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

BULLETIN No. 27

THE GEOLOGY OF THE ORD-VICTORIA REGION, NORTHERN AUSTRALIA

by

D. M. TRAVES.

Issued under the Authority of Senator the Hon. W. H. Spooner.
Minister for National Development.
1955.

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN No. 27

THE GEOLOGY OF THE ORD-VICTORIA REGION, NORTHERN AUSTRALIA

by

D. M. TRAVES.

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

1955.

A

Commonwealth of Australia

DEPARTMENT OF NATIONAL DEVELOPMENT

Minister: SENATOR THE HON. W. H. SPOONER

Secretary: H. G. RAGGATT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Director: P. B. NYE

Deputy Director: J. M. RAYNER

This Bulletin was prepared in the Geological Section

Chief Geologist: N. H. FISHER

CONTENTS

SUMMARY 1

INTRODUCTION 1

General 1

Location 2

Climate 2

Previous Investigations 4

Field Methods 6

TOPOGRAPHY 6

STRATIGRAPHY 9

General 9

Precambrian 12

General 12

Halls Creek Metamorphics 12

Lamboo Complex 14

Upper Proterozoic Rocks of Kimberley Plateau 15

Victoria River Group 18

Undifferentiated Precambrian 25

Mt. Winnecke Sandstone 26

Granophyre 27

Basic Igneous Rocks 27

Precambrian Volcanics 28

Cambrian 28

General 28

Antrim Plateau Volcanics 29

Montejinni Limestone 32

Negri Group 35

Elder Sandstone 45

Ragged Range Conglomerate 46

Carlton Group 47

Ordovician 53

General 53

Carlton Group contd. 54

Devonian 57

General 57

Cockatoo Sandstone 57

Burt Range Limestone 62

Carboniferous 65

Enga Sandstone 65

Septimus Limestone 66

Permian 69
General 69
Weaber Group 71
Port Keats Group 79
Jurassic and Cretaceous 81
General 81
Mullaman Group 82
Tertiary 84
White Mountain Formation 84
Laterite 85
Alluvium 88
Quaternary 88
Fluviatile and Estuarine Alluvium 88
Soils 89

TECTONICS 90

GEOLOGICAL HISTORY 93

ECONOMIC GEOLOGY 95
General 95
Metallic Deposits 95
Gold 95
Lead 96
Copper 96
Uranium 96
Hydrology 97
Petroleum Prospects 102
Bauxite 104
Ochre 105

ACKNOWLEDGMENTS 106

REFERENCES 107

APPENDIX A 110

APPENDIX B 125

APPENDIX C 127

APPENDIX D 130

APPENDIX E 133

ILLUSTRATIONS

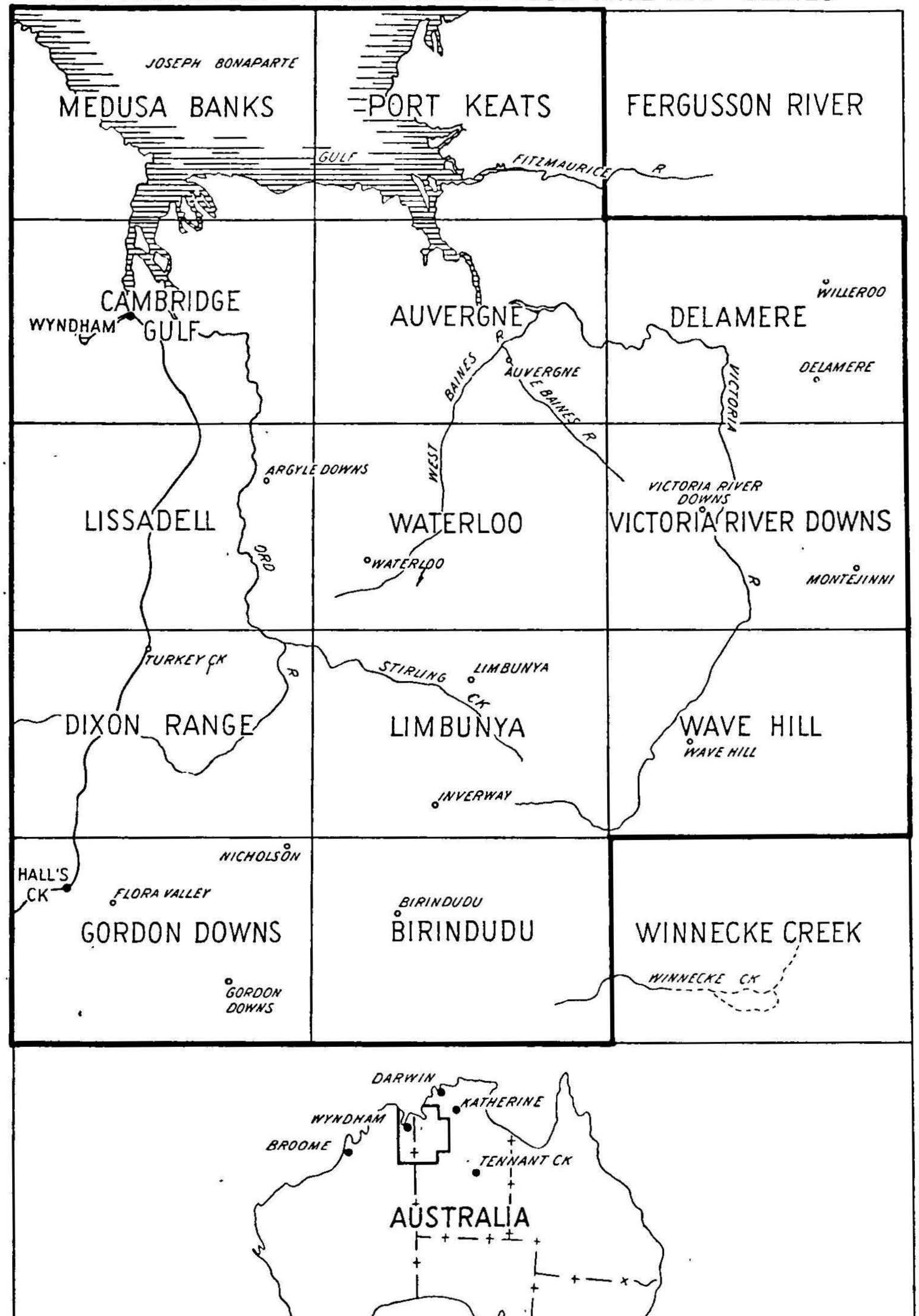
Figure 1.—Locality Map	1
Figure 2.—Rainfall Map	3
Figure 3.—Rainfall Distribution at representative stations, 1911-1940 (after Slatyer, 1952)	4
Figure 4.—Rainfall intensity, expressed as points per wet day, at representative stations, 1911-1940 (after Slatyer, 1952)	4
Figure 5.—Mean monthly maximum and minimum temperature and relative humidity at representative stations (after Slatyer, 1952)	5
Figure 6.—Geomorphological Divisions and Sub-divisions of Ord-Victoria Region (after Paterson, 1952)	7
Figure 7.—Field relationship of stratigraphical units	11
Figure 8.—Folding in marble, Halls Creek Metamorphics, east of Turkey Creek ..	13
Figure 9.—Sections of the Upper Proterozoic sediments on the Kimberley Plateau	17
Figure 10.—Sub-horizontal sandstone of Victoria River Group in scarp at Victoria River	19
Figure 11.—Mud cracks on vertical slab, and swash or interference ripple marks on the pavement; Victoria River Group, Victoria River Crossing, Coolibah ..	20
Figure 12.—Ripple marks in sediments of Victoria River Group; Victoria River Crossing, Coolibah	21
Figure 13.—Oblique Air-Photo showing jointing in sandstones of Victoria River Group (by courtesy of R.A.A.F.)	23
Figure 14.—Bioherm of *Collenia*, Top Spring	24
Figure 15.—Ord River Dam Site in Undifferentiated Precambrian	25
Figure 16.—Chert nodules in Montejinni Limestone between Montejinni and Wave Hill	34
Figure 17.—Sections of Middle Cambrian Negri Group, Hardman Basin	36
Figure 18.—Eroded nose of Kelly Creek Anticline near Blackfellow Rock Hole ..	38
Figure 19.—Panorama of western scarp of Ragged Range	46
Figure 20.—Diagrammatic sketch of western scarp of Ragged Range	47
Figure 21.—Hart Spring Sandstone at Hart Spring	49
Figure 22.—Sketch Map from Air Photo No. 5029 Run 7, Cambridge Gulf	51
Figure 23.—Pander Greensand at Pander Ridge	54
Figure 24.—Sketch Map from Air Photo No. 5103 Run 8, Cambridge Gulf	56
Figure 25.—Cross Bedding in Cockatoo Sandstone, Cockatoo Sands	58
Figure 26.—Panorama of central Burt Range	64
Figure 27.—Sketch Map from Air Photo No. 5207 Run 13, Auvergne	68
Figure 28.—Oblique Air Photo of Burt Range (by courtesy of R.A.A.F.)	70
Figure 29.—Nigli Gap Sandstone at Nigli Gap	73
Figure 30.—Nigli Gap Sandstone unconformably overlying Halls Creek Metamorphics in the southern portion of Burt Range	75
Figure 31.—Laterite mesa on Antrim Plateau Volcanics, west of Catfish Hole ..	86
Figure 32.—Laterite Profile in sink hole between Wave Hill and Limbunya	87
Figure 33.—Tectonic Map	91
Figure 34.—Ochre Mine, 8 miles west of Alligator Spring	105

Plate 1.—Geological Map of Bonaparte Gulf Basin with sections, scale 4 miles to 1 inch	At end of Bulletin
Plate 2.—Geological Map of Harman Basin with sections, scale 4 miles to 1 inch ..	At end of Bulletin
Plate 3.—Regional Geological Map of Ord-Victoria Region with sections, scale 16 miles to 1 inch	At end of Bulletin

Table 1.—Stratigraphy of the Ord-Victoria Region	10
Table 2.—Mineral Production—Kimberleys	facing 95

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

FIG 1



BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, MAY 1954

G3-19
WK

THE GEOLOGY OF THE ORD-VICTORIA REGION, NORTHERN AUSTRALIA

By D. M. TRAVES.

SUMMARY

The Ord-Victoria Region, an area of over 70,000 square miles in the north-western portion of Northern Territory and north-eastern portion of Western Australia, is drained by the Ord and Victoria River systems. The geological reconnaissance of the Region was made primarily to provide a geological background for assessment of land utilization by the Land Research and Regional Survey Unit of the Commonwealth Scientific and Industrial Research Organization, and secondly to provide information on the stratigraphy and economic geology.

This Bulletin presents the results of the geological reconnaissance and includes a geological map at the scale of 16 miles to 1 inch of the Region and two geological maps at a scale of 4 miles to 1 inch of the more important Palaeozoic basins in the Region.

Rock units of Precambrian, Cambrian, Ordovician, Devonian, Carboniferous, Permian, Jurassic, Cretaceous, Tertiary, and Recent ages were mapped and described, and fossil collections were made from more than 50 localities. The discovery of Permian volcanics—the only confirmed post-Cambrian volcanics in Northern Territory—is recorded.

Mineral production for the Kimberley Field is listed, and occurrences of gold, silver, lead, tin, copper, ochre, and bauxite are discussed. Aerial scintillometer surveys are recommended to determine if uranium deposits occur in the Halls Creek metamorphics.

A study of hydrology was made and the underground water conditions in different areas are discussed. Petroleum prospects in the different basins are considered and it is thought that the possibility of finding petroleum in commercial quantities in the Region is slight.

INTRODUCTION

General

The Land Research and Regional Survey section of C.S.I.R.O., on advice from the Northern Australia Development Committee, began field work in the region of the Ord and Victoria Rivers in 1949.

The immediate objectives of the Survey were "to record accurately the nature of the country, to establish a sound basis upon which the production possibilities of the region may be appraised, and to make general recommendations concerning development and further investigation".

Because no regional geological map was available a geologist from the Bureau of Mineral Resources, Geology and Geophysics was attached to the Unit to provide a regional geological map which would form the basis of soil and land-use mapping. Although this was the primary function of the geologist, it was intended that he should do as much detailed mapping as possible because this Region contains a number of Palaeozoic basins, including the important Bonaparte Gulf Basin.

The writer accompanied the Unit, for four months, on all their traverses in the field in 1949 and spent a month at the end of the field season with Dr. A. A. Öpik of the Bureau of Mineral Resources, revisiting and collecting from known fossil localities. W. C. Smith of the Bureau of Mineral Resources joined the Unit for six weeks to record more detailed geology in the vicinity of base camps.

Field work could not be completed untl 1952, when the writer again accompanied the Land Research and Regional Survey Unit during their four-months' field season. Dr. Öpik joined the Unit for a month's field work in the area of Palaeozoic sediments.

Location

The Ord-Victoria Region, an area of over 70,000 square miles, two thirds of which is in the Northern Territory, and one third in Western Australia, is drained by the Ord and Victoria River Systems.

The area surveyed in 1949 and 1952 includes the Four-Mile Map Sheets of Delamere, Victoria River Downs, Wave Hill, Birrindudu, Limbunya, Waterloo, Auvergne, and Port Keats, in the Northern Territory, and Medusa Banks, Cambridge Gulf, Lissadell, Dixon Range, and Gordon Downs in Western Australia (See Fig 1).

Land utilization is restricted almost entirely to the pastoral industry, and large cattle stations cover the area. There are only two towns in the Region: Wyndham, a small port on the West Arm of Cambridge Gulf, which provides a meatworks and centre for the pastoral industry; and Halls Creek, a former gold-mining town which is now a small centre for the surrounding cattle industry.

There are no bitumen roads, but a main gravel road from Broome to Wyndham passes through Halls Creek. In the east, the Montejinni Track to Newcastle Waters and the King River Road to Katherine provide outlets to the Stuart Highway, the sealed road from Alice Springs to Darwin.

Numerous graded tracks interlink cattle stations and bores; these tracks are trafficable throughout the dry season but almost all are impossible during the wet season.

Most stations have a bi-weekly to fortnightly plane service from Alice Springs, Wyndham, or Darwin; and all homesteads are equipped with transreceiver wireless sets linked with the Flying Doctor Services for medical calls and telegraphic communication.

Climate

The Region, which lies between the latitudes of 14° and 19° S, has a warm dry monsoonal climate with a short rainy season in summer and a long dry season in winter.

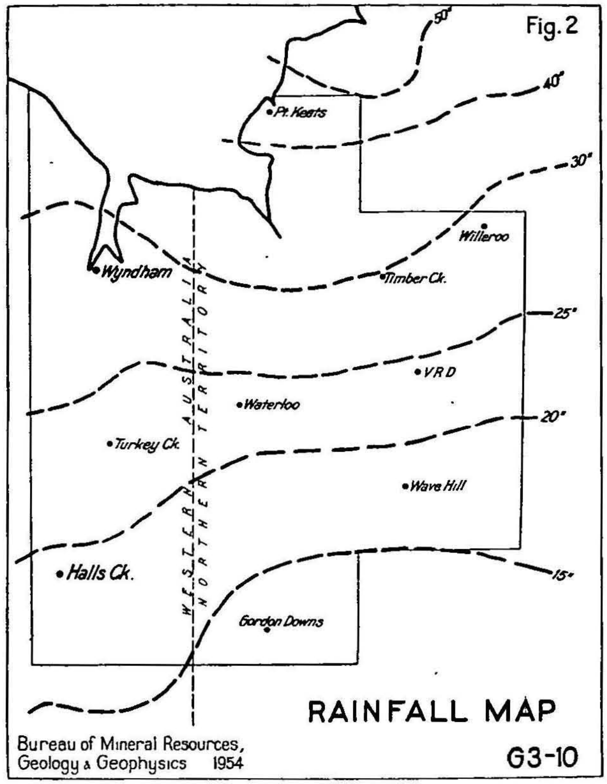


Figure 2—Rainfall Map

The annual rainfall ranges from 15 in. in the south to 50 in. in the north. The increase northwards is gradual to the 30 in. isohyet near the coast, whence the increase becomes more rapid in the Port Keats area. Most of the Region receives less than 30 in. of rain per annum.

The rain falls mainly in summer, although in the drier southern portions winter rains are of some importance. This is illustrated by Figure 3, which shows the rainfall distribution and also the rainfall intensity at Wyndham and Halls Creek. The rainfall is nowhere very variable and in the wetter portion is as reliable as anywhere in Australia. The variability increases inland as the rainfall decreases.

Day temperatures throughout the Region are high: night temperatures vary according to geographical position and show a much greater variation throughout the year than day temperatures. The moderating influence of the sea is noticeable in the coastal areas, whereas farther inland the diurnal variation is large. Maximum daily summer temperatures often exceed 100°F; yet in the southern portion of the Region there are occasional frosts in winter.

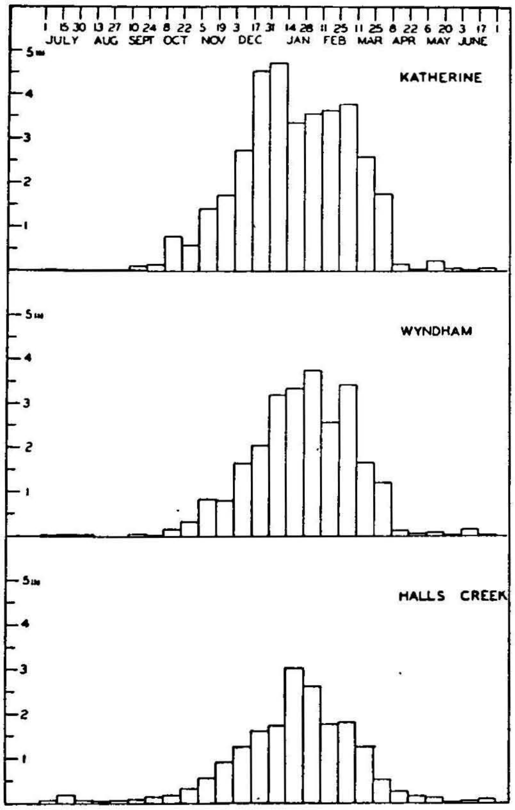


Figure 3—Rainfall distribution at representative stations 1911-1940

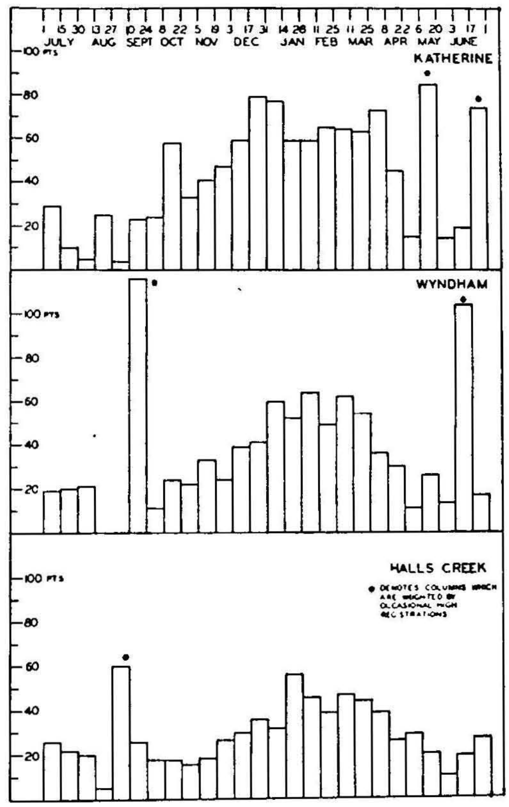


Figure 4—Rainfall intensity expressed as points per wet day at representative stations 1911-1940 (after Slatyer 1952)

The length of daylight for the longest day of the year ranges from 13¼ hours in the south to 13 hours in the north and the length of the shortest day ranges from 11¼ hours to 11 hours.

A more detailed discussion of the climate of the Region is given by Slatyer (in preparation), Part 2 of the General Report on Survey of Ord-Victoria Area, C.S.I.R.O. Land Research Series No. 4.

Previous investigations

The first geological studies in the area were by Commander Stokes in 1837-1843, and the Rev. Tennison Woods in the latter part of the nineteenth century; H. Y. L. Brown carried out between 1895 and 1909 the first systematic geological work in the Region and R. Etheridge Junior collaborated with him and studied his fossil collections. This was followed by reconnaissances by Woolnough (1912), and Jensen (1915). In 1924 Wade travelled through the Kimberley District to investigate the petroleum prospects.

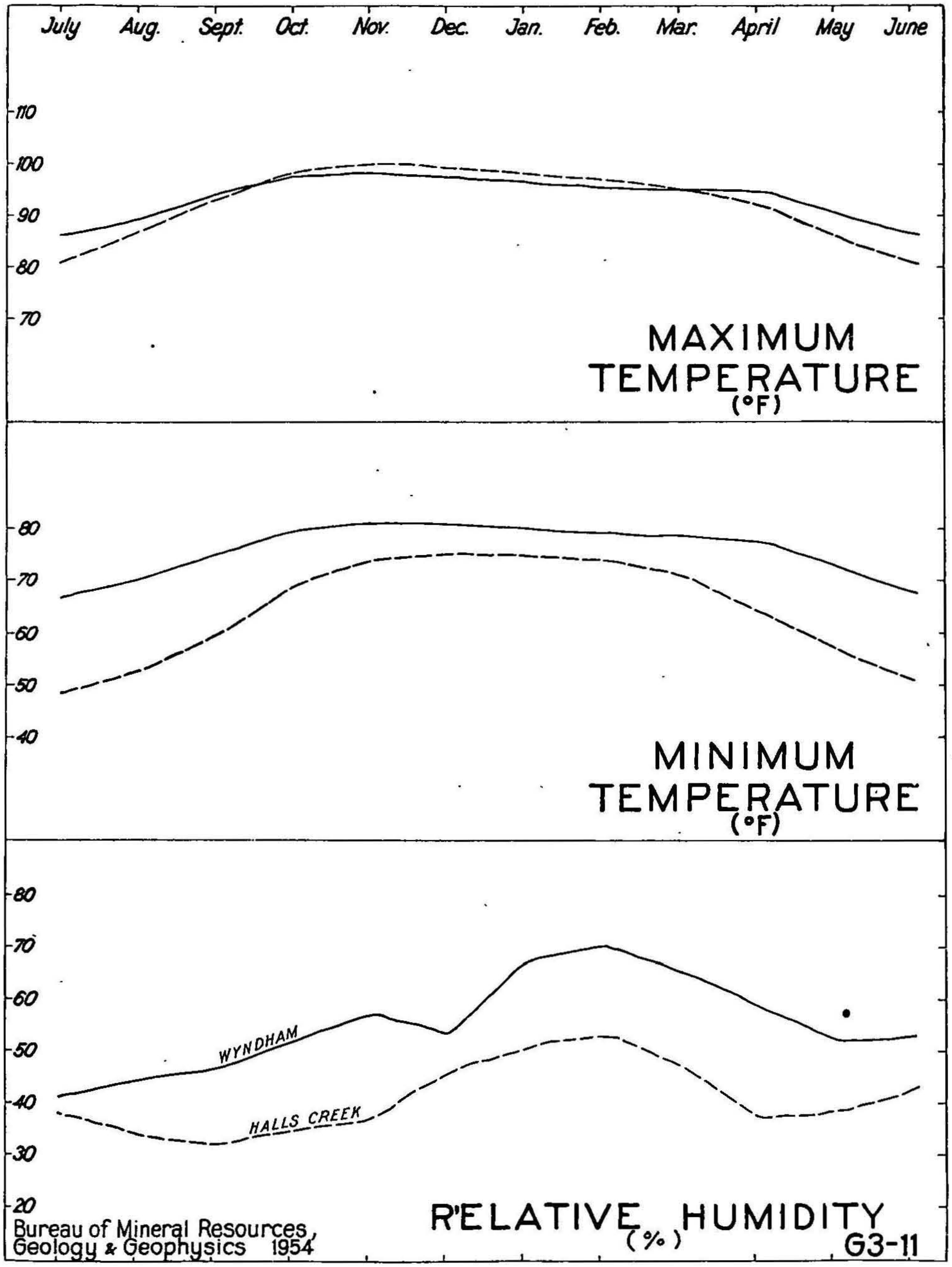


Figure 5—Mean monthly maximum and minimum temperature and relative humidity at representative stations (after Slatyer 1952)

The Aerial, Geological and Geophysical Survey of Northern Australia began field work in the Northern Territory in 1935, and until 1940 examined small areas in the Region. In 1941, F. G. Forman made the first collection of fossils from the Bonaparte Gulf Basin, and later Matheson and Teichert (1948) described the geology of the southern portion of this Basin. Noakes in 1946 made a geological reconnaissance in the Katherine-Darwin Region (Noakes, 1949), and Reeves (1948) examined the Bonaparte Gulf Basin for its petroleum possibilities.

The investigation of individual areas and stratigraphical units is more thoroughly described in the appropriate sections.

Field Methods

The R.A.A.F. photographed the Region in 1948. Before the 1949 field season, the photographs were laid out in rough mosaics and patterns were recognized and delineated. These patterns are produced by surface features which include topography, rock outcrops, stream patterns, distribution and type of vegetation, and some soil features. Traverses were planned to cross these patterns.

In the field the geology was plotted on to the photographs and definite boundaries drawn where contacts of stratigraphical units were observed. Before the 1952 field season, the photographs were again laid out in mosaics and, by interpolation and extrapolation from known points, the boundaries of the units were drawn, and preliminary maps prepared. The 1952 traverses were planned to check photographic interpretation, to investigate complex areas, and to collect more detailed information on chosen areas. After the 1952 field work, the final mapping was done on individual photographs under the stereoscope and all geological information was visually transferred to compiled four-mile maps which have the boundaries of the individual photographs marked. These maps were photographically reduced to 10-mile scale and fitted to the map prepared by the National Mapping Section, Department of the Interior. This map was drafted at 10-mile scale and photographically reduced for publication at the scale of 16 miles to 1 inch (Plate 3).

Each of the two maps—Plates 1 and 2—at a scale of 4 miles to 1 inch, of Bonaparte Gulf Basin and Hardman Basin, was compiled from portions of two four-mile maps on the National Grid. The three maps at 1-mile scale—Figures 22, 24 and 27—were sketched from aerial photographs and reduced.

TOPOGRAPHY

The topography is best described in the individual geomorphological divisions and sub-divisions, Figure 6. Paterson (1954) has divided the Region into eight units: Joseph Bonaparte Gulf Depression, Cambridge Gulf Lowlands, Victoria River Plateau, Victoria River Plains and

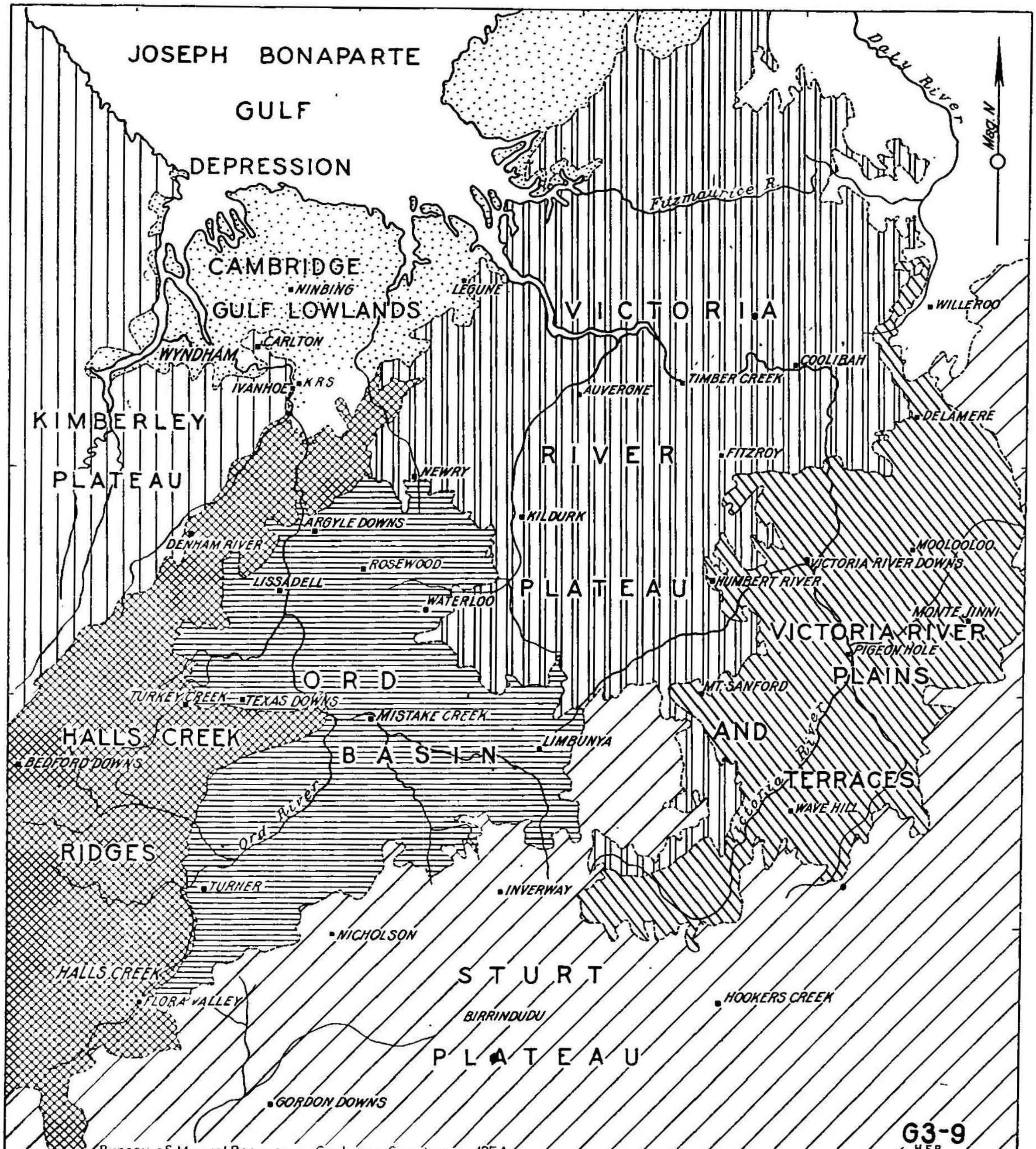


Figure 6—Geomorphological Map

Terraces, Ord Basin, Halls Creek Ridges, Sturt Plateau, and Kimberley Plateau.

The Joseph Bonaparte Gulf Depression is the large area of shallow water of Bonaparte Gulf into which drain the Ord and Victoria River Systems.

The Cambridge Gulf Lowlands consists of the low country which borders Joseph Bonaparte Gulf. The margins of this unit in most places are low swampy salt-flats, although some sandy beaches and cliffs occur in the Port Keats area. Inland from these margins there are large areas of sandy lowlands which contain isolated small hills and ridges up to 300 ft. high. Numerous salt arms, estuaries of rivers, and creeks transect the lowlands.

Victoria River Plateau. To the east of Cambridge Gulf Lowlands the country rises, leading to the dissected plateau of the Victoria River, where numerous rivers have cut deep gorges into sub-horizontal sediments, and the more resistant sandstone beds from several plateau levels. These plateau levels between the Victoria and Fitzmaurice Rivers range up to 600 ft. in altitude, and the bottoms of the gorges range from sea-level to approximately 300 ft. Farther inland, in the headwaters of Humbert River, the plateau levels reach an altitude of 1,000 ft.

Victoria River Plains and Terraces. This unit, in the middle to upper tracts of Victoria River, stretches from Delamere to Wave Hill. The altitude of the unit ranges from 300 ft. to 700 ft., and the topography is mainly one of rounded hills and undulating plains with a few flat-topped hills caused by more resistant horizons in Antrim Plateau Volcanics. The unit has the rolling downs topography characteristic of basic volcanics.

The Ord Basin, which is the area drained by the Ord River, ranges in altitude from the mountainous country of the Hardman Range to undulating plains underlain by Cambrian volcanics and sediments. In the Hardman Range, the sandstone peaks reach an altitude of 1,500 ft.; in the rugged, hilly country underlain by Antrim Plateau Volcanics, isolated peaks such as Mt. Napier approach this height; but the undulating plains in the Cambrian basins range in altitude from 400 ft. to 800 ft. The remarkable "walls" which occur in this unit are described more fully on p. 37. The Ord River and its tributaries form a prominent part of the topography of the unit and in some places have built up small areas of alluvium.

The Halls Creek Ridges constitute the roughest country in the Region and contain numerous strike ridges and controlled streams, and large areas with the typical dendritic stream patterns of granite topography. The altitude increases from about 1,000 ft. in the north southwards to Mt. Coghlan (2,020 ft.), the highest point in the Region. The rough hilly country in the vicinity of Halls Creek ranges from 1,100 ft. to 1,500 ft.

The Sturt Plateau covers a large area in the south and south-east of the Region and forms an almost flat land surface—a remnant of the Tertiary surface—with poorly marked senile inland drainage. The altitude of this plateau ranges from about 1,000 ft. at Hookers Creek to nearly 1,200 ft. at Gordon Downs and 1,500 ft. north of Inverway.

The Kimberley Plateau consists of dissected sub-horizontal sediments with plateau levels ranging from a few hundred feet at the coast to almost 1,600 ft. at Mt. Cockburn. It is dissected by numerous coastal rivers which drain into Cambridge Gulf. Where the dip of the beds increases, the rivers have controlled courses such as the middle and upper tracts of Chamberlain River.

STRATIGRAPHY

General

Rocks of almost all systems are represented in the Ord-Victoria Region, and the Palaeozoic units are highly fossiliferous. Units of Precambrian, Cambrian, Ordovician, Devonian, Carboniferous, Permian, Jurassic, Cretaceous, and Tertiary age are listed in the accompanying stratigraphical table. Units found in different areas and their relationships to one another are given in Figure 7.

The three main areas underlain by Middle Cambrian sediments in the Ord River area have been previously named Hardman Basin, Argyle Basin, and Rosewood Basin, and although they are not depositional but topographical basins, these three names are retained.

The area of Middle Palaeozoic sediments in the north-western portion of the Region was first named Burt Range Basin by Matheson and Teichert (1948), when they examined Palaeozoic sediments in Burt Range. Reeves (1948) and later Noakes in Noakes et alia (1952) used the name "Bonaparte Gulf Basin" for the large area of Palaeozoic sediments which included those that crop out in Burt Range. In this Bulletin the name *Bonaparte Gulf Basin* is used for all the Palaeozoic sediments that crop out in the vicinity of Joseph Bonaparte Gulf; *Burt Range Basin* is used for the area of sediments that were deposited in an embayment and now form Burt Range; and the name *Carlton Basin* is introduced for the area of Middle Palaeozoic sediments which crop out north and east of Carlton Station. Thus Burt Range Basin and Carlton Basin refer to special areas in Bonaparte Gulf Basin.

Existing names of rock units have been used wherever possible, with slight revision in accordance with the Australian Code of Stratigraphical Nomenclature (Raggatt, 1950). Many new names for formations and groups are introduced and units are described under the systems to which they belong.

Complete fossil lists are not available because much of the collection was seriously damaged or lost in the fire in the Bureau of Mineral Resources in 1953. It is hoped that in the next few field sasons the fossil localities will be revisited and new collections made.

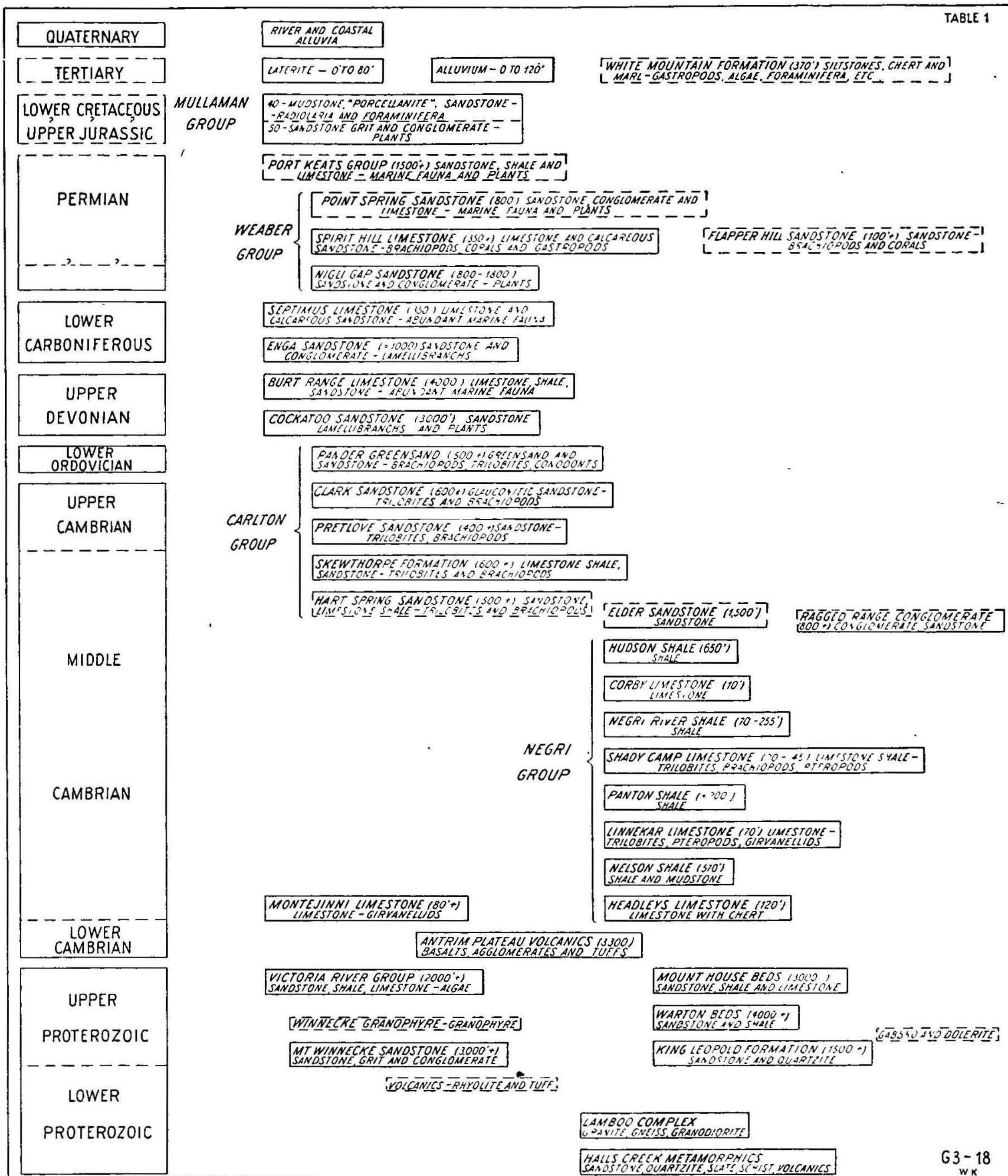


Table 1—Stratigraphy of the Ord-Victoria Region

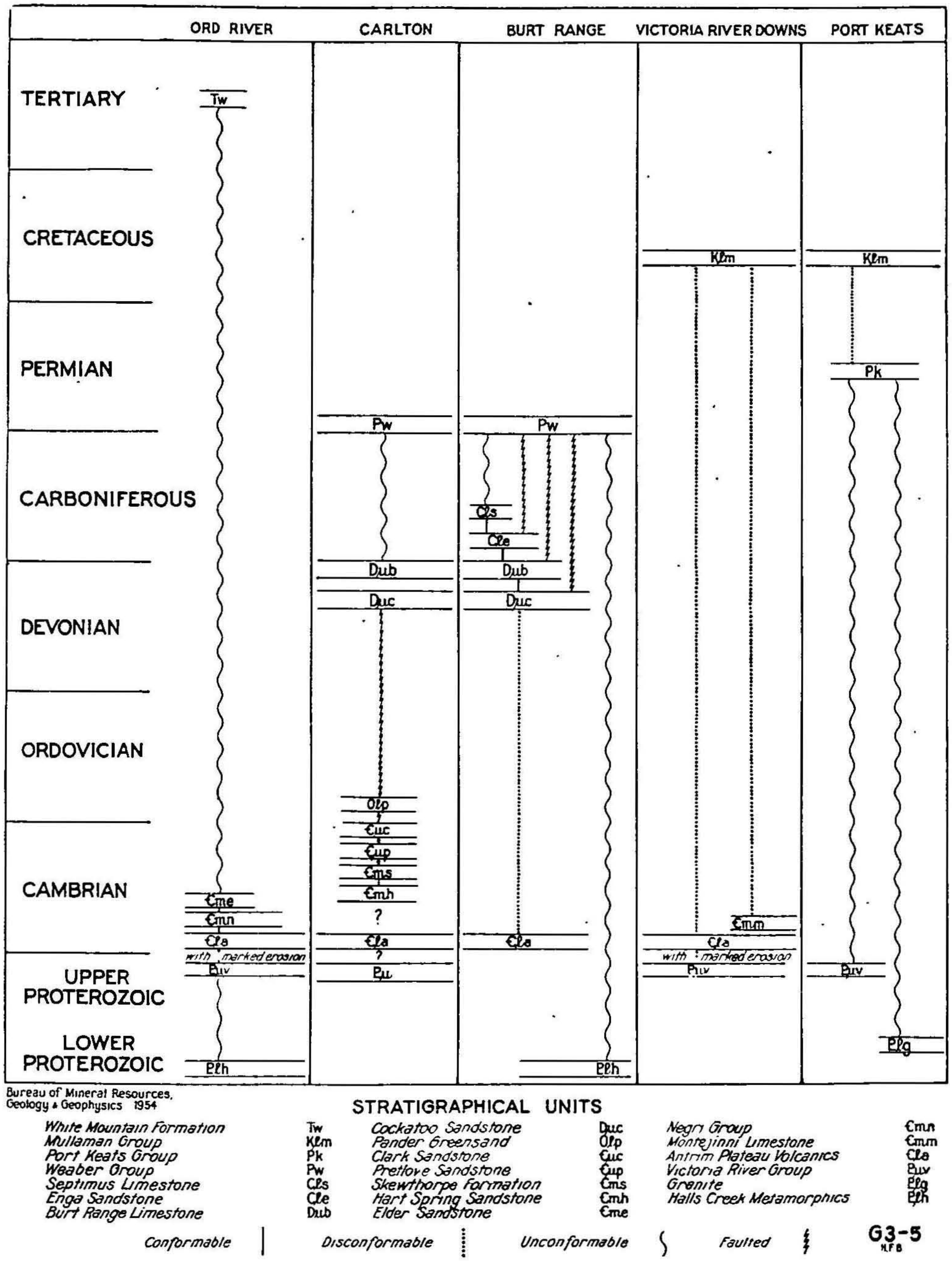


Figure 7—Field Relationships of Stratigraphical Units

B

PRECAMBRIAN

General

Precambrian rocks crop out over an area of more than one-third of the whole Region and form part of the Australian Precambrian Shield. As in other parts of Australia, the division of these rocks into units without the help of fossils or detailed mapping is difficult, and any division attempted must be regarded as merely a framework to guide more detailed work in the future. The oldest rocks exposed in the Region are the Lower Proterozoic geosynclinal metamorphic rocks which are given the group name of *Halls Creek Metamorphics*. They have been intruded and granitized; and the extensive outcrop of granitic rocks now exposed is included in the *Lamboo Complex*.

In the Kimberley Plateau, the Halls Creek Metamorphics are unconformably overlain by a great thickness of Upper Proterozoic sediments and volcanics, which can be divided into five distinct rock units. In the eastern portion of the Region, the Upper Proterozoic sediments have not been divided and have been named the *Victoria River Group**. The Victoria River Group probably represents only the top portion of sediments found in the Kimberley Plateau, but an exact correlation cannot be made at present.

Sediments of probable Upper Proterozoic age occur in the geosynclinal belt; but, because they have been subjected to more movement and metamorphism than the Victoria River Group, their position is not certain, and they have been mapped as undifferentiated Precambrian.

Basic igneous rocks that have intruded the base of the sediments of the Kimberley Plateau are not included in the older Lamboo Complex.

In the south-eastern portion of the Region the isolated *Mt. Winnecke Sandstone* has been named, but its relationship to the other Upper Proterozoic sediments is not completely determined. This formation is intruded by *Winnecke Granophyre*. An area of Precambrian acid volcanics has been mapped on the south-western border of the Lamboo Complex; but little is known of its age or relationship to other Precambrian units.

Halls Creek Metamorphics

The Halls Creek Metamorphics are the metamorphic rocks which crop out in the vicinity of Halls Creek and in isolated areas north-north-east at least as far as Keep River. These rocks were deposited in the Lower Proterozoic geosyncline which trended north-north-east from Halls Creek.

Because in 1882 gold was discovered in these Metamorphics near Halls Creek, they have been studied in some detail. Most workers, however, have included them in units established farther south in Western Australia and have not given the unit a separate name; but as the unit is

---

*Under the recent (1954) ruling of the Stratigraphical Nomenclature Committee, this name must be amended to 'formation': but the ruling was given too late to amend the text and plates of this Bulletin.

isolated, it is difficult, if not impossible, to correlate it accurately with southern outcrops of Precambrian rocks; and confusion has arisen. For example, Finucane (1939) placed the Metamorphics in the "Mosquito Creek Series". Matheson and Guppy (1949), when on a brief reconnaissance east from the West Kimberley District, divided the Metamorphics, in the vicinity of Halls Creek, into Halls Creek Group and McClintock Greenstones; but as the greenstones form an integral part of the Metamorphics and the proposed boundaries of Matheson and Guppy could not be found in the field, the writer has included both "groups" in the group name Halls Creek Metamorphics, although it is realized that more detailed work

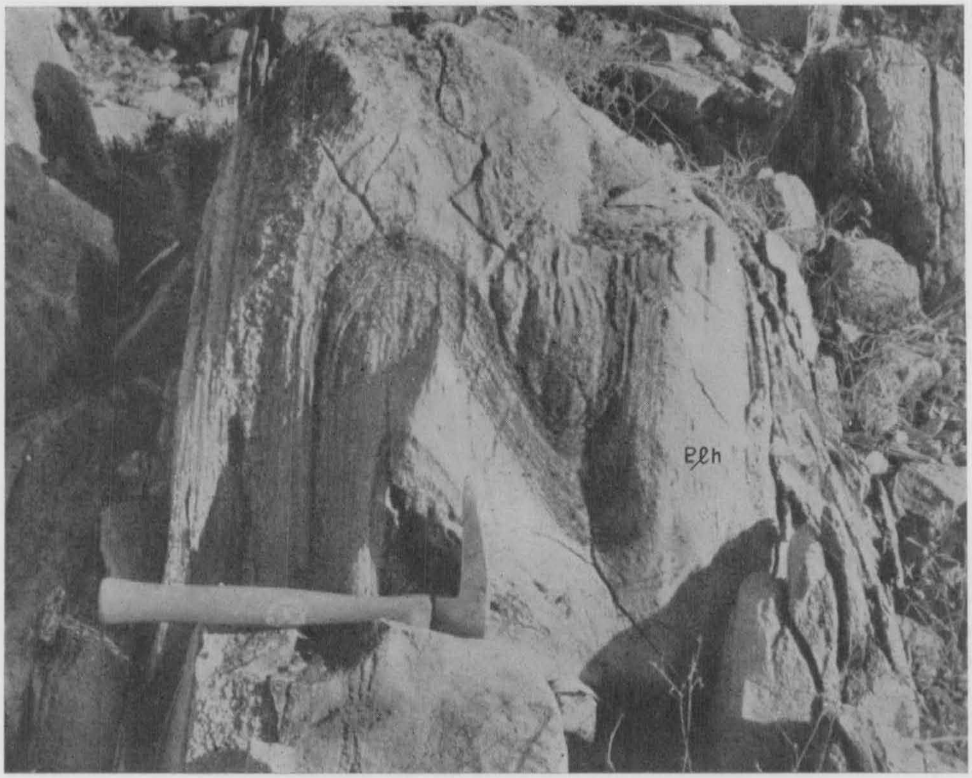


Figure 8—Folding in marble—Halls Creek Metamorphics, East of Turkey Creek

will show that these Metamorphics can be divided into a number of units.

The rock-types of the unit in the vicinity of Halls Creek are quartzite, schist, phyllite, sandstone and slate, which have been intruded by dolerite, and quartz veins. Finucane (1938) lists the rock-types of the Halls Creek/Ruby Creek area as: quartzite, sandstone, slate, and shale with interbedded lavas; and at Mary River as: shale, slate, and micaceous sandstone, foliated quartz amphibolite, and massive augite-actinolite-hornblende rocks.

Between Rock Hole Homestead and Ruby Creek, the main rock types are quartzite, greywacke, altered andesite, and amphibolite. Petrological descriptions of specimens from the altered andesite (R6009) and amphibolite (R6011) are included in Appendix A. The outcrop of highly folded metamorphics extends from south of Halls Creek to Turkey Creek. A few miles east of Turkey Creek, marble, garnet amphibolite, knotted schist, and skarn rocks—metamorphosed calcareous sediments—crop out.

Small isolated outcrops are found farther north. A small outcrop was examined on the Ord River, east of Texas, where rocks of the unit are unconformably overlain by Upper Proterozoic sandstones. The rock types in this outcrop of steeply dipping metamorphics are: slate, phyllite, schist, and amygdaloidal andesite (R6007 in Appendix A).

The Metamorphics crop out in a large area from north-west of Argyle to east of Burt Range—known as the "Golden Gate Country". Matheson and Teichert (1948) divided the metamorphic rocks into a "Greenstone Series" and "Mosquito Creek Series" but state that the division was made chiefly on lithological grounds. In this Bulletin, all metamorphic rocks of this belt are included in Halls Creek Metamorphics.

Where the road from Argyle to Wyndham cuts across the belt, the main rock types are slate, phyllite, quartzite, and altered andesite; whereas the road from Cockatoo Spring to Newry crosses slate, phyllite, andesite and andalusite schist (R6008 in Appendix A).

Isolated outcrops east of Burt Range are mainly of schist and altered andesite.

The Halls Creek Metamorphics have been severely folded and faulted and no estimate of the thickness of the group has been made.

The degree of folding and metamorphism and the relationship of these rocks with younger Upper Proterozoic sediments indicate that Halls Creek Metamorphics are of Lower Proterozoic age. Although it is unwise to attempt to correlate Lower Proterozoic units in Northern Australia because of the scanty knowledge available, equivalents of these Metamorphics may exist in the older rocks south of the King Leopold Range, in the Brocks Creek Group (Noakes, 1949), and possibly in the older rocks in the vicinity of Tanami.

Lamboo Complex

The Lamboo Complex was the name used by Matheson and Guppy (1949) for the undifferentiated massive granite, granitic gneiss, and undigested remnants of Halls Creek Metamorphics, which outcrop in the vicinity of Lamboo Station, Mt. Amhurst Station, and other localities west of Halls Creek. Rocks of the complex crop out in a long belt that extends north-north-east through Turkey Creek and forms a continuous outcrop west of Argyle Homestead. Farther north, isolated outcrops of granitic rocks, the north-north-easterly continuation of the belt, have been examined east of Burt Range. Still farther north, probable granitic rocks which have been mapped by photo-interpretation near Fitzmaurice River suggest that this granitic complex may be correlated with Litchfield Granite (Noakes, 1949).

In this Bulletin, the name Lamboo Complex is used to cover all the granitic rocks that crop out in this belt. The distribution of these granitic rocks clearly reflects the trend of the Lower Proterozoic geosyncline which developed in a mobile belt between the Kimberley Block and the Sturt Block. The Lamboo Complex may contain many phases of granitic intrusion and granitization; and petrologically it is known to contain a wide range of igneous rocks.

The main rock type of the complex between Denham River and Turkey Creek is a porphyritic biotite granite with large orthoclase phenocrysts up to 2 inches long (Appendix A, R6014). Similar porphyritic granite, containing numerous basic dykes, was examined west of Argyle Homestead and along the track to Ord River Dam Site.

Also in this area is a finer-grained acid granite, which appears to be younger than the porphyritic granite; it probably belongs to a later phase but is included in the Lamboo Complex.

South of Turkey Creek, the rocks of the complex are more basic and gneissic, and outcrops of granodiorite, gneissic granite, gneiss, and amphibolite were examined.

In many places near the borders of the complex, relict structures of granitized Halls Creeks Metamorphics can be seen, and in places small pockets of Halls Creek Metamorphics remain in the complex. South of Turkey Creek numerous intrusions of basic igneous rocks into the granitic gneiss (R6021, Appendix A) have hitherto been mapped as part of the complex; but they may belong to the later basic intrusion which, in places, penetrated sediments of King Leopold Formation.

The Lamboo Complex is younger than the Halls Creek Metamorphics, and intrusion does not affect the Upper Proterozoic sediments: it is accordingly assigned to the Lower Proterozoic.

Upper Proterozoic Rocks of Kimberley Plateau

In previous literature, Upper Proterozoic rocks of the Kimberley Plateau have been referred to as "Nullagine"; but as they are completely separated from the Nullagine "Series" at Nullagine by a large Palaeozoic and Mesozoic Basin, and as "Nullagine" was defined as a rock-unit term, this name is not applicable.

In the Ord-Victoria Region, sediments of the Kimberley Plateau crop out in the north-western portion; the area of Upper Proterozoic rocks in the vicinity of Texas Station and the elongated area of outcrop of sediments north and south of Flora Valley are similar in lithology and sequence, and have been included in the same unit.

Guppy and Lindner (1954), working to the south-west of the Ord-Victoria Region, have divided the rocks into five units—King Leopold

Formation, Mornington Volcanics, Warton Beds, Walsh Tillite and Mt. House Beds. With the exception of the Walsh Tillite and the Mornington Volcanics, the units have been traced on aerial photographs into the Ord-Victoria Region, so that Guppy's nomenclature can be accepted for Upper Proterozoic rocks that outcrop south-west of Wyndham.

Very little field work was done on these rocks and most of the information was obtained from photo-interpretation.

The *King Leopold Formation* is described by Guppy and Lindner as follows: "the unit outcrops typically in the King Leopold Range and Precipice Ranges . . . . The sediments, which are mainly quartzites in outcrop, unconformably overlie the Lamboo Complex and are unconformably overlain by the Mornington Volcanics".

In the Ord-Victoria Region, sandstones of this unit crop out in long strike ridges which form a scarp on the western side of outcrops of the Lamboo Complex.

In the section south of Mt. Cockburn (Fig. 9), 1,500 feet of coarse-grained massive strongly jointed sandstone and quartzitic sandstone underlie sandstone and slate of the Warton Beds. South-west of Texas Station, about 1,800 feet of sandstone of the King Leopold Formation are exposed. In this area, the strongly jointed sandstone is underlain by well-bedded sandstone which unconformably overlies Halls Creek Metamorphics. This lower sandstone has not been examined in the field, so that its position in the sequence is not definitely known: it may be a part of the King Leopold Formation, or it may be an older formation.

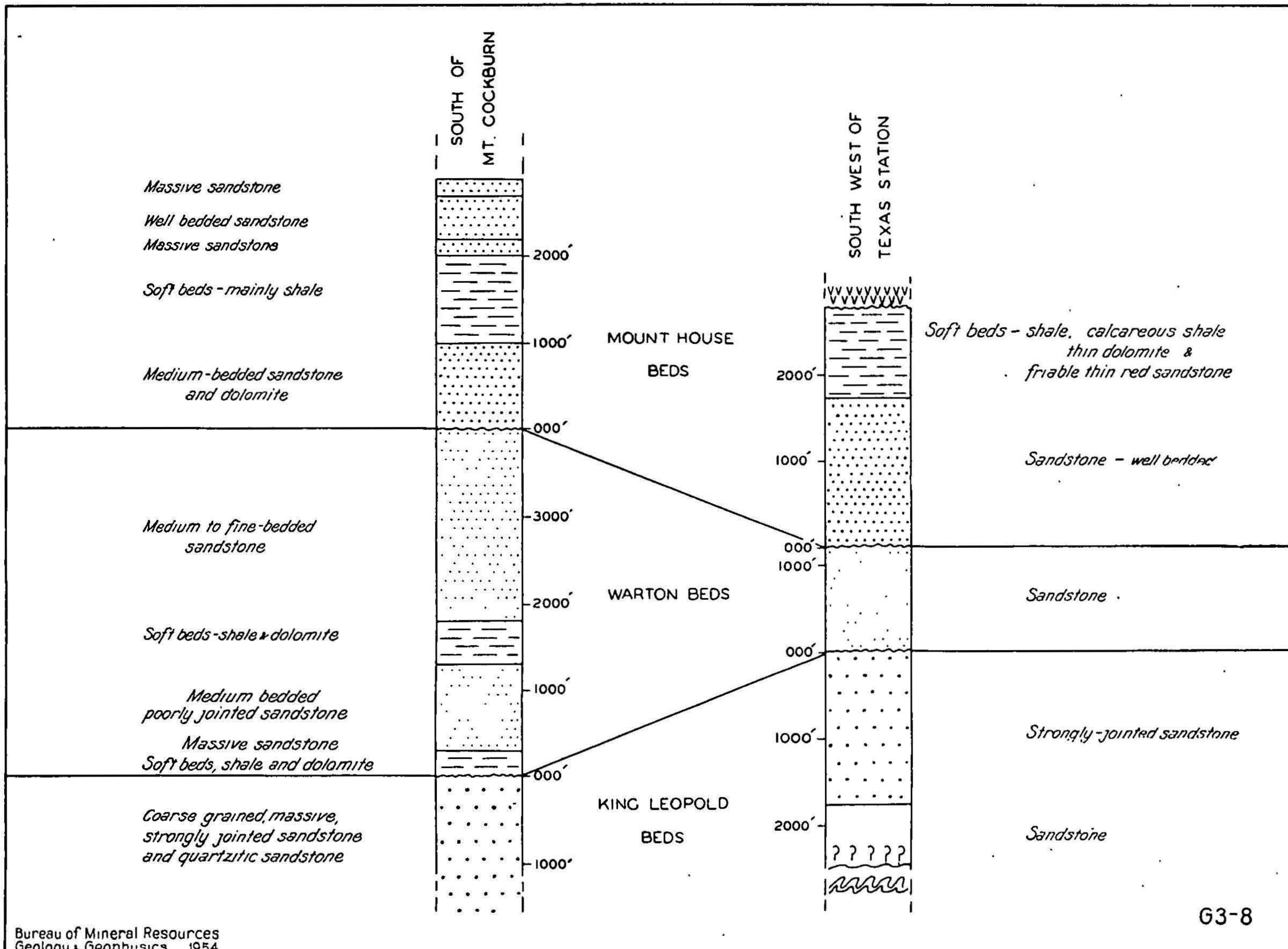
The *Mornington Volcanics,* which unconformably overlie the King Leopold Formation and are conformably overlain by the Warton Beds (Guppy and Lindner, 1954), have been traced to the western border of the Region, but they are little exposed in the east, and are not present in the two sections studied (Fig. 9).

The *Warton Beds,* in this Region, are represented by medium-bedded to thin-bedded sandstone with at least two horizons of softer beds, probably shale and thinly bedded dolomite. In the section measured from aerial photographs south of Mt. Cockburn, the basal 300 feet of this unit are composed of easily erodable beds, probably shale and dolomite. These are overlain by 1,000 feet of massive and poorly bedded slightly jointed sandstone, which itself is overlain by 500 feet of softer beds in which the Chamberlain River has cut its course for many miles. These beds are overlain by 2,200 feet of medium-bedded to thin-bedded sandstone.

In the section measured from aerial photographs south-west of Texas Station, the Warton Beds appear to be much thinner and are composed of about 1,200 feet of sandstone.

No definite outcrops of *Walsh Tillite* have been found in the Region, although suspected areas were seen on aerial photographs. In the west

Figure 9—Sections of Upper Proterozoic rocks in Kimberley Plateau ☞


SOUTH OF MT. COCKBURN
SOUTH WEST OF TEXAS STATION
Massive sandstone
Well bedded sandstone
Massive sandstone
Soft beds - mainly shale
Medium-bedded sandstone and dolomite
MOUNT HOUSE BEDS
Medium to fine-bedded sandstone
WARTON BEDS
Soft beds - shale & dolomite
Medium bedded poorly jointed sandstone
Massive sandstone
Soft beds, shale and dolomite
KING LEOPOLD BEDS
Coarse grained, massive, strongly jointed sandstone and quartzitic sandstone
2000′
1000′
000′
3000′
2000′
1000′
000′
1000′
Soft beds - shale, calcareous shale thin dolomite & friable thin red sandstone
Sandstone - well bedded
Sandstone
Strongly-jointed sandstone
Sandstone
2000′
1000′
000′
1000′
000′
1000′
2000′
? ? ? ? ?
G3-8
Bureau of Mineral Resources Geology & Geophysics 1954

Kimberleys, this formation unconformably overlies the Warton Beds and is conformably overlain by Mount House Beds.

In the section south of Mt. Cockburn, the *Mount House Beds* commence with 1,000 feet of medium-bedded sandstone which possibly contains some dolomite. The sandstone is overlain by 1,000 feet of shale, which in turn is overlain by well-bedded and massive sandstone.

In the section south-west of Texas Station, the Warton Beds are overlain by roughly 1,700 feet of sandstone below 1,000 feet of shale, calcareous shale, thinly bedded dolomite, and thinly bedded friable red sandstone, which are exposed along the road from Texas Station to Turkey Creek.

About 1,000 feet of shale of the Mount House Beds are exposed in the slopes of the Bastion at Wyndham. This shale is capped by a few hundred feet of sandstone. Bore records show that the shale continues to 156 feet below the surface and is underlain by at least 690 feet of sandstone. This section is very similar to that in the Mount House Beds south of Mt. Cockburn.

The section at Flora Valley is: a few hundred feet of shale at the base, covered by a thin band of limestone and a massive quartzitic sandstone—which forms the long scarp—and limestone. Above this is a thick bed of chocolate-brown shale that crops out near Flora Valley Homestead. This shale bed is correlated with the thick shale bed that crops out on the road from Texas to Turkey Creek, on the slopes of the Bastion and House Roof Hill, and, in the section south of Mt. Cockburn, at 1,000 feet above the base of the Mount House Beds.

A rather similar section was examined on the McIntosh River, north-west of Turner Homestead, where calcareous shales are overlain by massive quartzitic sandstone, which forms the continuation of the scarp mentioned in the Flora Valley section. The sandstone is overlain by limestone which dips beneath Antrim Plateau Volcanics.

The Mount House Beds probably include higher beds of sandstone and dolomite.

Probably the greatest thickness of Upper Proterozoic sediments in North Australia is exposed on the Kimberley Block, and a complete sequence from this area would facilitate the correlation of the numerous isolated outcrops of Upper Proterozoic rocks throughout North Australia.

The age of the units cannot yet be definitely determined, but, as Antrim Plateau Volcanics lie over them with an erosional unconformity, and they overlie Halls Creek Metamorphics with an angular unconformity, it is suggested that they were deposited wholly in Upper Proterozoic time —although deposition of the upper portion of the Mount House Beds may have extended into the lower Cambrian Epoch.

Victoria River Group

Sediments of the Victoria River Group were first named by Brown (1895), who gave the name Victoria River Sandstone and Victoria River Shale to the sandstone and shale which crop out in the scarps of both sides of the lower tracts of Victoria River. Since then, Matheson and Teichert (1948) and Reeves (1948) have used the general term "Nullagine" for

Figure 10—Subhorizontal sandstone of Victoria River Group in scarp at Victoria River

sediments of this unit. Reeves correlates his "Nullagine Series" with the "Elvire Series" supposedly given by Wade (1924); though Wade mostly used the term "Lower Cambrian" for the sediments under discussion. The sub-horizontal sandstone, shale, dolomite, and limestone which crop out in the vicinity of the middle and lower tracts of Victoria River form the Victoria River Group; and the unit is extended to include similar sediments which outcrop farther south and at Wave Hill Police Station.

The main area of outcrop of the unit extends from west of Port Keats and east of Willeroo in the north, to Wave Hill Police Station and Limbunya in the south. This includes the rough, dissected plateau country between Victoria River Downs and Auvergne.

The complete sequence of the Victoria River Group has not been obtained, and, in the large area of outcrop, facies changes complicate the sequence.

The sequence north of Newry Homestead is:

Top
55 ft. sandstone, well-bedded to current-bedded, ripple-marked;
15 ft. sandstone, massive;
100 ft. dolomite, thinly bedded, overlying massive dolomite, overlying dolomite and shale;
130 ft. covered by scree—probably shale;
— sandstone.

Figure 11—Mud cracks and swash or interference ripple marks in Victoria River Group—Victoria River Crossing, Coolibah

A rather similar section is exposed in the saddle on the road from Newry to Auvergne, where 300 feet of well-bedded sandstone, massive dolomite, thinly bedded dolomite, sandstone, and shale crop out. The section west of Auvergne in the Pinkerton Range is:

Top

80 ft sandstone, medium-bedded, with ripple marks, mud pellets, and mud cracks;

60 ft. quartzite, massive;

140 ft. dolomite or limestone;

10 ft. scree;

70 ft. sandstone, thin to medium bedded, with ripple marks and mud pellets and beds of shale;

620 ft. scree.

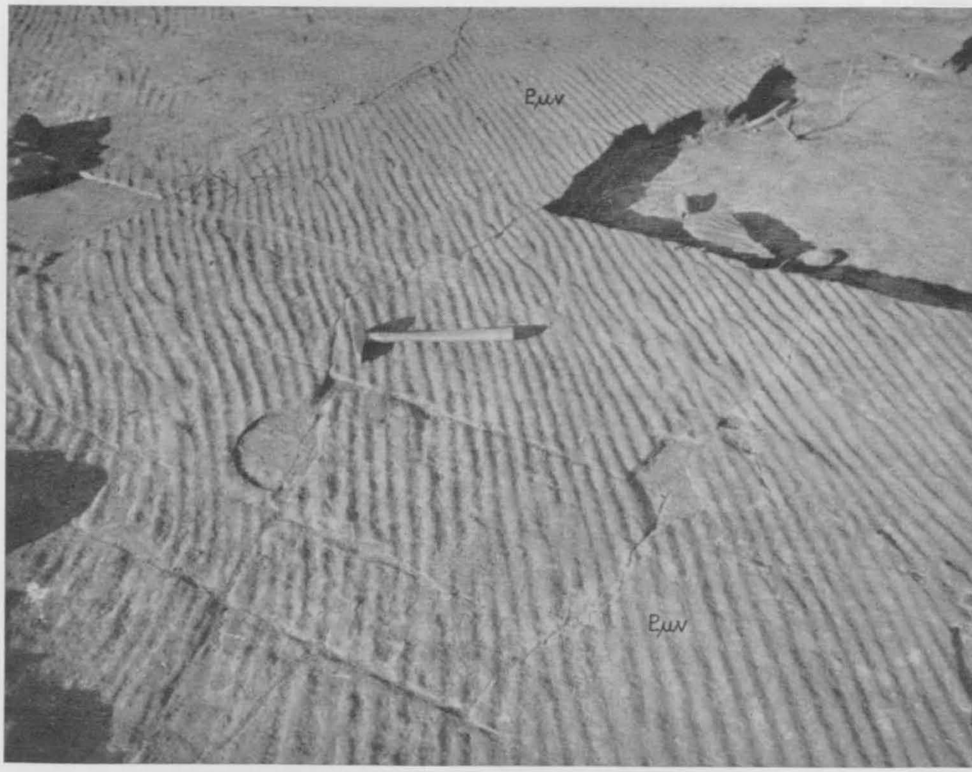


Figure 12—Ripple marks in sediments of Victoria River Group—Victoria River Crossing, Coolibah

These beds dip northwards at a low angle. The ripple marks examined in the top horizon have a wave-length of $4\frac{1}{2}$ cm. and an amplitude of 1 cm., with broad troughs and sharp ridges; they are transected by sun cracks.

Shallow-water markings in sediments of Victoria River Group are well illustrated in the shale, siltstone, and shaly limestone exposed in the bed of Victoria River at Coolibah. Large mud cracks now form ridges up to 4 cm. high and 3 cm. wide on the underlying beds. Areas of ripple marks, with a wave length of $3\frac{1}{2}$ cm. and an amplitude of $\frac{1}{2}$ cm., and swash marks or interference ripple marks are well preserved in the thinly bedded fine sediments.

The general sequence between Coolibah and Bradshaw is:

Top

60 ft. sandstone and quartzite, white to grey;

150 ft. fine sandstone and sandy shale and siltstone, ironstained;

15 ft. quartzite with mud pellets;

? ft. limestone;

400 ft. shale, siltstone, and shaly limestone;

400 ft. sandstone—the upper beds containing large ripple marks with wave lengths up to 45 cm. and amplitudes up to 5 cm.; limestone and shale.

Between the northern end of Jasper Gorge and Timber Creek a large area of limestone apparently forms the lower portion of the Victoria River Group. The greatest thickness measured was exposed in a small anticline 13.4 miles south-east of the junction of the Jasper Gorge track with the road from Coolibah to Timber Creek.

The section is:

Top

185 ft. limestone, massive, grey crystalline;

340 ft. limestone, massive to well-bedded, with chert nodules;

224 ft. limestone, grey and pink, with thin bands of sandstone;

10 ft. sandstone, medium-grained;

30 ft. limestone, pink and grey;

50 ft. limestone, grey, fine, crystalline.

400 feet of sub-horizontal ripple-marked friable to silicified sandstone are exposed in Jasper Gorge (Fig. 13).

In the dissected plateau country north of Gordon Creek Outstation, the dissection exposes 400 feet of sediments of the Victoria River Group. The first scarp is 285 feet above plain level and exposes thinly bedded limestone and shale under hard sandstone, which is overlain by 100 feet of ripple-marked sandstone.

In the vicinity of Johnson's Billabong on the road from Victoria River Downs to Mt. Sanford, the following section is exposed in the hills:

Top

110 ft. sandstone, finely bedded, coarse-grained, friable, well jointed and with some current bedding;

60 ft. sandstone and grit, poorly sorted, friable to silicified, with ripple marks and mud pellets;

240 ft. calcareous shale and platy limestone.

These beds strike at 100° and dip north at 11°. The complete sequence of Victoria River Group has not been measured; but, excluding the large thickness of limestone which apparently underlies the other sediments, the general sequence appears to be:

Top

80+ft. sandstone and quartzite, white to grey, with mud pellets and ripple marks;

60+ft. sandstone, massive;

250 ft. to 400+ft. limestone, shale, and thin beds of sandstone;

100 ft. to 400+ft. sandstone, ripple marked, well jointed, with mud pellets;

60+ft. quartzite or massive sandstone;

50+ft. limestone or dolomite;

240+ft. shales with thin bands of dolomite and sandstone.

Figure 13—Oblique aerial photograph showing jointing in sandstone of Victoria River Group

The thickness of the Victoria River Group is at least 2,000 feet; but it may be much thicker.

Abundant fossils have been collected from two isolated inliers of silicified sediments in the Volcanics, which are presumed to belong to the Victoria River Group. The better exposure is at Top Spring, north of

Montejinni Homestead, where an algal bioherm is exposed for a length of many hundred yards.

This outcrop has been surrounded by basalt so that it has been entirely silicified, and quartz veins, rock crystal, and basalt are found throughout the outcrop. The alga has been identified as *Collenia* cf. *frequens* Walcott (Traves, 1954).

Similar algae were seen in an inlier in the Volcanics between Catfish

Figure 14—Bioherm of *Collenia*, Top Spring

Hole and Inverway; and algal structures are present in the limestone at Wave Hill Police Station.

Throughout the area of outcrop, the sediments of the Victoria River Group are broadly folded and in places faulted. The highest angle of dip observed was about 40°, although the attitude in many places is subhorizontal.

The Victoria River Group is separated from the overlying Antrim

Plateau Volcanics by an erosional unconformity which indicates that it is older than the middle Lower Cambrian Epoch. The group is placed in the Upper Proterozoic, although the upper portion may extend into the Lower Cambrian. It is correlated with the Mount House Beds.

Undifferentiated Precambrian

Many isolated inliers of Precambrian sediments and metamorphics are found in the strongly folded belt on the southern edge of Bonaparte

Figure 15—Ord River Dam Site in undifferentiated Precambrian

Gulf Basin. As may be expected, these rocks have been folded and faulted more severely than the sediments that outcrop on the Blocks, so that their classification is difficult, and in this Bulletin they have been mapped as undifferentiated Precambrian. It is thought that most, if not all, of the rocks mapped thus are of Upper Proterozoic age, but insufficient knowledge of the nature of these inliers and of the complete Upper Proterozoic sequence prevents their being placed in one or other of the known units.

One such inlier is the Pincombe Range, which, at its southern end, is composed of red and white sandstone dipping south-east at 5°; farther north the dip steepens. Matheson and Teichert (1948) list the lithology as quartzite, shale, and phyllite, with quartz veins.

Mt. Cecil is a faulted inlier of massive quartzite which has been included in the undifferentiated Precambrian.

A large area of rugged country along the Ord River, south-west of Burt Range and in the vicinity of the Ord River Dam Site, has also been mapped under this heading: the sediments in this area have been folded and severely faulted and the sequence has not been worked out.

At the Dam Site the rock is a dense grey quartzite which dips north-east at 40° and appears to be the north limb of a fairly steeply pitching anticline. A few hundred yards down-stream, thinly bedded fine sandstone, shaly sandstone, and shaly limestone are exposed in the eastern bank. These sediments contain abundant shallow-water features such as ripple marks, swash marks, and mud cracks, and are distinctly reminiscent of the sediments of Victoria River Group which crop out at Coolibah. However, the beds are so buckled that the small folds are almost overturned, and quartz veins up to 2 inches in width cut through them. Farther downstream 50 feet of white quartzite overlie 100 feet of well-bedded, strongly jointed, slaty shale. The shale is faulted against medium-bedded sandstone and siltstone. No doubt these rocks are the folded and faulted equivalents of known Upper Proterozoic sediments, but until the sequence is worked out in this area it is thought best not to include them in any group or formation.

Other Precambrian outcrops whose position is not clear because of folding and faulting have been mapped under the heading of undifferentiated Precambrian.

Mt. Winnecke Sandstone

Poorly sorted sandstone, grit, and fine conglomerate that crop out in the vicinity of Mt. Winnecke, south of Wave Hill Station, are given the formation name of Mount Winnecke Sandstone. These arenites were examined by Jensen (1915), but otherwise have received very little attention. They crop out in the south-eastern portion of the Ord-Victoria Region and were examined along the old track from Hookers Creek to Tanami.

In the rugged hills 40 miles from Hookers Creek Mission the rock types are poorly sorted coarse-grained sandstone, grit, and fine conglomerate which contains pebbles up to 1 inch in diameter of quartz, chert, and greenstone. These rocks contain numerous stringers and reefs of quartz and are feebly mineralized. They range from poorly cemented to silicified, are poorly bedded and strongly jointed, and are folded with dips ranging from 45° to 70°.

3,000 feet of Mount Winnecke Sandstone were examined between the track and the outcrop of Winnecke Granophyre. The beds in this locality dip east at 45° and the dip increases to 74° at the contact with the granophyre. The rock types are poorly sorted coarse sandstone and grit. Within half a mile of the contact felspathization of the sandstone was observed, and farther west the sediments merge into the granophyre until all sedimentary structure is lost. Except for the intrusion of the granophyre into the Winnecke Sandstone, no relationship of this formation with any other unit has been observed.

No definite age can be given to the unit, although an Upper Proterozoic age is indicated, and it is tentatively correlated with the basal portion of the Upper Proterozoic rocks on the Kimberley Plateau, i.e., King Leopold Formation.

The lithology also bears a distinct resemblance to that of the Ashburton Sandstone, which was mapped in the Barkly Region in 1948 (Ivanac, 1954).

Winnecke Granophyre

The Winnecke Granophyre crops out in a small area in the south-east of the Region in the upper reaches of Winnecke Creek and its tributaries. The only rock type observed was a granophyre which contains mainly orthoclase and quartz. A detailed description of this rock is given in Appendix A—R6025. Outcrops of the unit were examined on the track from Hookers Creek to Tanami and west of the track at the intrusive contact of the Winnecke Granophyre with Mount Winnecke Sandstone. The sandstone has been granitized at the contact and effects of the intrusion are noticeable for half a mile east of the contact. In most places the edges of the Winnecke Granophyre disappear below a sand cover. The age of the unit is not known; but all granitic rocks of known age in the Region are older than Middle Cambrian, and probably are Upper Proterozoic; therefore the Winnecke Granophyre is assumed to be Upper Proterozoic.

This intrusion may possibly be correlated with the basic intrusion which affected the King Leopold Formation.

Basic Igneous Rocks

At some localities in the Ord-Victoria Region there are outcrops of basic igneous rocks which are not included in the Lamboo Complex; they are probably of Upper Proterozoic age.

Rocks mapped under this heading were examined on the Bedford Downs Track 2 miles to 12 miles from the homestead. They consist of dolerite (R6018) and gabbro (R6020) which intrude sandstone of the King Leopold Formation.

R6019 is described in Appendix A as a felspathized fine-grained sandstone. This specimen was collected at the contact of the sandstone with a gabbro (R6020) which intruded a faulted basin in the King Leopold Formation.

Intrusions of gabbro (R6021 in Appendix A) also occur in the Lamboo Complex, but they have not been mapped; nevertheless it is thought that they belong to this Upper Proterozoic basic intrusive phase.

Between Deception Range and Denham and Ord Rivers, an outcrop of roughly 10 square miles of basic igneous rock has been mapped; it is fairly uniform throughout the outcrop, although porphyritic and intrusive contact material was found at the margin. A specimen (R6023) from this intrusion is described in Appendix A as a quartz diorite or gabbro. This rock body shows little sign of stress and its relationship to other units is hidden because the outcrop forms heavy soil downs. However, it is thought that this intrusion may also belong to the Upper Proterozoic intrusive phase.

Precambrian Volcanics

A small belt of Pre-Cambrian volcanics has been mapped on the south-western side of the Lamboo Complex. These volcanics were examined along the track from Halls Creek to Bedford Downs. In the hand specimen they appear to be rhyolitic porphyry, but petrological examination of R6016 shows it to be a very strongly welded rhyolite tuff. The petrological description is given in Appendix A.

The age of the unit and its relationship with neighbouring units is not known: it is faulted against rocks of the Lamboo Complex on the eastern side, and its relationship with the Upper Proterozoic rocks of the Kimberley Plateau is obscured by sand on the western side.

In the hand specimen these volcanics look rather similar to the rhyolite porphyry which outcrops north-east of Cockatoo Spring and is described in Appendix A (R6017) as a metamorphosed igneous rock, probably originally a porphyry or possibly a volcanic rock. Weathered specimens of this rock form the igneous portion of the boulders in the Permian conglomerate.

CAMBRIAN

General

During the Cambrian Period in North Australia voluminous outpourings of plateau basalts were followed by marine transgressions which deposited fossiliferous sediments. These sediments were discovered in 1885 by Hardman, who declared them to be Carboniferous, although, in England, Cambrian forms were recognised from his fossil collection. Wade (1924) reclassified them as Upper Cambrian and mapped many of the Upper Proterozoic rocks as Lower Cambrian. Matheson and Teichert in 1945 investigated Wade's "Upper Cambrian" sediments in the East Kimberleys and assigned to them a Lower Cambrian age; they are now assigned to the Middle Cambrian. Since then Reeves (1948) discovered Cambrian sediments in the Carlton Basin.

Sedimentation during the Cambrian Period in the Ord-Victoria Region may be divided conveniently into three parts:

1. *Montejinni Limestone,* the oldest Cambrian sequence mapped, which forms a thin capping in the eastern portion of the Region, i.e., east of Wave Hill in the Northern Territory;

2. The *Negri Group, Elder Sandstone,* and *Ragged Range Conglomerate,* which crop out near the border between Northern Territory and Western Australia;

3. *Hart Spring Sandstone, Skewthorpe Formation, Pretlove Sandstone* and *Clark Sandstone,* of the *Carlton Group,* which crop out as fault blocks in the Carlton Basin.

The lowest fossiliferous horizon in the Negri Group indicates an early Middle Cambrian age; below this lie 700 feet of unfossiliferous shale and limestone. The contact of the basal limestone with the Volcanics appears to be conformable and there is no evidence to suggest a large time break between the Volcanics and the basal limestone: therefore the Volcanics are considered to be of Lower Cambrian age. Below the Volcanics, a marked unconformity, with erosional valleys up to 200 feet deep, indicates a time break between the deposition of the top beds of the Mt. House Beds and Victoria River Group and the outpouring of the plateau basalts.

Antrim Plateau Volcanics

Rocks of the Antrim Plateau Volcanics were examined by Hardman (1885), Jack (1906), Mahony (1922), Wade (1924), and Blatchford (1927), before David (1932) referred to the unit as "Antrim Plateau Basalts." The geographical name Antrim Plateau was given to the dissected hilly volcanic country south of the Hardman Basin. Basalts constitute much of the unit, but as agglomerates and tuffs are also found in it the name is revised to Antrim Plateau Volcanics. The word "Plateau" should be retained to avoid confusion in world geology with the well-known Antrim Basalts of Ireland.

The lack of regional mapping, and the fact that most work on the Volcanics had been done in Western Australia, where the continuity of the Volcanics is not apparent, led to discussions on the age and relationship of the different localities in which the Volcanics outcropped. Plate 3, the regional geological map, clearly shows the distribution of Antrim Plateau Volcanics and the continuity of outcrop from Flora Valley almost to the southern end of Burt Range. The map also shows that the Hardman and Rosewood Basins lie entirely within the Volcanics. The Argyle Basin is more doubtful: as shown on the map, this basin has Volcanics on the northern, eastern, and southern sides, but no Volcanics are mapped on the western side. It is believed by the writer that there is a thin continuous band of Volcanics on the western side; but in many places it is obscured by soil or alluvium and, in any case, it is too narrow to be represented on a regional map of this scale. This narrow band has been observed between Argyle Homestead and the well-known "zebra stone" locality, and also in the Ord River bed on the Lissadell track.

The name Antrim Plateau Volcanics is extended to cover the large belt of volcanics which crops out from Hookers Creek, through Wave Hill, to Willeroo and farther north. Continuity of outcrop cannot be completely traced from Antrim Plateau because of the veneer of laterite, but near Gregory's Depot only a few miles of Upper Proterozoic rocks, from which the Volcanics have been eroded, separate the eastern and western belts.

Numerous isolated outcrops of volcanics, including those in the vicinity of Burt Range, Wyndham, and Denham River, are included in the Antrim Plateau Volcanics. The use of the term "Argyle Basalt" (Edwards and Clarke, 1940) should be discontinued now that it has been proved that the Basalt is part of the Antrim Plateau Volcanics.

The Volcanics consist of a number of flows of basalt and some agglomerate and tuff beds. The fine-grained to coarse-grained basalts are vesicular or amygdaloidal at the tops of flows.

The Oakes-Durack Bore, which penetrates Antrim Plateau Volcanics for 408 feet, illustrates this; and Clarke (1940) is of the opinion, from the bore log recordings of "ashy" and vesicular layers, that this section is made up of six flows. In many places the flows produce an appearance of bedding in the dissected hills, and more resistant layers give rise to mesa-like topography. Many specimens from large flows have a doleritic appearance.

Edwards (1940), in a petrological study of basalts collected from Antrim Plateau Volcanics in the East Kimberleys by Clarke, divides them into several distinct groups: (1) olivine basalt; (2) felspar basalt; (3) aphyric basalt; (4) quartz basalt; (5) pyroxene basalt; (6) sub-ophitic basalt; and (7) aphanitic basalt. In conclusion, he states that the basalts "range from olivine basalt to quartz basalt and have distinct affinities with the tholeiitic or plateau basalts ..... and appear to form a single basaltic province".

Much less petrological study has been done on specimens of Antrim Plateau Volcanics in the Northern Territory. Glover, in 1948, examined crushed material from a percussion drill-hole sunk in Antrim Plateau Volcanics on Victoria River Downs. Most of the material examined was basalt which consisted essentially of fine-grained plagioclase, medium-grained monoclinic pyroxene, and a few patches of a bright green material, probably bowlingite, which may represent original olivine.

A more recent study by Glover of specimens (R6026 and R6027) of quartz dolerite or quartz-bearing basalt from Antrim Plateau Volcanics near Stirling Creek, south of Limbunya, is given in Appendix A.

In many places the joints and vesicles in the basalts are filled with chalcedony, rock crystal, calcite, and prehnite; and on the volcanic downs, the surface in places is thickly strewn with pieces of these minerals. The rock crystals range from clear to smoky or rose-coloured. Poor quality amethyst and prehnite litter the surface south of Wave Hill. Between

Hookers Creek and Inverway calcite lies abundantly on the surface, and north-east of Mistake Creek Homestead is abundant rock crystal: although some of the rock crystal is of good quality, no crystals of the size required for commercial use were seen.

In most places the Antrim Plateau Volcanics are sub-horizontal, so that it is difficult to estimate thickness. Estimates of thickness range from 660 feet by Jack to 4,000 feet by Mahony. The greatest thickness measured during the recent field work was at a locality west of Trig. Point J.37, north of Turner Homestead. At this locality the Volcanics dip east at 35° and the thickness is 3,300 feet. Near Wave Hill Station the thickness is estimated to be about 1,000 feet; Bore No. 9, Wave Hill, penetrates 600 feet of the Volcanics without reaching the base; but on Inverway Station the Volcanics are much thinner and the greatest thickness recorded in bore logs is 260 feet. A bore sunk at Hookers Creek shows that in that area the Volcanics are at least 160 feet thick.

Inliers of silicified Precambrian sandstones have been examined in many localities between Wave Hill and Willeroo, and a rubble of silicified sandstone lies on the surface of the Volcanics south-east of Mt. Connection and at Pigeon Hole. The contact of the Volcanics with Precambrian sandstone has provided good material for artifacts, and chipping grounds are numerous.

The relationship of Antrim Plateau Volcanics to other units has been examined in many localities. Where the Volcanics unconformably overlie sediments of Upper Proterozoic age and conformably underlie the basal formation—Headleys Limestone—of the Negri Group, their age can be deduced. This relationship has been examined west of Trig. Point J.37. In this section the Upper Proterozoic sediments overlie Lower Proterozoic Halls Creek Metamorphics with an angular unconformity, and Antrim Plateau Volcanics overlie the deeply dissected Upper Proterozoic sediments unconformably with marked erosion. Farther east the Volcanics are overlain by Headley's Limestone and the contact appears to be conformable. This contact between the Volcanics and the basal Limestone of Negri Group has been examined in many places on the borders of the Hardman and Rosewood Basins, and, although in places on the borders the dip of the beds increases, no angular or erosional unconformity has been observed.

A similar contact was observed between the Volcanics and Montejinni Limestone in the eastern portion of the Region. In this area the Volcanics, in places, are disconformably overlain by Mullaman Group.

In the Burt Range, the Volcanics are overlain by Cockatoo Sandstone. At a locality $3\frac{1}{2}$ miles north-west of Cockatoo Spring, Matheson and Teichert (1948) have recorded 80 feet of volcanic agglomerate unconformably overlying Precambrian sediments and flatly overlain by Cockatoo Sandstone. Although they interpret these volcanics as a portion of the main Volcanics, they suggest that this outcrop could represent volcanics of a younger age. The author does not agree with this suggestion and the volcanic agglomerate of this locality is included in Antrim Plateau Volcanics.

In the Carlton Basin, the volcanics which outcrop south-west of Mt. Connection appear to overlie Upper Proterozoic sediments unconformably, but their contact with Middle Cambrian Hart Spring Sandstone is soil-covered.

The erosional unconformity between Upper Proterozoic sediments and the Volcanics is well illustrated along the Victoria River between Coolibah and Willeroo. In this area the Volcanics are found in old valleys, some of them 200 feet deep, in sediments of Victoria River Group and, on casual observation, appear to be sills within the older Group. Closer examination at the sides of the valleys shows that the Volcanics transgress a number of beds of the Victoria River Group. This erosional unconformity causes difficulty in mapping Antrim Plateau Volcanics in the Upper Proterozoic sediments south-west of Wyndham, where Mornington Volcanics (Guppy and Lindner, 1954) are found in the sequence. Antrim Plateau Volcanics lie in the valleys and give the appearance of being interbedded with the sediments, although closer examination shows that they are transgressive. The Mornington Volcanics belong to an andesitic rather than a basaltic suite, so that it is possible to distinguish between the two units in hand specimens.

The exact age of Antrim Plateau Volcanics has not been determined. However, as they overlie Upper Proterozoic sediments with an erosional unconformity and are overlain apparently conformably by Negri Group, their position is very probably somewhere in the Lower Cambrian Epoch. The lack of any visible break between the Volcanics and the Negri Group indicates that the age of Antrim Plateau Volcanics is probably upper Lower Cambrian.

The Antrim Plateau Volcanics form the main mass of plateau volcanics erupted at that time in Northern Australia, but smaller isolated outcrops of volcanics have been studied and named to the north-east, north-west and east: Helen Springs Volcanics to the east, Leight Creek Volcanics (Rattigan, unpublished) to the north-east, and the Cambrian Volcanics in the North Kimberleys to the north-west are all thought to belong to this one period of vulcanicity.

Montejinni Limestone

Montejinni Limestone is the formation name given to the limestone exposed in the small hills of 20 to 30 feet in the vicinity of Montejinni Homestead. This limestone has not previously been mapped or named. The underlying Antrim Plateau Volcanics are exposed on the road at the gate of the homestead paddock, but the homestead itself is built on limestone, and 30 feet of grey crystalline limestone are exposed in the home paddock.

Montejinni Limestone crops out in a long, almost meridional, strip in the eastern portion of the Region and forms the cappings of many of the isolated mesas. Jensen (1915) stated that Brown had discovered the fossil *"Salterella" hardmani (Biconulites hardmani)* in calcareous rocks near Wave Hill. The only reference the writer could find was Brown (1909), in which he stated that the limestone at Wave Hill is of similar age to that of Daly River and east of Powell Creek, in which Cambrian fossils have been found. The limestone examined in the vicinity of Wave Hill is Precambrian and it is thought that no Cambrian sediments crop out in that area.

At the bottom of the typical section of the formation are about 40 feet of crystalline limestone, thickly bedded to massive, fine to coarse grained, grey, cream and brown, containing abundant chert nodules which are commonly found along the bedding planes. This is overlain by 20 to 40 feet of crystalline limestone, thinly bedded, fine grained, grey, and with very few, if any, chert nodules.

Along the track from Top Spring to Wave Hill the formation is exposed in many places. At 6.5 miles from Top Spring, the isolated mesa to the east is capped with limestone, which overlies the Volcanics. In the scarp are exposed 30 feet of fine-grained crystalline cream limestone, coarse brown limestone, and medium-grained grey limestone, with abundant layers of nodular white chert. At 14.0 miles, the track runs on to Montejinni Limestone and for miles runs over abundant outcrops of sub-horizontal, broadly folded, fine grey crystalline limestone containing few, if any, chert nodules. Farther along the track to Wave Hill, 7 miles south of Bore 49, a mesa to the east, with Montejinni Limestone capping the Volcanics, exposes 30 to 40 feet of thickly bedded grey crystalline limestone which, when freshly broken, has a distinct odour of sulphuretted hydrogen. This limestone has abundant chert nodules along the bedding plane, is strongly jointed, and has weathered into typical karst topography. This more massive limestone is overlain by 10-15 feet of thinly bedded fine-grained grey crystalline limestone.

The scarp 3.7 miles east of Chumgamidgee Water Hole (east of Wave Hill) has a very similar sequence, with 30 feet of thickly bedded grey crystalline limestone with abundant chert nodules overlying the Lower Cambrian Volcanics and overlain by at least 20 feet of thinly bedded fine grey crystalline limestone. At this locality, the thinly bedded limestone is overlain by a remnant of silicified lateritized shale, which may be of Cambrian age, but is more probably a remnant of shale of Mullaman Group of Cretaceous age.

On the Murrenji Track, east of Top Spring, there are poor outcrops of grey crystalline limestone of the formation, but little can be seen of the sequence. The limestone is overlain by grey mudstone, probably of Cretaceous age.

On the track between Top Spring and Birrimbah, Montejinni Limestone is exposed at 9.6 miles from Top Spring, as a fine to coarse crystalline, grey to pink, sub-horizontal limestone with some chert nodules. Farther along the track, the Montejinni Limestone is overlain by lateritized Cretaceous sediments. On the track from Birrimbah to Moolooloo, at 16.5 miles from Birrimbah, the veneer of lateritized Mullaman sediments has been eroded to expose an inlier of Montejinni Limestone. 1.2 miles farther

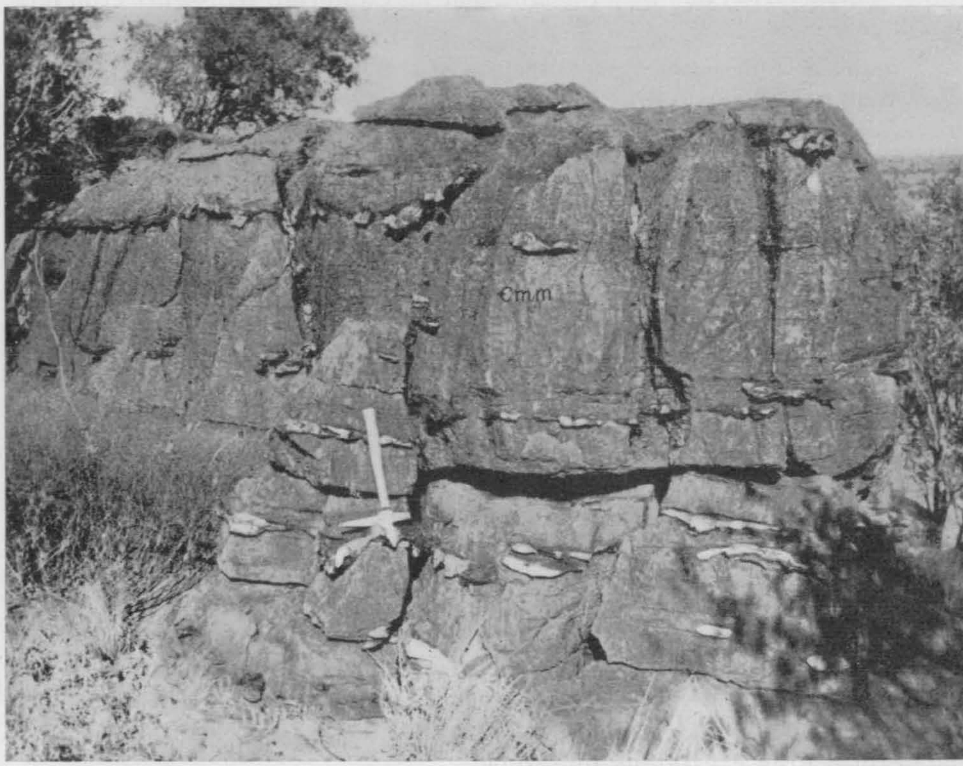


Figure 16—Chert nodules in Montejinni Limestone between Montejinni and Wave Hill

down the track, Montejinni Limestone is again exposed as a medium-bedded to thinly bedded grey crystalline limestone in sections 30 feet thick. At 17.9 miles, abundant girvanellids were collected from a grey crystalline limestone. These are the only fossils that have been found in the formation.

Beds of Montejinni Limestone are generally sub-horizontal, although broadly folded and slightly buckled. Between Top Spring and Birrimbah, dips up to 30° north-east and 20° south-west have been recorded, and small anticlines and synclines were observed between Top Spring and Wave Hill.

In all observed contacts, Montejinni Limestone overlies rocks of the Antrim Plateau Volcanics and underlies sediments of the Mullaman Group. The girvanellids do not indicate an exact age, but show that the Montejinni Limestone belongs to the Cambrian Period. By its relationship to the Lower Cambrian Volcanics and its marked resemblance in position and lithology to Headleys Limestone of the Negri Group, the age of the formation may be given as the top of Lower Cambrian or the bottom of Middle Cambrian.

It is regarded as the eastern extension of Headleys Limestone, although, geographically, there is a large gap between these formations. Also, no doubt, its equivalent exists in the Daly River Group (Noakes, 1949) to the north. The Precambrian Ashburton Sandstone, which forms the Ashburton Range in the Northern Territory, probably formed a ridge in Cambrian time, which separated Montejinni Limestone from the Cambrian sediments of the Barkly Tableland; but it may be correlable with the lower beds in that area.

Negri Group

Sediments of the Negri Group form the largest and most studied unit in the Cambrian sequence. The name "Negri Series" was first used by Mahony in his manuscript (Hobson, 1936) and the portion of the "Series" that crops out in Western Australia has been adequately described by Matheson and Teichert (1948). The name is revised to Negri Group to comply with the present Australian Code of Stratigraphical Nomenclature, and the Group is divided into eight formations. They are, in ascending order: *Headleys Limestone, Nelson Shale, Linnekar Limestone, Panton Shale, Shady Camp Limestone, Negri River Shale, Corby Limestone,* and *Hudson Shale.* Matheson and Teichert divide the outcrops into three separate basins, the Argyle Basin, the Rosewood Basin, and the Hardman Basin. Further mapping has shown that there are also at least seven isolated areas of sediments of this group.

The Hardman Basin (Matheson and Teichert, 1948) contains the best development, and in this area the group is split into eight formations which can be readily recognized in the other basins. The next largest area of sediments of the group is in Rosewood Basin, and Matheson and Teichert describe Argyle Basin as the smallest. However, as shown on Plate 3, a small area west of the Ord River (north of Lissadell) is possibly an extension of the south-western end of Argyle Basin, and another area north of Bow River Crossing on the track from Lissadell to Texas, and possibly two small areas south of the Hardman Basin, roughly six miles east of Flora Valley Homestead, may also be referred to the group. A small section of these sediments is also exposed beneath the Ragged Range Conglomerate in the western scarp of Ragged Range.

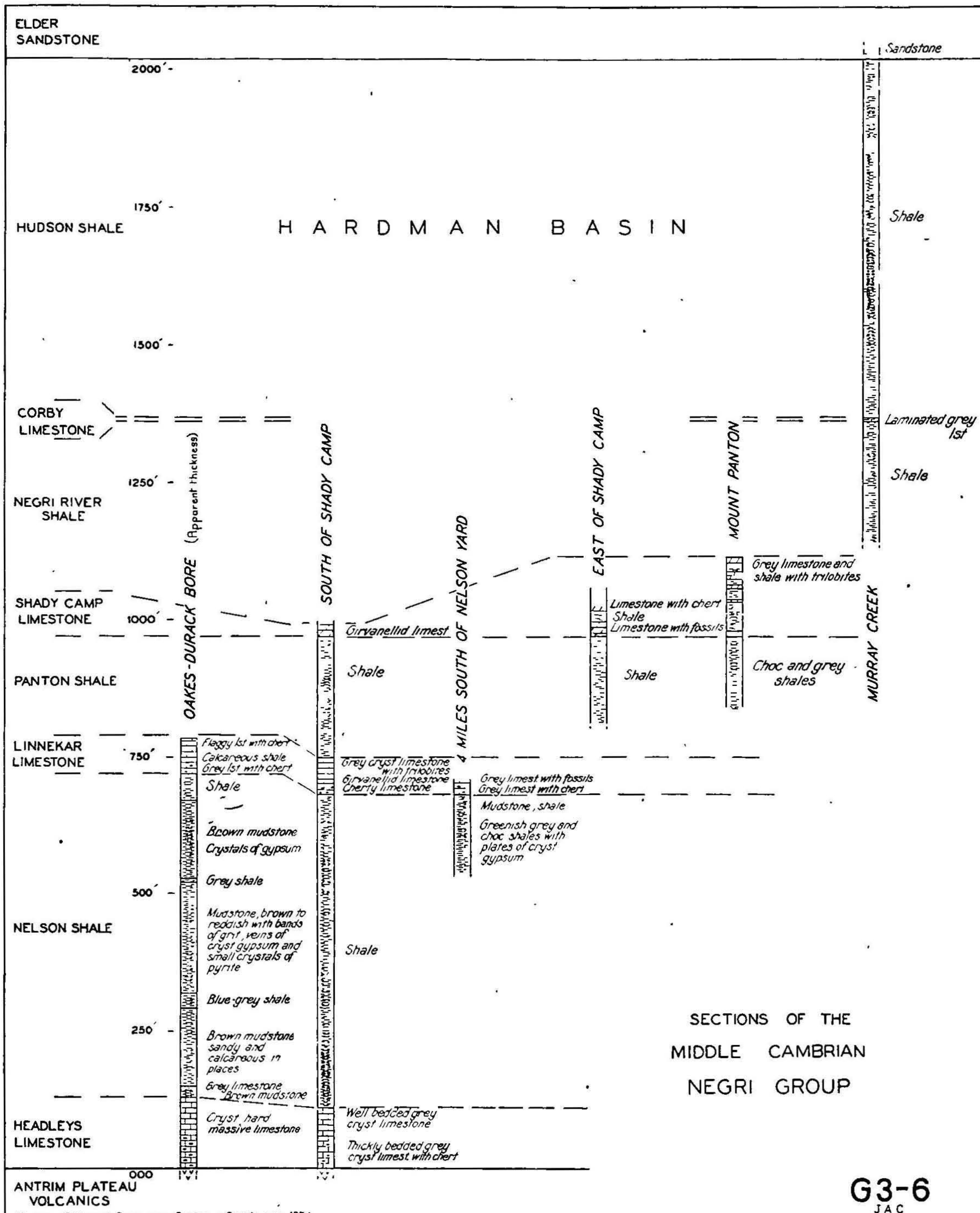


Figure 17—Sections of Middle Cambrian Negri Group

In most of these areas Headleys Limestone forms the base of the sequence. Matheson and Teichert defined the Negri "Series" as containing four limestone units and three shale units. The fourth shale unit, which, on the south slopes of Mt. Elder and in the Ragged Range, is seen to change rapidly to sandstone at the top, was included in the Elder Sandstone, and the boundary of the Negri "Series" was taken at the top of the fourth limestone unit. In this Bulletin it was thought advisable to include the four shale and limestone units in the Negri Group and to draw the boundary of the group at the top of the fourth shale, thus making the Elder Sandstone a more complete arenaceous unit. The greater part of the group consists of shale (see Fig. 17) ; but the limestone, being harder, is more prominent, and the basal beds of each limestone formation are useful marker beds.

Headleys Limestone

Headleys Limestone is the formation name given to the basal limestone of Negri Group.

It is defined as the limestone which overlies the Antrim Plateau Volcanics, apparently conformably, and is overlain conformably by Nelson Shale. The type locality is at Headleys Knob, eleven miles south-east of Ord River Homestead. The typical sequence of the formation is 60 feet of thickly bedded grey crystalline limestone with abundant tuberous bodies of chert along the bedding-planes, overlain by 50 to 60 feet of thinly bedded grey crystalline limestone. The chert nodules decrease in abundance from the base and none was observed in the thinly bedded limestone. The recorded apparent thickness of the formation encountered in the Oakes-Durack Bore was 130 feet. However, thicknesses throughout this bore are greater than others recorded, so that the beds penetrated must be dipping slightly; although, from surface observations, the bore-site is very close to the axis of Kelly Creek Anticline.

The formation is very resistent to weathering and in many places forms cappings on the Volcanics. Where the beds have been tilted at the edges of the basins, the limestone protrudes above the surrounding country in characteristic "walls". One such well-known "wall" can be traced from Rosewood Homestead along the northern and south-eastern sides of the Rosewood Basin. This feature has also been observed along the eastern limb of the Kelly Creek Anticline (north of Mt. Napier, in the Hardman Basin) and on the eastern side of the small area north of the Bow River Crossing. These "walls" have been formed by differential erosion in the steeply dipping portions, which apparently have been tilted during isostatic movement and adjustment in the basement blocks.

Limestones of the formation have been examined in many localities. On the roads between Inverway and Nelson Springs and from Nicholson to Turner, and at the limestones six miles east of Flora Valley, sub-horizontal to gently dipping beds of this basal unit are seen overlying

Antrim Plateau Volcanics. In other places, already mentioned, beds of this formation are tilted up to vertical.

No fossils have been found in the Headleys Limestone, but the position of the formation in the sequence suggests an age of uppermost Lower Cambrian or basal Middle Cambrian. The similarity in lithology, thickness, and sequence suggests that it is equivalent to the Montejinni Lime-

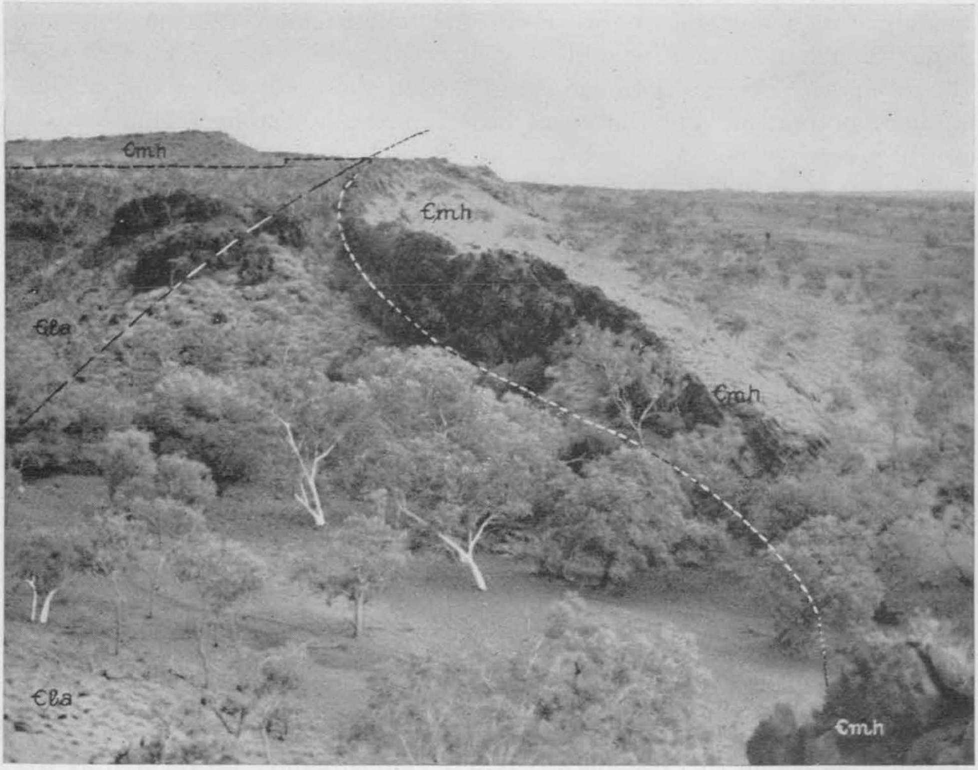


Figure 18—Eroded nose of Kelly Creek Anticline near Blackfellow Rock Hole

stone, and it may be correlable with the basal portions of the Daly River Group (Noakes, 1949) and Cambrian sediments in the Barkly Tableland.

Nelson Shale

The formation name Nelson Shale is given to the lowest shale unit in the Negri Group. Poor outcrops of this shale have been examined in the vicinity of Nelson Springs and Nelson Yard, and beds of the unit are exposed in the middle to upper tracts of Nelson Creek.

North of Blackfellow Rockhole, on a tributary of Headleys Creek, the Nelson Shale lies conformably between Headleys Limestone and

Linnekar Limestone. At this locality, the dip ranges from 60° at the base to 45° at the top, and the thickness of the formation is 570 feet.

The Oakes-Durack Bore encounters an apparent thickness of 590 feet of Nelson Shale—the driller's record of the strata is given in Figure 17. Matheson and Teichert quote the thickness of the formation, measured south of the junction of the Ord and Negri Rivers, as 525 feet, and north-west of Mt. Napier as 240 feet, and state that the thickness of the Shale decreases to the south in the Hardman Basin; but the above measurements do not support this.

The upper 150 feet of the Nelson Shale were examined at the south-east point of the scarp four miles south-south-west of Nelson Yard. At this locality 150 feet of red and grey shales and a thin limestone bed 1 foot thick are exposed. Large gypsum plates up to 18 inches long, a secondary product from leaching of the gypsiferous shales, lie on the surface at the bottom of the slope. The shales are overlain by three feet of silty mudstone, which is overlain by the 12 feet of grey to brown crystalline limestone that forms the base of Linnekar Limestone.

Nelson Shale has not yielded any fossils, but as it conformably underlies the fossiliferous Linnekar Limestone, its age may be given as lower Middle Cambrian.

Linnekar Limestone

Linnekar Limestone is the name given to the second limestone unit of Negri Group. Highly fossiliferous beds of this formation crop out in the banks of Linnekar Creek at its junction with Brooks Creek. The typical section is 5-10 feet of bedded grey to brown crystalline limestone with abundant chert nodules, overlain by 50-60 feet of thinly bedded grey limestone with intercalated thin shale beds. The upper portion of this formation contains abundant trilobites, pteropods, and girvanellids.

As mentioned by Matheson and Teichert, Linnekar Creek, where it is crossed by the road from Ord River to Turner, affords an excellent fossil locality for the formation. The thinly bedded shaly limestone, exposed in the banks of the creek, contains abundant well-preserved specimens of *Redlichia* and *Biconulites*, and on one horizon large ripple marks are exposed in which the crests are almost entirely composed of casts of *Biconulites*.

The formation is well exposed north of Blackfellow Rockhole, where the beds range in dip from 45° to 30°. The thickness of the unit in this section is 70 feet. The bottom 10 feet are bedded limestone with abundant chert nodules, overlain by a thin bed of girvanellid limestone which is overlain by thinly bedded grey shaly limestone.

A few hundred yards south-east of this section, at a small drag-fold, the thinly bedded grey limestone contains numerous fragments of *Redlichia* and some *Biconulites* (Locality 46).

At Locality 49 the base of the formation forms the top of the scarp four miles south-south-west of Nelson Yard. Above Nelson Shale are exposed twelve feet of grey and brown crystalline cherty limestone overlain by thinly bedded grey crystalline limestone containing fragments of *Redlichia.*

Linnekar Limestone crops out in the vicinity of the Oakes-Durack Bore Site and the bore-log reveals a thickness of 59 feet of this formation. The sequence as given by Wade (1924) is:

Top.

27 feet blue limestone, flaggy, with nodular fossils *(Girvanella);*

24 feet blue shale, calcareous, with thin seams of gypsum and thin bands of hard crystalline limestone; some pyrite; fossils;

8 feet blue to dark grey limestone with nodular fossils.

Other exposures of the formation were examined along the tracks from Nelson Spring to Ord River, from Ord River to Mistake Creek, and from Mistake Creek to Spring Creek.

The fossils of the formation are the trilobite *Redlichia forresti* (Eth. Jun.), *Biconulites hardmani,* and *Girvanella.*

Teichert (1948) includes this assemblage in the *Redlichia*-zone which he placed in the Lower Cambrian Epoch. Dr. Öpik places this *Redlichia* sequence in the lower Middle Cambrian Epoch; the age of Linnekar Limestone is therefore regarded as lower Middle Cambrian.

Panton Shale

Panton Shale is the second shale unit of Negri Group and it lies conformably between Linnekar Limestone and Shady Camp Limestone. The upper portion of the formation crops out on the slopes of Mt. Panton. Accurate measurements of the shale have not been made, but the approximate thickness south of Shady Camp Yard is 200 feet: thus this shale unit is much smaller than the other three in the Group.

On the slopes of Mt. Panton about 120 feet of red and grey shale of this unit are exposed, overlain conformably by fossiliferous beds of Shady Camp Limestone.

Poor exposures of this shale have also been examined between Linnekar Yard and Ord River Homestead and between Shady Camp Yard and Nelson Spring.

The position of the formation in the Negri sequence indicates a lower Middle Cambrian age for the unit.

Shady Camp Limestone

The name Shady Camp Limestone is proposed for the third limestone unit of the Negri Group. It conformably overlies Panton Shale and crops out in the ridges on the eastern side of Negri River, a few miles east of Shady Camp yard.

In this area, the formation consists of interbedded fossiliferous limestones and shales. It appears to be better developed in the Mt. Panton area than in other parts of the Basin. Matheson and Teichert gave the thickness of their third limestone unit as 10-20 feet and correlated the upper portion of the Mt. Panton sequence with the unfossiliferous upper portion of the Negri Group. However, from field mapping, it is seen that the upper portion of the Mt. Panton sequence is equivalent to the outcrops of the formation east of Shady Camp, which can be traced around the Basin to outcrops of the third limestone unit as described by Matheson and Teichert.

In most of the Basin, the Shady Camp Limestone consists of 10-20 feet of grey crystalline limestone which contains girvanellids and pteropods; but in the Mt. Panton area the formation includes 145 feet of highly fossiliferous limestone and shale.

Matheson and Teichert list the following sequence at Mt. Panton:

Top.
10 feet hard, massive limestone with *Girvanella* and *Biconulites hardmani;*
16 feet grey shale, unfossiliferous;
12 feet flaggy limestone with trilobite layers;
12 feet grey shale;
6 feet flaggy limestone with abundant *Xystridura;*
19 feet grey shale with *Redlichia* and *Xystridura;*
5 feet flaggy limestone;
24 feet grey shale;
1 foot limestone with *Biconulites hardmani* and *Wimanella* sp.;
9 feet grey shale;
1 foot limestone with *Biconulites hardmani* and *Wimanella* sp.;
20 feet grey shale with *Redlichia* sp;
10 feet hard massive limestone with *Girvanella* and *Biconulites hardmani;*

Wade (1924) also gives a sequence for Mt. Panton, but his sequence is more generalized and he has omitted the thin limestone beds in the lower portion. The silicification of a number of minor faults, which do not affect the sequence in the area, has strengthened it so that, with differential erosion, this isolated residual remains.

A section similar to that exposed at Mt. Panton has been examined along the track from Shady Camp to Nelson Spring, where the beds dip gently to the west (Locality 47). The ridge 1.1 miles east of Negri River Crossing is capped with a fine-grained grey crystalline limestone containing *Biconulites,* brachiopods and trilobite fragments, and is probably the basal limestone of the unit. The next resistant horizon is encountered 0.4 miles to the west where a fine-grained crystalline limestone containing *Biconulites* is exposed. A few hundred yards farther to the west is an outcrop of grey crystalline limestone with abundant *Biconulites,* brachipods, and some trilobite fragments. 0.15 miles farther west is an outcrop of creamy-grey limestone with chert nodules.

The above sections show the Mt. Panton development of Shady Camp Limestone. The other development of 10-20 feet of girvanellid limestone is more common throughout the Basin and is well illustrated at Ord River Homestead, where, in the banks of Forrest Creek, the girvanellid limestone overlies yellowish-grey to purple beds of Panton Shale. The girvanellid limestone was examined on the banks of White Mountain Creek and along the road from Mistake Creek to Spring Creek.

The fossil assemblage found in Shady Camp Limestone includes the trilobites *Xystridura* and *Redlichia*, the brachiopods *Wimanella* sp. and *Billingsella* cf. *humboldti* (Walcott), the pteropod *Biconulites hardmani*, and girvanellids. This assemblage had not been recorded previously in Australia, and Teichert (1948), because of the wider distribution of *Redlichia*, regarded it as part of the *Redlichia*-zone of Lower Cambrian and thus included all Negri Group in the Lower Cambrian Epoch.

Dr. Öpik in his recent studies of Cambrian fossils throughout northern Australia has shown that the *Redlichia* and *Xystridura* assemblage is quite common and has assigned to it a lower Middle Cambrian age. Thus the age of the Shady Camp Limestone is lower Middle Cambrian; it may be correlated with the Gum Ridge Formation east of Tennant Creek, which Öpik regards of lower Middle Cambrian age (Ivanac, 1954).

Negri River Shale

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

The Shale forms poor outcrops and no thicknesses were measured. Matheson and Teichert list it as 70-235 feet thick.

Poor exposures were examined in the vicinity of Negri River Crossing on the track from Nelson Springs to Ord River, and between White Mountain Creek and White Mountain; the exposures at both places are of red to grey calcareous shale.

No fossils have been found in this formation; but as it conformably overlies the fossiliferous Shady Camp Limestone its age is given as lower Middle Cambrian.

Corby Limestone

The formation name Corby Limestone is given to the fourth limestone unit of Negri Group. The formation takes its name from Corby Creek, a small western tributary of Negri River, which flows through limestone outcrops of this unit.

Matheson and Teichert state that the unit is 10 feet thick.

Between White Mountain Creek and White Mountain, outcrops of the formation were examined along a strike ridge, where a dense laminated steel-grey crystalline limestone with small chert nodules is exposed.

Limestone of the formation was examined near Mistake Creek Homestead. Matheson and Teichert (1948) chose the top of this formation as the top of their Negri "Series": but though the limestone forms a definite marker-horizon which may be easily traced around the basin, it does not complete the cyclic deposition of the Negri Group.

The formation appears to be unfossiliferous and of lower Middle Cambrian Age.

Hudson Shale

Hudson Shale, which conformably overlies the Corby Limestone, is the formation name given to the top unit of the Negri Group. Beds of the formation are well exposed in the banks of Hudson Creek, a small creek flowing into White Mountain Creek from the western slope of White Mountain. As mentioned above, this unit was included in the "Mt. Elder Series" by Matheson and Teichert, but they noted that it was similar to some shales of the "Negri Series". In this Bulletin it is placed as the top unit of the Negri Group. It consists of about 650 feet of red and grey shales. At the top there is a rapid transition to the arenaceous facies of Elder Sandstone. This transition was examined in the banks of Hudson Creek, where the shale grades upwards into siltstone, and the siltstone into shaly sandstone with abundant mud-pellets and then into ripple-marked sandstone of the Elder Sandstone type. This transition is complete within 20 feet of section.

A similar transition was examined in the slopes of the western scarp of Ragged Range, where shale of the unit grades into the basal sandstone of the Ragged Range Conglomerate. The age of the Hudson Shale may be given as Middle Cambrian.

These eight formations have been named and mapped in the Hardman Basin, the largest remnant of Cambrian deposition. Many of them also occur in the other Cambrian basins. In Rosewood Basin, the basal cherty limestone, the equivalent of Headleys Limestone, can be easily traced on the edges of the basin, overlying Antrim Plateau Volcanics. In many places it forms the characteristic "wall" with dips ranging to vertical. This limestone is overlain by an unknown thickness of shale which is conformably overlain, on Boundary Hill, by a thin layer of cherty limestone equivalent to the Linnekar Limestone. In the small area of Cambrian sediments north of the Lissadell-Texas road crossing of the Bow River, differential erosion has exposed the steeply dipping basal limestone, which is overlain by poorly exposed shale.

The correlation of the Argyle Basin with the Hardman Basin is not yet clear. The basal limestone appears to be absent and, in this area, the Volcanics are overlain by a great thickness of chocolate shale which is overlain by a sequence of limestones and shales. At least three limestone formations provide marker-beds in this Basin, the second limestone being conspicuous because of the abundance of girvanellids and *Biconulites*. This horizon may be equivalent to the Shady Camp Limestone.

An interesting outcrop of reddish crystalline glauconitic limestone contains fragments of trilobites, brachiopods, and *Biconulites*, at the second creek-crossing on the road from Argyle to Wyndham, about two miles north-east of Argyle Homestead. This is probably one of the upper beds of the basin and is underlain by red and grey shales which overlie a grey cherty crystalline limestone.

At Argyle Homestead and near the aerodrome, a friable sandstone is poorly exposed. Matheson and Teichert have mapped this area as belonging to the "Mt. Elder Series". This may be so; but the sandstone may represent a slight facies-change in the Negri Group, and in this Bulletin they are not differentiated.

In the slopes of the western scarp of Ragged Range a small section of the Negri Group is exposed, lying between Antrim Plateau Volcanics and Ragged Range Conglomerate. The greatest thickness observed was 100 feet, which consists of 40 feet of chocolate shale, overlain by 40 feet of greenish-brown crystalline glauconitic limestone—similar to that described at the locality two miles north-east of Argyle Homestead and containing abundant *Biconulites* and some trilobite fragments—overlain by 20 feet of grey and chocolate shales, which, 20 feet above the limestone, grade into shaly fine sandstone, then to fine-grained reddish sandstone of the Elder Sandstone type.

The basal shale overlying the Antrim Plateau Volcanics contains a few volcanic pebbles.

In all observed contacts, sediments of Negri Group overlie Antrim Plateau Volcanics. However, photo-interpretation indicates, in such places as the northern edge of Argyle Basin, that Negri sediments may be in contact with older rocks of Precambrian age. The contact is soil covered; so there may be a thin sequence of Volcanics not exposed.

The Negri Group, particularly in the Hardman Basin, displays a rhythmic deposition of limestone and shale formations. Another interesting feature is the abundance of chert nodules at the base of each of the first three limestone formations. Wade (1924) published the following analysis, by J. C. Watson, of a limestone of the Negri Group collected from Bottle Creek Crossing on the Ord River.

SiO_2,	15.96%;	Loss on ignition (H_2O and Co_2),	33.86%;
Al_2O_3,	3.92%;	H_2O,	0.71%;
Fe_2O_3,	2.00%;	TiO_2,	strong trace;
FeO,	n.d.;	P_2O_5,	0.31%;
MgO,	1.68%;	MnO,	n.d. but present;
CaO,	41.68%;	Total,	99.74%;
Na_2O,	n.d.;	S.G.,	2.60%
K_2O,	n.d.;		

The structure of the major basins makes an interesting problem. The beds close to the edges of the basin are steeply dipping—in places vertical or even slightly overturned. Towards the centres of the basins, the beds flatten and for the most part are sub-horizontal. This structural feature is regarded as the reflection of movement and adjustment of the basement blocks in reaching equilibrium after the outpouring of the Antrim Plateau Volcanics.

Sedimentation of the Negri Group probably began at the end of the Lower Cambrian Epoch or the beginning of the Middle Cambrian Epoch and continued during Middle Cambrian. A detailed discussion on the age of the Negri Group will be published by Dr. Öpik.

Elder Sandstone

The name "Mt. Elder Series" was proposed by Mahony (in Hobson, 1936) and used by Matheson and Teichert (1948) for the shale and sandstone which overlie the fourth limestone unit of the Negri "Series" in the vicinity of Mt. Elder. This name is changed to Elder Sandstone to comply with Australian stratigraphical nomenclature and, as mentioned previously, the shale unit has been included as the top formation of the Negri Group, thus making the Elder Sandstone essentially an arenaceous unit, about 1,500 feet thick. The Elder Sandstone crops out in three areas, the largest being in the Hardman Basin, west of the Ord River, where sandstones of the formation form the Dixon Range, Mt. Buchanan, and Glass Hill. Between the Ord River and Mistake Creek Homestead, there is an extension of these outcrops, in which Mt. Elder is the most prominent feature. The third area, the Hardman Range, is an isolated fault-zone which trends south-east from Turner Homestead.

At Hudson Creek, on the western slopes of White Mountain, the basal beds of the formation are well exposed, dipping 28°N. Above the transition from the Hudson Shale are fine-grained sandstones containing abundant mud pellets. Higher in the sequence is brown micaceous shaly sandstone, exhibiting numerous shallow-water markings, and overlain by poorly cemented, well-sorted, medium-grained to fine-grained reddish sandstone, cross-bedded in places.

The Hardman Range outcrops are even-grained poorly cemented massive sandstone, with abundant quartz veins which provide a hard backbone to the otherwise easily erodable sediments. Matheson and Teichert (1948) mapped the sandstone of the Hardman Range as continuing across the basin to the Antrim Plateau Volcanics; but field mapping does not show any evidence for this continuation, and even the projected fault-line is not visible in the Headleys Limestone at the edge of the basin.

Wade (1924) described Glass Hill and Mt. Buchanan as large isolated masses of massive sandstone showing very pronounced current bedding. In all observed contacts the Elder Sandstone lies conformably above the Negri Group; but on the north-west side of the Hardman Basin the Elder

Sandstone appears to overlap on to the Antrim Plateau Volcanics. This may be a faulted overlap, as there is some evidence of faulting along that edge; or it could be caused by a slight variation of the Elder transgression. No fossils have been recorded from the Elder Sandstone, so an exact age cannot be given. However, as it is continuous in sedimentation with the fossiliferous Negri Group, at least the lower portion is Middle Cambrian in age, and it is suggested that all sedimentation took place in the Middle Cambrian Epoch. No satisfactory correlations can be made with the upper Middle Cambrian and Upper Cambrian sediments in the Carlton area. It is possible that part of the Elder Sandstone may be equivalent to the Hart Spring Sandstone, but the correlation is vague.

Ragged Range Conglomerate

The Ragged Range Conglomerate is the formation name for the conglomerate and sandstone that form Ragged or Conglomerate Range, which is situated a few miles east of Denham River Homestead.

Figure 19—Panorama of western scarp of Ragged Range

Blatchford (1928) examined this sandstone and conglomerate and was doubtful whether they were of Upper Proterozoic or Carboniferous age.

Matheson and Teichert (1948), from Blatchford's description of the lithology, equated the unit to the Permian conglomerate in the vicinity of Cockatoo Spring. Reeves (1948) visited the locality and discovered that the conglomerate and sandstone conformably overlie sandy shale in which there are thin beds of grey siliceous limestone containing the pteropod *Biconulites hardmani;* so he correlated the sandstone and conglomerate with the "Mt. Elder Series."

800 feet of sandstone and conglomerate, dipping gently east, are exposed in the western scarp of Ragged Range. They overlie the uneven

surface of the Antrim Plateau Volcanics, and, in the fossil valleys, they conformably overlie shales of the Negri Group.

The shale-sandstone boundary shows a rapid transition similar to that seen at White Mountain. The shale ranges upwards into siltstone, then to shaly fine-grained reddish sandstone which has abundant ripple marks and other shallow-water markings.

In the western scarp there are three main beds of conglomerate up to 100 feet thick, each with numerous lenses of sandstone. The conglomerate consists of poorly cemented well-rounded pebbles and boulders, ranging from two inches to two feet in diameter, which are mainly quartzite, although some are strongly weathered granite. No signs of glacial abrasion were observed on the pebble faces. The sandstones range from fine-

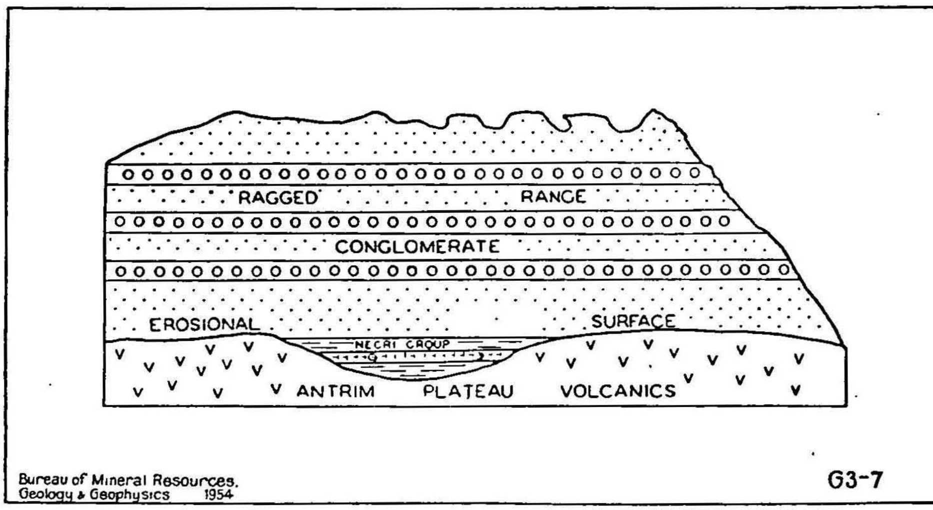


Figure 20—Diagrammatic Sketch of western scarp of Ragged Range

grained to coarse-grained with pebbles, and exhibit ripple-marking and cross-bedding.

Blatchford (1928) reports that the conglomerate rapidly thickens eastward and is 600 feet thick in Conglomerate Bluff.

No fossils have been found in the formation; but the rapid transition from shales of the Negri Group indicates a Middle Cambrian age. The Ragged Range Conglomerate is a local development of the Elder Sandstone, and is not to be correlated with the Upper Palaeozoic Conglomerate —to which it is lithologically rather similar—found at the base of the Upper Palaeozoic sequence in the Burt Range.

Carlton Group

Cambrian sediments crop out to the north-north-east and north-west of Carlton Homestead, and form the Onslow Hills. These sediments were not known until 1947, when Reeves (1948) discovered Cambrian fossiliferous limestone ten miles north-east of Carlton Station; Teichert identified the fossils as species of the genus *Solenoparia* and gave the age as Middle Cambrian. Reeves named these sediments the Carlton "Series" and described a section one mile south of the Ninbing track, 10 miles north-east of Carlton Homestead. This section contains sediments of Middle and Upper Cambrian and possibly Lower Ordovician.

More recent work shows that the sediments are strongly strike-faulted, so that, without detailed work, it is impossible to obtain a complete sequence. The strike faults, marked only by small quartz veins and some slickensides, are very hard to discern; but the displacement may be over 1,000 ft., and, within a few yards, the section may change from Middle Cambrian to Upper Cambrian or even Ordovician in age. From the outcrops examined, it appears that there was continuous sedimentation from Middle Cambrian to Lower Ordovician. Noakes et alia (1952) used the name "Carlton Formation" for the known Middle Cambrian and the probable Upper Cambrian sediments and remarked that this formation was apparently conformably overlain by the "Pander Sandstone" of Lower Ordovician age. The Pander Greensand is here included in the Carlton Group.

From remnants in the isolated fault blocks it is possible to divide the Carlton Group into five units: *Hart Spring Sandstone, Skewthorpe Formation, Pretlove Sandstone, Clark Sandstone,* and *Pander Greensand.* The sequence is determined on fossil evidence, and was proposed by A. A. Öpik. Because of the lack of time and the serious damage to and loss by fire of much of the fossil collections, no complete lists of fossils are available at present. The fossil names used are field determinations by A. A. Öpik. It is hoped that, in the next few field seasons, the fossil localities may be revisited and new collections adequately described, as the Carlton area affords a wealth of well-preserved fossils ranging from Middle Cambrian to Ordovician in age.

Hart Spring Sandstone

Hart Spring Sandstone is the formation name given to the sandstone with some impure limestone and shale, which crops out in the vicinity of Hart Spring on the western side of Onslow Hills. This formation is the oldest unit in the Carlton Group. At Hart Spring 500 feet of reddish fine-grained sandstone are exposed; they dip gently north-east at 7-12°.

The sandstone crops out in the sides of the valley which runs north-east from Hart Spring through Onslow Hills. About a mile along the valley, there is an outcrop of reddish sandstone which contains brachiopods. Farther on, at three miles and four miles from Hart Spring, the red sandstone is overlain by fossiliferous limestone and white friable calcareous sandstone of the Skewthorpe Formation. Numerous strike-faults prevented the measurement of a section in this area.

Hart Spring Sandstone is well exposed in the western scarp of Onslow Hills. At the north-western end, 230 feet of red fine-grained sandstone with some impure limestone are conformably overlain by more massive red fine-grained sandstone which dips north-east at 10°. Farther to the north-west, an area of Middle Cambrian sediments is partially surrounded by volcanics. Outcrops are restricted to isolated hills which expose 200 feet of fine-grained red sandstone with ripple marks, sun cracks, and mud

Figure 21—Hart Spring Sandstone at Hart Spring

pellets, and intercalated impure limestone beds. At one locality, near the eastern side of this area, a small knob exposes current-bedded ripple-marked sandstone dipping east at 15°, and 800 yards farther east an outcrop of 100 feet of impure grey crystalline limestone, with mud pellets, dips west at 50°. No fossils were found in this area; but these sediments have been included in Hart Spring Sandstone.

At fossil locality 35, seven miles north-east of Carlton, a low outcrop of 200 feet of red sandstone containing abundant *Hyolithes* overlies white sandstone containing brachiopods. These outcrops are placed in the Hart

Spring Sandstone. Separated from them by a strike fault to the east is a low ridge of oolitic limestone and friable white sandstone of Skewthorpe Formation.

The red sandstone and shale on the western side of Clark Jump-Up may also belong to Hart Spring Sandstone.

The fossils found in the formation are brachiopods which probably belong, or are closely related, to the genus *Billingsella,* and an undescribed *Hyolithes.* This fossil assemblage and the position of the formation —underlying the more fossiliferous Skewthorpe Formation—indicate that Hart Spring Sandstone belongs to the Middle Cambrian Epoch. It is not possible to correlate the formation with any part of the Negri Group or Elder Sandstone, although it may have its equivalent in part of the Elder Sandstone.

Skewthorpe Formation

Skewthorpe Formation is the name given to the sediments which crop out at Skewthorpe Ridge, a small ridge on the north-western side of the Legune Track, seven miles north-east of Carlton Homestead (Locality 13, Figure 22), where fossiliferous oolitic limestone and white friable sandstone dip north-east at 31°.

This unit contains limestone, shale, and sandstone, and is characterized by fossiliferous oolitic limestone. It was from sediments of this formation that Reeves (1948) collected the first Cambrian fossils in the Carlton area.

Another outcrop of the unit was examined at Locality 38, where 300 feet of sediments are exposed in an isolated broad bridge lying between two ridges of rocks of Pander Greensand. The sequence dips north-east at 28° and the lower portion consists of 90 feet of reddish-yellow thinly bedded micaceous sandstone, exhibiting the shallow-water features of mud pellets, ripple marks, and worm burrows. This is overlain by 200 feet of limestone, which is mainly fine grey crystalline limestone with some chert nodules, but which contains, in some horizons, sandy limestone and calcareous friable white sandstone. Oolitic limestone beds containing brachiopods are present in the upper portion.

One mile north of this outcrop, north of the Ordovician fossil locality 39, is a steep ridge with a prominent fault on the western side. East of the fault are exposed 20 feet of grey to green shale overlain by 100 feet of slabby, grey to cream, crystalline limestone overlain by red sandstone. This section is considered to be very near the top of Skewthorpe Formation and above the sediments which outcrop at Locality 38.

Four miles north-east of Hart Spring, 80 feet of sediments of the formation dip north-east at 13°. Grey oolitic limestone with trilobite fragments crops out at the base and is overlain by grey limestone and

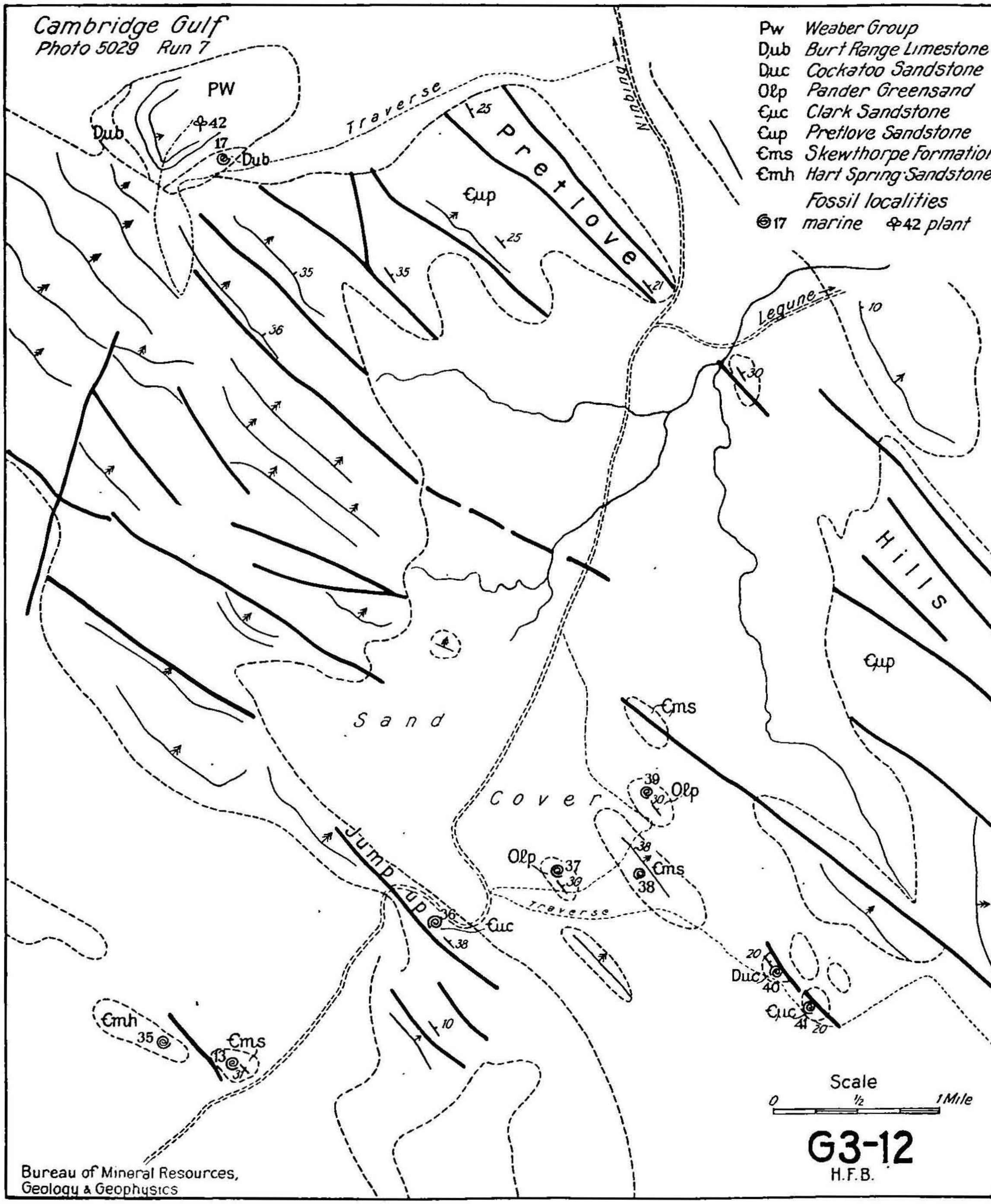


Figure 22—Sketch Map from Air-Photograph No. 5029, Run 7, Cambridge Gulf

calcareous sandstone, above which is medium to coarse sandstone with mud pellets, overlain by white friable calcareous sandstone and limestone containing abundant brachiopods.

All the localities mentioned above are either fault blocks or isolated ridges surrounded by sand cover, so that the complete sequence of the formation is not known. The total thickness is estimated at more than 600 feet. The Cambrian fauna collected from the formation includes the trilobites *Solenoparia* sp. nov., *Damesella* sp., and *Blackwelderia* sp., and the brachiopods *Acrotreta* sp., *Obolus* sp., and *Lingulella* sp. Teichert (in Reeves 1948) identified the genus *Solenoparia* and gave the age of the beds as Middle Cambrian. Öpik (1950) points out that the presence of *Damesella* and *Blackwelderia* indicates that the formation is high in the Middle Cambrian Epoch and that it may be taken as the top of Middle Cambrian.

It is thought that the Skewthorpe Formation is younger than any of the Cambrian formations that crop out in the southern portions of the Region.

Pretlove Sandstone

The formation name Pretlove Sandstone is given to the sandstone that crops out in the Pretlove Hills near the junction of the Ninbing and Legune tracks. The sequence in these hills has been interrupted by numerous faults, but at least 400 feet, and probably a much greater thickness, of reddish well-bedded sandstone are exposed.

The lithology of the westward continuation of these strike-faulted sandstones, south of the Devonian fossil locality 43, is mainly medium-grained to coarse-grained white sandstone with some silty yellowish sandstone. Although these sandstones have not proved fossiliferous, their age is thought to be lower Upper Cambrian. The fossiliferous sandstone, Locality 7, which crops out ½ mile north of Pander Ridge is included in the Pretlove Sandstone. At this locality, a low ridge of white to iron-stained friable sandstone, containing abundant trilobites and brachiopods, crops out. The trilobites belong to the genus *Crepicephalus* or a closely related genus, which indicates an age low in the Upper Cambrian Epoch. This horizon is regarded as being very near the bottom of the Pretlove Sandstone and is probably the lowest fossiliferous horizon.

In the hills 1½ miles north-east of Locality 7—a continuation of the Pretlove Hills—fine-grained to medium-grained felspathic sandstone and fine silty sandstone are exposed. No fossils were found, but these sediments are also thought to be part of the Pretlove Sandstone. No glauconite grains were seen in the sandstone of this formation, although in the younger units the percentage of glauconite increases until it reaches a maximum in the Pander Greensand of Lower Ordovician age.

No complete sequence or thickness is available for this formation. The age may be given as lower to middle Upper Cambrian.

Clark Sandstone

The formation name Clark Sandstone is assigned to the sandstone which crops out on the eastern side of the fault at Clark Jump-Up on the track from Carlton to Legune.

At this locality, No. 36, 430 feet of dark, greenish to reddish, glauconitic sandstone and friable red sandstone dip north-east at 38°. The base of this sequence is separated by a fault from red sandstone with abundant mud pellets. The top of the sequence disappears below the sand cover. This section is highly fossiliferous and contains trilobites of the dikelocephalid type and brachiopods.

At Locality 2, in the area of Upper Cambrian sediments that have probably been faulted up into the Devonian Cockatoo Sandstone, west of Ninbing, a low outcrop of highly ferruginous dark even medium-grained sandstone appears to be dipping gently to the west. This sandstone contains abundant trilobites, brachiopods, and gastropods, and may be equivalent to a part of the Clark Sandstone slightly older than the actual beds examined at Clark Jump-Up.

One mile farther west, at Locality 1, a large fault protects, and possibly strengthens, a hill of Cambrian sediments. The reddish to yellow (leached) sandstone exposed contains numerous trilobites and brachiopods. The trilobites are of the dikelocephalid type, and this outcrop is thought to be the same as the lower portion of the sequence examined at Clark Jump-Up. An outcrop probably belonging to the same horizon was examined on the western side of a hill at Locality 41 (Figure 22), where iron-indurated sandstone contains abundant trilobites and brachiopods. These beds dip east at 20° and are overlain by strike-faulted white friable sandstone.

The full section of the Clark Sandstone has not been obtained. The predominant trilobite of the dikelocephalid type indicates that the age of the formation is in the middle to upper portion of the Upper Cambrian Epoch.

ORDOVICIAN

General

Ordovician sediments were not known in Australia to the north or west of Amadeus Trough of Central Australia until the field season of 1949, when separate field parties discovered Ordovician outcrops in the East and West Kimberleys. W. C. Smith, working in the East Kimberleys, collected a specimen of glauconite sandstone in which Dr. Öpik recognised conodonts and other fragments of fossils which indicated an Ordovician age. This specimen came from a small unnamed ridge in the Carlton area which has since been named Pander Ridge. This is the type locality for the Pander Greensand. More detailed work has been done in this area and two other Ordovician outcrops have been discovered and examined.

Pander Greensand

Pander Greensand is the formation name given to the glauconite sandstone which forms Pander Ridge. This sandstone or greensand is composed of poorly cemented medium-sized grains of glauconite with numerous white, probably phosphatic, fragments of fossils. Some of the glauconite grains have broken down to iron oxides giving a red, green,

Figure 23—Pander Greensand at Pander Ridge

and white speckled appearance to the rock. In places where the glauconite is not altered to iron oxides, the rock has a dark green colour. In other places, well-rounded medium-sized iron-stained quartz grains form bands in the greensand.

At Pander Ridge, about 100 feet of glauconite sandstone are exposed, dipping 30° east. The Ridge is 30 feet high and extends along the strike for a quarter of a mile. It is bounded on the north, east, and south sides by faults. Ripple-marked worm-burrowed finely bedded sandstones of Cambrian age crop out east of the fault on the eastern side. At the southern end of the ridge a crystalline limestone is exposed. The age of this limestone is not certain; it may form lenses in the greensand or it may be another portion of the Lower Palaeozoic sediments faulted against the formation.

The glauconite sandstone contains fragments of brachiopods, trilobites, and conodonts. The most abundant brachiopod is *Lingulella*, and among the conodonts *Drepanodus* Pander and *Acontiodus* Pander have been identified.

A small unnamed ridge 10 miles north-east of Carlton Homestead (fossil locality 37) exposes 400 feet of Pander Greensand. The beds strike 50° west of north and dip north-east at angles ranging from 27° to 31°. Most beds show cross-bedding, worm tracks, and mud pellets. The section, calculated from the most common dip of 30°, is:

Top

45 feet	glauconite sandstone, weathered, crumbly, pinkish to greenish, medium-grained to coarse-grained, with abundant white specks of organic remains—fragments of trilobites;
36 feet	glauconite sandstone, weathered, friable, dark green, coarse, with white specks of organic remains;
36 feet	glauconite sandstone, greenish to reddish, coarse, friable;
36 feet	sandstone, coarse-grained, well rounded, red, with some glauconite and glauconitic sandstone;
12 feet	glauconitic sandstone, coarse-grained, greenish;
82 feet	sandstone, friable, coarse-grained, red, with trilobite and lingulellid fragments;
57 feet	glauconitic sandstone, crumbly, weathered;
33 feet	glauconitic sandstone, laminated, more firmly cemented, with trilobites and brachiopods;
64 feet	glauconitic sandstone, well cemented (probably calcareous), with bands of more friable glauconitic sandstone.

Total 401 feet.

This is the thickest section observed in Pander Greensand.

In a small ridge 11 miles north-east of Carlton Homestead, at Locality 39, 250 feet of crumbly dark green to reddish to pinkish glauconite sandstone containing trilobite and brachiopod fragments overlie a few feet of poorly exposed red sandstone. The section is thought to represent the top part of the above section, i.e., from the red sandstone upwards, and probably extends slightly above it. The beds in this ridge dip north-east at angles ranging from 28° to 34°. Current-bedding, worm tracks, and mud pellets were observed in many of the beds.

Owing to the isolation of these outcrops and the great complexity of

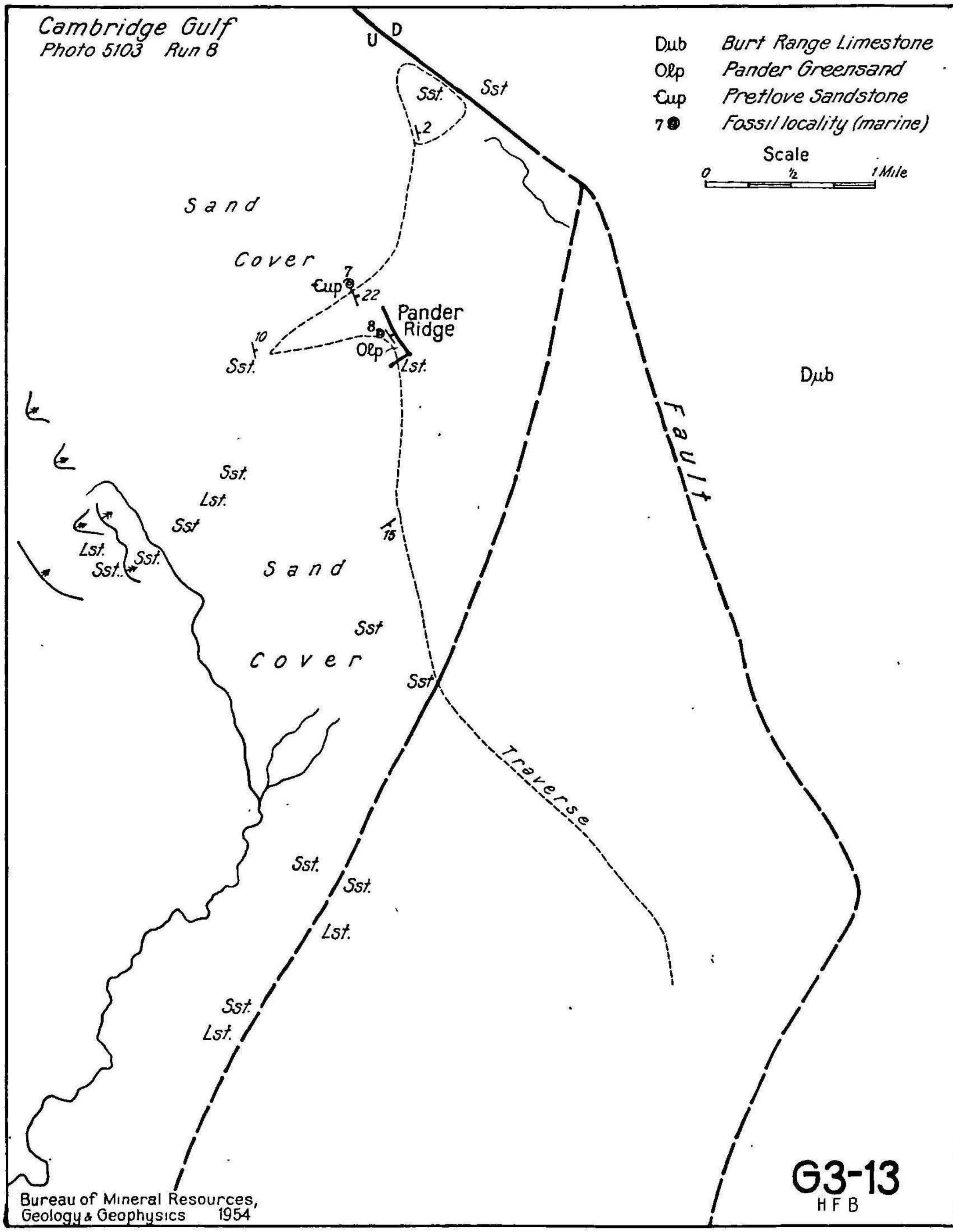


Figure 24—Sketch Map from Air-Photograph No. 5,103, Run 8, Cambridge Gulf

strike faulting throughout the area of the Carlton Basin, the complete sequence and dimensions of Pander Greensand have not been obtained. The thickness of the formation is at least 550 feet and may be much greater.

Öpik states that the lithology is identical with that of the Upper Tremadocian Baltic "Glauconite Sandstone" from which Ch. Pander, more than a century ago, discovered and described the first known assemblage of conodonts.

The conodonts, brachiopods, and trilobites indicate a Lower Ordovician age for the formation, and it may be correlated with part of the Ordovician sediments (Guppy and Öpik, 1950) found in the Fitzroy area of the West Kimberleys.

The Pander Greensand is the topmost formation in the Carlton Group and, as far as is known at present, was the final sedimentation in the Lower Palaeozoic marine transgression of the Carlton area.

DEVONIAN

General

There is no evidence of any sedimentation in the Bonaparte Gulf Basin between the Pander Greensand of Lower Ordovician age and the Cockatoo Sandstone of Upper Devonian age. A somewhat similar gap has been noted in the West Kimberleys, although sedimentation recommenced there in the Middle Devonian Epoch. No Silurian sediments have been recorded anywhere in north-western Australia.

It is interesting to note that Jack (1906) showed, on his map, a large area of Devonian rocks south of Wyndham, which actually included the Devonian sediments as known to-day: his evidence on which to base this age determination was meagre. Wade (1924) examined the Cockatoo Sandstone while making a hurried traverse through the area and commented on its similarity to the Elder Sandstone of Middle Cambrian age which he had examined in the Hardman Basin. It was not until 1941 that Forman collected the first fossils from this Palaeozoic basin at a locality 15 miles east of Ivanhoe Station. Teichert (1943) reported them to be of Devonian age. Matheson and Teichert (1948) mapped the south-western portion of the Burt Range and described two Upper Devonian units, the Cockatoo "Series" and the Burt Range "Series." These two names have been retained, but the rank has been altered to comply with present day nomenclature; the contents also have been slightly amended.

Cockatoo Sandstone

Matheson and Teichert (1948) gave the name Cockatoo "Series" to the "soft, cross-bedded sandstone with pebble beds" which crops out along the road five and a half miles north of Cockatoo Spring.

They reported that similar sandstone covers a considerable area "between Mt. Hensman in the south, and Martins Gap and the Pincombe Range in the North." This area in the Burt Range Basin forms the main outcrop of the Cockatoo Sandstone; other outcrops of similar sediments have been mapped and tentatively included in this formation. Underlying the Burt Range Limestone, west of Ninbing, is a large area of similar sediments; there is also an area farther west towards Cambridge

Figure 25—Cross Bedding in Cockatoo Sandstone, Cockatoo Sands

Gulf and possibly one to the north at Cape Domett. East of Dillon Springs two areas have been included in this unit.

On the Wyndham Road, north of Cockatoo Spring, the isolated knobs of this cross-bedded sandstone display the typical lithology. To the west are the basal beds of the formation, overlying a thin section of the Antrim Plateau Volcanics and dipping east at 30°. To the east, the Cockatoo Sandstone is conformably overlain by the Burt Range Limestone, which forms the first ridges of Burt Range.

Good exposures of the Cockatoo Sandstone were examined in the ridges between the Kimberley Research Station and Mt. Cecil. In this section the sandstone is medium-grained and poorly cemented, with some pebbles, and is sub-horizontal or dipping gently eastward.

At Mt. Cecil, the Devonian sandstone laps a faulted inlier of Precambrian sandstones. Matheson and Teichert (1948) described Mt. Cecil as an anticline in the Cockatoo Sandstone, but Reeves (1948) suggested a core of Precambrian sandstones. Present field work supports Reeves. Matheson and Teichert record the occurrence of *Lepidodendron (Leptophloeum) australe* (McCoy) in hardened silicified sandstone near the south-west corner of Mt. Cecil; this was the only fossil known to occur in the Cockatoo Sandstone until, in 1949, Öpik and Traves collected fossils from the soft reddish coarse-grained sandstone in the central southern slopes of Mt. Cecil.

J. M. Dickins, in a preliminary identification of these fossils, lists the occurrence of the following forms:

Mt. Cecil—southern end:
Paleoneilo cf. *P. maxima* (Conrad) 1841.
Modiomorpha sp.
Parallelodontidae gen. cf. *Leptodesma* sp.
cf. *Allerisma inflatum* Steininger.
Trigoniidae gen. et sp.

The contact of the Cockatoo Sandstone and Burt Range Limestone, between Mt. Cecil and Mt. Septimus, is sand-covered, but isolated beds of calcareous sandstone and sandy limestone were observed; the top of the Cockatoo Sandstone probably merges, therefore, into sediments of the Burt Range Limestone. Matheson and Teichert gave the thickness of the Cockatoo Sandstone in the Burt Range Basin as 4,000 feet, but Reeves points out that this calculation was made on the assumption that Mt. Cecil was an anticline. If Mt. Cecil is regarded as a faulted inlier, the formation is thinner, and Reeves estimated a maximum thickness of 3,000 feet for the unit.

The sandstone that crops out near Emu Creek, west of Ninbing, is similar in lithology, stratigraphical position, and fossil content to the Cockatoo Sandstone outcropping in the Burt Range Basin and the two sandstones may be included in the one unit.

Outcrops are very poor in the Emu Creek area, and only isolated hills which have been silicified and strengthened by fault zones are found. On the eastern side of the hills, at locality 3, the sandstone dips N.E. at 13°. It is a friable medium to coarse sandstone with mud pellets and some sub-rounded quartz pebbles. It is strongly jointed and cross-bedded, and the dip-slope, jointing, and friable nature of the sandstone have produced weird weathering forms. Slumping, probably to the east, suggests a deltaic origin for these sediments. A doubtful impression of a fish plate was examined.

On the western side of the hills, west of a fault, friable sandstones overlie a finer-grained flaggy sandstone which contains mud pellets and abundant fossils.

Dickins, in his preliminary identification, lists the following:

Cockatoo Sandstone—Locality 3:

Nucula? sp.

Modiomorpha sp.

Modiella? sp.

Leiopteria (cf. *L. conradi Hall* 1883).

Pelecypoda gen. ind.

Impressions of dermal plate of a fish.

West of Emu Creek, isolated hills contain sandstone of similar lithology. The sandstone dips north-east at 15-17° as far as the boundary of the faulted inlier of Upper Cambrian sediments. West of this inlier are more isolated faulted hills of white friable medium-grained sandstone, which, on lithological grounds, is included in the Cockatoo Sandstone. At one such hill examined, the sandstone dipped south-east at 20°.

In this northern area between Ninbing and Mt. Connection, the Cambrian sandstone is predominantly red, and ranges from yellow to red in colour, whereas the Devonian sandstone is mainly white and ranges from white to yellow. Also the Devonian sandstone is probably more pure and friable because it forms a very loose sand cover, difficult to traverse by vehicle. This is well illustrated in the Burt Range Basin by the notorious Cockatoo Sands on the Argyle-Wyndham road.

From photo-interpretation, a small area of Cockatoo Sandstone has been mapped to the east of Cape Domett, at Shakespeare Hill.

A section which may be correlable with Cockatoo Sandstone was examined in the faulted basin, east of Dillon Springs—Locality 9.

The section into the basin is:

Bottom

1,300 feet	sandstone, reddish, medium to coarse, well-bedded felspathic, with some bands of grit and pinkish coarse felspathic sandstone containing fossils;
200 feet	sandstone, reddish, felspathic, with some fine-grained flaggy sandstone;
300 feet	limestone, dense, well-bedded, fine-grained, crystalline, and calcareous sandstone;
400 feet	sandstone, light-coloured, well-jointed, cross-bedded;
300 feet	sandstone, medium to coarse, red, with mud pellets and ripple marks.

Top

Total 2,500 feet.

Dickins in his preliminary identification of the fossils lists the following:

Cockatoo Sandstone—Locality 9.

Parallelodontidae gen. cf. *Leptodesma* sp.

Öpik (pers. comm.) doubts the validity of this correlation: it may be generally correlable in terms of age, but the possibility that it is Lower Devonian, even Silurian, in age must not be ignored.

North of the junction of Card Creek and the Denham River are exposed 40 feet of fine-grained dense crystalline limestone, overlain by 100 feet of felspathic fine to coarse sandstone and grit which display abundant shallow-water features such as ripple marks, swash marks, and mud cracks. This section is similar to part of that listed above, i.e., the section north-east of Dillon Springs—Locality 9.

Seven miles south-west of Ivanhoe Homestead a small fault block of Palaeozoic sediments is downfaulted into Precambrian sandstones. The sediments are friable brown sandstone overlying a crystalline limestone. No fossils were found in this isolated outcrop; it may, doubtfully, be referred to the Cockatoo Sandstone.

From the position of the Cockatoo Sandstone in the general stratigraphical sequence, that is, conformably overlain by the highly fossiliferous Burt Range Limestone, an Upper Devonian age is indicated for the formation.

Dickins noted that the closest affinities of the faunas at Locality 3 and Mt. Cecil are with forms of upper Middle Devonian age; but the fauna could be Middle to Upper Devonian in age. The species mentioned above (cf. *Leptodesma* sp.) is almost certainly common to Mt. Cecil and Locality 9; probably this same species occurs in the Devonian of the Carnarvon Basin.

Two interesting localities of Devonian fossils were discovered in the highly faulted Cambrian and Ordovician sediments in the Carlton Basin. In 1949, W. C. Smith collected a piece of brown crystalline limestone, which contained abundant spirifers, in a scree slope in the Onslow Hills. The bed from which this specimen came could not be found.

In 1952, similar spirifers were found in a small isolated fault block at Locality 40 (Figure 22). At this locality a small ridge about 30 feet high exposes 50 feet of crystalline limestone and marl which contains one very thin fossiliferous band, from which were collected numerous spirifers. These have not yet been thoroughly examined, but Dr. Öpik considers them to be older than the Burt Range Limestone and probably within the Cockatoo "Series" of Matheson and Teichert.

On the eastern side of this Devonian outcrop is a large fault, and to the east of the fault are outcrops of Cambrian sandstone. It is thought that there are at least two, and probably more, small downfaulted blocks of Devonian sediments in this area, and until further investigation is done, the two blocks have been tentatively included in the Cockatoo Sandstone.

Burt Range Limestone

The name Burt Range "Series" was used by Matheson and Teichert (1948) for the limestone with intercalated shale and sandstone, overlain by 1,000 feet of sandstone, which is exposed in an extensive area west of the Burt Range. In this Bulletin, the Burt Range Limestone is used as a formation name for the limestone with intercalated shale and sandstone. The overlying sandstone has been separated to form the Enga Sandstone. The base of the Burt Range Limestone is accepted as that chosen by Matheson and Teichert: "the limestone bed which outcrops about a quarter to half a mile east of Eight Mile Creek and whose northern continuation was found two miles south-east of the eastern end of Martin's Gap".

The top of the formation is defined as being at the top of the poorly-bedded brown calcareous sandstone and sandy limestone, where there is a rapid transition to well-bedded well-jointed white to reddish sandstone of the Enga Sandstone. This contact is well-exposed in the scarp eight miles north-north-east of Cockatoo Spring.

Matheson and Teichert described the sediments of the Burt Range "Series" from two separate localities, the Burt Range Basin and the Ivanhoe Graben. It now appears that the Ivanhoe Graben is the southern extension of the Upper Devonian fossiliferous limestone which crops out in a long narrow strip from the coast, through Ninbing and south to the Ord River, and which is included in the Burt Range Limestone.

Sediments of the Burt Range Limestone that crop out in the Burt Range Basin have been described by Matheson and Teichert. The lithology is essentially limestone with some beds of calcareous sandstone and shale. The limestone beds were examined in isolated strike ridges between Mt. Cecil and Mt. Septimus where the beds dip gently east at 5° to 10°. The limestone is highly fossiliferous, but no systematic collections were made from the sequence. The isolated collections of fossils that were made confirm the results obtained by Matheson and Teichert.

The collection from the limestone ridge five miles west of Mt. Septimus (Locality 32) contain the following forms, identified by Dr. Öpik:

Syringopora sp.
Productella sp.
Athyris sp.
Schuchertella sp.

and gastropods:

Bellerophon	*Ceraunochilis*
Euomphalus	*Murchisonia*
Straparolus	*Trochonema*
Platyschisma	*Eunema*
Naticopsis	*Meekospira*

This list is not complete; the collection contains other gastropods which have not yet been determined.

A second collection, from the uppermost limestone bed exposed at Locality 31, 3.7 miles west of Mt. Septimus, yielded the following:

Leptaena cf. analoga
Fenestrellina sp.
Camarotoechia cf. *pleurodon*
Naticopsis sp.

and Ostracoda.

Dr. Öpik remarked on the similarity of this fauna to that collected from the Septimus Limestone, which confirms the suggestion of continuous sedimentation from Upper Devonian to Lower Carboniferous.

The area between this upper limestone bed and the limestone outcrops at the base of Mt. Septimus is covered with sand; so no outcrops of Enga Sandstone were examined in this section.

The upper portion of the Burt Range Limestone and its contact with Enga Sandstone were examined in the scarp eight miles north-north-east of Cockatoo Spring (Figure 27).

The following section was exposed, with the beds dipping north-east at 12°:

65 feet	sandstone, well-bedded, well-jointed, friable to silicified, of Enga Sandstone white to reddish, with abundant worm tracks and, in places, lamellibranchs and gastropods;
80 feet	calcareous sandstone and sandy limestone, grey to brown, poorly bedded, and containing few fossil horizons of crinoid stems;
30 feet	crystalline limestone and shaly limestone, thinly bedded, grey, with abundant brachiopods, gastropods, and crinoid stems;
75 feet	limestone, grey, sandy and friable calcareous sandstone containing few fossils.

The top of the grey to brown calcareous sandstone of the Burt Range Limestone grades rapidly into the well-bedded fossiliferous sandstone of Enga Sandstone.

Sediments of Burt Range Limestone were also examined in the north-pitching anticline in the centre of the Burt Range (Locality 23), where 200 feet of highly fossiliferous grey limestone and sandy limestone underlie Enga Sandstone. The fauna from this locality has not yet been studied.

The occurrence of the Burt Range Limestone at Buttons Crossing of the Ord River has been described by Matheson and Teichert (1948) under the heading of "Ivanhoe Graben"; as already mentioned, it is suggested that this is the southern extension of the long tongue of Devonian sediments which crops out from the coast, through Ninbing, and south to the Ord River. The beds that crop out at Buttons Crossing belong to the lower portion of the Burt Range Limestone and overlie beds of the Cockatoo Sandstone.

Both biohermal and biostromal limestones are found in this locality.

Dr. Öpik has identified the following fossils:

Several genera of ostracods.

Brachiopods:

Productella
Meristella
Chonetes

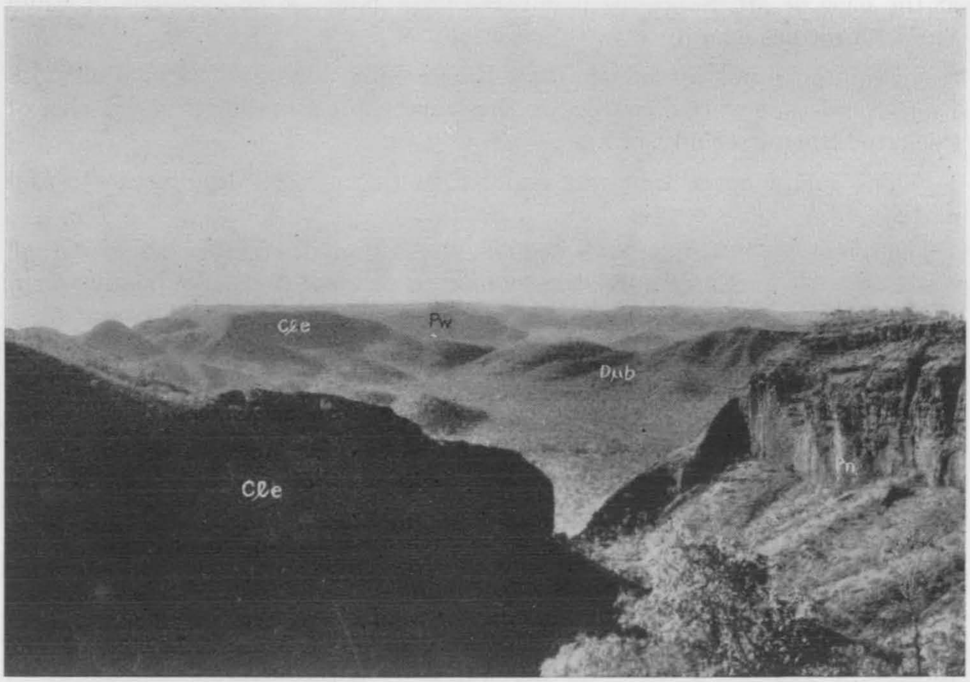


Figure 26—Panorama of Central Burt Range

Gastropods:

Straparolus
Trochonema
Murchisonia

A species of rugose corals.

Syringopora

Stromatoporoids and calcareous algae.

He remarks that *Chonetes* has been recorded previously from higher horizons in the Burt Range Limestone, but that this appears to be the first record of *Chonetes* in the Button Crossing outcrops.

The fauna bears a marked similarity to that mentioned previously from 5 miles west of Mt. Septimus.

North and east of the Ninbing turn-off, on the track from Carlton to Legune, there are numerous hummocks of fossiliferous grey crystalline limestone of the Burt Range Limestone. A slightly reworked biohermal dolomitic limestone crops out on the Legune track, five miles east of the Ninbing turn-off; the fauna includes *Spirifer, Productella, Athyris, Atrypa,* stromatoporoids, and ostracods.

South of Ninbing are large masses of biohermal limestone, with fossiliferous biostromal limestone dipping away from the bioherms. Crinoid stems, brachiopods, and stromatoporoids are abundant in the grey crystalline biostromal limestones. A similar lithological type was observed between Ninbing and Surprise Creek. West of Surprise Creek, outcrops of yellowish-grey limestone and calcareous sandstone dip east at 10°-15°; no fossils were found in these outcrops. These beds are in the lower portion of the Burt Range Limestone.

No accurate measurements of thickness of the Burt Range Limestone have been made: Matheson and Teichert (1948) estimated the thickness as 4,000 ft.

The Burt Range Limestone conformably overlies the Cockatoo Sandstone and in the Burt Range Basin is conformably overlain by the Enga Sandstone. East of Ninbing, the Burt Range Limestone is overlain by the Weaber Group with little apparent unconformity, although in the Burt Range Basin it is known that an orogeny occurred during Middle or Upper Carboniferous time.

The fossil content of the formation indicates an Upper Devonian age, and the top of the unit is thought to coincide with the end of the Devonian Period.

Teichert correlates the Burt Range Limestone with his stages IV, V, and VI of the Upper Devonian sediments in the West Kimberleys.

Carboniferous.

Enga Sandstone (Snowie Sandstone)

Matheson and Teichert (1948) included in their Burt Range "Series" a unit of sandstone which they thought was a shallow-water deposit that represented the last stage in Devonian sedimentation. This sandstone unit, which outcrops in Enga Ridge, the western ridge of Burt Range, is given the formation name Enga Sandstone. The formation does not crop out in the Carlton area, where Upper Devonian Burt Range Limestone is overlain by Permian sediments of the Weaber Group. The formation is essentially arenaceous and ranges from fine to coarse sandstone. The name Snowie Sandstone was given to the unit (Traves 1949) and subsequently used by Noakes et alia (1952) and Fairbridge (1953). However, the proposed topographical name Snowie Ridge was finally rejected by the Lands and Survey Department, W.A., and the name Enga Ridge substituted, so that the formation name Snowie Sandstone becomes invalid.

The basal beds of Enga Sandstone, conformably overlying Burt Range Limestone; were examined in the scarp 8 miles north-north-east of Cockatoo Spring (Figure 26). Towards the top of the scarp are exposed 65 feet of well-jointed even medium-grained sandstone, friable to silicified, white to reddish in colour, with abundant worm tracks, some mud pellets, and in some beds numerous poorly preserved fossils. The sandstone dips basinwards—north-east—at 12° to 20°, and shows minor faulting and slight folding. Dickins in his preliminary identification of the fossils from this locality, lists the following:

Cardiopsis? sp.
Pelecypoda gen. ind.
Bellerophontidae gen. ind.
Pleurotomariidae gen. ind.

He remarks that *Cardiopsis* is recorded only from beds of Carboniferous age, so that, if this genus is actually present, a Carboniferous age would be indicated; but somewhat similar forms occur in the Upper Devonian Epoch.

The contact of the formation with the overlying Septimus Limestone has not been observed because, west of Mt. Septimus, sand obscures the junction.

The complete sequence of the formation is not known, but the approximate thickness is 1,000 feet.

Öpik (1950) first queried the Upper Devonian age assigned to the formation by Matheson and Teichert (1948). After an examination of fossils collected from the Burt Range Limestone and Septimus Limestone he stated that the Devonian fossils of Burt Range Limestone indicate an age at the top of the Devonian Period, whereas an age slightly younger than the bottom of Lower Carboniferous is indicated for Septimus Limestone. Thus, as Enga Sandstone lies conformably between these two formations, it probably represents the first sedimentation in the Carboniferous Period rather than the close of sedimentation in the Devonian Period.

The recent studies by Dickins of fossils from Enga Sandstone indicate that if *Cardiopsis* is actually present, the sediments are correctly assigned to the Lower Carboniferous.

Septimus Limestone

Limestones containing a Carboniferous fauna were first discovered in Burt Range by Matheson and Teichert (1948). Reeves (1948) examined similar limestones at Mt. Septimus and gave the unit the name of Mt.

Septimus "Series". Noakes et alia (1952) used the preliminary name Mt. Septimus Limestone (Traves 1949). The revised formation name, Septimus Limestone, is used for the limestone and calcareous sandstone which outcrop on the slopes of Mt. Septimus; included in this unit are the Carboniferous exposures of limestone which were examined by Matheson and Teichert in central Burt Range.

The formation crops out on the slopes of Mt. Septimus and the western slopes of Central Burt Range. Small outcrops of Septimus limestone were also found near Milligans Lagoon; it has not been found in the Carlton area of Palaeozoic sediments.

The following section is exposed in the western slopes of Mt. Septimus and was measured by W. C. Smith:

Weaber Group	280 feet	gritty dark brown sandstone with some conglomerate;
	6 feet	obscured;
	....	
90 feet	crinoidal limestone, massive, with numerous fossils—crinoid stems, *Athyris*, *Rhipidomella*, a spiriferid (No. 3), and a productid at the top, and earthy bands near the base;	
20 feet	calcareous sandstone with thin crinoidal bands;	
5 feet	crinoidal limestone;	
60 feet	calcareous sandstone, current-bedded, with thin crinoidal bands at the top;	
20 feet	calcareous sandstone with thin crinoidal bands;	
20 feet	sandy limestone with *Athyris*, spiriferids (Nos. 2 and 3), crinoid stems, *Camarotoechia* and productids;	
50 feet	crinoidal limestone, bedded, with some brachiopods;	
15 feet	limestone, thinly bedded, with *Athyris*, spiriferids (Nos. 1 and 2), *Leptaena*, *Rhipidomella*, crinoid stems, *Euomphalus*, and tabulate corals;	
30 feet	crinoidal limestone with a rich *Camarotoechia* band at the top;	
45 feet	granular limestone, bedded with brachiopod and crinoidal fossil fragments.	

Total 355 feet of Septimus Limestone.

The base of Septimus Limestone at Mt. Septimus is obscured by sand. An interesting feature in the lithology at Mt. Septimus is that most of the limestones contain quartz grains. The limestone and sandstone exhibit current bedding and ripple marks which illustrate the shallow-water marine environment under which these sediments were deposited. Öpik (1950) has recognized more than 25 genera from the fossil collection made at Mt. Septimus. He lists the following: *Syringopora*, *Michelinia*, a solitary

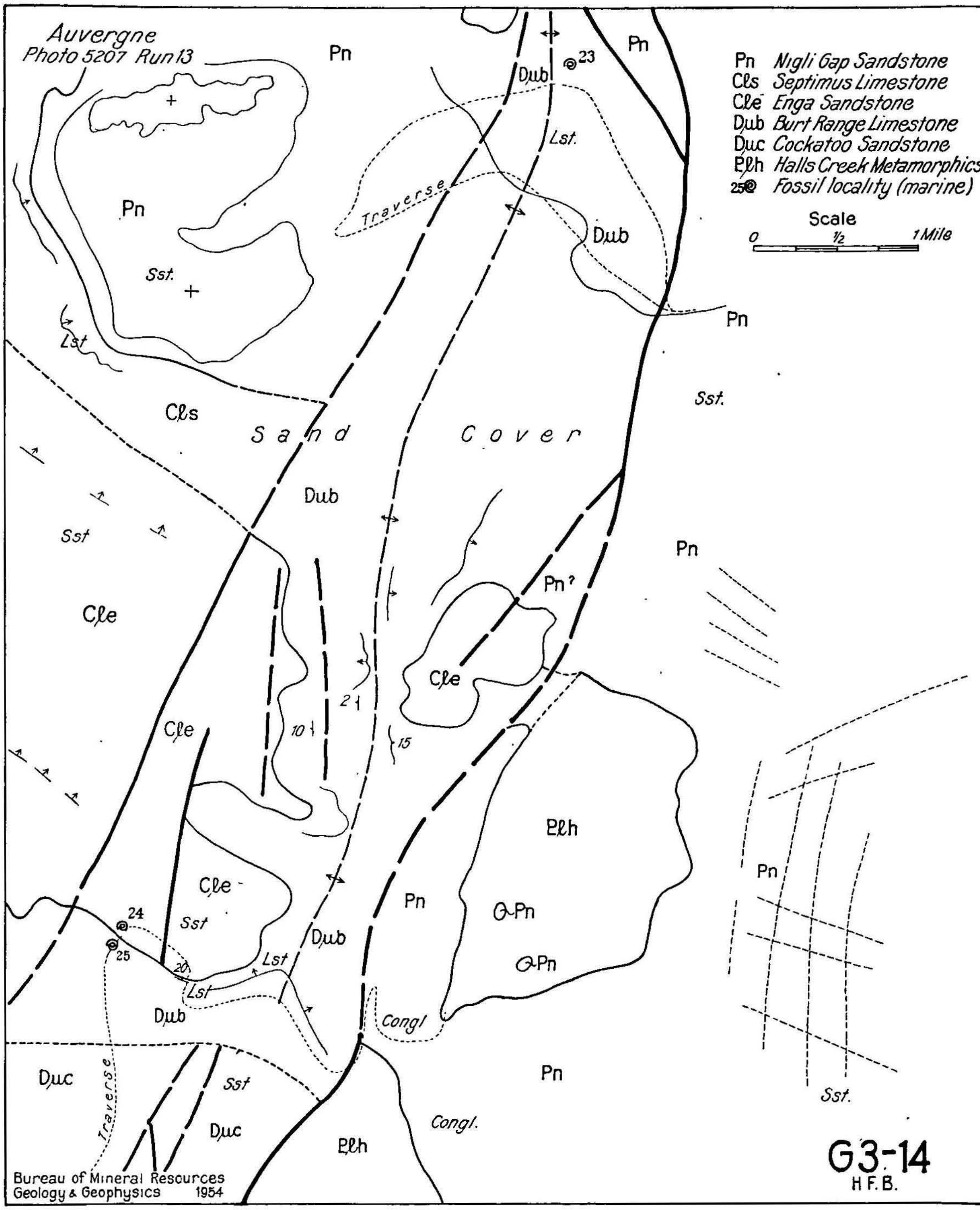


Figure 27—Sketch Map of Air-Photograph No. 5,207, Run 13, Auvergne

rugose coral, crinoids, *Fenestrellina, Chaetetes,* Trepostomata, *Rhipidomella* cf. *australis* (McCoy), *Leptaena analoga* Phillips, *Productus (Marginirugus)* sp. nov., four genera of spiriferids—including *Spirifer* s.s., *Tylothyris* and perhaps a new genus—, *Reticularia, Athyris, Composita, Camarotoechia* aff. *pleurodon* (Phillips) *Euomphalus, Orthonychia,* fragments of trilobites, and three genera of ostracods. He remarked that the lower portion of the formation is rich in *Camarotoechia,* spiriferids, and productids, and the upper portion is characterized by the abundance of *Rhipidomella* and *Composita.* The presence of *Leptaena analoga* Phillips indicates a definite Lower Carboniferous age and the presence of *Productus (Marginirugus),* according to Sutton (1938), indicates an age at the top of the lower half of the Mississippian, i.e., Lower Carboniferous.

Öpik summarized the position of Septimus Limestone and Enga Sandstone in the following table (slightly adopted from Noakes et al. (1952)).

General Time Unit	Formation in Mississippi Valley (Sutton, 1938)		Burt Range
	11. U. Chester		
	10. M. Chester		
Mississippian	9. L. Chester		
	8. St. Genevieve		
(Lower Carboniferous)	7. St. Louis		
	6. Salem		
	5. Warsaw	*Marginirugus*	Septimus
	4. Keokuk		Limestone
	3. Burlington		
	2. Fern Glen		Enga
	1. Kinderhook		Sandstone

Matheson and Teichert described 350 feet of fossiliferous limestone at a locality $2\frac{1}{4}$-$2\frac{1}{2}$ miles east of Trig. Station HJ 15, and list a similar faunal assemblage. As at Mt. Septimus, the junction of this formation with Enga Sandstone is obscured, but the two formations are believed to be conformable. At both localities, the Septimus Limestone is unconformably overlain by sediments of the Weaber Group, although the apparent unconformity is very slight. The thickness of the formation may be given as 350 feet plus the obscured basal portion; the age is Lower Carboniferous. Septimus Limestone is the last recorded unit of sedimentation in the Middle Palaeozoic epicontinental marine sea.

PERMIAN

General

Sediments of Permian age in the Ord-Victoria Region were first examined in the very early days of Australian history. Commander Stokes, during the voyage of H.M.S. **Beagle** in 1837-1843, named Fossil

Summit, a prominent hill near the coast on the northern side of Joseph Bonaparte Gulf, where sediments of the Port Keats Group crop out. This locality was examined by H. Y. L. Brown (1895), who made collections of fossils which were studied by Etheridge (in Brown 1895); as a result of this study a Carboniferous age was allocated to sediments in this area. This age-determination was followed by a drilling programme in search of coal, and Brown (1905) lists the sequence obtained in four bores in the Port Keats area. He also mentions other fossil localities which he examined between Fossil Summit and Cape Ford. No economic coal

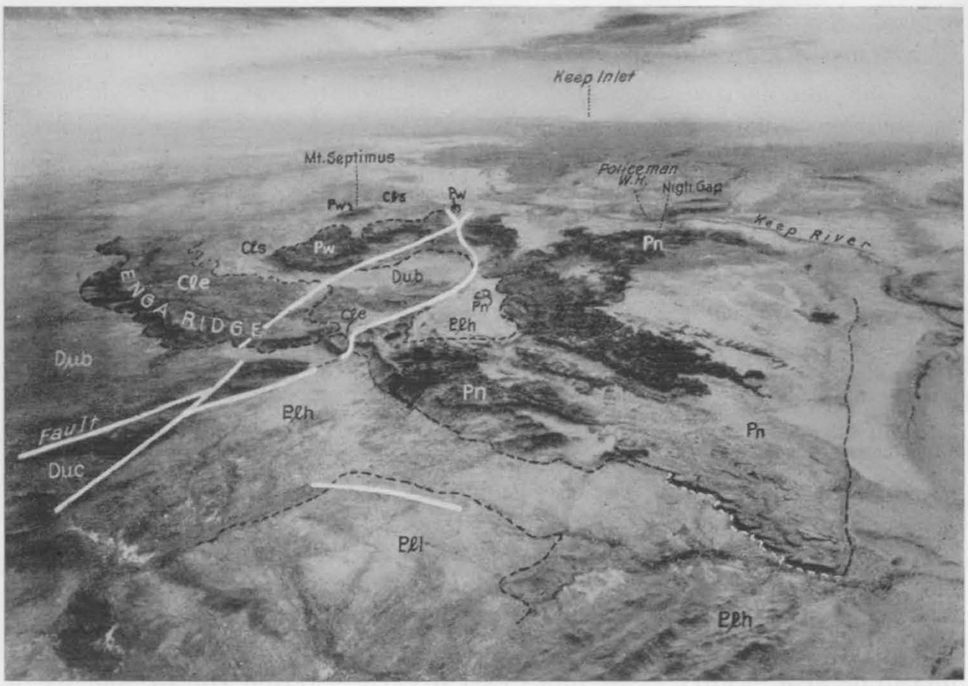


Figure 28—Oblique Air Photograph, Burt Range

seams were found and the advance of geological knowledge in this area stagnated for nearly half a century.

In 1946, Noakes (1949) examined Permian sediments in the vicinity of Mt. Greenwood and formally named these sediments the Port Keats Group. In the meantime, Matheson and Teichert (1948), working in the southern portion of the Burt Range, mapped a number of areas as Permian and named them the "Mt. Brooking Series."

Reeves (1948) discovered the Permian sediments in the Weaber Range and named them "Weaber Range Series", and obtained many sections in the Port Keats area. He regarded the "Mt. Brooking Series" as

Precambrian; present field work indicates that it is part of the Victoria River Group of Upper Proterozoic age.

In this Bulletin, Reeves' "Weaber Range Series" is renamed the Weaber Group; it has been divided into a number of formations. It was not possible to traverse into Port Keats; so the Port Keats Group is mapped and described from available previous literature and air-photo interpretation.

Sediments of the Weaber Group, 8 miles north-north-east of Cockatoo Spring (Figure 27) have been faulted down so that they are now in contact with Cockatoo Sandstone, Burt Range Limestone, and Enga Sandstone, and they unconformably overlie rocks of Precambrian age; so, even though there is no great apparent unconformity where they overlie Septimus Limestone at Mt. Septimus, there was an orogeny in the interval between the end of deposition of the Septimus Limestone and the beginning of deposition of the Weaber Group. Thus the distribution of Weaber Group in no way reflects the distribution of Upper Devonian and Lower Carboniferous sediments: this is an important fact when the oil potentialities of the area are being assessed. Granite is recorded in the bore log of one bore in the northern part of the area underlain by Port Keats Group; so, at least in this locality, the Port Keats Group also directly overlies Precambrian rocks.

An interesting discovery is the presence of Permian volcanics in Nigli Gap Sandstone of the Weaber Group; this is the first record of post-Cambrian volcanic activity in the Northern Territory—though post-Triassic volcanic plugs are known in the West Kimberleys.

It is not possible yet to correlate any parts of the Port Keats and Weaber Groups; faunal assemblages so far collected are completely different. It is thought that the Port Keats Group is younger than the Weaber Group; in fact, part of the latter Group may belong to the Upper Carboniferous Epoch.

Weaber Group

Reeves (1948) gave the name "Weaber Range Series" to the sandstone and sandy shale that crop out in Weaber Range, south-east of Ninbing. This name is revised to Weaber Group to comply with the Australian code of stratigraphical nomenclature; and the limits of the Group may be defined as the conglomerate member of the rafted pebble sandstone of Nigli Gap Sandstone and the highest bed in Point Spring Sandstone.

Outcrops of sediments of this Group cover a roughly triangular area with the apex at the south-eastern end of Burt Range and the base extending from north of Ninbing to Legune. To the north the unit passes beneath Quarternary alluvium.

In the area between Ninbing and Legune which Reeves examined in 1947 and the writer in 1949, a number of isolated outcrops are difficult to correlate. Because of this, the isolated fossiliferous outcrops were given temporary names (Traves, 1949; Öpik, 1950) such as Point Spring Sandstone, Sandy Creek Limestone and Flapper Hill Sandstone.

On the eastern and north-eastern sides of Burt Range, good outcrops of Weaber Group sediments elucidate the sequence. Hence new formation names have been added; the tentative name Sandy Creek Limestone has been discarded and in the future the name Flapper Hill Sandstone may also be unnecessary.

The Weaber Group is now divided into four formations. They are: *Nigli Gap Sandstone, Spirit Hill Limestone, Point Spring Sandstone,* and *Flapper Hill Sandstone.* The first three formations are regarded as the complete sequence of Weaber Group. The fourth formation, the isolated fossiliferous sandstone of Flapper Hill, belongs to Weaber Group, but its position in the sequence is not known.

Nigli Gap Sandstone

Nigli Gap Sandstone is the formation name proposed for the sandstone that crops out in Nigli Gap, which is situated less than a mile south of the south-eastern end of Policeman Waterhole on the Keep River. Sediments of Nigli Gap Sandstone form most of the southern and eastern portion of Burt Range. The sediments are essentially arenaceous, and most of the formation is of sandstone with numerous rafted pebbles. The unit also includes conglomerate members throughout the sequence, although the most significant conglomerate member occurs at the base. The marginal development of this member in the south-west, that is, north-east of Cockatoo Spring, attains a thickness of 1,000 feet of unsorted conglomerate, although the more common development throughout the basin is expressed by a number of conglomerate beds in the basal sandstone.

An isolated outcrop of the marginal basal conglomerate was examined in a rugged hill about a mile north-east of Cockatoo Spring. At this locality, 500 to 1,000 feet of conglomerate dip south-west at 20°, and unconformably overlie Precambrian metamorphics and granites except on the western side, which is bounded by the Cockatoo Fault. The conglomerate is poorly sorted, with sub-rounded pebbles and boulders ranging up to 2 feet in diameter, with an average diameter of 4 inches to 6 inches. Most of the pebbles and boulders are of quartzite, some showing quartz veins and others exhibiting the mud-pellet facies typical of sandstones of the Victoria River Group; there are also smaller, well-rounded, pebbles and boulders of a much weathered igneous rock which appears to have been porphyry, and a few quartz and slate pebbles. The conglomerate contains some lenses of grit and massive or current-bedded brown sandstone up to 1 foot thick. From its lithology and geographical position, this conglomerate is regarded as an isolated remnant of the conglomerate which crops out in the scarp a few miles to the north and forms the southern portion of Burt Range. This latter conglomerate was examined 8 miles north-north-east of Cockatoo Spring (Figure 27), where 1,000 feet of conglomerate with sandstone members unconformably overlies Pre-cambrian rocks and is faulted against the Middle Palaeozoic sequence of Burt Range. This conglomerate is very similar to that already described, although it contains larger boulders, with the quartzite boulders ranging up to 2 feet in diameter and the igneous boulders more plentiful and

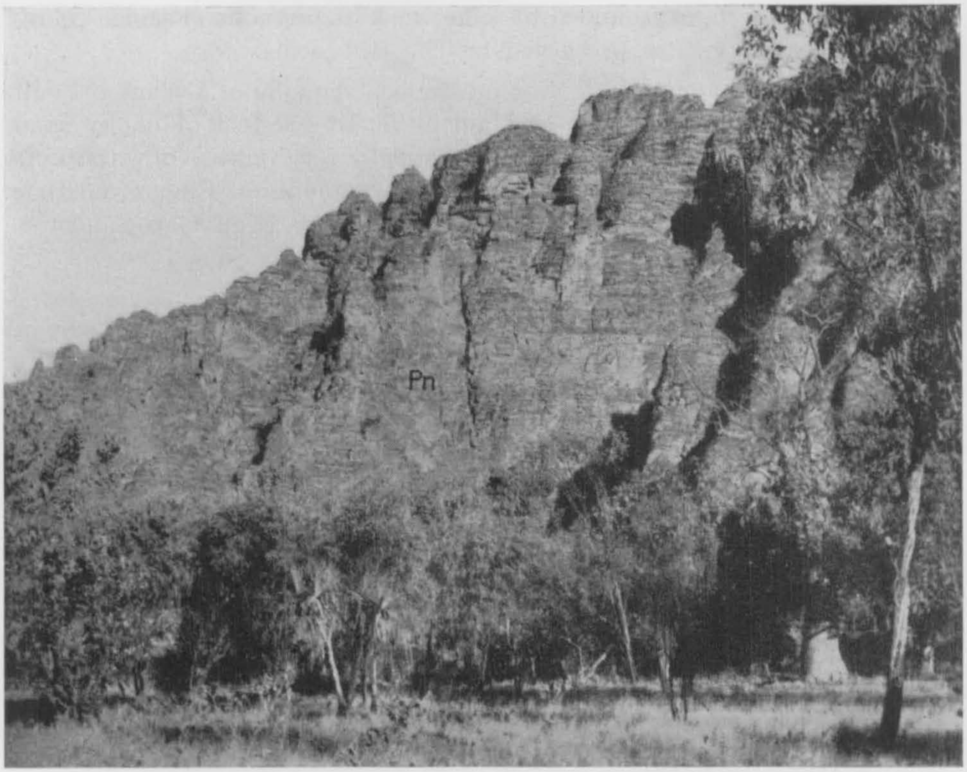


Figure 29—Nigli Gap Sandstone at Nigli Gap

ranging up to 1 foot in diameter. The conglomerate contains numerous lenses of sandstone, grit, and fine conglomerate, which are about a foot thick and may extend 20 yards or more. In this area, 20 feet of sandstone overlie the main conglomerate member.

The poorly bedded, unsorted nature of these conglomerates suggests a glacial origin, although no evidence of glacial abrasion on faces of the boulders was observed. Farther south, at the southernmost exposure of sediments of Weaber Group, the conglomerates are represented by bands

30 feet thick in the basal sandstone which unconformably overlies rocks of Lower Proterozoic age.

In Nigli Gap, 500 feet of rafted-pebble sandstone with thin beds of pebble conglomerate and flaggy sandstone dip very gently to the east and overlap on to a ridge of sheared conglomerate of indefinite age—probably Precambrian.

Specimens of *Equisetales* stems were examined in the rafted-pebble sandstone at Locality 26 in Nigli Gap. Some beds are current-bedded, and weathering in this jointed, easily erodable sandstone has produced pillars up to 200 feet high, surrounded by a network of tortuous chasms. Many aboriginal paintings are preserved on the cliff walls.

Farther west along Nigli Gap, on the eastern side of Cockatoo Fault, the rafted-pebble sandstone is overlain by 50 to 100 feet of flaggy sandstone. At Cockatoo Fault, Nigli Gap Sandstone is faulted down against Burt Range Limestone, which is overlain by remnants of Enga Sandstone. The fault at this locality dips steeply westward. Nigli Gap Sandstone on the eastern side is sub-horizontal and Enga Sandstone on the western side dips east into the fault at 10°.

Associated with the rafted-pebble sandstone at the eastern end of Nigli Gap is an old volcanic vent of vesicular and scoriaceous trachyte which has apparently been injected along an old fault line (R6030-R6043). The vent was probably of the explosive type, with little, if any, lava flow. Four miles south of this vent on the same fault line is an outcrop of vesicular trachyte, with billy at its contact with the rafted-pebble sandstone, and fine siliceous veins penetrating the sandstone. Thin layers of trachyte were also observed in the hills to the east and north-east of fossil locality 18. In this area, the sequence appears to be:

Top	
80+feet	sandstone;
30 feet	sandstone, ripple-marked, flaggy, with bands of pebble conglomerate up to 6 feet thick;
2 feet	trachyte;
—	sandstone, flaggy and shaly, with shallow-water features.

Nigli Gap Sandstone also crops out in the faulted and broadly folded area around Localities 18 and 19.

At the ochre mine at Locality 34, 350 feet of conglomerate and sandstone form a large isolated outcrop in the coastal alluvium. Because of the lithology and sequence of these sediments they are tentatively included in the Nigli Gap Sandstone, although their exact position in the Weaber Group is doubtful. 100 feet of conglomerate and pebbly sandstone form the lower portion of the sequence. The conglomerate is poorly sorted, and the pebbles are slabby and mostly range from 2 inches to 6 inches in their longest measurement, although some boulders a foot long were observed. These pebbles and boulders are of Precambrian sandstone and quartzite. The pebbly sandstones are medium to coarse in grain and contain gravel and pebble horizons and show cross-bedding and ripple marks. They are overlain by 240 feet of medium to coarse well-jointed pebbly sandstone which contains mud pellets and, in places, has been silicified. The red ochre deposit overlies the conglomerate; it may be a sedimentary lens deposit or a secondary deposit introduced by the large fault on the eastern side. The discovery of a probable plant stem

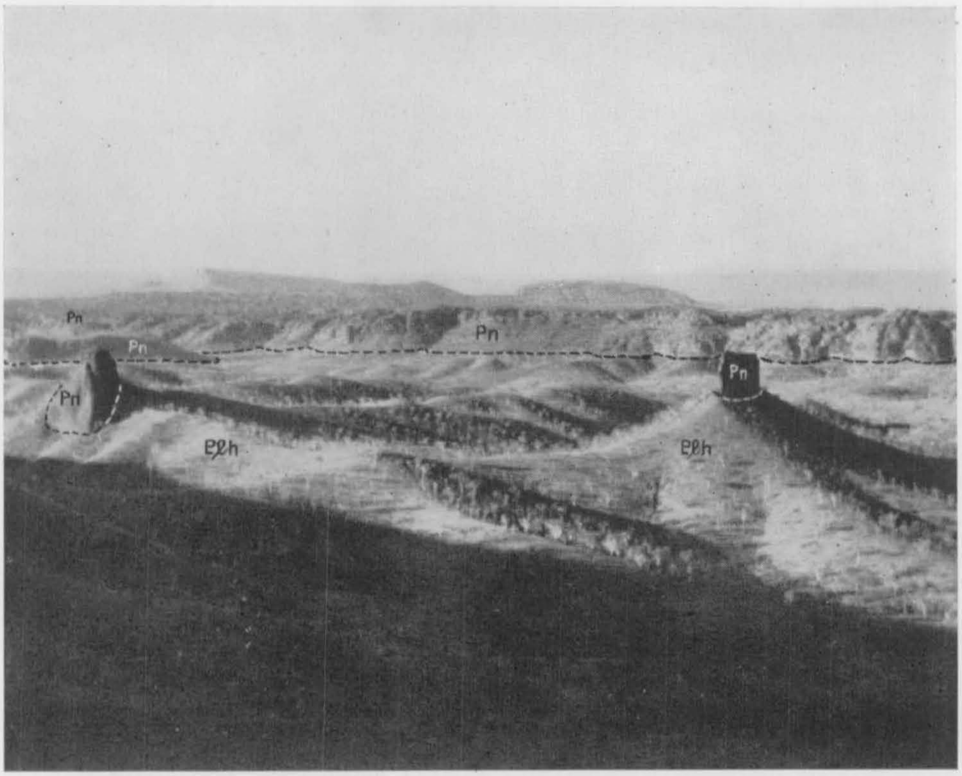


Figure 30—Nigli Gap Sandstone unconformably overlying Halls Creek Metamorphics in the southern portion of Burt Range

in the ochre points towards a sedimentary origin. The sequence dips a few degrees west of north at 18°.

The thickness of Nigli Gap Sandstone is largely dependent on the development of the basal conglomerate member, which may reach a thickness of 1,000 feet. The other sediments of the formation have an estimated thickness of 800 feet.

In all observed contacts, the Nigli Gap Sandstone unconformably overlies rocks of Precambrian age or is faulted against the Middle Palaeozoic sediments of Burt Range Basin.

If the sandstone and conglomerate of the Weaber Group, which overlie the Septimus Limestone, belong to Nigli Gap Sandstone, then the Nigli Gap Sandstone overlies Septimus Limestone with little or no apparent unconformity. The Nigli Gap Sandstone is conformably overlain by Spirit Hill Limestone.

Spirit Hill Limestone

The sandy limestone and calcareous sandstone which crop out at Spirit Hill at Locality 21 are given the formation name of Spirit Hill Limestone.

At this locality 350 feet of well-bedded sediments of this formation dip north-east at 7° to 15° and contain abundant poorly preserved fossils. Öpik in his field determinations listed:

Syringopora
A single rugose coral
Euomphalus
Straparolus
Abundant crinoid stems
Chonetes

A good view of the distribution and broad folding of the Weaber Group is obtained from the top of Spirit Hill.

Other outcrops of Spirit Hill Limestone were examined at Localities 18, 19, and 20. At Locality 20, 40 feet of calcareous sandstone, interbedded with sandy limestone and overlain by 20 feet of friable sandstone, dip north-east at 5°. The lower beds contain abundant crinoid stems and poorly preserved *Chonetes*. More than 100 feet of sediments of Spirit Hill Limestone are exposed at Locality 19 on the north-eastern side of a fault which trends north-west. On the south-western side are exposed rafted-pebble sandstone and conglomerate of Nigli Gap Sandstone. The calcareous sandstone contains crinoid stems and *Chonetes* and is overlain by friable medium to coarse sandstone. At Locality 18, low outcrops of calcareous sandstone and sandy limestone, dipping 10° west, contain a similar faunal assemblage to that listed from Spirit Hill.

The isolated outcrop at the Legune track crossing of Sandy Creek has been examined by Reeves, and his fossil collection was studied by Teichert, who, from meagre evidence, suggested a Carboniferous age.

The following section is exposed at the crossing:

Top

100+feet silicified sandstone with limonitic staining and nodules, and poorly preserved fossils, which overlies a highly silicified sandstone;

80-100 feet sandy limestone, fossiliferous, grey, and calcareous sandstone;

20+feet limestone, grey crystalline, with numerous fossil horizons and nodules of limonite.

Table 2 — Mineral Production

KIMBERLEYS

	GOLD									OTHER MINERALS			
	Brockman	Halls Creek	Mt. Dockrell	Panton	Mary River	Ruby Creek	District generally	Total production reported to Mines Dept.	Bullion entered for export and gold received at Royal Mint	Silver	Ochre	Tin	Lead
	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	fine oz.	Tons	Tons	Tons
									270				
1886									4,359				
1887									3,125				
1888									2,204				
1889									4,002				
1890									2,415				
1891									974				
1892	32.0	23.3			194	787.3		1,036.6	1,451				
1893									527				
1894									784				
1895									798				
1896	75.9					153.4		229.3	496				
1897	37.75			16.4		76.0		130.15	258				
1898	97.15					403	417	917.15	1,004				
1899	26.4					213.75	331	571.15	605				
1900						133.06	164	297.06	601				
1901						195.4	151.0	346.4	380				
1902						543	197	740	434				
1903						86.51	119.33	205.84	32				
1904						382.04	114.1	496.14	546				
1905						16.77	148.95	165.72	648				
1906						157.14	179.43	336.57	362				
1907						58.71	91.45	150.16	338				
1908							134.52	134.52	169				
1909							265.53	265.53	487				
1910							171.45	171.45	149				
1911							271.63	271.63	295				
1912									266				
1913							453.29	453.29	196				
1914							144.34	144.34	221				
1915							161.91	161.91	250				
1916							82.25	82.25	109				
1917							15.08	15.08	116				
1918							150.73	150.73	240				
1919									132				
1920							49.35	49.35	49				
1921							5.01	5.01	5				
1922							30.55	30.55	31				
1923							12.77	12.77	13				
1924							29.43	29.43	34				
1925							64.61	64.61	65				
1926							193.89	193.89	194				
1927							40.38	40.38	40				
1928							184.27	184.27	184				
1929							62.97	62.97	63				
1930							1.54	1.54	2				
1931							63.70	63.70	64				
1932							182.29	182.29	182				
1933							225.02	225.02	225				
1934							390.49	390.49	390				
1935			86.86				236.54	323.4	312				
1936			86.29				310.94	397.23	364				
1937	14.83	8.59	154.53			167.26	314.01	659.22	789				
1938	30.46	5.55	189.82			396.53	342.73	965.09	824				
1939	32.58		82.91	3.00	29.47	271.73	302.01	721.7	768	93			
1940	12.36	15.27	136.1		24.19	361.4	337.73	887.05	807	(from Mt.			
1941	27.54	43.24	17.9			412.37	467.12	968.17	606	Dockrell)			
1942		52.08	11.85			198.28	64.05	326.26	250				
1943							199.20	199.20	154				
1944							107.38	107.38	114			.6	
1945							233.47	233.47	168				
1946				1.77		93.19	332.5	427.46	351	2.14 Ruby Cr.			2.73
1947							495.5	495.5	438	12.64 Halls Cr.			1.78
1948		29.87					239.1	268.97	272	5.9			
1949								2,408.00	1,136			.13	
1950								123.00	104				
1951								391.00	328	15.08	20.61		1.73
1952													
1953													
	386.97	148.03	796.13	21.17	247.66	5,106.84	9,282.54	18,911.34	38,569	128.76	20.61	.73	6.24

The dip of the beds is 5 to 10° basinwards, i.e., slightly west of north. This outcrop is probably near a fault as the whole section has been silicified and limonitised. Many of the vugs in the limestone are filled with rock crystal and secondary calcite. In 1952 a large collection of fossils was made from this outcrop, particularly from the grey crystalline limestone, which yielded well-preserved brachiopods. These specimens have not yet been studied and it is feared that they have been lost or badly damaged by fire.

From fossils collected in 1949 from Locality 27, Öpik (1950) gives the following list:

Dictyoclostus
Chonetes cf. *pratti* (Davidson)
Syringopora
a rugose coral
gastropods
an indeterminable nautiloid cephalopod.

The name Sandy Creek Formation was used by Öpik (1950) but, because of similarity in faunal assemblage and lithology, and its geographical position, this outcrop is included in the Spirit Hill Limestone.

The thickness of Spirit Hill Limestone is approximately 350 feet.

Flapper Hill Sandstone

The formation name Flapper Hill Sandstone was given by Öpik (1950) to the fossiliferous sandstone which crops out in the isolated Flapper Hills, west of Legune Homestead. Fossils were collected from this locality by Dr. Öpik and the writer in 1949.

The hills are composed of a white to brown friable sandstone which has been strongly silicified in places to give a hard white quartzite. The beds dip west at about 30° and at least 100 feet sandstone are exposed. The sandstone yielded a rich fauna including the following:

Chonetes sp. cf. *pratti* (Davidson) (similar to that found at Sandy Creek Crossing)
Syringopora
Cleiothyridina
Rhipidomella
Two species of *Spirifer*
Productids
Orthotetinae

The outcrop is surrounded by a large belt of alluvium, so the position of the formation in the Weaber Group is not clear, and, until it can be fitted into the known sequence, the formation name should be retained. Öpik (1950) points out that although *Chonetes* and *Syringopora* form a stratigraphical link with the outcrops at Sandy Creek, the stratigraphical relationship between Point Spring Sandstone, Flapper Hill Sandstone, and the outcrops of Sandy Creek is not clear. He suggests that the better represented marine fauna at Flapper Hill may be older, although he recognizes the possibility of an inter-fingering of Spirit Hill Limestone with Flapper Hill Sandstone.

The formation may be represented in the eastern portion of the Burt Range by the sandstones either above or below the Spirit Hill Limestone, but more detailed work is necessary to link this isolated outcrop to the main sequence; no doubt its equivalent does exist there.

Point Spring Sandstone

The name Point Spring Sandstone was used by Öpik (1950) for the sandstones which crop out at fossil localities 29 and 30, half a mile east of Point Spring in the southern scarp of Weaber Range. In this Bulletin, Point Spring Sandstone is defined as the formation name for the sandstone and other sediments which crop out in Weaber Range, and includes most, if not all, of Reeves' sequence of his "Weaber Range Series".

In the cliff half a mile east of Point Spring, sandstone with the marine fossils *Dictyoclostus,* a productid, and spiriferids, is overlain by a current bedded sandstone which contains various tracks and burrowings and is rich in plant remains. Öpik (1950) listed the following plant fossils:

Cordaites-like leaves
Calamites stems (perhaps *Phyllotheca*)
Stigmaria.

He noted that representatives of the *Glossopteris* flora are absent.

Reeves (1948) gave two interesting sections of Point Spring Sandstone. They are:

"Section east of Ninbing Station

Top	
120 feet	sandstone with thin shales;
10 feet	5-foot (sic) bed of gritty, impure limestone overlain a few feet by 3in.-4in. of a limonitic sandy bed rich in *Productus.* A few feet below this limestone marker, *Spirifer* and other fossil moulds and casts occur in a thin ferruginous liminitic layer;
150 feet	concealed;
50 feet	coarse to fine, arkosic, sandstone with pebbly layers containing quartz pebbles up to ½ in. diameter;
25 feet	greyish, friable sandstone. Base concealed by talus.
	Section in Weaber Range 4 miles north-west of State Boundary.
30-40 feet	cross-bedded pebble conglomerate; pebbles chiefly quartzite, 1 in-2 in. in diameter;
10 feet	boulder conglomerate, with cemented boulders of quartzite, 1 in-6 in. in diameter. This conglomerate with overlying members weathers into high castle rocks at the east end of Weaber Range;
150 feet	well-bedded, massive to cross-bedded, fine to medium ferruginous sandstone;
10-30 feet	concealed;
5 feet	grey, pitted sandstone, with casts of Productid;
60 feet	shaly, ferruginous sandstone;
25 feet	shaly sandstone;
5 feet	brown, gritty limestone, with fossils;
25 feet	brown, well-bedded, ferruginous sandstone, forms cliffs 125 feet above flats at base of range;
100 feet	talus, no exposure."

South-east of Ninbing, the scarp in Permian sediments which overlie the Devonian Burt Range Limestone exposes 70 feet of medium to coarse sandstone and gravel conglomerate which contain worm tracks and poorly preserved plant fossils.

Reeves (1948) estimated that 500 to 800 feet of sediments of this formation were exposed in the Weaber Range area. The beds dip gently basinwards, that is, northwards. The isolated outcrops of the formation in the sandy low-lying country north of Weaber Range have not been visited.

Point Spring Sandstone forms the top unit of Weaber Group. The age of each individual formation in the Group has not been discussed because of the lack of collections and study of the fossil content.

Öpik (in Noakes et alia, 1952) tentatively correlates the Noonkanbah Formation in the West Kimberleys with the Spirit Hill Limestone and Flapper Hill Sandstone, and the Erskine Sandstone with the Point Spring Sandstone. Further work has shown that this correlation is not correct: the Erskine Sandstone is now known to be Triassic in age (Brunnschweiler, 1954b).

It appears that Weaber Group is very low in the Permian, and as the faunal assemblage is completely different from that found in Permian sediments in the Fitzroy Basin, it is possible that sedimentation began in the Upper Carboniferous. The geological history of the area shows that the earlier circle of sedimentation, which began in the Upper Devonian, was completed in the Lower Carboniferous and was followed by an orogeny in either Middle or Upper Carboniferous. The later cycle of sedimentation may have begun in either Upper Carboniferous or Lower Permian, and sediments from this cycle have a different distribution from sediments of the earlier cycle. More detailed work on fossil assemblages in this group is required before the complete sequence and exact age of the group can be given*.

Port Keats Group

Although sediments of the Port Keats Group were examined as early as 1839, the unit was not officially named until Noakes (1949) proposed the name Port Keats Group for those sediments which "outcrop in a belt along the western seaboard of the area south of Port Blaze in the Katherine-Darwin Region". He stated that the beds warrant classification as a group because they comprise considerable thicknesses of both marine and fresh-water sediments.

The group consists of fresh-water and marine shales and sandstones with some thin limestone beds and narrow bands of coal. The soft friable nature of the sediments is reflected in the poor outcrops throughout the area. The best outcrops are found along the coastline and in a few isolated hills which have been strengthened by silicification along fault lines.

*G. A. Thomas, who has made a preliminary examination of some of the fossils from the Weaber Group (see Appendix D), is inclined to assign to them an Upper Carboniferous age.

The records of the coal bores put down during the early part of this century afford the best sequences of this Group. They have been recorded by Brown (1906-1908) and later by Reeves (1948). The log of No. 4 coal bore, Port Keats, is given in Appendix E as a typical section of Port Keats Group.

Brown commented that much of the core which had been recorded as shale and sandstone was highly calcareous and some specimens were limestone.

Cliff Head No. 1 Bore passed into granite at 720 feet. It is situated in the north-eastern portion of the basin where the thickness of the sediments would naturally be less than towards the centre of deposition in the Port Keats area. Thus, like the Weaber Group in most places, the Port Keats Group probably unconformably overlies Precambrian rocks and it is very improbable that any Lower Palaeozoic sediments are present at depth.

Evans (in Reeves 1948) gives the following section, measured at Table Hill:

"10 ft.	Laterite;
Mesozoic 50 ft.	white shale, and sandstone;
1-2 ft.	conglomerate, quartzite pebbles up to 6 in. in diameter;
1½-2 ft.	salmon-pink shale;
5 ft.	brown, medium to coarse sandstone;
15 ft.	white shale;
7 ft.	brown to white, medium sandstone; irregular shale streaks and occasional shale pebbles;
3 ft.	white shale;
27 ft.	medium to fine grained sandstone, white to brown, irregularly bedded;
6 ft.	white to brown, well-bedded, medium sandstone;
56 ft.	fine-grained, white, evenly bedded sandstone;
10 ft.	fine-grained, white, cross-bedded sandstone;
20 ft.	Cover;
10 ft.	medium-grained, white irregularly bedded sandstone;
5 ft.	coarse, arkosic sandstone, with irregular thin shale bands;
5 ft.	Cover;
25 ft.	medium to fine-grained sandstone, with ¼ in. to ½ in. irregular shale bands every 5 in. to 10 in., bedding very irregular;
3 ft.	sandstone with irregular ¼ in. shale bands;
30 ft.	white shale, somewhat irregularly bedded;
65 ft.	Cover;
15 ft.	medium to coarse sandstone, irregularly bedded, white to brown;
2 ft.	coarse, arkosic, sandstone, with lens of white argillaceous sandstone;
5 ft.	coarse, arkosic, sandstone and grit, current bedded, brown to grey;
3 ft.	white shale;
49 ft.	Cover."

Two of the coal bores at Port Keats were put down to 1,500 feet or so without reaching the base of the Port Keats Group; so the maximum thickness of this Group may be given as greater than 1,500 feet.

In the isolated lateritized mesas, sediments of Port Keats Group are overlain by Mesozoic sediments. These mainly belong to the Mullaman Group (Noakes, 1949) of Lower Cretaceous or Upper Jurassic age; but, in places, thin remnants of Triassic sediments may be present. Etheridge (1907) in his description of fossils collected from Bore No. 4, Port Keats, noted the occurrence of *Estheria,* which he thought indicated a Lower

Mesozoic age for the upper beds in the Port Keats area. Teichert (in Reeves, 1948) states that *Estheria* has a long range and is found in the Permian Period as well as in the Mesozoic Era; Brunnschweiler (1954b) regards them as of Triassic age and states the identical *Isaura** shales are known from the Port Keats bores.

The fossil assemblages from many localities in the Port Keats Group have been studied and listed by Etheridge (1907), Crockford (1943), Crespin (1947), and Teichert (in Reeves, 1948) and they have identified at least 40 species of Permian fossils; but in no two localities are the faunal assemblages comparable; much more detailed collections and identifications are required before the complete stratigraphical and palaeontological sequence is worked out. When this has been done, correlations with the Weaber Group and the other Permian sediments in northern and western Australia may be made. Noakes, et alia (1952) recognized and correlated two stages: a lower one containing *Glossopteris browniana* Brongniart and other plant fossils recorded from Bore No. 4, which they correlate with the Poole Sandstone of the Fitzroy Basin, and an upper one with a marine fauna which they correlate with the Noonkanbah Formation and the lower part of the Liveringa Group.

JURASSIC AND CRETACEOUS

General

Sediments of Mesozoic age have a wide distribution throughout northern Australia; although they were first recognized in the late 19th century, the study of their distribution and age is not complete. Tenison-Woods in 1886 reported on the geology of the Northern Territory and stated that he had seen no trace of Cretaceous sediments; but Brown (1895) examined sediments near Darwin and, from the fossil content, mapped the area as of Cretaceous age. Etheridge, (1895) listed the following forms from the collection:

"Point Charles—Point Darwin;
Ammonites, allied to *A. varians Sby.*: common;
A. belus, D'Orb., *A. geultardi*, D'Orb.: common;
Ancyloceras or Hamites;
Scaphites;
Aucella;
Nucula.
Bony-scute-tubercles."

Woolnough (1912) mapped many areas of Cretaceous rocks in the northern part of the Northern Territory. Jensen (1915) examined Mesozoic rocks east of Willeroo but was uncertain of their age. In 1937, the Aerial, Geological and Geophysical Survey of North Australia (Hossfeld, 1937) reported the occurrence of plant fossils from its "Plateau Sandstone series". Walkom (in Hossfeld, 1937) determined the fossil *Otozamites bengalensis*, and a Jurassic age was assigned to these sediments.

Voisey (1938) produced a sketch-map of part of the Northern

*The name *ISAURA* Joly, 1841 replaces *ESTHERIA* Rup. according to Bock (1953).

Territory in which he showed the sediments around Darwin to be of Cretaceous age, and large areas farther south to be of Jurassic age.

Noakes (1949) gave the formal name Mullaman Group to the Mesozoic sediments in the Katherine-Darwin Region and realized that the group included at least two formations—a younger marine formation for which he suggested the name Darwin Formation, and an older formation of lacustrine sediments which he did not name.

Subsequent regional work in the eastern part of the Northern Territory has substantiated this division, and marine fossils were collected by the writer from numerous localities near Borroloola, Mallapunyah, and Creswell, and plant fossils from 7 miles south of Creswell, and the Causeway, a few miles north of Newcastle Waters.

Because only regional geology has been done in this area and the lithology and fossil content of these outcrops are similar to those in the Katherine-Darwin Region, the name Mullaman Group has been extended to include the Mesozoic sediments in the Barkly Region. Similarly, in this Bulletin, the name Mullaman Group is used for the Mesozoic sediments which have been examined in the Ord-Victoria Region.

Mullaman Group

Sediments of the group have been mapped in the north-eastern and north-western portions of the Region and, although the sediments are masked by laterite, the sequence and lithology can be obtained from scarps.

A section of lateritized sediments of the Mullaman Group was examined in a scarp 2 miles south-south-east of Willeroo Homestead. The base of the scarp is composed of Antrim Plateau Volcanics. These are overlain by 1 foot of lateritized shaly sandstone, which is in turn overlain by 20 feet of lateritized fine conglomerate containing rounded gravel with a maximum diameter of 1 inch, and an average diameter of ¼ inch to ½ inch. The gravel consists of quartz, rock-crystal, quartzite, and chert. The conglomerate is overlain by a coarse ferruginous sandstone which contains poorly preserved plant stems. East of the scarp, on the plateau, is a small hill in which is exposed 40 feet of "porcellanite" which belongs to the marine portion of the group and has yielded the following micro-fossils, determined by Miss I. Crespin.

Radiolaria cf. *Cenosphaera*
Dictyomitra

Foraminifera: cf. *Haplophragmoides.*

The contact between the freshwater and marine units is obscured.

The mudstone, which bears a resemblance to the fossiliferous Cretaceous mudstone that outcrops north of Mallapunyah, is apparently overlain by a bed of sandstone, of which only remnants are found on the surface.

An outcrop of lateritized sandstone was examined 8 miles south of Birrimba on the road from Birrimba to Top Spring. This outcrop contains poorly preserved plant stems, indicating that the sandstone belonged to the lacustrine unit of Mullaman Group. Farther south along this road and also along the road from Birrimba to Moolooloo, the lateritized Mullaman capping thins out to expose the underlying Montejinni Limestone and Antrim Plateau Volcanics.

4.7 miles east of Chumgamidgee Water Hole are some isolated remnants of highly silicified and lateritized shale overlying Montejinni Limestone. These are thought to belong to the Mullaman Group, although they may be of Cambrian age.

The distribution of the Mullaman Group in the desert in the south-eastern portion of the Region is ill-defined, but it is thought that sediments of the group continue beneath the laterite across to the outcrops of Mullaman Group examined by the writer in 1948 at the south-eastern end of the Murrenji track near Newcastle Waters.

Sediments of Mullaman Group that outcrop in the Port Keats area were not examined, but Evans (in Reeves 1948) gives the following description:

> "Rocks of probable Mesozoic age occur as thin cappings on many of the prominent mesas and hills south-east of Port Keats Mission. Good exposures were observed at the north end of Table Hill, Sugar Loaf Range, and Mt. Goodwin. These consist of a thin veneer of laterite, limonite clays and sandstones with a basal conglomerate. The laterite which varies from a foot to 6 ft. thick, is usually limonitic but some siliceous phases were observed. The clays and sandstones are fairly well bedded and often strongly impregnated with limonite making them difficult to separate from the laterite cap".

Evans lists 150 feet of possible Mesozoic sediments in the bore logs of the coal bores of Port Keats.

Mullaman sections examined in the Region do not give a complete sequence of the group. The greatest observed thickness of lacustrine sediments was 50 feet and of the marine sediments 40 feet, but the marine unit, at least, is thought to be much thicker. In all observed contacts, sediments of Mullaman Group overlie Antrim Plateau Volcanics or Cambrian Montejinni Limestone. No sediments were seen overlying the Mullaman Group; this explains why, in all outcrops examined, sediments of the Group are severely lateritized.

The age limits of the Group are still a matter of controversy. The plant fossils have Jurassic affinities in Australia, although in other parts of the world forms such as *Otozamites bengalensis* also occur in the Triassic and Cretaceous. Brunnschweiler (See appendix C) after examination of the plant fossils, considers the lacustrine sediment to be of Jurassic age; but the marine fossils indicate a Lower Cretaceous age, and Crespin* considers that all the species examined from the Region are typical of Lower Cretaceous: they have been described from the Lower Cretaceous surface and sub-surface beds of the Great Artesian Basin of Australia (Crespin, 1953).

*Personal Communication.

It appears that deposition of the group began in Upper Jurassic or Lower Cretaceous in low-lying swamps, lakes, or even estuaries, on an almost peneplaned surface, which was later invaded by an epeiric sea in which were laid down the marine sediments of the group. This Lower Cretaceous epeiric sea covered most of North Australia.

TERTIARY

White Mountain Formation

Lacustrine sediments which unconformably overlie Elder Sandstone in the vicinity of White Mountain, north of Ord River Homestead, have been named "White Mountain Series" by Matheson and Teichert (1948). This name is revised to White Mountain Formation. Matheson and Teichert list the following section from the south-west slope of a ridge south-east of Trig. Station J.40 where there are good exposures of White Mountain sediments:

"5 feet chert with *Planorbis hardmani;*
10 feet siltstone;
30 feet chert, unfossiliferous;
55 feet siltstone;
215 feet marl;
55 feet siltstone with basal chert layers.
Total 370 feet."

Fossils have been collected and studied from the top chert layer, and Chapman (1937) has described *Planorbis hardmani, Planorbis* cf. *essingtonensis, Bullinus* sp., and algae, foraminifera, sponges, ostracods, and insect remains.

Matheson and Teichert also give a small section which they measured at the hill of Trig. Station J40. It is:

"10 feet chert with *Planorbis hardmani;*
35 feet siltstone;
50 feet glauconitic and quartzose sandstones with siliceous bands and nodules, pisolitic chert, etc., poorly exposed.
Total 95 feet".

The difference in thickness between these sequences suggests deposition on an uneven surface of tilted Elder Sandstone.

The lacustrine sediments have also been slightly tilted and buckled, showing that there has been some movement after their deposition.

The fossil content of the formation does not indicate a definite age. Chapman (1937) compared the faunal assemblage with that found in the Helicidae Limestone of Bass Strait and the Helicidae Limestone of Gregory River. Matheson and Teichert point out that the limestone at Bass Strait is an aeolian deposit of Pleistocene age, and so is not comparable with this formation, and that according to Whitehouse (1940) the Limestone of Gregory River—recently named Verdon Limestone*—is a spring deposit of most probably late Pliocene age, and is also not comparable. This interpretation by Matheson and Teichert of Whitehouse's

*Named by Traves and accepted by the Stratigraphical Nomenclature Committee of Queensland, but not yet published. Probable Dinosaur bones in the Verdon Limestone were tentatively identified by H. O. Fletcher (pers. comm., 1953) as Upper Cretaceous.

suggestion is not accepted, as the origin of this Limestone appears to be lacustrine, although calcareous waters from springs may have formed part of the supply to the lake. Thus Chapman's correlation cannot be denounced on grounds of different modes of deposition.

However, there are a number of isolated outcrops of Tertiary and Pleistocene sediments throughout Queensland and the Northern Territory such as *Austral Limestone, *Brunette Limestone, Glendower "Series," Siltstone "Series", and numerous others: no correlation of these isolated deposits with White Mountain Formation is possible with the present limited knowledge of Cainozoic stratigraphy and palaeontology in North Australia.

The abundant deposition of silica in this formation suggests, but does not prove, that the origin of these sediments is related to lateritization.

On the Barkly Tableland, the Austral Limestone and Brunette Limestone have been formed in lakes which received the soluble constituents leached during the process of lateritization. This may also have been partly the source of the White Mountain Formation, although this unit contains more clastic material than is found in the Brunette or Austral Limestone. The extrapolated level of the lateritized Tertiary land-surface obtained from the mesas and plateau to the south of White Mountain would be 1,100 feet to 1,200 feet and the sediments of the formation now have an altitude of approximately 700 feet to 1,000 feet; so that, allowing for some slight movement as shown by the present attitude of the beds, it is possible that the area around White Mountain formed a depression during lateritization into which soluble constituents and possibly some clastic material collected.

At present, no definite age or origin can be given to this Formation; and although a Tertiary age is suggested, a Pleistocene age is not inconceivable.

Laterite

Although it is realized that the formation of laterite is essentially a pedological process and strictly should not be included in units of stratigraphy, the presence of a large area covered by laterite in the Region necessitates a brief description of its occurrence. In many places on the Sturt Plateau it is impossible to determine the nature of the rock that underlies the thick mantle of laterite; so areas of laterite have been delineated on the regional map, and where possible the underlying unit is also shown.

Throughout this Bulletin, the word "laterite" is used for all, or any, of the zones of a profile produced by lateritization, and the distinct zones are referred to by special names such as ferruginous, mottled, pallid, and siliceous. This terminology is used by most geologists throughout Australia, although soils officers prefer to restrict the term "laterite" to a certain development of the ferruginous zone.

*See note on opposite page.

The most extensive areas of laterite occur in the plateau region of the south-east and south, which has not been dissected by coastal rivers.

Smaller remnants of laterite are also found in the north east and north-west corner of the Region. The laterite throughout the centre of the Region has been removed by the Ord and Victoria River Systems.

These large areas of laterite are believed to have been formed contemporaneously during one stage in the Tertiary Period, but, because of the lack of Post-Cretaceous fossiliferous sediments, the age of this lateritization cannot be determined exactly. It is thought that the

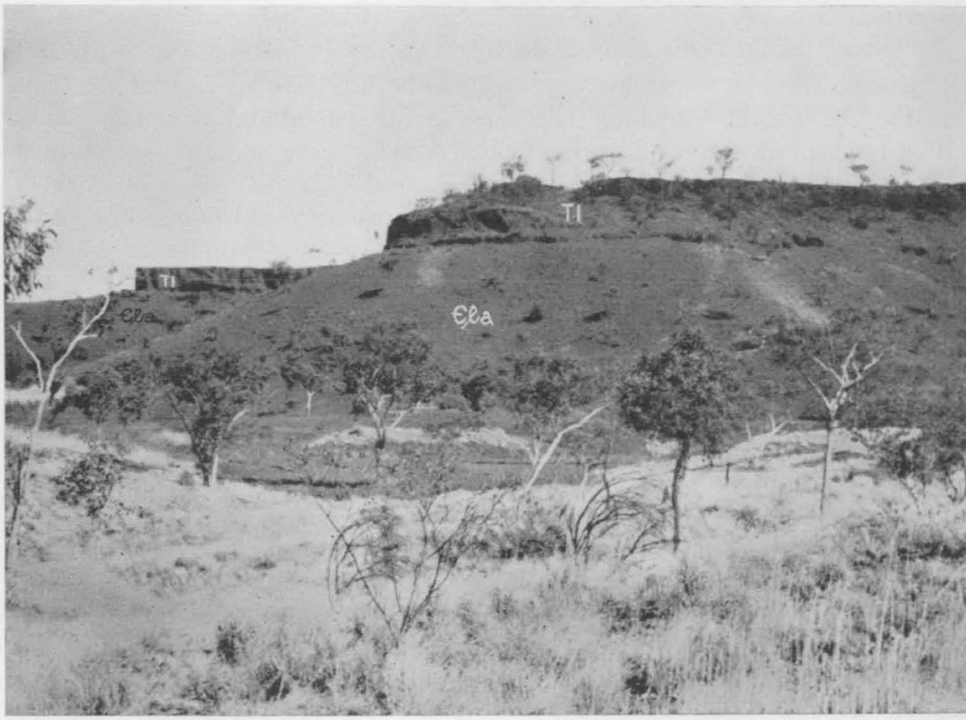


Figure 31—Laterite mesa on Antrim Plateau Volcanics, west of Catfish Hole

laterite belongs to the period of lateritization which affected most of North Australia and a large part of the Australian continent*. South of Hooker's Creek, there may be some evidence of two periods of lateritization, as it appears that two levels exist—one at plain level and one at the surface of Mt. Winnecke Sandstone. However, the upper laterite is believed to be the result of perched ground-water conditions and probably does not indicate a second period of lateritization.

Poorly developed younger laterite has been observed in streams and

*For a general discussion of the age of formation of Australian laterite, see Owen (1954).

swamps, but, in all exposures examined, only a thin section of ferruginous zone was exposed, which cannot be confused with the well-developed profiles of the Tertiary laterite.

The profile of the laterite is dependent on the nature of the parent material. In the Ord-Victoria Region, the laterite is formed mainly on rocks of Mullaman Group, Antrim Plateau Volcanics, and Victoria River Group.

Figure 32—Lateritic Profile in Sink Hole between Wave Hill and Limbunya

The typical profile developed on fine-grained clastics such as mudstones and siltstones of Mullaman Group is an uneven thickness of red or yellow sandy soil underlain by ferruginous zone, generally of the vermicular type, although concretions are present in varying abundance. The ferruginous zone, which has a maximum thickness of 20 feet, merges into a vivid mottled zone which may extend for 40 feet before it fades into the pallid zone. The siliceous zone is very indefinite and may occur in one or both of the mottled and pallid zones. Faint signs of bedding are visible in the mottled zone and become more pronounced in the pallid zone. The whole profile may attain a thickness of 100 feet.

In the typical profile developed on volcanics, the ferruginous zone is generally vermicular, with tubules, some small iron concretions, and plates or coatings of limonite surrounding iron-stained quartz grains. In some sections, residual fragments of chert and rock crystal remain in the profile. The ferruginous zone grades imperceptibly into the mottled zone, which is a fairly even reddish-brown colour with little or no mottling but rather a fine speckled appearance. This colouring fades slowly through pink to the grey of the rotten weathered volcanics. Relics of onion weathering, jointing and vein lines are visible in the mottled zone. The profile over volcanics differs from that over fine-grained clastics in the absence of a definite pallid zone, of mottling in the mottled zone, and of concretions in the ferruginous zone, and the presence of relic onion weathering, jointing, and vein lines in the mottled zone.

Profiles formed on sandstones of Mullaman Group and Victoria River Group are not so well developed and consist of a loosely-cemented concretionary ferruginous zone overlying iron-stained to leached sandstone.

These three profiles show the three main types of development of laterite in the Region, although intermediate profiles occur on heterogeneous parent materials. In many places profiles have developed on a thin capping of Mullaman sediments and extend down into Volcanics.

A number of specimens of lateritized volcanics have been analysed to determine the bauxite content, and the results are given on p.

*Alluvium**.

Areas of Tertiary heavy-textured alluvium have been mapped on Sturt Plateau, where dissection has not removed the Tertiary land surface. This alluvium was probably deposited in swamps and depressions at the same time that laterite was forming on the higher, better drained country: no lateritic remnants are found in the alluvium, and the two are complementary in extent, so they are conjectured to be contemporaneous. Soluble constituents from the laterite profile have also drained into the depressions to form a calcic heavy soil, and in places pieces of marl are found. The origin of this heavy-textured Tertiary alluvium is probably similar to that postulated for the formation of the heavy soils and limestones on the Barkly Tableland.

Bore records show that, on the Sturt Plateau, alluvium attains a thickness of 120 feet. Some sand and gravel layers may be present towards the bottom of the deposit.

Heavy-textured alluvium forms almost flat grasslands which, although not as good as the volcanic downs, provide fair grazing country.

QUATERNARY

Fluviatile and Estuarine Alluvium

Areas of river and coastal alluvium have been delineated on the geological map of the Region. The largest area of river alluvium ex-

*This loose usage of the term "alluvium" is accepted in Australia, and so is used here, although it is contrary to normal usage elsewhere.

tends in a north-easterly belt along the Baines and Angalarri Rivers, east of Pinkerton Range. This depression was probably formed by a down-warp in the late Tertiary orogeny, and heavy textured alluvium now lies in the depression. Numerous other areas of heavy-textured alluvium are found in the upper middle tracts of Victoria River and in the lower tracts of Ord River. The Ord River alluvium was probably deposited after the last significant submergence of the coast line which Brown (1945) places at the close of the Pleistocene Epoch. A large area of coastal light-textured alluvium has been mapped between Wyndham and Port Keats. This is a result of the last eustatic movement which Noakes (1949) considers to have been a 20-foot fall of sea-level in Mid-Recent Time. A more detailed study of the alluvia is given by Paterson (1954).

Soils

A more detailed description of soils of the Region is given by Stewart (1955), but it is interesting to note the relationship of some of the residual soils to the underlying rock. Also, many stratigraphical boundaries are marked by a distinct change in soil types; and where the underlying geology is masked by a soil cover, the stratigraphical boundary has been mapped on the soil boundary.

The following is a list of soil types and parent material:

Precambrian metamorphics and Granites	shallow skeletal soils with some sandy yellow podsols;
Basic granitized rocks which contain abundant biotite	shallow skeletal soils with some red-brown earths and grey soils of heavy texture;
Precambrian sandstone and quartzite	shallow skeletal soils with some sandy yellow podsols;
Precambrian and Palaeozoic limestones	shallow skeletal soils of grey brown calcareous desert soils, with some red earths, and grey soils of heavy texture, and yellow podsols;
Antrim Plateau Volcanics	stony heavy-textured grey soils;
Cambrian shales	grey and brown calcareous desert soils, with some brown soils of heavy texture;
Palaeozoic sandstones	deep sandy red earths;
Calcic alluvium	heavy-textured grey soils and red-earth soils;
Non-calcic alluvium	yellow podsolic soils and red-earth soils.

The heavy-textured stony downs formed on Antrim Plateau Volcanics provide the best pastoral country, the downs formed on Cambrian shale the next best. The sandy soils of sandstones and quartzites provide poor grazing country, and the skeletal soils are nearly useless.

TECTONICS

A study of tectonics in the Ord-Victoria Region provides evidence for the welding of this part of the Australian continent to form part of the Precambrian Shield and delineates the framework which influenced sedimentation throughout geological history.

Tectonically the Region includes a portion of the Kimberley Block, the south-western portion of the Pine Creek Geosyncline (Noakes, 1953), which in this Bulletin is called the Halls Creek Mobile Zone, a small portion of the westerly extension of the Warramunga Mobile Zone, and a large portion of the Sturt Block (Noakes, 1953). Fairbridge (1953) points out that Andrews proposed the name "Stuart Block" after Central Mount Stuart in 1938, and the same area was labelled "Sturtian Nucleus" by Hills (1946), and later "Sturt Block" by Noakes (1953): but the Block referred to by Noakes as Sturt Block does not include Central Mount Stuart, but does include Sturt Plains from which Hills originally named his "Nucleus".

The Halls Creek Mobile Zone is found in the vicinity of Halls Creek; it can be traced by numerous outcrops of granitic and metamorphic Lower Proterozoic rocks in a north-north-easterly direction to the eastern side of Burt Range. Farther north the orogen has not risen as much, and outcrops of lower Proterozoic rocks are few because they are obscured by Upper Proterozoic sediments. However, the zone may be traced to the Litchfield Granite (Noakes, 1949), east of Port Keats, by the belt of folding and faulting in the otherwise gently folded sediments.

Rocks which crop out in the Halls Creek Mobile Zone show much more disturbance than those which crop out on the Blocks. The Lower Proterozoic Halls Creek Metamorphics are strongly faulted and dip steeply. Remnants of Upper Proterozoic sediments in this zone are faulted and in some places folded with medium to steep dips. Upper Proterozoic sediments which were deposited in the nuclear basins (Umbgrove, 1947) on the Blocks have been only slightly disturbed, and, although the beds are faulted and folded into broad synclines and anticlines in places, most of them are sub-horizontal. The axes of the broad folds are mostly parallel to the trend of the nearest Mobile Zone.

The Winnecke Granophyre in the south-eastern corner of the Region is probably the only evidence seen in the Region to indicate the presence of the Warramunga Mobile Zone, although the east-west axes of the broad folds in the southern area indicate the presence of a mobile belt south of the Region.

Since Precambrian time the Kimberley and Sturt Blocks have been tilted, have risen and sunk, but actual deformation of sediments on the Blocks has been very slight. The mobile zones, although welded into the Precambrian Shield, have remained zones of movement, and Upper Proterozoic and later sediments in the belts have undergone much more

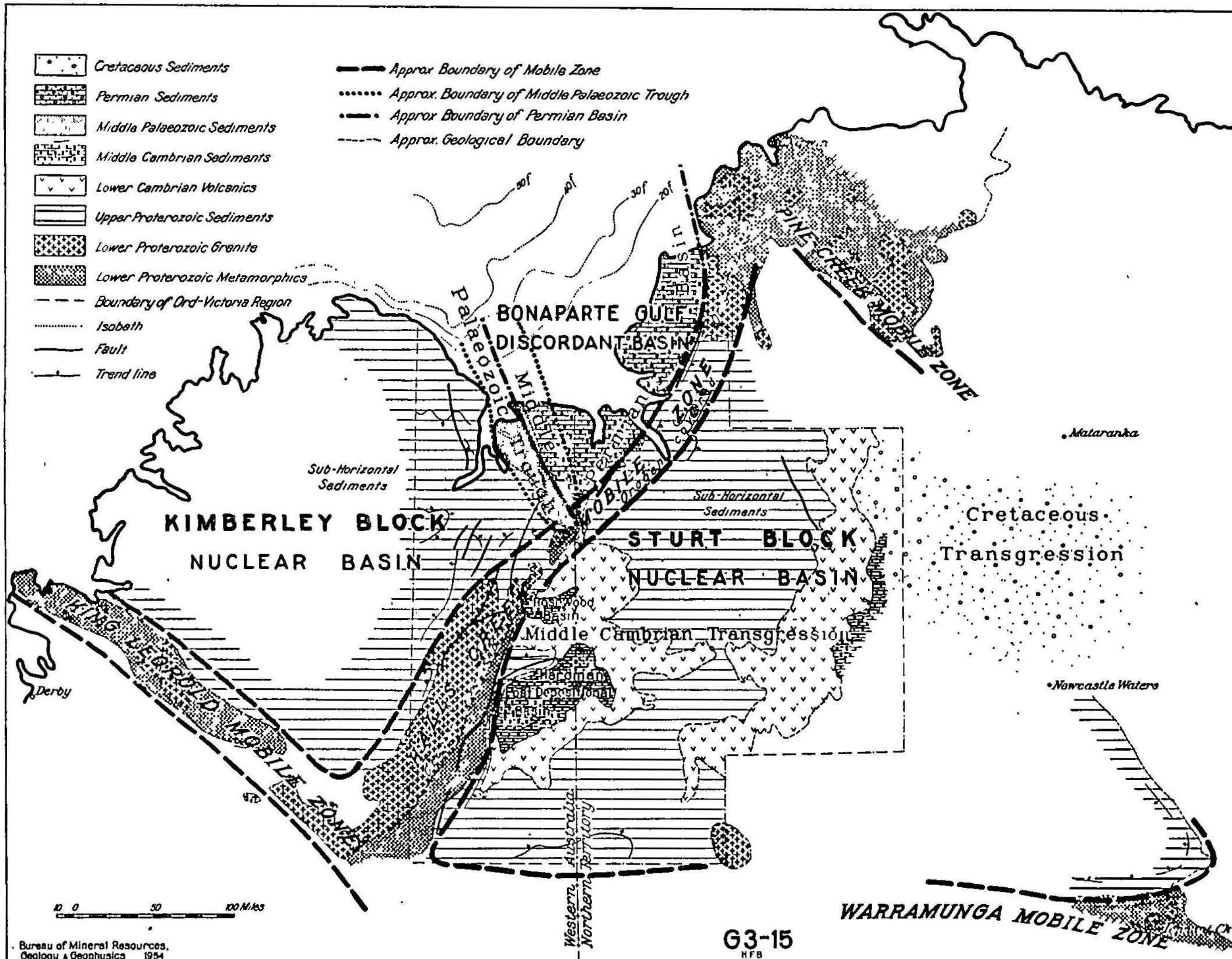


Figure 33—Tectonic Map

folding and faulting than their equivalents on the Blocks. The main set of faults is parallel to the Halls Creek Mobile Zone, i.e., north-north-east, and many of the faults can be traced for over 100 miles.

Re-adjustment of the western part of the Sturt Block after the outpouring of the Antrim Plateau Volcanics has formed post-depositional basins in which remnants of Cambrian sediments are preserved. Dips on the edges of these basins are up to 90°.

Middle Palaeozoic sediments in Bonaparte Gulf Basin were deposited in a discordant, probably faulted, trough, normal to the mobile zone and lapping on to it in the Burt Range. A second set of faults has been formed which is approximately parallel to the trough in this northern area.

Palaeozoic sediments in the Burt Range Basin have low dips, but in the Carlton Basin, Cambrian, Ordovician, and Devonian sediments dip north-east at 25° to 35° and are strongly strike-faulted.

The main orogenies occurred in Lower Proterozoic time before the deposition of Upper Proterozoic sediments, although throughout geological history the orogens of the mobile belts have been active.

Four important diastrophic movements can be traced since Lower Proterozoic times:

(1) Before the Middle Cambrian (probably in the Lower Cambrian); during this movement the trough was formed in which the Lower Palaeozoic sediments were deposited;

(2) In Upper Ordovician or Silurian time; an uplift caused the break in sedimentation now represented by the gap between Lower Ordovician and Middle Devonian sediments;

(3) In Middle Devonian; a renewed sinking allowed sedimentation to begin again in the Bonaparte Gulf Basin;

(4) In the Middle or Upper Carboniferous; sedimentation in Permian times was differently distributed from that of Devonian and older Periods.

Throughout the Region faulting is more prevalent than folding, but the age of faulting is not everywhere known. The majority of faults occurred in Precambrian, probably Lower Proterozoic, time, and since then there has been movement along the old fault lines and possibly new faults initiated in many periods. Permian sediments, the youngest sediments which cover a significant area in the Region, have been faulted. Silicified fault zones form prominent ranges such as at Mt. Misere.

Late Tertiary movement has slightly folded the sediments of White Mountain Formation and caused the submergence of part of Bonaparte Gulf Basin to form the present Joseph Bonaparte Gulf.

The tectonic studies in one region must form part of a complete picture: the relationship of the tectonics of the Ord-Victoria Region to its surroundings is given in Figure 33.

A mobile belt extends from Halls Creek to east of Port Keats and forms the western border of the Sturt Block and the eastern border of the Kimberley Block. Similarly the Warramunga Mobile Zone and its extension—the King Leopold Mobile Zone—form the southern border to the Sturt and Kimberley Blocks. The northern and eastern borders of the Sturt Block are not so clear. The large area of geosynclinal rocks in the Katherine-Darwin Region may represent a junction similar to that south of Halls Creek; or it may be only an enlarged area at a bend. It may be proved in the future that the Pine Creek Geosyncline as shown by Noakes consists of two geosynclines—one trending north-north-east from Halls Creek to Darwin and one trending south-east from Darwin and possibly joining the Warramunga Geosyncline or the Carpentaria Geosyncline.

If a geosyncline existed between Darwin and Tennant Creek and was obscured by the Palaeozoic and Mesozoic epeiric sediments, it would afford an explanation of the change in trends from east to north in the Ashburton Sandstone, north of Tennant Creek. However, at the present time, the eastern boundary of the Sturt Block is indefinite, and further mapping is necessary before the complete picture of the tectonics of north-western Australia can be obtained.

GEOLOGICAL HISTORY

The oldest rocks exposed in the Region are the Halls Creek Metamorphics, of Lower Proterozoic age, which are now exposed between the Kimberley Block and the Sturt Block. These sediments and accompanying volcanics were folded and metamorphosed and a part was intruded and granitized to form the Lamboo Complex. In Upper Proterozoic time the Kimberley and Sturt Blocks sank to form nuclear basins in which were deposited sediments which unconformably overlie the Halls Creek Metamorphics. The older sediments on the Kimberley Block—King Leopold Formation—were intruded by dolerite and gabbro, and, farther west in the Kimberley Block, volcanic activity formed the Mornington Volcanics (Guppy 1954). At the end of the Precambrian Era these Blocks were elevated to a land surface and deeply dissected before the outpouring through fissures of Antrim Plateau Volcanics, which heralded the epeirogenic Cambrian movements and Middle Cambrian transgression which gave rise to the Negri Group and Montejinni Limestone. The Ashburton Range of Upper Proterozoic sediments apparently formed a barrier between this sea and the one to the east, in which were laid down sediments on the Barkly Tableland.

At the end of the rhythmic deposition of shales and limestones of the Negri Group, slight movement changed the deposition to sandstones of the Elder Sandstone and the marginal facies of Ragged Range Conglomerate. At the recession of this Middle Cambrian sea, sedimentation began in the Middle Palaeozoic trough in the Bonaparte Gulf Basin and sediments of

Middle Cambrian to Ordovician ages were laid down in the Carlton Basin. There is no record of Middle and Upper Ordovician, Silurian, or Lower Devonian sedimentation; during this time the Bonaparte Gulf Basin was probably a land surface. In the Middle or Upper Devonian the sea again transgressed the Bonaparte Gulf Basin, and Cockatoo Sandstone and Burt Range Limestone of Upper Devonian age and, in the Burt Range Basin, Enga Sandstone and Septimus Limestone of Lower Carboniferous age were laid down. Recession, perhaps dissection, and orogeny followed before the Upper Carboniferous or Permian deposition began with marginal deposits of conglomerate up to 1,000 feet thick, which, to the east, grade into the rafted-pebble sandstone of Nigli Gap Sandstone. The presence of this thick boulder conglomerate and the rafted-pebble sandstone indicates that high mountains existed to the south-west of the Permian sea, probably with large mountain glaciers; but there is no evidence of a continuous ice-sheet such as has been postulated by some writers as covering Australia in the Permian Period (David ed. Browne, 1950). Permian deposition fluctuated from marine to lacustrine and probably transgressed to the north-east, as it is thought that the Port Keats Group is younger than the Weaber Group.

Most, if not all, of the Region was a land surface during the earlier part of the Mesozoic Era. The break in deposition ended in the Upper Jurassic Epoch, when fresh-water lakes developed in the mature land surface, and lacustrine sandstones and fine conglomerates of the lower Mullaman Group were deposited. In the Lower Cretaceous Epoch, the lakes were inundated by the epeiric sea which covered most of Northern Australia, and sandstones, shales, and siltstones, containing abundant micro-fossils, were deposited. This upper part of the Mullaman Group formed a thin veneer over the mature land surface and subsequent uplift must have been slight and even to preserve the easily erodable sediments. Noakes (1949) remarked that "the cycle of erosion which was initiated in Cretaceous time and continued until the late Middle Tertiary probably began with a fairly low-lying land surface which presented little scope for erosion".

During the Tertiary Period this mature land surface was severely lateritized and profiles up to 80 feet thick were developed. In many places the Cretaceous veneer had been eroded before lateritization so that the laterite profile is developed on Antrim Plateau Volcanics or sediments of the Victoria River Group.

Swampy or low-lying areas in which lateritization did not take place formed depositional areas for Tertiary "alluvium". The origin of White Mountain Formation—the only Tertiary rock unit— is not definitely known, though it is suggested that it was formed in a lake, into which were drained calcareous and siliceous solutions leached from the profiles then being formed. The fossil content does not indicate an exact age, however, and this formation may have a lacustrine origin younger than the one main period of lateritization which affected the Region.

A late Tertiary or post-Tertiary mild orogeny slightly folded sediments of White Mountain Formation and warped the Tertiary laterite surface, and initiated the present cycle of erosion which, in the vicinity of tributaries of the Ord and Victoria Rivers, has cut down many hundreds of feet below the Tertiary laterite level.

This last chapter of geological history—geomorphogeny—is described in detail by Paterson in his study of the geomorphology of the Ord-Victoria Region (1954).

ECONOMIC GEOLOGY

General

Metallic deposits are mainly confined to the belt of Lower Proterozoic rocks, in which gold, silver, lead, and copper have been found, although no large mines are working at present. The possibilities of the occurrence of uranium in this belt and of low-grade copper ore in the Antrim Plateau Volcanics are discussed. Table 2 summarises mineral production in the region.

The non-metallic deposits are more important at the present time, and hydrology, petroleum and bauxite prospects, and ochre-mining are discussed.

Metallic Deposits

Although specimens of many metallic minerals are found throughout the Region, there has been very little production, because no major ore-bodies have been located. Gold, silver, lead, tin, copper, and ilmenite have been found.

Table 2, compiled by Miss Wagschall, Bureau of Mineral Resources, from tables published by W.A. Mines Department, shows the recorded production from the Kimberley Mineral Field. The table shows that gold has been the most important metal, and production of silver, lead, and tin has been very small. No copper production has been recorded.

Gold

Gold has been won from many localities in the Halls Creek Metamorphics. Woodward (1891) agreed with the local miners that the field was the richest yet discovered in Western Australia; but, although production towards the end of the 19th Century was high, very little has been produced since. The main centre was Halls Creek and the main districts were Ruby Creek, Mount Bradley-Brockman, Mary River, Elvire River, Panton and Mt. Dockrell. Production figures for these areas are given in Table 2.

All production figures are based on recorded gold: actual figures, particularly during the early years, may have been much higher.

The geology of the individual workings is described by Finucane (1939a and b).

The gold is found in small reefs and veins in the Halls Creek Metamorphics, and some alluvial gold is recovered from the creek beds.

In 1952, a small amount of gold was obtained from this field by a few white people and a number of aborigines. Mr. Williams, the owner of Rock Hole Station, said that he and the aborigines on the station had collected 300 oz. of gold from the surface in the last year. A small battery was examined north-west of Ruby Plains Homestead. The ore treated by this battery is hand-picked from the surface of the surrounding country; ore over 4 oz. per ton is crushed and amalgamated and the average yield per year is approximately 200 oz.

Total production of the Kimberley Field reported to the Mines Department, Western Australia, for 1952 is recorded as 391.00 fine oz.

Traces of gold have been found in other localities in the Region. The "Golden Gate Country" north of Argyle has yielded gold and reports have been made of gold discoveries in the Winnecke Creek area, north of Tanami.

Lead

Small deposits of silver-lead ore have been discovered in the Halls Creek Metamorphics. Blatchford (1928) has reported on Martin's silver-lead show on Spearwah Station, and Bowley (1926) has examined silver-lead ores north-east of Halls Creek near Panton River, and 70 miles south of Wyndham on the Ord River. Production has been very small.

Copper

No copper has been produced from the Kimberley Field, but Antrim Plateau Volcanics contain possible low-grade deposits of copper. The Antrim Plateau Volcanics are, at their maximum development, 3,500 feet thick, and consist of basaltic flows, tuffs, and agglomerates which outcrop over an area larger than 10,000 square miles. Throughout the outcrops the Volcanics show copper staining.

Secondary copper minerals, malachite and azurite, were observed in the overlying basal limestone in the "Rosewood Wall".

Uranium

Deposits of uranium ore have been discovered in Lower Proterozoic rocks that crop out over a large area between Katherine and Darwin in the Northern Territory. A continuation of this belt of Lower Proterozoic rocks may be traced across to Daly River and west of Port Keats and, although it is thereafter covered in places by Upper Proterozoic and Cretaceous sediments, its continuation may be the Lower Proterozoic rocks which crop out east of the Burt Range and which can be traced down to Halls Creek in an almost unbroken line of outcrop. They have also been intruded in many areas by granite; and the prospects of uranium discovery in these rocks are good. An aerial survey of the region has recently been carried out by the Bureau.

HYDROLOGY

The study of hydrology is most important in the Ord-Victoria Region because at the present time water is one of the main limiting factors in any development.

The rainfall of the Region is low (Figure 2) and evaporation is high—over 100 inches per annum — so that all surface and underground waters should be fully utilized. In many areas, surface waters are very inadequate; supplies of underground water are essential for the preservation and growth of the pastoral industry which to-day, is the most important industry in the Region.

Surface Water

The Region is drained by numerous river systems, the more important being Ord, Victoria, Keep, Chamberlain and Fitzmaurice, which drain into Joseph Bonaparte Gulf, and Hookers Creek and Sturt Creek, which flow inland into the desert. Although some of these rivers are very large and during the wet season contain a copious supply of water, none of them flow permanently. In the long dry season, the rivers shrink to a chain of waterholes, and the inland rivers are completely dry. However, in many of the coastal rivers, especially the Ord and Victoria, large permanent waterholes provide ample supplies for watering of stock and, in many cases, homestead needs.

Records of measurements of stream flow are only available for the Ord River at the Gauging Site near the proposed dam site. The figures quoted below are for the summer of 1949-50.

13th December - 26th December	431,000 acre-feet
18th January - 24th January	70,200 acre-feet
27th January - 30th January	25,550 acre-feet
4th February - 10th February	347,000 acre-feet
Total	873,750 acre-feet

The volume of water flowing in the Ord River ranges from 10,000 to 3,000,000 acre-feet per year.

In 1952, gauging stations were established on the East Baines, West Baines, Victoria River, and Daly River, but no records are yet available.

The highly folded and faulted area from Halls Creek towards Port Keats contains many springs and seepages issuing from faults and cliff bases. Palm Spring, east of Halls Creek, provides a supply of water from the Lower Proterozoic rocks. Pompey Springs, north-east of Mistake Creek, are an example of springs originating from faults in the Volcanics. Useful springs such as Point Spring, Hart Spring and Alligator Spring occur in the Carlton area.

Many of the springs are utilized for watering stock by piping the supply to neighbouring creeks or troughs: important watering places on Lissadell, Argyle, Carlton, and Legune Stations are of this nature.

Because there are no dams in the Region, much of the surface water escâpes to the sea during the wet season. A dam site has been selected on the Ord River, and many other good sites are available on this and other rivers.

In this Region, where development is limited by water, a careful study of methods of retention of surface waters should be made, to provide supplies throughout the year.

Underground Water

Underground water may be divided into two types: ground or non-pressure water, and confined or pressure water. Pressure water may be subdivided into artesian and sub-artesian, depending on whether or not the pressure is great enough to force the water to the surface through the drill hole. All these types have been found in the Region. Owing to the heterogeneity of rocks and structures, it is impossible to discuss the Region as a whole; and as the underground water conditions bear a definite relationship to the stratigraphical units they will be discussed under those headings.

Volcanics

The greatest demand for underground water is in the good grasslands that overlie rocks of Antrim Plateau Volcanics, which cover an area of over 10,000 square miles. A study of the bores on Wave Hill Station illustrates the conditions of underground water in the Volcanics. The following are the bore records obtained from this station in 1949:

TABLE 3.
Bore Records — Wave Hill Station

Bore No.	Total depth feet	Static water level	Pump depth feet	Yield by pumping g.p.h.
1.	72	35	70	1200
2.	254	30	70	1200
3.	105	30	90	1200
4.	62	30	47	300-400
5.	62	26	60	300
5a.	219			300
6.	198	30	70	800
7.	82	20		1200
9.	600			
11.	73			
12.	71	35	70	700-800
14.	288	40	110	1800
15.	93	20		300
16.	85	20		600
17.	155	30	100	750
18.	237	62		1000
19.	268			1450
20.	218			
22.	71			1500
25.	125			good
28.	35			
29.	74	17	73	2400
Post Office Bore	50			small

Bores 18 and 19 are situated 84 and 90 miles west of Wave Hill and are not included in the discussion of underground water at Wave Hill.

Although the records are very incomplete, they provide some interesting information.

A study of the total depths shows that the average bore is 70 to 80 feet deep and that the static water level is mostly around 30 feet. This indicates that most of the Wave Hill bores tap shallow ground water and, as can be expected, the supply is small, ranging from 1,500 gallons an hour to nothing. Bore 29 is the exception: although it is only 74 feet deep with a static water level at 17 feet it produces 2,400 gallons an hour.

Two bores have been sunk deeper than 270 feet: No. 9 bore was drilled to a depth of 600 feet, and apparently did not give a satisfactory yield; and Bore No. 14, sunk to a depth of 288 feet, yielded on test 1,800 galls. an hour. The driller's log records that the water supply came from the bottom of this bore and that the water rose to 40 feet. This probably indicates that sub-artesian water was encountered.

Underground water in the Antrim Plateau Volcanics is contained in joints, faults, cracks, and other openings, but is generally not contained in definite aquifers, although Matheson (1951) suggested that in the Argyle Basin a semi-pervious layer of agglomerate in the volcanics forms an aquifer.

In the sub-horizontal volcanics, the shallow ground water may provide a sufficient supply; but if not it is necessary to penetrate the volcanics until an opening is found which yields a good supply.

In the vicinity of the Palaeozoic Basins, the volcanics are gently folded and provide a better catchment for underground water, and in many places seepages of underground water occur. Shallow bores sunk in these seepages provide excellent supplies of water. At Soda Spring, east of Argyle Homestead, casing has been sunk to 18 feet and a good yield of artesian water has been obtained, which rises to just above the surface. It is very soft, has a pH of 8.4, and contains a quantity of bicarbonates, with some carbonates and chlorides.

Pompey Springs, north-east of Mistake Creek Homestead, also are seepages from the volcanics: these springs are not fully utilized. They occur as a number of springs along a fault-line in the volcanics. The occurrence of asphaltite around these seepages is discussed under the heading of Petroleum Prospects.

Precambrian Rocks

Very little is known of underground water conditions in the Lower Proterozoic rocks, but, for the pastoral industry, the demand for underground water in areas of these rocks is not great, as carrying capacities are very low and small springs and rock holes mostly provide enough water. But underground water in these rocks may be tapped if a suitable location is chosen after a careful study of lithology and structure or by drilling at a seepage or spring.

The Upper Proterozoic sediments underlie many thousands of square miles in the Ord-Victoria Region and in some places underlie fair pastures. Underground water supplies in these rocks are dependent on lithology and structure and in places very good yields have been obtained. At Wave Hill Police Station, a bore drilled 700 feet into sediments of the Victoria River Group tapped an artesian supply which, at the present time, fluctuates from artesian to sub-artesian.

On the other hand in 1948 on Auvergne Station, which is underlain by sediments of the Victoria River Group, four bores were sunk, and for a total of 1,200 feet of drilling, only one good water supply was obtained. A more detailed study of the geology in this Station should indicate more favourable sites. On the Sturt Plateau the structures in the Upper Proterozoic sediments are masked by laterite, alluvium, and, in some places, a layer of volcanics. This makes the selection of favourable sites very difficult, if not impossible.

The bore records of Inverway Station on Sturt Plateau illustrate the conditions in that area. The following records were obtained from the Manager, Mr. W. Hamel, in 1952:

Blinka Bore:
Strata 0 ft. - 90 ft. black soil and limestone,
90 ft. - 350 ft. volcanics,
350 ft.-500 ft. - limestones, etc.
Total depth - 500 ft.
Yield - 300 g.p.h.

Wingranin Bore:
Strata 0 ft. - 90 ft. black soil,
90 ft. - 250 ft. volcanics,
250 ft. - 350 ft. shales.
Total depth - 350 ft.
Yield - 1,500 g.p.h. - good water.

Bunda Bore:
Strata similar to Wingranin Bore strata.
Total depth - 320 ft.
Yield - 1,800 g.p.h. - good water.

Bohemia Bore:
Strata - limestone.
Total depth - 107 ft.
Yield - 800 g.p.h.

Killowie Bore:
Strata - limestone.
Total depth - 104 ft.
Yield - 1,800 g.p.h.

Homestead Bore:
Strata - black soil, limestone, and shale.
Total depth - 104 ft.
Yield - 1,500 g.p.h.

These bore records show that in many parts of Inverway Station as much as 90 feet of Tertiary alluvium with some Tertiary limestone or marl are underlain by volcanics, which in turn are underlain by limestone, shale, and sandstone of Victoria River Group of Upper Proterozoic age.

The volcanics in this area provide practically no supplies of water, the main supplies being obtained from the underlying sediments of Victoria River Group. Most of this water is sub-artesian, although at least one bore on Sturt Plateau yields artesian water.

Palaeozoic Sediments

Most of the Palaeozoic sediments occur in basins which form good structures for the retention of underground water. However, as most of the Palaeozoic sediments are near the coast and underlie poor pastures, the demand for underground water is not great, except on the Middle Cambrian Basins of the Negri Group, on which are good pastures. In these basins any pervious beds in the limestone and shale provide good aquifers. A study of the bores sunk on Argyle Station illustrates underground water conditions in Cambrian basins in the Region. The following are the bore logs collected from Argyle Station in 1949:—

Bore Records — Argyle Station

Bore No.	Situation (miles from Homestead)	Total Depth feet	Static water level feet	Yield by pumping g.p.h.
1.	4 W.	140	35	1200+
2.	10 N.W.	45		
3.	5 N.N.W.	42	23	1400
4.	20 N.N.E.	60	14	1300
5.	5 S.E.	160	40	1200
6.	6 S.W.	300	160	600
7.	Sutton's Hole	47	18	1300
S.R.1.	3 S. of Newry	109	21	1300
Glenowry Bore	27.2 N.N.E.	300		1200

Although some of these bores are outside the Cambrian basin, they show the general picture in the area: a fair supply of underground water is obtained from small depths.

No information was obtained about bores sunk in the Hardman Basin, but this basin probably has similar underground water conditions to those of the Argyle Basin.

No bores have been sunk in the Burt Range basin except at Cockatoo Spring at the edge, for which records are not available. At present, stock drink at the permanent waterholes in the Keep River; but underground water should be easily obtained from this basin if desired.

In the Palaeozoic sediments between Carlton and Legune there are many springs and waterholes, which supply almost enough water, although some bores have been sunk near the coast. Records of these bores have not been obtained, but as the Permian sediments dip seaward, abundant underground water should be available.

From this discussion on underground water of the Ord-Victoria

Region, it is seen that underground water is available throughout most of the Region, although conditions for selection of a favourable site differ. On the volcanics and on the Sturt Plateau selection is difficult, and bores if possible should intersect fault zones or other openings. In other places where sedimentary rocks occur, it should be possible, after an examination of the geological structure, to select favourable sites which, when drilled, will yield good supplies of underground water. It is essential for managers of Stations to realize the importance of keeping accurate records of any drilling carried out on their stations, so that the geologist, when selecting new sites for them, can refer to previous records of boring. In past years many stations in the Ord-Victoria Region have neglected to keep such records.

PETROLEUM PROSPECTS

The possibility of the occurrence of petroleum in the East Kimberleys was first seriously considered in 1920 when Mr. Oakes discovered a specimen of asphaltite near the junction of the Ord and Negri Rivers. The Oakes-Durack Kimberley Oil Company was formed and a bore was sunk on the Kelly Creek Anticline, north of Ord River Homestead, in sediments of the Middle Cambrian Negri Group. The bore began in Linnekar Limestone, passed through Nelson Shale and Headleys Limestone, and penetrate over 400 feet into Antrim Plateau Volcanics. No indications of the presence of oil were found and Wade (1924) stated that it was impossible that oil was present in commercial quantities in the Ord River area.

Specimens of asphaltite have been collected from many other localities in the area, and it is always associated with the Antrim Plateau Volcanics. It forms a black shiny residue in the vesicles and cavities in the basalt.

The origin of this asphaltite is still not certain; as Mahony (in Wade, 1924) points out, there are three possible sources:

(1) from sediments of Negri Group which have since been eroded;
(2) from the Antrim Plateau Volcanics;
(3) from the underlying Upper Proterozoic sediments of Victoria River Group.

Wade is of the opinion that the asphaltite is an oil residue from the Negri Group.

One occurrence of asphaltite was examined by Dr. Öpik and the writer in 1949 at Pompey Springs, 15 miles N.N.E. of Mistake Creek Homestead. At this locality there are a number of water seepages along a fault line in the Antrim Plateau Volcanics, and on the margins of the seepages and in the neighbouring outcrops of vesicular basalt a shiny black coating of asphaltite has been deposited. The water of the seepages is of a dark colour and appears to be bringing up the oil residue. The nearest outcrops of Negri Group are at least 10 miles south-west; so in this locality the asphaltite had its origin either in the Antrim Plateau Volcanics or the underlying Victoria River Group. The waters of the seepages are not noticeably warm, so they do not come from a great depth. The most likely explanation is that the oil originated from the dark shales of the Victoria River Group, which contain remnants of some life, and were sealed by the layer of Antrim Plateau Volcanics.

Neither source postulated for the origin of the asphaltite improves the possibilities of a commercial supply of petroleum from this area, unless oil from Lower Cambrian or Precambrian rocks is envisaged.

The discovery of the great thickness of Palaeozoic sediments in the Bonaparte Gulf Basin once again revived the search for oil.

The thickness and lithology of the Palaeozoic sediments are:

Permian	Port Keats Group	1,500+ft sandstone, conglomerate, shale, and limestone
	Weaber Group	2,000 ft sandstone, conglomerate, and limestone.
Carboniferous	Septimus Limestone	350+ft limestone and calcareous sandstone.
	Enga Sandstone	1,000 ft sandstone
Devonian	Burt Range Limestone	4,000 ft limestone, shale, and calcareous sandstone.
	Cockatoo Sandstone	3,000 ft sandstone.
Ordovician	Pander Greensand	550+ft greensand.
Cambrian	Clark Sandstone	600+ft sandstone
	Pretlove Sandstone	400+ft sandstone
	Skewthorpe Formation	600+ft limestone, shale, and calcareous sandstone.
	Hart Spring Sandstone	600+ft sandstone, limestone, and shale.

The total thickness of the Palaeozoic sediments in the Bonaparte Gulf Basin is about 15,000 ft; but the thickness of Palaeozoic sediments in any one locality may not be more than 5,000 feet. An explanation of this is shown in Figure 7.

In the Burt Range there are no Cambrian sediments, and the Upper Devonian sediments overlie Antrim Plateau Volcanics. In the Carlton Basin, Devonian sediments overlie the Cambrian and Ordovician Carlton Group, but no late Palaeozoic sediments have been found.

Also, throughout the Bonaparte Gulf Basin, the distribution of Permian sediments in no way reflects the distribution of older Palaeozoic sediments, and in some places the Permian sediments directly overlie Precambrian rocks.

In the Burt Range Basin, the possible source rocks of Burt Range Limestone are overlain by possible reservoir sediments of Enga Sandstone. Unfortunately these are exposed throughout most of the Burt Range, and only in a very small area are they capped by Septimus Limestone. To the north of the Burt Range, the Septimus Limestone, capped by sandstones of the Weaber Group, dips below the alluvium of the Keep Plain, and it is in this area that at least the three requirements of source, reservoir, and seal may be found. Geophysical methods will be required to investigate structure.

In the Carlton Basin, complex strike-faulting makes estimation of the actual thickness of Palaeozoic sediments at any one locality impossible, and the fault blocks of Cambrian sediments are not regarded as oil prospects. Farther north-west, east of Ninbing, the Upper Devonian Burt Range Limestone, a possible source of oil, is overlain by sediments of the Weaber Group; but how far the Burt Range Limestone extends east below the Weaber Group is unknown. No trace of it has been discovered on the eastern side of the Permian sediments near Legune, where they overlie Precambrian sediments. Consideration must be given to the possibility of off-shore drilling in Joseph Bonaparte Gulf. Fig. 33 shows the contours of the sea bottom, but no indication of the distribution of stratigraphical units was gleaned from the study of soundings.

Reeves (1948) discovered granite boulders near the littoral, north-north-east of Cleanskin Bore. If these boulders were derived from a shallow basement of granite, the thickness of Palaeozoic sediments must be very limited. But it is possible that the granite boulders were derived from glacial or fluvio-glacial Permian sediments, and do not restrict the expected thickness of Palaeozoic sediments.

The whole Bonaparte Gulf Basin, although only slightly folded, has been severely faulted. No traces of oil have been found at any of these faults at the surface or in any water issuing from springs and seepages. Very few fold structures are found in the basin, although numerous fault blocks could provide oil traps.

An important discovery in 1952 was the occurrence of Volcanics in the lower portion of Weaber Group, but they have a very restricted distribution.

In conclusion, it is the writer's opinion that, on present knowledge of stratigraphical units and their distribution in the Bonaparte Gulf Basin, the possibility of finding an oilfield is slight; but the Keep River area warrants further investigation.

Bauxite

Many thousand square miles of Antrim Plateau Volcanics have been lateritized, and the possibility of the occurrence of aluminous laterite was investigated. Eighteen samples were collected from different horizons in the laterite profiles in the vicinity of Willeroo, Wave Hill, and Birrindudu.

Analysis of the samples showed that the silica content ranged from 26 per cent. to 70 per cent. and the ignition loss ranged from 6 to 11 per cent. The high silica content and low ignition loss show that these samples did not contain any aluminous laterite which could be considered a bauxite ore.

Ochre

A small quantity of red ochre is mined at irregular intervals from a deposit at the top of a hill 8 miles west of Alligator Spring and 2 miles

Figure 34—Ochre Mine, 8 miles west of Alligator Spring

north of the Legune Track. This deposit occurs in arenaceous sediments of Weaber Group.

A small open cut about 15 feet deep and 8 feet to 10 feet wide has been dug in the deposit. The ochre is blasted at the face and shovelled into 44 gallon drums which are loaded on to trucks and hauled to the port of Wyndham, 120 miles away, and shipped to Perth.

No estimates of reserves were made. However, the deposit was traced for some hundreds of feet to the west, and, at the present rate of mining, should be sufficient for many years. At least 30 full drums were seen at the mine and many more were awaiting shipment at Wyndham.*

The origin of this ochre is not definitely known. On the eastern side of the deposit is a large fault which may have introduced the iron oxides, but more probably they form a sedimentary lens deposit in Nigli Gap Sandstone. The occurrence of a questionable plant stem in the ochre supports this latter view.

The very limited demand for red ochre in Australia, the low prices, and the isolation, make this deposit more of scientific interest than of economic value.

ACKNOWLEDGEMENTS

The writer gratefully acknowledges the assistance and co-operation of all members of the Land Research and Regional Survey Unit, especially G. A. Stewart, R. A. Perry, S. J. Paterson, R. O. Slatyer, and Miss J. A. Clark. Sincere thanks are tendered to the owners and managers of many stations in the Region for their hospitality and information.

Figures 13 and 28 are reproductions of aerial photographs published with permission of the Royal Australian Air Force. The base maps were prepared by National Mapping Section, Department of the Interior.

*The only figures available for production are for the first Quarter 1953, when 20.61 tons valued at £329/7/9d. were recorded.

REFERENCES.

BLATCHFORD, T., 1922.—Interim report on the oecurrence of glance pitch near the junction of the Negri and Ord Rivers, known as "Oakes' Find". *Geol. Surv. W. Aust. Ann. Rep.* 1927, 20-22.

BLATCHFORD, T., 1927.—The Geology of portions of the Kimberley Division, with special reference to the Fitzroy Basin and the possibilities of the occurrence of mineral oil. *Geol. Surv. W. Aust. Bull.* 93.

BLATCHFORD, T., 1928.—Geological observations made while travelling in West Kimberleys up the valleys lying between the Pentecost and King Rivers, then eastward across the Denham and Ord Rivers as far as Argyle Station on the Behn River. *Geol. Surv. W. Aust. Ann. Rep.* 1927, 10-15.

BOWLEY, H., 1926.—Analyses of the silver lead ores. *Chem. Br., Dep. Min. W. Aust., Ann. Rep.* 1926, 15.

BROWN, H. Y. L., 1895.—Government Geologist's report on explorations in the Northern Territory. *S. Aust. Parl. Pap.* 82.

BROWN, H. Y. L., 1906.—Explorations made by the Government Geologist and staff during 1905. *S. Aust. Parl. Pap.* 55.

BROWN, H. Y. L., 1908.—Government Geologist's reports on the Tanami gold country. *S. Aust. Parl. Pap.*

BRUNNSCHWEILER, R. O., 1951.—Notes on the geology of Dampier Land, North Western Australia. *Aust. J. Sci.*, 14, 6-8.

BRUNNSCHWEILER, R. O., 1954a.—Geology of Dampier Peninsula, North Western Australia. *Bur. Min. Resour. Aust. Rep.* 13 (in press).

BRUNNSCHWEILER, R. O., 1954b.—Additions to the Mesozoic stratigraphy of North Western Australia. *J. geol. Soc. Aust.*, 1, 35.

BRYAN, W. H., and JONES, O. A., 1946.—The geological history of Queensland; a stratigraphical outline. *Univ. Qd. Paps. Dep. Geol.*, n.s. 2 (12), 103.

CARROLL, D., 1947.—Heavy residues of soils from the lower Ord River Valley, Western Australia. *J. sediment. Petrol* 17 (1), 8.

CHAPMAN, F., 1924.—On the age and contents of limestone specimens from the Negri Series, Kimberley Division. *Geol. Surv. W. Aust. Ann Rep.* 1924, 31.

CHAPMAN, F., 1937.—Cherty limestone with *Planorbis* from the Mt. Elder Range, Western Australia. *Proc. roy. Soc. Vict.*, 50, 59-66.

CLARKE, E. de C., 1931.—Precambrian succession in some parts of Western Australia. *Rep. Aust. Ass. Adv. Sci.*, 20, (Brisbane, 1930), 155-192.

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

CRESPIN, I., 1953.—Lower Cretaceous Foraminifera from the Great Artesian Basin, Australia. *Contr. Cushman Fdn*, 4 (1).

CROCKFORD, J., 1943.—Bryozoa from the Port Keats bore, Northern Territory. *Proc. Linn. Soc. N.S.W.*, 68, 145-148.

DAVID, T. W. E., 1932.—EXPLANATORY NOTES TO ACCOMPANY A NEW GEOLOGICAL MAP OF THE COMMONWEALTH OF AUSTRALIA. London, Arnold.

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

EDWARDS, A. B., and CLARKE, E. de C., 1940.—Some Cambrian basalts from the East Kimberley, Western Australia. *J. roy Soc. W. Aust.*, 26, 77-94.

ETHERIDGE, R. (in Brown 1895).—Official contributions to the Palaeontology of South Australia. *S. Aust. Parl. Pap.* 82, 33-34.

ETHERIDGE, R., 1896.—Official contributions to the Palaeontology of South Australia. *S. Aust. Parl. Pap.* 127, 13-16.

ETHERIDGE, R., 1907.—Official contributions to the Palaeontology of South Australia. *S. Aust. Parl. Pap.* 55.

FAIRBRIDGE, R. W., 1948.—The juvenility of the Indian Ocean. *Scope (J. Sci. Un., Univ. W. Aust.)*, 1 (3), 29-35.

FAIRBRIDGE, R. W., 1950.—Problems of Australian geotectonics. *Ibid.*, 1 (5), 22-28.

FAIRBRIDGE, R. W., 1951.—The Aroe Islands and the continental shelf north of Australia. *Ibid.*, 1 (6), 25-28.

FAIRBRIDGE, R. W., 1953.—AUSTRALIAN STRATIGRAPHY. Univ. W. Aust. Text Book Board.

FARQUHARSON, R. A. (in Blatchford) 1922.—Report upon the occurrence of glance pitch at Oakes' Find. *Geol. Surv. W. Aust. Ann. Rep.* 22-23.

FINUCANE, K. J., 1938.—The Halls Creek - Ruby Creek area, East Kimberley District. *Aer. Surv. N. Aust., W. Aust. Rep.* 27.

FINUCANE, K. J., 1939a.—The Grants Greek gold mining centre, East Kimberley District. *Ibid.*, 40.
FINUCANE, K. J., 1939b.—The Twelve Mile Alluvial workings and Elvire dredging reserves (893M and 948M), Halls Creek, East Kimberley Division. *Ibid.*, 42.
FINUCANE, K. J. and SULLIVAN, C. J., 1939.—The Mary River gold mining centre, East Kimberley District. *Ibid.*, 41.
GLOVER, J. E., 1948.—Petrological description of eleven samples from a bore on the Victoria River Downs Station. *Bur. Min. Resour. Aust.* (unpubl.)
GUPPY, D. J., and LINDNER, A. W., 1954.—An introductory note on the Upper Proterozoic sequence of the Kimberley Plateau, Western Australia (in press).
GUPPY, D. J. and ÖPIK, A. A., 1950.—Discovery of Ordovician rocks, Kimberley Division, Western Australia. *Aust. J. Sci.*, 12, 205-206.
HARDMAN, E. T., 1885.—Report on the geology of the Kimberley District, Western Australia. *W. Aust. Parl. Pap.* 34.
HILLS, E. S., 1946.—Some aspects of the tectonics of Australia. *J. roy. Soc. N.S.W.*, 79, 67-91.
HOBSON, R. A., 1930.—"Zebra Rock" from the East Kimberley. *J. roy Soc. W. Aust.*, 57-70.
HOBSON, R. A., 1936.—Summary of petroleum exploration in Western Australia to January, 1935. *Geol. Surv. W. Aust. Ann. Rep.* 1935.
HOSSFELD, P. S., 1937a.—The Fletchers Gully area, Daly River District. *Aer. Surv. N. Aust. Rep. N. Terr.* 17.
HOSSFELD, P. S., 1937b.—The tin deposits of the Buldiva-Collia area, Daly River District. *Ibid.*, 18.
IVANAC, J. F., 1954.—The geology and mineral deposits of the Tennant Creek Gold-Field, N. T. *Bur. Min. Resour. Aust., Bull.* 22.
JACK, R. L., 1906.—The prospects of obtaining artesian water in the Kimberley district. *Geol. Surv. W. Aust. Bull.* 25.
JENSEN, H. I., 1915.—Geological report on the country between Pine Creek and Tanami. *Bull. N. Terr.* 14.
LARCOMBE, C. O. G., 1925.—Rock specimens from Ord River and Oakover River. *Geol. Surv. W. Aust. Ann. Rep.* 1924, 19.
LARCOMBE, C. O. G., 1927.—Some rocks from four miles east of Argyle Station, Ord River, King District, Kimberley division. *Ibid.*, 1926, 23-24.
MAITLAND, A. GIBB, 1903.—Water supply, Wyndham. *Dep. Min. W. Aust. Ann. Rep.* 1902, 20.
MAITLAND, A. GIBB, 1920.—Note on the specimen of supposed bitumen from Turkey Creek, Kimberley division. *Ibid.* 1920, 8.
MATHESON, R. S., 1951.—Ground water supplies, Rosewood and Argyle Stations, East Kimberleys, Western Australia. (Unpub.).
MATHESON, R. S., and TEICHERT, C., 1948.—Geological reconnaissance in the eastern portion of the Kimberley Division, Western Australia. *Dep. Min. W. Aust. Ann. Rep.* 1945, 73.
MATHESON, R. S. and GUPPY, D. J., 1949.—Geological reconnaissance in the Mount Ramsay area—Kimberley Division, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1949/31 (Unpub.).
MAWSON, D., and SPRIGG, R. C., 1950.—Subdivision of the Adelaide System. *Aust. J. Sci.*, 13, 69.
NOAKES, L. C., 1949.—A geological reconnaissance of the Katherine-Darwin Region, Northern Territory. *Bur. Min. Resour. Aust. Bull.* 16.
NOAKES, L. C., 1953.—The structure of the Northern Territory with relation to mineralization. In Geology of Australian Ore Deposits, *Vth Emp.* Min. Metall. Congr., 284.
NOAKES, L. C., ÖPIK, A. A., and CRESPIN, I., 1952.—Bonaparte Gulf Basin, North Western Australia: a stratigraphical summary with special reference to the Gondwana System. *Cong. Int. Géol. XIXième Sess. Alger*: Symposium sur les series de Gondwana. 91-106.
ÖPIK, A. A., 1950.—Notes on Palaeozoic stratigraphy, Cambrdige Gulf area. *Bur. Min. Resour. Aust. Rec.* 1950/13, (Unpub.).
OWEN, H. B., 1955.—Bauxite in Australia. *Bur. Min. Resour. Aust. Bull.* 24.
PATERSON, S. J., 1954.—General report of the survey of the Ord-Victoria Area: Geomorphology. *Sci. Ind. Res. Org. Melb., Land Res. Ser.*, 4 (in preparation).
PRESCOTT, J. A. and PENDLETON, R. L., 1952.—Laterite and Lateritic soils. *Commwlth. Bur. Soil Sci. Tech. Comm.* 47.
REEVES, F., 1948.—Report on geology and oil possibilities of the Bonaparte Gulf Basin. *Private Report for Standard Vacuum Ltd.* (Unpub.).

REEVES, F., 1951.—Australian oil possibilities. *Bull. Amer. Ass. Petrol. Geol.*, 35, 2479-2525.
SIMPSON, E. S., 1921.—Bitumen, Texas Station, Kimberley Division. *Geol. Surv. W. Aust. Ann. Rep.* 1920, 23.
SLATYER, R. O., 1954.—General report of the survey of the Ord-Victoria Area: Climate. *Sci. Ind. Res. Org., Melb., Land Res. Ser.* No. 4 (in preparation).
STEWART, G. A., 1954.—Idem: Soils. *Ibid.*
SUTTON, A. H., 1938.—Taxonomy of Mississippian Productidae. *J. Paleont.*, 12 (6), 537-569.
TALBOT, H. W. B., 1910.—Geological observations in the country between Wiluna, Halls Creek and Tanami. *Geol. Surv. W. Aust. Bull.* 39.
TENISON-WOODS, J. E., 1886.—Report of the geology and mineralogy of the Northern Territory. *S. Aust. Part. Pap.* 122.
TRAVES, D. M., 1949.—Preliminary report on survey of Ord-Victoria Region, Northern Australia Regional Survey. *Bur. Min. Resour. Aust. Rec.* 1949/22 (unpub.).
TRAVES, D. M., 1953.—A study of underground water at Wave Hill, Northern Territory. *Ibid.* 1953/91 (unpub.).
TRAVES, D. M., 1954.—*Collenia frequens* in Upper Proterozoic Rocks of the Northern Territory of Australia. *Proc. Linn. Soc. N.S.W.*, 79 (3-4), 95.
UMBGROVE, J. H. F., 1947.—THE PULSE OF THE EARTH. The Hague, Nijhoff. 2nd rev. ed., p. 358.
VOISEY, A. H., 1938.—Notes on the stratigraphy of the Northern Territory of Australia, with special reference to the Jurassic System. *J. roy. Soc. N.S.W.*, 72, 136-159.
WADE, A., 1924.—Petroleum prospects, Kimberley District of Western Australia and Northern Territory. *Geol. Surv. W. Aust., Parl. Pap.* 142, 1924.
WARD, L. KEITH, 1950-1951.—Underground water in Australia. *Chem. Engng Min. Rev.*, Oct. 1950 - May, 1951.
WELLS, L. A., 1907.—The Victoria River and the adjacent country. *S. Aust. Parl. Pap.*
WHITEHOUSE, F. W., 1940.—Studies in the late geological history of Queensland. 5. The climates of Queensland since Miocene times. *Univ. Qd. Pap. Dep. Geol.*, n.s., 2 (1), 62-72.
WOODWARD, H. P., 1891.—Report on the gold fields of the Kimberley District, Western Aust. *W. Aust. Parl. Pap.* 18.
WOOLNOUGH, W. G., 1912.—Report on the Geology of the Northern Territory. *Bull. N. Terr.* 4.

APPENDIX A.

DESCRIPTION OF SELECTED ROCK SPECIMENS FROM THE ORD-VICTORIA REGION

by J. E. Glover

PETROGRAPHY OF SPECIMENS FROM LOWER PROTEROZOIC HALLS CREEK METAMORPHICS.

Specimen R 6007
(Volcanic rock in Halls Creek Metamorphics)

Hand-specimen

The rock is dark grey-green and porphyritic, with light grey euhedral plagioclase phenocrysts in a dark grey-green fine-grained to aphanitic groundmass in which minute felspar laths and irregular dark green serpentine patches can be seen.

Thin section

Phenocrysts up to 1.5 mm long of plagioclase (An_{40}-An_{47}) make up 10% of the rock: the groundmass consists of randomly oriented minute (0.25 mm long) plagioclase laths, colourless augite grains ($2V \simeq 50°$, $Z \wedge C \simeq 42°$), and brown, partly devitrified glass. In a few rare grains of augite $Z \wedge C = 24°$. Plagioclase, both in phenocrysts and groundmass, is altered to sericite, and augite is locally converted to chlorite. About 10% of the rock is made up of irregularly shaped antigorite clots, most surrounded by a narrow chalcedonic rim; some of the clots appear to be infillings of former vesicles. Black iron-ore granules, probably magnetite, are distributed throughout. Overall composition of the specimen is as follows:

Calcic andesine (phenocrysts and groundmass)	25%
augite	10%
brown glass	50%
antigorite	10%
black iron ore	5%

The rock is andesite.

Specimen R 6008

Hand-specimen

The rock is brown, with grey idioblastic andalusite porphyroblasts up to 4 mm long in a brown fine-grained micaceous and schistose groundmass.

Thin section

Idioblastic, completely sericitized, andalusite porphyroblasts of average length 3 mm lie in a fine-grained, poorly decussate to lepidoblastic groundmass. Porphyroblasts make up about 10% of the rock and their sericitization may have been due to retrograde metamorphism. The groundmass comprises finely divided quartz (50%), sericite flakes (30%) and ragged, bleached, somewhat pleochroic flakes of brown biotite (20%).

The rock is andalusite-biotite-sericite schist.

Specimen R 6009

(Volcanic rock in Halls Creek Metamorphics)

Hand-specimen

The rock is dark grey-green and porphyritic, with abundant light grey plagioclase phenocrysts in a dark grey aphanitic groundmass.

Thin Section

The rock is porphyritic with subhedral to euhedral highly altered plagioclase (An_{45} as nearly as can be determined) in a pale green microcrystalline groundmass. Phenocrysts, all partly altered to carbonate, attain 5 mm in length, make up 30% of the rock, and have a roughly parallel alignment. The groundmass consists of finely disseminated chlorite flakes, carbonate granules, minute plagioclase laths, and black iron ore. Larger aggregates of granular carbonate commonly replace both phenocrysts and groundmass, and carbonate veins locally traverse the rock. A common association in the groundmass is that of leucoxene with chlorite clots. Composition of the groundmass is chlorite 50%, carbonate 30%, felspar 15%, ilmenite and leucoxene 5%.

The rock is andesite.

Specimen R 6010

(Volcanic rock in Halls Creek Metamorphics)

Hand-specimen

The rock is dark grey-green, amygdaloidal and porphyritic. About 10% of the rock is made up of light grey plagioclase phenocrysts, about 15% of ovoid grey and brown amygdales: the groundmass is dark grey-green and aphanitic.

Thin section

Euhedral to subhedral phenocrysts up to 3 mm long of finely twinned sodic to intermediate oligoclase, extensively altered to carbonate, are common. They are in a groundmass of minute (0.1-0.2 mm long) plagioclase laths, black iron ore, cloudy epidote granules, and pale green chlorite. Chlorite constitutes about 80% of the groundmass, and is probably an alteration product of glass. Ovoid carbonate amygdales, commonly stained brown near the core by iron oxide, attain diameters of up to 5 mm.

The rock is amygdaloidel andesite.

Specimen R 6011

Hand-specimen

The rock is fine-grained, dark grey and holocrystalline: it consists mainly of randomly oriented hornblende crystals and a little quartz.

Thin section

Aggregates of somewhat fibrous hornblende, moderately pleochroic from pale green to green, with Z $\wedge$ C $\simeq$ 18°, and generally with decussate texture, make up 80% of the rock. Quartz and possibly albite granules are scattered throughout, in places as small, irregular but somewhat linear bands. Granules of black iron ore are present.

The rock is amphibolite.

Specimen R 6012

Hand-specimen

The rock is metamorphic with euhedral to anhedral light grey blastophenocrysts up to 2 mm long, and less common grey quartz euhedra and anhedra up to 1 mm long, in a grey-brown aphanitic groundmass. Some anhedral grains of the light grey mineral (determined in thin section as sericitized felspar) have curved surfaces, and some otherwise euhedral quartz grains have small embayments in them.

Thin section

Texture of the rock is blastoporphyritic with large aggregates of sericite pseudomorphing felspar (probably plagioclase) phenocrysts, the long axes of the pseudomorphs being more or less parallel. Most blastophenocrysts are euhedral, some are angular, and others again have curved outlines. Large quartz grains vary from almost euhedral habit to highly irregular shapes. Embayments in the euhedra suggest partial resorption of the grains into an igneous groundmass, whereas quartz anhedra may have been introduced into the rock during metamorphism. The groundmass of the rock is made up of sericite and quartz, with here and there irregular lenticular aggregates of green biotite and chlorite, the lenses being approximately parallel to the preferred orientation of sericite pseudomorphs. A quartz vein traverses the slide, and much, perhaps most, of the quartz in the groundmass was introduced.

Texture and mineralogy indicate a metamorphosed tuffaceous acid to intermediate rock.

PETROGRAPHY OF SPECIMENS FROM LOWER PROTEROZOIC LAMBOO COMPLEX

Specimen R 6013

Hand-specimen

The rock is grey, holocrystalline and porphyritic, with euhedral white orthoclase phenocrysts up to 3 cm long in a coarse groundmass of grey quartz, pale green altered plagioclase, black biotite, and orthoclase. Texture of the groundmass is hypidiomorphic granular.

Thin section

The rock is porphyritic with phenocrysts of locally perthitic orthoclase (50%) set in a hypidiomorphic granular mass of sericitized plagioclase (15%), quartz (20%), microcline (5%), orthoclase (5%), and chloritized biotite (5%). Vermicular inter-growths of quartz are present in orthoclase, and are most obvious near borders of phenocrysts.

The rock is porphyritic biotite granite.

Specimen R 6014

Hand-specimen

The specimen is grey, holocrystalline, and porphyritic, with light grey euhedral phenocrysts of orthoclase over 2 cm long in a coarse-grained hypidiomorphic granular groundmass of quartz, biotite, orthoclase, and plagioclase. Biotite is common as poikilitic inclusions in orthoclase phenocrysts. Composition is about as follows: orthoclase 65%, quartz 15%, biotite 10%, plagioclase 10%.

Thin section

In the thin section studied, the specimen is mainly made up of one orthoclase phenocryst containing poikilitic brown biotite inclusions and vermicular intergrowths of quartz, the latter being most abundant toward the borders of the phenocryst. The biotite has pleochroic halos. Other constituents are quartz and plagioclase (sodic andesine).

The rock is porphyritic biotite granite.

Specimen R 6015

Hand-specimen

The rock is grey, holocrystalline, and porphyritic, with grey ovoid felspar phenocrysts approaching 2 cm in diameter containing poikilitic biotite inclusions, in a coarse-grained groundmass made up of dark green biotite, quartz, and white felspar.

Thin section

The rock is porphyritic with ovoid microcline phenocrysts in an allotriomorphic granular groundmass of sodic andesine, quartz, biotite and muscovite. Phenocrysts exhibit poikilitic texture enclosing small grains of plagioclase, biotite, and muscovite, and contain vermicular quartz, the latter being concentrated mainly on borders of phenocrysts. Biotite commonly has pleochroic halos. Composition of the rock is as follows: microcline 35%, quartz 30%, sodic andesine 25%, biotite 8%, muscovite 2%.

The rock is porphyritic biotite-microcline-quartz monzonite.

PETROGRAPHY OF SPECIMENS FROM LOWER (?) PROTEROZOIC VOLCANICS.

Specimen R 6016

Hand-specimen

The rock is porphyritic, with euhedral, subhedral, and anhedral phenocrysts of grey quartz (average length 1-2 mm) and pink felspar (average length 5 mm) in a dark grey aphanitic groundmass. Phenocrysts make up about 15% of the rock.

Thin section

Phenocrysts of anhedral to subhedral quartz, commonly showing minor resorption into the groundmass, and of kaolinized and fractured plagioclase (sodic oligoclase), also showing resorption, are abundant. Orientation of phenocrysts is random. Angular fragments of these minerals are also common.

The groundmass is mainly siliceous but is not uniform in texture. One area of the slide comprises partly devitrified brown glass shards that are bent round phenocrysts, and spherulitic chalcedony. This area is separated sharply from the rest of the groundmass, made up of fine-grained to microcrystalline silica, and slender arcuate brown-rimmed colourless shards replaced by very finely granular quartz. Shards are bent and highly contorted near phenocrysts. Several areas of groundmass showing other minor variations in texture, sharply separated from each other, can be distinguished. Throughout, except where contorted, shards generally have a preferred orientation. Iron ore, chlorite, and epidote are minor constituents.

The rock is a rhyolite tuff. Contortion and compression of shards in many places, particularly next to phenocrysts, show that vitreous constituents were plastic when deposited, becoming bent and compressed by weight of succeeding material. The rock is therefore a very strongly welded rhyolite tuff.

Specimen R 6017

Hand-specimen

The rock is porphyritic with anhedral dark-grey quartz phenocrysts (1 mm diameter), light-grey and light grey-green highly altered plagioclase phenocrysts (up to 5 mm long), and dark grey subhedral ferromagnesian phenocrysts (1 mm diameter), in a dark grey aphanitic groundmass.

Thin section

The rock contains euhedral felspar phenocrysts, some with remnants of multiple and simple twinning, set in a finely granular and silicified groundmass. Felspar phenocrysts are plagioclase with perhaps some orthoclase, but extensive alteration to sericite, chlorite, epidote, and zoisite precludes their precise determination. Unusually shaped "phenocrysts" of quartz are common—most, but not all, can be shown to have replaced aggregates of a lath-shaped mineral, probably felspar. Chlorite clots appear, from their shape, to be secondary after ferromagnesian phenocrysts.

The finely granular and silicified groundmass contains minute granules of epidote, zoisite, chlorite, and accessory iron ore, mainly ilmenite with some leucoxene.

The indeterminate composition of felspar phenocrysts and uncertainty concerning the presence of primary quartz prevents exact naming of the rock. It is a highly altered silicified volcanic rock of acid to intermediate composition.

PETROGRAPHY OF SPECIMENS FROM UPPER PROTEROZOIC GABBRO AND DOLERITE.

Specimen R 6018

Hand-specimen

Under the hand lens the rock is seen to be medium-grained to fine-grained and holocrystalline, with white plagioclase and dark green pyroxene apparently associated in sub-ophitic texture. Overall colour is dark grey.

Thin section

The rock is composed essentially of colourless to very pale brown pyroxene (47%) and plagioclase (50%) and has a sub-ophitic to ophitic texture. Pyroxene varies considerably in optical properties, and is pigeonitic or subcalcic augite perhaps grading into augite, as the following properties show: 2V (+) variable (25° to at least 40°); $Z \wedge C = 28°$ to $> 40°$, but mainly between 28° and 35°. The mineral is locally altered to chlorite. The plagioclase varies from basic andesine to sodic labradorite and is in places made over to a cloudy aggregate, probably of sericite and epidote. Black iron ore (probably ilmenite) is scattered throughout the rock as small granules.

The rock is dolerite.

Specimen R 6019

(Sedimentary rock in contact with specimen R 6020)

Hand-specimen

The rock is pink with irregularly shaped pale green patches unevenly distributed throughout, and is medium-grained and well consolidated. Well sorted subangular quartz grains make up 70% of the specimen.

Thin section

The main constituent of this rock is clastic quartz as fairly well sorted subangular grains of average diameter 0.4 mm. Cement is fairly abundant and is of two types, namely very pale green plumose muscovite, and felspar. The felspar, almost completely altered to a clay mineral that has been stained red-brown, is intergrown granophyrically with quartz, and owes its presence to partial felspathization of the sediment. The plumose structure in muscovite indicates recrystallization of original cementing media of the rock.

The rock is a felspathized medium-grained sandstone.

Specimen R 6020

Hand-specimen

The rock is grey, holocrystalline, medium to coarse in grain, and has hypidiomorphic granular texture. White plagioclase and a dark green ferromagnesian mineral can be distinguished, and between them make up most of the rock.

Thin section

The rock is composed mainly of plagioclase (60%) and monoclinic pyroxene (35%) and has a hypidiomorphic granular texture. The plagioclase is fairly fresh calcic labradorite, locally kaolinized and sericitized. Two varieties of monoclinic pyroxene are present, namely: colourless to very pale brown non-pleochroic pyroxene with 2V (+ve) = 0° - 5° and $Z \wedge C$ = 29° - 31° (pigeonite), and colourless to very pale brown non-pleochroic pyroxene with 2V (+ve) ≏ 55° and $Z \wedge C$ ≏ 43° (augite). Pigeonite is the more abundant, and both varieties are generally fresh but locally altered to brown biotite and pale green biotite. Interstitial quartz is a minor constituent, and apatite, ilmenite, and zircon are accessories.

The rock is gabbro.

Specimen R 6021

Hand-specimen

The rock is grey and holocrystalline, with a poorly hypidiomorphic granular texture and an average grain size of 2 mm. Light grey plagioclase and a dark grey ferromagnesian mineral are distinguishable with the hand lens.

Thin section

Texture of the rock is poorly hypidiomorphic granular, and constituent minerals are as follows: calcic labradorite (60%), hypersthene (25%), augite (10%), biotite (4%), black iron ore (1%). Hypersthene has a fine lamellar structure, and is noticeably pleochroic from pink to green, and augite is very pale brown and non-pleochroic with $Z \wedge C = 45°$. Grains of both pyroxenes are here and there rimmed by brown biotite, and locally they are altered to chlorite.

The rock is hypersthene gabbro.

Specimen R 6022

Hand-specimen

The specimen is dark grey, heavy and holocrystalline, with a fine sugary texture. Plagioclase and a dark green ferromagnesian mineral can be distinguished with the hand lens.

Thin section

This rock has a sugary texture over much of the thin section, and is finer grained than specimen R 6021. Main constituents are plagioclase (labradorite-bytownite) and proxene (hypersthene, slightly pleochroic from very pale green to very pale orange, with 2V (-ve) = 80° - 90°, a few grains of which have fine lamellar structure; and colourless augite with 2V (+ve) ≏ 50° and $Z \wedge C = 45°$). Black iron ore and biotite are accessories. The approximate composition is plagioclase 60%, pyroxene 35%, accessories 5%.

The rock is hypersthene gabbro.

Specimen R 6023

Hand-specimen

The rock is dark grey holocrystalline with hypidiomorphic granular texture, and is made up of euhedral, white to pale green, apparently saussuritized grains of plagioclase up to 1.5 mm long, and a dark green ferromagnesian mineral, locally light green from conversion to chlorite.

Thin section

The rock has a hypidiomorphic granular texture and is made up of pliagioclase (andesine), normally strikingly euhedral, with many grains almost completely converted to a sericite-chlorite-(?)zoisite aggregate; augite ($2V \doteq 50°$; $Z \wedge C = 49°$) locally altered to chlorite and also commonly euhedral; interstitial quartz and skeletal ilmenite and epidote granules as accessories. Composition of primary minerals is plagioclase 59%, augite 35%, quartz 5%, accessories 1%.

The rock is augite-quartz diorite.

Specimen R 6024

Hand-specimen

The rock is dark grey-green, holocrystalline and medium-grained. Under the hand lens, texture appears hypidiomorphic granular and the following minerals can be seen: grey to pale green plagioclase, dark green ferromagnesian minerals, minor quartz and pyrite.

Thin section

Essential constituents of the rock, which has hypidiomorphic granular texture, are plagioclase (65%), hornblende (23%) and quartz (7%). Plagioclase (An_{50}) is converted to a fine aggregate of sericite, epidote, and zoisite, and all hornblende crystals are at least partly chloritized. Unaltered hornblende is strongly pleochroic from green, through pale green, to very pale yellow-green, with absorption $Z > Y > X$, and with $Z \wedge C \doteq 16°$. Skeletal ilmenite altering to leucoxene, and minor pyrite and apatite, are the remaining constituents.

The rock is hornblende-quartz diorite.

Discussion of Petrology of Upper Proterozoic Igneous Rocks.

Edwards (1942) has examined 35 specimens of basaltic rock of Nullagine (i.e. Upper Proterozoic) age that display marked uniformity of petrological character, from the North Kimberley region.

All but one of analysed specimens are saturated with respect to silica, or nearly so, and chemically they have many features in common with Kennedy's tholeiitic basalt (Kennedy, 1933). Mineralogically the rocks are related to tholeiites and their derivatives, and form a distinctly calc-alkaline suite grading toward andesites rather than toward the more alkaline types accompanying olivine basalts. Dolerites and andesine basalts contain two pyroxenes (augite with (+) 2V > 45°, pigeonite with (+) 2V = 0° - 10°), and some dolerites contain intersertal patches of granophyric quartz and orthoclase.

Mineralogy of Upper Proterozoic igneous rocks from the Ord-Victoria area that have been examined miscroscopically indicates derivation from a tholeiitic magma with calc-alkaline differentiates. Deep erosion has exposed hypabyssal and plutonic rocks (dolerite, gabbro) probably approximating in composition to the original magma, and calc-alkaline rocks (diorites) that may be differentiates of it. Kennedy's mineralogical criteria of tholeiitic basalts, as contrasted with olivine basalts, include absence of olivine, prevalence of pigeonitic pyroxene and common presence of a glassy or quartzo-felspathic residuum. According to Turner & Verhoogen (1951, p. 178), a common association in coarse tholeiites (presumably products of relatively slow cooling) is pigeonite (2V very small) with diopsidic augite (2V = 45° - 55°); in finer grained, more rapidly chilled rocks a single, probably metastable pyroxene, sub-calcic augite (2V = 30° - 45°), is more typical. Turner points out that though pigeonites and sub-calcic augites are probably more widely prevalent in tholeiitic than in olivine basalts, they are known and may perhaps prove to have wide distribution in the latter series.

Six Upper Proterozoic igneous rocks are described above, and four of them (dolerite and gabbro) may approximate to the original magma type. Olivine is absent from all rocks; specimen R 6018 (dolerite) contains pigeonitic or sub-calcic augite (2V (+) variable, 25° to at least 40°, $Z \wedge C$ = 28° to > 40°); specimen R 6020 (gabbro) contains pigeonite (2V (+) = 0° - 5°, $Z \wedge C$ = 29° - 31°), augite (2V (+) $\simeq$ 55°, $Z \wedge C$ $\simeq$ 43°) and minor interstitial quartz.

In specimen R 6021 (gabbro) the pyroxenes are augite and finely lamellar hypersthene, and in specimen R 6022 (gabbro) the pyroxenes are augite and hypersthene with a few grains of the latter showing poorly developed fine lamellar structure. It is notable that Hess (1941) considers lamellar structure in hypersthene as due to unmixing of minor amounts of excess diopside on inversion of pigeonite to hypersthene with falling temperature.

No generalization is made from examination of six specimens, but their similarity in age to rocks farther west described by Edwards, and their apparent derivation from tholeiitic magma, suggest that they are members of the same suite.

Petrography of a Specimen of Upper Proterozoic Winnecke Granophyre

Specimen R 6025

Hand-specimen

The rock is medium-grained and pink, with the following minerals distinguishable: grey quartz, pale green, pink, and white felspar, and black to dark green biotite. Granophyric intergrowth between quartz and felspar is clearly visible with the hand lens.

Thin section

The most striking aspect of the rock in thin section is the micrographic intergrowth of grey, turbid, kaolinized orthoclase with clear quartz, the two minerals between them comprising 85% of the rock. Other minerals are sodic plagioclase, highly kaolinized (5%), brown biotite partly converted to green chlorite (9%), and accessory black iron ore. Much of the felspar, particularly plagioclase, is impregnated with red iron oxide, and exact determination of the plagioclase is not possible: it is probably oligoclase.

The rock is granophyre.

Petrography of Specimens from Lower Cambrian Antrim Plateau Volcanics.

Specimen R 6026

Hand-specimen

The fresh rock is grey: under the hand lens a network of grey-white plagioclase laths, and laths of a green iridescent mineral with simple twinning and perfect cleavage at 80 - 90° to the twin plane, can be distinguished. Between the laths are shiny black iron-ore grains, and a pink, apparently felspathic, fine-grained to aphanitic groundmass.

Thin section

Microscopically, the rock consists of randomly oriented laths of labradorite (An_{60}) and pyroxene up to 3 mm long, the two forming an interlocking network, and black iron-ore grains up to 1 mm in diameter, in a groundmass of plagioclase, serpentine, black iron ore, epidote granules, quartz, and a cloudy, almost isotropic, indeterminate mineral that may be devitrifying glass. The pyroxene is colourless, commonly simply twinned, and has the following properties: 2V (+ve) $\simeq$ 50°, with plane of optic axes parallel to (010), and $Z \wedge C \simeq 47°$. There is a fairly prominent parting parallel to (100). Nearly all grains are at least partly altered to yellow-green bastite with perfect cleavage in one direction (probably (001))—this is the cleavage so obvious in hand-specimen. Boundaries between the pyroxene and groundmass are commonly marked by a concentration of black iron ore and hematite. Plagioclase is somewhat sericitized.

Composition of the rock is approximately as follows:

Phenocrysts	Pyroxene	15%
	Plagioclase	20%
	Iron Ore	5%
Groundmass		60%

The rock is dolerite.

Specimen R 6027

Hand-specimen

The rock resembles specimen R6026: it is dark grey and porphyritic, with prominent phenocrysts (1-2mm long) of a simply twinned green mineral and black iron ore, and less prominent felspar phenocrysts in a pink and grey groundmass.

Thin section

Microscopically, the rock is similar to specimen R6026. Labradorite and pyroxene phenocrysts are however shorter, and do not form a network. The pyroxene is colourless or very pale brown with 2V (+ve) about 45° and $Z \wedge C \doteq 41°$; it is commonly rimmed by a cloudy alteration product and by black iron ore. Pyroxene grains are altered, partly or wholly, to dark yellow-brown or green-brown slightly pleochroic serpentine with perfect basal cleavage and second order birefringence that resemble bowlingite rather than the bastite (antigorite) of specimen R 6026. Labradorite is partly sericitized. The groundmass is composed of anhedral quartz, patches of green serpentine, felspar laths, and grey cloudy material packed with minute chlorite flakes and iron ore granules.

The rock is dolerite.

Specimen R 6028

(Sedimentary rock in contact with Antrim Plateau Volcanics).

Hand-specimen

The rock is grey to pink-grey, laminated and predominantly silty, with scattered angular lenses averaging 2 mm diameter of white and grey quartz. Examination with the hand lens reveals many quartz lenses to be made up of a grey core and white periphery. Narrow quartz veinlets traverse the specimen.

Thin section

The rock is made up mainly of clastic quartz varying in grain size from a fine paste to angular grains of 0.25 mm diameter (60%), chlorite (25%), green biotite (10%), and muscovite (5%). Segregation of chlorite and mica into parallel bands, and poor preferred orientation of clastic quartz grains, together define bedding. Scattered throughout the rock are angular or lenticular aggregates of granular quartz. Mean diameter of the aggregates is 2 mm, here and there with a large constituent quartz grain attaining 1 mm; there is a decrease in grain size from the centre outward, reflected in the appearance of the aggregates in hand-specimen, where they appear to have a grey core and white periphery. Narrow veinlets of quartz are also present. Quartz of both aggregates and veins has been introduced by associated vulcanism.

The rock is micaceous chloritic sandy siltstone that has been metasomatized with addition of quartz.

Discussion of Petrology of Lower Cambrian Volcanic Rocks

Only two specimens of igneous rock from the Antrim Plateau Volcanics are described in this appendix; previous work by Edwards and Clarke (1940), however, strongly suggests that the East Kimberley basalts form a homogeneous petrographical province. Mineralogy and chemistry of the rocks described by Edwards indicate their tholeiitic tendencies, and their derivation from a magma on the borderline between under-saturation and over-saturation. The two dolerites (R 6026, R 6027) described in this appendix lack olivine, and contain one pyroxene (augite) and an acid (quartz-bearing) groundmass. They differ considerably from seven specimens of olivine basalt collected from a shallow water-bore put down on Victoria River Downs Station in August 1949 and described previously by the writer. The specimens unfortunately were fragments and most covered only a very small area of thin section, but their mineralogy was established. Olivine abounds as small phenocrysts with (+) $2V \simeq 85°$, and therefore containing at least 90% of the forsterite molecule, pyroxene is augite with (+) $2V \simeq 60°$, $Z \wedge C \simeq 45°$. Alteration and small size of plagioclase laths precluded determination of their composition. Examination of the few thin sections of Antrim Plateau Volcanics mentioned above sustains Edwards' remarks that the suite ranges from olivine basalt to quartz basalt.

Petrography of a Specimen from Lower Ordovician Pander Greensand

Specimen R 6029

Hand-specimen

The sandstone specimen is brown, medium-grained, well sorted, and moderately well indurated. Constituents seen with the hand lens are angular quartz, green glauconite, and red-brown ferruginous cement.

Thin section

The rock is made up mainly (70%) of angular quartz grains varying in size between 0.2 mm, and 0.6 mm, with a few grains outside both these size limits. Secondary quartz growths in optical continuity with quartz grains are common, and on some grains have caused formation of straight crystal edges. Glauconite, as sub-rounded to well-rounded grains with an average diameter of 0.2 mm, makes up 15% of the rock. Angular felspar grains (mainly microcline with a little orthoclase and sodic plagioclase) constitute 5%.

Cement (10%) is iron ore. It is generally black but locally red in strong transmitted light and in reflected light is mainly red with small cores of black shiny mineral. In places the mineral that is red in reflected light is translucent. Nearly all the iron ore is therefore hematite: the small cores of black mineral (i.e. black in reflected light) may be magnetite or ilmenite, or may be thick flakes of hematite. Hematite inclusions (perhaps alteration products) are common in glauconite.

The rock is a medium-grained glauconitic sandstone.

Petrography of Specimens from Upper Carboniferous or Lower Permian Nigli Gap Sandstone.

Hand-specimen

All specimens collected from the volcanic flow are weathered to brown or red-brown, with close inspection revealing fairly sparsely distributed small white felspar phenocrysts (commonly 3mm long) in an aphanitic groundmass. Most specimens are notably amygdaloidal, and on exposed surfaces, amygdales have weathered out to give a vesicular appearance. White and grey amygdaloidal quartz can be recognized in some hand-specimens, and amygdales, generally subspherical, may approach 1 cm. in diameter.

Thin section

Eleven thin sections were studied. All specimens are weathered, so that impregnation with hematite obscures mineralogy in many slides: nevertheless, data combined from study of all specimens reveal the flow to consist of weathered amygdaloidal sanidine trachyte.

Specimen R 6034 is the least weathered, and is therefore described in some detail immediately below. Texture varies from porphyritic to glomeroporphyritic, with felspar phenocrysts measuring approximately 0.6 x 0.2 mm in a groundmass of interstitial texture consisting of randomly oriented felspar laths (0.3 x 0.04 mm), and biotite. Phenocrysts form 3% of the rock, felspar in the groundmass 72%, and biotite 25%.

Felspar phenocrysts exhibit only simple (Carlsbad) twinning, but closely packed glomeroporphyritic crystal aggregates, commonly with close parallelism of long crystal axes, appear at first sight to represent individual crystals with multiple twinning. The mineral is optically negative, with no visible dispersion and small optic axial angle ($<15°$), and the optic axial is parallel to the twin plane; refractive indices are α: 1.520+.001, β: 1.525+.001. The mineral is therefore sanidine. The small size of felspar laths in the groundmass normally precludes their precise determination, but they appear also to be sanidine. Minute flaky inclusions are common in felspar of phenocrysts and groundmass; some, but by no means all, such inclusions can be identified as biotite.

Biotite in the groundmass, where fresh, is strongly pleochroic from dirty green-brown, through slightly paler green-brown, to very pale yellow-brown, with absorption $Z > Y > X$, and has a small optic axial angle ($-2V \simeq 10°$). Biotite in specimen R 6033 is almost wholly converted to a pale, yellow-brown, non-pleochroic mineral with low birefringence and aggregate structure, resembling antigorite. In most slides, abundant hematite "staining" completely obscures biotite, and commonly renders opaque up to 30% of the thin section. Hematite granules and flakes are also very common inclusions in felspar. In some specimens (e.g., R 6037) sanidine is partly replaced by quartz, and in specimen R 6039 introduced quartz is scattered through the groundmass.

Most specimens are notably amygdaloidal: thus R 6038 contains about a score of sub-spherical amygdales of mean radius 3 mm in the area of one thin section. In this specimen the infilled mineral is quartz, perhaps representing two generations, for most amygdales have a rim of finely granular quartz separated from the internal mass of coarser-grained quartz by a wavy line of hematite inclusions. Elsewhere, in specimen R 6031, vesicles are filled with pale green fibrous serpentine, with minute, length-slow, radially arranged fibres of moderate birefringence having a mean refractive index of 1.530-1.535. In specimen R 6032, fibres of amygdaloidal serpentine are interleaved with elongate hematite flakes, and in some vesicles granular quartz and rare grains of a partly kaolinized colourless mineral (felspar or a zeolite), with relief and birefringence both less than quartz, are present. Quartz and serpentine, irregularly intergrown, commonly occupy the same vesicles in specimen R 6035.

A notable feature of all rocks, apparent despite obscuring of mineralogy by hematite "staining" in many specimens, is their alkalinity and freedom from primary quartz. The rocks invariably contain sanidine phenocrysts, and up to 75% of the groundmass appears also to be sanidine.

Specimen R 6041

(at contact with interbedded volcanic rocks)

Hand-specimen

The specimen is composite, with red-brown amygdaloidal volcanic rock in contact with a strongly indurated red-brown silicified fine-grained sandstone. Most amygdales have weathered out of the volcanic rock, which is mainly aphanitic, so that it appears vesicular.

Thin section

The fine-grained sandstone has been silicified, but the original shape of constituent quartz grains is outlined by an iron-oxide coating that once surrounded them. Grains were originally sub-rounded to rounded and only moderately well sorted, with an average diameter of 0.15 mm. Nearly all space between grains is occupied by secondary quartz of variable orientation, in optical and crystallographic continuity with those grains to which it is adjacent. Quartz makes up 93% of the sandstone, glauconite 1%, iron oxide 1%, with rare grains of leucoxene, chert, plagioclase, quartz-sericite schist, sphene, and rounded tourmaline.

The thin section was cut very close to the contact of sandstone with volcanic rock. About 5% of the rock in this section is amygdaloidal volcanic rock (trachyte), the amygdales consisting of pale yellow-brown to colourless serpentine. Silicification of the sandstone was probably connected with emplacement of the flow.

Specimen R 6042

(near contact with interbedded volcanic rocks)

Hand-specimen

The rock is red-brown, strongly indurated and conglomeratic, with sub-rounded flattened siltstone pebbles cemented by a matrix of medium-grained silicified sandstone.

Thin section

50% of the rock in this thin section is made up of rounded siltstone pebbles averaging 4 mm diameter. Composition of the pebbles is 90% angular quartz (average diameter 0.04 mm), the remainder being black iron ore and hematite. The siltstone pebbles are cemented together by a matrix of sub-rounded to well rounded clastic quartz grains of average diameter 0.8 mm, and secondary quartz. The secondary quartz is in optical continuity with clastic quartz grains that it immediately surrounds; original shape of the clastic grains is clearly outlined by a film of red iron oxide that once coated them. Rare microcline grains and remnants of foraminifera can be seen in the matrix.

Composition and grain-size of the rock would result in its being named, according to Condon's (1953) classification, fine silicified greywacke conglomerate. Silicification was probably due to vulcanism.

Specimen R 6043 .

(near contact with interbedded volcanic rocks)

Hand-specimen

The rock is a well indurated, moderately to poorly sorted, grey quartz sandstone, irregularly ironstained, and made up mainly of medium-sized subrounded to rounded grains.

Thin section

The rock is a moderately to poorly sorted sandstone, partly made up of rounded to sub-rounded clastic quartz grains about 0.3 mm in diameter. A few rounded quartz grains show secondary enlargement in optical continuity with the original grain. Some vein-like areas in the thin section contain only a few clastic grains and are made up mainly of quartz paste: the irregular distribution of these bands is not consistent with sedimentary origin and the finely divided quartz is more likely to have been introduced into the rock during vulcanism. Hematite impregnates much of the rock, staining it red-brown and brown, but in the thin section studied it is nowhere found in areas of finely divided intrusive quartz.

The rock is a silicified medium-grained quartz sandstone.

REFERENCES

CONDON, M A., 1953.—Nomenclature of sedimentary rocks—glossary. *Bur. Min. Resour. Aust. Rec.*, 1953/131. (unpub.).

EDWARDS, A. B., 1942.—Some basalts from the North Kimberley, Western Australia. *J. roy. Soc. W. Aust.*, 27, 73-83.

EDWARDS, A. B. and CLARKE, E. de C., 1940.—Some Cambrian basalts from the East Kimberley, Western Australia. *J. roy Soc. W. Aust.*, 26, 77-94.

HESS, H., 1941.—Pyroxenes of common mafic magmas. *Amer. Miner.* 26, 515-535, 573-594.

KENNEDY, W. Q., 1933.—Trends of differentiation in basaltic magmas. *Amer. J. Sci.* 25, 239-256.

TURNER, F. J. and VERHOOGEN, J., 1951.—IGNEOUS AND METAMORPHIC PETROLOGY. N.Y., McGraw-Hill.

APPENDIX B.

FOSSIL LOCALITIES—ORD-VICTORIA REGION.

No.	Age.	Unit	Locality
1	Upper Cambrian	Clark Sandstone	Cambridge Gulf Run 3 Photo No. 5099
2	Upper Cambrian	Clark Sandstone	Cambridge Gulf Run 3 Photo No. 5099
3	Upper Devonian	Cockatoo Sandstone	Cambridge Gulf Run 3 Photo No. 5095
4	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 3 Photo No. 5093
5	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 4 Photo No. 5163
6	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 5 Photo No. 5179
7	Upper Cambrian	Pretlove Sandstone	Cambridge Gulf Run 8 Photo No. 5103
8	Lower Ordovician	Pander Greensand	Cambridge Gulf Run 8 Photo No. 5103
9	Upper Devonian	Cockatoo Sandstone	Cambridge Gulf Run 14 Photo No. 5127
10	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 10 Photo No. 5197
11	Middle Cambrian	Hart Spring Sandstone	Cambridge Gulf Run 5 Photo No. 5183
12	Upper Devonian	Cockatoo Sandstone	Cambridge Gulf Run 12 Photo No. 5049
13	Middle Cambrian	Skewthorpe Formation	Cambridge Gulf Run 7 Photo No. 5029
14	Middle Cambrian	Negri Group	Lissadell Run 3, Photo No. 5113
15	Middle Cambrian	Negri Group	Lissadell Run 5A, Photo No. 5077
16	Middle Cambrian	Negri Group	Lissadell Run 5 A, Photo No. 5065
17	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 7 Photo No. 5029
18	Permian	Weaber Group	Auvergne Run 8 Photo No. 5093
19	Permian	Weaber Group	Auvergne Run 8 Photo No. 5093
20	Permian	Weaber Group	Auvergne Run 9 Photo No. 5039
21	Permian	Weaber Group	Auvergne Run 9 Photo No. 5039
22	Lower Carboniferous	Septimus Limestone	Auvergne Run 9 Photo No. 5027 (actually on Cambridge Gulf 4 mile sheet)
23	Upper Devonian	Burt Range Limestone	Auvergne Run 13, Photo No. 5207
24	Lower Carboniferous	Enga Sandstone	Auvergne Run 14, Photo No. 5081 (actually on Cambridge Gulf 4 mile sheet)
25	Upper Devonian	Burt Range Limestone	Auvergne Run 14, Photo No. 5081 (actually on Cambridge Gulf 4 mile sheet)
26	Permian	Weaber Group	Auvergne Run 12, Photo No. 5135
27	Permian	Weaber Group	Auvergne Run 7, Photo No. 5075
28	Permian	Weaber Group	Auvergne Run 3, Photo No. 5113
29	Permian	Weaber Group	Auvergne Run 7, Photo No. 5083 (on Cambridge Gulf 4 mile sheet)
30	Permian	Weaber Group	Auvergne Run 7, Photo No. 5083 (on Cambridge Gulf 4 mile sheet)
31	Upper Devonian	Burt Range Limestone	Auvergne Run 12, Photo No. 5131 (on Cambridge Gulf 4 mile sheet)
32	Upper Devonian	Burt Range Limestone	Auvergne Run 12, Photo No. 5131 (on Cambridge Gulf 4 mile sheet)
33	Upper Devonian	Burt Range Limestone	Auvergne Run 12, Photo No. 5131 (on Cambridge Gulf 4 mile sheet)
34	Permian	Weaber Group	Auvergne Run 5, Photo No. 5199
35	Middle Cambrian	Hart Spring Sandstone	Cambridge Gulf Run 7, Photo No. 5029
36	Upper Cambrian	Clark Sandstone	Cambridge Gulf Run 7, Photo No. 5029
37	Lower Ordovician	Pander Greensand	Cambridge Gulf Run 7, Photo No. 5029
38	Middle Cambrian	Skewthorpe Formation	Cambridge Gulf Run 7, Photo No. 5029
39	Lower Ordovician	Pander Greensand	Cambridge Gulf Run 7, Photo No. 5029

No.	Age.	Unit	Locality
40	Upper Devonian	Cockatoo Sandstone?	Cambridge Gulf Run 7, Photo No. 5029
41	Upper Cambrian	Clark Sandstone	Cambridge Gulf Run 7, Photo No. 5029
42	Permian	Weaber Group	Cambridge Gulf Run 7, Photo No. 5029
43	Middle Cambrian	Skewthorpe Formation	Cambridge Gulf Run 5, Photo No. 5183
44	Middle Cambrian	Negri Group	Dixon Range Run 9, Photo No. 5195
45	Tertiary	White Mountain Formation	Limbunya Run 4, Photo No. 5116 (on Dixon Range 4 mile sheet)
46	Middle Cambrian	Negri Group	Limbunya Run 7, Photo No. 5087
47	Middle Cambrian	Negri Group	Limbunya Run 6, Photo No. 5205
48	Middle Cambrian	Negri Group	Limbunya Run 6, Photo No. 5207
49	Middle Cambrian	Negri Group	Limbunya Run 7, Photo No. 5083
50	Upper Proterozoic	Victoria River Group	Limbunya Run 15, Photo No. 5105
51	Middle Cambrian	Montejinni Limestone	Victoria River Downs Run 1, Photo No. 5045
52	Upper Proterozoic	Victoria River Group	Victoria River Downs Run 10, Photo No. 5163
53	Jurassic	Mullaman Group	Delamere Run 5, Photo No. 5163
54	Cretaceous	Mullaman Group	Delamere Run 5, Photo No. 5163
55	Jurassic	Mullaman Group	Delamere Run 6, Photo No. 5220
56	Upper Devonian	Burt Range Limestone	Cambridge Gulf Run 7, Photo No. 5027
57	Cretaceous	Mullaman Group	Victoria River Downs Run 11, Photo No. 5042
58	Cretaceous	Mullaman Group	Victoria River Downs Run 11, Photo No. 5040.

APPENDIX C

REPORT ON MESOZOIC PLANTS FROM THE MULLAMAN GROUP IN THE VICINITY OF WILLEROO STATION, NORTHERN TERRITORY

by

R. O. Brunnschweiler

Six species belonging to four genera of Mesozoic plants are identified in a small collection from the basal sandstones of the Mullaman Group. The flora is regarded as Jurassic, possibly Middle Jurassic, in age.

The Traves-F-12 collection discussed here was received not long before the fire which gutted the Bureau's premises in April, 1953. Only a preliminary examination of the material had by then been carried out; the notes were destroyed in the fire.

The present report is based chiefly upon such material as has been recovered from the ashes; the presence among the assemblage of *Otozamites* can no longer be demonstrated by a specimen. But the writer identified this form in the F-12 collection before the fire.

The F-12 samples are all from the basal part of the Mullaman Group (Noakes, 1949). There are about two dozen rock specimens, most of them fine-grained sandstone, yellowish or grey in colour and evidently solidified by secondary silicification. A few specimens consist of a more ferruginous type of the same silicified sandstone.

The following form-genera and species are present in both types of sandstone:

Filicales

Cladophlebis cf. *C. roylei* Arber
Cladophlebis sp. nov. *aff. C. roylei* Arber

Bennettitales

Taeniopteris spatulata McClelland
Taeniopteris cf. *T. tenison-woodsi* Eth. fil.
Otozamites sp. indet.

Coniferales

Elatocladus cf. *E. plana* (Feistm.)

This plant assemblage seems to be characteristic of the lower part of the Mesozoic sequence in the Northern Territory. It has previously been found in collections from the Cloncurry-Camooweal area and the Barkly Tableland.

The most abundant forms are the species of *Cladophlebis* and *Elatocladus* cf. *E. plana.* Only about one fifth of the assemblage consists of species of *Taeniopteris*. *Otozamites* Braun appears to be extremely rare.

The absence of the genus *Brachyphyllum* Brong. *(Cupressineae)* is somewhat surprising, because it is a fairly common form in the other collections from the Northern Territory mentioned above. However, its absence is not believed to be of any particular significance and is probably due to the chances of collecting.

It can be said with some certainty that the present assemblage is a post-Triassic but pre-Cretaceous one, because typically Triassic and typically Cretaceous plants are absent. But an exact determination even of the relevant Epoch is not possible.

The relative abundance of a form closely akin to *Cladophlebis roylei* may appear to be very suggestive of an early to middle Jurassic age, because that species—which is particularly characteristic of the Permian "Bowen Series" of Queensland—is generally believed to have failed to survive into the Cretaceous Period. It was probably already extinct by late Jurassic times. However, the apparent affinity of the Mullaman *Cladophlebis to Cladophlebis roylei* may not be real, and it is possible that the Mullaman species is either a variety of the ubiquitous *Cladophlebis australis* (Morris), which ranges from the Upper Triassic well up into the Cretaceous, or a new species altogether.

The species of *Taeniopteris* in the Mullaman flora are the same as those characteristics of the Triassic (Ipswich) and Jurassic (Walloon) sequence in Queensland. According to modern views (Walton, 1940; Moret, 1949) *Taeniopteris* is chiefly a Jurassic genus. It appeared in the late Triassic and became extinct with the onset of the Cretaceous Period. *Otozamites* has a similar range. In the Mullaman flora there is therefore only one form whose range is known to cover not only the whole of the Jurassic but also most of the Cretaceous Period; this form is the ubiquitous *Elatocladus*.

The above discussion of this flora leads to the conclusion that the plant-bearing sandstones in the lower part of the Mullaman Group are of Jurassic age, possibly Middle Jurassic.

On present knowledge the Mullaman Group appears to be a rather heterogeneous stratigraphical unit. Since its upper part is said to be of Middle Cretaceous age it seems that it incorporates deposits of two sedimentary cycles, a Middle/Upper Jurassic and a Middle Cretaceous one. There is, however, no evidence of a break in the Mullaman sequence; all geologists who have studied it regarded it as one unit. On the other hand it is unlikely that this unit is a "Serie comprehensive" reaching from the Middle Jurassic to the end of the Middle Cretaceous. The conclusion is that our present knowledge about the Mesozoic sequence in the Northern Territory is both inadequate and in need of revision.

The problem presented by the Mullaman Group can only be solved by a revision of the stratigraphy and palaeontology of key areas such as

Pt. Charles near Darwin, Bathurst Island, Melville Island, etc. The Mesozoic sequence in these areas has always been known only in a very sketchy way, and it is evident that extrapolations based on it and applied to the Mesozoic sediments on the continental hinterland are liable to be fallacious.

REFERENCES.

MORET, L., 1949.—MANUEL DE PALÉONTOLAGIE VÉGÉTALE. Paris, Masson.

NOAKES, L. C., 1949.—A geological reconnaissance of the Katherine-Darwin region, Northern Territory. *Bur. Min. Resour. Aust. Bull.* 16.

WALTON, J., 1940.—AN INTRODUCTION TO THE STUDY OF FOSSIL PLANTS. London, Black.

APPENDIX D

PRELIMINARY NOTE ON SOME ORD RIVER PALAEOZOIC FOSSILS, COLLECTED BY D. M. TRAVES IN 1954.

by

G. A. Thomas.

Listed below are preliminary notes on fossils collected by D. M. Traves in the Upper Palaeozoic Weaber Group, in the Ord-Victoria Rivers Area, Northern Territory.

1. *SANDY CREEK LOCALITY* (Fossil Locality 27)—In partly silicified calcareous rock:

Cleiothyridina sp.: this is a small species with both valves convex and very little, if any, sign of sulcus and fold. It is definitely not close to any West Australian Permian species and appears to me to be closer to such species as *C.orbicularis* McChesney of the Pennsylvanian, or *C. casteri* Dresser of Middle Pennsylvanian age from Brazil, or even Mississippian species like *C.lenticularis* Weller, than it is to any West Australian Permian form.

"Spirifer" sp. A: two incomplete moulds of a small alate simple-ribbed spiriferid about 2.5 mm wide at the hinge line. This form has simple ribs, very slightly developed fold and sulcus. I know nothing like this in the West Australian Permian. It appears to me to resemble Mississipian species like *S. legrandensis* Weller or *S. biplicoides* Weller more than any Permian species. It has some resemblance externally to *Prospira prima* Maxwell of the Queensland Lower Carboniferous.

"Spirifer" sp. B: one incomplete specimen of similar size to *"S."* sp.A., with a sulcus and with the ribs dividing. This does not resemble any W.A. Permian form.

"Spirifer" sp. C.: there are about a dozen examples of a brachythyrid spiriferid with the ribs very faintly developed on the ventral valve and more pronounced on the dorsal valve, which has a fairly strong fold. The ribs are simple. The area is well developed. Nothing at all like this specimen occurs in the West Australian Permian. In the external characters it somewhat resembles a lower Carboniferous species from China named *Martinia semiconvexa* Chao, but the ventral internal structure appears to be like that of *Choristites mosquensis* of Moscovian age. Better material is necessary to work out its affinities.

Largest specimen—length: 3mm.
width: 2.8 mm. near hinge line.

"Spirifer" sp. D.: a few specimens of a relatively wider form than the last species. It is also flatter with only a slight fold and sulcus. The

ribs are simple. No internal details are available. Nothing like this species occurs in the West Australian Permian: it can be more closely compared with Lower and Mid-Carboniferous species from China and North America than with any Permian species.

Dimensions of only complete specimen:

width: 3.6 mm.
length: 3.3 mm.

Syringopora? sp. The only *Syringopora*-like coral known to me in the West Australian Permian occurs in the upper beds of the Liveringa Group; it is not the same species as this. The associated fauna in the Fitzroy area is very distinctly different and has no affinities whatever with the Weaber Group faunas. The genus is most common in Devonian and L. Carboniferous rocks.

II. *FLAPPER HILL.* (Fossil Locality 28)—fine brown and medium-grained yellow sandstone.

Chonetes sp.: mainly internal moulds of a fairly small non-sulcate *Chonetes* about 1½ mm wide. This bears a general resemblance to some forms in the Permian of the Fitzroy Basin but is not identical with any. There are at least half a dozen undescribed species of *Chonetes* in the Western Australian Permian. The Flapper Hill species is quite distinct from an undescribed species which occurs in the lower beds of Liveringa Group and from the species in the upper beds of the Group. It is also distinct from the form in lowest fossiliferous Permian of Fitzroy basin—i.e., the Nura Nura beds. As far as I can see, the Flapper Hill species has no features that clearly indicate it to be Permian rather than Carboniferous. *Chonetes* of approximately the same size and general form are described from the Pennsylvanian and the Mississippian of North America.

Orthotetid genus: there are several dorsal valves of an orthotetid. The largest specimen is 4 mm wide at the hinge line. The valves are very flat, in marked distinction from all the Fitzroy Basin species of orthotetids. The plates surrounding the cardinal process are much more divergent than those of any Fitzroy Basin species. The genus cannot be determined until internal features of the ventral valve are seen, but the flat dorsal valve is suggestive of the genus *Schuchertella,* which is mainly known from the Devonian and lower Carboniferous but recorded from the Permian. Neither the genus *Schuchertella* nor any form like the Flapper Hill species has been observed among the Western Australian Permian orthotetids which I am studying at present.

"Spirifer" sp. A.: a few incomplete impressions of a small alate, simple-ribbed spiriferid are present. This is very similar to the spiriferid from Sandy Creek locality, recorded above.

Rynchonellacean genus: one incomplete mould of a rhynchonelliform brachiopod is present. This is indeterminate on the available material, but is clearly not identical with any of the West Australian species of *Camarophoria,* a comparatively rare genus in the Western Australian Permian. There is no feature that would indicate this form as Permian rather than Carboniferous.

III. *Beds* 0.7 *miles East of POINT SPRING* (Fossil Locality 29)—in fine white sandstone.

Brachiopoda indet: indeterminate moulds of a smooth form, possibly an athyrid.

Heteropectinid sp.: impression and mould of a small heteropectinid were identified by Mr. J. M. Dickins. He does not know of this group extending into the Permian: it is characteristically Carboniferous. The specimen is quite distinct from any West Australian Permian species known to him.

In the material before me, the "*Spirifer*" sp. A provides a link between the beds at Flapper Hill and those at Sandy Creek. The Point Spring material is inadequate to determine its local correlation.

Dr. Öpik (1950) recorded, in addition, a *Dictyoclostus* from Sandy Creek. There are none in the present collection. Several species of this genus occur in the West Australian Permian, but it ranges from Lower Carboniferous to Permian. The genotype is Lower Carboniferous in age. Dr. Öpik recorded also *Rhipidomella* from Flapper Hill. This genus—not present in this latest collection—ranges in age from Devonian or lower to Permian. It is not known in the West Australian Permian.

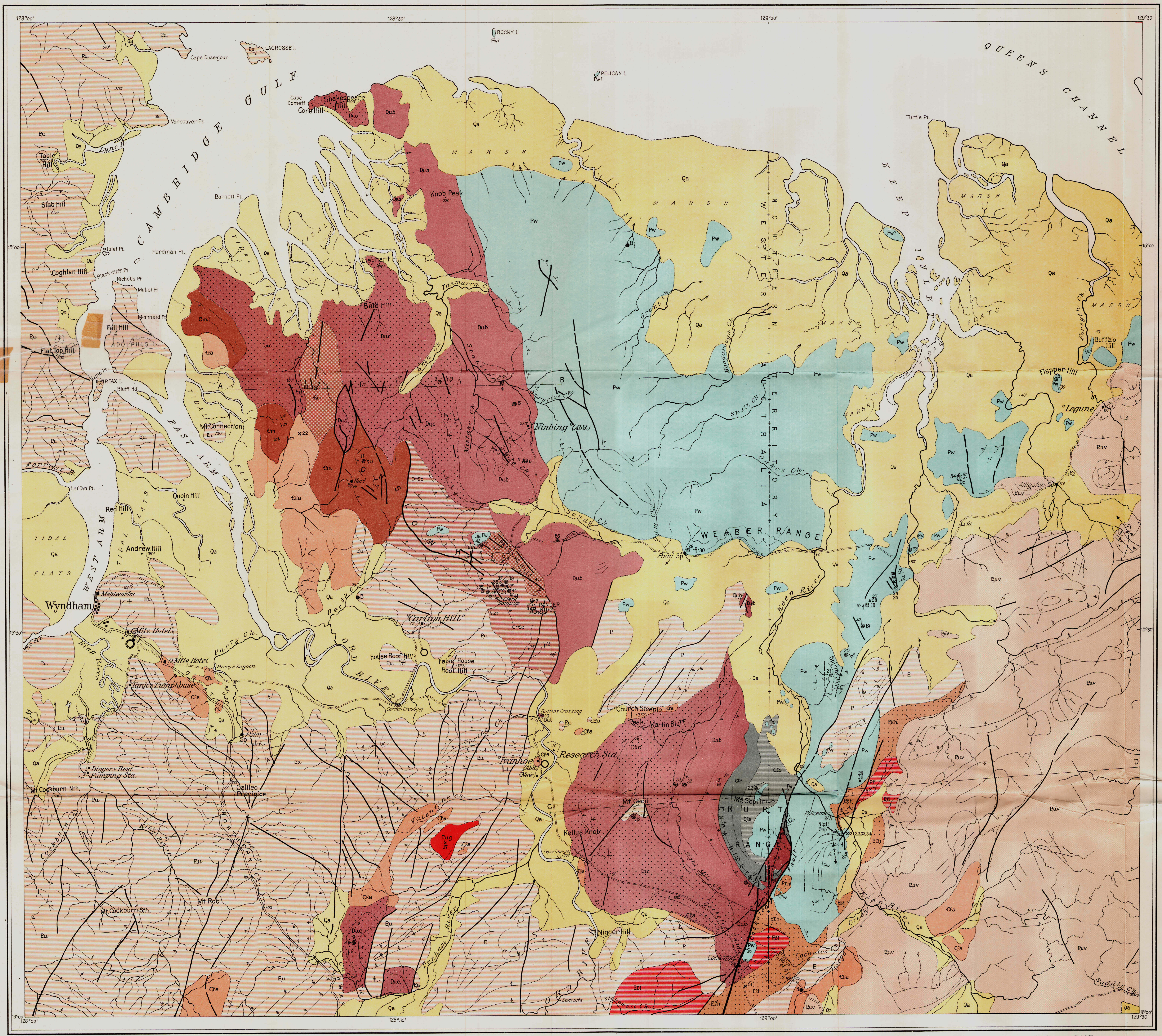
I have made only a preliminary examination of this collection, but have the strong impression that the faunas should not be correlated with any from the Permian of West Australia. Moreover, it seems to me that the correlation should be rather with the Middle or Early Upper Carboniferous rather than with late Upper Carboniferous. A considerable affinity with Lower to Middle Carboniferous forms seems to be indicated by the Spiriferids. Further study and better material are necessary to work out more precisely the affinities of this very interesting fauna.

APPENDIX E
LOG OF NO. 4 COAL BORE, PORT KEATS.

Depth in feet	Foreman's Record of Strata
0-3	Ironstone rubble
3-13	Sandy clay
13-15	Soft, light coloured clay
15-16	Red clay
16-36	Dark clay
36-56	Blue clay
56-66	Brown clay
66-327½	Blue clay or shale
327½-350	Sandstone
350-352	Brown shale
352-422	Sandstone
422-431	Shale with sandstone layers
431-455	Dark shale intermixed with sandstone
455-465	Green sandstone
465-480	Green sandstone, dark shale and sandstone layers
480-488	Carbonaceous sandstone, very friable
488-514	Sandstone
514-553	Firm dark shale (Definite thickness of strata not given below this depth)
570	Layers of blue mud
589	White sandy sediment
597	Sand filled up bore 23 feet from bottom
602½	Loose sand
616	Loose sand; washed large amount of stone and some heavy gravel from inside casing
628	Extremely soft sandy formation
648	Soft sandy formation
669	Very soft, no water returning
679	Water returning, with sediment
707	Very soft sandstone
726½	Sandstone, extremely soft
752½	Sandstone
775	Soft sandstone
812	Layer of shale 810 ft. to 812 ft.
820	Grey sandy shale, with soft sandstone
833½	Very soft sandstone, with thin layers of shale
846	Very soft sandstone
860	Soft sandstone
869	Firm shale
884	Firm shale, with sandstone layers
894	Sandstone, firmer at 890 ft, sandstone to 895 ft, then 1 in. shale
910	Firm carbonaceous sandstone
921	Very soft carbonaceous sandstone
931	Firm carbonaceous sandstone
942	Sandstone and shale
959	Sandstone and shale, with pyritic balls
973	Very soft sandstone, with carbonaceous streaks
981	Soft carbonaceous sandstone with a little shale
990	Loose sandstone, absorbing large quantites of water
995	Very loose sandstone
1,000	Very soft carbonaceous sandstone
1,010	Soft sandstone, losing large quantity of water
1,019	Very soft sandstone
1,027	Sediment troublesome
1,035	Very soft sandstone
1,055	Very soft sandstone, with pyrites
1,068	Very soft sandstone, with little shale
1,086	Soft sandstone
1,118	Very soft sandstone
1,132	Firm sandstone, with shale layers
1,143	Very soft sandstone
1,149	Soft sandstone
1,178	Sandstone, with small veins of coaly matter
1,185	Sandstone, with large pyritic balls and veins of shale
1,200	Sandstone
1,205	Sandstone, with veins of coaly matter
1,215	Hard and soft layers of sandstone
1,229	Shale and soft sandstone
1,243	Sandy shale
1,273	Firm sandstone, with shale layers
1,282	Sandy shale
1,291	Shale and sandstone
1,314	Vein of coal
1,334	Sandy shale
1,351	Sandstone and shale with pyrites
1,357	Sandstone
1,363	Sandstone and shale
1,392	Shale and sandstone, with pyritic balls
1,404	Dark shale and sandstone
1,425	Firm dark shale
1,457 ft.	to 1,458 ft. white pipeclay running into bore
1,505	Black shale to 1,499 ft, white fossilised formation to 1,505 ft. (Shell limestone).

WHOLLY SET UP AND PRINTED IN AUSTRALIA BY MERCURY PRESS PTY. LTD., 91-93 MACQUARIE STREET, HOBART, TASMANIA.

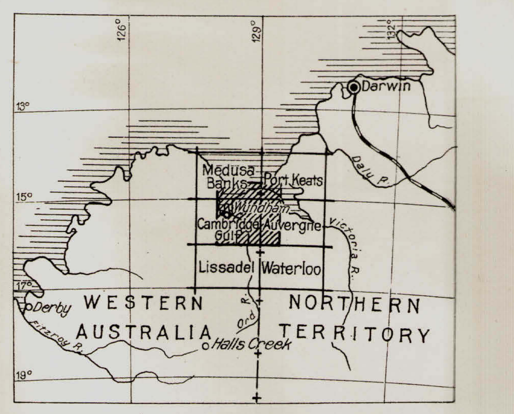
BONAPARTE GULF BASIN



Legend

QUATERNARY		Qa	Alluvium
PERMIAN	Weaber Group	Pw	Sandstone, Conglomerate, Limestone
LOWER CARBONIFEROUS	Septimus Limestone	Cℓs	Limestone, calcareous Sandstone
	Enga Sandstone	Cℓe	Sandstone, Conglomerate
UPPER DEVONIAN	Burt Range Limestone	Dub	Limestone, calcareous Sandstone
	Cockatoo Sandstone	Duc	Sandstone, Conglomerate
ORDOVICIAN & CAMBRIAN	Carlton Group	O-Ꞓc	Pander Greensand, Pretlove Sandstone, Clark Sandstone, Skewthorpe Formation, Hart Spring Sandstone
CAMBRIAN UPPER	Carlton Group	Ꞓu	Pretlove Sandstone, Clark Sandstone
CAMBRIAN MIDDLE	Carlton Group	Ꞓm	Skewthorpe Formation, Hart Spring Sandstone
CAMBRIAN LOWER	Antrim Plateau Volcanics	Ꞓℓa	Basalt, Agglomerate, Tuff
PROTEROZOIC UPPER	Victoria River Group	Ꝑuv	Sandstone, Dolomite, Shale
	Mt.House Beds, Warton Beds, King Leopold Form^n	Ꝑu	Sandstone, Shale, Dolomite
		Ꝑug	Gabbro, Dolerite
PROTEROZOIC LOWER	Lamboo Complex	Ꝑℓl	Granite, Gneiss, Granodiorite
	Halls Creek Metamorphics	Ꝑℓh	Sandstone, Quartzite, Slate, Schist, Volcanics
PROTEROZOIC	Undifferentiated	Ꝑ	Sandstone, Slate, Quartzite

- Geological boundary, position approximate
- Inferred geological boundary
- Fault
- Joint
- Trend line — gentle dip; medium to steep dip
- Anticlinal axis, Synclinal axis — showing direction of plunge of fold
- Dip & strike — inclined; horizontal
- 24, 26 — Fossil locality with index number
- × 34 — Locality of rock specimen described in Appendix A
- Oc — Ochre Mine
- "Legune" — Homestead
- Highway
- Vehicle track
- Sp, B — Spring, Bore
- W.H., R.H — Water hole, Rock hole
- Yd — Yard
- Aerodrome
- 830' — Spot height



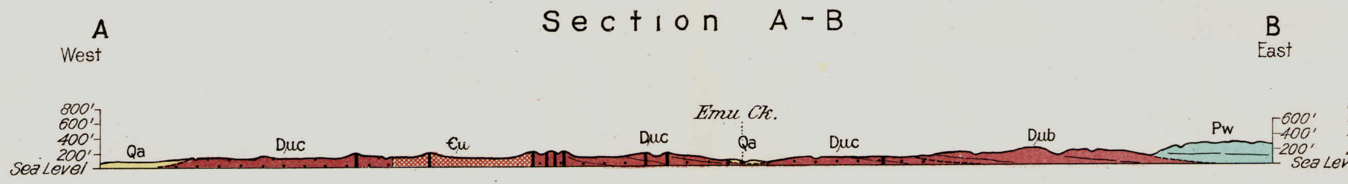
Locality map with reference to Australian Four Mile Map Series

Bureau of Mineral Resources, Geology & Geophysics 1954
Base map compiled by National Mapping Office
Department of the Interior, Canberra

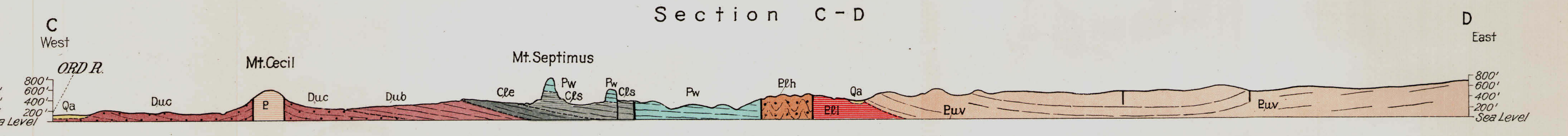
Geology by D.M.Traves

Scale
4 Miles to 1 Inch
1 = 253 440

Section A-B



Section C-D

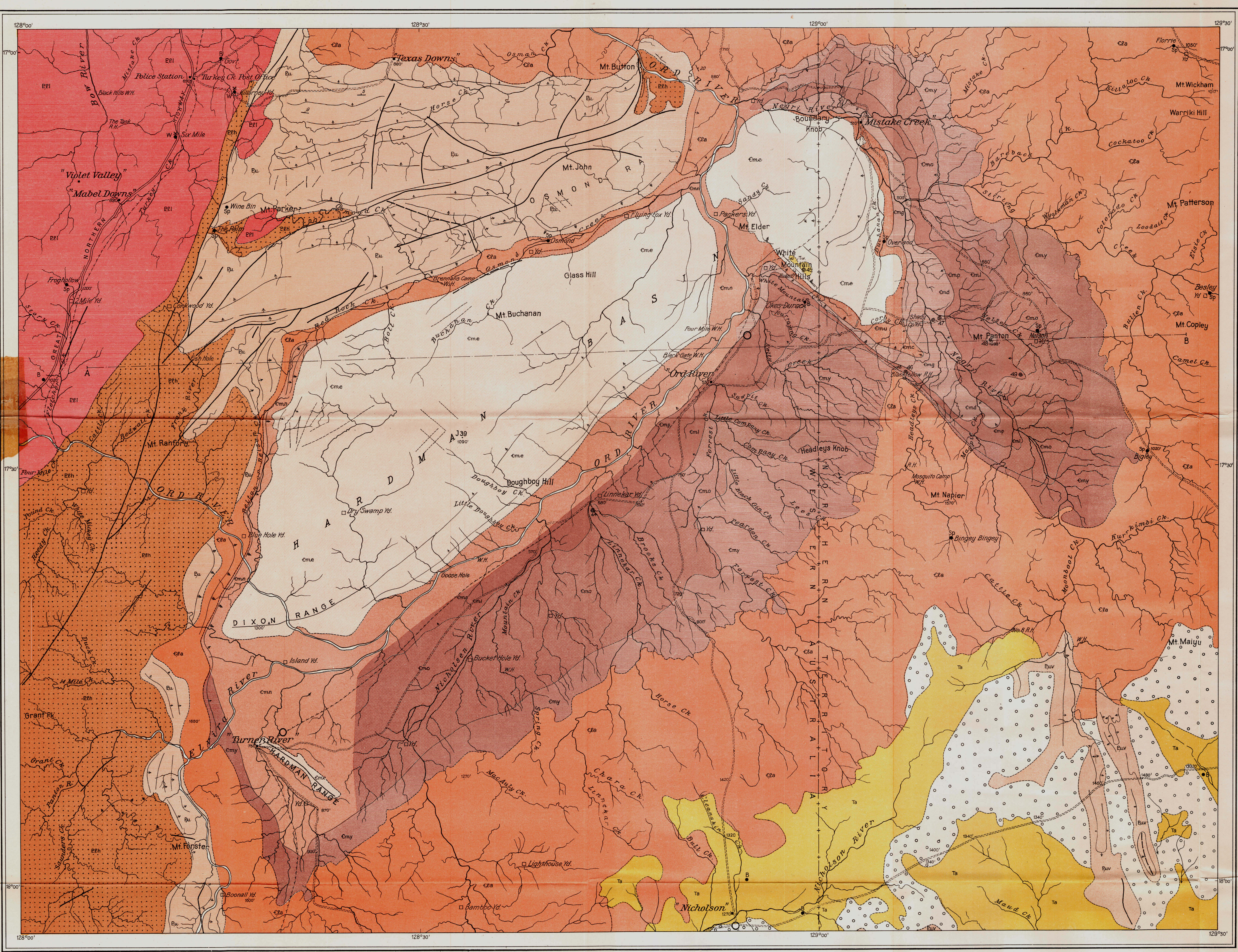


G3-3
H.F.B.

MERCURY PRESS, HOBART.

HARDMAN BASIN

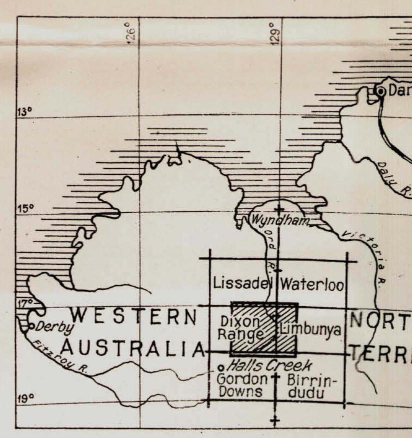
Plate 2



Legend

TERTIARY		Ta	Alluvium
			Laterite
	White Mountain Formation	Tw	Siltstone, Chert, Marl
MIDDLE CAMBRIAN	Elder Sandstone	€me	Sandstone
	Negri Group	€mn	Negri Group Undifferentiated
		€mu €mc	Hudson Shale Corby Limestone
		€mg €md	Negri River Shale Shady Camp Limestone
		€mp €ml	Panton Shale Linnekar Limestone
		€mo	Nelson Shale
		€my	Headleys Limestone
LOWER CAMBRIAN	Antrim Plateau Volcanics	€a	Basalt, Tuff, Agglomerate
UPPER PROTEROZOIC	Victoria River Group	Buv	Sandstone, Shale
	Mt.House Beds Warton Beds (King Leopold Form.)	Bu	Sandstone, Shale
LOWER PROTEROZOIC	Lamboo Complex	Bℓl	Granite, Gneiss, Granodiorite
	Halls Creek Metamorphics	Bℓh	Sandstone, Quartzite Slate, Schist, Volcanics

Geological boundary, position approximate
Fault
Joint
Trend line — gentle dipping; medium to steep dipping
Dip & strike
Fossil locality with index number
"Ord River" Homestead
Highway
Vehicle track
Telephone line
Bore, Spring
Well with windmill
Water hole, Rock hole
Yard
Aerodrome
Spot height



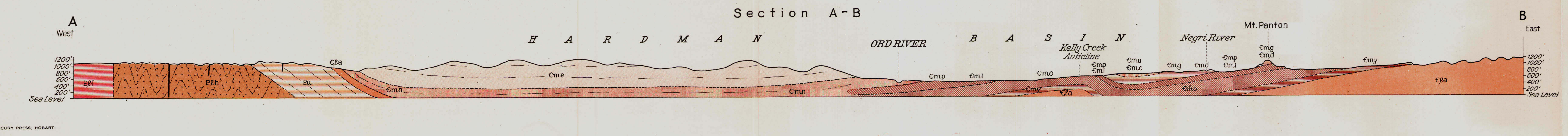
Locality map with reference to Australian Four Mile Map Series

Bureau of Mineral Resources, Geology & Geophysics 1954
Base map compiled by National Mapping Office
Department of the Interior, Canberra

Scale
4 Miles to 1 Inch
1: 253 440

Geology by D.M.Traves

Section A-B



G3-4
H.F.B

MERCURY PRESS, HOBART

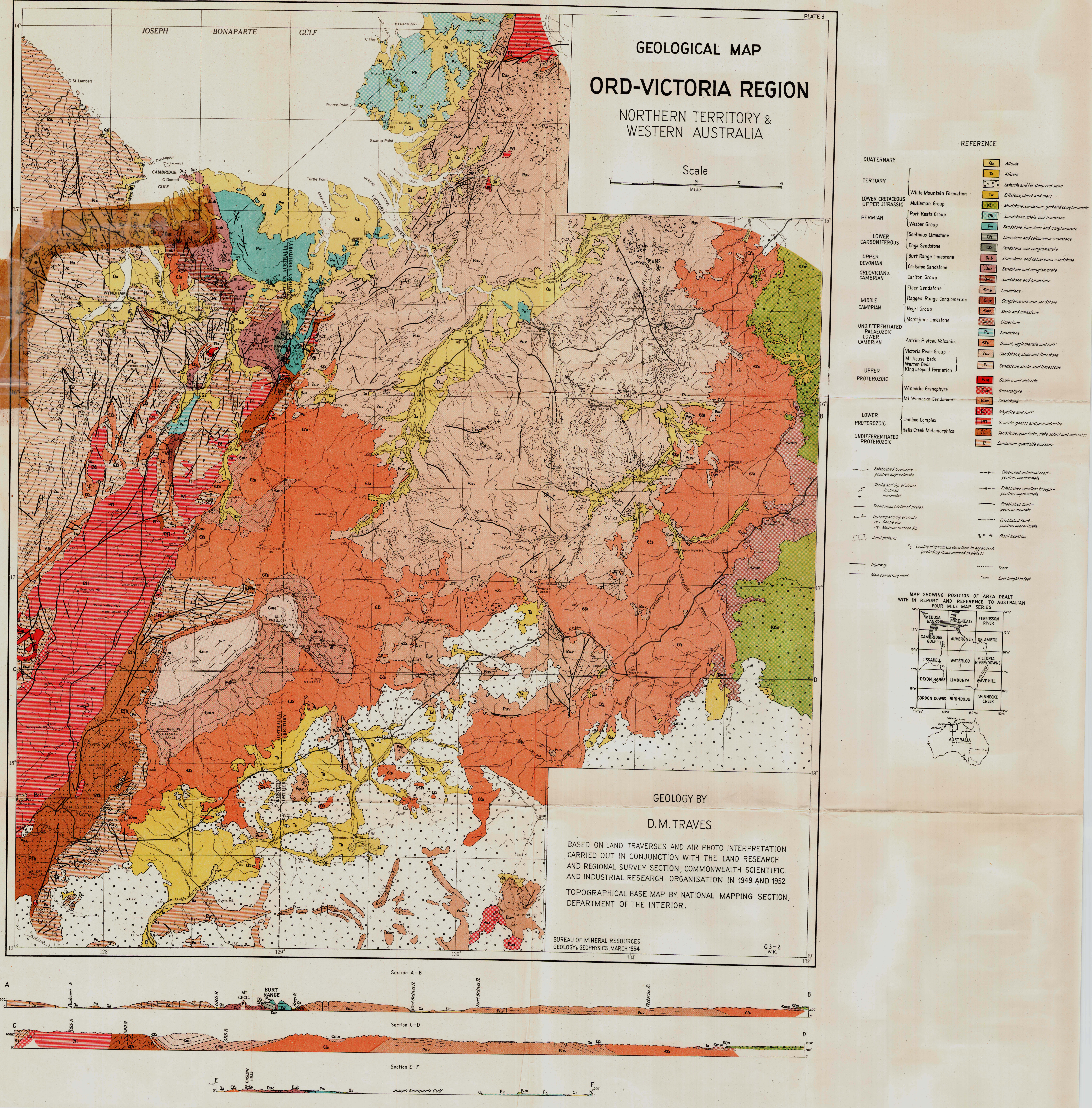


PLATE 3
GEOLOGICAL MAP
ORD-VICTORIA REGION
NORTHERN TERRITORY &
WESTERN AUSTRALIA
Scale
MILES
REFERENCE
QUATERNARY
TERTIARY
White Mountain Formation
LOWER CRETACEOUS
UPPER JURASSIC
Mullaman Group
PERMIAN
Port Keats Group
Weaber Group
LOWER CARBONIFEROUS
Septimus Limestone
Enga Sandstone
UPPER DEVONIAN
Burt Range Limestone
Cockatoo Sandstone
ORDOVICIAN & CAMBRIAN
Carlton Group
MIDDLE CAMBRIAN
Elder Sandstone
Ragged Range Conglomerate
Negri Group
Montejinni Limestone
UNDIFFERENTIATED PALAEOZOIC
LOWER CAMBRIAN
Antrim Plateau Volcanics
UPPER PROTEROZOIC
Victoria River Group
Mt House Beds
Warton Beds
King Leopold Formation
Winnecke Granophyre
Mt Winnecke Sandstone
LOWER PROTEROZOIC
Lamboo Complex
Halls Creek Metamorphics
UNDIFFERENTIATED PROTEROZOIC
Qa Alluvia
Ta Alluvia
Laterite and/or deep red sand
Tw Siltstone, chert and marl
Klm Mudstone, sandstone, grit and conglomerate
Pk Sandstone, shale and limestone
Pw Sandstone, limestone and conglomerate
Cls Limestone and calcareous sandstone
Cle Sandstone and conglomerate
Dub Limestone and calcareous sandstone
Duc Sandstone and conglomerate
O-Єc Sandstone and limestone
Єme Sandstone
Єmr Conglomerate and sandstone
Єmn Shale and limestone
Єmm Limestone
Pz Sandstone
Єla Basalt, agglomerate and tuff
Puv Sandstone, shale and limestone
Pu Sandstone, shale and limestone
Pug Gabbro and dolerite
Pur Granophyre
Puw Sandstone
Plv Rhyolite and tuff
Pli Granite, gneiss and granodiorite
Plh Sandstone, quartzite, slate, schist and volcanics
P Sandstone, quartzite and slate
Established boundary – position approximate
Strike and dip of strata
Inclined
Horizontal
Established anticlinal crest – position approximate
Established synclinal trough – position approximate
Established fault – position accurate
Established fault – position approximate
Highway
Main connecting road
Track
Fossil localities
Joint patterns
MAP SHOWING POSITION OF AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN FOUR MILE MAP SERIES
MEDUSA BANKS
PORT KEATS
FERGUSSON RIVER
CAMBRIDGE GULF
AUVERGNE
DELAMERE
LISSADELL
WATERLOO
VICTORIA RIVER DOWNS
DIXON RANGE
LIMBUNYA
WAVE HILL
GORDON DOWNS
BIRRINDUDU
WINNECKE CREEK
AUSTRALIA
JOSEPH BONAPARTE GULF
CAMBRIDGE GULF
WYNDHAM
VICTORIA RIVER
NORTHERN TERRITORY
WESTERN AUSTRALIA
GEOLOGY BY
D. M. TRAVES
BASED ON LAND TRAVERSES AND AIR PHOTO INTERPRETATION CARRIED OUT IN CONJUNCTION WITH THE LAND RESEARCH AND REGIONAL SURVEY SECTION, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION IN 1949 AND 1952
TOPOGRAPHICAL BASE MAP BY NATIONAL MAPPING SECTION, DEPARTMENT OF THE INTERIOR.
BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS, MARCH 1954
G3-2
Section A–B
MT CECIL
BURT RANGE
Section C–D
Section E–F
Joseph Bonaparte Gulf