to rounded, hard, brittle cavernous. Suggestion of large-scale cross-bedding. Bedding varies from massive to crudely bedded.

326 feet—*Calcarenite* as above.

650 feet—*Calcarenite,* light brown, weathering to grey, calcareous cement, grains angular, hard, brittle, porosity low, cavernous. Slumping well developed.

402 feet—*Limestone breccia,* medium to coarse grained with calcareous cement, similar to unit below.

316 feet—*Limestone breccia,* oolitic in part, light brown weathering to dark grey, calcareous cement, fragments of calcarenite stromatoporoids, hard, brittle, porosity low, cavernous, some evidence of slumping. Brachiopods, corals, crinoids.

Unconformable on Precambrian.

Napier Formation (Locality DN1, Barker Gorge).

80 feet—*Calcarenite,* very sandy, medium to coarse, cross bedding, as massive lens over *calcarenite,* trace of sand, red to red-brown, medium to coarse unsorted. Scattered bioherms throughout.

130 feet—*Calcarenite,* sandy, and *calcarenite,* pure light, grey-brown, fine to medium, interbedded with *calcarenite,* red-pink and grey, fine-grained, and *calcareous siltstone* with biotite flakes. Bioherm at top.

66 feet—*Calcarenite,* sandy with silty base, coarse to medium, biotite flakes and general earthy appearance. Flattened surface of quartz grains, suggests origin from schist; over *calcarenite,* sandy, grey and white milky precipitated calcite infilling vugs. Scattered bioherms.

117 feet—As above.

249 feet—*Calcarenite,* commonly sandy, reddish-brown and grey, fine to coarse grained, unsorted weathering bedded to thick bedded. Tending toward recrystallization producing pseudo-sandy effect; interbedded with *calcarenite,* light grey to white, medium to coarse, unsorted, clear calcite matrix—tending toward fine breccia in sandy calcarenite base.

85 feet—*Calcarenite,* mainly recrystallized, red-brown, medium, flecked with calcite.

80 feet—*Calcarenite,* recrystallized, red-brown, medium. At top of unit, red-brown calcarenite alternates with 1-2 feet beds of *calcarenite,* medium, pale grey in clear calcite matrix and containing some coarse to very coarse grains.

57 feet—*Limestone breccia,* red-brown in milky calcite base, fine, interbedded with *siltstone,* calcareous, and silty *calcarenite,* red-brown, with biotite. Biohermal masses (up to 30 feet by 50 feet) scattered through section, consist of *limestone* crystalline, pinkish white, with associated medium to coarse *limestone breccia.* Corals and brachiopods.

3336/57.—7

57 feet—*Limestone breccia,* interbedded with calcareous *sandstone* (or sub-greywacke) clastic material, quartz, biotite, schist, felspar, mottled red-brown to grey, friable. Breccia fine to coarse, unsorted.

41 feet—*Limestone,* dense, recrystallized, clear calcite vugs with lenses and pockets of calcareous sandstone interbedded with *limestone breccia,* light red-brown, sandy fine.

Fragments consist of calcareous *siltstone,* red, rounded.

Sand grains unsorted, fine to coarse.

57 feet—*Limestone,* recrystallized, vugs of clear calcite.

Lenses, pockets and rare beds of calcareous *sandstone,* sub-angular to angular.

Unconformably on Precambrian metamorphic rocks.

Fairfield Beds (Locality DF2, South of Burramundi Range).

104 feet—*Calcarenite,* sandy (quartz and biotite), medium and coarse, brown and grey-brown (weathering to yellow-brown), interbedded *siltstone,* calcareous green-grey, weathering to yellow-grey and forming caliche on surface.

113 feet—*Calcarenite,* grey-brown, weathering to yellow-brown, fine to medium grained, dense, nodular.

58 feet—No outcrop.

104 feet—Outcrop poor. At top, two beds of about one foot of dense *calcarenite,* sandy, with quartz and felspar.

9 feet—*Calcarenite* and *sandy calcarenite,* with grains of quartzite, igneous and metamorphic rocks. Light yellow brown.

84 feet—*Siltstone,* fine, sandy, and *siltstone,* calcareous, light-yellow, friable, weathering to caliche.

Occasional bed of *calcarenite,* nodular, fine to medium, dense.

10 feet—Outcrop poor, but probably similar to unit below.

12 feet—*Calcarenite,* yellow-grey to grey-brown, fine and medium grained, weathering to rubble.

85 feet—Mostly no outcrop, but bands of *calcarenite,* weathering to rubble, silicified fossils; *calcarenite,* crinoidal, and *calcarenite,* crinoidal with *Camarotoechia,* spiriferids.

PERMIAN.

Grant Formation (Locality Poole Range, No. 3 Bore).

151 feet—*Clay,* sandy yellow.
61 feet—*Shale,* dark grey.
6 feet—*Quartz sandstone,* broken.
186 feet—*Shale,* grey with thin limestone bands at 357 feet depth.
4 feet—*Quartz sandstone,* calcareous, fine-grained.
152 feet—*Shale,* grey.
27 feet—*Tillite.*
130 feet—*Shale,* grey.
80 feet—*Quartz sandstone,* fine-grained.
15 feet—*Shale,* grey.
88 feet—*Shale,* sandy with hard bands.
90 feet—*Shale,* grey.
28 feet—*Quartz sandstone,* silty.
85 feet—*Shale,* sandy.

144 feet—*Quartz sandstone,* clayey.
75 feet—*Quartz sandstone.*
75 feet—*Shale.*
216 feet—*Quartz sandstone,* fine-grained, and *quartz sandstone,* clayey.
4 feet—*Shale,* grey.
42 feet—*Quartz sandstone,* clayey.
18 feet—Alternate beds, *shale* and *quartz sandstone,* fine-grained.
20 feet—*Quartz sandstone.*
13 feet—*Shale,* puggy.
122 feet—*Quartz sandstone.*
175 feet—*Shale,* sandy.
63 feet—*Shale* with bands of *limestone* and *sandstone.*
250 feet—*Quartz sandstone,* fine-grained with thin beds of *quartz sandstone,* clayey, hard.
Oil coating on cable and floating on water surface in upper part of unit.
10 feet—*Shale,* sandy.
92 feet—*Quartz sandstone,* clayey in part, fine-grained.
10 feet—*Shale,* sandy.
92 feet—*Quartz sandstone,* clayey in part, fine-grained.
10 feet—*Shale,* sandy.
16 feet—*Quartz sandstone,* fine-grained.
5 feet—*Shale,* sandy.
81 feet—*Quartz sandstone,* clayey fine-grained.
15 feet—*Quartz sandstone,* coarse.
83 feet—*Quartz sandstone,* clayey fine-grained.
21 feet—*Shale,* light brown.
44 feet—*Quartz sandstone,* clayey in part, fine-grained.
4 feet—*Shale,* calcareous brown.
92 feet—*Quartz sandstone,* fine-grained.
25 feet—Alternating bands of *sandstone,* clayey, fine-grained, and *shale,* sandy or calcareous.
5 feet—*Shale,* sandy brown.
6 feet—*Quartz sandstone,* fine grained.
20 feet—*Shale,* slightly calcareous brown.
39 feet—*Quartz sandstone,* very fine grained.
59 feet—*Quartz sandstone,* medium grained ?Tourmaline in lower ten feet.
128 feet—*Sandstone.*
71 feet—*Quartz sandstone,* fine grained.
37 feet—*Shale,* grey, extremely hard.
44 feet—*Shale,* brown, hard.
15 feet—*Sandstone.*
5 feet—*Shale,* brown puggy.
29 feet—*Quartz sandstone,* clayey fine-grained.
15 feet—*Shale,* brown.
Base—Base, bottom of the hole. Total thickness 3,264 feet.

Poole Sandstone (Locality PP1—Eastern plunge of Grant Range).

Top—No outcrop—alluvium.
42 feet—*Quartz sandstone,* grey-brown, blue-grey, brownish-white, fine and medium grained, interbedded, friable, porous, subangular to angular; some beds show concretions and tessellations, thick bedded, ripple marked in part. Thin pellet beds occur along bedding planes. Fossil wood.

67 feet—*Quartz sandstone* micaceous, silty, dark grey and light grey, fine-grained, speckled appearance gives pseudo-coarser grain-size, thin-bedded, weathering thick-bedded. Bedding planes often contain ferruginized concretions. Fossil wood.

26 feet—Lithology similar to unit immediately below.
Siltstone beds, thin, replacing siltstone lenses.

57 feet—*Quartz sandstone,* micaceous, dark grey-brown to dark brown and sometimes speckled, thick-bedded, fine to medium-grained, with thin lenses of *siltstone.* Fossil wood common in pellet beds. Beds often tessellated on surface of vertical joint planes. Ripple marks and cross-bedding common.

41 feet—*Quartz sandstone,* light grey-brown, fine-grained and laminated, some pellet beds 6 inches to 10 inches thick, with siltstone pellets up to 4 inches.

83 feet—*Quartz sandstone,* micaceous light grey-brown and grey, thin-bedded to wavily bedded, laminated, cross-bedded, fine-grained, interbedded with *siltstone,* dark brown, slightly micaceous. Ripple-marked.

83 feet—*Quartz sandstone,* micaceous to rarely micaceous, light brown to light yellow-brown, weathering dark brown and ferruginous, concretionary platey outcrop and float with *quartz sandstone,* silty, and *siltstone,* weathering to "chips". Rare wood and plant fragments in intraformational pellet beds.

36 feet—Lithology similar to unit immediately below. Bedding becomes cross-bedded and ripple marks more common.

180 feet—*Quartz sandstone,* micaceous, silty (or rock "flour") matrix, white to light grey, weathering bright red, weathers poorly bedded tending to bedded. Rare wood impressions. Ripple-marked, wind-directed, shallow-water type.

52 feet—No outcrop at base. *Quartz sandstone,* micaceous, speckled light grey to brown, light purple banded, concretionary, ferruginized, fine and fine to medium, poorly sorted, massive, thin-bedded, bedded, interbedded, current bedded, ripple-marked.

10 feet—*Quartz sandstone,* grading to *conglomerate,* yellow to black, mottled, friable, coarse-grained to cobble, poorly sorted, basal bed thin. Overlain by *quartz sandstone,* purple to black, fine to medium grained, heavily ferruginized, concretionary. Overlain by *quartz sandstone,* silty, light purple, weathering light red to brown, fine-grained, crudely bedded.

Base unconformably on Grant Formation: *Quartz sandstone,* white, medium grained, angular to sub-angular, with fine clayey matrix, bedded, thin-bedded and partly cross-bedded. Total thickness 675 feet.

PERMIAN.

Noonkanbah Formation (Locality PN1—Brutens Yard, Christmas Creek Station).

Top—not exposed, but overlain by Liveringa Formation.

10 feet—*Quartz sandstone,* iron-oxide coated, brown and red-brown, medium and coarse, well sorted into ½-inch beds, friable, porous.

9 feet—*Quartz sandstone,* micaceous, light brown, fine, bedded to thin bedded, porous, with rare lenses of ferruginized to reddish black *siltstone,* heavy.

48 feet—*Quartz sandstone,* micaceous, silty, slightly calcareous, dark-brown, dark-brown speckled white (felspar?), chocolate-brown, fine, medium with subrounded to subangular grains, very fine, finely cross-bedded, ferruginized, with one *siltstone* lens, containing phosphatic fossil fragments.

12 feet—*Quartz sandstone,* silty, slightly micaceous, fine, very thin bedded, friable, interbedded with *siltstone,* thin-bedded, ferruginized.

64 feet—*Limestone* at base, sandy, red-brown, with concretions and bryozoa, rare pelecypods, *Strophalosia, Chonetes.* Overlain by siltstone, calcareous, fine, sandy, light brown, dark brown to black, brown and red-brown; rarely interbedded with *quartz sandstone,* silty, slightly calcareous, micaceous, light brown, grey, grey-brown, fine, thin-bedded, weathers well bedded.

7 feet—*Siltstone,* light brown, concretionary, well bedded, with *quartz sandstone,* calcareous, micaceous, fine, thin bedded, weathers paper-bedded, light grey-brown, with oblate, spherical and dumb-bell shaped concretions of *quartz sandstone,* which is micaceous, calcareous, yellow in centre, weathers reddish and very deep brown on surface. Rare fossils at base.

31 feet—Increasing amounts of float consisting of *calcareous siltstone,* silty *limestone,* interbedded with a sandstone-siltstone-shale sequence (as in unit immediately below). In lenses of calcareous siltstone occur productids, spirifers, *Strophalosia,* gastropods. Near top of unit ochreous *siltstone* with more fossils.

29 feet—*Siltstone* lens at base, slightly calcareous, dull earthy brown colour, concretionary, in various browns; 7 feet above base float of *siltstone,* calcareous, dark red-brown, spirifer fragments. Overlain by *quartz sandstone,* colour laminated yellowish, interbedded with fine *siltstone* and gypseous *shale* in percentages sandstone 30%, shale 25%, siltstone 45%. At 22 feet above base laterally a *limestone* lens with productids, spiriferids.

31 feet—At base interbedded *calcareous sandstone* and *siltstone.* Overlain by interbedded silty fine *quartz sandstone, shale,* and *gypsum;* overlain by interbedded thin bedded *siltstone* and fine, laminated *quartz sandstone,* and some *shale.*

63 feet—At base discontinuous float of *limestone,* sandy or calcareous, fine, grey-brown, and *siltstone,* calcareous, dark red-brown almost fontainebleau: At 20 feet above base of unit float of *siltstone,* calcareous, broken, tessellated, yellow and brown. At 32 feet above base, line of float *quartz sandstone,* calcareous, slightly micaceous, colour-banded grey and grey-brown, fine, thin-bedded. At top of unit *quartz sandstone,* calcareous, micaceous, grey and reddish grey staining, thin bedded, finely laminated, leaches friable.

21 feet—No outcrop basal 17 feet, then discontinuous lines of rubbly float of *quartz sandstone,* calcareous, micaceous, grey-brown, fine, thin bedded, and *siltstone,* sandy, yellow-brown, red-brown; "pellet" concretions of *siltstone,* sandy micaceous, fine; poorly preserved brachiopods in *limestone,* sandy, red-brown, brown, fine.

148 feet—At 5 feet above base, lenses of *quartz-sandstone,* micaceous, slightly calcareous, light grey-brown, fine, poorly thin-bedded, weathers bedded, slightly cross-bedded. At 27-30 feet above base interbedded (half-inch beds) *quartz sandstone,* silty, fine, laminated, and *siltstone,*

3336/57.—8

odd mica flakes, gypsum, grey; at 34 feet above base *quartz sandstone* and *calcareous quartz sandstone,* light grey-brown and light grey. Lenses are 10 to 20 feet in diameter. Sandstones are evenly thin-bedded to slightly cross-bedded, tend to weather-bedded to thick-bedded. At 44 feet above base, lens of *siltstone,* calcareous, fontainebleau, dark red, brown. At 47 feet above base lens of *quartz sandstone,* silty calcareous, light earthy red-brown; laterally it varies to thin interbedded *sandstone,* silty, fine, and *siltstone,* grey. The large sandstone lenses tend to weather spherical and simulate exfoliated sheets; from 122 to 138 feet above base lenses are smaller (5 to 10 feet) and still show no lineation that would indicate strike of beds.

48 feet—*Siltstone,* calcareous, yellow, yellow-brown, dark red-brown, "pellet" concretions, slightly micaceous and yellow-brown, interlensed with *siltstone,* calcareous, sandy, with lime grains, yellow-brown. Poor fossils in red calcareous siltstone. At top of unit, *siltstone,* calcareous, tessellated, yellow and yellow-brown.

4 feet—At base, *quartz sandstone,* silty, fine, and *siltstone,* sandy, thin-bedded and laminated, interbedded with *sandstone,* calcareous, slightly micaceous, fine, evenly thin-bedded to finely cross-bedded, and *siltstone,* calcareous, and siltstone, sandy, calcareous, red and brown, brown and dark brown.

70 feet—Poor outcrop. About 12 feet from base *quartz siltstone,* calcareous, fine and sandy, mottled reddish brown and dark brown, rubbly, concretionary. Overlain by *siltstone,* calcareous to fontainebleau, mottled dark brown and red brown.

13 feet—*Quartz sandstone,* calcareous, and non-calcareous interbedded, light grey, fine, even and thin-bedded to cross-bedded; overlain by interbedded lenses of *quartz sandstone,* calcareous, micaceous, grey, and *siltstone,* calcareous, brown, red-brown, dense. Top half fossiliferous and along strike to west a rich locality of bryozoa and brachiopods.

59 feet—At base interlensing *siltstone,* dark red, and *quartz sandstone,* calcareous, fine concretions up to 4 inches across, fossil fragments, Overlain by interbedded *quartz sandstone,* calcareous, green, grey-brown, grey, fine, and *siltstone,* calcareous, earthy red, micaceous pellet concretions; quartzite pebbles in intraformational concretionary bed.

4 feet—Interbedded lenses of *quartz sandstone,* calcareous, non-calcareous, micaceous, light grey-brown, fine, laminated, thin-bedded, cross-bedded, ripple-marked, friable, and *siltstone,* sandy, calcareous, earthy red-brown, dark red-brown.

5 feet—Interbedded *quartz sandstone,* calcareous, micaceous, light grey, light grey-brown, fine, thin-bedded, finely cross-bedded, partly travertinized, friable; and *siltstone,* calcareous, yellow-brown, brown, red-brown, concretionary, colour-banded.

21 feet—*Quartz siltstone,* sandy, calcareous, red-brown, light-brown, rubbly, fine laminated crenulations, poorly bedded; spiriferids. Also a little shale and sandstone.

10 feet—At base, *quartz sandstone,* calcareous, grey, very thin-bedded, weathers paper-bedded, cross-bedded, fine float outcrop. Overlain by interbedded *quartz sandstone,* silty, slightly micaceous, fine porous, grey and yellow-grey, and *shale,* grey and light grey-brown.

15 feet—Interbedded float of *siltstone,* dark red-brown, mammillated surface, rare oolites, some fossils, and *quartz sandstone,* calcareous, silty, red and dark red, light grey-brown, bedded and thin-bedded; at top *shale,* grey.

30 feet—Interbedded *quartz sandstone,* silty, light grey, thin to wavily bedded, fine, deeply weathered, *shale,* and *quartz siltstone,* gypsum, above hard *calcareous sandstone* beds, grey and light brown. Fifteen feet from base of unit is *quartz siltstone,* slightly calcareous, fine sandy in places, yellow-brown. Near top grey and brown *siltstone* and *shale.*

18 feet—Interbedded and interlensing *quartz siltstone,* calcareous, dense, yellow, brown, dark red-brown, *limestone,* silty yellow-brown, dark red-brown; spiriferids, crinoids, bryozoa; and *quartz sandstone,* calcareous, grey, thin-bedded, and *shale.*

30 feet—Interbedded *quartz sandstone,* calcareous, light grey, grey, thin-bedded, wavily cross-bedded, fine, spiriferids, and *quartz siltstone,* oolitic at base, calcareous, sandy grey-brown, dark brown speckled pepper-brown, ochreous yellow, concretionary, and some *shale,* light brown.

17 feet—*Quartz sandstone,* calcareous, fine, thin-bedded, finely to wavily cross-bedded, interbedded with *quartz siltstone,* calcareous, brown, spiriferids.

8 feet—*Quartz siltstone,* slightly calcareous, concretions and tessellated, yellow, brown, dark red-brown.

30 feet—Interbedded float of *quartz sandstone,* calcareous, micaceous, silty, light grey, and colour-banded grey to grey brown, fine, thin-bedded, cross-bedded, weathers platey; *quartz siltstone,* calcareous, earthy yellows, brown to dominant hematite brown-red; and *shale,* seen in gullies, gypseous, blue-grey to dark grey, parting of siltstone, micaceous.

21 feet—As in unit immediately below, plus *quartz siltstone,* calcareous, lime oolitic, spiriferids, *Chonetes.*

64 feet—Interbedded float of *quartz siltstone,* red, brown, yellow, light brown, and grey, earthy, calcareous, ferruginized in places, fossils, and *limestone,* silty red, brachiopods.

½ foot—Prominent line of float, of *siltstone,* calcareous, grey to grey-brown and brown, calcite veins, lenses of *limestone,* pellet-shaped concretions of micaceous sandy siltstone, productids, spiriferids.

23 feet—Float of *quartz siltstone,* brown and red-brown, concretionary; overlain by float of *quartz sandstone,* calcareous, light grey-brown, fine, thin and evenly bedded, weathers platey.

7 feet—*Siltstone* float, calcareous, grey to grey-brown and brown.

52 feet—*Quartz sandstone* float, calcareous, light grey-brown, fine, thin-bedded, finely cross-bedded; overlain by *siltstone,* calcareous, dull brown and red-brown, with lenses of *limestone,* sandy, brachiopods and bryozoa. At about 14 feet from base, float of *limestone,* yellow to grey mottled, sometimes reddish. Overlain by float of *siltstone,* calcareous, yellow-brown, brown, to purplish black, concretionary.

12 feet—Float of *quartz sandstone,* calcareous, light grey and light grey-brown, fine, well and thin-bedded, *siltstone,* calcareous, reddish fossil fragments, and *limestone,* sandy, fine quartz, mottled yellow and dark brown, brachiopods and bryozoa.

11 feet—*Siltstone,* calcareous, brown, and *quartz sandstone,* bryozoa, brachiopods.

8 feet—Interbedded *siltstone,* yellow and brown, and *quartz sandstone,* micaceous, fine; gastropods and pelecypods.

30 feet—Interbedded *quartz siltstone,* calcareous, and *quartz sandstone,* calcareous, grey.

2 feet—*Quartz siltstone,* calcareous, yellow-brown, tessellated, interbedded with *quartz sandstone,* light grey-brown, fine, dense.

11 feet—Float of *siltstone,* calcareous, purple-brown, and *quartz sandstone,* calcareous, light grey, fine-grained.

3 feet—Interbedded *siltstone,* calcareous, or sandy, brown and dark red-brown, purple, and *quartz sandstone,* calcareous in part, grey-brown, fine, thin-bedded, concretionary, gastropods and pelecypods rare.

41 feet—Interbedded *quartz siltstone,* sandy, calcareous, concretionary, yellow-brown, and *quartz sandstone,* calcareous, micaceous, grey and light grey, fine to coarse, sometimes gritty, intraformational siltstone pellets, outcrop mainly lines of float.

154 feet—A few scattered lines of float of *quartz sandstone,* calcareous, grey, in places colour-laminated, fine-grained; gastropods (several species), pelecypods.

32 feet—Soil changes from red to yellow-brown clay. Near top of unit *quartz siltstone,* calcareous, slightly concretionary, dull yellow-brown to brown, overlain by *quartz sandstone,* calcareous, micaceous, light grey-brown, weathers dull red-brown and brown.

8 feet—*Quartz siltstone,* yellow-brown and purple-brown, ferruginized concretionary, only appears as float.

Base—Base not exposed, but underlain by Poole Sandstone. Total thickness 1,331 feet.

Liveringa Formation. (Locality P1, Central South flank of Grant Range.)

Top—No outcrop, alluvium.

233 feet—*Quartz sandstone,* silty, colour light or white, light red, yellow-brown, pastel shades, speckled white or ferruginized to "sintery" black, thin-bedded, bedded, to massive, grain-size fine to medium. Silty or rock-flour matrix prevalent throughout unit. One thin bed (three-quarter inch) conglomerate occurs approximately 30 feet above base. Exposure poor, mostly no outcrop.

66 feet—*Quartz sandstone,* micaceous, grey and light grey, thin-bedded, colour-bedded, fine-grained and medium-grained, with coarse-grained beds more ferruginized and more frequent towards top of unit, often silty, ripple-marked (wind-moved shallow-water), concretionary, spherical and oblate spheres ranging 1 inch to 12 inches.

10 feet—*Quartz sandstone,* light red to brick-red, bedded to thick-bedded, cross-bedded, medium and coarse-grained, rounded to sub-angular with clay blebs $\frac{1}{16}$ inch to $\frac{1}{4}$ inch and clay pellets up to 1 inch.

101 feet—*Quartz sandstone,* micaceous, grey and light grey, thin-bedded, colour-bedded, fine-grained and medium-grained, often silty, ripple-marked (wind-moved shallow-water), concretionary, spherical and oblate spheres, ranging 1 inch to 12 inches. Lenses of *quartz sandstone,* white (weathering red-brown), coarse-grained. Toward top of unit, lenses are replaced by thin beds.

15 feet—*Quartz sandstone,* white (weathering bright red), bedded to well bedded, strongly cross-bedded, weathering massive, coarse-grained, rounded, friable, porous. Jointed silica impregnation along joint-planes. Grain-size in part ranges from medium to very coarse, but mostly unit is well sorted, coarse-grained.

71 feet—*Quartz sandstone,* micaceous, grey and light grey, thin-bedded, colour-bedded, fine-grained and medium-grained, often silty, ripple-marked (wind-moved shallow-water), concretionary, spherical and oblate spheres, ranging 1 inch to 12 inches.

136 feet—*Quartz sandstone,* micaceous in part, light grey to brown, thin-bedded, silty in part, grain-size varying from fine to coarse, sorted to unsorted, friable, with lenses of coarse *sandstone.* Basal bed is a concretionary silty to coarse-grained *quartz sandstone* with clay pellets, poor fossils and wood fragments.

66 feet—Interbedded *quartz sandstone,* micaceous, light to dark brown, fine to medium grained, poorly sorted, with some *quartz sandstone,* light brown to speckled yellow-brown, unsorted, silty to coarse, friable and porous, and *quartz sandstone,* calcareous, light dull brown, fine-grained with scattered quartz pebbles up to two inches.

224 feet—Interbedded *quartz sandstone,* calcareous, grey-brown, fine to silty (with rare calcareous *siltstone*), travertinized, with *quartz sandstone,* micaceous, brown and grey-grown, fine to silty, tending to concretionary, *sandstone* lens toward top of unit contains fragments of fossil wood. Outcrop generally poor.

30 feet—Interbedded *quartz sandstone,* calcareous, grey-brown, medium and coarse grained, subangular to angular, rare grains of black chert, and *siltstone,* calcareous, grey-brown and red-brown, dense.

117 feet—Unit poorly exposed, lithology similar to underlying unit, with addition of *quartz sandstone,* calcareous, light grey, thin-bedded, cross-bedded, medium-grained.

88 feet—Interbedded *quartz sandstone,* varying from silty to poorly sorted, medium-grained, light to grey-brown, speckled, laminated, wavily-bedded, with *siltstone* and *sandy siltstone,* light brown to grey-brown. Some beds concretionary, tending to tessellated.

102 feet—*Quartz sandstone,* speckled grey-brown and red-brown, ferruginized to dark red-brown and blueblack. Medium-grained, thick to crudely bedded, friable and porous. Speckling due to decomposition of feldspar grains.

80 feet—*Siltstone,* yellow, yellow-brown, purple, speckled with white blebs, 0.5 mm.—5 mm. of siliceous material (?opal); unit has been silicified. Contains fossil wood, indet. plants and ? bone. Rare thin lenses of *quartz sandstone,* calcareous. No bedding apparent.

38 feet—*Quartz sandstone,* slightly micaceous, light yellow-grey (weathering light yellow-brown to light red-brown), fine-grained, well-bedded and wavily bedded, weathering to bedded; animal burrows in bedding planes. Some beds of *siltstone,* sandy, dark purple, tessellated, with occasional ripple marks. No outcrop in upper portion.

34 feet—*Quartz sandstone,* silty, red-brown to purple, with intraformational pellets, fossiliferous; passing into interbedded sequence of *siltstone, quartz sandstone,* silty, concretionary, tending to tessellated, yellow-brown, *quartz sandstone,* calcareous, light grey to light red-brown, well sorted, and minor amounts of *quartz sandstone,* micaceous, fine-grained, light grey-brown.

29 feet—*Siltstone,* thin-bedded, colour-laminated with blister concretions, passing up into interbedded *concretionary sandstone,* quartz, fine-grained, and *siltstone,* sandy, micaceous with rare fossils, overlain by *quartz sandstone,* poorly sorted, medium and coarse grained, red-brown and white, with concretions of *quartz sandstone,* oolitic, medium-grained.

34 feet—*Quartz sandstone,* slightly micaceous, well sorted, medium-grained, bedded to well bedded, weathered red-brown with pink inclusions. Overlain by sandstone, fine-grained, bedded, and *siltstone,* sandy, red-brown, tessellated and concretionary.

19 feet—*Quartz sandstone,* poorly sorted, medium to coarse, thin-bedded, with *siltstone* and *quartz sandstone,* fine-grained, thin-bedded and finely cross-bedded, laminated.

48 feet—*Quartz sandstone,* silty, fine-grained, slightly micaceous, well bedded, interbedded with *siltstone,* sandy, and *siltstone,* concretionary and ferruginized. Colour predominantly red-brown. Top of unit reverts to *quartz sandstone,* fine-grained, slightly micaceous, subangular, thin to well bedded, red-brown.

34 feet—*Quartz sandstone,* slightly micaceous, fine-grained, well sorted, subangular to subrounded, thin to well bedded, red-brown, increasing amounts of silt in matrix, interbedded with thin *siltstone* lenses. Rare fossils. No outcrop for upper half of unit.

48 feet—*Quartz sandstone,* slightly micaceous, fine-grained, well sorted, subangular to subrounded, thin to well bedded, red-brown. Near base, discontinuous bed of *quartz sandstone,* iron-oxide-coated, poorly sorted, medium to coarse, well rounded to rounded, with fossils. No outcrop for upper half of unit.

39 feet—*Sandstone* as for unit above. Thin bedded, ranging to thick bedded, and interbedded with thin lenses of light-coloured *calcareous sandstone.*

19 feet—*Quartz sandstone,* slightly micaceous, fine-grained, well sorted, subangular to subrounded, thin to well bedded, colour red-brown.

24 feet—*Quartz sandstone,* and *greywacke* slightly micaceous, fine-grained, well sorted, subangular to subrounded, bedded to thick bedded.

79 feet—As for unit above, but thin bedded to well bedded, concretionary to tessellated.

34 feet—*Quartz sandstone,* and *greywacke,* slightly micaceous, fine grained, well sorted, subangular to subrounded, bedded to thick-bedded.

20 feet—*Quartz sandstone,* micaceous, calcareous, compact, weathers to chips, travertinized in part. Colour yellow, yellow-brown, yellow-grey. Quartz grains commonly cemented with iron oxide.

Base—Base overlies Noonkanbah Formation. Thickness 1,850 feet.

TRIASSIC.

Erskine Sandstone (Locality TRE 1; Erskine Hill).

Meda Formation, unconformably overlying:

27 feet—*Quartz sandstone,* rarely micaceous, fine-grained, laminated, colour yellow-brown and purple, interbedded with *siltstone,* white; bedded and cross-bedded, ripple-marked. Pellet beds occur in the unit.

31 feet—*Quartz sandstone,* micaceous, light red-brown, yellow-brown, fine-grained (coarser than unit below), thin-bedded, wavily-bedded, cross-bedded, ripple-marked, occasional pellet bed. Basal bed $\frac{1}{4}$ inch to $\frac{1}{2}$ inch of *siltstone,* sandy, dark brown, strongly ferruginized.

31 feet—*Quartz sandstone,* micaceous (white), light yellow-brown, fine-grained, with siltstone pellets; overlain by *quartz sandstone,* micaceous, light brown weathering yellow-grey, friable, three feet thick: overlain by *quartz sandstone,* micaceous, silty, colour-laminated light brown, yellow-grey, and light grey, fine-grained, thin-bedded, cross-bedded, weathers massive blocky. Basal bed *siltstone,* ferruginized, about one inch thick.

Conformable over *Blina Shale,* 94 feet: *Siltstone,* micaceous, quartzose light grey, brown to purple-brown, weathering light yellow and yellow-grey, grain-size tends to claystone or shale, thin laminated bedded, fissile, tends to weather into slabs about one inch thick. Presence of calcareous or phosphate cement gives harder beds. Pipe-like concretions in beds vertical ½ inch diameter giving rise to blister concretions on bedding surfaces. Scree slopes outcrop ferruginized chippy. Uppermost six feet interbedded *siltstone* (as above) and quartz sandstone, yellow, fine-grained.

Mudjalla Sandstone (Locality JM1, 5.5 miles N.N.W. of Mudjalla Yard, Luluigui Station).

73 feet—*Siltstone,* micaceous, white, laminated alternately with *sandstone,* red-brown, fine, flat-bedded and gently cross-bedded.

At 105 feet *sandstone* with angular blocks up to eight inches of white siltstone, eroded laterally from 40-foot lens of white sandy *siltstone.*

Base of unit is *sandstone,* large rare mica flakes, slightly silty, medium, well-sorted, bedded to thick-bedded and cross-bedded up to 26°, porous, friable; interbedded with *siltstone,* sandy, with numerous clay pellets, white, thin-bedded.

14 feet—*Quartz sandstone,* large mica flakes and clay pellets, poorly sorted, medium with rare fine and coarse, bedded to thick bedded, cross and flat bedded; interbedded with *siltstone,* sandy, slightly micaceous, white, thin-bedded with poorly preserved plant fragments.

16 feet—*Sandstone,* micaceous, silty, light grey to light yellow and marked yellow-brown, banded to mottled, fine, with scattered coarse grains, thick-bedded, difficult to break along bedding, fragmental plants; changing laterally at top of unit to be interbedded with *quartz sandstone,* coarse subangular to subrounded pebbles ¾ inch to 2 inches, rare cobbles, in lenses.

32 feet—*Quartz sandstone,* slightly micaceous and silty, light brown, medium; interbedded with *quartz sandstone,* very micaceous and clayey, light grey and light brown, fine, finely cross-bedded; and *sandstone,* light red-brown, usually poorly sorted, fine and medium to coarse, commonly with ¼ inch to ½ inch clay pellets, thick-bedded and flat-bedded to cross-bedded. Restricted horizons of fragmental plant fossils locally, at 24 feet, 26 feet above base.

Contact with Liveringa Formation not seen, but about 20 feet below lowest exposure.

Alexander Formation (Locality JA1, Mount Alexander).

52 feet—*Quartz sandstone* slightly micaceous, interbedded with (i) intermingled lenses *quartz sandstone,* fine-grained, and *siltstone* white to light red-blue, poorly wavily-bedded; (ii) *quartz sandstone,* white

to red-blue, fine-grained, well bedded, breaks unevenly; (iii) *quartz sandstone,* brown, medium-grained, occasional thin beds; (iv) *quartz sandstone,* white, fine-grained, friable, finely cross bedded; (v) *siltstone,* white, silicified, massive, weathers massive.

Topmost beds fossiliferous.

58 feet—*Quartz sandstone,* micaceous, white to light brown, wavily-bedded thin-bedded, fine-grained and medium-grained, alternately bedded with *siltstone,* white, thin-bedded, weathers thin-bedded platey. Ripple-marked (wind-directed shallow-water type). Beds lensing, never more than two inches thick.

12 feet—*Quartz sandstone,* slightly micaceous, grey-brown to yellow-brown, weathering red-brown, current-bedded, weathering poorly massive, irregularly jointed, medium-grained, porous, slightly friable.

10 feet—No outcrop.

Unconformity.

24 feet—Jurgurra Sandstone.

James Sandstone (Locality MJ1, Mount James).

107 feet—*Quartz conglomerate,* ferruginized fine rounded quartz pebbles; matrix quartz sandstone, fine to coarse grained, poorly sorted (3 to 4 inches): grading up into *quartz sandstone,* dark blue-black, weathering same, weathering massive, becoming cross bedded at top, fine-grained to coarse-grained, poorly sorted, angular to subangular with layers quartz pebbles (up to one inch) along bedding planes and occasional conglomerate lenses up to one foot thick. Weathered boulders and surfaces often exfoliated. Occasional *siltstone* lenses up to three inches thick near top.

Unconformity:

Poole Sandstone or Liveringa Formation.

Jarlemai Formation (Locality JJ1, Mount Jarlemai).

171 feet—*Siltstone* with scattered quartz grains ranging fine to coarse, colour white with dark brown, yellow-brown with red-blue, light brown-grey with brown markings, white, pastel shades of yellow, red, mauve, olive-green, blue-grey: weathers bright red-brown; crudely bedded, weathers rubbly and jointed. Siltstone tends to claystone in places. Uppermost 20 feet silicified, possibly owing to lateritization.

APPENDIX III.

REPORT ON SAMPLES FROM FRENEY-KIMBERLEY NERRIMA No. 1 BORE, WESTERN AUSTRALIA, AND ON SCATTERED OUTCROP SAMPLES.

By Irene Crespin.

(Examined in 1940-41; the determinations were revised in 1956.)

Specimens from:
(feet)

39 feet—*Shale,* friable, pale ochreous to grey, bedded, micaceous. Washings—almost entirely fragments of micaceous shale, with some black fragments (? carbonaceous), and foraminifera (cf. *Tetrataxis*).

Specimens from.
(feet)

52 feet—*Shale,* hard, dark grey, mottled with lighter patches, micaceous. Washings—almost entirely fragments of dark grey to light grey shale, with some carbonaceous material and foraminifera (*Nodosaria* raggatti).

59 feet—*Shale,* (a), grey shelly with foraminifera (*Calcitornella*) and remains of brachiopod shells (cf. *Productus* and spines). Washings—foraminifera (*Calcitornella heathi, C. stephensi, Apterinella* sp., *Frondicularia woodwardi, Geinitzina caseyi* Crespin MS., *G. striatosulcata* Crespin MS., *Nodosaria raggatti* Crespin MS., spines of brachiopoda, small gasteropoda (*Ptychomphalina maitlandi*) and ostracoda (*Amphissites* sp., *Bairdia* spp., *Bythocypris* sp., and genera indeterminate).

Shale, (b), grey, micaceous, roughly bedded, and with pyrites. Washings—chiefly aggregates of pyrites with mica, quartz grains, foraminifera (*Pseudohyperammina radiostoma* Crespin MS.) and ostracoda (*Bairdia* spp.).

62 feet—*Mudstone,* mottled, dark to light grey, micaceous with foraminifera (*Nodosaria raggatti*).

69 feet—*Mudstone,* bedded, dark grey, passing into mottled dark to light grey micaceous sandy mudstone with impressions of brachiopoda. Washings of shelly portion—numerous quartz grains, foraminifera (*Ammodiscus nitidus, Frondicularia woodwardi, F. parri, Geinitzina striatosulcata, Calcitornella heathi, Dentalina grayi, Nodosaria raggatti*), and ostracoda.

89 feet—*Shale,* grey, micaceous, sandy. Washings—fragments of shale, fine quartz grains, foraminifera (*Hyperammina* sp., *Frondicularia* sp.) and ostracoda indeterminate.

90 feet—*Sandstone,* grey, fine-grained, micaceous.

95 feet—Ditto, with bands of dark grey mudstone. Washings—almost entirely fragments of micaceous sandstone.

103 feet—*Mudstone,* hard, grey, calcareous, with occasional shell fragments, foraminifera (*Calcitornella* sp.) and veins of calcite. A thin section shows fine angular quartz grains, mica flakes, and carbonaceous material.

108 feet—*Mudstone,* dark grey, micaceous, with light grey bands, with ostracoda indeterminate and slightly micaceous. Washings—foraminifera (*Ammodiscus nitidus, Thuramminina phialaeformis* Crespin MS., *Hyperammina acicula, Frondicularia parri*) and ostracoda indeterminate.

113 feet—Ditto, with foraminifera and ostracoda indeterminate.

129 feet—*Mudstone,* dark grey, carbonaceous, with foraminifera (*Calcitornella*), numerous bryozoa (*Hexagonella australe*) and shell fragments. Washings—numerous foraminifera, bryozoa, shell fragments and ostracoda.

FORAMINIFERA—Ammodiscus nitidus, Apterinella sp., *Calcitornella stephensi, C. heathi, Frondicularia woodwardi, F. parri, Dentalina grayi, Geinitzina triangularis, G. striatosulcata, Hemigordius harltoni, H. schlumbergi, Hyperammina expansa, Orthovertella* sp., *Pseudohyperammina radiostoma, Plummerinella kimberleyensis* Crespin MS., *Streblospira kimberleyensis, S. meandrina Thurammina phialaeformis, Tolypammina* sp.

Specimens from:
(feet)

OSTRACODA—*Bairdia* spp.; *Healdia* sp.; cf. *Jonesina*; *Hollina* sp.; *Cytherella* sp.; genera indeterminate.

143 feet—Mudstone, hard, shelly, calcareous, with *Calcitornella stephensi* (common), *Linoproductus* cf. *cancriniformis, Chonetes pratti* and *Aviculopecten* sp.

172 feet—Mudstone, banded, dark to light grey, micaceous.

187 feet—Mudstone, dark grey to light grey, micaceous, passing into shelly mudstone, with *Calcitornella stephensi* (common), *Chonetes pratti* and numerous ostracoda.

194 feet—Mudstone, mottled, dark to light grey, micaceous, with *Chonetes pratti* and *Linoproductus* sp. Washings—foraminifera *Frondicularia woodwardi, Nodosaria raggatti, Pseudohyperammina radiostoma.*

200 feet—Mudstone, mottled, grey to dark grey, micaceous.

216 feet—Ditto.

236 feet—Ditto, with vein of calcite.

248 feet—Mudstone, mottled, dark to light grey.

262 feet—Ditto.

266 feet—Mudstone, hard, grey, passing into fine-grained, shelly sandstone, with *Calcitornella* and shell fragments indeterminate.

272 feet—Mudstone, mottled, light to dark grey, carbonaceous, micaceous. Washings—foraminifera (*Ammodiscus nitidus, Frondicularia woodwardi, F. Parri, Nodosaria raggatti, Pseudohyperammina radiostoma*) and ostracoda indeterminate.

292 feet—Mudstone, dark to light grey, highly micaceous on some of the fractured surfaces.

309 feet—Sandstone, hard, fine-grained, grey, micaceous, calcareous.

314 feet—Mudstone, dark grey to grey, micaceous, carbonaceous.

352 feet—Mudstone, finely bedded, dark to light grey, micaceous.

404 feet—Mudstone, banded and mottled, dark to light grey, micaceous.

409 feet—Sandstone, light grey, fine-grained, micaceous. Washings—fine, angular quartz grains and mica flakes (no organisms).

424 feet—Mudstone, fine, grey, with patches of shelly sandstone, also *Calcitornella stephensi* and fragments of brachiopoda indeterminate.

433 feet—Mudstone, dark grey.

444 feet—Mudstone, dark to light grey, banded, micaceous and carbonaceous. Washings—entirely fragments of mudstone.

476 feet—Ditto.

488 feet—Ditto.

500 feet—Ditto.

518 feet—(a) Sandstone, grey, micaceous, passing into calcareous sandstone with carbonaceous particles.

(b) Mudstone, dark to light grey, banded, micaceous, with ? worm tracks.

541 feet—Mudstone, dark grey, with patches of light grey.

563 feet—Mudstone, dark grey, micaceous.

584 feet—Mudstone, banded, dark to light grey, micaceous, with shell remains on dark grey surface (cf. *Cleithyridina* and *Myalina* sp. nov.).

607 feet—Mudstone, dark grey, micaceous, with thin layers of light grey material.

626 feet—Ditto, with shell fragments indeterminate.

644 feet—Ditto, with large segregations of pyrites. Washings—fragments of mudstone, with pyrites.

650 feet—Sandstone, grey micaceous.

Specimens from:
(feet)

660 feet—Ditto. Washings—chiefly moderately fine angular quartz grains, with mica flakes. No organisms.

669 feet—Mudstone, alternating bands of light and dark grey, micaceous, carbonaceous.

690 feet—Ditto, with pyritic concretion.

714 feet—Mudstone, banded and mottled, light to dark grey, micaceous.

739 feet—Sandstone, light grey, fine-grained, with fine bands of dark grey mudstone, irregularly bedded. Washings—chiefly angular quartz grains and mica flakes (no organisms).

760 feet—Alternating bands of micaceous mudstone and sandstone.

785 feet—Ditto.

810 feet—Sandstone, mottled, grey to light grey, micaceous, with fragments of fossil wood indeterminate.

825 feet—Sandstone, grey, micaceous, felspathic, with inclusion of carbonaceous material, passing into pyrites.

867 feet—Sandstone, grey, micaceous. Washings—almost entirely of angular quartz grains, with mica flakes and pyritic fragments.

880 feet—Sandstone, grey, felspathic, showing rough bedding.

911 feet—Sandstone, grey, micaceous, felspathic, with occasional patches of grey mudstone.

932 feet—Ditto, with patches of pyrites.

955 feet—Sandstone, light to dark grey, micaceous, roughly bedded, with mica, common along the surface of bedding planes, also patches of pyrites. Washings—almost entirely angular quartz grains with mica flakes.

966 feet—Mudstone, banded, dark grey, micaceous and light grey, micaceous sandstone, showing rough bedding.

996 feet—Sandstone, coarse, greenish-grey, micaceous, with layers of dark grey mudstone.

1,024 feet—Similar to 966 feet, with finer bedding.

1,027-1,042 feet—"Hard Band". Sandstone, hard, grey, micaceous felspathic.

1,077 feet—Sandstone, friable, grey, micaceous felspathic. Washings—chiefly angular quartz grains, with mica flakes and pyrite crystals.

1,082 feet—Ditto.

1,119 feet—Sandstone, grey, micaceous, felspathic.

1,140 feet—Sandstone, bright green, glauconitic, micaceous.

1,153 feet—Ditto. Washings—chiefly angular quartz grains, all stained green, also mica flakes.

1,160 feet—Ditto, with patches of mica. Washings—chiefly angular quartz grains, all stained green, some glauconite grains and mica flakes.

1,176 feet—Thin bands of dark grey mudstone alternating with grey, micaceous sandstone, showing current bedding.

1,178 feet—Patches of green glauconitic, micaceous sandstone in grey sandstone.

1,202 feet—Sandstone, greenish, micaceous.

1,220 feet—Sandstone, pale, greenish-grey, interbedded with dark grey, carbonaceous mudstone. Washings consist chiefly of fragments of carbonaceous mudstone, with fine, angular quartz grains and mica flakes.

1,240 feet—Sandstone, grey, micaceous, interbedded with dark grey, carbonaceous mudstone. Washings—chiefly angular quartz grains, with carbonaceous mudstone fragments.

1,339 feet—Shale, hard, dark grey, micaceous, carbonaceous, interbedded with pale grey, fine-grained, micaceous sandstone.

Specimens from:
(feet)

1,380 feet—Sandstone, hard, pale grey, micaceous, with some carbonaceous remains.

1,643 feet—Ditto, with inclusion of carbonaceous material.

1,653 feet—Ditto. Washed crushings—almost entirely fine, angular quartz grains fairly uniform in size, and some mica flakes.

1,740 feet—Shale, irreguarly banded, light to dark grey, micaceous, with carbonaceous remains.

1,810 feet—Shale, ditto, with concretionary nodules of dark grey, carbonaceous.

1,920 feet—Shale, hard, fine-grained, grey, micaceous.

1,930 feet—Ditto.

1,940 feet—Ditto.

2,035 feet—Sandstone, hard, cream to grey, micaceous, with fine bands of dark grey shale.

2,170 feet—Sandstone, grey. Washed crushings—chiefly subangular to angular quartz grains, with a few mica flakes, carbonaceous fragments and a little pyrites.

2,200 feet—Ditto, with patches of coarse material containing rounded pebbles.

2,285 feet—Sandstone, hard, pale grey, fine-grained.

2,445 feet—Mudstone, hard, grey, sandy, showing shearing and with some fine veins of carbonaceous material.

2,514 feet—Sandstone, pale grey. Washed crushings—almost entirely angular to subangular quartz grains, with occasional mica flakes.

2,693 feet—Shale, hard grey, with occasional veins of dark grey, carbonaceous material.

2,770 feet—Shale, dark grey, carbonaceous.

2,825 feet—Shale, pale grey, with fine bands of dark grey, micaceous, carbonaceous shale.

2,935 feet—Sandstone, hard, grey, gritty. Washed crushings—angular to rounded, coarse to fine quartz grains, with fragments of reddish and greenish rocks.

2,954 feet—Ditto.

3,005 feet—Sandstone, fine-grained, dark grey, micaceous, carbonaceous, with patches of grey, micaceous shale. Thin section of rock—fine to coarse, angular to subangular quartz grains in carbonaceous groundmass.

3,151 feet (A)—Sandstone, hard, dark grey, with large inclusions of pale grey to greenish, micaceous sandstone.

3,151 feet (B)—Ditto, with small inclusions of greenish sandstone. Crushings consisted chiefly of moderately coarse, rounded to fine, angular grains of clear quartz, with fragments of dark grey sandstone.

3,170 feet (A)—Sandstone, pale grey, fine-grained, roughly bedded and with a few inclusions of dark material.

3,170 feet (B)—Ditto, showing slight dip.

3,216 feet—Sandstone, white, with small dark inclusions. Crushings consisted chiefly of angular to subangular grains of clear quartz, a few fragments of greenish mineral, and a little quartz and pyrites.

3,261 feet—Sandstone, pale grey, with carbonaceous markings. Washings—entirely fine, angular quartz grains.

3,320 feet—Sandstone, whitish.

3,373 feet—Ditto. Washings similar to 3,261 feet.

3,428 feet—Sandstone, pale grey to grey, current bedded.

3,510 feet—Sandstone, whitish.

3,611 feet—Ditto. Washings entirely rounded to subangular quartz grains.

Specimens from:
(feet)

3,659 feet—Ditto.
3,661 feet—Shale, dense, dark grey, showing bedding.
3,662 feet—Ditto.
3,673 feet—Shale, dark to light grey, current bedded.
3,707 feet—Sandstone, grey, with patches of carbonaceous material. Washings—angular quartz grains.
3,714 feet—Sandstone, dark grey. Thin section shows the rock to be a banded, carbonaceous sandstone.
3,806 feet—Sandstone, whitish. Washings—angular to rounded quartz grains and fine fragments of dark grey material.
3,832 feet—Sandstone, greyish, with irregular banks of dark grey shale.
3,945 feet—Sandstone, grey and whitish, current-bedded.
3,956 feet—Ditto, with whitish sandstone predominating, and inclusion of carbonaceous material.

The bore terminated at 4,271 feet.

NOONKANBAH FORMATION.

The Noonkanbah Formation extends from 39 feet to 785 feet. From 39 feet to 59 feet, the beds consist of grey to dark grey shales, and from 62 feet to 785 feet, the sequence is alternating mudstones and micaceous sandstone, varying from dark grey to light grey in colour, with frequent mottling. Marine fossils are represented down to 584 feet.

Fossils, especially foraminifera and ostracoda, are fairly abundant in some of the samples, and are sparingly represented in several more.

Foraminifera are fairly well represented and include *Calcitornella stephensi, C. heathi, Ammodiscus nitidus, Thurammina phialaeformis* Crespin MS., *Nodosaria raggatti* Crespin MS., *Frondicularia woodwardi, F. parri, Geinitzina triangularis,* and *G. striatosulcata* Crespin MS. *Calcitornella stephensi* is one of the most characteristic species found in the Callytharra Formation in the Carnarvon Basin and is restricted to that horizon. It has been previously recorded from the Noonkanbah Formation as well as the Gascoyne Area. *Frondicularia woodwardi* and *Geinitzina triangularis* have described from the Irwin River Beds.

Bryozoa are especially well represented at 129 feet, both the species recorded—*Hexagonella australis, Ramipora ambrosioides*—being known Callytharra forms.

The brachiopoda, though fairly common at some depths, are usually crushed. *Linoproductus cancriniformis* and *Chonetes pratti* are amongst the determinable forms, and productid spines are common.

Molluscan remains are rare. *Aviculopecten* sp. and *Ptychomphalina maitlandi* are amongst the recognizable forms. A well-preserved but slightly crushed specimen of *Myalina,* most probably a new species, occurs at 584 feet. Its closest ally is *Myalina congeneris* Walcott from the Permian of the Eureka District, Nevada, United States of America.

Ostracoda are extraordinarily well developed in some of the samples, at 59 feet, 69 feet, 129 feet and 194 feet. The following genera, typical of the Permian beds of the United State of America, are recognizable—*Bairdia, Hollinella, Cavellina, Bythocypris, Amphissites, Healdia, Hollina,* and *Kirkbya.* Numerous other specimens were not comparable with any of the other forms available for comparison. At 518 feet, remains probably referable to worm tracks were present.

The following Permian foraminifera have been determined from different localities:—

(a) From an outcrop 1 mile north of B.M.R. No. 1 Jurgurra Creek; upper part of Noonkanbah Formation—
Ammodiscus nitidus.
Hyperammina acicula.
Hypermminita rudis.
Pelosina ampulla.
Reophax ellipsiformis Crespin MS.
Thurammina phialaeformis Crespin MS.

(b) Cuttings taken from between 20 feet and 60 feet in the B.M.R. No. 1, Jurgurra Creek contained specimens of *Hyperammina acicula* and *Thurammina phialaeformis.*

(c) Bruten's Yard Section—
10 feet below top of Noonkanbah Formation—
Ammodiscus nitidus.
Hyperammina acicula.
H. expansa.
H. sp.
Reophax subasper.
Thurammina phialaeformis.
Thuramminoides sphaeroidalis.
T. cf. *teicherti.*
Trochammina cf. *subobtusa.*
55 feet below top—
Thurammina phialaeformis.
525 feet below top—
Digitina cf. *recurvata.*
Ammodiscus nitidus.
600 feet below top—
Ammodiscus nitidus.
Hyperammina sp.
Thuramminoides teicherti.

(d) 374 feet below top of Noonkanbah Formation, Grant Range—
Ammodiscus nitidus.
Hyperammina acicula.
Reophax ellipsiformis.
Thurammina phialaeformis.
Thuramminoides teicherti.

(e) Mount Marmion—
Frondicularia woodwardi.
Nodosaria raggatti (Crespin MS.).
Rectoglandulina serocoldensis.

(f) Near Liveringa Homestead, 8 feet above base of Poole Sandstone—
Hyperammina sp.

(g) Dusty Creek Bore, 10 miles north-west of Christmas Creek Homestead—
Hyperammina acicula.

APPENDIX IV.

ALTERNATIVE INTERPRETATION OF FENTON AND PINNACLE FAULTS.

By M. A. Condon and J. N. Casey.

The two major structural surface features of the Fitzroy Basin are the "Pinnacle Fault" and its extension to the north-west, and the "Fenton Fault". Although faulting has been established in places along these two structures, it may be not the dominant structure, but a secondary feature representing the surface trace of an underlying unconformity or subsurface "high". The terms will therefore be used in the sense of structural features or lines rather than implying a fault in the strict sense.

The "Pinnacle Fault", which crops out on the north-east side of the Basin, forms the south-west limit of outcrop of both Ordovician and Devonian rocks. The outcrops of Devonian rocks show that the area to the north-east of this structure was a shelf area in Devonian time, and it was probably not transgressed to any larger extent by later seas.

Near The Pinnacles, faulting has taken place on the structure since the deposition of the Grant Formation. On the north-east side of the structure the Grant Formation and Devonian limestone outcrops are shattered, but on the south-west side the Liveringa Formation, Noonkanbah Formation, and Poole Sandstone are unaffected by any fault movement.

There is no certain fault phenomenon along a possible north-west extension of the "Pinnacle Fault", but the outcrop pattern of the Permian formations in this area suggests that the structure is mainly an unconformity with some faulting in the Christmas Creek area. The Fitzroy Basin was therefore subsiding south-west of the "Pinnacle Fault", during at least the deposition of the Poole Sandstone, Noonkanbah Formation, and Liveringa Formation, and deposition of these units more or less kept pace with subsidence. The Basin, however, may have been subsiding throughout Devonian, Ordovician and earlier times and recent seismic work in the Prices Creek area (Smith, 1955) suggests a structural depression of about 18,000 feet immediately south-west of the "Pinnacle Fault". Smith estimates about 1,600 feet to "basement" north-east of the structure and about 19-20,000 feet south-west of the structure. In the section of the southern side of the "Pinnacle Fault" there is an unconformity at 8,000 feet and probably a second at 13,000 feet. The 18,000-foot structural depression south of the "Pinnacle Fault" suggests either that the depression was controlled by a fault which was active throughout most of the Palaeozoic or that the "Pinnacle Fault" represents the seaward extension of a basement "high" or shelf and would therefore mark the seaward extent of the Ordovician and Devonian shelf deposits represented in the outcrop area.

The history of the "Fenton Fault" may be similar to that of the "Pinnacle Fault". The "Fenton Fault" represents almost the southern limit of the outcrop of Permian sediments of the Fitzroy Basin, and the northern limit of marine Jurassic sediments of the Canning Basin. There is considerable stratigraphical discontinuity across some sections of the structure and practically none across others. Between Nerrima Creek and Mount Fenton the fault plane has been studied at several localities; it dips north at 50° to 60°. In the Mount Arthur area, Poole Sandstone crops out on both sides of the fault. The "Fenton Fault", like the "Pinnacle Fault", may not be the major structure and may only be the surface expression of a large subsurface structure, not necessarily a fault.

The strike of the faults closely parallels the 310° axial trend of the Upper Proterozoic folds in the King Leopold Range.

A gravity survey across the "Fenton Fault" (Wiebenga, 1953) suggests a structure with a "downthrow" or depression to the north of 12,000 feet near Mount James, 7,000 feet near Barnes Flow, 6,000 feet near Green Spring and Mount Density, and no displacement at Jurgurra Creek. The gravity contours of the area suggest a "low" appearing on the south side and a "high" on the north side of the possible north-west extension of the "Fenton Fault". These gravity results could be interpreted as a fault-controlled depression forming the southern edge of the Fitzroy Basin; but like the "Pinnacle Fault", the "Fenton Fault" could represent the northern extension of a basement or older Palaeozoic "high", in which case it would represent the northward extension of a southern shelf-type pre-Permian sediment which would grade into a deeper-water sediment in the Fitzroy Basin proper.

A recent seismic section near Barnes Flow (K. Vale, Bureau of Mineral Resources, personal communication) has shown a profile very similar to that produced by Smith (1955) across the "Pinnacle Fault", and also shows a "depression" on the north side of the "Fenton Fault". The depth to the "high" south of the "Fenton Fault" is between 3,000 and 5,000 feet.

Airborne magnetometer traverses across the "Fenton Fault" in 1955 (B. Clarke, Bureau of Mineral Resources, personal communication) suggests that a definite subsurface ridge runs parallel with the surface trace of the "Fenton Fault" and the northern extension of this ridge almost coincides with the position of the "Fenton Fault".

A bore drilled south of the structure on Jurgurra Creek for stratigraphical information penetrated the Noonkanbah Formation from near the surface to 645 feet and continued to 1,680 feet in Poole Sandstone and possibly Grant Formation; this agrees with Wiebenga (1953), who concludes that there is no displacement across the "Fenton Fault" at Jurgurra Creek.

It is suggested that, according to the recent geological, gravity, seismic and magnetometer evidence, the "Fenton Fault" is not a major fault line, but represents the northern edge of a north-west-trending ridge; and therefore a thicker section of sediments may be expected further to the south (over the ridge) in the Canning Basin as well as to the north in the Fitzroy Basin. This ridge could have saddles such as the gravity "low" shown to the west of Jurgurra Creek (Wiebenga, 1953). The Mesozoic sediments in the Edgar Range would represent a basin of deposition south of the ridge, and a structure similar in appearance to the "Fenton Fault" (but now covered by Mesozoic sediments and sand) would mark the southern extent of the ridge. This ridge would be the logical place to test the pre-Permian structure of the area by drilling.

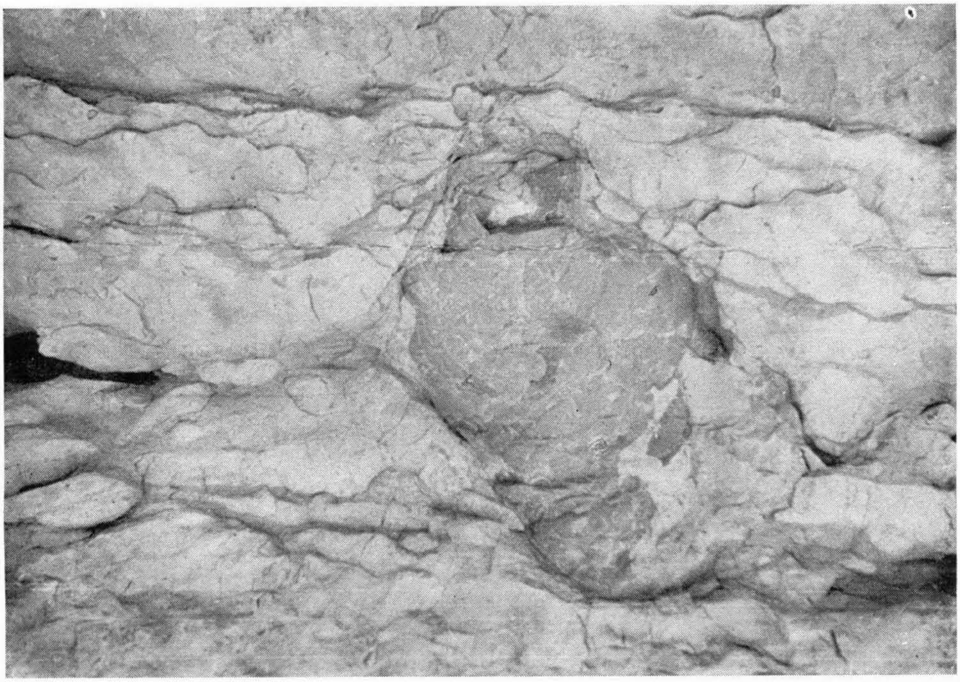


Fig. 1.—Stromatoporoid colonies (biostromes) at base of Pillara Formation; near Geikie Gorge.

Fig. 2.—?Stromatoporella biostrome and colonies in Pillara Formation calcarenite; Pillara Range.

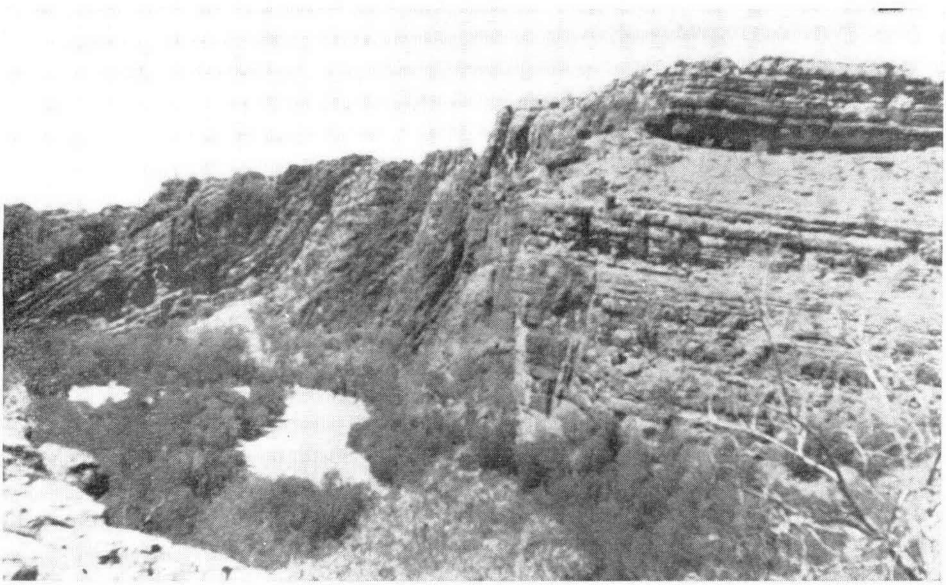


Fig. 1.—Napier Formation dipping steeply off sub-horizontal Pillara Formation; Windjana Gorge.

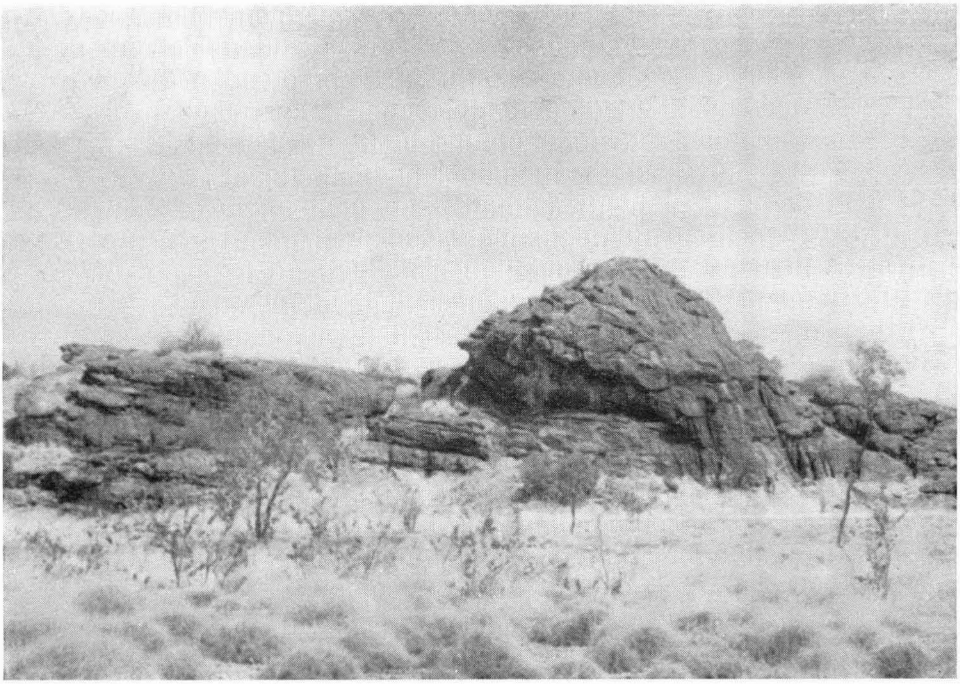


Fig. 2.—Sadler Beds unconformably overlying Pillara Formation; Pillara Range.

Fig. 1.—Basal Bed of Napier Formation, showing two types interbedded.

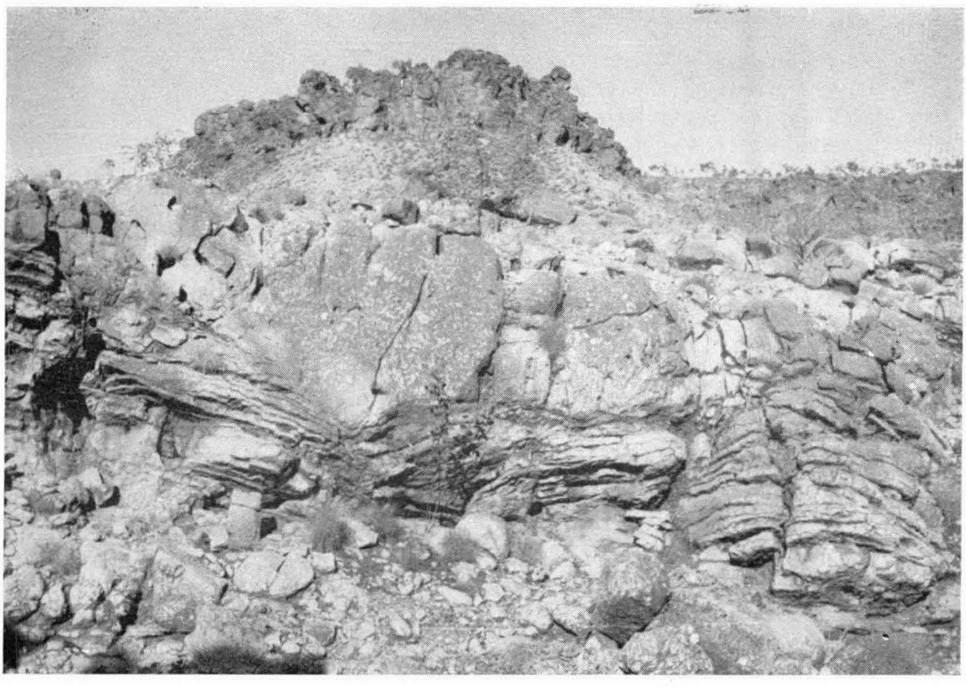


Fig. 2.—Bioherm in upper Bugle Gap Limestone: Grant Formation in background; Bugle Gap.

Fig. 1.—Poole Sandstone, separated from Grant Formation (in foreground) by a fault; Mount Tuckfield, St. George Range.

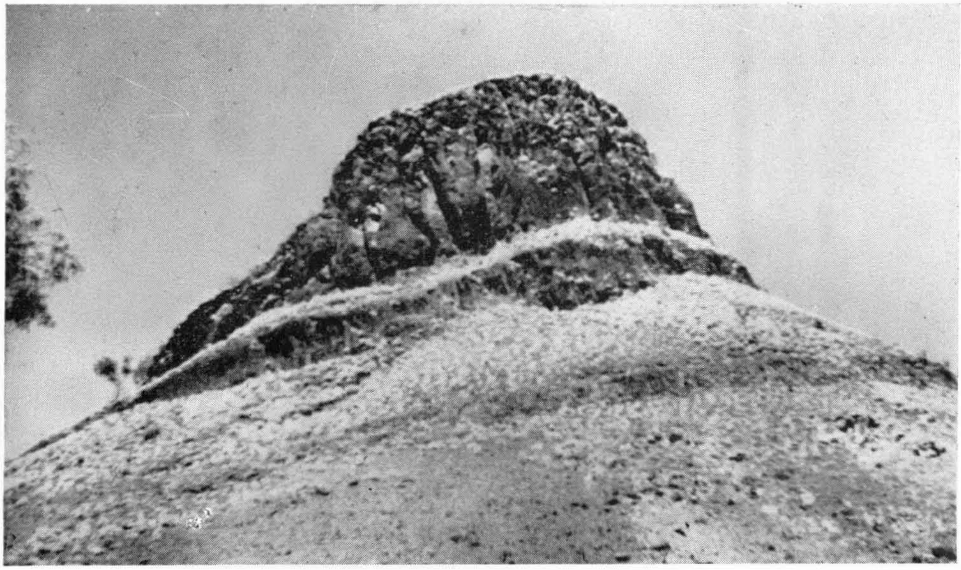
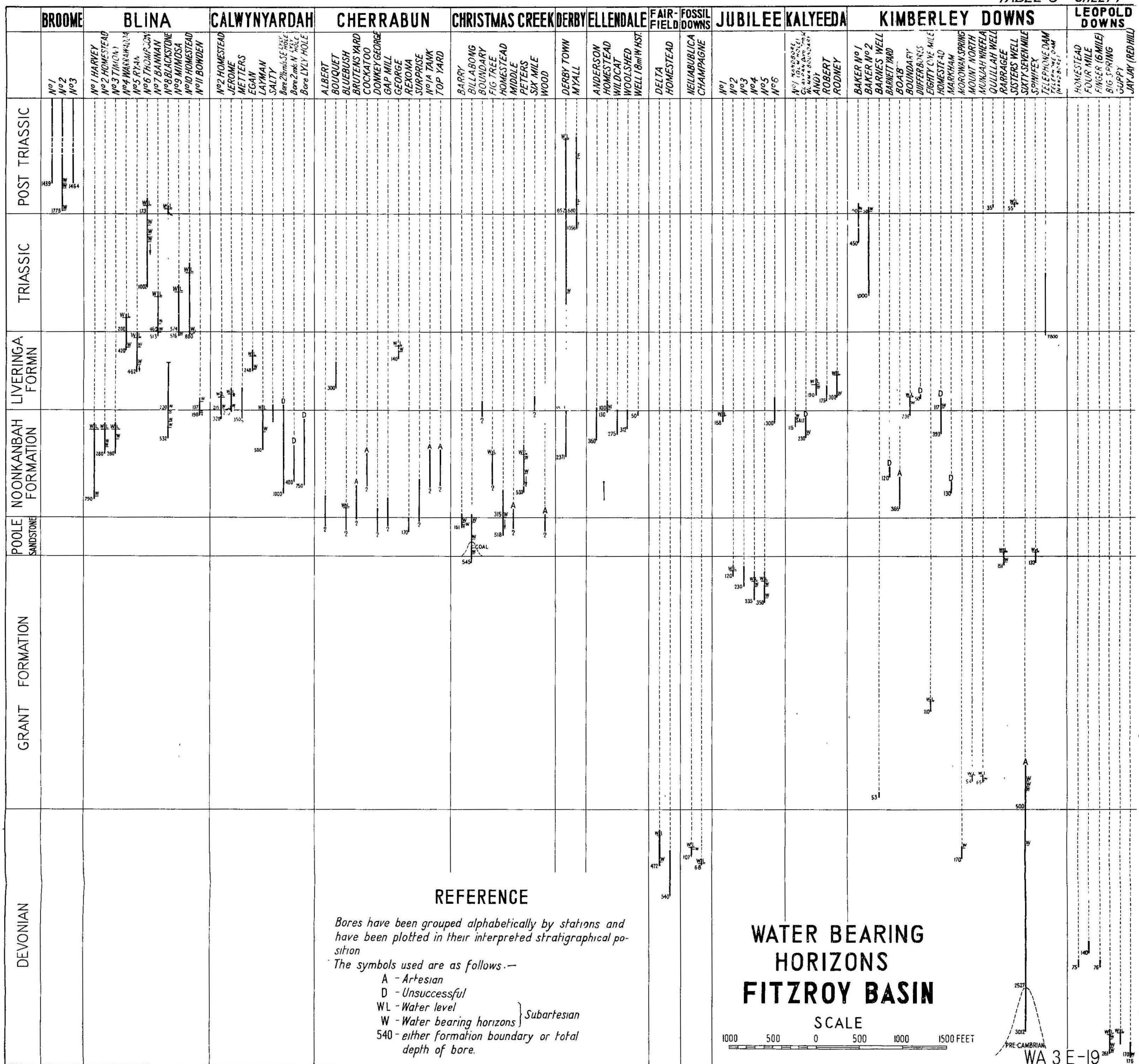


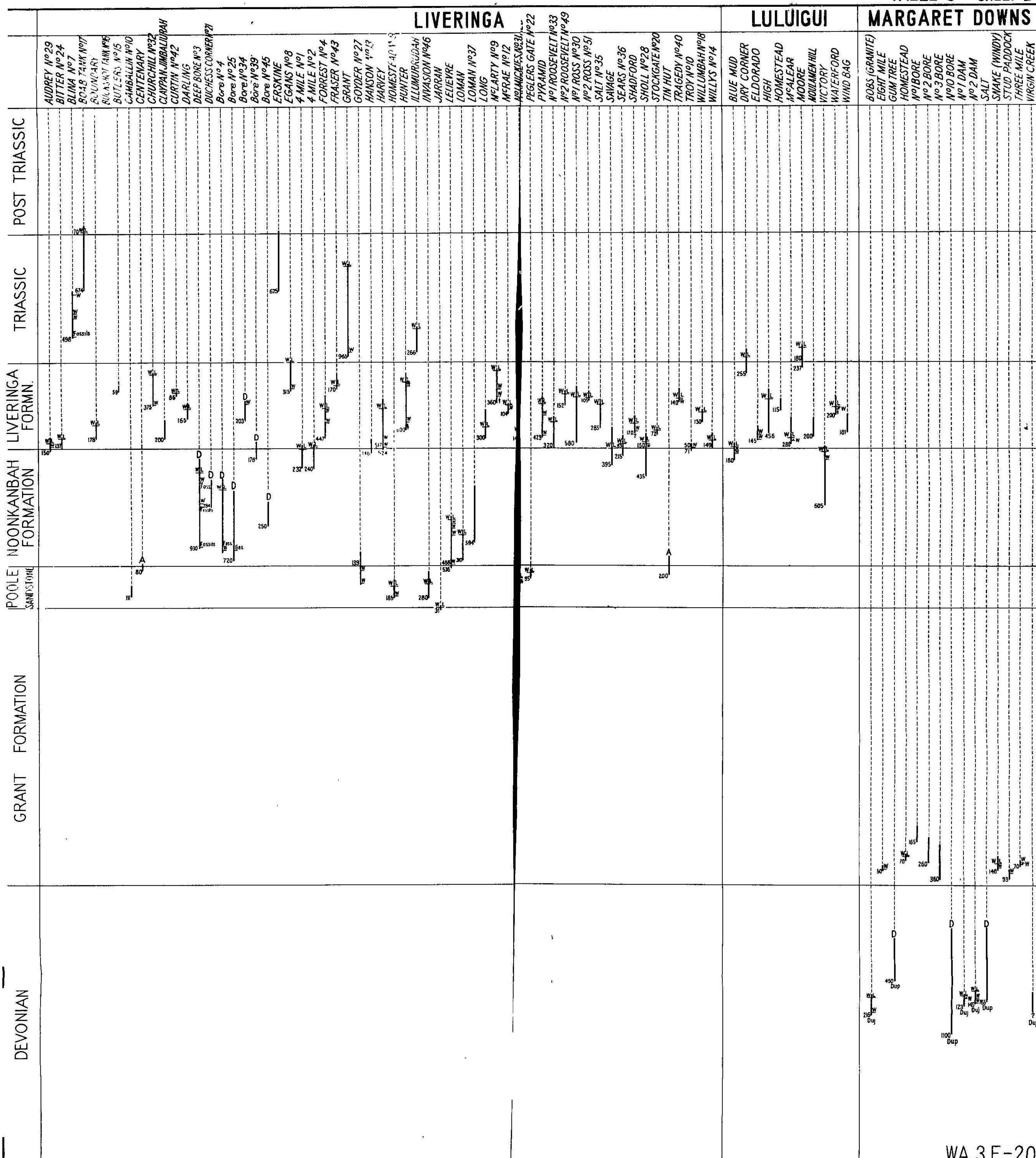
Fig. 2.—Mount North, a lamproite plug.

TABLE 6 · SHEET 1



BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS, CANBERRA A.C.T.

TABLE 6 · SHEET 2



WA 3 E-20

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS CANBERRA A.C.T.

TABLE 6 · SHEET 3

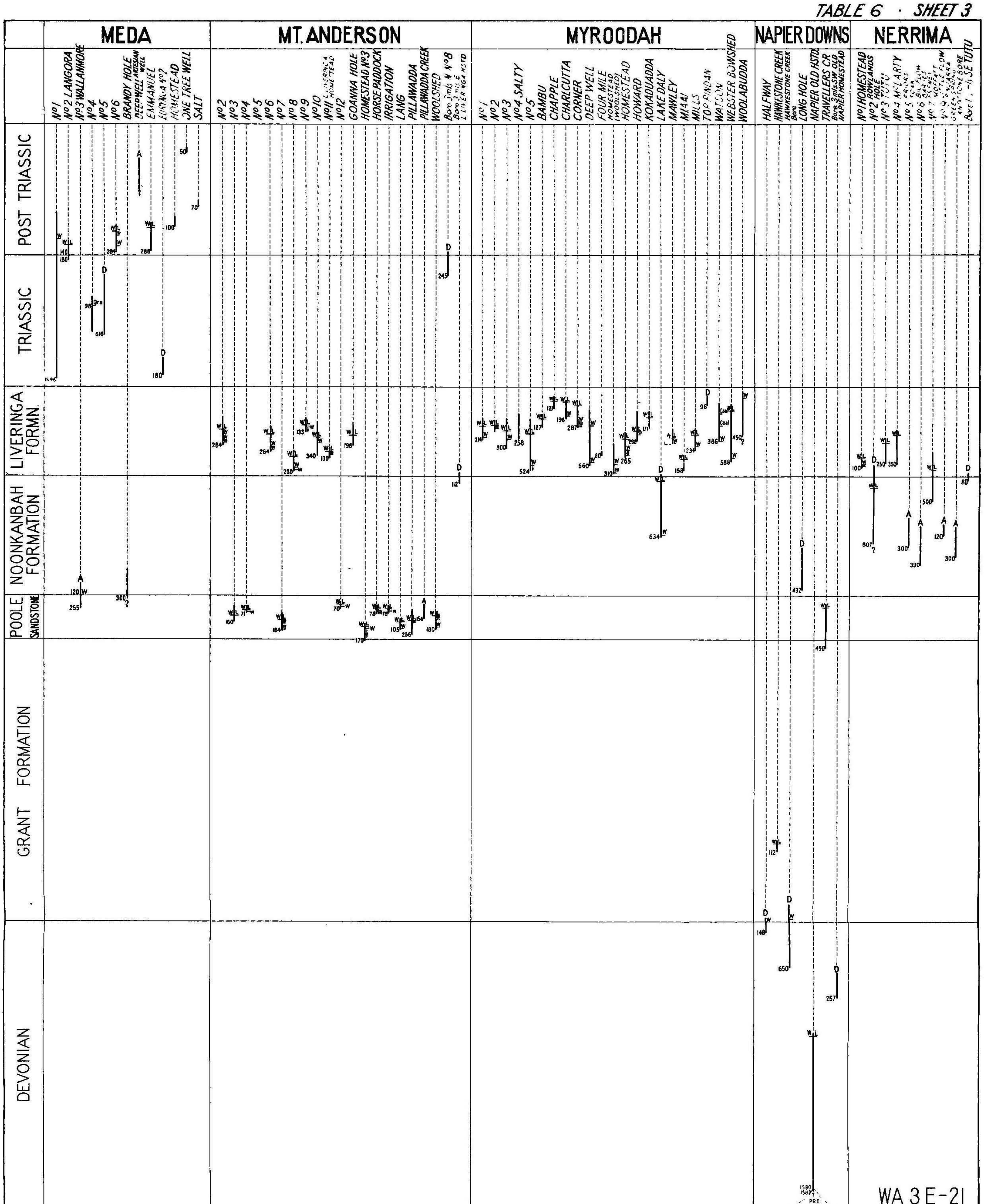
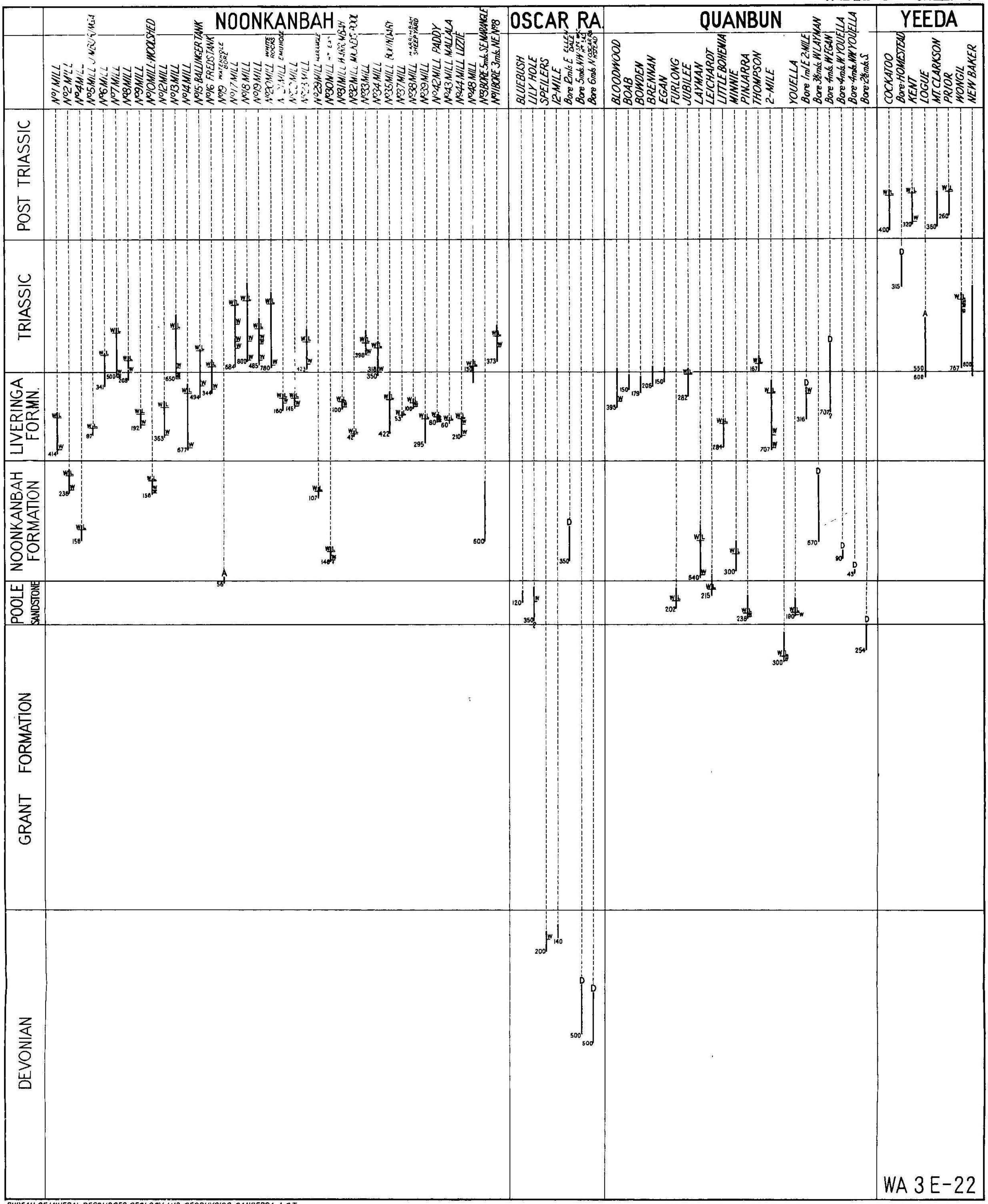


TABLE 6 · SHEET 4



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, CANBERRA A C T

FITZROY BASIN
WESTERN AUSTRALIA

Bureau of Mineral Resources, Geology and Geophysics. July 1956.

Printed by Mercury Press, Hobart

SCALE
8 0 8 16 24 32 40 MILES

WA 3E-17

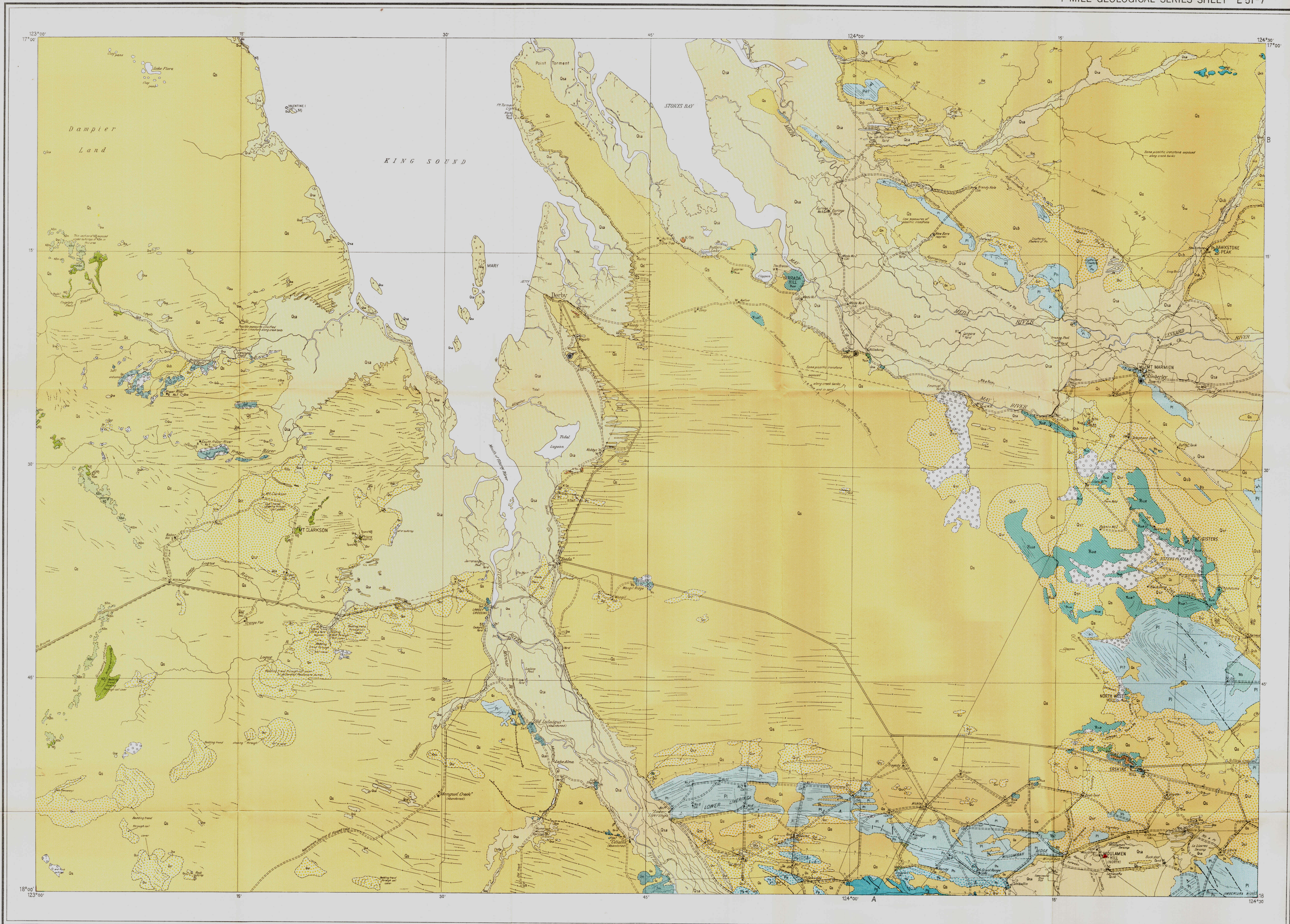
AUSTRALIA 1:253,440

DERBY

WESTERN AUSTRALIA

4 MILE GEOLOGICAL SERIES SHEET E 51-7

FIRST EDITION 1956



Reference

QUATERNARY
- Qzb — Residual black soil
- Qzr — Other residual soils
- Qza — Alluvium
- Qs — Sand, dunes

TERTIARY
- Pisolitic ironstone

CRETACEOUS OR TERTIARY ?
- Meda Formation — K/Tm — Conglomeratic unsorted sandstone and dark ferruginized unsorted current-bedded sandstone;

CRETACEOUS
- Melligo Quartzite — Klm — Quartz sandstone, medium to coarse grained, rounded quartz grains
- Jowlaenga Sandstone — Klj — Quartz sandstone, commonly ferruginous fine to medium grained, angular quartz grains, well bedded. Near shore deposit

JURASSIC
- Juf — Hard, yellowish, silicified nodular limestone
- Juu — Nodular, greenish to white sandy and glauconitic siliceous siltstone interbedded with thin beds of white micaceous shale
- Mudjalla Sandstone — Jm — Unsorted medium and coarse sandstone; some plant remains

? Unconformity ?

POST TRIASSIC
- Fitzroy Lamproite — fv — Leucite-rich volcanic rocks

TRIASSIC
- Erskine Sandstone — Rue — Fine silty sandstone and massive fine sandstone and siltstone cross-bedded, ferruginized, and plant bearing

Unconformity

- Blina Shale — Rb — Grey and brown siltstone, shale and sandy shale exposed; blue grey shale in bores; marine fauna

? Unconformity ?

PERMIAN
- Liveringa Formation — Pl — Micaceous silty sandstones, conglomeratic sandstone and silty sandstones; strongly ferruginized
- Noonkanbah Formation — Pn — Shale, siltstone, limestone, intraformational conglomerate

Disconformity

- Poole Sandstone — Pp — Well or thinly bedded micaceous silty sandstone and sandstone; well developed current bedding and ripple marking

Disconformity

- Grant Formation — Pg — Massive aqueoglacial unsorted silty sandstone, conglomeratic sandstone, tillite, siltstone, shale, and varved rocks

Geological boundaries
- Established boundary, position accurate
- Established boundary, position approximate
- Probable boundary
- Inferred, probable or indefinite boundary concealed

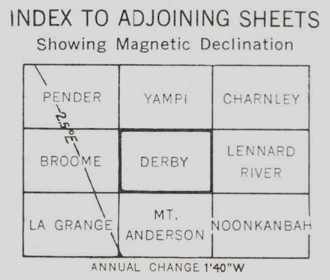
Strike and dip of strata
- Inclined
- Dip 0°-15° from photo-interpretation
- Trend lines, photo-interpretation

Faults
- Established fault - position accurate
- Established fault - position approximate
- Probable fault
- Established fault concealed by younger formation
- Inferred, probable or indefinite fault concealed

- Road
- Vehicle track
- Track
- Homestead
- Hut
- Yard
- Fence
- Telephone or telegraph line
- Aerodrome
- E.L.G. Emergency landing ground
- W Well with wind pump
- W Well
- A Artesian bore with wind pump
- A Artesian bore
- SA Sub-artesian bore with wind pump
- SA Sub-artesian bore
- B Bore
- T Tank
- Dune
- Mangrove
- ·346' Spot height in feet

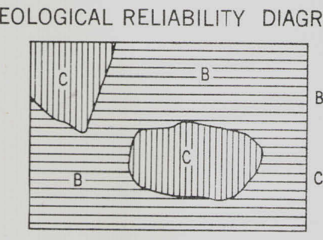
Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base from compilations by Royal Australian Survey Corps and Department of Lands and Surveys, Western Australia, from vertical small scale air photography by the Royal Australian Air Force. Published by the Bureau of Mineral Resources. Transverse Mercator Projection.

INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



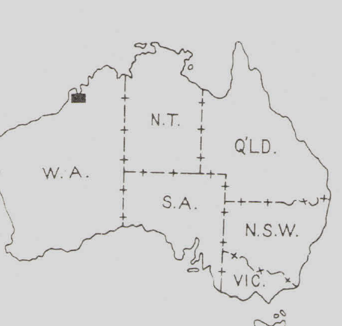
Scale
4 Miles to 1 inch

GEOLOGICAL RELIABILITY DIAGRAM



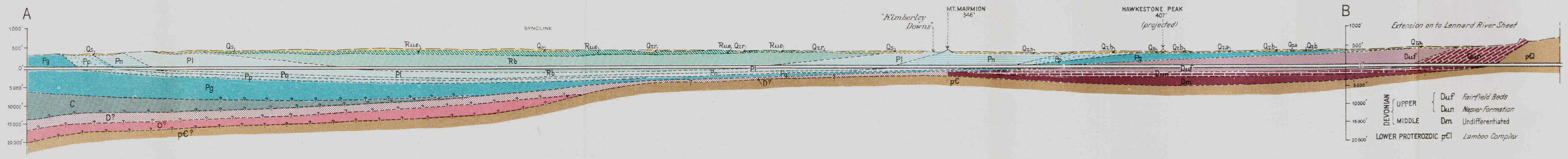
B Detailed reconnaissance - numerous traverses with photo-interpretation
C Photo-interpretation

Geology and compilation by : D. J. Guppy, A. W. Lindner, J. H. Rattigan, J. N. Casey, R. O. Brunnschweiler, A. B. Clarke December 1955.
Section compiled by : M. A. Condon August, 1956.
Drawn by : W. G. Krause.



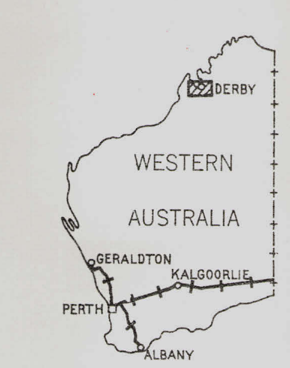
Section A-B

VERTICAL SCALES:
ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE



IN SECTION ONLY: Undifferentiated — C CARBONIFEROUS — D DEVONIAN — O ORDOVICIAN — pC PRECAMBRIAN

Printed by Mercury Press, Hobart



DERBY

SHEET E51-7

Copies of this map may be obtained from Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Geological Survey of Western Australia, Perth, W.A.

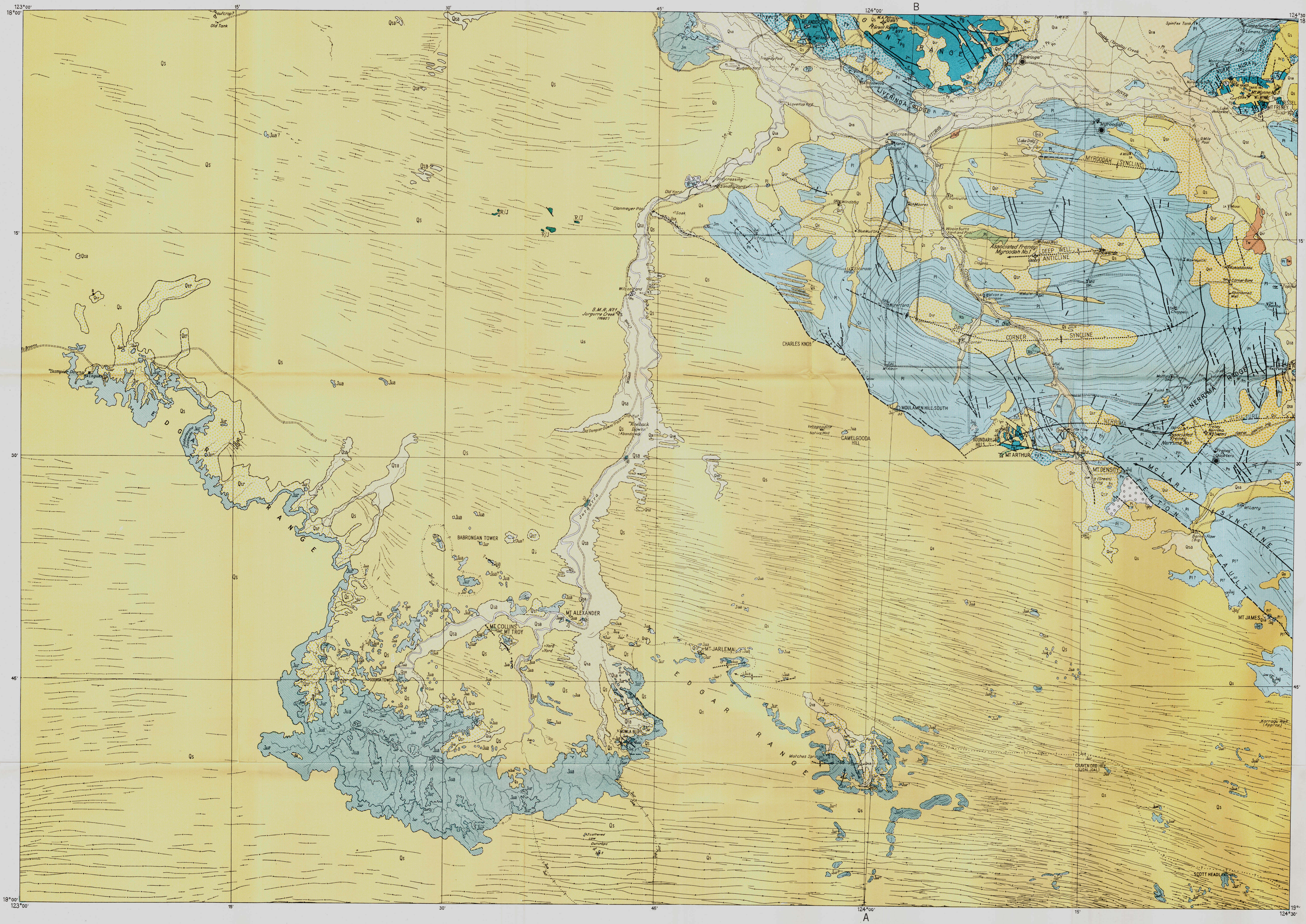
AUSTRALIA 1:253,440

MT. ANDERSON

WESTERN AUSTRALIA

4 MILE GEOLOGICAL SERIES SHEET E 51-11

FIRST EDITION 1956



Reference

QUATERNARY		Qzr	Residual soil
		Qza	Alluvium
		Qs	Sand, dunes
TERTIARY			Pisolitic ironstone
	Warrimbah Conglomerate	Tw	Poorly consolidated boulder beds forming old river terraces
JURASSIC	Mowla Sandstone	Juo	Sandstone, siltstone and conglomerate.
			Disconformity
	Jarlemai Formation	Jur	Poorly bedded or massive unsorted sandy siltstone and silty sandstone; marine fossils
	Alexander Formation	Jua	Thin bedded sandstone with alternations of siltstone; marine fossils
	James Sandstone	Juj	Strongly cross-bedded ferruginized conglomeratic sandstone
	Mudjalla Sandstone	Jm	Unsorted medium and coarse sandstone; some plant remains
JURASSIC?	Jurgurra Sandstone	Jj	Cross-bedded medium and coarse mica-bearing sandstone with thin siltstone beds
TRIASSIC-JURASSIC		R/J	Sandstone
			? Unconformity ?
TRIASSIC	Blina Shale	Rb	Grey and brown siltstone, shale and sandy shale exposed; blue grey shale in bores; marine fauna
			? Unconformity ?
PERMIAN	Liveringa Formation	Pl	Micaceous silty sandstones, conglomeratic sandstone and silty sandstones; strongly ferruginized
	Noonkanbah Formation	Pn	Shale, siltstone, limestone, intraformational conglomerate
			Disconformity
	Poole Sandstone	Pp	Well or thinly bedded micaceous silty sandstone and sandstone; well developed current bedding and ripple marking
			Disconformity
	Grant Formation	Pg	Massive aqueoglacial unsorted silty sandstone, conglomeratic, sandstone, tillite, siltstone, shale, and varved rocks

Geological boundaries

- Established boundary, position accurate
- Established boundary, position approximate
- Probable boundary
- Established boundary, concealed by younger formation
- Inferred, probable or indefinite boundary, concealed

Strike and dip of strata

- 20 Inclined
- Inclined showing prevailing dip
- Dip 0°-15° from photo-interpretation
- Trend lines photo-interpretation

Folds

- Established anticlinal crest – position accurate
- Established anticlinal crest – position approximate
- Inferred, probable or indefinite crest
- Established synclinal trough – position accurate
- Established synclinal trough – position approximate
- Inferred, probable or indefinite trough

(showing direction of plunge)

- Established fold axis, concealed, – position accurate
- Established fold axis, concealed, – position approximate.

Faults

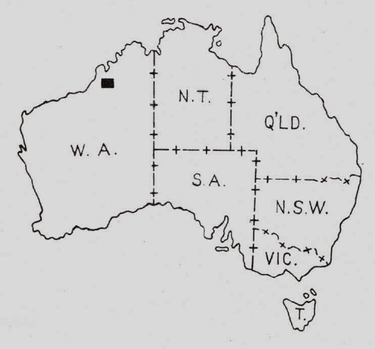
- Established fault — position accurate
- Established fault — position approximate
- Probable fault
- Established fault concealed by younger formation
- Inferred, probable or indefinite fault, concealed
- ✱PL1 Text reference-B.M.R. Bull. 36

- Track
- Homestead
- Hut
- Yard
- Fence
- Aerodrome
- (B) Bore with wind pump
- (A) Artesian bore with wind pump
- (SA) Sub-artesian bore with wind pump
- (W) Well
- (S) Spring
- (T) Earth tank
- (9072') Dry oil bore with show of oil
- (12915') Dry oil bore, S= stratigraphic bore only

(showing depth)

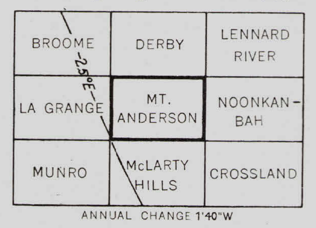
- Dune
- △1150 Trig. Station, height in feet

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base from compilations by Royal Australian Survey Corps and Department of Lands and Surveys, Western Australia, from vertical small scale air photography by the Royal Australian Air Force. Published by the Bureau of Mineral Resources. Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS

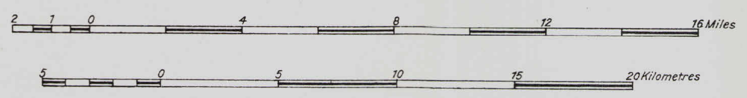
Showing Magnetic Declination



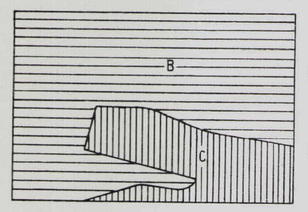
ANNUAL CHANGE 1'40"W

Scale

4 Miles to 1 inch



GEOLOGICAL RELIABILITY DIAGRAM



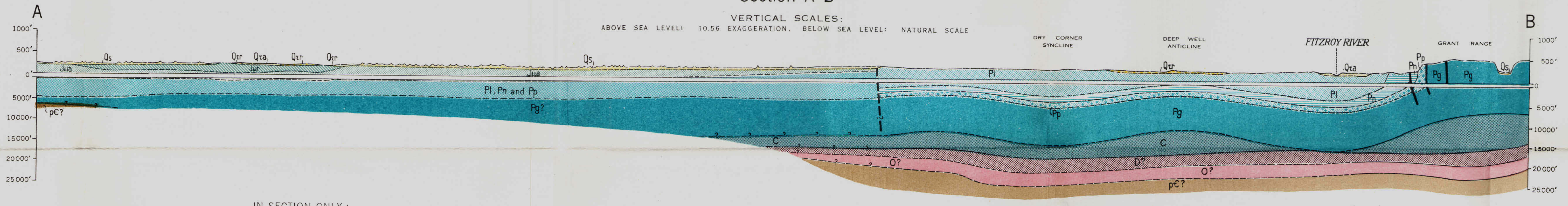
B Detailed reconnaissance - numerous traverses with photo-interpretation

C Photo-interpretation

Geology and compilation by: D. J. Guppy, A. W. Lindner, J. H. Rattigan, J. N. Casey, R. O. Brunnschweiler, A. B. Clarke December, 1955. Section compiled by: G. A. Thomas and M. A. Condon August, 1956.

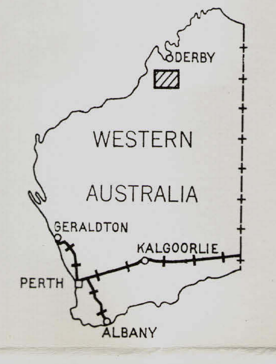
Section A-B

VERTICAL SCALES: ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE



IN SECTION ONLY: Undifferentiated

C	CARBONIFEROUS
D	DEVONIAN
O	ORDOVICIAN
pC	PRECAMBRIAN



MT. ANDERSON

SHEET E51-11

Printed by Mercury Press, Hobart

AUSTRALIA 1:253,440

LENNARD RIVER

WESTERN AUSTRALIA

4 MILE GEOLOGICAL SERIES SHEET E 51-8

FIRST EDITION 1956

Reference

Geological boundaries

- Established boundary, position accurate
- Established boundary, position approximate
- Probable boundary
- Established boundary concealed by younger formation
- Inferred, probable or indefinite boundary, concealed

Strike and dip of strata

- Inclined
- Inclined showing prevailing dip
- Dip 0°-15° (determined by photo-interpretation)
- Dip 15°-45° (determined by photo-interpretation)
- Dip > 45° (determined by photo-interpretation)
- Horizontal (determined by photo-interpretation)
- Trend lines (determined by photo-interpretation)

Joints

- Joint patterns from photo-interpretation

Folds

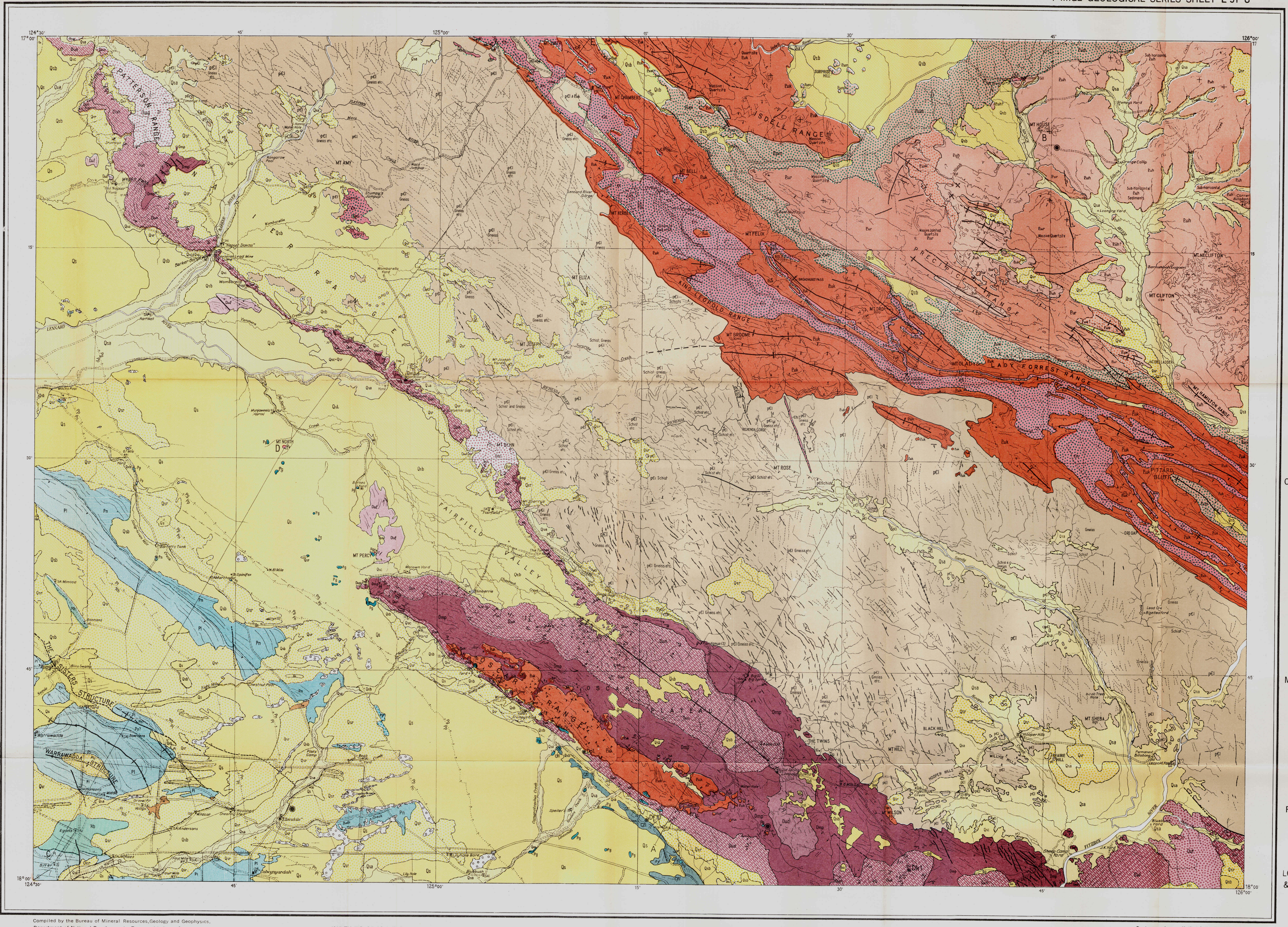
- Established anticlinal crest - position accurate (showing direction of plunge)
- Established anticlinal crest - position approximate (showing direction of plunge)
- Inferred, probable or indefinite crest (showing direction of plunge)
- Established synclinal trough - position accurate (showing direction of plunge)
- Established synclinal trough - position approximate (showing direction of plunge)
- Inferred, probable or indefinite synclinal trough (showing direction of plunge)
- Fold axis concealed by younger formation

Faults

- Established fault - position accurate
- Established fault - position approximate
- Probable fault
- Established fault concealed by younger formation
- Inferred, probable or indefinite fault, concealed

- Dyke; q= quartz ; d= dolerite
- ✱DMP4 Text reference-B.M.R. Bull. 36

- Road
- Vehicle track
- Fence
- Homestead
- Hut
- Yard
- Aerodrome
- (B) Bore with wind pump
- (B) Bore
- (SA) Sub-artesian bore with wind pump
- (SA) Sub-artesian bore
- (S) Spring with wind pump
- (S) Spring
- (W) Well
- (A) Artesian bore
- (E) Engine
- Dune
- Trig. Station, height in feet
- •2760' Spot height in feet



Reference

QUATERNARY		Qzb	Residual black soil
		Qzr	Other residual soils
		Qza	Alluvium
		Qzc	Travertine, tufa (caliche)
		Qs	Sand, dunes
TERTIARY			Pisolitic ironstone
	Warrimbah Conglomerate	Tw	Poorly consolidated boulder beds forming old river terraces
	? Unconformity ?		
POST-TRIASSIC	Fitzroy Lamproite	fv	Leucite-rich volcanic rocks
	Unconformity		
TRIASSIC	Blina Shale	Rb	Grey and brown siltstone, shale and sandy shale exposed; blue grey shale in bores; marine fauna
	? Unconformity ?		
PERMIAN	Liveringa Formation	Pl	Micaceous silty sandstone, conglomeratic sandstone and silty sandstones; strongly ferruginised
	Noonkanbah Formation	Pn	Shale, siltstone, limestone, intraformational conglomerate
	Disconformity		
	Poole Sandstone	Pp	Well or thinly bedded micaceous silty sandstone and sandstone; well developed current bedding and ripple marking
	Disconformity		
	Grant Formation	Pg	Massive aqueoglacial unsorted silty sandstone, conglomeratic sandstone, tillite, siltstone shale, and varved rocks
	Unconformity		
CARBONIFEROUS	Laurel Beds	Cℓl	Calcarenite, sandy and silty limestone
	? Disconformity ?		
UPPER DEVONIAN	Fairfield Beds	Duf	Limestone breccia, calcarenite sandy and silty limestone, marl and sandstone
	Napier Formation	Dun	Calcarenite, reef limestone, and clastic limestone
	Patterson Conglomerate	Dug	Boulder and pebble conglomerates, and sandstone
	Behn Conglomerate	Duc	Boulder and pebble conglomerates, and sandstone
	Oscar Formation	Duo	Limestone breccia, calcarenite, and biohermal limestone
	Brooking Formation	Duk	Limestone breccia, calcarenite, sandy and oolitic limestones, and small bioherms
	Copley Formation	Duh	Limestone breccia, calcarenite, sandy and oolitic limestones
	Stony Creek Conglomerate	Dut	Boulder conglomerate, greywacke, and sandstone
	Fossil Downs Formation	Dul	Calcarenite, limestone breccia, limestone, and biohermal limestone
	Sadler Formation	Dud	Clastic limestone, silty limestone, and sandy limestone
	Unconformity		
MIDDLE DEVONIAN	Pillara Formation	Dmp	Biostromal limestones, well-bedded limestone, calcareous sandstone, siltstone, and marl
	Unconformity		
CAMBRIAN ?	Hart Basalt	Єh	Basalt and dolerite - mainly flows
	? Unconformity ?		
UPPER PROTEROZOIC	Mt. House Beds	Puh	Well bedded sandstone, shale and dolomite
	Walsh Tillite	Puw	Massive unsorted boulder-bearing tillite
	Unconformity		
	Warton Beds	Pur	Conglomerate, quartzite, sandstone and shale.
	Mornington Volcanics	Pum	Andesitic and basaltic lavas, pyroclastic rocks, and tuffaceous sediments
	Unconformity		
	King Leopold Beds	Puk	Quartzite
	Unconformity		
LOWER PROTEROZOIC & (?) ARCHAEOZOIC	Lamboo Complex	pЄl	Schists, gneiss, slate, phyllite, granite, and granitized sediments

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base from compilations by Royal Australian Survey Corps and Department of Lands and Surveys, Western Australia, from vertical small scale air photography by the Royal Australian Air Force. Published by the Bureau of Mineral Resources Transverse Mercator Projection.

INDEX TO ADJOINING SHEETS

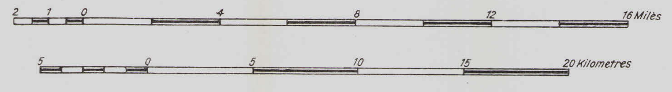
Showing Magnetic Declination

YAMPI	CHARNLEY	MT. ELIZABETH
DERBY	LENNARD RIVER	LANSDOWNE
MT. ANDERSON	NOONKANBAH	MT. RAMSAY

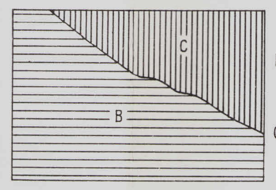
ANNUAL CHANGE 1'40"W

Scale

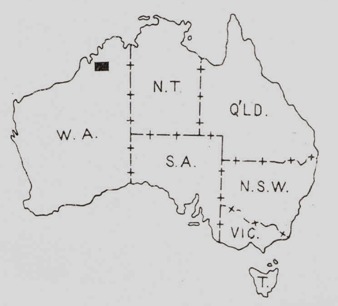
4 Miles to 1 inch



GEOLOGICAL RELIABILITY DIAGRAM

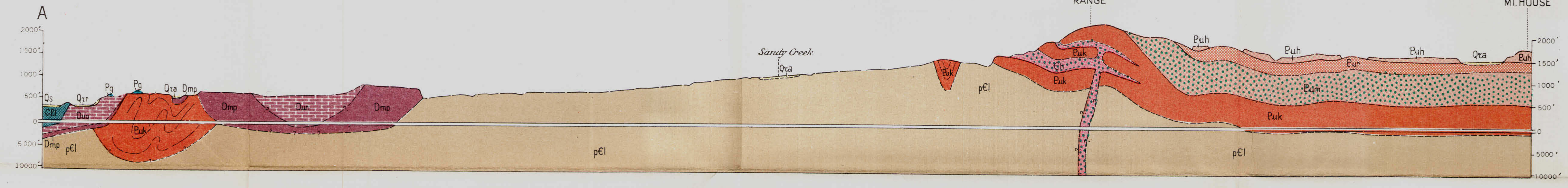


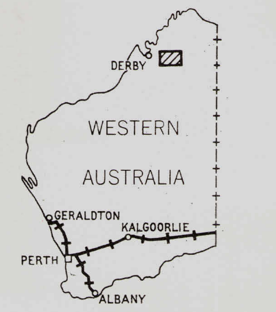
Geology and compilation by: D. J. Guppy, A. W. Lindner, J. H. Rattigan, J. N. Casey, December, 1955.
Sections compiled by: G. A. Thomas and M. A. Condon. August, 1956.



Section A-B

VERTICAL SCALES:
ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE





LENNARD RIVER

SHEET E51-8

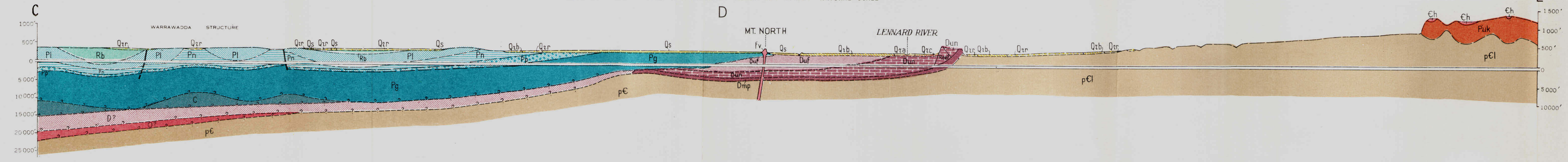
Copies of this map may be obtained from Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Geological Survey of Western Australia, Perth, W.A.

Section C-D-E

VERTICAL SCALES:
ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE

IN SECTION ONLY:
Undifferentiated

- C CARBONIFEROUS
- D DEVONIAN
- O ORDOVICIAN
- pЄ PRECAMBRIAN



Printed by Mercury Press, Hobart

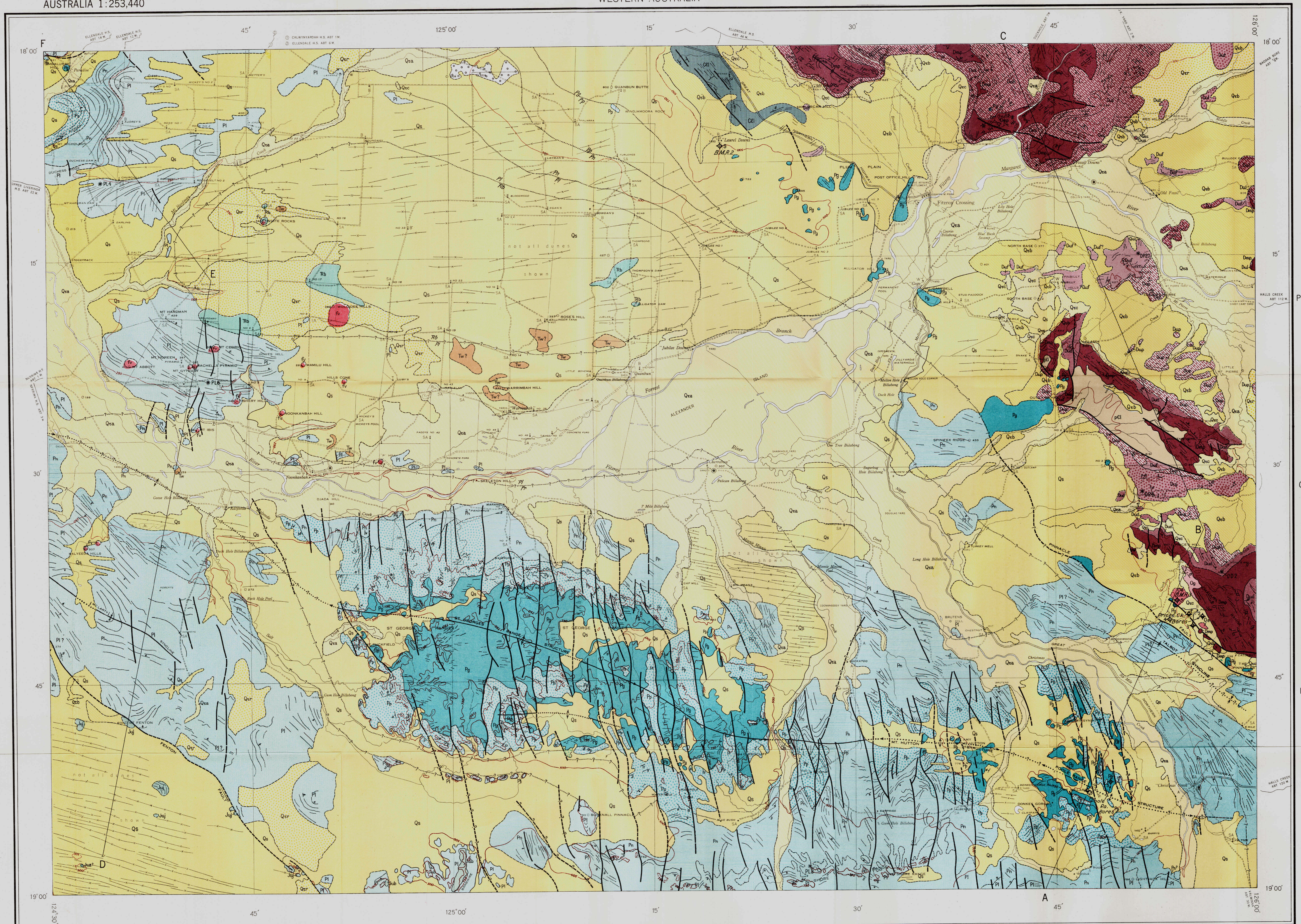
AUSTRALIA 1:253,440

NOONKANBAH

WESTERN AUSTRALIA

4 MILE GEOLOGICAL SERIES SHEET E51-12

FIRST EDITION 1956



Reference

Geological boundaries

- Established boundary, position accurate
- Established boundary, position approximate
- Inferred, probable or indefinite boundary
- Established boundary, concealed by younger formation
- Inferred, probable or indefinite boundary, concealed

Strike and dip of strata

- Inclined
- Dip 0°-15° } from photo-interpretation
- Dip 15°-45° } from photo-interpretation
- Trend of bedding } from photo-interpretation

Folds

- Established anticlinal crest - position accurate (showing direction of plunge)
- Established anticlinal crest - position approximate (showing direction of plunge)
- Established synclinal trough - position accurate (showing direction of plunge)
- Established synclinal trough - position approximate (showing direction of plunge)
- Established fold axis concealed, position accurate
- Established fold axis, concealed, position approximate

Faults and Joints

- Established fault - position accurate
- Established fault - position approximate
- Probable fault
- Established fault concealed by younger formation
- Inferred, probable or indefinite fault, concealed
- Joint patterns from photo-interpretation

- *PL6 Text reference-B.M.R. Bull. 36

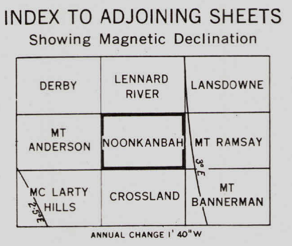
- Highway
- Vehicle track
- Homestead
- Telephone or telegraph line
- Fence
- Aerodrome
- Bore with wind pump
- Sub-artesian bore with wind pump
- Tank
- Well
- Spring
- Swamp
- Dune
- Minor control points.
- Dry oil bore; S= stratigraphic bore only
- Dry oil bore with show of oil,
- Contour - interval 250 feet
- Spot height in feet

Reference

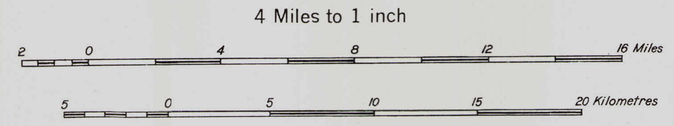
QUATERNARY		Qrb	Residual black soil
		Qrr	Other residual soils
		Qra	Alluvium
		Qrc	Travertine, tufa (caliche)
		Qs	Sand, dunes
TERTIARY			Pisolitic ironstone
	Warrimbah Conglomerate	Tw	Poorly consolidated boulder beds forming old river terraces
? Unconformity ?			
JURASSIC	Alexander Formation	Jua	Thin bedded sandstone with alternations of siltstone; marine fossils
	James Sandstone	Juj	Strongly cross-bedded ferruginised conglomeratic sandstone
	Barbwire Sandstone	Jub	Unsorted conglomeratic silty sandstone, and white siltstone
? Unconformity ?			
POST TRIASSIC	Fitzroy Lamproite	fv	Leucite-rich volcanic rocks
Unconformity			
TRIASSIC	Blina Shale	Rb	Grey and brown siltstone, shale and sandy shale exposed; blue grey shale in bores; marine fauna
? Unconformity ?			
PERMIAN	Liveringa Formation	Pl	Micaceous silty sandstones, conglomeratic sandstone and silty sandstones; strongly ferruginised
	Noonkanbah Formation	Pn	Shale, siltstone, limestone, intraformational conglomerate
	Disconformity		
	Poole Sandstone	Pp	Well or thinly bedded micaceous silty sandstone and sandstone; well developed current bedding and ripple marking
	Unconformity		
	Grant Formation	Pg	Massive aqueoglacial unsorted silty sandstones, conglomeratic sandstone, tillite, siltstone shale, and varved rocks
Unconformity			
CARBONIFEROUS	Laurel Beds	Cl	Calcarenite, sandy and silty limestone, and siltstone
Unconformity			
UPPER DEVONIAN	Fairfield Beds	Duf	Limestone breccia, calcarenite, sandy and silty limestone, marl and sandstone
	Geikie Formation	Dug	Grey calcarenite, oolitic limestone, and limestone breccia; small bioherms
	Oscar Formation	Duo	Limestone breccia, calcarenite, and biohermal limestone
	Brooking Formation	Duk	Red, grey and mottled limestone breccias, calcarenite, sandy limestone, silty limestone, oolitic limestone, small bioherms
	Copley Formation	Duc	Interbedded grey, red, and mottled clastic limestone, oolitic limestone, sandy limestone, and silty limestone
	Fossil Downs Formation	Dud	Calcarenite, limestone breccia, limestone, and biohermal limestone
	Stony Creek Conglomerate	Dut	Boulder and pebble beds
	Mt. Pierre Group	Dup	Grey and brown-bedded limestone, siltstone, and shale; and red calcareous siltstone, silty limestone, shale, and bioherms
	Sparke Conglomerate	Duy	Boulder and pebble beds
	Sadler Formation	Dud	Clastic limestone, silty limestone, sandy limestone, and bioherms
Unconformity			
MIDDLE DEVONIAN	Pillara Formation	Dmp	Biostromal limestones, well bedded limestone, calcareous sandstone, siltstone, and marl
Unconformity			
ORDOVICIAN (Prices Creek Group)	Gap Creek Formation	Og	Dolomite, sandstone, and silty dolomitic limestone
	Emanuel Formation	Oe	Limestone and shale
Unconformity			
LOWER PROTEROZOIC & (?) ARCHAEOZOIC	Lamboo Complex	pЄl	Schists, gneiss, slate, phyllite, granite, and granitized sediments

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base from compilations by Royal Australian Survey Corps and Department of Lands and Surveys, Western Australia, from vertical small scale air photography by the Royal Australian Air Force. Published by the Bureau of Mineral Resources Transverse Mercator Projection.

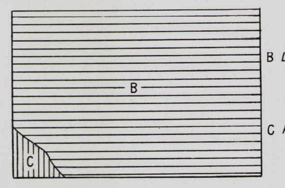
INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



Scale
4 Miles to 1 inch



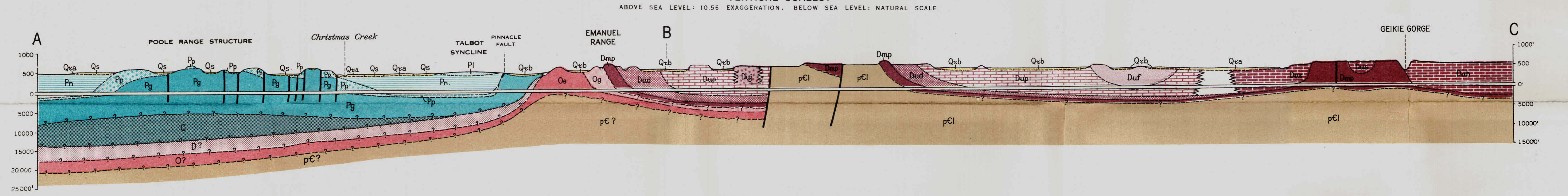
GEOLOGICAL RELIABILITY DIAGRAM



Geology and compilation by: D. J. Guppy, A. W. Lindner, J. H. Rattigan, J. N. Casey, J. O. Cuthbert, G. A. Thomas. December, 1955
Sections compiled by: G. A. Thomas and M. A. Condon August, 1956.
Drawn by: A. J. Saunders.

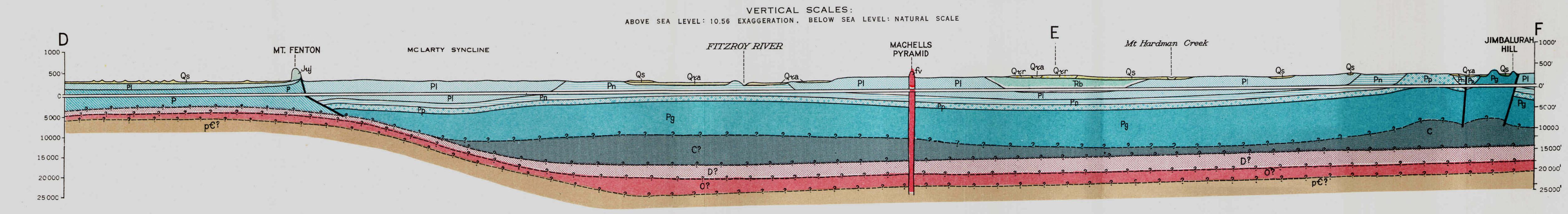
Section A-B-C

VERTICAL SCALES:
ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE



Section D-E-F

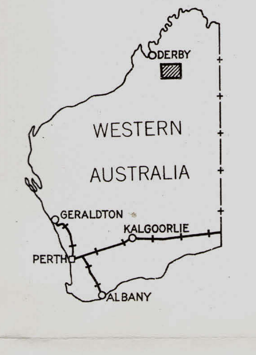
VERTICAL SCALES:
ABOVE SEA LEVEL: 10.56 EXAGGERATION. BELOW SEA LEVEL: NATURAL SCALE



IN SECTION ONLY:

Undifferentiated

- P PERMIAN
- C CARBONIFEROUS
- D DEVONIAN
- O ORDOVICIAN
- pЄ PRECAMBRIAN



NOONKANBAH

SHEET E51-12

Copies of this map may be obtained from Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Geological Survey of Western Australia, Perth, W.A.

Printed by Mercury Press, Hobart