COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

Copy 8.

RECORDS 1967/61

THE GEOLOGY OF THE GEORGINA BASIN

Compiled by

K.G. Smith

15928/65

THE GEOLOGY OF THE GEORGINA BASIN

Compiled by

K. G. SMITH

Records 1967/61

THE GEOLOGY OF THE GEORGINA BASIN

Compiled by

K.G. SMITH

Records 1967/61

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

TEXT FIGURES

SUMMARY

The Georgina Basin is a large Palaeozoic sedimentary basin extending from north-western Queensland into the Northern Territory. Field parties from the Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics mapped some of the Queensland part of the Basin in the early 1950's, and the remainder of the Basin in the period 1957-1965; officers of the Geological Survey of Queensland participated in most of the Queensland surveys. Since 1957, petroleum exploration companies have made geological, gravity, aeromagnetic and seismic surveys in selected areas, and the Geophysical Branch of the Bureau aeromagnetic and reconnaissance gravity surveys over most of the Basin, and seismic surveys in Queensland and small areas in the Northern Territory. Nineteen wells have been drilled but all failed to produce commercial quantities of oil or gas; three of these wells were drilled by the Bureau, which also drilled an aggregate of about 10,000 feet in shallow scout holes. This work has resulted in considerable advances in knowledge of the geology of the Georgina Basin, and in this report the author has compiled all available significant geological information, both published and unpublished.

The Georgina Basin covers an area of about 125,000 square miles and extends in a belt trending north-west from latitude 25°S in north-western Queensland to about latitude 18°S in the Northern Territory. The Basin has a maximum length of about 600 miles and a maximum width of about 300. The south-western, western, northern and eastern margins are defined by Precambrian outcrops but the north-western and south-eastern margins are concealed by Mesozoic sediments. The position of the north-western margin has not been resolved but the south-eastern margin has been defined approximately by gravity, seismic and aeromagnetic surveys and by limited stratigraphic drilling.

The Georgina Basin contains Cambrian and Ordovician marine sediments, and Devonian or Siluro-Devonian fresh-water sequences. Middle Cambrian sediments are widespread, but Upper Cambrian, Ordovician and Devonian rocks are restricted to the southern part of the Basin. There are no known Palaeozoic intrusive rocks, and no evident metamorphism.

Early Middle Cambrian sediments are regarded as the basal units of the Georgina Basin succession, but in many places around the margins and within the Basin they are underlain, unconformably or disconformably, by several thousands of feet of un-metamorphosed sediments of late Precambrian and/or Lower Cambrian age. These older sediments are either non-magnetic or have low magnetic susceptability, and therefore in some areas the sedimentary section above magnetic basement includes the late Precambrian/ Lower Cambrian rocks. In these areas, economic basement lies above magnetic basement because the petroleum prospects of the pre-Middle Cambrian sediments are not highly regarded.

Most of the northern half of the Georgina Basin contains a thin blanket of marine Middle Cambrian sediments consisting of shale, limestone, dolomite and minor sandstone. Some of these are richly fossiliferous and may be potential source rocks for petroleum; many of the carbonate rocks are vuggy and cavernous and yield large quantities of water. The thickness seldom exceeds 1200 feet, and the maximum known is 1750 feet. The Middle Cambrian sequence has been strongly faulted, along the northern margin of the Basin, but elsewhere structural deformation is not evident. An anticline (the Lake Nash Anticline) occurs in this northern part of the Basin, but its formation is attributed to compaction over a Precambrian high. Most of the sediments in the Northern Territory part of the northern Georgina Basin are of early Middle Cambrian age, and a complete sequence of Middle Cambrian rocks is known only in the Camooweal-Undilla area of Queensland.

In the southern half of the Georgina Basin, Cambrian and Ordovician marine sequences occur, and the thickest exposures are in the Huckitta, Tobermory-Glenormiston and Boulia areas, where measured sequences range from 4000 to 6000 feet.

The Georgina Basin sediments of the Huckitta and Tobermory-Glenormiston areas were deformed in ?Carboniferous time during an orogeny named locally the Alice Springs Orogeny, but the Boulia area was not affected by this orogeny, and the main tectonic events there occurred in Lower Ordovician time, with a mild recurrence of faulting near the end of Lower Cretaceous.

The Alice Springs Orogeny was not accompanied by igneous intrusions. Structural deformation is locally intense and consists mainly of parallel faults trending north-west, with the north-eastern blocks down-thrown. These faults are parallel to, and in some cases coincident with, faults in Precambrian basement rocks. The faults are mainly normal with throws of several thousands of feet in some cases, but some overthrusting may have occurred along the south-western flank of the Toko Syncline, in Queensland. The faults shaped the south-western preserved margin of the Georgina Basin, and the south-western flanks of the asymmetric Dulcie and Toko Synclines. A complementary set of faults trending north-east is evident in the northern part of the Toko Syncline; these are normal faults, with the south-east block down, but with throws not exceeding 200 feet. The importance of compressive folding during the Alice Springs Orogeny is difficult to assess because many of the known anticlines, synclines and monoclines are related to faulting movements.

In the Burke River structural belt, tectonism reached a climax in Lower Ordovician time, but the stratigraphic record indicates numerous vertical movements of a meridional block of the Precambrian Cloncurry Complex. These movements began during Middle Cambrian time and continued intermittently until the Lower Ordovician climax, when folding and later faulting produced structures trending north. A mild rejuvenation of faulting occurred in late Cretaceous time in this area, but there is no evidence of Mesozoic tectonism in the Toko Syncline area or west of it.

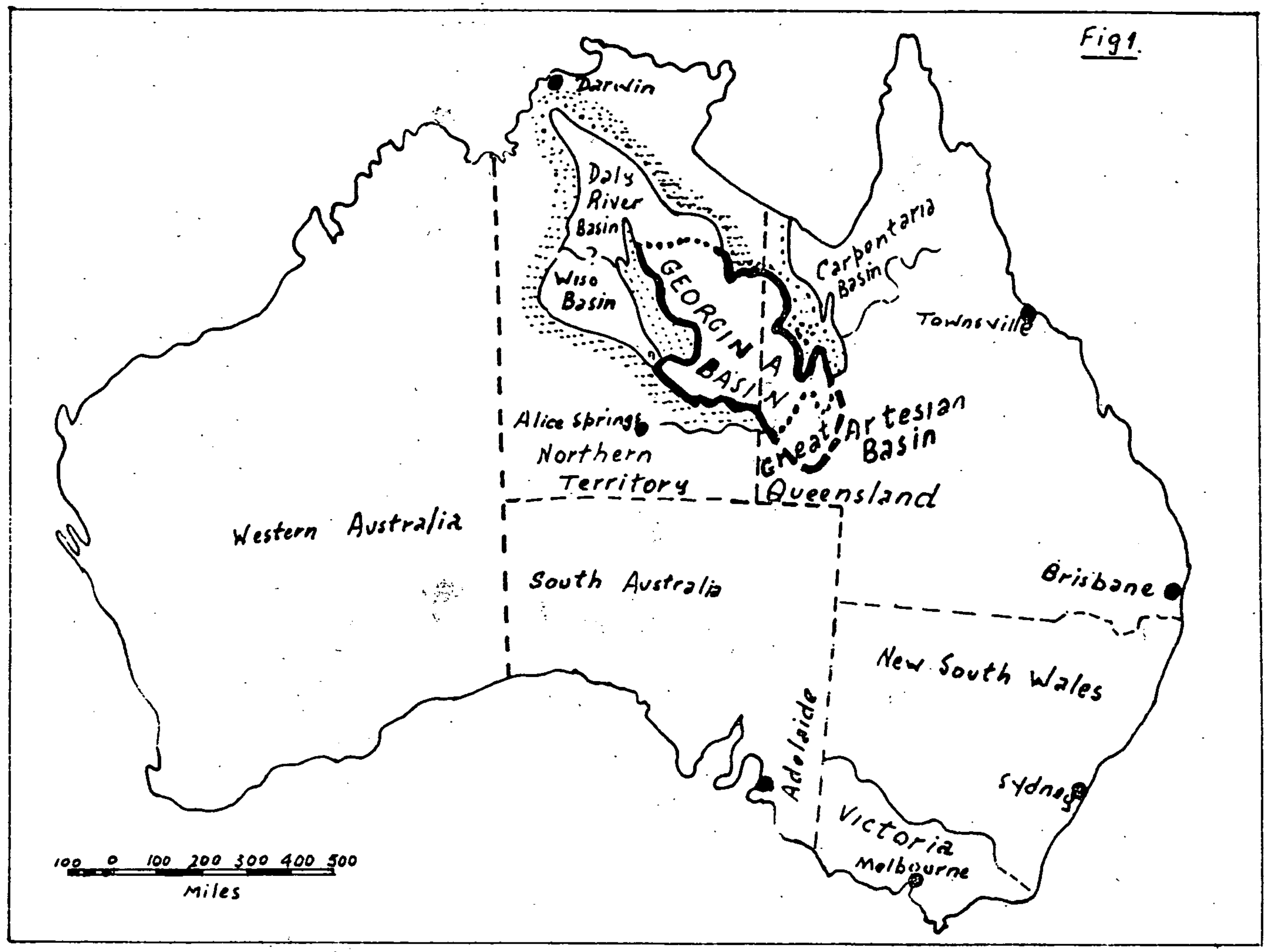
To 31st December, 1966, nineteen wells have been drilled but only one of them tested the Middle Ordovician sequence; seven wells tested only Middle Cambrian sediments, eight tested Middle Cambrian and Upper Cambrian-Lower Ordovician rocks, and three penetrated unprospective Precambrian sediments beneath the Mesozoic.

The only hydrocarbons found were small quantities of gas in Farmout-Place Ammaroo No. 1 Well, and globules of oil, with some gas, in the BMR 13 (Sandover) Well. Both of these occurrences were in Middle Cambrian sediments. Many of the richly-fossiliferous Middle Cambrian units of the Georgina Basin may provide potential source rocks, and petroliferous odours have been reported from fresh specimens of limestone and shale in many localities. However, in the northern half of the Basin these sediments are thin and apparently structureless, suitable cap rocks are unknown, and the only possible reservoir rocks are vuggy and cavernous carbonates which have produced large volumes of water. In the southern part of the Basin, potential source rocks may be present in Cambrian and Ordovician rocks, and there are porous sandstones and carbonates, and shales to act as cap rocks. Most of the obvious anticlines in this area have been drilled.

No metals of economic importance have been mined from the Georgina Basin sequence, but some prospects of galena in carbonate rocks have been tested, and oolitic hematite is known in Middle Ordovician sediments. An apparently large deposit of phosphate rock has recently been discovered in Middle Cambrian sediments of the Duchess area, in north-western Queensland and testing of the deposit is in progress.

Supplies of groundwater are generally adequate for the present method of grazing cattle. The pastoral industry of the Basin area depends on groundwater, and supplies are readily available from carbonate rocks in the northern half, and good production is usually obtained from sandstone and from some of the carbonate rocks in the southern part.

PART I



LOCALITY MAP, GEORGINA BASIN

To accompany Records 1967/61

INTRODUCTION

This Bulletin deals with the geology of the Georgina Basin, which is a large Palaeozoic sedimentary basin trending north-west from western Queensland into the Northern Territory. By definition (page 23) the basal beds of the Georgina Basin are of lower Middle Cambrian age, and the basin contains Cambrian and Ordovician marine sediments and Devonian or Siluro-Devonian fresh-water sequences. Precambrian outcrops define the south-western, western, northern and eastern margins of the Basin (Fig. 1) but the north-western margin is obscured by Mesozoic sediments which conceal a probable connection with the Daly River Basin; Mesozoic sediments of the Great Artesian Basin conceal the south-eastern margin but geophysical surveys and limited drilling have indicated the extent of the Palaeozoic sediments in that area. In the west, Quaternary sand conceals a probable connection with the Palaeozoic Wiso Basin.

Location

The outlines of the Georgina Basin, including its probable subsurface extension in the south-east, are shown on Figs. 1 and 2. No accurate assessment has been made of the area occupied by Palaeozoic sediments in the Basin's south-eastern extension.

There are no large towns within the Georgina Basin area, but Camooweal (population 251)* and Urandangi (population about 30) are small local centres. The main commercial centres serving the area are outside its outcropping margins and are Mount Isa (population 13,338), Cloncurry (2438), Boulia (300) and Dajarra (184) in Queensland, and Alice Springs (4638) and Tennant Creek (837) in the Northern Territory.

Development

Some of the Georgina Basin's surface is unoccupied desert, but most of the land is divided into large areas, sometimes exceeding 1000 square miles, known as "stations". Most of the stations run beef cattle but sheep are raised on a few in the Northern Territory and several in Queensland. Climatic conditions and the present stage of development support the open range system of grazing,

*Population figures are taken from 1961 Commonwealth Census, except for Urandangi whose population of less than 50 is not published.

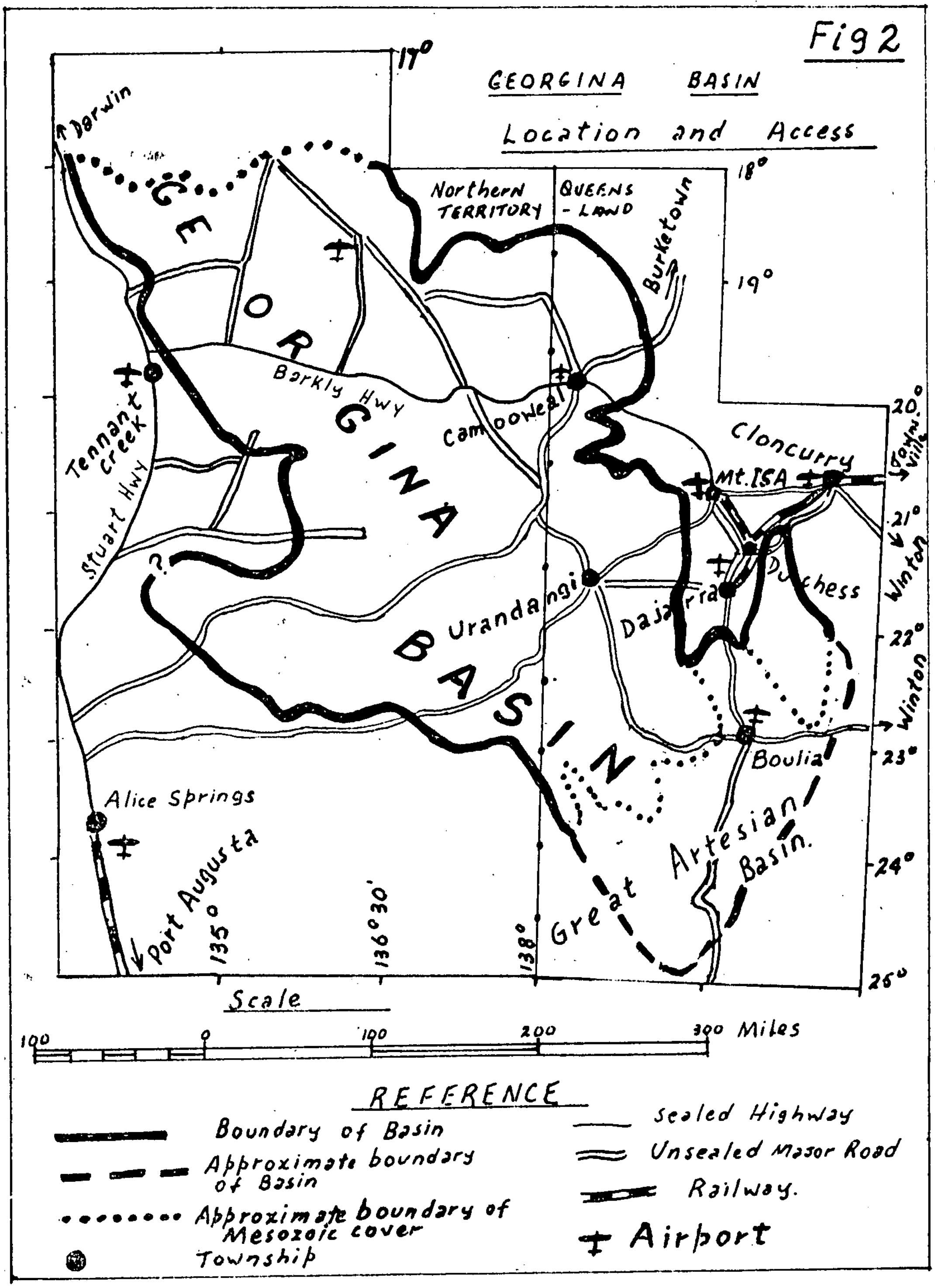
i.e., large areas with few subdivision fences. There are no major water storage systems, no power outside the towns and no base-metal mining. A few road-houses on major highways cater for tourists, who pass in large numbers in the winter months but who seldom venture on secondary roads.

Thus the bulk of the population is engaged directly or indirectly in the pastoral industry. The published census figures for towns include the populations in adjacent rural areas and therefore accurate figures for white residents in the Georgina Basin are unknown, but the number probably does not exceed 3000.

Access and Communications

There are no railway lines within the Basin area, and it is therefore dependent on road transport from railheads, and to some extent on air transport. Alice Springs is the northern terminus of a 3'6" (mainly) gauge railway line originating at Port Augusta (South Australia), and operated by Commonwealth Railways. The same organisation operates a railway line of 3'6" gauge from Darwin to Larrimah, which is about 100 miles north of the north-western margin of the Georgina Basin. In the eastern part of the Basin, Mount Isa is linked by railway of 3'6" gauge, owned and operated by the Queensland Government Railways, with the coastal port of Townsville, 600 miles to the east. This railway is the main supply line for much of north-western Queensland, and also for the north-eastern part of the Northern Territory. The line also passes through the towns of Cloncurry and Duchess, and Dajarra is the terminus of a spur line from the main railway.

The scarcity of railway facilities places strong reliance on road transport. The main roads serving the Georgina Basin area are the sealed Stuart Highway connecting Alice Springs with Darwin, 956 miles to the north, the sealed Barkly Highway which links Tennant Creek with Mount Isa, a distance of 420 miles, and an unsealed road (now being sealed) linking Boulia with Winton, 220 miles to the east. These roads, and most of the main secondary roads of the area are shown on Fig. 2; all of the secondary roads are unsealed, and many of them are impassable for several days after heavy rainfall. Since 1962, the Commonwealth and Queensland Governments have sponsored the construction of several good quality "beef roads" to enable cattle to be transported by road to railheads. Some of these roads serve the Georgina Basin,



To accompany Records 1967/61

but not all are shown on Fig. 2 and on Plates 1-4 because some have been constructed after the latest topographical surveys. Throughout the populated parts of the Georgina Basin, networks of station tracks lead to watering places for stock and provide good access for field work; off the roads and tracks, access is generally good for four-wheel drive vehicles.

In the Northern Territory there are no scheduled services for surface mail except along the sealed highways, but most of the Queensland part of the Georgina Basin is served by regular surface mail services controlled by the Postmaster-General's Department and originating at Camooweal, Boulia, Cloncurry and Mount Isa. The Northern Territory mail services are operated by light aircraft which carry mail, passengers and freight on regular flights from Alice Springs to most stations, where airstrips suitable for light aircraft are maintained by pastoralists.

In the Northern Territory normal telegraph and telephone facilities are available only at places on the sealed highways and at Lake Nash and Austral Downs, but there is a wider spread of these services in north-western Queensland and many homesteads in the Camooweal, Mount Isa, Cloncurry, Boulia, Dajarra, Duchess and Urandangi areas have telephones installed. The general lack of telegraphic facilities is offset by the radio service operated by the Royal Flying Doctor Service. This organisation has base stations at Alice Springs and Mount Isa, and provides prompt medical attention and regularly transmits to, and receives telegrams from, hundreds of station homesteads and mining communities which operate radio transceivers.

Major airports at Alice Springs, Tennant Creek, Mount Isa and Cloncurry are served regularly by Australian domestic airlines; Alice Springs and Tennant Creek are on the Adelaide-Darwin air-route, and Mount Isa is linked with Darwin, Townsville, Brisbane, and Sydney. Cloncurry is a port of call on feeder services between Mount Isa and each of Townsville and Brisbane, and in the Northern Territory both Brunette Downs and Alexandria stations have gravel-surfaced aerodromes served by DC3 or Fokker F27 aircraft; similar aircraft operate regular fortnightly services from Mount Isa to Boulia and numerous stations - Glenormiston, Springvale, Marion Downs and Brighton Downs. Air charter services operating light twin and single-engined aircraft, are based in Mount Isa and Alice Springs.

Climate

Most of the Georgina Basin lies north of the Tropic of Capricorn, and the climate is therefore tropical, tempered by the position of some areas near the centre of the Australian continent. Long, hot summers and short mild winters are typical. As a result of these climatic conditions field work is performed most efficiently in the winter months between June and September. The area north of 20^{o} south latitude is virtually frost-free, and therefore frosts are unknown in the northern part of the Georgina Basin, and are infrequent in the southern part. The prevailing winds are from the south-east and these blow strongly for most of the year; in times of drought they are heavily charged with dust and sand.

Table 1 contains the temperature records for Alice Springs, Tennant Creek, Camooweal, Urandangi and Boulia; recording stations in the Georgina Basin are few, and it is necessary to use information from some centres outside the area, e.g., Alice Springs, which is in the same general climatic belt.

The whole of the Georgina Basin area lies inside the 20-inch isohyet, and in general the rainfall decreases from north to south, with increasing distance from the northern Australian coast; in the northern fringes of the Simpson Desert the annual rainfall is less than six inches. Rainfall figures for twelve selected localities are shown on Table 2, and the localities are plotted on Fig. 3.

Table 2 shows that most of the rain falls in the period November-March. During this period, the south-east trade winds are interrupted frequently by north-west monsoons, the source for most of the rainfall. Table 2 and Fig.3 show clearly that the rainfall decreases progressively with distance inland. Other sources of heavy rainfall are tropical cyclones, which affect the northern parts of the Georgina Basin and occasionally reach the southern areas.

In general, the reliability of rainfall is low, particularly in the southern third of the Georgina Basin, and periods of drought are frequent.

TABLE 1

MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURES (°F)

LOCALITY		MONTH												MEAN
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
ALICE SPRINGS	maximum	95.3	94.7	90.1	81.3	73.3	67.1	66.9	72.5	80.1	87.6	91.7	94.7	82.9
	minimum	69.8	68.3	62.8	53.8	46.0	41.2	38.9	43.2	49.2	58.5	64.0	68.2	55.3
TENNANT CREEK	maximum	98.5	96.8	94.5	88.8	81.7	76.0	75.4	81.3	88.6	95.1	98.3	99.8	89.6
	minimum	75.9	74.5	72.1	66.1	59.0	53.3	51.1	54.2	60.7	67.9	72.7	75.5	65.2
CAMOOWEAL	maximum	97.9	96.2	94.6	90.8	83.8	78.6	78.2	83.0	89.6	96.0	98.8	99.3	90.6
	minimum	75.2	74.0	70.3	63.5	55.5	49.8	47.5	51.2	58.6	66.5	71.7	74.8	63.2
URANDANGI	maximum	100.9	99.5	96.3	90.5	82.1	76.1	75.4	80.9	88.2	95.2	99.8	101.5	90.5
	minimum	74.7	73.8	68.4	58.5	52.7	47.8	45.2	47.7	54.8	63.4	69.0	73.7	60.8
BOULIA	maximum	101.8	99.1	96.2	88.1	80.9	73.8	72.8	78.4	86.2	93.2	97.8	100.8	89.1
	minimum	76.0	74.8	71.0	61.9	53.5	48.1	45.8	46.8	55.6	63.2	69.7	73.7	61.7

TABLE 2

MEAN MONTHLY RAINFALL (INCHES)

LOCALITY	NUMBER OF YEARS	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YEARLY AVERAGE
ALICE SPRINGS	30	1.74	1.32	1.09	0.39	0.60	0.52	0.29	0.31	0.28	0.71	1.15	1.53	9.93
TENNANT CREEK	30	4.04	3.54	2.08	0.35	0.21	0.35	0.25	0.06	0.11	0.40	1.07	1.39	13.85
NEWCASTLE WATERS	13	5.14	3.33	1.88	0.83	0.74	0.01	0.15	0.02	0.09	1.37	1.15	3.13	17.84
WONARAH	13	3.06	2.21	0.81	0.44	1.08	0.29	0.20	0.03	0.11	0.59	0.67	2.12	11.62
BRUNETTE DOWNS	11	4.13	3.53	1.04	0.52	0.98	0.05	0.03	0.02	0.02	0.59	0.57	2.52	14.00
ANTHONYS LAGOON	13	6.40	4.09	1.55	0.41	1.23	0.03	0.09	0.01	0.14	0.47	1.49	3.61	19.42
CAMOOWEAL	13	3.80	3.72	2.46	0.76	0.96	0.19	0.15	0.02	0.10	0.62	1.05	2.42	16.24
LAKE NASH	13	2.50	2.89	1.79	0.35	1.10	0.46	0.51	0.06	0.13	0.50	0.43	1.21	11.96
URANDANGI	30	2.05	2.26	0.96	0.29	0.50	0.51	0.43	0.12	0.25	0.47	0.83	0.97	9.64
BOULIA	56	1.69	1.98	1.53	0.99	0.42	0.53	0.32	0.26	0.29	0.53	0.90	1.30	10.34
CHATSWORTH	28	2.49	2.85	1.63	0.52	0.60	0.69	0.42	0.08	0.26	0.57	0.85	1.52	12.48
GLENORMISTON	44	1.10	1.70	0.97	0.20	0.31	0.41	0.28	0.12	0.21	0.47	0.45	1.17	7.44

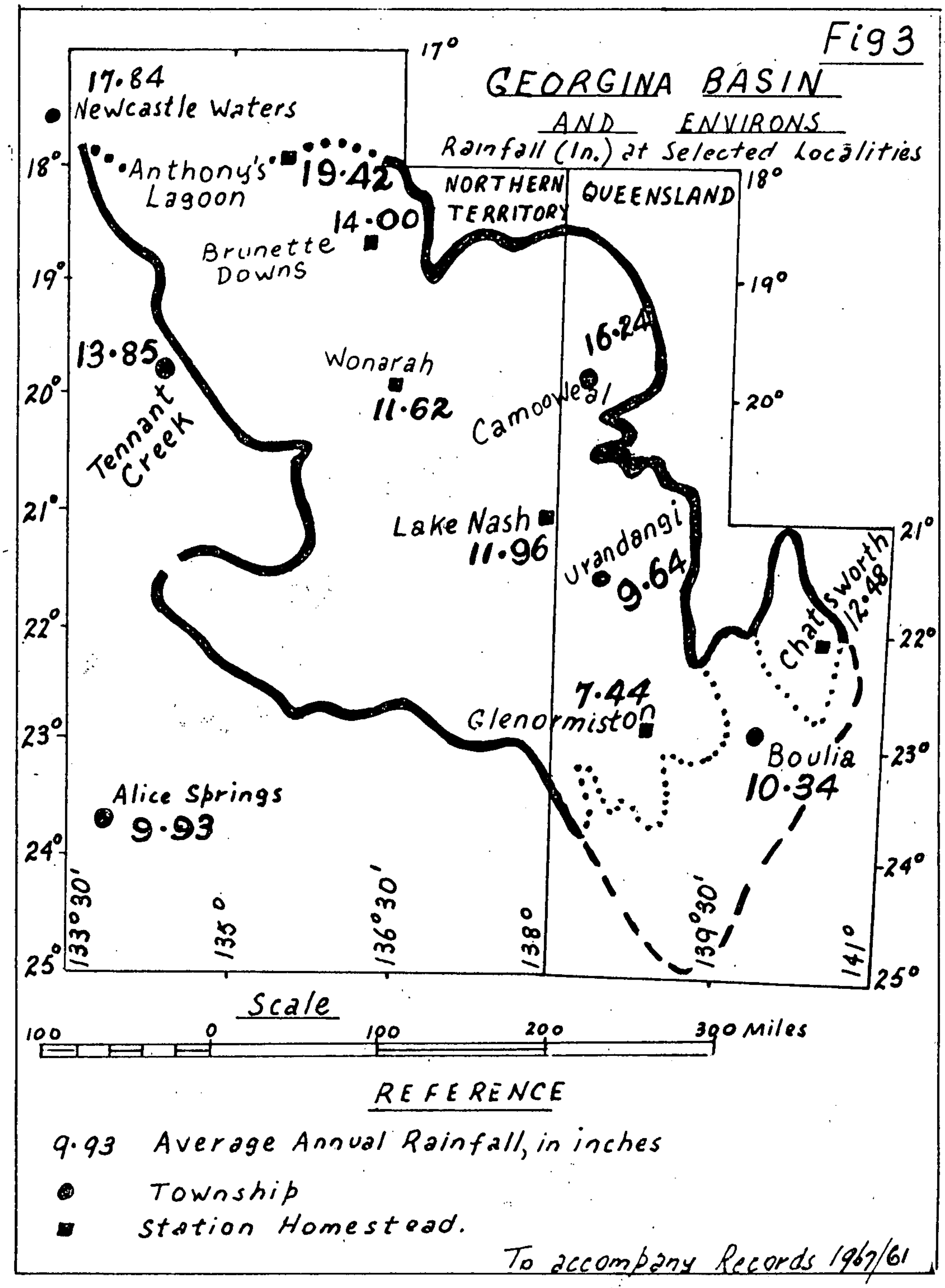


Fig 3
GEORGINA BASIN
AND ENVIRONS
Rainfall (In.) at Selected Localities
NORTHERN TERRITORY
QUEENSLAND
17.84
Newcastle Waters
Anthony's Lagoon
19.42
14.00
Brunette Downs
13.85
Tennant Creek
Wonarah
11.62
16.24
Camooweal
Lake Nash
11.96
Urandangi
9.64
Chatsworth
12.48
7.44
Glenormiston
Boulia
10.34
Alice Springs
9.93
17°
18°
19°
20°
21°
22°
23°
24°
25°
133°30'
135°
136°30'
138°
139°30'
141°
Scale
100
0
100
200
300 Miles
REFERENCE
9.93 Average Annual Rainfall, in inches
Township
Station Homestead.
To accompany Records 1967/61

Water Supplies

There are very few localities where permanent supplies of water are available in the Georgina Basin, although many large waterholes of a semi-permanent nature hold water for several months after heavy rainfall. Most of these waterholes are in the Georgina River. Earth tanks and dams have been constructed on many stations, but evaporation in summer months causes losses of up to 50% of the stored water. The pastoral industry therefore depends on supplies of underground water from bores, and most stations operate many of these for stock and domestic purposes. The number on any station depends on several factors, including available finance, availability of water and the depths at which adequate supplies are obtained. For the watering of cattle, the primary stage of development of a property requires one bore per 70-100 square miles, but many properties have attained higher stages of development.

Vegetation

Since the Georgina Basin lies within a rainfall belt ranging from 20 to 6 inches, where droughts are frequent, the vegetation is characterised by drought-resisting and drought-evading types of trees, shrubs and grasses. (Drought-resisting vegetation continues to grow during drought, but drought-evading types lose their leaves, growth stops, and the vegetation appears dead). The wide range of rainfall, soil types and local drainage patterns produce many variations in vegetation, but in general terms the northern fringe of the Georgina Basin, where rainfall exceeds 15 inches, is characterised by *Eucalyptus* spp., and the remainder by *Acacia* spp. (Perry 1960). This generalisation does not exclude *Eucalyptus* spp. from the southern areas, but there the trees of this family are found mainly along the banks of major streams.

In the non-eucalypt area, the most abundant trees are mulga (*Acacia aneura*), but gidyea, ironwood, witchetty bush (all *Acacia* spp.), supplejack (*Ventilago viminalis*) and whitewood (*Atalaya hemiglanca*) are fairly common; all are drought-resisting species, seldom growing more than 20 feet high. Important drought-resisting shrubs in the southern part of the Basin are saltbush (*Atriplex* spp.) and southern bluebush (*Kochia* spp.), which have nutritive value for stock. Most areas of the southern part of the Basin are covered by various species of *Triodia* or *Plectrachne*, which are sclerophyllous grasses forming large hummocks and collectively called spinifex; these grow on sand plains, dune fields, and on most of the stony hills.

Several perennial drought-evading species of grasses flourish on the virtually-treeless plains of the Barkly Tableland and extend south-east down the plains of the Georgina River (Perry and Christian, 1948); the best-known species is Mitchell grass (Astreleba spp.), which grows in tussocks, but Flinders grass (Iseilema spp.) is also common. Both are very important to the pastoral industry and provide a nutritive food for cattle; often they are the only grasses available for fodder.

PREVIOUS INVESTIGATIONS

A large number of individuals, including explorers, surveyors and geologists, have made geological observations in the Georgina Basin and around its margins, but a clear picture of the Palaeozoic geology did not emerge until the late 1950's; however, by 1931 Palaeozoic strata had been correctly recognised on both the south-western and eastern margins of the Basin. Many of the early observations were made after the discovery of metals at Cloncurry (gold, in 1867), Mount Isa (silver-lead, in 1923), Jervois Range (copper, in 1929) and Tennant Creek (gold, in 1932); these discoveries were all within a few miles of the margins and inevitably stimulated exploration into the margins of the Basin, particularly in north-west Queensland. Other geological observations, apart from those made by explorers, were recorded during reconnaissance surveys for a proposed transcontinental railway line across the Barkly Tableland, and during investigations into artesian water supplies from Mesozoic cover rocks in the south-east. The published works are listed in the bibliography, and only the more important investigations, or those of historical interest, are mentioned here.

The explorers A.C. Gregory (1861), Burke and Wills (In Jackson, 1862), Landsborough (1862), and McKinlay (1863) made random observations on outcrops in north-west Queensland, and Gregory and Landsborough continued their journeys into the Northern Territory, where they made additional observations. John McDouall Stuart, in 1861, skirted the western margin of the Georgina Basin and named Central Mount Sturt (later changed to Central Mount Stuart) and Winnecke (1884) journeyed westward from Sandringham station to the Hay River, and followed it upstream for much of its course before deviating to the Jervois Range and thence to Alice Springs.

Daintree (1872) made geological investigations in the Mount Isa area and produced a reconnaissance geological map of Queensland on which he showed the whole of the outcrops of northwestern Queensland as Cretaceous, except for an inlier of Silurian metamorphic rocks around the Cloncurry Gold Field. For the next 50 years there was considerable confusion regarding the age of the rocks in north-western Queensland.

The surveyor Hodgkinson (1877) made random, geological observations in the eastern part of the Georgina Basin, and he named the Cairns (now Toko) Range and reported sandstone and limestone there. Jack (1885) reported on observations made during traverses to examine the feasibility of a railway to Cloncurry and beyond to the west, and he was also (1895) involved in artesian water supply problems. He observed that unfossiliferous limestone of the Barkly Tableland rested unconformably on metamorphic rocks of the Cloncurry region, and he and Etheridge (1892) outlined the extent of the metamorphic belt. Jack's reports were first published as Parliamentary Papers, and later (1898) re-issued, with revisions, as a Queensland Geological Survey publication. Jack (1895) quoted Hodgkinson's (1877) description of rocks in the Cairns Range and correlated these rocks with the metamorphic rocks of the Cloncurry area, because boring between the two areas had failed to produce artesian water. Jack (op. cit) concluded that "the metamorphic rocks of the Cairns Range are continuous to the Cloncurry area at or very near to the surface". Jack (1897) identified Orthoceratites amongst fossils forwarded to him from the Cairns Range and considered its age to be Lower Silurian (here he used "Lower Silurian" for the age now called "Ordovician"); this determination, and his (1895) correlation between rocks of the Cairns Range and those at Cloncurry, were sited for many years as evidence of the Ordovician age of the Cloncurry Series.

Cameron (1900) inspected silver-lead prospects at Lawn Hill, and (1901) recorded geological observations in north-west Queensland; in this paper he regarded the metamorphic rocks of the Cloncurry area as Silurian, and stated that they were overlain by sandstone and limestone of possible Devonian age. Ball (1911) reported on the Lawn Hill Field (Burketown Mineral Field) and on the geology of the surrounding area, but incorrect identification of fossils misled him into regarding Cambrian strata as Tertiary, and it was not until about 1930 that Shepherd (In Ball, 1931) recognised that the strata were Cambrian.

Woolnough (1912) traversed from Darwin to Cloncurry, and he regarded the rocks of the Barkly Tableland and around Calton (Hills) station as Cambrian, and the metamorphic rocks to the east as Precambrian. This was a major advance in geological knowledge but was not universally accepted. Dunstan (1913, Pl. 20) showed that the Cloncurry Series extended from Cloncurry to the Northern Territory border; the same author (1920, Pl. 1) shows the limit of the Cloncurry Series fairly accurately, but still of Silurian age. He also showed limestones of north-west Queensland as Jurassic because of their stratigraphic position beneath marine Cretaceous rocks. Dunstan (1920) also recorded mud springs on the Hamilton River, and 6-foot seams of brown coal in water bores on Sandringham Station, as well as coal from bores east of the Hamilton River, near its junction with the Georgina River.

Woolnough's earlier (1912) ideas on the ages of rocks in north-west Queensland were substantiated in part by Saint-Smith (1924) who recorded the discovery (by Campbell Miles, a discoverer of the Mount Isa lodes) of Cambrian trilobites in the headwaters of the Templeton River. This important discovery provided the first evidence of the probable Precambrian age of the metamorphic strata to the east. Shepherd in 1927 made the first stratigraphical division of the Precambrian of north-western Queensland, but did not publish it; David (1932) used Shepherd's division.

Whitehouse published a series of important papers (1930, 1931, 1936, 1939, 1941, 1945(a)) dealing with the Cambrian geology and palaeontology of north-west Queensland, including the eastern margin of the Georgina Basin. In his first paper (1930) he named the "Templeton Series" of Lower to Middle Cambrian age, and the Ordovician "Glenormiston Series" of the Toko Range area; he believed that these Series occurred in separate basins. Whitehouse (1931) identified trilobites and other fossils which Ogilvie had collected from limestone "in and around the Georgina River", and he (Whitehouse) adopted Ogilvie's suggestion that the rocks be named the "Georgina Limestones"; Whitehouse also suggested that there was probably a complete sequence, ranging from upper Lower Cambrian to Ordovician, in this region.

Whitehouse (1936, 1939, 1941, 1945(a)) identified and described fossils which he had collected from the Palaeozoic rocks of north-west Queensland, and made revisions to regional geology. In his 1936 paper he divided the rocks into four Series (Templeton, Georgina, Pituri and Ninmaroo Series, in ascending order), and divided the three older (Cambrian) Series into eleven Stages, based on their trilobite faunas. In this paper, he also re-named his (1930) Glenormiston Series the Toko Series, and described the Ninmaroo Series at Black Mountain the Boulia area. In 1939 he increased his eleven Stages to twelve, by adding two and deleting one, and he also suggested that the Templeton Series was a local, non-calcareous variant of the Georgina Series. In 1941 he decided that the fossil zones required modification, and gave a provisional reduction in the number of Stages. Whitehouse (1945b) dealt extensively with the Mesozoic rocks of the Great Artesian Basin, and he gave (1954) a complete summary of Mesozoic and Cainozoic stratigraphy, and named the Boulia Shelf as an extension of shallow bedrock along the western margin of the Great Artesian Basin. Whitehouse's work on the Palaeozoic rocks of north-west Queensland and on the Mesozoic rocks of the Great Artesian Basin formed the basis of part of summaries of the geology of Queensland by Andrews (1937), Bryan and Jones (1946), David (1950) and Hill (1951); it was also used on a Geological Map of Australia and New Guinea (Bureau of Mineral Resources, 1952) and on a Geological Map of Queensland (Queensland Department of Mines, 1953).

Other valuable work on the Palaeozoic of north-west Queensland was done by officers of the Aerial, Geological and Geophysical Survey of North Australia; this organisation, known generally by the abbreviation A.G.G.S.N.A., was established by the Commonwealth, Queensland and Western Australian Governments to carry out geological and geophysical investigations of known mineral fields in northern Australia. In addition, the organisation used aerial photographs for geological mapping and pioneered the use of geophysical prospecting techniques in Australia. The Survey operated from 1935 to 1941. Most of the work in north-west Queensland concerned mineral fields in Precambrian rocks, but Honman (1937) accurately delineated (but did not name) the Burke River Outlier in the Duchess area, and Nye and Rayner (1941) described it as a "tongue of Middle Cambrian rocks". Jensen (1941a and b), and A.G.G.S.N.A. (1940a and b) recognised the existence of probable Upper Proterozoic rocks.

Investigations in the Northern Territory began about the same time as those in north-west Queensland, and generally followed the same pattern, i.e.

random observations by explorers and surveyors, and more detailed assessments of mineral prospects and the country surrounding them. However, since the Northern Territory was administered by South Australia until 1911, most of the earlier investigations, both Government and private, originated in Adelaide.

The explorer John McDouall Stuart skirted the western margin of the Georgina Basin in 1861 and made some random geological observations, as well as naming Central Mount Sturt (later changed to Central Mount Stuart). Other explorers - Barclay (1878), Winnecke (1884) and Lindsay (1889), crossed parts of the Georgina Basin and also made random observations on the geology.

Brown (1895, 1897, 1903) made geological reconnaissances over much of the Georgina Basin and its western margins. He reported (1895) the occurrence of Cambrian fossils in spoil from an old well 7 miles north-west of Alexandria station homestead; these fossils were trilobites, originally believed to be Olenellus sp., but later described as Xystridura brownii (Etheridge). Brown (1897) investigated the Huckitta area; he named Grant Bluff and described the sediments in it, as well as the arkose (now named Oorabra Arkose) which crops out nearby. He later (1903) journeyed through the Davenport and Murchison Ranges.

Davidson (1905) led a prospecting expedition through the Davenport Range and in the course of his journey discovered Cambrian trilobites about 45 miles south-east of the (old) Elkedra homestead; Etheridge (1902) described these fossils, and Whitehouse (1936) re-described them; Etheridge had previously (1897) described the fossils found by Brown near Alexandria homestead, and he later (1917) added to this fauna.

Chewings (1928) and Mawson and Madigan (1930) reported on the geology between Alice Springs and Barrow Creek, and Hossfeld (1937) mapped the Home of Bullion copper mine near Barrow Creek, as part of A.G.G.S.N.A. operations. The anthropologist Tindale (1931) examined and measured a sedimentary sequence in the Mopunga Range (near Huckitta homestead) and named the sequence the "Mopunga Beds". He also measured and described a thickness of 800 feet of sandstone and siltstone at Mount Ultim (in the Dulcie Range) and found Ordovician fossils in the slopes; his measured section included both Ordovician and

Devonian sediments, but Tindale did not find fossils in the upper (Devonian) part of his section.

Perhaps the most active of the early geologists was Madigan, who showed considerable interest in the Simpson Desert, the MacDonnell Ranges (Amadeus Basin) and the Huckitta-Tobermory areas of the Georgina Basin, bordering the Simpson Desert. He (1929) flew across the Simpson Desert at about the latitude of Lake Caroline (Hay River Sheet area) and published an account of his flights. He also (1932b) journeyed from Alice Springs through the eastern MacDonnell Ranges to the Elyuah and Mopunga Ranges, and considered that some of the sedimentary sequences in those latter ranges were equivalent to some which he had previously (1932a) mapped and named in the western MacDonnell Ranges; Madigan (1932b) also reported Ordovician fossils in the scarp of the Dulcie Range near Huckitta homestead, and he discovered poorly-preserved ?Archaeocyathids about $1\frac{1}{2}$ miles north-west of Oorabra Rockholes. In a later journey Madigan crossed the Huckitta and Tobermory Sheet areas to Tobermory station, and (1937) gave the first account of the geology of this area. He examined the Tarlton Range and found Ordovician fossils there, and also ventured southwards into the fringes of the Simpson Desert. In 1939 he led an expedition across the Simpson Desert from west to east.

In post-war years, most of the investigations in the Northern Territory part of the Georgina Basin were made by officers of the Bureau of Mineral Resources, Geology and Geophysics, which had been established in 1946. Opik (1949, unpubl.) examined the Upper Proterozoic sequence in the Jervois Range, and Joklik (1955) published the results of a survey of mica mines in the Plenty River Field, and a reconnaissance through the sedimentary rocks of the Huckitta-Oorabra Rockholes area; he named the Oorabra Arkose and considered that it formed the local base of the Upper Proterozoic succession. Noakes and Traves (1954) accompanied a survey party from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) which made a land research study of the Barkly Region in 1947-48. This survey covered a wide area between Tennant Creek and Mount Isa, and Noakes and Traves reported on both Precambrian and Palaeozoic rocks. They named the Barkly Group (Palaeozoic) and found fragments of well-preserved Cambrian fossils in pebbles on the flood plain of the Sandover River near Argadargada homestead, but did not locate the outcrops from which the pebbles had been derived.

Noakes and Casey in 1953 (pers. comm.) made a reconnaissance from Alice Springs to Tobermory homestead via the Elyuah and Jervois Ranges, with side traverses both north and south of the main route. Casey in 1954 (pers. comm.) accompanied a CSIRO survey concerned with toxic effects of the gidyea tree in the general Georgina region; he made the first collection of Middle Cambrian fossils in the Marqua area, and the first known collection of Upper Cambrian fossils in the Huckitta-Marqua region. In the same year N.O. Jones, the Bureau's Resident Geologist at Alice Springs, collected Middle and Upper Cambrian fossils from new localities on Lucy Creek Station (Huckitta Sheet area). Opik (In Ivanac, 1954) named the lower Middle Cambrian Gum Ridge Formation near Tennant Creek and identified its fauna.

Apart from sporadic traverses by the Bureau's Resident Geologist staff at Alice Springs, Bureau field investigations of the Northern Territory part of the Georgina Basin ceased between 1954 and 1957. However, other work had been done in the Camooweal-Mount Isa-Urandangi area of Queensland; Opik had accompanied combined Bureau of Mineral Resources - Queensland Geological Survey field parties which had mapped the Precambrian mineral belt of north-west Queensland in 1950-1954 (Carter, Brooks and Walker, 1961), and he had begun an investigation of the Cambrian sediments bordering the western part of the Precambrian. Opik, Casey and Randal mapped much of the Cambrian out-crops area in 1953, and together with mapping done by Noakes and Traves previously, this work enabled the completion of the mapping of the following sheets at 4-mile scale: Urandangi, Mount Isa, Camooweal and Lawn Hill. Although this work has been presented unchanged, except for minor corrections, on Plates 1-IV of this Bulletin, and the stratigraphy is used in this text, the work is referred to as "Previous Investigations" because it belonged to an earlier phase of mapping, separate from the 1957-1965 period of the Bureau's activities in the Georgina Basin, and has been reported separately in short publications, in various Explanatory Notes and has been shown on a 10-mile Geological Map of North-west Queensland compiled by Carter and Opik (1961). Inevitably, some overlap between publication of the 1949-1954 phase of Bureau activities in the Georgina Basin and the 1957-1965 phase of mapping has occurred, and in fact laboratory work on systematic palaeontology based on the 1949-1954 work and augmented by new information from the second phase, is still in progress.

Many of the results of the 1949-1954 phase of Bureau activities in the Georgina Basin were published in 1956. Opik (1956a) gave an account of the Cambrian geology of Queensland, and (1956b) described the Cambrian geology of the Northern Territory; in these papers he included much authoritative stratigraphy and palaeontology of units now known to constitute part of the Georgina Basin succession, and recognised that the Middle Cambrian faunas of north-west Queensland were different in aspect to those of the same age in the Northern Territory. He postulated a median divide of dolomite - the Camooweal Dolomite, of Upper Proterozoic or Lower Cambrian age - separating the two faunal provinces.

Noakes (1956) published an account of Upper Proterozoic rocks of the Northern Territory, and in this paper he named the Mopunga Group and published a composite section which included a tillite he had discovered in the Tobermory area. Casey and Tomlinson (1956), published an account of the stratigraphy and palaeontology of the Huckitta-Marqua region of the Northern Territory.

Other workers in the Georgina Basin included Reeves (1951) who investigated the Barkly Tableland area for Vacuum Oil Co. and regarded the petroleum prospects as unpromising because the Palaeozoic sequence was thin. Hossfeld (1954) published an account of the stratigraphy and structure of the Northern Territory; his observations were made mainly as a member of the A.G.G.S.N.A. organisation and he supplemented them by a study of aerial photographs which became available in the late 1940's and early 1950's. Small areas on the Huckitta Sheet were mapped in 1956 (Sprigg, 1958).

RELATED INVESTIGATIONS

Four Bureau surveys prior to 1957 were instrumental in mapping much of the Precambrian margin of the Georgina Basin: Ivanac (1954) mapped the Precambrian Warramunga Group and intrusive rocks, on the Tennant Creek Goldfield; Joklik (1955) mapped Precambrian metamorphic and igneous rocks in the Harts Range and Plenty River areas; Carter, Brooks and Walker (1961) mapped the Cloncurry Complex and younger Precambrian sequences; Smith, Stewart and Smith (1961) mapped the Davenport and Murchison Ranges, and Smith and Roberts (1963) mapped Precambrian rocks in the South Nicholson Basin.

MORE RECENT INVESTIGATIONS

The second phase of Bureau investigations of the Georgina Basin began in 1957 and were completed in 1965. Little mapping was done in some of these years, but scout drilling and stratigraphic drilling supplemented the surface mapping in an effort to clarify some of the problems encountered. Initially, two parties were in the field: one, staffed by Bureau geologists, began work in the Huckitta Sheet area and the other, staffed jointly by Bureau Officers and geologists from the Geological Survey of Queensland, began work in the Boulia Sheet area of Queensland. Two field parties operated from 1957 until the end of 1958, one each in the Northern Territory and Queensland, with representatives of the Geological Survey of Queensland in the Queensland party. The Queensland mapping then ended, apart from short surveys to re-evaluate information in north-west Queensland, and this work and related surveys of the Great Artesian Basin, was done by Bureau Officers. After 1958, most of the mapping was done by one field party each year, but there were two in 1961, and at other times field mapping and drilling proceeded simultaneously.

Officers who worked on the survey were:

1. Queensland

1957 - J.N. Casey (Party Leader), M.A. Reynolds, D.B. Dow, P.W. Pritchard, R.R. Vine (all BMR) and R.J. Paten (Geological Survey of Queensland)

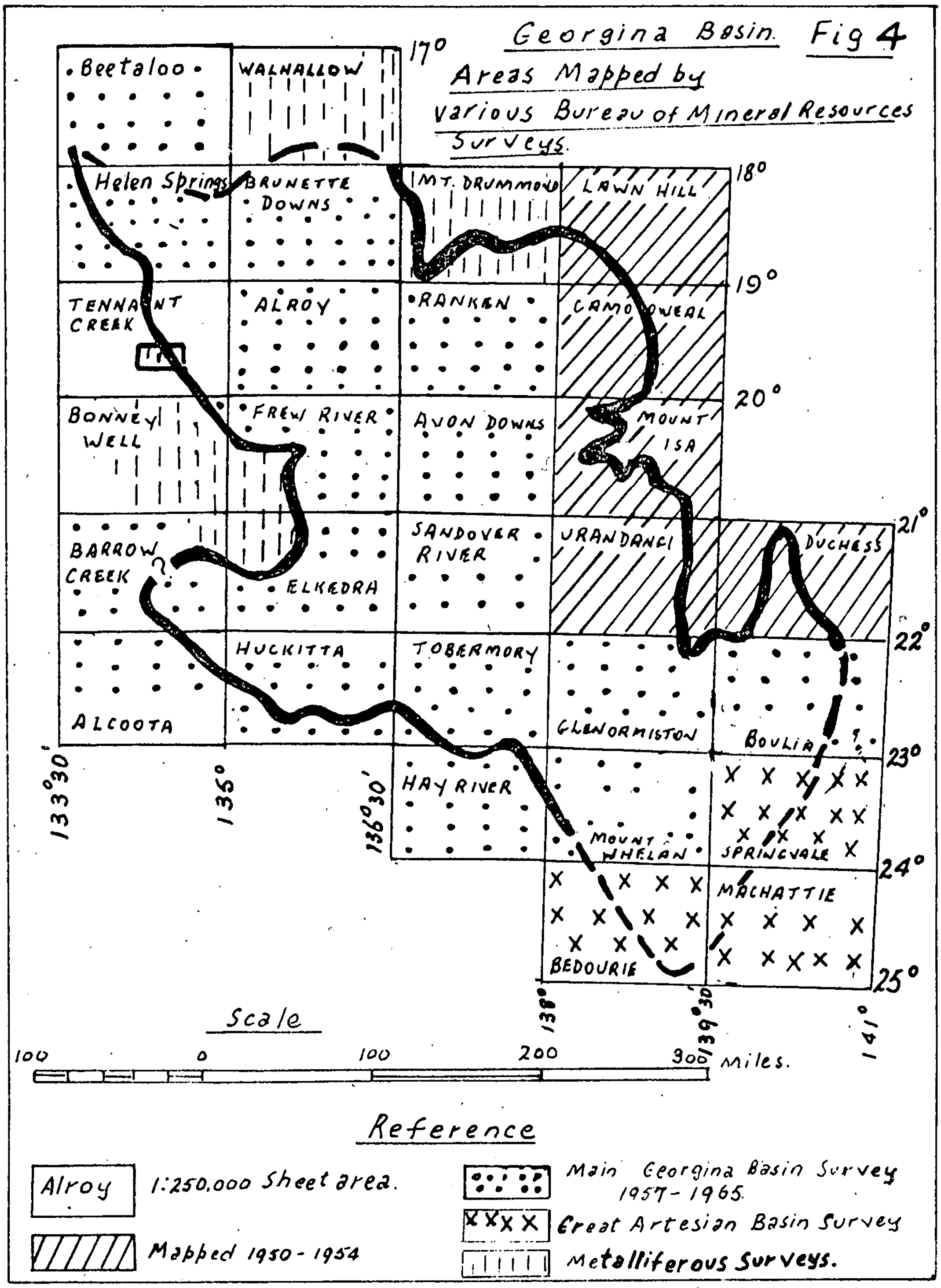
1958 - J.N. Casey (Party Leader), M.A. Reynolds, P.W. Pritchard, K.G. Lucas (all BMR) and R.J. Paten (Geological Survey of Queensland)

1960 - M.A. Reynolds (Party Leader), F. Olgers and W. Jauncey (all BMR)

1961 - M.A. Randal (Party Leader) and G.A. Brown

2. Northern Territory

1957 - K.G. Smith (Party Leader), J.W. Smith, D.R.G. Woolley, and J.M. Pulley



Georgina Basin. Fig 4

Areas Mapped by various Bureau of Mineral Resources Surveys.

To accompany Records 1967/61

1958 - K.G. Smith (Party Leader), K. Gough, D.R.G. Woolley and R.R. Vine

1959 - K.G. Smith (Party Leader), P.W. Pritchard, D.R.G. Woolley, R.R. Vine, D.J. Forman and A.R. Jensen

1960 - K.G. Smith (Party Leader), R.R. Vine, E.N. Milligan and P.J. Jones

1961 - K.G. Smith (Party Leader) and E.N. Milligan.
M.A. Randal (Party Leader) and G.A. Brown

1962 - Core Drilling: E.N. Milligan (Party Leader), A.R. Lloyd, G.A. Brown, J.M. Drummond, P.J. Jones, N.E.A. Johnson and K.G. Smith
Field Mapping: M.A. Randal (Party Leader) and R.A.H. Nichols

1963 - K.G. Smith (Party Leader), E.N. Milligan and R.A.H. Nichols

1963 - Stratigraphic Drilling: R.A.H. Nichols, N.E.A. Johnson, and K.G. Smith

1964 - Stratigraphic Drilling: A.R. Lloyd, R.D. Shaw, R.A.H. Nichols and M.A. Randal

1965 - M.A. Randal (Party Leader), M.C. Brown and H.F. Doutch

In the early stages of the survey, the air photographs provided the only accurate available record of topography, but the Commonwealth Government's Division of National Mapping subsequently prepared topographic base maps at air photo scale and at 1:250,000 or 4-mile scale; these were compiled by the slotted template method and controlled by astro-fixes at a few ground stations in each sheet area. After 1960, approximately, levels obtained for, and from, helicopter-borne gravity surveys were of considerable assistance to the geological field parties.

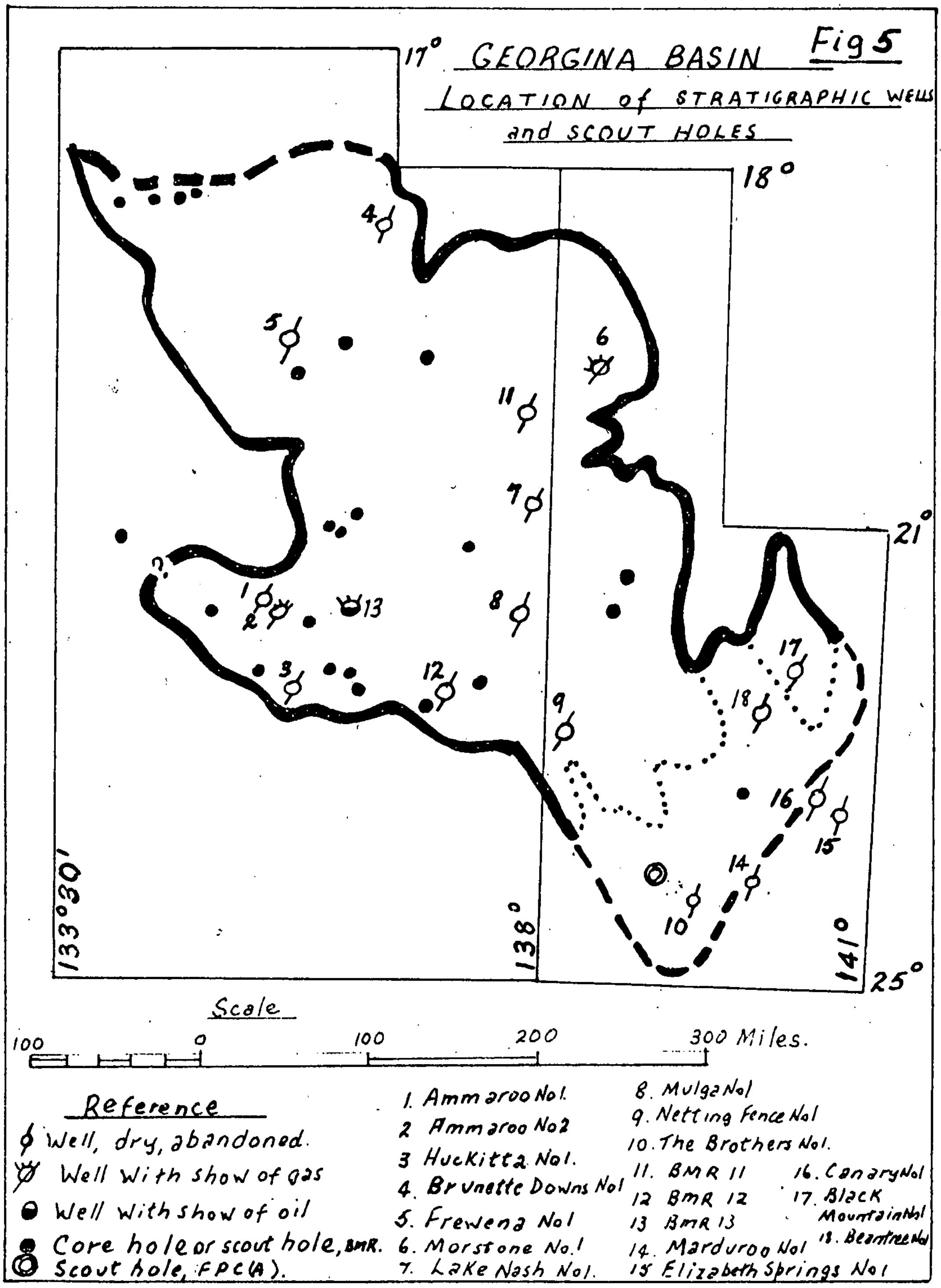
Results: Fig. 4 shows the area mapped during 1957-1965, and the areas of related surveys, including earlier ones in the Georgina Basin.

After each Sheet area had been mapped, an account of the geology was written in the Bureau's unpublished Records Series and made available to interested parties as soon as possible; each Record was accompanied by a Preliminary Edition of the appropriate 1:250,000 Sheet, prepared by reduction of the photo-scale templates. Other Records were prepared on various facets of the investigation, e.g., water, which required separate treatment. Later, Explanatory Notes, accompanied by a coloured 1:250,000 scale map, were prepared for most Sheet areas, and in a few cases the geology of particular areas has been published in the Bureau's Report Series, or in outside journals. To date, Explanatory Notes for most of the sheets mapped in the 1957-1965 programme have been either published or are in preparation; Explanatory Notes for most sheets mapped in North-west Queensland have also been published, but the accompanying maps are at 4-mile scale instead of 1:250,000. Plates 1-4 of this Bulletin have been compiled by reduction of all published 1:250,000 or 4-mile sheets.

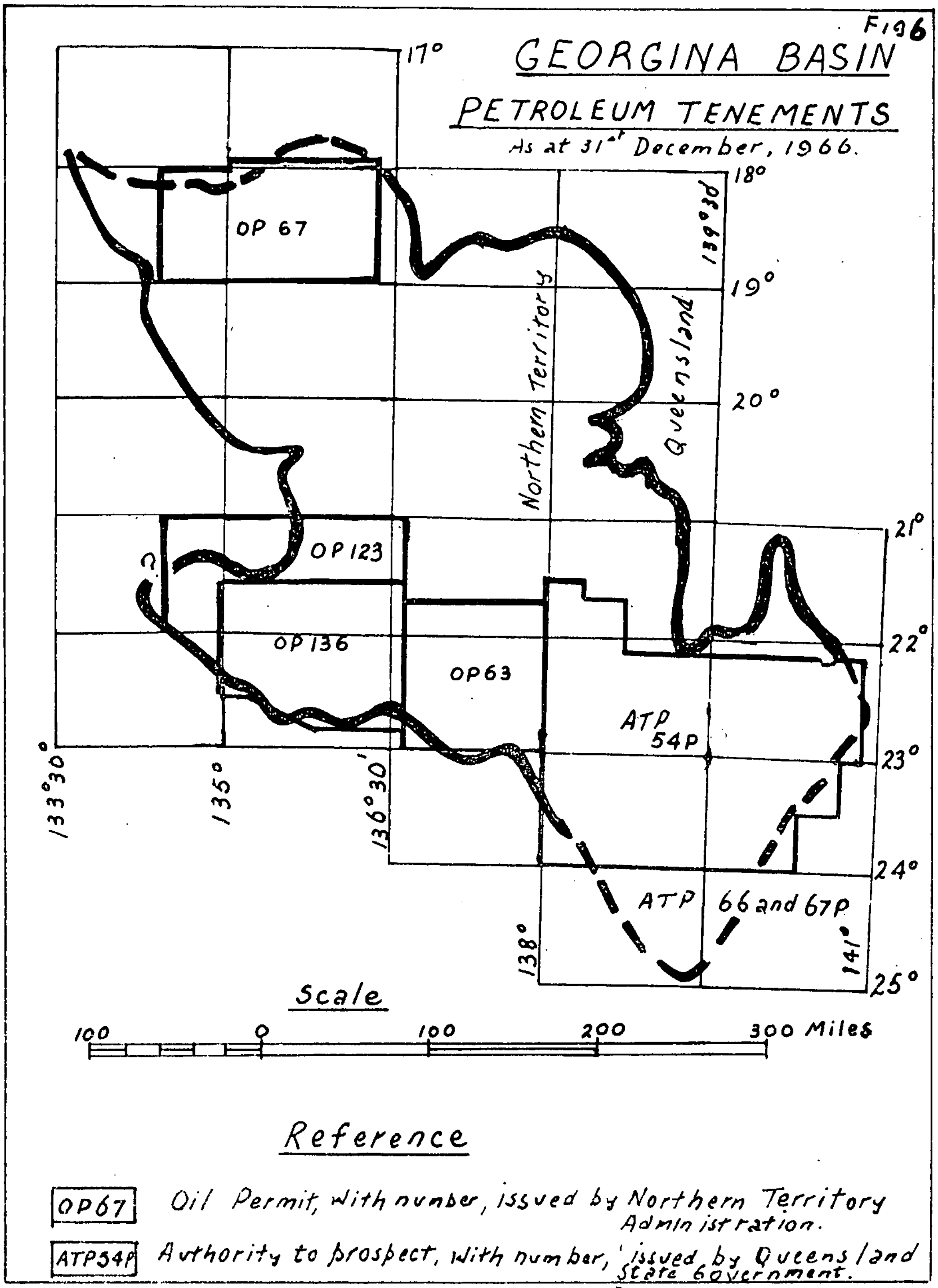
COMPANY ACTIVITIES

In 1956 a small show of gas was discovered near Ammaroo homestead, Northern Territory, during water-boring activities (Mackay and Jones, 1956, unpubl.). This discovery stimulated petroleum search in the immediate vicinity and soon much of the surrounding area was held under Oil Permits granted by the Northern Territory Administration to companies or individuals to enable them to have sole prospecting rights for petroleum over certain areas not exceeding 10,000 square miles. Each permit is valid for a limited period, and may be renewed annually, subject to satisfactory performance by the permittee. In Queensland, the permit is called an Authority to Prospect and it is held under much the same conditions as those in the Northern Territory, but the periods for which the Authority is valid are generally longer in Queensland.

At certain times since 1956 the whole of the Georgina Basin area and much of its margins have been held under petroleum prospecting titled, but the fortunes of various companies have fluctuated and to date none have succeeded in producing either oil or gas in commercial quantities. Many areas have now (1966) been relinquished and the areas held at 31.12.66 are shown on Fig. 6.



To accompany Records 1967/61



To accompany Records 1967/61

Petroleum search in the Georgina Basin has led to a considerable amount of company work, both geological and geophysical, and some of this work has been performed under the terms of the Commonwealth Government's Petroleum Search Subsidy Act, which was introduced in 1957 to add impetus to petroleum exploration. This Act, and amendments made in 1959, 1961 and 1964 (Petroleum Search Subsidy Act, Sixth Annual Statement, 1964-1965) currently enables companies engaged in petroleum search to be subsidized for the cost of some operations, namely stratigraphic drilling, test drilling and geophysical surveys, provided that such operations have the prior approval of the Minister for National Development.

Very few of the subsidized operations have yet been published, but the unpublished final reports are released, under the Act, six months after the completion of the operation.

Company geological activity has included field mapping, photogeological evaluation of parts or all of the area, and stratigraphic drilling. Exploration companies have drilled 15 wells (eight in Queensland and seven in the Northern Territory); the locations and names are shown on Fig. 5. 13 of these wells were drilled under the P.S.S.A.. The total footage is 51,069; the deepest well is Netting Fence No. 1 (6666 feet), which is the only well to penetrate most of Palaeozoic sequence in the Georgina Basin. All wells have been plugged and abandoned.

All unpublished reports of subsidized operations, both geological and geophysical, together with several confidential geological reports made in the course of company investigations in the Georgina Basin, are listed in a separate section of the bibliography. Inevitably the list of geological reports will be incomplete, because several companies who have not held titles have made geological investigations, and particulars of their reports are unknown.

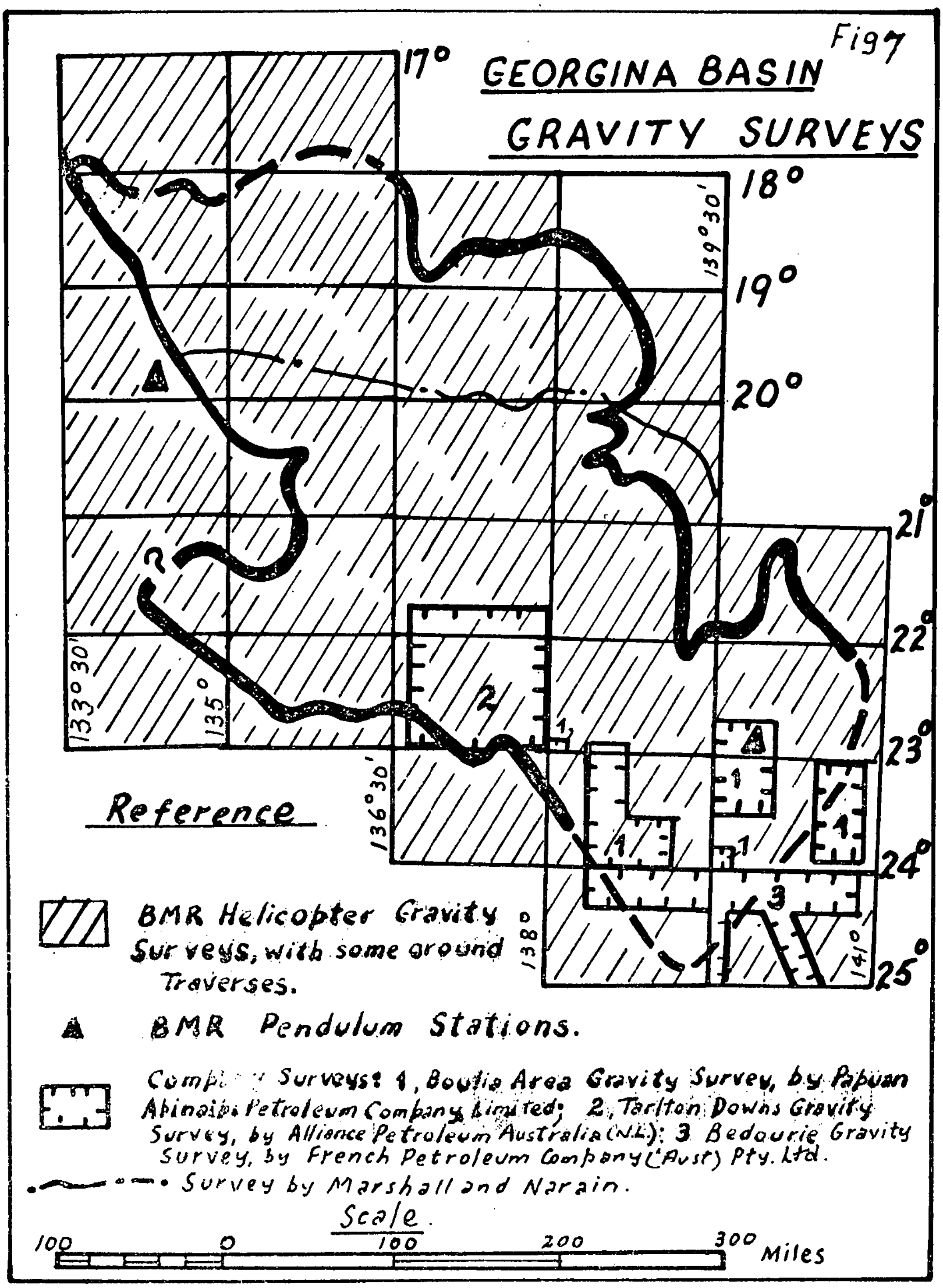
GEOPHYSICAL SURVEYS

Before 1957 the only geophysical investigations within the Georgina Basin consisted of a gravity traverse by Marshall and Narain (1954). Since 1957 much gravity, aeromagnetic and seismic work has been done, both by the Bureau and by oil exploration companies. Many of the surveys, particularly seismic, overlap and in some cases the Bureau has made its basic aeromagnetic data available for re-interpretation by holders of Oil Permits.

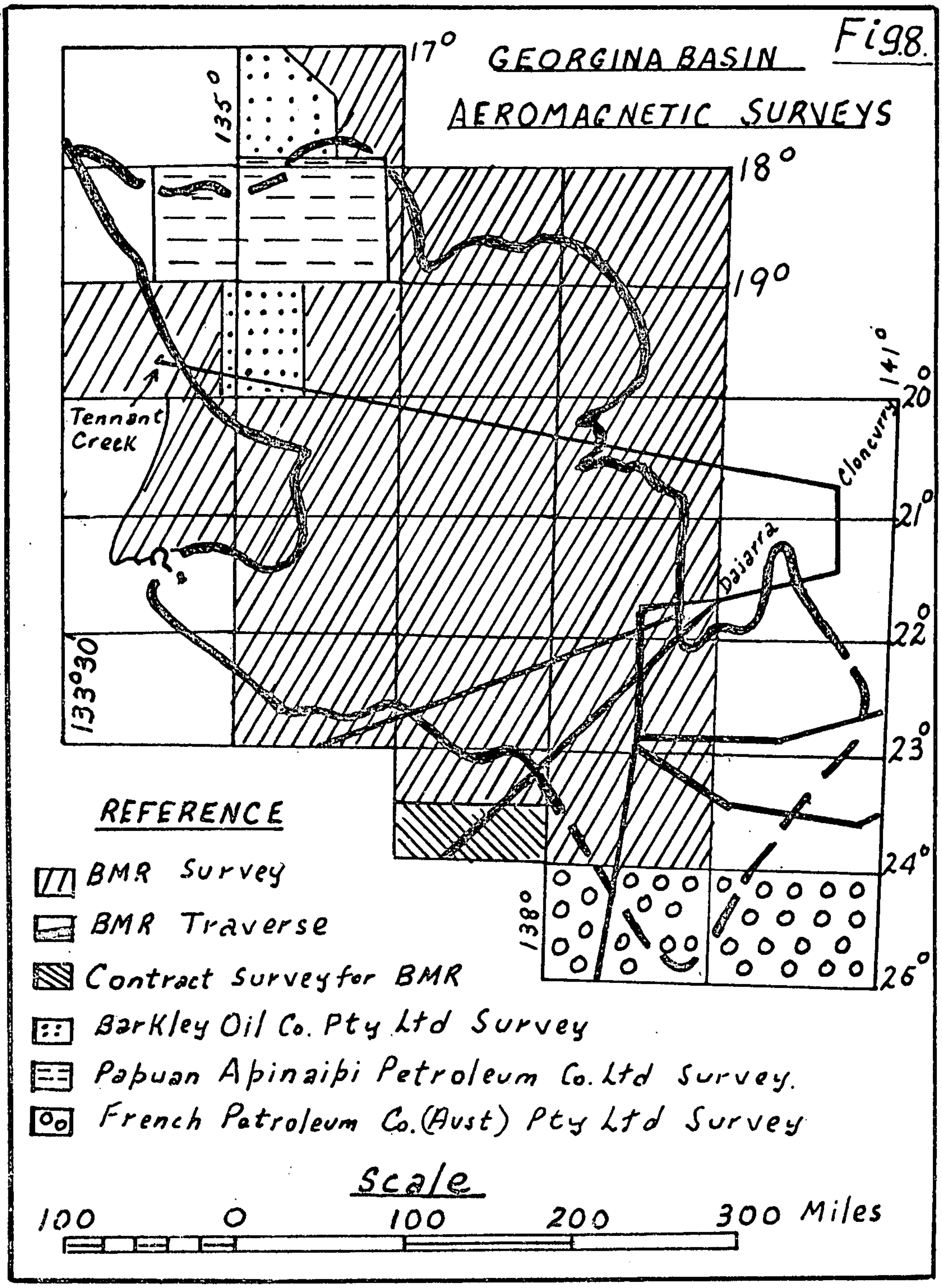
Gravity Surveys in the Georgina Basin are shown on Fig. 7. Most of these have been made by the Bureau. All of the company surveys were subsidized under the Petroleum Search Subsidy Act and Fig. 7 lists the official titles. In some cases these gravity surveys were made concurrently with seismic surveys, by taking readings at shot-points.

The Bureau's surveys began with ground traverses in the Boulia and Glenormiston Sheet areas in 1957, 1958 and 1959 (Neumann, 1959a and b, unpubl.) and similar work was done in the Huckitta, Tobermory, Hay River, Sandover River and Elkedra Sheet areas (Barlow, 1965, unpubl.). These traverses provided control for later reconnaissance surveys which used helicopters for transport. By the end of 1965 the Georgina Basin had been covered by this method, which usually involved establishing gravity stations on a square grid of side approximately seven miles, with additional stations being read to follow up interesting results from the prime survey. These reconnaissance surveys indicated numerous regional gravity features including the concealed south-eastern part of the Basin. Interpretation of results has been difficult because of insufficient density contrasts between Palaeozoic carbonate sequences and basement rocks. Gibb (1966, unpubl.), Barlow (1965, unpubl., and 1966, unpubl.) and Flavelle (1965, unpubl., and 1967, in prep.) have reported the results of the Georgina Basin gravity surveys and older rocks.

The Bureau has established Pendulum Stations at Tennant Creek (Northern Territory) and at Boulia (Queensland).



To accompany Records 1967/61



To accompany Records 1967/61

Aeromagnetic surveys in the Georgina Basin are shown on Fig. 8. Most of the coverage has been obtained by the Geophysical Branch of the Bureau, using a DC3 aircraft. The Bureau's work in the Tennant Creek-Davenport Range areas was done in 1956 and 1960, in the course of metalliferous surveys; maps showing magnetic intensity contours were published, and Spence (1962, unpubl.) reported on the 1960 survey. Jewell (1960, unpubl.) reported on the Bureau's traverses shown on Fig. 8, which were flown to obtain reconnaissance information on both the Georgina and Great Artesian Basins. The remainder of the Bureau's work has been concerned directly with the Georgina Basin survey; traverses were flown at 2-mile spacing across each Sheet area and contour maps showing depth to magnetic basement have been produced as well as total magnetic intensity profiles for individual Sheet areas. The magnetic basement contours are shown on Fig. 36 (Wells, Milsom and Tipper, 1966, unpubl.). Although there is sparse well control in the Georgina Basin there is sufficient to indicate, by comparison with the magnetic basement contours, that a thick sequence of non-magnetic, unprospective Adelaidean (Upper Proterozoic) and perhaps older sediments lies above magnetic basement in many places. In addition to providing the main aeromagnetic coverage of the Georgina Basin the Bureau has made its basic data available on request to interested oil companies, and Alliance Petroleum Australia N.L. (1963) has reinterpreted Bureau data for the area covered by OP63 (Fig. 6) in the Northern Territory.

The company surveys shown on Fig. 8 have all been subsidized under the Petroleum Search Subsidy Act. Both the Alroy-Walhallow aeromagnetic survey (Barkly Oil Company Pty Limited, 1965, unpubl.) and the Brunette Downs magnetometer survey (Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.) contributed to the knowledge of magnetic basement depths in parts of the Barkly Tableland, and the Coopers Creek aeromagnetic survey (French Petroleum Company (Aust.) Pty Limited, in conjunction with Delhi-Santos, 1964 unpubl.) assisted in the delineation of most of the south eastern extension of the Georgina Basin, and in confirming seismic information on depths to basement.

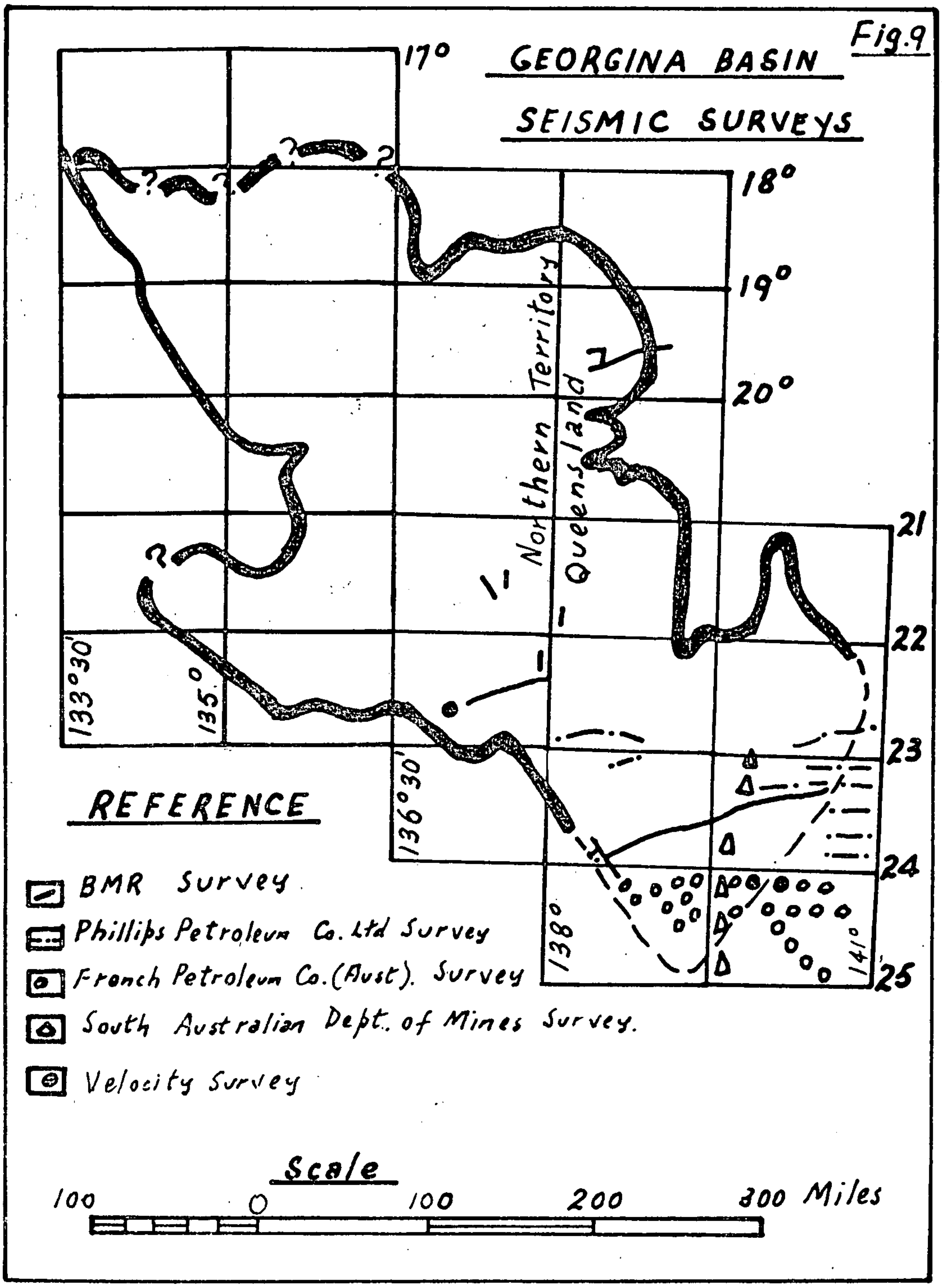
No ground magnetometer surveys have been made in the Georgina Basin area but they have been used extensively by mining companies in the Tennant Creek area where gold is often associated with concentrations of magnetite in Lower Proterozoic basement sediments. Daly (1957) has reported on magnetic prospecting by the Bureau in the Tennant Creek area.

Seismic surveys in the Georgina Basin are shown on Fig. 9. In general, poor results have been obtained from reflection traverses in areas underlain by thick sequences of cavernous and fractured Palaeozoic carbonate rocks. The Bureau conducted experimental surveys in areas of carbonate rocks near Camooweal (Robertson 1963, unpubl.) and in the Tobermory-Lake Nash areas (Davies 1966, unpubl.) but in both cases the results were very poor, and no further work in those areas is contemplated at present. The traverses in the Tobermory-Lake Nash area are the only ones in the Northern Territory part of the Georgina Basin; most of the seismic survey has been done in Queensland, and it has been linked with other surveys probing beneath the Great Artesian Basin Basin in western Queensland and South Australia.

In Queensland, little work has been done in the outcropping part of the Georgina Basin, but the subsidized Springvale-Toko seismic survey (Phillips Petroleum Company Limited, 1961, unpubl.) included traverses in the Glenormiston area where about 250 feet of closure was determined over the Netting Fence Anticline (a surface feature) and a sedimentary thickness of about 6500 feet was indicated. On this survey, traverses between the Netting Fence Anticline and Glenormiston homestead and from Marion Downs homestead to Watchie Hut yielded no data. However, several good reflecting horizons were obtained in the Canary area, where subsequent drilling showed that Palaeozoic carbonate rocks are absent beneath the Mesozoic cover.

Milton and Seedsman (1961, unpubl.) reported the results of a refraction and reflection survey made between Marree (South Australia), Birdsville and Boulia; the deepest persistent reflection obtained on this survey was believed to originate at the base of the Mesozoic, but it was too shallow to be recorded north of Breadalbane homestead.

The Geophysical Branch of the Bureau conducted reconnaissance reflection surveys in the south-eastern extension of the Georgina Basin in 1963, 1964 and 1965. The work was specifically directed towards investigating the probable extension of the Toko Syncline south-eastwards from outcrop, and to determine the presence or absence of Palaeozoic sediments between Adelaidean (Upper Proterozoic) outcrops at Sylvester Creek and Canary No. 1 Well, which had penetrated ?Adelaidean sediments beneath Mesozoic cover, at 504 feet. This latter objective was not attained satisfactorily, because of poor quality data, but the surveys proved that the Toko Syncline extends south-east from outcrop,



To accompany Records 1967/61

and that the sedimentary section increased in thickness south-eastwards. A strong reflector was mapped at a depth of about 9000 feet near the western edge of the Toko Syncline (Pulchera Waterhole area) and it was followed eastwards to a point where it was about 300 feet below the surface; here a core was cut in the reflecting horizon (a limestone) at a depth of 320 feet, and fossils in the core indicated that it belonged to the Ninmaroo Formation of Cambro-Ordovician age. On the western edge of the Syncline deeper events were recorded to about 16000 feet, which depth is interpreted as the base of the Adelaidean sequence. The depth of 9000 feet, when compared with known thicknesses of Mesozoic and Ordovician, indicated considerable thicknesses of post-Ninmaroo Formation - pre-Mesozoic sediments in the subsurface extension of the Toko Syncline. The results of the Bureau's seismic surveys in this area have been reported by Robertson (1965, unpubl.), Jones (1965, unpubl.) Robertson and Montecchi (1966, unpubl.), and Robertson (1967, unpubl.).

The French Petroleum Company (Aust.) Pty Limited (F.P.C.) has carried out three subsidized seismic surveys which have also added to knowledge of the south-eastern extension of the Toko Syncline. The Annandale seismic survey in 1963, was made generally west and south-west of the south-western limb of the Syncline, but some traverses were made in the Lake Wickamunna area, where indications of the Toko Syncline were found. The Bedourie seismic survey covered a large area in the Bedourie area and joined with the 1963 Bureau survey, near Pulchera Waterhole; this F.P.C. survey delineated the southern part of the Toko Syncline and also its eastern edge; it also provided some information on the extension of the Georgina Basin east of the Syncline.

The Sandringham seismic survey, conducted in 1965, was designed to investigate the eastern edge of the Toko Syncline more thoroughly. It covered much of the same area as the Bedourie seismic survey, but with different techniques which resulted in improved record quality.

The three surveys have been reported by French Petroleum Company (Aust.) Pty Limited, and are listed in the bibliography, but they have not yet been published.

NOMENCLATURE

Except where indicated in the text, the name of all rock units used in this bulletin are in accordance with the Australian Code of Stratigraphic Nomenclature and all names have been approved by the appropriate State or Territories Sub-Committee on Stratigraphic Nomenclature. The exceptions are mostly the Cambrian units around the margins of the Basin, and some units named by well-site geologists.

This Bulletin also follows current practice of the Bureau of Mineral Resources in adopting time rock units for the division of the Proterozoic in Australia. The divisions are:

> Adelaidean, which includes all rocks which are time correlates of the sediments in the Adelaide Geosyncline above the base of the Willouran Series and below the base of the Cambrian. The tentative age of the base of the Willouran Series is 1420 m.y..

> Carpentarian, which includes all rocks which are time correlates of the sequence above the base of the Cliffdale Volcanics and below the base of the Adelaidean in the Carpentaria area of the Northern Territory. The age of the base of the Carpentarian is about 1800 m.y..

Rocks which were deposited between the top of the Archaean and the base of the Carpentarian are referred to as Lower Proterozoic, pending the definition of a satisfactory time-rock term for the interval. The age of the top of the Archaean is probably between 2400 and 2600 m.y..

Where reasonable doubt exists on the age of any rocks, the general terms Proterozoic or Precambrian are used.

DEFINITION OF THE GEORGINA BASIN

Table 3 is a synopsis of previous usages of the name "Georgina Basin". Earlier workers used the name in topographical and geographical senses as well as for a sedimentary basin. Those who used the name for a sedimentary basin usually either included or excluded one or more of the Barkly, Oban,

TABLE 3

SYNOPSIS OF PREVIOUS USAGE OF TERMS FOR THE AREA NOW REFERRED TO AS THE GEORGINA BASIN

AUTHOR	YEAR	USAGE	INTERPRETATION	REMARKS
JACK	1895	Used "Georgina Basin" in the title of a paper on artesian water supplies.	Geographical	First use of "Georgina Basin"
WHITEHOUSE	1931	On p118 the author referred to a collection of Cambrian trilobites from "grey limestones in and around the basin of the Georgina River.	Drainage basin	
DAVID	1932	Used "Camooweal Basin" to denote the eastern end of an important belt of limestone extending from beyond the Western Australian border to Boulia, via Wave Hill, Katherine, Daly Waters, Newcastle Waters, Anthony's Lagoon, Alexandria Downs and Camooweal. On David's map, p116, the Camooweal Basin occupies the approximate area of the Barkly Tablelands, and on p118 he gives the age of sediments in the basin as Cambrian to Proterozoic.	Sedimentary basin	
WHITEHOUSE	1936	On p64 the author discusses limestones in the basin of the Georgina River, and includes a map showing "geology of the Georgina Basin".	Drainage basin	
WHITEHOUSE	1940	On p23 he refers to Tertiary limestones "in the southern portion of the Georgina River Basin".	Drainage basin	
DAVID	1950	On p115 the author refers to the "Georgina Region" having an area of 60,000 square miles, partly in Queensland and partly in the Northern Territory, and mainly in the basin of the Georgina River. The boundaries of the region are given in a sketch map (after Whitehouse, 1936) entitled "Geology of the Georgina Basin"; the basin as shown extends from Elkedra to Brunette Downs, Riversleigh and south to Boulia. On p694 the author states "in the Georgina bain the Cambrian beds......." and also that "the Cambrian strata of the Georgina Region were deposited.........".	Drainage basin and Sedimentary basin	
REEVES	1951	On p2485 the author classified the Georgina Basin as one with no oil prospects, and covering 60,000 square miles. An accompanying map shows the position of the basin as approximately that of the Barkly Tableland.	Sedimentary basin	
NOAKES	1952	This author used "Georgina Valley" and "Barkly Internal Drainage Basin" (subsequently referred to as 'Barkly Basin') as the two physiographic units of the Barkly Tableland.	Drainage area	
HOSSFELD	1954	Named the Barkly Basin and showed it (Fig. 6, p132) on the eastern side of the Ashburton-Davenport Range; he considered it as an area of Upper Proterozoic and Cambrian deposition.	Sedimentary basin	
NOAKES AND TRAVES	1954	On p39, the authors state "The Georgina Basin" had already been established as an internal drainage basin, and the topography of the Georgina Valley was much as it appears now.	Drainage basin	
STEWART	1954	On p43, the author uses "Georgina Basin Division" as one of his geomorphological units of the Barkly Region.	Drainage basin	
TRAVES AND STEWART	1954	On p60, the authors use "Georgina Basin" and "Barkly Basin" as drainage units.		
RAGGATT	1954	Figured the Georgina Basin as an area similar to the Barkly Tableland.	Sedimentary basin	
CONDON	1956	Figured the Georgina Basin as an area similar to that of the Barkly Tableland.	Sedimentary basin	The basin was not defined in the text.
BMR	1958	In referring to the Georgina Basin (p60) stated "little is known of the detailed stratigraphy and structure of this basin except where it overlaps the Precambrian of the Mount Isa-Cloncurry area.... The Ammaroo Bore is at the western margin of this basin". Also on p60, mention is made of the Barkly Basin; "apparently shallow, contains Proterozoic and Cambrian sediments, probably marine. Little is known of the details of stratigraphy and structure".	Sedimentary basin	The basin was not defined in the text. The Barkly Basin is figured as including the present Daly River Basin, although the latter is not named.

TABLE 3: Sheet 2

ÖPIK	1956	On p3, Öpik mentions that the Georgina Series (Whitehouse 1931) included the Camooweal Dolomite (Upper Proterozoic or Lower Cambrian) "as well as rocks of the Undilla Basin which do not belong to the Georgina Basin at all. The locality of the Georgina Series is described as being 'in and around the basin of the Georgina River". On p242, in referring to the Barkly Tableland, Opik states that "It is sometimes referred to as the Barkly Basin but no basin structure is evident for the Cambrian rocks form a blanket and the Camooweal Dolomite is an extended Sheet".	Drainage basin; Sedimentary basin for Undilla Basin.	
BMR	1960	Figured the Georgina Basin much as it is known today, but showed only indications of a south-eastern extension; included Ordovician rocks of Tarlton and Toko Range areas, and Cambrian of Ammaroo area.	Sedimentary basin	Barkly Basin also shown, but much reduced from Condon et al's 1958 area. Daly River Basin shown.
CASEY	1960 (unpubl.)	Defined Georgina Basin in terms broadly acceptable today, but excluded the Undilla Basin and the Camooweal Dolomite and, by inference, the Barkly Tableland area.	Sedimentary basin	Did not show a map of the Georgina Basin.
G.S.A.	1962	On Tectonic map of Australia, showed correct outlines of Georgina Basin with regard to south-west, and south-east margins; Undilla and Oban Basins shown, but no basin named in Barkly Tableland area.	Sedimentary basin	
SMITH	1965	Defined Georgina Basin as it is now known, but extended north-western margin slightly northwards of its present accepted position.	Sedimentary basin	First published definition, but not accompanied by map. This definition was followed by Reynolds (1965, unpubl.).

Undilla and Ammaroo Basins, but these are now regarded as part of the Georgina Basin and their names are discontinued.

The Georgina Basin is defined as a sedimentary basin containing lower and middle Palaeozoic sediments, which extend in a belt trending north-west from western Queensland to the northern part of the Northern Territory; it is bounded on the east, west, south-west and north by Precambrian rocks, but the north-western and south-eastern margins are covered by Mesozoic sediments. Early Middle Cambrian sediments are regarded as the basal units of the Georgina Basin succession, but in some marginal areas several thousands of feet of un-metamorphosed Adelaidean/Lower Cambrian sediments underlie the Middle Cambrian sequence.

The outcrop area of the Georgina Basin is about 110,000 square miles; in the south-east an additional area of about 15,000 square miles is concealed; the margins of this area have been defined approximately by geophysical surveys and test drilling but the Palaeozoic stratigraphy is little known and the available evidence indicates the preservation of Palaeozoic sediments in grabens separated by horsts of Precambrian and/or Lower Cambrian rocks.

The north-western margin of the Georgina Basin has not been delineated by geophysical means; at present this boundary is placed at roughly the locations where a continuous sheet of Mesozoic sediments cover the Middle Cambrian units. However, it is likely that Cambrian units of the Georgina Basin will join in the subsurface with those of the Daly River Basin, which are covered by Mesozoic at about latitude 16°S; alternatively, if the Daly River and Georgina Basins are separated by a basement high, this divide may trend northerly, in accordance with the strike of Precambrian rocks of the Katherine-Darwin region which would form this divide.

A small part of the western boundary of the Georgina Basin has not been determined. This is in the Barrow Creek area, where Cambrian sediments of the Georgina Basin may be continuous in the subsurface with those of the Wiso Basin (Fig. 1); however, this has not been proved, and at present there is no evidence to support the possibility.

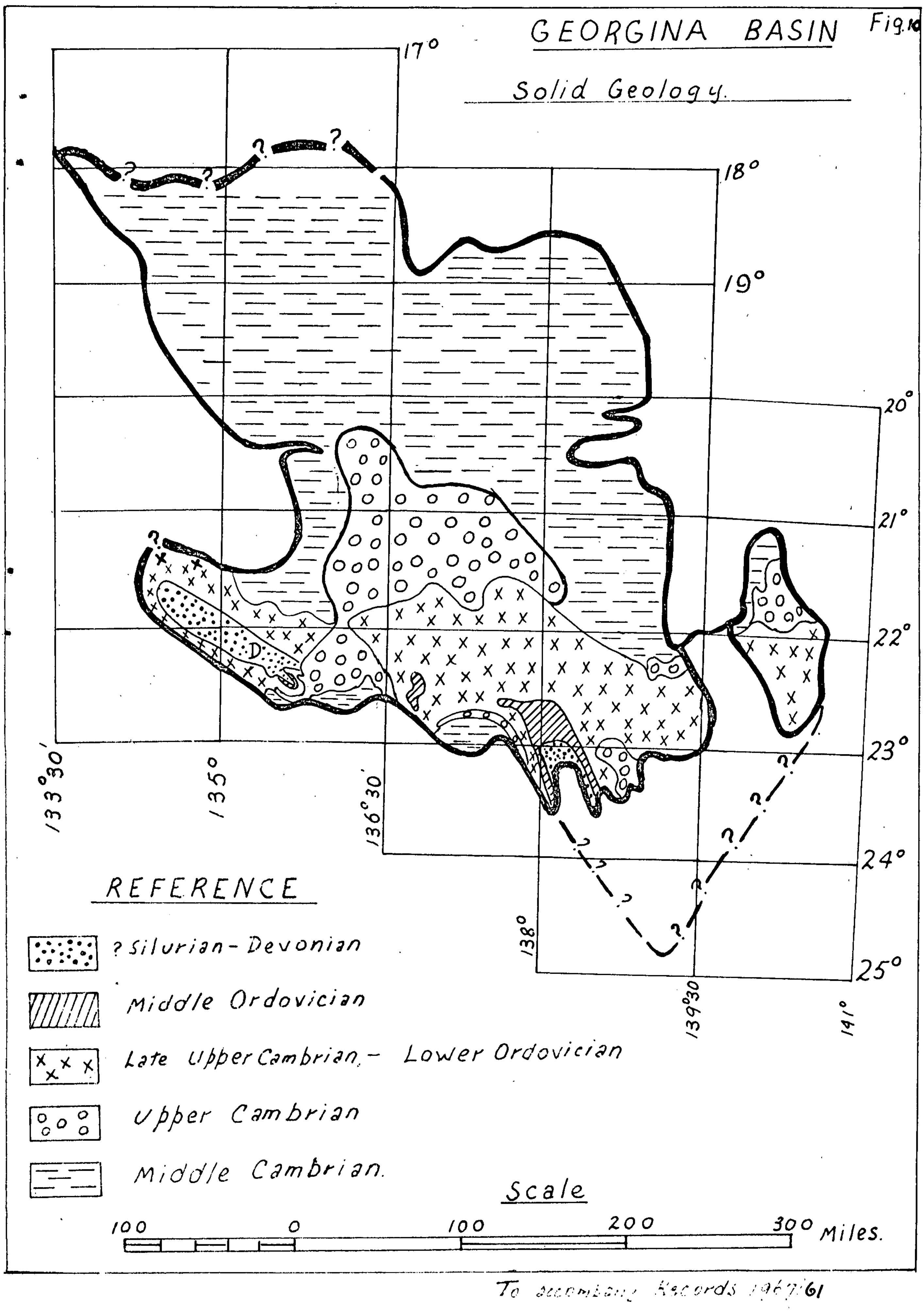
OUTLINE OF THE GEOLOGY

The Georgina Basin contains Cambrian and Ordovician marine sediments and Devonian and ?Siluro-Devonian fresh-water sequences. The Cambrian and Lower Ordovician sediments consist predominantly of carbonate rocks, and sandstone and siltstone comprise most of the Middle Ordovician sequence. Sandstone predominates in the Devonian and ?Siluro-Devonian formations. The only volcanic rocks known in the Georgina Basin are Middle Cambrian basalts near the northern margin in the Mount Drummond Sheet area (Plate 2).

The Georgina Basin sequence has been neither metamorphosed nor intruded by igneous rocks and large areas have not been disturbed tectonically. Although there are well-documented breaks in sedimentation, many of them were caused by uplift and erosion without faulting and folding. The most severe deformation occurred in the southern part of the Basin during the post-Devonian Alice Springs Orogeny (named by Forman, Milligan & McCarthy, 1967); faulting predominated and most of the deformation is south of latitude 22°S, but some faults extend northward to about latitude 21°30'. In the east, an earlier (Lower Ordovician) tectonism affected Cambrian and Lower Ordovician rocks of the Duchess-Boulia area, but in the north the deformation is confined to the northern margin, where Middle Cambrian sediments have been disturbed along faults trending west. The age of this faulting is unknown.

The distribution of sequences in the Georgina Basin is shown on Fig. 10. Most of the northern part of the Basin consists of a thin, structureless blanket of Middle Cambrian carbonate rocks, with Upper Cambrian sediments in the Burke River Outlier (Opik, 1961) and some doubtful Upper Cambrian carbonate rocks in the Avon Downs and Frew River Sheet areas. Ordovician and ?Silurian-Devonian sediments, and most of the Upper Cambrian sediments, are restricted to the southern part of the Basin. The thickest sequences exposed at the surface are in the Huckitta, Tobermory-Glenormiston and Boulia areas.

Huckitta area: 5500 feet of dominantly carbonate rocks, with subordinate sandstone, siltstone and shale. This sequence ranges from Middle Cambrian to Middle Ordovician in age; parts of it are richly fossiliferous, and it includes potential source, reservoir and cap rocks for petroleum. The sequence is capped by about 2100 feet of Devonian fresh-water sandstone, and is underlain by Lower Cambrian and Adelaidean sediments.



To accompany Records 1967/61

TABLE 4

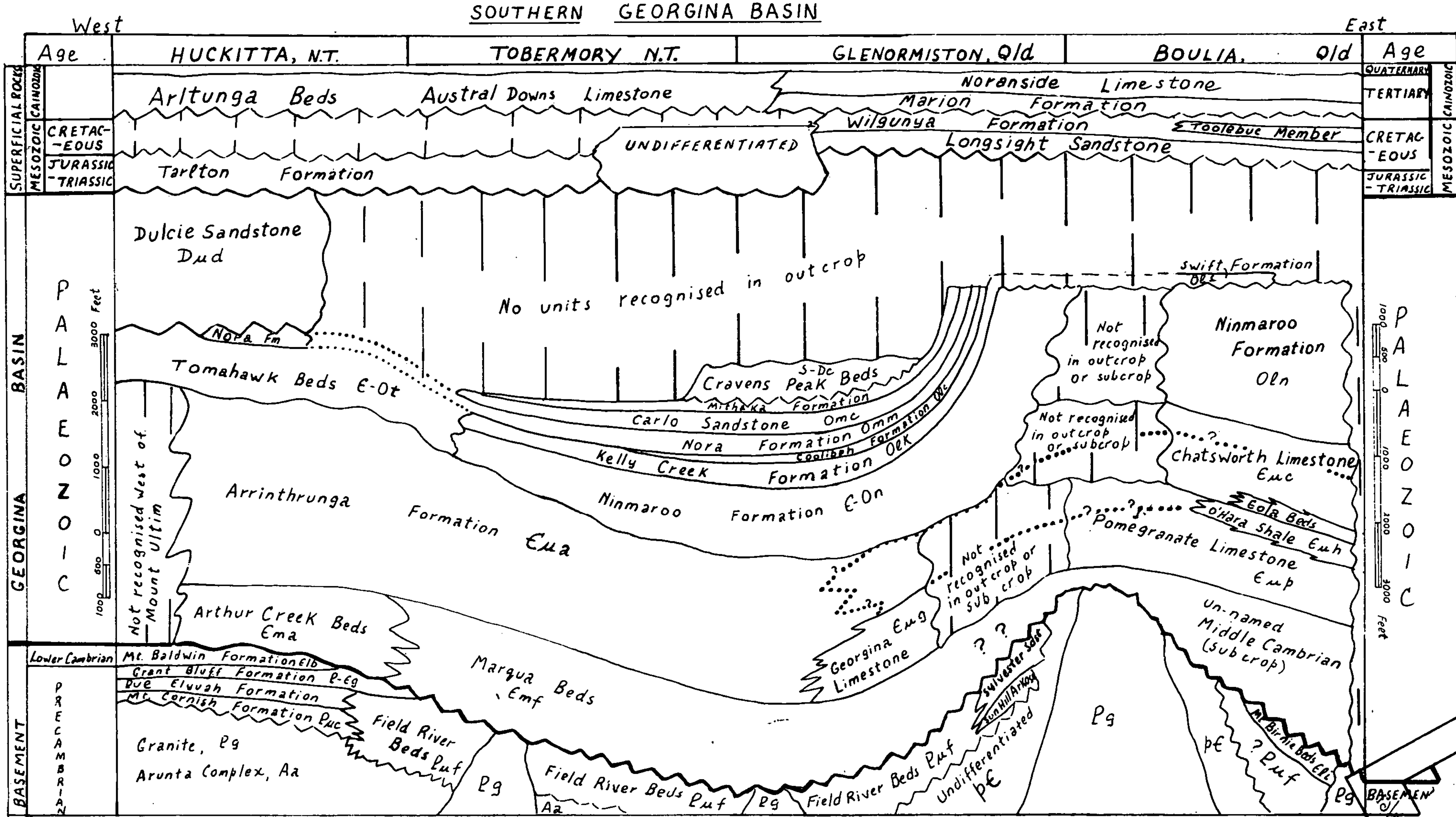
STRATIGRAPHIC UNITS, SOUTH AND SOUTH-EASTERN GEORGINA BASIN

Age	HUCKITTA		TOBERMORY-GLENORMISTON		BOULIA		SOUTH-EASTERN EXTENSION	
	Formation	Thickness (feet)	Formation	Thickness (feet)	Formation	Thickness (feet)	Formation	Thickness (feet)
Upper Devonian	Dulcie Sandstone	2100						
Upper Silurian? -Upper Devonian			Cravens Peak Beds	450+				
	UNCONFORMITY		UNCONFORMITY					
	Nora Formation	400+	TOKO GROUP (Mithaka Formation (Carlo Sandstone (Nora Formation (Coolibah Formation	300+ 400 300 250				
			?DISCONFORMITY					
Lower Ordovician			Kelly Creek Formation	550	Swift Formation	60+		
					UNCONFORMITY			
Lower Ordovician -Upper Cambrian	Tomahawk Beds	800	Ninmaroo Formation	1200	Ninmaroo Formation	2500		
	DISCONFORMITY		?DISCONFORMITY					
Upper Cambrian	Arrinthrunga Formation	3200	Arrinthrunga Formation	2200	Chatsworth Limestone	1500	Undifferentiated. Subsurface only	3020+ Middle and Upper Cambrian sediments, (1153-4173 feet) in The Brothers No. 1 Well
Middle Cambrian	Arthur Creek Beds	1000	Marqua Beds	700+	Subsurface only	2259 in Black Mountain No. 1 Well		
	?DISCONFORMITY		UNCONFORMITY					
Lower Cambrian -Adelaidean	Mount Baldwin Formation	1300	Field River Beds	6000-8000				

Fig. 11

DISTRIBUTION OF ROCK UNITS

SOUTHERN GEORGINA BASIN



To accompany Records

Tobermory-Glenormiston area: 6000 feet of dominantly carbonate rocks and sandstone and shale. These sediments are also richly fossiliferous in parts, and they include potential source, reservoir and cap rocks for petroleum. The basal Middle Cambrian unit rests unconformably on an Adelaidean sequence, and ?Upper Silurian-Devonian sediments overlie the youngest Middle Ordovician formation.

Boulia area: 4000 feet of dominantly carbonate rocks, with minor sandstone and siltstone, ranging in age from Upper Cambrian to Lower Ordovician. Middle Cambrian sediments are unknown in outcrop, but about 2250 feet of siltstone and carbonate rocks are known in the subsurface in Black Mountain No. 1 Well.

The stratigraphic units in each of the Huckitta, Tobermory-Glenormiston and Boulia areas are shown on Table 4, and Fig. 11 shows the distribution of units in these areas, and the basement and cover rocks. For completeness, the only known Palaeozoic sequence in the south-eastern extension is shown on Table 4.

Details of the stratigraphy and lithology of all of the mapped formations of the Georgina Basin are given in a later section of this Bulletin, and the marginal rocks and cover rocks are also described; the present section is concerned with the regional stratigraphy and structure within the preserved basin margins, and comments on the geology of the south-eastern extension are included wherever the scanty available knowledge is applicable.

The most widespread stratigraphic units are of Middle Cambrian age. They crop out in many isolated localities along the western, south-western, northern and eastern margins of the Basin, and at several localities within the northern half, i.e., north of latitude 21°S approximately. They are known also in The Brothers No. 1 Well (French Petroleum Company (Aust.) Pty Limited, 1965, unpubl.) at latitude 24°15'40"S, longitude 139°20'30"E, in the south-east, and in Beantree No. 1 Well (Phillips Petroleum Company, 1963, unpubl.). The surface distribution of the Middle Cambrian units is shown on Fig. 10, and it is assumed that they underlie most of the outcropping part of the Georgina Basin, although sub-surface information away from the margins south of latitude 21°S is limited to identification in the following wells:

B.M.R. 12 (Cockroach), B.M.R. 13 (Sandover), Lucy Creek No. 1, Mulga No. 1, Netting Fence No. 1 and Black Mountain No. 1 (Fig. 5).

The Middle Cambrian sediments are often richly fossiliferous, and Öpik (1956a, 1956b, 1960 and 1961) has made extensive studies of the faunas particularly north-west Queensland. Essentially, Öpik's work has resulted in (1) a revision and re-arrangement of the stages formulated by Whitehouse (1936, 1939). (2) the recognition of early, but not earliest, Middle Cambrian species of Xystridura. (3) the recognition that the trilobites in north-western Queensland belong to the Swedish zones and the formulation of a zonal arrangement which includes a three-fold division of the zone of Leiopyge laevigata. (4) the correlation of isolated Middle Cambrian units in the Northern Territory, and their correlation with one or more units low in the Queensland sequence. (5) the recognition that the Queensland and Northern Territory sequences contained no trilobite species in common. (6) the identification of Archaeocyathus cf. atlandicus in some definite Middle Cambrian faunas of Northern Territory, thereby indicating the unreliability of Archaeocyathus cf. atlandicus as a Lower Cambrian index. (7) the recognition of a similarity between the fauna of the Sandover Beds and that of the Spence Shale and/or Ptarmigania faunas of the Rocky Mountains area of the United States of America.

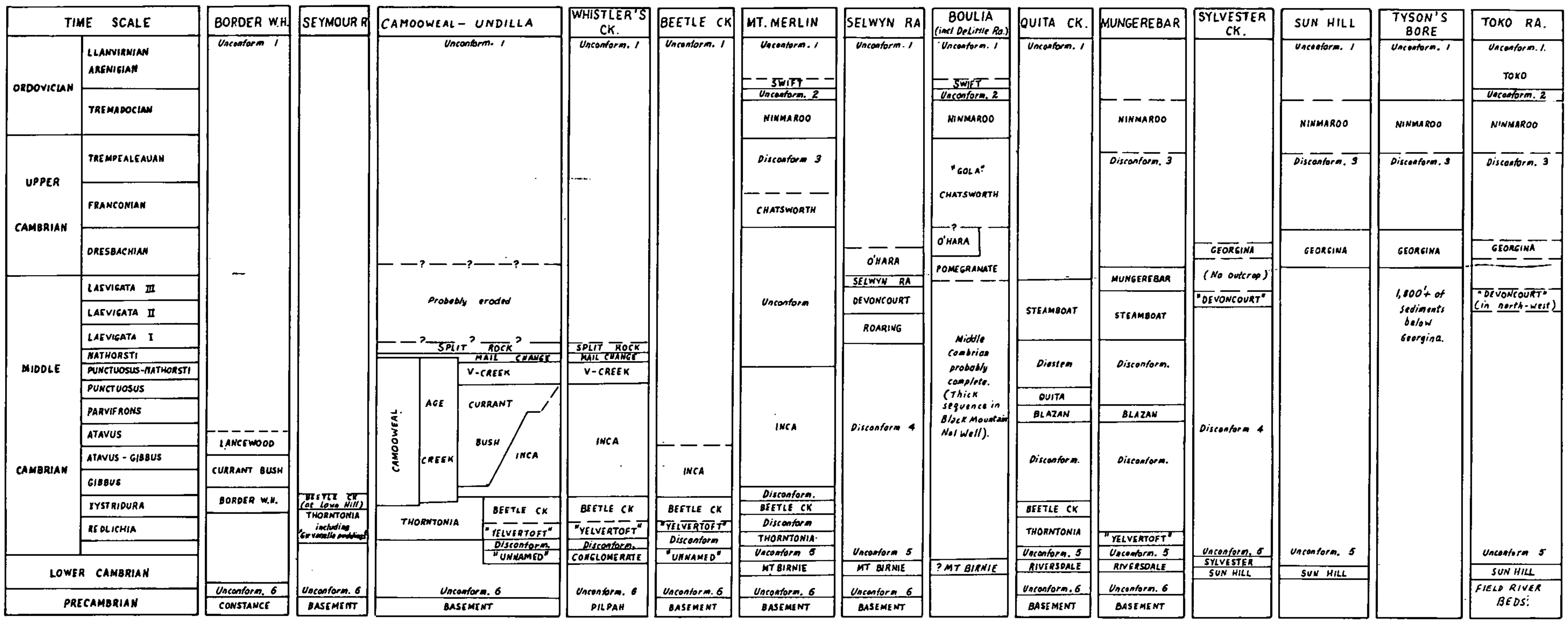
Öpik's correlation chart (1960) for north-western Queensland is reproduced on Fig. 12 with slight modifications, namely, the stratigraphic position of the Camooweal Dolomite has been changed because it is now known to be of Middle Cambrian age, and the Undilla Basin has been deleted.

In the Northern Territory, palaeontological work on the Middle Cambrian faunas has not been completed, and therefore details of the fossil assemblages are not available. Also, the fact that in some cases neither the tops nor the bottom of the sequences are available has dictated the prudence of naming many units "Beds" rather than formations. The Middle Cambrian units of the Northern Territory, together with their thicknesses and their probable correlation with each other, (where applicable) and with Queensland formations, are shown on Table 5. The details of the Northern Territory units are given in accord with the common practice of assigning a Middle Cambrian age, and the unit name, to each "cylinder" of carbonate rock revealed in stratigraphic wells,

CAMBRIAN AND ORDOVICIAN CORRELATION CHART, NORTH-WESTERN QUEENSLAND

Fig. 12

After A.A. ÖPIK (1960, with minor modifications.



To Accompany Records 1967/61

TABLE 5

CORRELATION CHART, MIDDLE CAMBRIAN OF THE NORTHERN TERRITORY
(Thickness in feet; subsurface data in brackets)

TIME SCALE (AFTER ÖPIK 1960)	AREA			NORTHERN TERRITORY						QUEENSLAND			
	HUCKITTA	TOBERMORY	ELKEDRA	TENNANT CREEK	WONARAH	RANKEN	ANTHONY LAGOON	MOUNT DRUMMOND	AVON DOWNS	CAMOOWEAL-UNDILLA			
LAEVIGATA III	ARTHUR	MARQUA											
LAEVIGATA II													
LAEVIGATA I		BEDS											
NATHORSTI	CREEK								-?-?-				
PUNCTUOSUS-NATHORSTI													
PUNCTUOSUS		900+							CAMOOWEAL				
PARVIFRONS	BEDS	(1279+ in BMR 12);							DOLOMITE				
ATAVUS		(1510 in							(1420 in	CAMOOWEAL DOLOMITE 800	AGE		
ATAVUS-GIBBUS	1000'	Netting Fence							BMR 11, 995 in		CREEK	CURRANT BUSH	
GIBBUS		No. 1,	-------	-------	-------	-?-?-	-------	-------	Lake Nash No.1)		FORM-	LIME-	INCA
XYSTRIDURA		Q'ld)	SANDOVER BEDS 800'	GUM RIDGE FORMATION 75	WONARAH BEDS 50 (1000+)	RANKEN LIME-STONE 20+	ANTHONY LAGOON BEDS 60 (1044)	BURTON BEDS 75 (1750)			ATION	STONE	CREEK FORM-ATION
REDLICHIA								PEAKER PIKER VOLCAN-ICS 120	-?-?-?-?				BEETLE CREEK FORM-ATION
	DISCON-FORMITY	UNCON-FORMITY	UNCON-FORMITY	DISCON-FORMITY	?	?	UNCON-FORMITY	UNCON-FORMITY	UNCON-FORMITY		THORNTONIA LIMESTONE		YELVER-TOFT BED
LOWER CAMBRIAN	MOUNT BALDWIN FORMATION			HELEN SPRINGS VOLCANICS UNCONFORMITY					UNNAMED SAND-STONE				
PRECAMBRIAN		FIELD RIVER	HATCHES CREEK	WARRAMUNGA GROUP	?	?	MITTIE-BAH SAND-STONE	MITTIE-BAH SAND-STONE					

scout holes and water bores which began in, or near, outcrops of mapped units of Middle Cambrian age. In most cases, the age of the whole "cylinder" is not supported by fossils, and the lithology of the units concerned are insufficiently known to distinguish them from other units.

The correlation charts (Fig. 12 and Table 5) show several disconformities in the Middle Cambrian of Queensland, and a few localities where upper Middle Cambrian sediments are known in Queensland and in the Northern Territory. Table 5 also shows that the Northern Territory sequences are generally thin around the Basin margins; however, thicknesses in some wells show a considerable variation from those indicated by the sometimes scanty surface information. The following wells have provided subsurface information:

B.M.R. 11 (Cattle Creek), 1420 feet of Camooweal Dolomite;
Lucy Creek No. 1, 1190 feet of Middle Cambrian sediments;
B.M.R. 12 (Cockroach), 1279+ feet of Marqua Beds;
Netting Fence No. 1, 1510 feet of ?Marqua Beds;
Black Mountain No. 1, 2259 feet of unnamed, non-outcropping Middle Cambrian sediments, which are probably a thick southward extension from the Burke River Outlier;
Beantree No. 1, 136 feet of lower Middle Cambrian sediments, which indicate a considerable thinning westwards from Black Mountain No. 1, probably over a Precambrian high extending southwards from the Cloncurry Complex;
Morstone No. 1, 1100 feet of Middle Cambrian sediments overlying Precambrian; this gives the thickness of Middle Cambrian in the Camooweal-Undilla area;
Alexandria No. 1 water bore, 1750 feet of Burton Beds;
Brunette Downs No. 1, 1044 feet of Anthony Lagoon Beds;
Frewena No. 1, 1000+ feet of Wonarah Beds;
The Brothers No. 1, 1683+ feet of unnamed, non-outcropping Middle Cambrian sediments, in the interval 2490-4173 feet (T.D.); this

is not supported by fossils except in the interval 4153-4173 feet, and the information comes from a prominent break in the electric logs at 2490 feet (French Petroleum Company (Aust.) Pty Limited, 1965, unpubl.);

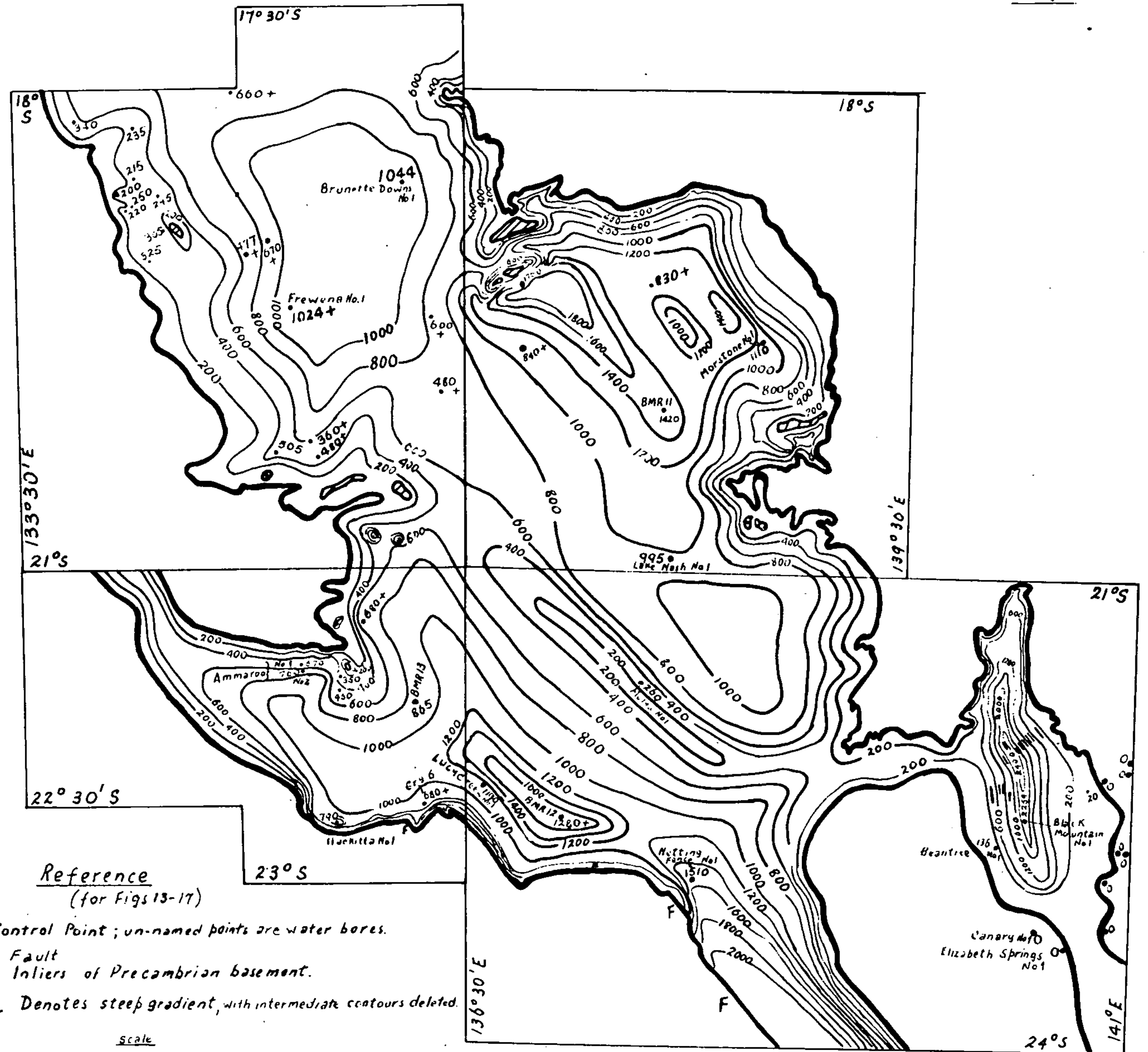
Mulga No. 1, 260 feet of Middle Cambrian, (1714-1974 feet); the sequence is not fossiliferous and has been identified from electric logs (Alliance Petroleum Australia N.L., 1965, unpubl.);

Lake Nash No. 1, 995 feet of Camooweal Dolomite, unconformably overlying unnamed pyritic red sandstone of Adelaidean or Lower Cambrian age.

Little assistance in computing the thickness of Middle Cambrian sediments of the Georgina Basin can be obtained from aeromagnetic surveys because the base of the Middle Cambrian often lies above magnetic basement. Reasonable estimates of thickness away from the margins are possible after study of well results and data from water bores, and the isopach map (Fig. 13) is based on these estimates.

The surface lithologies of the Middle Cambrian of the Georgina Basin consist predominantly of carbonate rocks, with some sandstone and shale units. Limestone predominates in the carbonate units near the margins of the Basin, and dolomite is more common away from the margins. No chemically-precipitated dolomite is known in Middle Cambrian sequences and all of the dolomite has resulted from the dolomitisation of limestone. This process, together with strong weathering of surface outcrops, has resulted in obliteration of many features of the original rocks. Weathering of dolutite produces a fine-grained siliceous rock which has been mapped as shale and siltstone in many instances (Wonarah Beds, Sandover Beds, Inca Creek Formation) and weathering of some dolarenites produces a rock of granular texture which superficially resembles sandstone. Much of the Middle Cambrian carbonate rock has been replaced by chert, which shows original structures (breccia, micro-slump folding, bedding, lamination, oolites). Weathering effects are confirmed by

Fig 13



Reference
(for Figs 13-17)

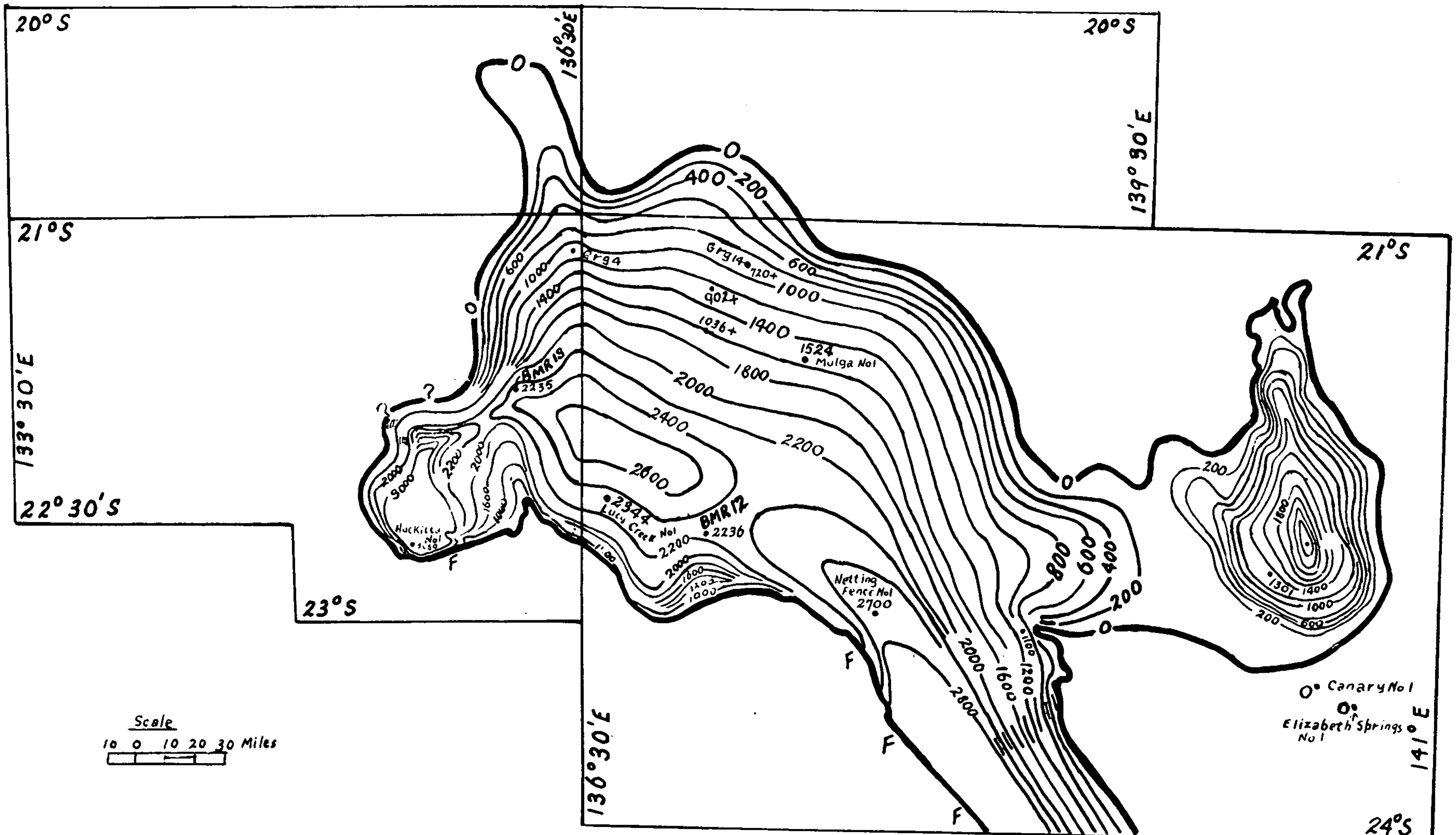
- Control Point ; un-named points are water bores.
- F Fault
- Inliers of Precambrian basement.
- Denotes steep gradient, with intermediate contours deleted.

Scale
10 0 10 20 30 Miles

Isopach Map of Middle Cambrian sequences, Georgina Basin.

To accompany Records 1967/61

Fig. 13.



Isopach Map of the Arrinthrunga Formation, Meeta Beds, Georgina Limestone, Chatsworth Limestone, Mungerebar Limestone, Gola Beds, Pomegranate Limestone, O'Hara Shale, Georgina Basin.

To accompany Records 1967/61

fresh rocks obtained from wells and water bores; although many of these have shale and siltstone interbeds, in general there is more carbonate rock, and less shale and siltstone, than the outcrop sequences suggest. Conglomerates are rare within the Middle Cambrian sequences, and frequently are absent from the basal units, although they are well exposed at the base of the Sandover Beds in the foothills of the Davenport Range. Evaporites are rare, but have been recorded in Frewena No. 1 Well (Barkley Oil Company Pty Limited, 1965, unpubl.). Sandstones are not common, but occur in higher stratigraphic units in the south-west and in the east.

All of the textures in the carbonate rocks, together with numerous coquinites, indicate shallow water deposition for the Middle Cambrian sediments, and the presence of algae in some parts indicates that water was very shallow.

The Upper Cambrian sequence, discussed next, excludes most late Upper Cambrian sequences, which are best included in a conformable late Upper Cambrian-Lower Ordovician succession. In many localities, Upper Cambrian sediments succeed Middle Cambrian sequences conformably, but in other places, e.g., on Frew River and Avon Downs Sheet areas the Upper Cambrian sediments are assumed to be disconformable on units low in the Middle Cambrian succession. However, the identification of Upper Cambrian units in these areas is not supported by fossils, and if incorrect, the Upper Cambrian distribution may be much less than shown on Fig. 10.

The distribution of Upper Cambrian units is shown on Fig. 10, and correlation between them in the southern part of the Basin is shown on Fig. 11. Plate 4 of this Bulletin shows the Selwyn Range Limestone as Middle Cambrian because the information was taken from the published map of Duchess, but in a later publication Öpik (1961) regarded this unit as Upper Cambrian, although it is apparently unfossiliferous. Accordingly, the Selwyn Range Limestone is discussed here with Upper Cambrian units.

There are two main areas of Upper Cambrian outcrop - one in the western Georgina Basin and one in the eastern part; between these areas the sequences may be continuous in the subsurface but have not been identified in most of the south-eastern part. Upper Cambrian sediments have been identified in the following wells, away from outcrop: B.M.R. 12 (Cockroach), Netting Fence No. 1, Beantree No. 1 and Black Mountain No. 1; in the south-east, they have been western Georgina Basin is shown on Fig. 11.

All of these formations are of small areal extent in the eastern Georgina Basin, and all surface exposures, with the exception of those of the Chatsworth Limestone, are thin; the following maximum thicknesses have been quoted for them:

Chatsworth Limestone, 1050+ feet; (Casey et al, 1960 unpubl.)
Pomegranate Limestone, 60+ feet; (Öpik, 1960)
O'Hara Shale, 200+ feet; (Öpik, 1960)
Georgina Limestone, 100+ feet; (Öpik, 1960)
Mungerebar Limestone, 100+ feet; (Reynolds and Pritchard, 1964 unpubl.)
Selwyn Range Limestone, 120+ feet; (Carter and Öpik, 1963).

In most cases, the thicknesses quoted are for incomplete sections; more recent information, mainly from the Black Mountain No. 1 and Beantree No. 1 Wells (Phillips Petroleum Company Limited, 1963, unpubl.) shows the following thicknesses:

Chatsworth Limestone,	1500 feet at Black Mountain; (combined surface and subsurface);
Pomegranate Limestone,	817 feet in Black Mountain No. 1 Well, increasing south-westwards to a thickness of 1301 feet in Beantree No. 1 Well;
O'Hara Shale,	162 feet in Black Mountain No. 1 Well, but the formation has not been recognised in Beantree No. 1 Well; since it is known to interfinger with the Pomegranate Limestone, its time equivalent could be present there.

These occurrences in Black Mountain No. 1 and Beantree No. 1 Wells show that the Pomegranate Limestone and O'Hara Shale extend south from their outcrop area, and at least the Pomegranate Limestone extended south-west to Beantree No. 1 Well; however, there is no Chatsworth Limestone in that Well, and the Pomegranate Limestone is overlain by Mesozoic sediments. The Chatsworth identified in The Brothers No. 1 Well.

In the west, the Upper Cambrian sediments comprise the Arrinthrunga Formation, with its Eurowie Sandstone Member, and the Meeta Beds which are equivalent to, and almost certainly continuous with, the lower part of the Arrinthrunga Formation. The Arrinthrunga Formation consists predominantly of dolomite, with interbeds of blue and blue-black limestone, red and green siltstone and quartz sandstone which includes the Eurowie Sandstone Member - a sequence whose thickness ranges from 50 to 100 feet, and which shows halite casts and ripple marks. Many of the quartz sandstone beds grade laterally and vertically to dolomite. Colonial algae, cross-lamination of sandy carbonate rocks, current-bedding in quartz sandstone lenses, and an abundance of oolites in limestone and dolomite attest the shallow water environment of deposition of the Arrinthrunga Formation. The Meeta Beds also show evidence of shallow water deposition, and consist mainly of pelletal dolomite (often weathered to chert, with outlines of pellets preserved) and cross-bedded quartz sandstone, with some oolitic limestone.

Fossils are rare in both the Arrinthrunga Formation and the Meeta Beds; only a few lower Upper Cambrian trilobites and hyolithids are known in the Arrinthrunga Formation, and a few gastropods in the Meeta Beds. The Arrinthrunga Formation is 3200 feet thick in the Huckitta homestead area, and thins eastward to about 2200 feet in B.M.R. 12 (Cockroach) and about the same thickness in outcrop on the western flank of the Toko Syncline; the drilled thickness in Netting Fence No. 1 Well is 2700 feet (Fig. 20).

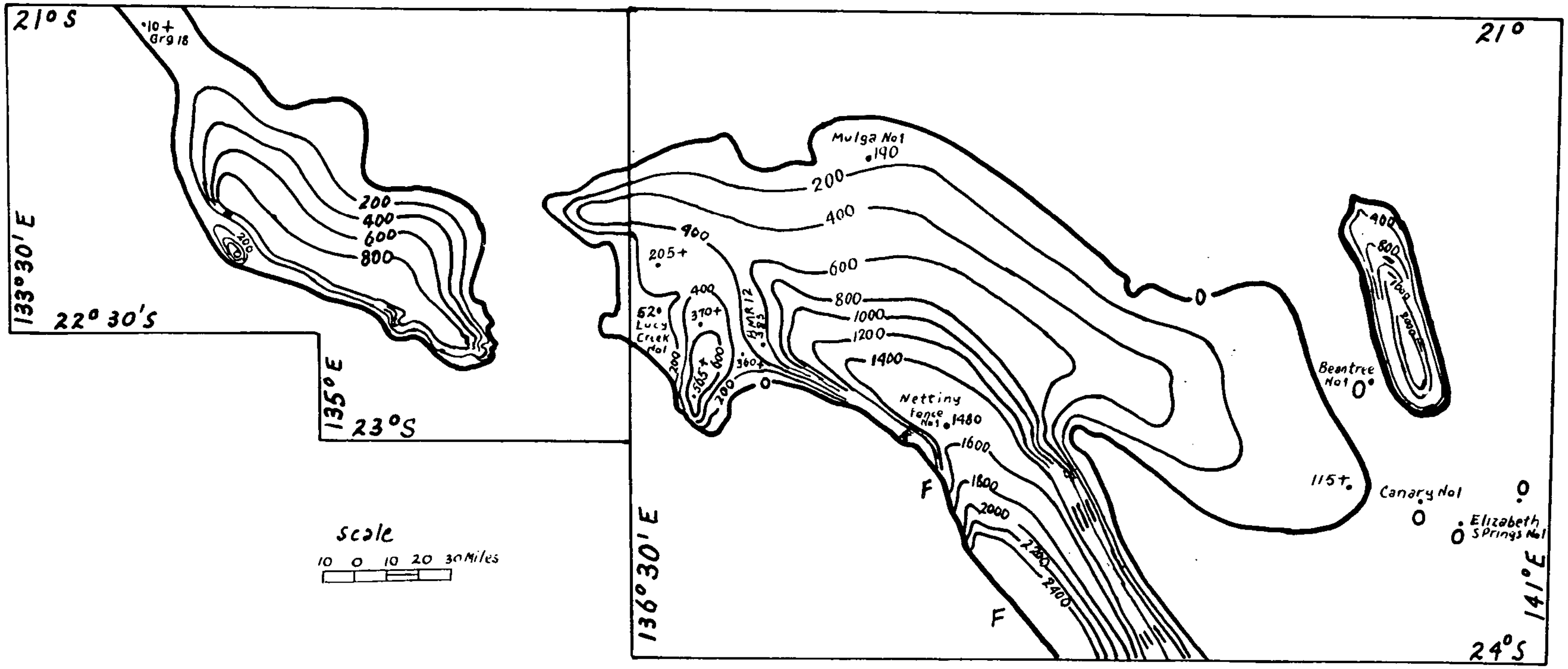
In the eastern part of the Georgina Basin, limestone predominates in the Upper Cambrian sequences, and fossils are abundant in many of the formations. Öpik (1960, 1961, 1963) has made thorough examination of the faunas, and has named stages - Mindyallan, with two zones, and Idamean with five - in early Upper Cambrian sequences; these stages correspond in general terms to the Maentursy and Ffestinog Stages of Britain, to the *Agnostus pisiformis* and *Olenus* zones of Scandanavia, to the Dresbachian of North America, and to the Kushanian and Parishanian of north-east Asia. The formations of early Upper Cambrian age - Georgina Limestone, Mungerebar Limestone, Selwyn Range Limestone, O'Hara Shale, Pomegranate Limestone, Chatsworth Limestone and Gala Beds - are shown on Fig. 12, and correlation of some units with Upper Cambrian of the

Limestone has not been identified in the subsurface west of the Burke River structural belt, and the surface outcrops of Georgina Limestone and Mungerebar Limestone are overlain disconformably by the Upper Cambrian-Lower Ordovician Ninmaroo Formation. Öpik (1963) believes that uplift occurred in the Glenormiston area about the end of the lower Upper Cambrian (Idamean) time, whereas the Franconian and Trempealeauan fossils in the Chatsworth Limestone of the Boulia Sheet area indicate middle and upper Upper Cambrian deposition. In Netting Fence No.1 Well, Papuan Apinaipi Petroleum Company Limited (1965, unpubl.) reported a sequence of limestone with subordinate calcarenite, dolomite, sandstone and shale, between the base of the Ninmaroo Formation (at 2381 feet) and 5080 feet; the company divided this into the Georgina Limestone, (2381-4090 feet), Mungerebar Limestone (4090-4355 feet) and Middle Cambrian Steamboat Sandstone (4355-5080 feet). However, Gatehouse (in Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.) identified fossils in Core No. 14 (4910-4920 feet) as being probably of early Upper Cambrian age, belonging to the zone of Glyptagnostus reticulatus (Idamean Stage). Therefore it would appear that the whole sequence, 2381-5080 feet, is Upper Cambrian Arrinthrunga Formation; since the dip averages 10 degrees, the true thickness is about 2600 feet, and this indicates a thickening of the Upper Cambrian westward from the outcrops of Georgina Limestone near Glenormiston homestead.

Öpik (1963) has described the environment of deposition of the Georgina Limestone, Pomegranate Limestone and O'Hara shale as epicontinental, in a shallow, sheltered sea where the water was mildly agitated at times (evidenced by mild cross-lamination of sand and fossil fragments) and motionless at other times, as evidenced by adult trilobites of diverse size embedded dorsum up and dorsum down in approximately equal numbers.

The description of the Chatsworth Limestone (Casey et al., 1960, unpubl.) shows that this formation includes coquinites and intraformational breccia and is cross-laminated in some beds, all of which indicate shallow water deposition. However, some change in deposition may be indicated because the Chatsworth Limestone contains few bituminous beds, whereas the Pomegranate Limestone, Georgina Limestone and O'Hara Shale contain many bituminous laminae and beds. Öpik (1961) has described the environment of deposition of the unfossiliferous Selwyn Range Limestone as near-evaporitic, but this is the only Queensland

Fig 15.



Isopach Map of the Tomahawk Beds and the Ninmaroo, Kelly Creek and Swift Formations, Georgina Basin.

To accompany Records 1967/61

Upper Cambrian formation deposited under these conditions.

The Upper Cambrian-Lower Ordovician formations (excluding Lower Ordovician in the Toko Group) consist of the Tomahawk Beds and the Ninmaroo, Kelly Creek and Swift Formations. All are restricted to the southern part of the Georgina Basin; the Swift Formation has a very limited extent, along the Burke River Structural Belt, and is unknown in the subsurface, but the other units are widespread in the south-west and south-east (Fig. 10); they are assumed to be present in the buried Toko Syncline in the south-east, although only the Ninmaroo Formation has been identified in the sub-surface (Robertson, 1966, unpubl.).

The Tomahawk Beds crop out on both sides of the Dulcie Range (Plate 3), and also in the Tarlton Range area (Plates 4 and 3). The Beds consist of quartz sandstone, calcareous sandstone, dolomite, limestone and siltstone, much of which is richly glauconitic; the lithologies of various measured sections are shown on Fig. 32. The sequence consists predominantly of quartz sandstone north-westwards from Huckitta homestead, whilst in other places, principally in the north-eastern part of Huckitta, south-eastern Elkedra and south-western Sandover River Sheet areas, rapid gradation from quartz sandstone to sandy dolomite and dolomite is common.

The Tomahawk Beds are richly fossiliferous, principally in trilobites and ribeirioids whose age ranges from late Upper Cambrian to Lower Ordovician; the time range is equivalent to that of the Ninmaroo and Kelly Creek Formations combined (Öpik and Tomlinson, pers. comm.) and this relationship is shown on Fig. 13 and on Fig. 11. In the Tarlton Range area the three units are actually in contact; in some places it is possible to separate the Kelly Creek Formation from the Tomahawk Beds, but deep weathering and lateritisation of carbonate rocks has produced many lenses of slumped "siltstone" and "sandstone" and this has hampered the mapping of a boundary between the Tomahawk Beds and the Ninmaroo Formation, and the boundary shown on Plate 4 is actually a facies boundary between an essentially carbonate sequence with some lenses of sandstone (Ninmaroo Formation) in the east, and a sandy formation, with beds and lenses of carbonate rocks, (Tomahawk Beds) in the west.

The Tomahawk Beds appear conformable and gradational on thick sequences of the Arrinthrunga Formation near Huckitta homestead, but north-west from there they transgress on to Precambrian sedimentary and igneous rocks; east of Lucy Creek homestead the Tomahawk Beds appear disconformable on the upper (but not top) part of the Arrinthrunga Formation, and in the Sandover River Sheet area the Tomahawk Beds are almost certainly disconformable on the Meeta Beds, which are equivalent to units stratigraphically low in the Arrinthrunga Formation. The cross-bedding and type of sediments in the Tomahawk Beds indicate shallow water deposits.

The Ninmaroo Formation is regional in extent, and is composed of dominantly carbonate sediments (Fig. 33) with subordinate sandstone, siltstone and shale. The formation is richly fossiliferous in trilobites, nautiloids and ribeirioids, and also contains many algal layers which, with intraformational breccias, scour and fill structures, and cross-lamination of sandy laminae, are evidence of deposition in shallow water.

The Ninmaroo Formation crops out in a narrow belt in the Duchess-Boulia area (Plate 4) and also in a wide belt extending from the Tarlton Range to the vicinity of Glenormiston homestead; Casey et al., (1960, unpubl.) believe that water-bore information indicates continuity of the Ninmaroo Formation in the subsurface between the western outcrop belt and Boulia township (refer cross-section on Plate 4); however, continuity between Boulia township and the eastern outcrop belt is not assured, and the Ninmaroo Formation is not present in Beantree No. 1 Well (Phillips Petroleum Company Limited, 1963, unpubl.).

The thickest sequences of the Ninmaroo Formation are at Black Mountain and Mount Ninmaroo, in the eastern outcrop belt, and in these places the Ninmaroo Formation appears conformable on the Chatsworth Limestone. However, to the north-west the formation has transgressed on to the Lower Cambrian Mount Birnie Beds, and Öpik's 1960 Correlation Chart (Fig.12) shows a disconformity between the Ninmaroo Formation and the Chatsworth Limestone in this (Mount Merlin) area.

In the western outcrop belt the Ninmaroo Formation has a maximum thickness of about 1200 feet, and it is disconformable on the early Upper Cambrian Georgina Limestone and on the Mungerebar Limestone. The nature of the contact between the Ninmaroo and Arrinthrunga Formations is indefinite because of structural complexity and because both formations are essentially composed of carbonate rocks; in one locality a thickness of about 225 feet of quartz sandstone in the base of the Ninmaroo Formation may indicate a disconformity between it and the underlying Arrinthrunga Formation, but elsewhere most of the Arrinthrunga Formation seems present beneath the Ninmaroo Formation. In the north, the Ninmaroo Formation is probably disconformable on the Meeta Beds, although no contact is observed.

The Kelly Creek Formation conformably overlies the Ninmaroo Formation and interfingers with the upper part of the Tomahawk Beds. Outcrops are restricted to the Tarlton and Toko-Toomba Range areas (Plate 4), but it can be recognised in the upper part of the Tomahawk Beds in the Dulcie Range area (Plate 3) although it is not a mappable unit there at 1:250,000 scale because of strong plications in it and the underlying beds. In the Tarlton Range the formation consists of calcareous, micaceous, glauconitic sandstone, cross-laminated in part, with interbeds of dolarenite and calcarenite; it is about 200 feet thick. In the Toko Range the outcrops are mainly sandstone, with some siltstone and dolarenite; the formation is 550 feet thick on the western side of the Range, and about 200 feet on the eastern side. The formation contains a rich fauna of nautiloids, brachiopods, trilobites, ribeirioids and gastropods.

The Swift Formation crops out only in the Duchess-Boulia area. It is very thin (about 60 feet preserved) and consists of chert with interbeds of coquinite, and siltstone which contains graptolites. The formation rests unconformably on the Ninmaroo Formation, (Casey et al., 1960, unpubl.) and the unconformity is regarded by Öpik (1960) as indicative of deposition after the main tectonic events of the Burke River Structural Belt; however, Casey et al. (op. cit) regard the unconformity as a minor event. The Swift Formation is equivalent in age to the Kelly Creek Formation (Öpik and Tomlinson, pers. comm.).

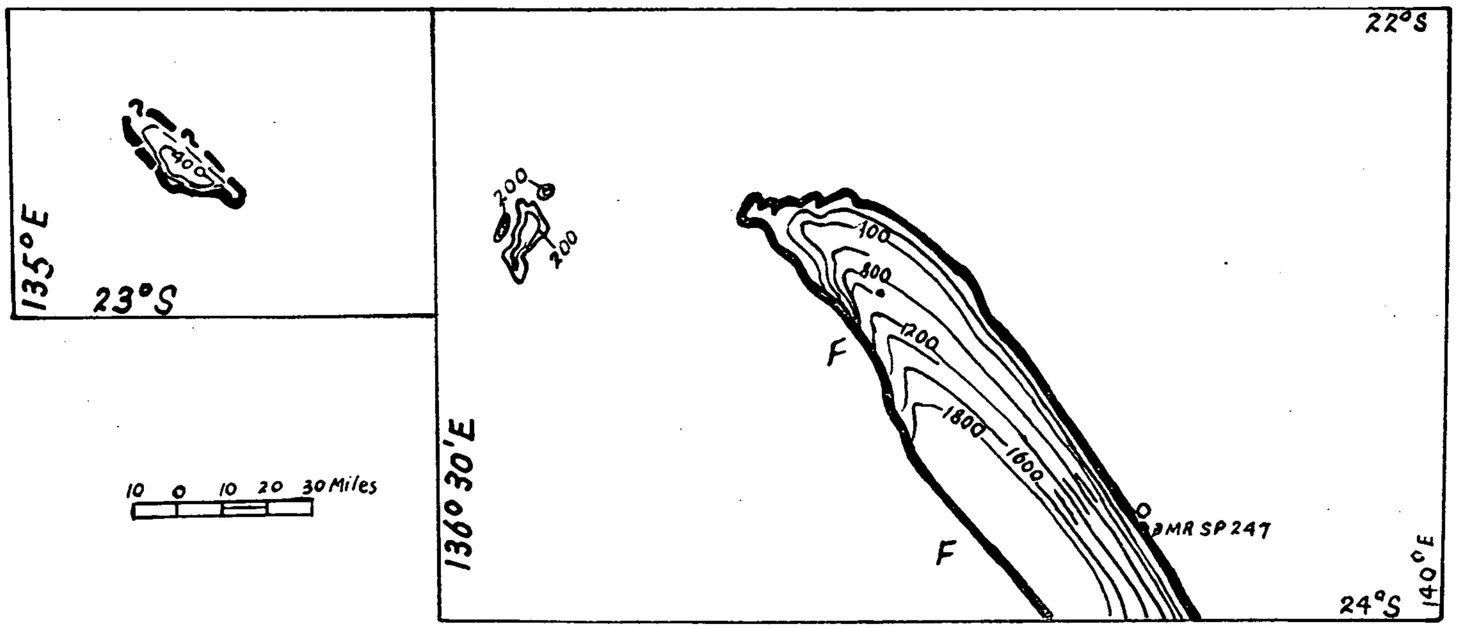
The Toko Group, which is mainly of Middle Ordovician age, is restricted to the southern part of the Georgina Basin. It consists of one Lower Ordovician unit (the Coolibah Formation) and the Middle Ordovician Nora Formation, Carlo Sandstone and Mithaka Formation. The Group is complete in the Toko Range, and presumably plunges south-eastward under the Simpson Desert, but there is no subsurface information to prove this. In the Tarlton Range all units except the Coolibah Formation have been identified, whilst eroded remnants of the Nora Formation are the only representatives of the Group in the Dulcie Range. Fig. 16 is an isopach map of the Toko Group.

Although no break has been detected in the field, Tomlinson (pers. comm.) believes that the fauna of the Kelly Creek and Coolibah Formations indicate a considerable time break between the two, and accordingly a disconformity at the top of the Kelly Creek Formation is usually shown on maps and charts. The Coolibah Formation, the basal unit of the Group, consists of chert, oolitic limestone and calcilutite. It thickens south-eastwards from about 50 feet near the north-western end of the Toko Range to 175 feet near latitude 23°S and 360 feet in the Toomba Range in Queensland. The fauna includes nautiloids, gastropods, ribeirioids, sponges and "horn-shaped corals".

The Nora Formation succeeds the Coolibah Formation, and consists of pelletal dolomite, coquinite, siltstone and micaceous and glauconitic sandstone. The formation is 370+ feet thick in the Dulcie Range, 200 feet in the Tarlton Range, 200 feet in the northern part of the Toko Range, and thickens to 400 feet south-eastwards in the flank of the Toomba Range. The lower part of the formation contains a rich fauna of pelecypods, brachiopods, trilobites, nautiloids, gastropods and bryozoa but the upper part contains few shelly fossils although tracks and trails are abundant.

The Carlo Sandstone conformably succeeds the Nora Formation in the Toko Range, but there is evidence of a mild depositional break between the two units at the northern end of the Tarlton Range. The formation consists of quartz sandstone which has numerous cross-beds, ripple marks and flute casts; clay pellets are abundant and a few thin beds of siltstone occur in the lower part of the unit. The Carlo Sandstone is about 120 feet thick in

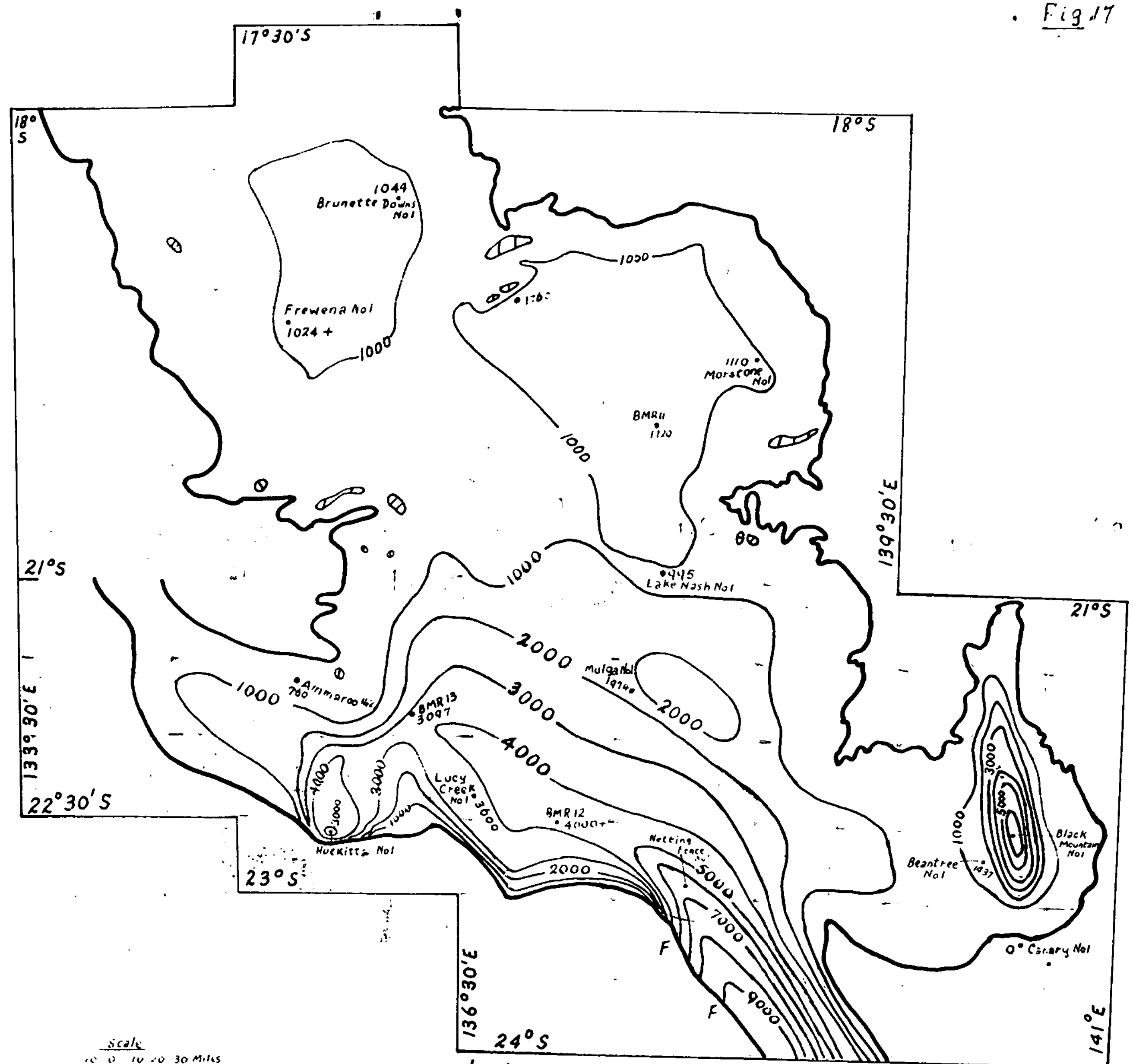
Fig 16



Isopach Map of the Toko Group, Georgina Basin

To accompany Records 1967/61

Fig 17



Isopach Map, Middle Cambrian–Middle Ordovician, Georgina Basin.

To accompany Records 1967/

Fig 17.

the Tarlton Range and 200 feet in the Toko Range; it thickens south-eastwards to more than 500 feet in the Toomba Range in Queensland. Fossils are uncommon, but nautiloids, brachiopods and pelecypods are known in the upper half, and trails and worm tracks have been observed throughout. The Carlo Sandstone is the first (and only) sandstone unit in the Cambrian-Ordovician sequence of the Georgina Basin: the currents appear to have been strong during its deposition, and in the Tarlton Range these came from the south-east (Fig. 35); no information on current direction is available in the Toko Range.

The Mithaka Formation is the youngest Middle Ordovician sequence preserved in outcrop; only a few thin residuals cap the Tarlton Range, but the formation is more extensive in the Toko Range, and continues south-eastwards in the Toomba Range. The formation crops out poorly, and generally only a small percentage of any one sequence is seen. Therefore the lithology is imperfectly known, but the following rocks have been observed: gypsiferous siltstone, shale and sandstone, calcareous sandstone, and glauconitic quartz sandstone. In addition, some thin coquinites are known. The sequence was deposited in shallow water.

Fossils found in the Mithaka Formation include trilobites, nautiloids, pelecypods, sponges, brachiopods and conodonts. The formation is 60 feet thick in the Tarlton Range, and 200-400 feet in the Toko Range, although these thicknesses are not regarded as reliable.

Silurian rocks are unknown in the Northern Territory, but some sediments whose age could range from Upper Silurian to Lower Devonian (Jones, in Reynolds and Pritchard, 1964, unpubl.) are known in Queensland, in the Toko Syncline. The rocks are part of the Cravens Peak Beds, which also contain Upper Devonian fresh-water placoderms (Tomlinson, 1967; Smith, 1965b). Another fresh-water Devonian sequence occurs in the Dulcie Range and is named the Dulcie Sandstone.

The Dulcie Sandstone crops out prominently in the Dulcie Range and extends north-west almost to Barrow Creek Settlement (Plate 3). It consists of strongly cross-bedded quartz sandstone, with some beds of silty sandstone, calcareous sandstone and pebble conglomerate. The formation is 2100 feet thick in the south-east, and thins to the north-west, although the thickness in the south-eastern part of the Barrow Creek Sheet area is about 1500 feet and most of the thinning is north-west from there.

Fresh-water placoderms found by Bureau geologists and by geologists of Frome-Broken Hill Pty Ltd have been described by Hills (1959) and assigned an Upper Devonian age. These fossils have been found in two horizons south-east of Huckitta homestead, the lower horizon being about 1600 feet above the local base of the formation. Smith and Milligan (1964) reported fragments of fossil fish in the Barrow Creek Sheet area and Öpik (pers. comm.) considered that these might be of Lower Devonian age. Positive identification has not been made, and the age of the Dulcie Sandstone is at present shown as Upper Devonian, in accordance with Hills' identification of 1959.

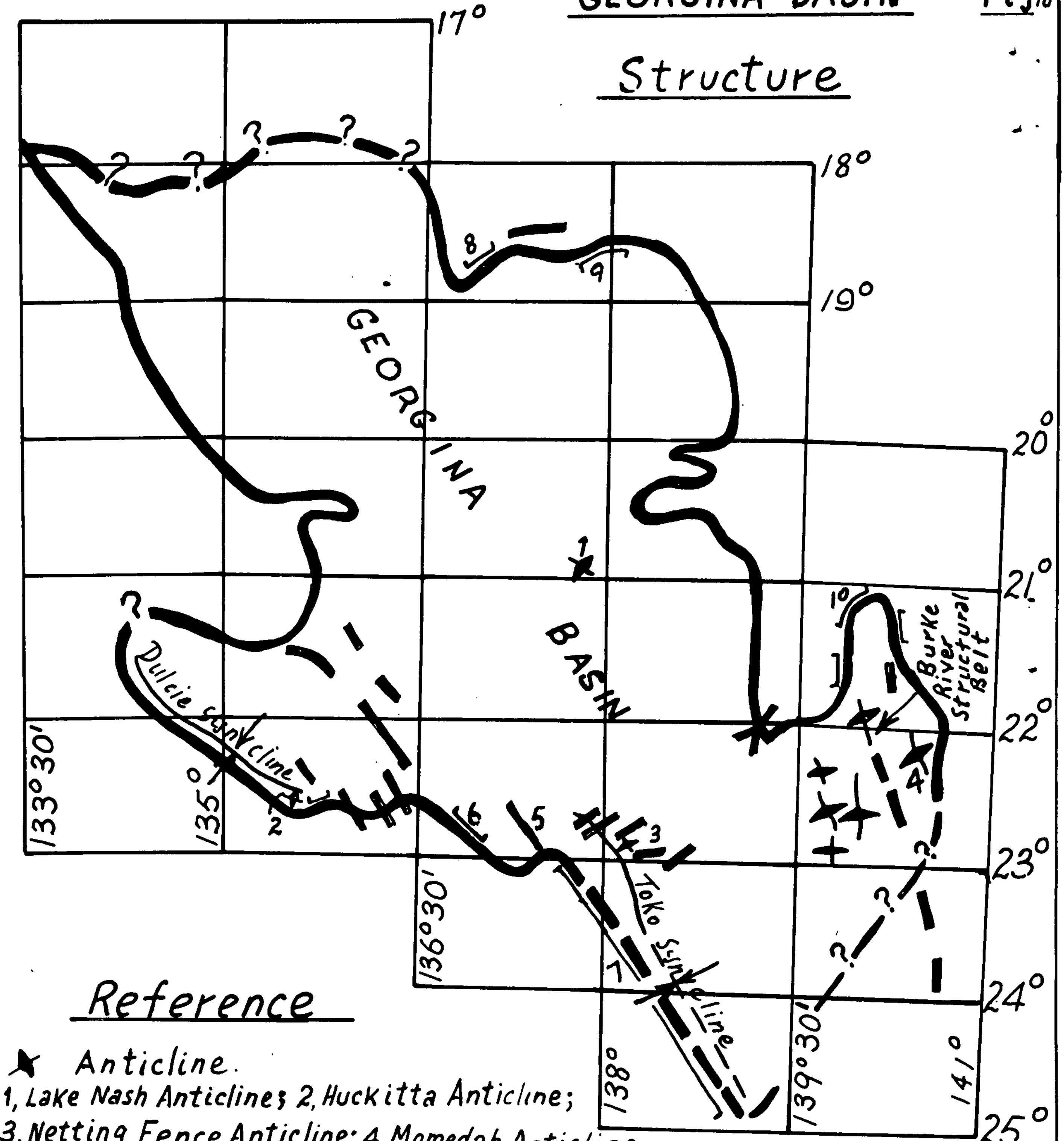
In the Toko Syncline, the beds containing the fossils which Jones (in Reynolds and Pritchard, 1964, unpubl.) regards as possible Lower Silurian do not crop out, and the fossils were obtained from seismic shot-hole samples. The outcropping Cravens Peak Beds consist of cross-bedded quartz sandstone and sandstone with abundant clay pellets; they are about 450 feet thick in the Toomba Range near the Queensland-Northern Territory Border. Although several specimens of fragmentary placoderms and one leaf fragment have been found, none has been in situ. However, it is almost certain that they came from the Cravens Peak Beds.

Some thin conglomerate beds in the Mount Whelan area have been regarded as ?Permian in age (Reynolds, 1964, unpubl.) but there is no fossil evidence to support this. Some of the beds may be of fluviatile glacial origin, which tends to confirm the Permian age, but another interpretation suggests they are former Adelaidean glacials which have been reworked and transported in early Mesozoic time. The deposits are shown on Plate 4 as ?Permian in age. They are important because there is the possibility of their thickening south-eastwards, and thus constituting part of the thick sequence in the buried Toko Syncline.

GEORGINA BASIN

Fig 18

Structure



Reference

Anticline.
1, Lake Nash Anticline; 2, Huckitta Anticline;
3, Netting Fence Anticline; 4, Momedah Anticline.

Syncline.
Concealed Syncline.

Fault
5 Craigie Fault

Faulted Margin
6, Tarlton Fault; 7, Toomba Fault; 8, Mitchiebo Fault;
9, Littles Range Fault;
10 Roaring Fault.

Scale
100 0 100 200 Miles

Record 1967/61

STRUCTURE

Faulting predominates over folding movements in the Georgina Basin and most of the visible folds are related to the faulting although a few isolated cases, e.g. the Lake Nash Anticline, are "draped" structures (Fig. 18). In the west and south-west the major tectonic events can be dated as post-Devonian but elsewhere the events can be dated only as post-Middle Cambrian, or post-Lower Ordovician, as the case may be, because of lack of outcrop of younger Palaeozoic rocks. Mild tectonic events at the end(?) of the Cretaceous, and during Tertiary time, are known in north-western Queensland.

Most of the Georgina Basin north of latitude 21°S consists of thin, gently-undulating sediments which contain no pronounced fold structures, except for the Lake Nash Anticline, and no faults except in a narrow zone along the northern margin in the Mount Drummond and Lawn Hill Sheet areas. It is quite likely that very broad domes and basins, with very low flank dips, are present in this northern area, but the absence of marker beds, the deep weathering and the paucity of outcrop prevents delineation of folding; the picture is further obscured by slumping in the carbonate rocks which predominate in the area. Any folds which may be present would be draped structures, as is almost certainly the case with the Lake Nash Anticline, which is a broad, gentle structure about 10 miles long, with some steeper dips due to slumping; the structure trends west and has no known parallel structures, or structures en echelon. The results of Lake Nash No. 1 Well (Amalgamated Petroleum Exploration Pty Limited 1963, unpubl.) show that the rocks in the structure consist of 995 feet of Cambrian carbonate rocks unconformably overlying a sandstone-dolomite sequence of either Adelaidean or Lower Cambrian age.

Two faults which have affected Middle Cambrian sediments along the northern margin are the Mitchiebo Fault (Smith and Roberts, 1963), and the Littles Range Fault (Smith and Roberts, 1963, op. cit., and Carter and Öpik, 1961) which extends from the Northern Territory into Queensland. Both faults trend west-south-west, parallel to the dominant trend of bedding in Precambrian basement and parallel to other fault systems in the basement north of the margin. The Mitchiebo Fault is about 35 miles long, and has severely disturbed both the Middle Cambrian Burton Beds and Precambrian sequences. The Littles Range Fault produced vertical dips in some Middle Cambrian strata (the Currant Bush Limestone and Lancewood Shale) but the Camooweal Dolomite was not deformed although the Constance Sandstone adjacent to the Dolomite was locally severely deformed. Carter and Öpik (1961, op. cit.) regarded these two pieces of evidence as indicative of both Precambrian and post-Middle Cambrian faulting periods, but these authors regarded the age of the Camooweal Dolomite as pre-Middle Cambrian; now that the Camooweal Dolomite is regarded as Middle Cambrian, the evidence for two periods of faulting along the northern margin of the Georgina Basin is not clearly documented. The age of the faulting in Middle Cambrian rocks of the area is unknown, but Carter and Öpik (1961, op. cit.) state that it was older than Lower Cretaceous. These authors and Smith and Roberts (1963, op. cit.) record minor faulting which has dislocated Mesozoic outcrops on the Lawn Hill-Mount Drummond Precambrian basement area, and Smith and Roberts (1963, op. cit.) state that the faulting was always along the line of pre-existing faults; the effect, if any, along pre-existing faults in Cambrian sediments may reasonably be regarded as minor. In the southern part of the Georgina Basin some mild faulting movements have affected Middle Cambrian sediments in the Elkedra Sheet area, but the major structures in the Barrow Creek-Huckitta-Tobermory-Hay River-Glenormiston-Mount Whelan Sheet areas are post-Devonian, and others which can be dated only as post-Lower Ordovician occur in the Duchess-Boulia area.

The post-Devonian structures of the west and south-western parts of the Georgina Basin generally mask older Palaeozoic structures, but faulting movements probably caused uplift in Upper Cambrian time and in post-Middle Ordovician time, as well as some suspected breaks in Middle Cambrian time. Faulting predominates in the post-Devonian tectonism, and the major structures are parallel faults, trending north-west. Several of these are shown in the Huckitta Sheet area (Plate 3), and in the Tobermory, Hay River and Mount Whelan Sheet areas (Plate 4), where the more important ones have been named the Tarlton, Craigie and Toomba Faults. The trend of these faults is parallel to the major north-west trend of Precambrian crystalline rocks and of major faults in them; this trend has been repeated in several units of younger Precambrian rocks.

All of the major faults trending north-west are normal faults, with down-thrown blocks on the north-east side; the throw is several thousands of feet, in some localities along the Tarlton, Craigie and Toomba Faults. The fault zones are narrow, and are marked by steep dips which flatten to the north-east; the intensity of the faults decreases northwards until monoclinal folds are the only evidence of disturbance, in some cases. The faults extend for many miles, and the Toomba Fault, which is the largest, probably has a length of about 80 miles from latitude 23°S, near the Queensland-Northern Territory Border, to about 24°S, near Pulchera waterhole. Along this fault, beds are overturned (by a maximum of 10 degrees) in a few places, and this has led some writers (Reynolds, 1964, unpubl., and 1965, unpubl.) to believe that the whole fault is a high-angle reverse fault, caused by thrusting from the south-west. However, the overturned dips occur in a few places only, are always in ridges of carbonate rocks (and therefore may be due to hill-creep, collapse, or slumping) and are always in areas where cross-faults are prevalent. The author believes that the Toomba Fault is a high-angle normal fault system, with complex cross faults.

The main effect of the Toomba Fault-Craigie Fault system has been the formation of the Toko Syncline, which is one of the two major folds in the Georgina Basin; the second major fold is the Dulcie Syncline. Both structures are asymmetric synclines trending north-west, with steep dips on the south-western flanks flattening rapidly north-eastwards to very low angles. Although no actual fault zone can be found on the surface along the south-western flank of the Dulcie Syncline, either near the Devonian sediments or away (south-west) from them, the author believes that faulting in the basement has caused the steep dips on the south-western limb of this syncline. There are no regional anticlinal structures complementary to the synclines, but there are several prominent drag folds associated with the Craigie Fault, and one anticline - the Netting Fence Anticline - within the Toko Syncline, and another - the Huckitta Anticline - near the south-western flank of the Dulcie Syncline. Both of these may have originally been compaction structures which have been accentuated later during movement of the downthrown block. Several sharp, minor monoclines in the Tomahawk Beds are known in the Lucy Creek-Tarlton Downs area and they may reflect deep-seated structures. Minor folds are known also in the Arrinthrunga Formation.

In the Toko Syncline there is a prominent set of faults, trending east-north-east, which are complementary to the major faults. These north-east faults are normal faults, with blocks down-thrown to the south-east; the throw does not exceed 200 feet, and is usually less than 100 feet. Another set of minor faults in the Toko Syncline strikes east-west, but these are less prominent and fewer in number than those trending east-north-east.

Many of the faults in the Dulcie Syncline-Toko Syncline areas, as well as the formation of the synclines themselves, can be dated as post-Upper Devonian but pre-Mesozoic, because the Upper Devonian sediments are structurally deformed. It is reasonable to correlate the post-Devonian orogeny with the Alice Springs Orogeny, (named by Forman et. al., 1967) which had its culmination at about the same time, and deformed Devonian and older sediments in the Amadeus Basin, south-west of the Georgina Basin in the Northern Territory. The Alice Springs Orogeny probably can be correlated with the Carboniferous Kanimblam Orogeny of eastern Australia.

Between the Dulcie and Toko Synclines, several major faults and some minor faults and folds cannot be dated precisely because they affect either Middle Cambrian or Upper Cambrian sediments only. However, it is reasonable to assume that the formation of these structures, or the latest movement on them, was associated with the Alice Springs Orogeny.

The Duchess-Boulia area is a structural entity, insofar as surface structures are concerned, and is known as the Burke River structural belt (Öpik, 1960); Öpik (op. cit.) has divided the Burke River structural belt into two segments, which are:

(1) the northern outliers (Burke River Outlier);
(2) the southern inliers, which protrude through Mesozoic cover.

The northern outliers occur in a graben, bounded by faults on the north, east and west, which at about latitude 22°S opens into a trough containing the rocks of the southern segment. The northern outliers contain Cambrian rocks which Öpik (1960, op. cit, and 1961) states are everywhere disturbed, and have been gently folded about axes which trend north-west; the intensity of folding decreases from west to east. Near the faults, dips are near vertical, and the trends of bedding parallel the faults, but the dips decrease away from the faults and the trend swings so that the beds dip regionally to the south-east. Öpik (1960, op. cit.) states that the vertical displacement along the faults is a maximum of 1000 feet on the Roaring Fault, and an estimated 700-800 feet on other faults.

In the southern segment, two prominent lines of structure have been described by Casey et. al. (1960, unpubl.). One structural line extends from Mount Birnie, to Black Mountain, Mount Ninmaroo and Dribbling Bore (in Upper Cambrian and/or Ordovician rocks), and its surface expression is visible in Cretaceous rocks farther south near Elizabeth Springs and near Mungeroo Knobs, south of Springvale homestead. Along this structural line, Palaeozoic rocks (as far south as Dribbling Bore) have been folded into anticlines and subsequently faulted (Casey et. al., 1960, op. cit.). The best exposures of the structure are in the Black Mountain-Mount Ninmaroo area, where Casey et al. (1960, op. cit.) state that the normal fault plane dips steeply east, and the sequence is downthrown about 1000 feet. The fault line is marked by dolomitisation and brecciation, and cuts off the eastern part of a dome in the Chatsworth Limestone. On the western side of the fault, dips are about 35°, but they flatten rapidly to 10° within a distance of 50 yards, and then decrease gradually westwards until they are almost horizontal; on the eastern side dips are vertical, but decrease to horizonal within a distance of 2 miles. During post-Cretaceous movement on the fault, a vertical displacement of about 600 feet is indicated at Mount Ninmaroo (Casey et al., 1960, op. cit.).

The other structural line is the Momedah Anticline, which extends from near Chatsworth homestead south-east almost to the Hamilton River, at about 22°32'S. This structure is approximately parallel to one through Black Mountain, but the only Palaeozoic rocks exposed are the Upper Cambrian Chatsworth Limestone in the north, and the Upper Cambrian Gola Beds in the south; the exposure of Gola Beds in the Momedah Anticline is the easternmost Palaeozoic outcrop in the Georgina Basin. The Cambrian sediments in the Momedah Anticline are folded into an asymmetrical anticline with dips of 65° on the western and low dips on the eastern limbs; the western side of the anticline is faulted and downthrown to the west (Casey et al., 1960, op. cit.). Both the Longsight Sandstone and the Wilgunya Formation have been disturbed along the line of the Momedah Anticline, and Casey et al. (1960, op. cit.) have calculated a vertical displacement of about 200 feet in the Wilgunya

Formation.

The age of the deformation in the Burke River Structural belt is conjectural, but some indications are given by the following evidence:

Middle Cambrian rocks in the Burke River Outlier and the Ardmore and Quita Creek areas, (i.e., two areas now separated by a land mass of the Cloncurry Complex) contain the Thorntonia Limestone, Beetle Creek Formation and Inca Creek Formation; however, after the deposition of the Inca Creek Formation, the depositional history of the eastern and western areas differed, as is shown by the Correlation Chart (Fig. 12) columns for the Mount Merlin and Quita Creek and Mungerebar areas (Fig. 12). Öpik (1960, op. cit.) regarded this evidence as indicative of upward movement of the Precambrian land mass in Middle and Upper Cambrian time; however, the initial formation of the fault structures cannot be dated.

The youngest Palaeozoic sequence affected in the Burke River structural belt is the Upper Cambrian-Lower Ordovician Ninmaroo Formation; this has been folded and then faulted (Casey et al., 1960, op. cit.).

Lower Cretaceous sediments have been folded and faulted along the same structural lines as Lower Ordovician sequences in some places, and in other localities they have been folded along trends parallel to those in the Ordovician rocks, although the sequences beneath the folded Cretaceous are unknown. The post-Lower Cretaceous deformation is a milder event than that which affected the Ordovician sediments, and can reasonably be regarded as a rejuvenation in late Cretaceous time.

The Lower Ordovician Swift Formation rests unconformably on the Ninmaroo Formation.

The Ordovician fossil sequence ends well before the close of Ordovician time.

Öpik (1960, 1961) considers that the uprising of the Precambrian land mass east of Duchess reached its climax in Lower Ordovician time, and that the main structures in the Burke River Outlier are of this age, i.e., post-

Ninmaroo but pre-Swift Formation time. However, Casey et al. (1960, op. cit.) believe that the "break" between the Ninmaroo and Swift Formations was a mild event, and, by inference, that the main deformation was post-Swift Formation. The author agrees with Öpik's views, and the palaeogeographic maps (Fig. 19) and interpretation of geological history of the Duchess-Boulia area are based on a Lower Ordovician (pre-Swift Formation) climax to tectonic events in the Burke River structural belt.

West of the Burke River structural belt, several asymmetric anticlines, trending either north-west or north, have been mapped in Cretaceous sediments of the Boulia Sheet area (Plate 4). Casey et al., (1960, op. cit) have described dips up to 25° along these structures, whereas the dips of the Cretaceous in adjacent localities is almost horizontal. However, erosion of the Cretaceous has not proceeded deep enough for underlying stratigraphy and structure to be determined. Other structures west of the Burke River include small downfaulted blocks of Middle Cambrian rocks as outliers in the Ardmore and Quita Creek areas (Urandangi and Glenormiston Sheet areas respectively).

GEOLOGICAL HISTORY

The history of the Georgina Basin began with the ingress of a shallow sea in early, but not earliest, Middle Cambrian time. In broad terms, this sea was part of a near-meridional sea extending from the Adelaide area of South Australia to the Joseph Bonaparte Gulf on the north-west of the continent.

The early Middle Cambrian sea covered the whole of the Georgina Basin and extended across at least the southern part of the Cloncurry Complex as well as covering part of its north-western area. The original coverage of the present Precambrian outcrop in the Mount Drummond Sheet area, and to the south-west across the present Simpson Desert area is not clear, nor is there any evidence to confirm or deny Middle Cambrian sedimentation to the east of the Boulia Sheet area. In the north, connections probably existed with the Daly River Basin, and in the west, with the Wiso Basin; the Davenport and Ashburton Ranges were probably islands in the Middle Cambrian sea, and their eastern edges formed a margin to the Georgina Basin. A connection with the Amadeus Basin, via part of the submerged Arunta Block is considered likely

(Öpik, 1956b) but this block probably consisted of a series of horsts and grabens and more than one seaway may have occurred between the two sedimentary basins.

In the northern Georgina Basin, Middle Cambrian sediments were deposited on a broad epicontinental platform with a maximum relief of about 1200 feet and with several parallel depressions trending north-west. Generally similar conditions prevailed in the west and south-west, but in the eastern part of the Basin the platform opened southwards into slightly deeper water of a meridional trough in the Chatsworth-Boulia area.

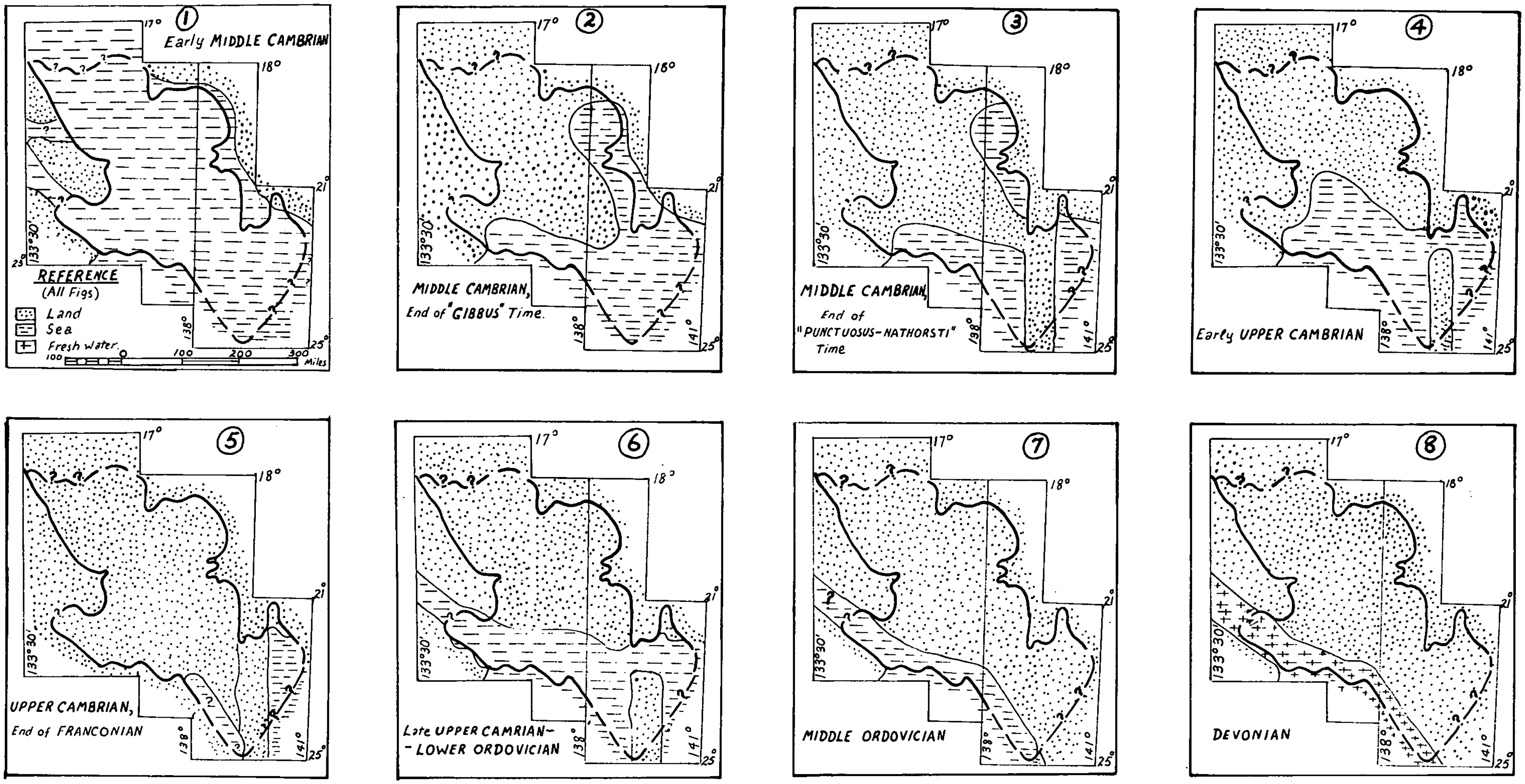
Very few basal conglomerates are known in the lower Middle Cambrian sequence, but they have been recorded around the margins of the Davenport Range, and in north-western Queensland (Fig. 12).

Carbonate rocks predominated in early Middle Cambrian time, but no chemically-precipitated dolomite is known and the original sediments consisted of limestone with some shale and siltstone. All of the sediments were deposited in shallow water, and most of the seas were rich in marine life; there were two completely different faunas, one in the Northern Territory and the other in north-western Queensland. Öpik (1956a and b) reported this difference in fauna and considered that there were two seas separated by a meridional ridge of Camooweal Dolomite of Lower Cambrian or Upper Proterozoic (Adelaidean) age. The Camooweal Dolomite is now known to contain Middle Cambrian fossils and its role as barrier between the two faunal areas is no longer tenable; an adequate explanation for the difference in faunas cannot be provided.

During "Gibbus" time (refer to Correlation Chart, Fig. 12) the Middle Cambrian seas regressed from most of the Northern Territory part of the Georgina Basin north of latitude 22°S, and this part of the Basin has been stable ever since except for faulting movements which affected the Sandover Beds in the south-eastern foothills of the Davenport Range and the Middle Cambrian units along the northern margin in the Mount Drummond and Lawn Hill Sheet areas. Prior to the regression, the thickness of early Middle Cambrian sediments deposited in parts of the Barkly Tableland area exceeded that of some other parts of the Basin, e.g., about 1000 feet in the Frewena-Brunette

PALAEOGEOGRAPHY, GEORGINA BASIN

Fig 19



To accompany Records 1967/61

Downs area, compared with 1000 feet and 1100 feet for complete Middle Cambrian sequences in the Huckitta and Camooweal-Undilla areas, respectively.

The regression in "Gibbus" time did not affect continuity of Middle Cambrian sedimentation in the southern part of the Georgina Basin, and it continued also in the Camooweal-Undilla area of the north, and in the Duchess-Boulia area in the east. All of the younger Middle Cambrian sediments were predominantly carbonates with local developments of shale, and sandstone lenses high in the sequence. All of the sequences are of shallow water type and most of them contain abundant fossils, but fossils are less common in the Camooweal Dolomite and the Age Creek Formation, both of which were deposited under more turbulent conditions. Öpik (1956a) reported a complete sequence of Middle Cambrian sediments in the Camooweal-Undilla area, and other complete sequences are indicated in the Huckitta, Tobermory and Boulia areas but palaeontological details of these sequences are incomplete. Continuity of sedimentation did not prevail everywhere, because an upward movement of the Cloncurry Complex in about "Punctuosus-Nathorsti" time (refer Fig. 12) caused a break in the Dajarra-Duchess area and thereafter the Middle Cambrian sedimentation differed on east and west sides of the Precambrian block.

The upward movement of the Cloncurry Complex and superimposed Adelaidean-Lower Cambrian sediments initiated an important chain of events in the history of the Georgina Basin: it formed a ridge of basement rocks extending to about latitude 25°S, which separated the Duchess-Boulia area from the remainder of the Georgina Basin in Upper Cambrian and Lower Ordovician time, and recurrent vertical movements of the ridge, or parts of it, affected the distribution of sediments along its flanks.

Because of the differences in history, it is more convenient to consider the Upper Cambrian and younger history separately for each part of the Georgina Basin. In these descriptions, the ridge of Cloncurry Complex and Adelaidean/Lower Cambrian rocks will be referred to as the "Precambrian ridge".

The Duchess-Boulia area

Sedimentation was continuous from Middle Cambrian into Upper Cambrian time in the Selwyn Range area, and the continuity was probably maintained also in the Chatsworth-Boulia area; the structural elements consisted of a platform in the north, opening southwards into a slowly-subsiding trough. However, the axis of the early Upper Cambrian had been displaced slightly westwards (indicated by westward thickening of the Pomegranate Limestone/ O'Hara Shale), due to subsidence of at least the eastern part of the Precambrian ridge. It is likely that at this time an east-west seaway connected the Duchess-Boulia area with the Mungerebar area.

At about the end of Dresbachian time, uplift occurred along the eastern part of the Precambrian ridge, and the sea withdrew from the northern part of the Duchess-Boulia area. At about this time, the major faults of the Burke River Outlier were initiated. A trough remained in the Chatsworth-Boulia area and persisted until late in Lower Ordovician time, but its axis shifted eastward to a position almost coincident with the Middle Cambrian axis. In this trough about 3500 feet of richly-fossiliferous carbonate rocks (the Chatsworth Limestone and the Ninmaroo Formation) were deposited in warm shallow seas where conditions favoured the growth of algal reefs. The eastern, western and southern extent of these seas is unknown, but the overall distribution of the Ninmaroo Formation suggests a westward connection with the remainder of the Georgina Basin in Lower Ordovician time.

The prevalence of beds of breccia in the Ninmaroo Formation suggests regularly-recurring tectonic pulses in the Precambrian rocks bounding the Lower Ordovician trough; these pulses reached a climax which resulted in Lower Ordovician folding and faulting of the trough sediments, and accentuation of the faults in Cambrian sediments to the north. At this time, the structures of the Burke River Structural Belt were established, and a subsidiary fault system, trending north-east along the present Hamilton River with the upthrown block to the south, may have been initiated.

After a short period of erosion, the Lower Ordovician sea returned and the Swift Formation was deposited in the northern part of the former Lower Ordovician trough. This transgression was short-lived, and after the sea withdrew there was no later Palaeozoic sedimentation in the Duchess-Boulia area. The Precambrian ridge, with its capping of Palaeozoic carbonate rocks, remained a positive, stable area until Mesozoic time.

The remainder of the Georgina Basin

West of the Precambrian ridge, sedimentation after "Punctuosus-Nathorsti" time (Fig. 12) continued in the Camooweal-Undilla area and was probably continuous in the Huckitta and Tobermory areas; the Huckitta area was a marine platform opening south-eastward to slightly deeper water. At the end of Middle Cambrian time the sea withdrew from the Camooweal-Undilla area and no younger Palaeozoic sediments were deposited there.

Continuous sedimentation from Middle to Upper Cambrian time occurred in the Huckitta-Tobermory area, and also in the Mungerebar area, but in the Sun Hill area the Georgina Limestone transgressed onto Adelaidean sediments. In Dresbachian time uplift occurred in the Sun Hill and Mungerebar areas, but in the Huckitta-Tobermory area sedimentation continued into Franconian time and considerable thicknesses of shallow water carbonate rocks, with interbedded siltstone and sandstone were deposited. Although subsequent Upper Cambrian erosional history is unknown, the preserved thicknesses of the Arrinthrunga Formation indicate that in Dresbachian-Franconian times a trough developed in the Huckitta area, and another in the south-east of the present Toko Syncline.

Uplift and erosion occurred in Franconian time in the Huckitta-Tobermory area, and the next event was the ingress of a late Upper Cambrian sea which covered the previously-deposited Upper Cambrian sediments and in the north-west transgressed onto Precambrian basement; in the north it lapped over early Middle Cambrian sediments. Sedimentation was continuous from late Upper Cambrian until near the end of Lower Ordovician time. The Huckitta area had reverted to platform conditions and received only 800 feet of sediment, but the Toko Syncline area became established as a site of thicker deposition and accumulated about 1600 feet of sediments in its north-western end and a thicker, but unknown, amount to the south-east.

A minor break in sedimentation, indicated by fossil evidence, occurred between the Lower Ordovician Kelly Creek and Coolibah Formations. The Coolibah Formation is the oldest unit of the Toko Group; deposition of the Group was confined to the Huckitta-Tobermory areas, and all of the sediments were deposited in shallow water. For the first time in the Basin's history, deposition of sand exceeded that of carbonate rocks and evidence from the Carlo Sandstone indicates a source in the south-east. The deposition of

Ordovician sediments ceased and uplift began, probably in Middle Ordovician time. These events may have been simultaneous in the Huckitta and Tobermory areas, but erosion before deposition of Devonian or Siluro-Devonian sediments masks the sequence of events.

Marine sedimentation ended in Middle Ordovician time. After uplift and erosion the next major event was the deposition of fresh-water sediments in either late Silurian or early Devonian time in the Toko Syncline area, and in either Lower or Upper Devonian time in the Huckitta-Barrow Creek areas. The extent of these fresh-water sequences is unknown; they are preserved today in one belt in the Toko Syncline and another in the Dulcie Syncline, and are known to extend north-westwards from Barrow Creek area into the Wiso Basin.

The major tectonic event in the history of the Georgina Basin occurred after deposition of the Devonian sediments; its precise date is unknown, but it probably occurred in early Carboniferous time and the event is tentatively correlated with the Kanimblan Orogeny of eastern Australia. In the Georgina and Amadeus Basins the event is known as the Alice Springs Orogeny. In the Georgina Basin the effects of the Alice Springs Orogeny are seen mainly south of latitude 22°S but some faults continue northwards to about latitude 21°30'. Faulting was dominant during the Orogeny and major faults developed with a north-west trend, parallel to or coincident with previous faults in the Precambrian basement. The faults are normal, with down-throw to the north-east, and some have throws of several thousands of feet. They shaped the south-western margin of the Basin and were responsible for the asymmetry of the Dulcie and Toko Synclines. The intensity of faulting decreased from south-east to north-west, along individual faults. Minor complementary faults trend east-north-east, and west. Folding movements were slight during the Orogeny and igneous intrusions are unknown. The rocks of the Duchess-Boulia area were not affected by the Alice Springs Orogeny.

The whole of the Georgina Basin underwent a long period of erosion until Mesozoic deposition began in late Triassic or early Jurassic time, but Permian sediments may have been deposited in the Toko Syncline area. The extent of the Triassic-Jurassic sedimentation is unknown but the present outcrop distribution indicates that it was widespread in the southern part of the Basin. After another period of erosion, Lower Cretaceous seas covered most, if not all, of the Basin, and thin sequences which increased in thickness to the south and south-east were deposited. A late Cretaceous movement rejuvenated faults and folds in the Boulia area, but there is no evidence of this tectonism in the Northern Territory part of the Basin.

The thin Mesozoic cover had been stripped from much of the Georgina Basin area, and a lateritic surface formed by late Miocene time, when thin Tertiary sediments were deposited in a series of fresh to brachish water lakes (Lloyd, 1966). Casey et. al., (1960, unpubl.), Öpik (1960) and Paten (1964) reported evidence of a gentle southward tilt which drained the lakes of the Boulia area in late Tertiary time, but evidence of tilting is not available in other parts of the Basin.

The final stages in the history of the Georgina Basin area included the stripping of laterite, the formation of clayey soils over carbonate rocks and a widespread sand and soil cover.

ECONOMIC GEOLOGY

No metalliferous deposits have been mined in the Palaeozoic rocks of the Georgina Basin, but a few prospects have been tested for galena and manganese. Since no igneous intrusions are known in the Palaeozoic rocks, the occurrence of hydrothermal ore bodies can be discounted, but the mobilisation and concentration of syngenetic metals during tectonism may have occurred. However, nothing of economic size has been discovered, although galena has often been observed in carbonate rocks and galena and arsenopyrite have been reported in samples from water bores. In recent times, samples from wells and core-holes have been examined for phosphate, and the samples from some core-holes have been tested unsuccessfully for significant concentrations of cobalt, nickel, lead, zinc, vanadium phosphorus and strontium (Nichols, 1966, unpubl.). The present company exploration in the Georgina Basin is directed mainly towards petroleum and phosphate, whilst water for grazing purposes is continually sought, mainly with Government assistance. These three targets are discussed below, together with prospects of lead, iron and manganese.

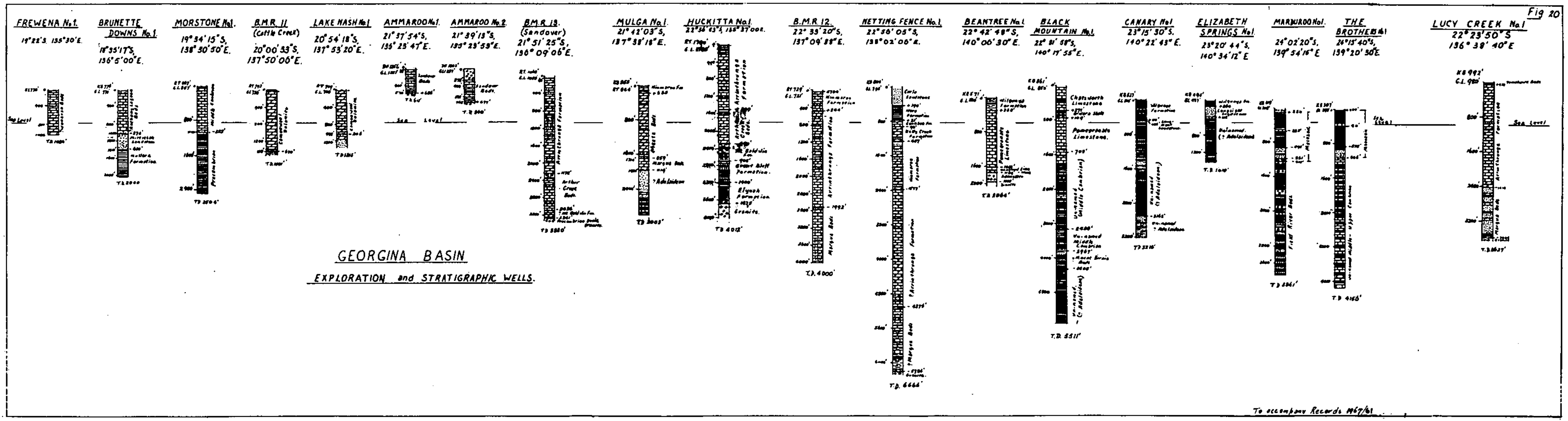
Iron. Beds of oolitic ironstone occur in the Nora Formation in the scarp of the Dulcie Range, and several beds of ferruginous sandstone are known in the Tomahawk Beds between Mount Ultim and the south-eastern tip of the Dulcie Range. (Vine, 1959, unpubl., and Smith, 1964a). The occurrences have not been sampled or mapped in detail, but visual estimation indicates low grade except in the south-eastern part of the Dulcie Range, where the iron-rich beds are very thin. Section HX30 of the Nora Formation contains a total of 6 feet of oolitic ironstone in the interval 37-69 feet above the base of the formation; a sample from one bed was analysed (Smith, 1964 op. cit.) and contained 39.6% Fe_2O_3 and 43.3% of insolubles which consisted mostly of sand grains forming the nucleus of the oolites. A specimen of ferruginous sandstone from the Tomahawk Beds east of Mount Ultim assayed 25.7% Fe_2O_3, and 53.4% insolubles, which again consisted mainly of sand grains (Smith, 1964 op. cit.).

Lead. Showings of galena have been tested near Box Hole Bore (22°16' 23"S, 135°51'E, about 8 miles north-east of Arapunyah Homestead, in the Huckitta Sheet area) by Consolidated Zinc Pty Ltd (1961, unpubl.), and Woolley (1961, unpubl.) examined the prospect for the Bureau of Mineral Resources; other prospects have been tested at Little Totts Creek, 25 miles north-north-east of Camooweal (Blanchard and Hall, 1942, p.59) and 10 miles north-north-east of Noranside homestead, at 22°01'S, 140°03'E approximately (Shepherd, 1945b, and Casey et al., 1960, unpubl.).

The largest of the galena prospects is the Box Hole deposit, where fairly extensive showings of galena were located in a bed of weathered, algal dolomite in the top unit of the Arrinthrunga Formation. The mineralisation extends over a distance of about two miles. It was found by a prospector in 1960, and subsequently mapped and drilled by Zinc Corporation Pty Ltd, but no further work has been done. A few tons of galena were gouged from the surface, but the grade of ore down dip is too low for economic development.

The deposit near Noranside homestead is small; Casey et al., (1960, unpubl.) report irregular blebs and patches of galena, up to two inches wide, in brecciated and vuggy dolomite of the Ninmaroo Formation, on the crest of an asymmetrical anticline in the Burke River structural belt. The deposit was tested by costeaning in 1956, but has not been worked since.

Fig 20



GEORGINA BASIN

EXPLORATION and STRATIGRAPHIC WELLS.

The Little Totts Creek deposit consists of small shows of galena in beds of Camooweal Dolomite. A few shallow pits have been sunk on the prospect, which has no economic importance.

Manganese. Several low grade occurrences of manganese have been noted, but none has been worked. Thin sandstone beds of the Tomahawk Beds contain manganese at a locality about 18 miles south of Murray Downs homestead, in the Barrow Creek Sheet area, but analysis by B.M.R. of the best specimens showed a grade of only 40% MnO_2. Noakes, Carter and Öpik (1959) reported low grade manganese in outcrops of the Steamboat Sandstone in the Urandangi Sheet area, and Casey et al. (1960, unpubl.) reported nodules and patches of manganese minerals in chert and siltstone of the O'Hara Shale, about 12 miles south-south-east of Buckingham Downs homestead; the same authors reported specimens of rhodocrosite, assaying 13.9% MnO_2, in Ninmaroo Limestone 12 miles north-east of Digby Peaks homestead, and also pyrolusite and psilomelane at the unconformity between the Ninmaroo Formation and the Swift Formation on the western side of the Swift Hills. All of the occurrences were probably concentrated during weathering processes.

Petroleum Prospects

No commercial quantities of oil or gas have been discovered in the Georgina Basin; 19 wells have been drilled, and although many of them showed traces of hydrocarbons, all have been plugged and abandoned. The logs of these wells are shown on Fig. 20.

Potential source beds are present throughout much of the Georgina Basin succession, particularly in Middle Cambrian formations but also in early Upper Cambrian and late Upper Cambrian/Lower Ordovician formations of north-western Queensland. These units consist of dark fossiliferous limestones, much of which has a strong petroliferous odour when freshly broken. Some of the dark shales of early Middle and early Upper Cambrian age may also be potential source beds.

Apart from the surface evidence of limestones with petroliferous odours, some early indications of hydrocarbons were reported during water-boring operations; Moss (1932 unpubl.) mentioned a driller's report of petroliferous odours in Tyson's No. 1 bore (8 miles south-west of Glenormiston homestead), which was drilled in 1910, and penetrated about 1800 feet of limestone of probable early Upper Cambrian and Middle Cambrian age. Other early indications came from drillers of water bores east and south of Boulia, but these bores penetrated Cretaceous sediments, as far as is known; although the source of gas and oil slicks is unknown they could originate in the underlying Palaeozoic sediments and escape into the Mesozoic rocks after the post-Lower Cretaceous tectonism. Hydrocarbon indications were reported from the Ammaroo area in 1956, when gas was discovered during water-boring operations in the early Middle Cambrian Sandover Beds (Mackay and Jones, 1956, unpubl.). Another indication was reported by Shepherd (1945a); a water bore on the main road between Camooweal and Mount Isa penetrated oil shale (of Middle Cambrian age) and a sample from the interval 205-206 feet yielded an estimated 15 gallons of petroleum per ton of sediment.

Konecki (<u>in</u> Casey et. al., 1960, unpubl.) has reported the results of analyses on several of the suspected source rocks in the Boulia area, and some of the results are listed below (the sample numbers refer to samples collected by the Bureau of Mineral Resources; the localities of these samples are plotted on air photographs held in the Bureau of Mineral Resources, Canberra):

Specimen No.	Formation	Residual Oil Content
D126(3)	Pomegranate Limestone	Zero
D124 S(1)	Chatsworth Limestone	7.5 bbl/acre foot
D124 S(2)	" "	0.23 " " "
B507 A(1)	" "	10.1 " " "
B510C	" "	4.8 " " "
B514	Ninmaroo Limestone	3.1 " " "

Konecki also reported low porosities, seldom exceeding 2%, in these specimens, and zero permeabilities in both horizonal and vertical directions.

TABLE 6

SYNOPSIS OF EXPLORATION AND STRATIGRAPHIC WELLS, GEORGINA BASIN (To 31st December, 1966)

Operator	Name of Well	Total Depth (Feet)	Main Stratigraphic Results	Significant Hydrocarbons	Remarks
Barkley Oil Company Pty Limited	FREWENA No. 1	1024	Middle Cambrian, surface to total depth.	Nil	Test of early Middle Cambrian sediments.
Papuan Apinaipi Petroleum Company Limited	BRUNETTE DOWNS No. 1	2040	Middle Cambrian to 670 feet; ?Middle-?Lower Cambrian to 1050 feet; Precambrian below 1050 feet.	Nil	Test of early Middle and ?Lower Cambrian sediments; carbonate sequence 1044 feet thick.
Amalgamated Petroleum Exploration Pty Limited	MORSTONE No. 1	2504	Middle Cambrian to 1100 feet; Precambrian below.	Nil	Test of Middle Cambrian sediments.
Bureau of Mineral Resources	BMR 11 (CATTLE CREEK)	1501	Middle Cambrian fossils in Camooweal Dolomite. Camooweal Dolomite to 1412 feet, ?Adelaidean below.	Nil	Stratigraphic well testing Middle Cambrian.
Amalgamated Petroleum Exploration Pty Limited	LAKE NASH No. 1	1315	Middle Cambrian fossils in Camooweal Dolomite; ?Adelaidean below 995 feet.	Nil	Test of Middle Cambrian sediments in Lake Nash Anticline.
Farmout Drillers N.L.	AMMAROO No. 1	612	Middle Cambrian, 38-570 feet; Arunta Complex below.	Nil	Test of early Middle Cambrian sediments.
Farmout Drillers N.L.	AMMAROO No. 2	840	Middle Cambrian, 273-765 feet; Precambrian granite below.	Small gas flow at 406 feet.	Test of early Middle Cambrian sediments.
Bureau of Mineral Resources	BMR 13 (SANDOVER)	3330	Upper Cambrian to 2235 feet; Middle Cambrian, 2235-3097 feet, ?Lower Cambrian, 3097-3304 feet, Precambrian metamorphics below.	Traces of oil and gas, 2952-2975 feet.	Stratigraphic well, spudded about 700 feet below top of Arrinthrunga Formation.
Alliance Petroleum Australia, N.L.	MULGA No. 1	3003	Palaeozoic carbonate sequence to 1974 feet; ?Adelaidean 1974 feet - total depth. Middle Cambrian (1714-1974 feet) very thin.	Nil	Spudded in Ninmaroo Formation, in an area where magnetic basement is indicated 6000-8000 feet below sea level.
Exoil Oil Co. Pty Limited	HUCKITTA No. 1	4012	Base of Arrinthrunga Formation at 1490 feet; base of Middle Cambrian, 2280 feet; Mopunga Group 2280-3665; granite below.	Nil	Tested Huckitta Anticline; spudded 820 feet below top of Arrinthrunga Formation.
Exoil Oil C. Pty Limited	LUCY CREEK No. 1	3627	Tomahawk Beds to 66 feet; Arrinthrunga Formation, 66-2410 feet; Middle Cambrian 2410-3600 feet; granite, 3600 feet - total depth.	Nil	Test of Upper and Middle Cambrian sediments.
Bureau of Mineral Resources	BMR 12 (COCKROACH)	4000	Ninmaroo Formation to 485 feet; Arrinthrunga Formation, 485-2721 feet; Marqua Beds 2721 feet - total depth.	Nil	Stratigraphic well, spudded near outcrops of fossiliferous Ninmaroo Formation.
Papuan Apinaipi Petroleum Company Limited	NETTING FENCE No. 1	6666	Middle Ordovician, Lower Ordovician, Upper Cambrian, Middle Cambrian, to 6590 feet; Precambrian granite below.	Nil	Test of Netting Fence Anticline, within Toko Syncline. The only well to drill most of the Georgina Basin sequence.
Phillips Petroleum Company Ltd	BEANTREE No. 1	2064	Mesozoic to 303 feet; Upper Cambrian, 303-1604 feet; Middle Cambrian 1604-1740 feet, Precambrian crystalline basement below.	Nil	Drilled near a gravity low. Ninmaroo Formation and Chatsworth Limestone missing.
Phillips Petroleum Company Ltd	BLACK MOUNTAIN No. 1	5511	Upper Cambrian to 1569 feet, Middle Cambrian to 3828 feet, ?Lower Cambrian to 4266 feet; ?Adelaidean 4266 - total depth.	Nil	Drilled on a half-dome truncated by a fault; thick sequence of non-outcropping Middle Cambrian.
Phillips Petroleum Company Ltd	CANARY No. 1	3218	Mesozoic to 504 feet; Adelaidean 504 feet - total depth.	Nil	Palaeozoic missing.

TABLE 6; Sheet 2

Phillips Petroleum Company Ltd	ELIZABETH SPRINGS No. 1	1410	Mesozoic to 383 feet; ?Adelaidean 383 feet - total depth.	Nil	Palaeozoic missing.
French Petroleum Company (Aust.) Pty Limited	MARDUROO No. 1	3861	Mesozoic to 1234 feet; ?Adelaidean 1234 feet - total depth.	Nil	" "
French Petroleum Company (Aust.) Pty Limited	THE BROTHERS No. 1	4156	Mesozoic to 1153 feet; Upper and Middle Cambrian, 1153 feet - total depth.	Nil	Stratigraphic test of sediments beneath Mesozoic, in concealed (south-eastern) part of the Georgina Basin.
	TOTAL FOOTAGE	54696			

Water bore records, and the results of some exploratory wells and scout holes, indicate that porous rocks are common in parts of the Georgina Basin sequence. Most of the porous rocks are carbonates, but some sandstones are clean and porous, whilst others are either calcareous or silty, without significant porosity. The carbonate rocks of the Georgina Basin might act as good reservoirs, because many formations are vuggy and cavernous, and may have some porosity induced by dolomitisation. However, recrystallisation is evident in many, and the permeabilities are probably low. Where some of the formations have not been dolomitised, they are generally hard and tight, as evidenced by the general failure to produce water from dark limestones, e.g., in the Chatsworth area of north-western Queensland, and in limestone of several Middle Cambrian formations in the Northern Territory. However, these formations have always been drilled for water away from known fold structures.

Cap rocks are present in many formations, e.g., the shale of the Nora Formation, but they are often thin, and drilling results show more siltstone and shaly siltstone than true shale.

Suitable anticlinal structures are few in the Georgina Basin, but some are large; for example, anticlines in the Burke River structural belt, and some of the asymmetric anticlines west of this belt, extend for many miles. The dominant structures are normal faults, which have shaped the south-western margins of the asymmetric Dulcie and Toko Synclines.

Admitting that source, reservoir and cap rocks are present in the Georgina Basin, and remembering that whilst the geological history shows many breaks in sedimentation, particularly in Middle Cambrian time, these have all been deduced from evidence near the margin of the basin, and thicker sections with more continuity of sedimentation are expected in deeper parts. The petroleum prospects at the present time may be summarised as follows:

Most of the northern part of the Basin, i.e., north of latitude 21°S, has poor prospects because the sequence is generally structureless and thin; the available thickness seldom exceeds 1000 feet, and the sequence consists almost entirely of vuggy and cavernous carbonate rocks which yield prolific quantities of water in the first few hundred feet at least, and for the entire section (1420 feet) in BMR 11 Well. The following wells have been drilled in this part of the Basin (for results, see Table 6); Lake Nash No. 1, Morstone No. 1, Brunette Downs No. 1, Frewena No. 1 and B.M.R. 11 (Cattle Creek).

In the southern part of the Basin, the thickness of section increases, but much of the sequence consists of Upper Cambrian exposed at the surface and sometimes Lower Ordovician; therefore the main target for petroleum here will be Middle Cambrian sequences in the base of the succession. The thickest sections, including Middle Ordovician and Devonian formations, crop out only near the south-western margin; they pitch south-eastwards in the Toko Syncline and, according to the geophysical evidence, thicken considerably under the Mesozoic cover.

The prospects are considerably improved in the southern part of the Georgina Basin, but here the first phase of exploration, i.e., the drilling of surface anticlines, has almost ended and to date has been unsuccessful. The second phase will be considerably more difficult because (i) the search for fold structures by seismic methods has been generally unsuccessful due to the difficulty of obtaining reflections through the sheet of carbonate rocks which is present in much of the Basin, (ii) economic basement often lies above magnetic basement, and therefore the depth to the base of the Middle Cambrian cannot be calculated from aeromagnetic surveys. However, the various aeromagnetic surveys have been very useful in determining the trends and extent of buried Precambrian ridges within the Basin, and the concealed south-eastern margin, as well as some subsurface faults,and (iii) the gravity results have been useful in delineating regional gravity features, but the work has been troubled by lack of density contrast between Palaeozoic carbonate rocks and Precambrian metamorphic and igneous rocks.

The author believes that at present the petroleum prospects in the northern part of the Georgina Basin are poor. In the southern part they are slightly better but not good, because of unsuccessful drilling of most of the available surface anticlines and the difficulty of selecting new drilling targets by geophysical methods in use at present.

Phosphate. The search for phosphate minerals has recently received the attention of many mining companies, the Authorities to Prospect are held by companies and individuals in several parts of the Georgina Basin; the areas receiving attention first are the marginal areas, where Middle Cambrian sediments, particularly shales deposited around and over Precambrian highs, are thought to offer good prospects. At present the prospecting programmes are at an early stage, but apatite and turquoise have been discovered by a prospector in a bed of the basal sandstone - conglomerate unit of the lower Middle Cambrian Sandover Beds in the south-eastern foothills of the Davenport Range, and the deposit is being investigated. In Queensland, Mines Exploration Pty Limited announced, late in 1966, the discovery of high grade phosphate deposits in Middle Cambrian sediments of the Duchess area. These deposits contain substantial tonnages and investigations are in progress.

The search for phosphate has involved field investigations and examination of cores and cuttings from stratigraphic wells and core-holes by mining companies and also by the Bureau. Mines Exploration Pty Limited (Russell, 1966, unpubl.) has examined cores and cuttings from thirteen stratigraphic wells, and has found that relatively high phosphate values were obtained "only in Middle Cambrian sediments characterised by black limestone, black shale, cherty shale and black chert. The phosphate is in the form of dark phosphatic limestone, and as nodular and pelletal phosphorite". Russell also stated that the occurrence of phosphate is accompanied by an increase in radioactivity in the gamma-ray log.

Mines Exploration Proprietary Limited examined material by first testing by the molybdate method, and checking higher values with the Shapiro Test, followed by semi-quantitative laboratory analysis of samples showing more than 1% P_2O_5 in the Shapiro Test. The main results from the tests are:

Ammaroo No. 1 53-315 feet, 0.5-2.0% P_2O_5

Black Mountain No. 1	3340-3350 feet, 11.9% P_2O_5	
	3360-3370 " , 11.2% "	
	3370-3380 " , 10.7% "	
	3380-3390 " , 8.7% "	
	3400-3410 " , 5.9% "	
	3410-3420 " , 3.6% "	
	3500-3510 " , 5.8% "	
	3510-3520 " , 3.2% "	

Core No. 12, 3355-3357 feet, contained the following lithologies and P_2O_5 content:

Black medium-grained limestone,	13.6% P_2O_5
Black fine-grained limestone	7.7% "
Black cherty limestone and chert	0.75% "

BMR 13 (Sandover)	3070-3080 feet, 2.05% P_2O_5
	3080-3090 feet, 4.5% "
	3090-3100 feet, 2.80% "
Lake Nash No. 1	880-890 feet, 3.9% P_2O_5, with 16.1% in black limestone fraction
	890-900 " , 4.1% "
	900-910 " , 3.8%
Morstone No. 1	860-870 feet, 6.8% P_2O_5
Netting Fence No. 1	Core No. 19, 6418'4"-6419', contained 10% P_2O_5 in fragments of bedded nodular and oolitic black phosphorite. Investigations are incomplete.
The Brothers No. 1	4080-4085 feet, 8.4% P_2O_5
	4085-4090 " , 10.4% "
	4090-4095 " , 3.2%

All of the relatively high values are in early Middle Cambrian sediments.

In the south-western part of the Georgina Basin, Casey (pers. comm.) has observed pellet phosphorite in the Middle Ordovician Nora and Mithaka Formations in the Toko Range, and in the Nora Formation in the Tarlton Range. A sample of the Nora Formation from Gaphole Creek in the Toko Range has 13% P_2O_5. The Ordovician sediments of the Georgina Basin might offer better prospects for phosphate than the early Middle Cambrian but are more remote from transport facilities.

Underground Water. Because of the general lack of permanent surface water in the Georgina Basin, the pastoral industry depends on supplies of bore water. The requirements of a successful water bore cannot be rigidly defined, because they differ from area to area, in accordance with opinions of individual pastoralists, and, more importantly, according to the carrying capacity of particular grazing areas. For example, a bore yielding 600 gallons per hour might be regarded as satisfactory in the southern part of the Georgina Basin, but would be of limited use in the Barkly Tableland area of the northern part, which has a higher stocking capacity. In general terms (and excluding artesian bores) a successful water bore in the Georgina Basin must yield at least 600 gallons per hour, and its pump depth should not exceed 600 feet.

Two broad areas may be defined in the Georgina Basin area for discussion of underground water - one east of longitude 139°E approximately, and the other west of this longitude. In the eastern area, water is obtained mainly from Mesozoic cover rocks, usually in sub-artesian bores, but with some artesian bores. In this area, limited numbers of bores obtain water from Palaeozoic and Cainozoic sediments. In the western area water is produced almost exclusively from Palaeozoic sediments, but some successful bores produce from Cainozoic aquifers, and a lesser number from the Mesozoic.

Since the Mesozoic of the eastern belt is part of the Great Artesian Basin, its hydrology has been studied along with the various hydrological studies of that basin. However, hydrological studies in the western belt have been lacking until Randal (1966, unpubl.) made a study of groundwater in the Barkly Tableland of the Northern Territory. The Bureau field parties have always gathered as much information as possible on bores drilled in the Georgina Basin area, and the collation of this information has been part of the field parties' normal tasks. Much of the information is in the Bureau's unpublished Records series, some has been published in Explanatory Notes, and Randal's work on the Barkly Tableland is in press. The information is available for inspection at the Bureau of Mineral Resources, Canberra, and records for Queensland are held in the offices of the Irrigation and Water

Supply, Brisbane. The Water Resources Branch of the Northern Territory Administration, Darwin, has records of water bores drilled in the Territory. The information will not be repeated in this Bulletin, which will be confined to a general account of aquifers.

In the eastern area most water bores produce from aquifers in the Lower Cretaceous Longsight Sandstone; in the northern part of the area, most of these bores are sub-artesian, but Casey et. al. (1960, unpubl.) record 40 artesian bores in the Boulia and northern part of the Springvale Sheet areas. Further south where sections are thicker the bores are all artesian. The Longsight Sandstone has usually produced water, but unsuccessful bores have been drilled in areas where the Sandstone pinches out against buried ridges of older rocks; the lack of success has been due either to salty water or to low yields. Other aquifers in cover rocks of the eastern belt have been tapped in the Lower Cretaceous Wilgunya Formation, in Tertiary limestone and in Quaternary gravel. There are few successful bores in the Palaeozoic rocks of this belt. The Middle Cambrian units, and early Upper Cambrian formations, consist of dark limestone and shale which has little or no permeability unless fractured. A few successful bores have tapped cavernous Chatsworth Limestone and Ninmaroo Formation, but always in structurally low positions between buried Precambrian ridges.

There are no artesian bores in the western area. Vuggy and cavernous Middle Cambrian dolomite yields large supplies of water in the northern part of this area, but most of the Middle Cambrian limestone-shale sequences near the Basin margins, and in the southern part of the area, seldom yield water except where they are strongly jointed, as in the case of the Sandover Beds on the south-eastern margin of the Davenport Range. The ground-water potential of the Middle Cambrian dolomites cannot be assessed because (1) the available information on yields is often incomplete, due to either inadequate testing, or the limited capacity of the testing equipment; (2) the water bores are completed when an adequate supply is obtained (generally at less than 500 feet) and the remainder of the sedimentary sequence is untested; (3) the degree of interconnection of these types of aquifers is unknown. An example of the yields from these aquifers is given by Randal (1966, unpubl.) who examined data from about 450 bores on the Barkly Tableland, and reported that more than 75 per cent produced more than 1500 gallons per hour, and most produced more than 1000 gallons per hour. The drilling of BMR 11 (Cattle Creek) Well provided information from depths greater than those normally penetrated in water bores: brief tests by air-lifting gave yields of up to 6000 gallons per hour at 410 feet (after yields of 1500-2000 gallons per hour higher in the well), and the whole sequence was so cavernous, and presumably interconnected, that complete loss of circulation occurred at 900 feet and could not be regained before the base of the Middle Cambrian sequence was reached at 1420 feet. Other wells and core holes in the Barkly Tableland area have also experienced circulation losses.

In the southern part of the western area, very good yields, ranging from 1000-1500 gallons per hour, have been obtained from vuggy and cavernous dolomite of the Meeta Beds and the Arrinthrunga, Ninmaroo and Kelly Creek Formations; sandstone interbeds have also provided good aquifers in the Arrinthrunga and Ninmaroo Formations.

The Upper Cambrian-Lower Ordovician sandstone of the Tomahawk Beds has always proved a good, high-yielding aquifer, and some successful bores have been drilled in the Dulcie Sandstone, but this formation, and the Ordovician Toko Group, usually crop out in topographically inconvenient locations, and they have been seldom drilled. In any case, the lithologies of the Nora Formation and the Mithaka Beds generally do not appeal as aquifers. The Carlo Sandstone has produced good supplies, but the water was too salty for human consumption, although suitable for stock.

The cover rocks of the western area consist of Tertiary Limestone, Quaternary sand, soil, alluvium and gravel, and Mesozoic sandstone, siltstone and conglomerate. The Mesozoic sediments are usually erosion residuals above ground level, and as such they are useless as aquifers, but one pocket of Mesozoic near the north-western end of the Tarlton Range produces 1200 gallons per hour of good water from a depth of 100 feet. Tertiary sediments usually occur above the piezometric surface, but some pockets of limestone produce good supplies of water. Quaternary sequences of sufficient thickness and permeability are rare, but gravels have yielded useful supplies in a few locations.

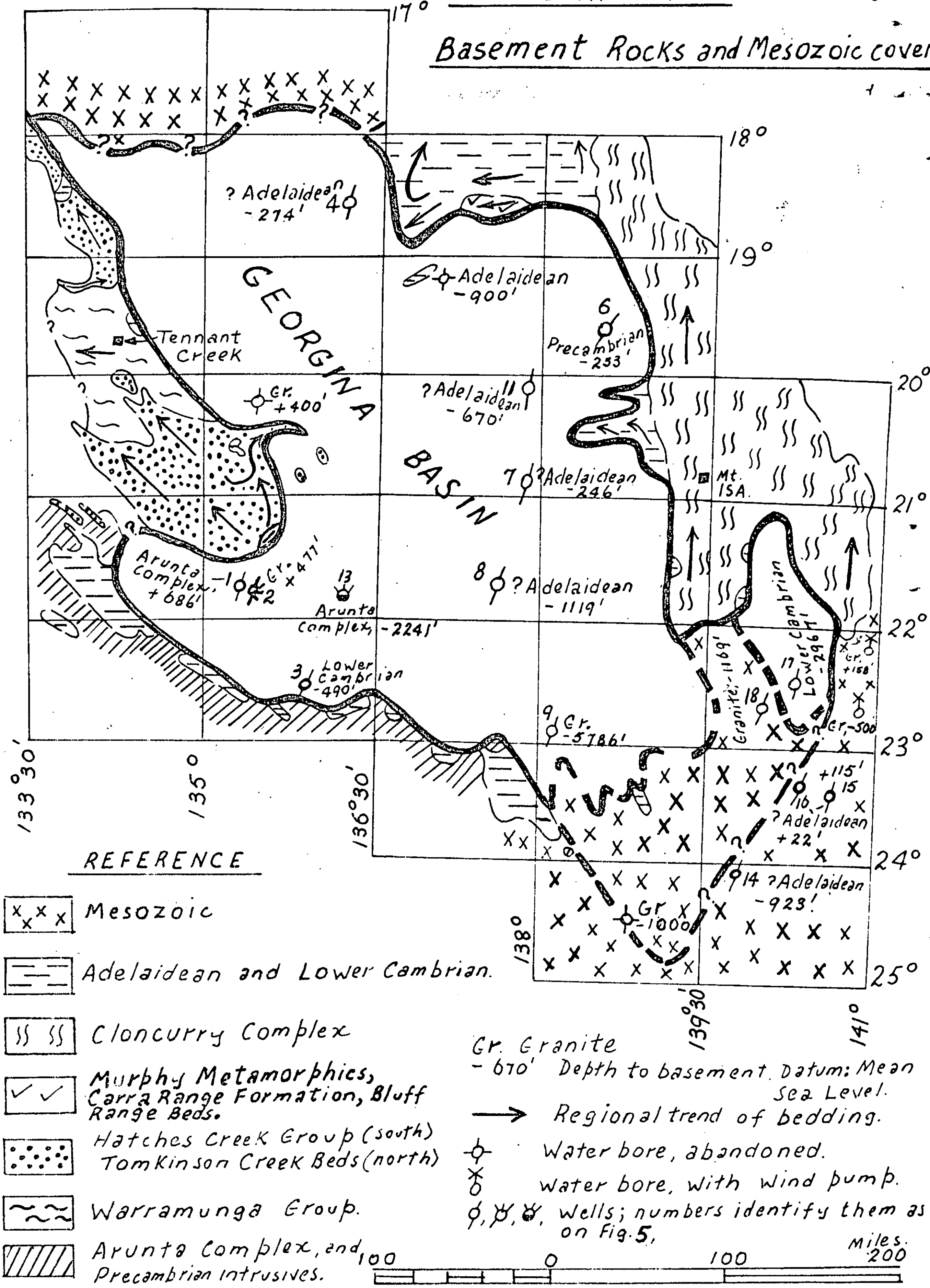
<u>Construction Materials</u>. Adequate supplies of dolomite are available for construction aggregate, but tests for its suitability have not been carried out because the need has not arisen within the Georgina Basin area. For the construction of the Barkly Highway, ferruginous residual soil material of lateritic origin was used; it covers considerable areas astride the Highway and was obtained from several small quarries alongside the road (Carter, Brooks and Walker, 1961, p.248). Similar deposits are used to repair the Highway (Randal and Brown, 1962b, unpubl.). Slabs of Mail Change Limestone and of Camooweal Dolomite have been used in the construction of low bridges on the Barkly Highway, and slabs of dolomite have been used for a variety of purposes, including tank stands, dwelling floors and even the walls of huts, on pastoral properties.

The northern part of the Georgina Basin has an acute lack of sand suitable for construction purposes, because the desert sands contain a prohibitive quantity of silt. The southern part of the Basin generally has adequate supplies of good sand in the beds of wide, dry rivers; some of this sand contains chert shed from Middle Cambrian sediments and local experience indicates that it is often unsuitable for concrete, presumably because cement does not bond well to the smooth surfaces of the chert.

PART II

GEORGINA BASIN — Fig. 21

Basement Rocks and Mesozoic cover



To accompany Records 1967/61

THE BASEMENT ROCKS

In many areas the basement rocks are overlapped by the local basal units of the Georgina Basin succession and in other places Palaeozoic rocks are faulted against basement, which facilitates the mapping of much of the preserved margins of the Basin. Most of the basement rocks are Precambrian, ranging in age from Archaean to Adelaidean, but in some places they include Lower Cambrian sediments which are in continuous sequence with Adelaidean rocks. Geological knowledge of basement rocks under the Basin is sparse, but it is known that the Adelaidean and Lower Cambrian sediments have low magnetic intensities, and the depths to magnetic basement computed from aeromagnetic surveys clearly indicate, by comparison with known Palaeozoic thickness, that several thousands of feet of Adelaidean/Lower Cambrian sediments underlie much of the Basin. These sediments may have some petroleum prospects but they are not highly regarded; therefore in the Georgina Basin economic basement generally lies above magnetic basement.

Fig. 21 shows the distribution of Precambrian and Lower Cambrian rocks around the margins of the Basin, and the geology of the marginal areas is shown in greater detail on Plates 1-4 at 1:500,000 scale. For convenience, each margin is discussed separately, and reference is made where appropriate to known occurrences of basement rocks beneath the Basin.

1. Western and South-western Margins

This part of the margin is mainly in the Northern Territory (Plates 1, 2 and 4). Crystalline rocks of probable Archaean age and two sequences of Lower Proterozoic sediments form most of the marginal rocks in these areas, but several sequences of Adelaidean/Lower Cambrian sediments also crop out, and there are a few outcrops of ?Lower Cambrian volcanics.

(a) The crystalline basement rocks crop out along and near the south-west margin, on the Mount Whelan, Hay River, Tobermory, Huckitta, Alcoota, Barrow Creek and Elkedra Sheet areas. Although the crystalline rocks seldom form the actual outcropping margin they are close to most of the south-west margin. In the Harts Range and its northern foothills (Huckitta Sheet area) outcrop of the crystalline rocks is often rugged, but elsewhere the crystalline rocks crop out in low, isolated peaks and in low ridges and hills. These rocks are included in the Arunta Complex, named by Mawson and Madigan (1930); they have been studied in most detail by Joklik (1955) in the Harts Range, and some units of his Harts Range Group (1955, p. 36) crop out in the south-west part of the Huckitta Sheet area. However, outcrop of the Arunta Complex in the marginal areas is generally poor and discontinuous and Joklik's stratigraphic units cannot be traced confidently outside the Harts Range area.

The Arunta Complex along the margins includes regionally metamorphosed sedimentary and igneous rocks, and a wide range of lithologies has been mapped; gneiss and schist are the commonest, but amphibolite, metaquartzite and marble are locally prominent. Gneiss predominates in the western part of the Huckitta Sheet area, but in all other places schist is more common. The grade of metamorphism is high on the south-west margin, and Morgan (1959, unpubl.) considers that the grade is high in the albite-epidote-amphibolite facies and that local intrusions of granite have superimposed some slight thermal effects on the regional metamorphism. The grade appears to decrease northwards towards the Barrow Creek area, but paucity of outcrop might give an erroneous impression of this.

Regional structure is not apparent in marginal rocks of the Arunta Complex, because of paucity of outcrop and lack of marker horizons. The planes of schistosity are approximately parallel to bedding of former sedimentary rocks; dips usually exceed 60° and are often vertical. The trends, where mappable, are generally west or west-north-west in the south and south-west, but swing towards north in the Barrow Creek area to the north.

The rocks of the Arunta Complex have not been dated, except for some isolated samples which are dated at about 400 my (Hurley, Fisher, Pinson and Fairbairn, 1961); this cannot be the age of the Arunta Complex, and is thought to represent the age of a metamorphism superimposed during a major Palaeozoic orogeny which Forman, Milligan and McCarthy (1967) have named the Alice Springs Orogeny. Therefore the age of the Arunta Complex is assessed roughly by its relationship with other rocks which have been dated. In the Huckitta area, it is intruded by unstressed granites dated by Hurley et al. (1961) using K-A methods, at 1440 m.y., one of these granites has been dated by Wilson, Jeffrey, Compston and Riley (1960) at 1840 m.y., using Rb-Sr methods, and this date is regarded as more reliable. Another line of evidence is available from the Tennant Creek area, where the Arunta Complex underlies the Warramunga Group with a minimum age of 1630 m.y.

The geological history of ?Archaean rocks is unknown, except for intrusion of unstressed granite twice during Lower Proterozoic time (Walpole and Smith, 1961). However, structural data available in the Northern Territory suggests that the last tectonic event before the Proterozoic era was the break-up of crystalline basement rock into polygonal blocks, along remarkably consistent fracture patterns trending north-west and east, with a minor trend northward (Walpole and Smith, 1961, op. cit). This break up, which initiated sedimentation in the Proterozoic era, was caused by tensional stress and it resulted in the upthrow of some blocks and the downthrow of others. Proterozoic sedimentation occurred in conformity with the fracture pattern, and the regularity of the pattern in Proterozoic stratigraphic units probably indicates periodicity in the tensional movements which caused the break-up. This pattern recurred in middle Palaeozoic time, when the major effects of the Alice Springs Orogeny in the Georgina Basin were caused by faults trending north-west.

The Bureau's aeromagnetic survey of the Georgina Basin has revealed buried structural features with a similar north-west trend in some areas, e.g. Sandover River Sheet (Wells and Milsom, 1965, unpubl.).

The subsurface extent of the Arunta Complex beneath the Georgina Basin is unknown, but aeromagnetic patterns attributable to the complex cover large areas of the south-eastern Northern Territory and extend into Queensland. It is unlikely to be basement to the Georgina Basin sediments at many localities because of the wide spread of Adelaidean sediments, but in Farmout-Place Ammaroo No. 1 Well Middle Cambrian sediments rest directly on a garnetiferous schist which the present author places in the Arunta Complex, and the Bureau's stratigraphic well BMR13 (Sandover) penetrated gneiss, at 3304' (Smith, 1967), which is also placed in the Arunta Complex. In this well, the gneiss is overlain by 207 feet of sediments which are tentatively regarded as Lower Cambrian, but may be part of a Middle Cambrian sequence first penetrated at 2235 feet.

(b) Lower Proterozoic sedimentary rocks consist of the Warramunga and Hatches Creek Groups, and the Tomkinson Creek Beds. Together they provide the basement rocks for about 300 miles of the western margin of the Georgina Basin, and are overlapped directly by lower Middle Cambrian sediments.

The Warramunga Group is the oldest Lower Proterozoic unit, and crops out in the Tennant Creek, Bonney Well and Frew River Sheet areas (Plate 1), and probably extends eastwards beneath thin Cambrian sediments for a considerable distance. Ivanac (1954) named the Warramunga Group in the Tennant Creek area, and Noakes (1953) named the Warramunga Geosyncline in which the Group was deposited; the limits of this syncline are unknown. The Group has been studied in most detail in the Tennant Creek area (Ivanac, 1954, op cit., Crohn and Oldershaw, 1964, unpubl., Dunnet, 1965, unpubl.), and Smith, Stewart and Smith (1961) have mapped it in the Bonney Well and Frew River Sheet areas.

The Warramunga Group consists essentially of siltstone, shale, greywacke, and sandstone, with subordinate grit and pebble beds. Graded bedding is common and slump structures are abundant, but there is little cross-bedding and ripple marks are rare (Crohn and Oldershaw, 1964, op cit.). The beds have a strong cleavage trending west, are deeply weathered and tightly folded. These features, together with the general absence of marker beds and the lateral gradation of lithologies has made subdivision of the Warramunga Group difficult. Therefore the Group has not been divided into Formations and the name does not conform to the Code of Stratigraphical Nomenclature although the name has been in common usage for a long period.

The full thickness of the Group has not been determined; Crohn and Oldershaw, 1964 (op cit.) have recorded a thickness of at least 2500 feet north-east of Tennant Creek township, and 3000 feet south-east of it, whilst Dunnet (1965, op cit.) measured 10,000 feet north of the township; none of these sequences is complete.

Folds axes in the Warramunga Group trend west generally, and the folding is often isoclinal. Prominent faults trending north-west cut the group; these faults are probably vertical, with a heave of not less than 5000 feet, and the north-east block is downthrown. Numerous quartz-filled shears trend north-east and north-west, and prominent shears associated with gold mineralisation trend west.

In the Tennant Creek area, ironstone and magnetite bodies in the Warramunga Group are often associated with gold mineralisation, and therefore a considerable amount of magnetic prospecting has been done both on the ground (Daly, 1957) and from the air (Spence, 1962, unpubl.); accordingly, the magnetic behaviour of the Warramunga Group has been studied more than that of any other Precambrian rocks marginal to the Georgina Basin. In the Tennant Creek area magnetite-rich bands in non-outcropping rocks of the Arunta Complex also give rise to magnetic anomalies, and therefore aeromagnetic surveys flown in the Georgina Basin adjacent to the Tennant Creek area (Barkley Oil Company Pty Limited 1965, unpubl.) cannot show conclusively that the Warramunga Group constitutes the shallow magnetic basement revealed by these surveys. However, the magnetic intensity contours in the Warramunga Group in the eastern part of Tennant Creek area (BMR maps G236-12 and G237-14 1962) match well with magnetic intensity contours of Barkley Oil's Alroy-Walhallow Survey in the Alroy Sheet area, and this, together with the strike of the Warramunga Group, and absence of major faulting, indicates that the Warramunga Group extends for some distance east of Tennant Creek. There is no subsurface geological information to support this, and in Frew River Sheet area an unsuccessful water bore confirmed a thin section of Cambrian sediments but the Precambrian basement, at 505 feet, consisted of granite (Smith, 1964b).

The age of the Warramunga Group is regarded as Lower Proterozoic. Hurley et al. (1961, op cit.) determined an age of 1630 m.y. for granite which intrudes the Group about 12 miles south-east of Tennant Creek. This age coincided with the mean age of the older of two groups of granite determined by Hurley et al., but one granite in the younger group has been dated also by Rb-Sr methods and its age of 1840 m.y. (Wilson et al., 1960) was considerably older than Hurley's result of 1440 m.y. Therefore the K-A ages are regarded as probably too young, and the granite at Tennant Creek is more likely to be older than 1800 m.y. Accordingly the Warramunga Group is at present regarded as Lower Proterozoic.

The Hatches Creek Group crops out in the Davenport and Murchison Ranges, where Smith, Stewart and Smith (1961, op cit.) mapped it and reported it lying unconformably on the Warramunga Group. The Group also crops out in the Crawford and Osborne Ranges (Barrow Creek Sheet area), where it rests unconformably on the Arunta Complex (Smith and Milligan, 1964).

Hossfeld (1954) named the Hatches Creek Group in the area near Hatches Creek Wolfram Field (Frew River Sheet area) but did not define any of its constituent formations. Smith, Stewart and Smith (1961) traced the Group throughout the Davenport and Murchison Ranges, and modified Hossfeld's definition slightly to include sediments, at the base of the sequence, which Hossfeld had separated from the Group. However, the definition of constituent formations was outside the scope of the survey of Smith et al., and the name "Hatches Creek Group" does not conform to the Australian Code of Stratigraphical Nomenclature. The name has been in common usage for many years and its retention has been allowed.

The Hatches Creek group occurs in the Davenport Geosyncline (Walpole and Smith, 1961) which contains at least 20,000 feet of mixed geosynclinal sediments, with both basic and acid lava flows. The sediments of the Crawford and Osborne Ranges are not marginal to the Georgina Basin as at present known, and are not considered here. The Davenport and Murchison Ranges are prominent topographic features, consisting of long strike ridges of steeply dipping, silicified psammites, separated by wide flat valleys underlain by softer psammites and pelites. Here the Hatches Creek Group consists of thin to medium-bedded, medium and coarse-grained, ripple-marked, cross-bedded, pink grey and brown silicified sandstone, silty sandstone and greywacke and some orthoquartzite with siltstone, shale and basic and acid lavas. The Group has not been metamorphosed except for some thermal metamorphism near intrusive bodies, and some dynamic metamorphism in fault zones where pelites have been converted to mica schist, and psammites to quartz schist.

The Hatches Creek Group has been strongly folded and faulted, and intruded by basic rocks, porphyry and granite during a Precambrian orogeny. The fold axes trend north-west for most of the Davenport-Murchison Range area, but east of Hatches Creek settlement the axes trend north-east. The folds comprise anticlines and synclines, domes and basins, and some of the synclines are about 60 miles long. Two major fault trends have been developed, one north-west and the other north-east.

The extent of the Hatches Creek Group beneath the Georgina Basin is unknown. The geological evidence is confined to the results from Farmout-Place Ammaroo No. 1 Well (Farmout Drillers, N.L., 1963, unpubl.) and the Bureau's BMR13 (Sandover) Well, where the basement rocks belonged to the Arunta Complex, in each case, and no sediments of the Hatches Creek Group were encountered.

These results, coupled with the small outcrops of the Arunta Complex about 35 miles north-east of Ammaroo homestead (Plate 3) might indicate that the Hatches Creek Group does not extend far to the south-east from the margins of the Davenport Range. However, Wells, Milsom and Tipper (1966, unpubl.) attribute the magnetic patterns in the south-eastern part of the Elkedra Sheet area to the Hatches Creek Group, and they also consider that rocks of this Group probably constitute magnetic basement at shallow depths over the whole of the Frew River Sheet area and the western part of the Avon Downs Sheet area.

The Tomkinson Creek Beds form most of the western margin north of Tennant Creek, and crop out prominently in the Ashburton Range. This stratigraphic unit was formerly known as the Ashburton Sandstone (Noakes and Traves, 1954; Ivanac, 1954; Crohn and Oldershaw, 1964 unpubl.), but the unit was never formally named, and some nomenclatural confusion existed with the Ashburton Beds in Western Australia. Accordingly, Randal, Brown and Doutch (1966, unpubl.) re-named the unit the Tomkinson Creek Beds, pending later division into formations and perhaps groups. Mapping of the Tomkinson Creek Beds is incomplete; Ivanac (1954) mapped part of the unit on the Tennant Creek Sheet area, and Randal, Brown and Doutch (1966 unpubl.) mapped the unit on the Helen Springs and Beetaloo Sheet areas.

The relationship between the Tomkinson Creek Beds and the underlying Warramunga Group is not clear; Ivanac (1954) considered that the Warramunga Group graded upwards into the (now) Tomkinson Creek Beds, and Crohn and Oldershaw (1964, unpubl.) supported this view, but stated that on the basis of regional structure an unconformity probably separates the two units. Randal et al. (1966, op cit.) mapped part of the Tomkinson Creek Beds which are stratigraphically well above the base, and therefore had no opportunity of adding to knowledge of the basal contacts. The present author, on the basis of regional geology, and the lithological similarities between the Hatches Creek Group and the Tomkinson Creek Beds, believes that a regional unconformity separates the Warramunga Group and the Tomkinson Creek Beds.

The Tomkinson Creek Beds crop out in strike ridges. Their southern outcrops, about 25 miles north of Tennant Creek, strike west, and the strike swings to north just east of the Stuart Highway and the beds crop out almost continuously to Newcastle Waters. They consist of fine, medium and coarse-grained ripple marked, cross-bedded quartz sandstone, siltstone and dolomite with minor pebble conglomerate (Randal et al., 1966 op cit.); Ivanac (1954) reported interbedded basic lavas in the Tennant Creek area, and he also estimated the total thickness in this area as 11,000 feet. In the section examined (only part of the outcrop) Randal et al. (1966 op cit.) estimate a thickness of 40,000 feet. The full thickness is unknown.

The Tomkinson Creek Beds have been strongly folded and faulted. The Beds are intruded by porphyry at a locality about 27 miles north of Tennant Creek, but no intrusions of granite are known.

Because of lithological and structural similarities to the Hatches Creek Group the Tomkinson Creek Beds are here regarded as being of the same age, but the nature of the contact with the Warramunga Group has not been resolved.

The eastern extent of the Tomkinson Creek Beds beneath the Georgina Basin area is unknown; complete aeromagnetic coverage is lacking on the Helen Springs Sheet area, and no subsurface geological information is available except from a few water bores near the eastern margin of the Beds.

(c) Precambrian Intrusive Rocks. Numerous bodies of Precambrian igenous rocks intrude the Arunta Complex and Lower Proterozoic sedimentary rocks near the south-western and western margins of the Georgina Basin, and in a few instances, both in the surface and subsurface, form basement to the Georgina Basin succession. The igneous rocks do not intrude Adelaidean and Lower Cambrian sediments.

Granite intrusions are common along the south-western and western margins, and porphyry and basic intrusions are numerous in the Tennant Creek-Davenport Range area. Many of the granite bodies have been named, and their names and descriptions are given on the published 1:250,000 Sheets and their accompanying Explanatory Notes, but these names have been deleted on the 1:500,000 Sheets. All of the granites shown along the western and south-western margins on Plates 1, 3 and 4 are believed to be of Precambrian and pre-Adelaidean age. Hurley et al. (1961,op cit.) used the K-A/ratio method to date eleven of these granites, during a programme of dating many intrusive granites from the Northern Territory. The results showed that the ages fell into two well-defined groups, one with an average age of 1630 m.y. and the other with an average of 1440 m.y. One granite, 12 miles south-east of Tennant Creek township, is included in the older group, and the others are in the second group. However, Wilson et al. (1960, op cit.) used Rb-Sr methods to obtain a date of 1840 m.y. for a granite in the Huckitta Sheet area which Hurley's results showed to be 1440 m.y. old. Therefore the age of the granites is in some doubt; the Rb-Sr age is regarded as more reliable, and all may be considerably older than Hurley's results indicated.

Porphyry intrusions are common in the Davenport Range-Tennant Creek area, and one intrusion into the Ashburton Sandstone has been noted. Basic intrusive rocks are also common in the Arunta Complex, and in the Hatches Creek and Warramunga Groups.

Smith, Stewart and Smith (1961, op cit.), established the order of intrusion in the Davenport Range as firstly basic rocks, then porphyry and lastly granite. Elsewhere the rocks are not in juxta-position. The extent of these igneous bodies under the Georgina Basin is unknown, and on aero-magnetic profiles the disturbed patterns of these rocks may not be distinguished easily from the patterns of the Arunta Complex. However, Wells and Milsom (1965, unpubl.) interpret some sharp peaks on the north-eastern Sandover River Sheet as basic dykes at shallow depth. Granite has been recorded in Ammaroo No. 2, BMR13 (Sandover) and Netting Fence No. 1 Wells and in a water bore on Epenarra Station (Frew River Sheet area), all near the Basin margins, and also at Kamaran Downs No. 3 water bore, which probably marks the western margin of the south-eastern extension of the basin.

(d) ?Adelaidean

The Rising Sun Conglomerate, named by Ivanac (1954, op cit.), crops out in small areas about 15 miles south-east of Tennant Creek township. The unit rests unconformably on the Warramunga Group and on Precambrian porphyry (Crohn and Oldershaw, 1964, unpubl.). The sequence is about 200 feet thick and consists of boulder conglomerate, grit and quartzite in the lower part, succeeded by sandstone, siltstone and mudstone. The thickness decreases from east to west, and the diameter of long axes of pebbles, cobbles and boulders also decrease from east to west, indicating a source in the east. The sequence has been faulted and folded.

There is little evidence of age of the Rising Sun Conglomerate; lithology and structural deformation are akin to those of the Hatches Creek Group and the Tomkinson Creek Beds, but it cannot be a remnant of either of these units unless the underlying porphyry is much older than the porphyries which intrude the two Lower Proterozoic units (at present all porphyries are assumed to be of the same general age). At present the age of the Rising Sun Conglomerate is referred to ?Adelaidean.

The possible extent of the Rising Sun Conglomerate beneath the Georgina Basin is unknown.

(e) Adelaidean and Lower Cambrian. Rocks of these ages crop out in many places along the south-western and western margins; they are mostly unmetamorphosed sediments, but they include some volcanics in the west. The Bureau's aeromagnetic results together with drilling results indicate that Adelaidean-Lower Cambrian sediments probably form thick sequences beneath Middle Cambrian rocks in much of the Georgina Basin.

The stratigraphy of the Adelaidean-Lower Cambrian rocks around all margins of the Georgina Basin is shown on Table 7, and Table 8 gives the stratigraphy on the western and south-western margins, where the oldest sediments are glacial sequences - the Field River Beds and the Mount Cornish Formation.

The Field River Beds are the oldest and thickest of the outcropping Adelaidean sequences. Smith (1963a) named the Beds in the Field River area of the Northern Territory, where they crop out in the north-eastern quadrant of

TABLE 7: STRATIGRAPHY OF ADELAIDEAN AND LOWER CAMBRIAN SEQUENCES ALONG MARGINS OF THE GEORGINA BASIN

Age	Rock Unit	Map Symbol	Lithology	Thickness (feet)	Fossils	Stratigraphic Relationship	Distribution: South-west	West	North	East	Principal References
Lower Cambrian?	Helen Springs Volcanics	Ꞓlh	Amygdaloidal basalt, tuff, agglomerate and rhyolite. Strongly weathered.	50+	-	Unconformably overlies Ashburton Sandstone and Warramunga Group	-	Helen Springs Tennant Creek.	-	-	Noakes and Traves (1954).
Lower Cambrian ?	Makbat Sandstone		Sandstone, with yellow flaggy siltstone near top. Minor brown shale, and conglomerate.	1000		Unconformable on Cloncurry Complex.				Duchess, Boulia	Carter, Brooks and Walker (1961).
Lower Cambrian ?	Mount Birnie Beds	Ꞓli	Conglomerate, sandstone, green shale, arkose.	250	*Diploeraterion*; *Crossochorda*	Rests unconformably on basement; overlain by Middle Cambrian sediments.	-	-	-	Duchess	Opik, 1960.
Adelaidean?	Sylvester Sandstone	Buy	Quartz sandstone.	2000?		Conformable on Sun Hill Arkose.				Mount Whelan	Casey, 1959.
Adelaidean?	Sun Hill Arkose	Buh	Arkose, green shale, pebble conglomerate, arkosic dolomite.	1000+	*Protichnites*		-	-	-	Mount Whelan	Casey, 1959.
Lower Cambrian ?	Riversdale Formation	Ꞓlr	Red sandstone, red conglomerate, red and purple dolomite.	10-100	-	Unconformable on Lower Proterozoic of Cloncurry Complex; overlain disconformably by Middle Cambrian sequence.	-	-	-	Urandangi (Ardmore Outlier). Glenormiston.	Noakes, Carter and Opik, 1959.
Lower Cambrian	Mount Baldwin Formation	Ꞓlb	Red quartz sandstone, red siltstone, red greywacke, red and yellow dolomite.	1400	*Archaeocyathids*, brachiopods	Conformable on Grant Bluff Formation; ?disconformable.	Huckitta	-	-	-	Smith 1964a.
Lower Cambrian to Adelaidean	Grant Bluff Formation	B-Ꞓg	Glauconitic grey quartz sandstone, red, green, blue shale, brown dolomite.	200-1900	Algae; *Helcionella* near Barrow Creek	Conformable on Elyuah Formation, conformable on Field River Beds.	Barrow Creek, Alcoota, Huckitta, Tobermory	-	-	-	"
Adelaidean	Elyuah Formation	Bue	Red and green shale; arkose	100-3500	-	Unconformable on Archaean.	Hay River				
						Disconformable on Mount Cornish Formation.	Huckitta	-	-	-	"
	Mount Cornish Formation	Buc	Boulder beds, cyclic siltstone and fine sandstone, arkose, dolomite. One ground moraine.	40-1200		Unconformable on Arunta Complex and on granite.	Huckitta	-	-	-	"
Adelaidean	Field River Beds	Buf	Boulder beds, cyclic siltstone and fine sandstone, green siltstone and tillitic texture, arkose, dolomite, red siltstone, limestone, quartz sandstone.	6000	-	Base not exposed, overlain by Grant Bluff Formation, and unconformably by Middle Cambrian sediments.	Tobermory, Hay River Mount Whelan				Smith 1963a.

Age		Rock Unit	Map Symbol	Lithology	Thickness (feet)	Fossils	Stratigraphic Relationship	Distribution: South-west	Distribution: West	Distribution: North	Distribution: East	Principal References
Adelaid-ean		Central Mount Stuart Beds	Bus	Red arkose, greywacke, sandstone, siltstone, dolomite; grey quartz sandstone.	100-1500				Alcoota, Barrow Creek			Smith and Milligan, 1964.
Adelaid-ean?		Colless Volcanics	Buo	Vesicular basalt, some intermediate lavas.	200?		Unconformably overlies the Mullera Formation; overlain unconformably by Middle Cambrian sediments.			Lawn Hill		Carter, Brooks and Walker, 1961.
Adelaid-ean	SOUTH NICHOLSON GROUP	Mittiebah Sandstone	Bsi	Quartz sandstone, glauconite sandstone, some pebble and cobble conglomerate.	9000+	-	Conformably overlies the Mullera Formation.			Mount Drummond, Ranken, Brunette Downs		Smith and Roberts, 1963.
Adelaid-ean	SOUTH NICHOLSON GROUP	Mullera Formation	Bsl	Siltstone, shale, sandstone.	1250-8000		Conformable on the Constance Sandstone.			Lawn Hill, Mount Drummond		Carter, Brooks and Walker, 1961; Smith and Roberts, 1963.
Adelaid-ean	SOUTH NICHOLSON GROUP	Constance Sandstone	Bsa	Quartz sandstone, pebbly sandstone, siltstone.	1000-5500		Disconformable on Carpentarian sediments.			Lawn Hill, Mount Drummond.		Carter, Brooks and Walker, 1961; Smith and Roberts, 1963.
Adelaid-ean?		Pilpah Sandstone	Bui	Sandstone; some pebble conglomerate.	1000		Unconformable on the Cloncurry Complex; overlain unconformably by Middle Cambrian sediments.				Mount Isa, Camooweal	Carter, Brooks and Walker, 1961.

the Hay River Sheet area. They extend north-west to the Tarlton Range area, and eastwards under the Toko Syncline and beyond, in the south-eastern extension of the Georgina Basin. The basal unit of the Field River Beds forms low, rounded hills, but units higher in the sequence form prominent strike ridges, which are separated by valleys underlain by poorly outcropping pelites and carbonate rocks. The full thickness of the Field River Beds is at least 6000 feet, but only about 60 per cent of this can be measured; in the north-eastern part of the Hay River Sheet area Smith (1963a) recorded the following sequence (in descending order):

Thickness (feet)	
	Grant Bluff Formation conformably overlying
565	quartz greywacke, grey and red, coarse-grained; arkose, brown, coarse-grained, cross-bedded, pebbly; siltstone, red, thin-bedded, dolomitic in part; dolomite, red, thin-bedded; concealed interval.
730	dolomite, yellow and grey, thin and medium-bedded, with thin interbeds of siltstone, yellow, dolomitic; Concealed interval.
250	arkose, brown, pebbly, medium to coarse-grained, micaceous.
240	shale, green; arkose, green, dolomitic, and dolomite, yellow and brown, medium-bedded; Concealed interval.
1775	siltstone, green, with "tillitic" texture; boulder beds; siltstone, green, hard, laminated, with lenses of sandstone, grey, purple, medium-grained;
Total 3560, whose base is not exposed.	

In this sequence, an estimated total of 2500 feet is concealed. The type of contact between successive units is not clear because of poor exposure in most localities. The basal unit of the Field River Beds is considered to be of glacial origin, because of the numerous bands and lenses of boulder beds in it; boulders, up to 4 feet in diameter, of gneiss, schist, meta-quartzite, orthoquartzite, granite, porphyry and algal dolomite are abundant, and many are faceted whilst some are striated and polished. The boulder beds are roughly stratified, with a matrix of green siltstone with "tillitic" texture, but no indubitable ground moraine is known, and no glaciated pavement has been observed on basement surfaces. Some boulders are contained in arkose units higher in the Field River Beds and may represent a second period of glaciation, but this is unproven.

In the south-eastern part of the Tobermory Sheet area, the top half, approximately, of the Field River Beds is missing and lower Middle Cambrian sediments unconformably overlie various stratigraphic levels of the Beds. Evidence of angular discordance in this area is not available, because of the masking effects of post-Devonian tectonics, but in the Hay River Sheet area horizontal lower Middle Cambrian sediments overlie steeply-dipping Field River Beds, and these contacts provide good evidence of tectonism in this area, probably in late Adelaidean time. Details of this tectonism are masked by later tectonic events during the Palaeozoic, but it is probable that faulting along north-west and west trends resulted in the formation of horsts and grabens, with the main part of the Field River Beds preserved in down-thrown blocks.

Sandstone sequences at Mount Knuckey and Mount Gardiner, in the Hay River Sheet area, are tentatively included in the Field River Beds. About 3500 feet are exposed at Mount Knuckey, and about 800 feet at Mount Gardiner.

The Field River Beds are correlated with the Areyonga Formation (Prichard and Quinlan, 1962) of the Amadeus Basin. This is a glacial sequence which disconformably overlies the Bitter Springs Formation.

The <u>Mount Cornish Formation</u> has been named from Mount Cornish (latitude 22°46'S, longitude 136°29'E, approximately) in the Huckitta Sheet area (Smith, 1964a). It crops out in a few localities at Mount Cornish, and in the Jervois, Elyuah and Mopunga Ranges. It is also regarded as a glacial sequence, but is correlated with the Olympic Member of the Pertatataka Formation (Wells et al., 1967) which is a glacial sequence in the Amadeus Basin, younger than the Areyonga Formation.

TABLE 8: DISTRIBUTION AND THICKNESS OF SOME ADELAIDEAN/LOWER CAMBRIAN SEDIMENTS, SOUTH-WESTERN AND WESTERN MARGINS OF THE GEORGINA BASIN

Unit	Barrow Creek	Alcoota	Huckitta			Tobermory		Hay River		
			Mopunga Range	Elyuah Range	Jervois Range	Keepera Ridges	South East	Mount Winnecke	Mount Barrington	Mount Woods - Queensland Border
Mount Baldwin Formation	Not present	Not present	600	1400	1200	Not present	Not present	Not present	Not present	Not present
Grant Bluff Formation	300	1000	420	530	530-680	1500	" "	1900	530	1500
Elyuah Formation	Not recognised; probably equivalent to part of the Central Mount Stuart Beds	Not recognised; probably equivalent to part of the Central Mount Stuart Beds	300-3600	100-630	450	Not present; may be equivalent to top part of the Field River Beds	Not present	Not present	Not present	Not present
Mount Cornish Formation	Not present	Not present	150	40-110	80	-	-			
Field River Beds	" "	" "	-	-	-	960	2200	Not present	Not present	?6000
Central Mount Stuart Beds	240-800	?1000	-	-	-	-	-	-	-	-

Note: The Central Mount Stuart Beds are not shown in strict order of superposition; they are probably time-equivalents of the Mount Cornish Formation and Elyuah Formation, and also of the Upper part of the Field River Beds.

The Mount Cornish Formation consists of blue green siltstone with "tillitic" texture containing boulders, cobbles and pebbles; laminated cyclic siltstone and sandstone, and minor dolomitic arkose and quartz greywacke. The formation rests unconformably on the Arunta Complex and on granite which intrudes the Complex, and is overlain disconformably by the Elyuah Formation.

The boulders in the Mount Cornish Formation consist of gneiss, schist, granite, metaquartzite, porphyry and dolomite. They are well-rounded, wedge-shaped, pyramidal and kidney-shaped, polished, and some are striated. No glaciated pavement on older rocks has been seen, but Condon (1958, unpubl.) has recorded one ground moraine in the north-eastern end of the Elyuah Range, where 10 feet of unstratified boulder clay contains boulders and cobbles of granite, and cobbles and pebbles of quartz and metaquartzite.

The thickness of the Mount Cornish Formation is 1200 feet in the type section at Mount Cornish, but elsewhere it ranges from 40-110 feet.

The subsurface extent of the Field River Beds and the Mount Cornish Formation beneath the Georgina Basin is unknown, but Adelaidean glaciation was widespread in the southern part of the Northern Territory and remnants of either the older or the younger units may be expected in many places. However, neither has been identified in wells drilled in the Northern Territory, but the older unit was probably widespread in Queensland (p. 88).

The Mopunga Group, named by Noakes (1956) and modified by Smith (1964a) consists of the Elyuah, Grant Bluff and Mount Baldwin Formations. The Group is complete only in the Huckitta Sheet area, but the resistant Grant Bluff Formation is widespread and extends intermittently from near Barrow Creek settlement south-eastwards almost to the Queensland border at about latitude 23°S. Table 8 shows the distribution and thickness of the Group in various Sheet areas of the western and south-western margins of the Georgina Basin, and gives similar information for units or parts of them which may be equivalent to the Elyuah Formation - the oldest unit of the Mopunga Group.

The Elyuah Formation consists of a basal arkose unit (locally called the Ocrabra Arkose Member in the Elyuah Range) and a younger shale unit. The arkose rests disconformably on the Mount Cornish Formation, and unconformably on the Arunta Complex and on Precambrian granite. The considerable variation in thickness of the Elyuah Formation is due to thickness changes in the arkose member. The shale member is usually about 350 feet thick when the full sequence is present.

The Grant Bluff Formation succeeds the Elyuah Formation conformably and gradationally in the Huckitta Sheet area; in the Hay River and Tobermory Sheet areas it conformably overlies the Field River Beds, and it conformably overlies the Central Mount Stuart Beds near Barrow Creek settlement. The type section is at latitude 22°44'S, 135°40'E, approximately, in the Elyuah Range (Smith, 1964a), where it is 530 feet thick. The Formation consists predominantly of grey, fine to medium-grained, thin-bedded, glauconitic quartz sandstone and sandy siltstone, with minor coarse-grained feldspathic sandstone, and siltstone, shale and thin algal dolomite beds. Worm trails are abundant, but the only fossil found in the formation is a Lower Cambrian *Helcionella* (Smith and Milligan, 1964) near Barrow Creek settlement. In the Huckitta Sheet area the Grant Bluff Formation underlies the fossiliferous Lower Cambrian Mount Baldwin Formation, and is generally regarded as late Adelaidean in age, but the diachronous nature of the unit is well illustrated in the Barrow Creek Sheet area, and it is probable that some of the additional section evident in the Tobermory and Hay River Sheet areas is also of Lower Cambrian age.

The Mount Baldwin Formation conformably overlies the Grant Bluff Formation, and is overlain, probably disconformably, by a basal lower Middle Cambrian unit (the Arthur Creek Beds) of the Georgina Basin succession. The type section of the formation is in the Elyuah Range and is a continuation of the type section of the Grant Bluff Formation (Smith, 1964a).

The Mount Baldwin Formation consists predominantly of dark red sediments - glauconitic sandstone, siltstone, shale, and greywacke, with minor pink and grey sandstone, and brown and yellow dolomite. Near the top of the formation, beds of dolomite contain archaeocyathids and brachiopods of Lower Cambrian age (Opik and Tomlinson, pers. comm.), but the position of these fossils in the Lower Cambrian time scale has not been determined.

There is no evidence in the Huckitta and western part of the Tobermory Sheet areas that sediments of the Mopunga Group have been deformed tectonically at the same time as were the Field River Beds and Grant Bluff Formation in the

Hay River - south-eastern Tobermory Sheet areas.

The extent of the Mopunga Group beneath the Georgina Basin is unknown. Several wells in the Northern Territory - BMR13, Mulga No. 1, Lake Nash No. 1 and BMR11 terminated in red sediments beneath lower Middle Cambrian units, but only one well (BMR13) contained fossils; however, these fossils have not been determined.

The Central Mount Stuart Beds (named by Smith and Milligan, 1964) crop out in a belt extending from the Sandover River (Alcoota Sheet area) north-west almost to Barrow Creek settlement, and some beds in the unit crop out in the south-western part of the Barrow Creek Sheet area. The sediments are dominantly red - arkose, greywacke, siltstone, dolomitic siltstone - mostly strongly cross-bedded, and some are ripple-marked. They include boulder beds near the local base in the north-western part of the Alcoota Sheet area, and the author has observed probable varves near the base of Central Mount Stuart (outside the mapped area, a few miles south-west of 22°S, 133°30'E), and therefore a glacial origin for the lower part of the Central Mount Stuart Beds is indicated.

The Central Mount Stuart Beds unconformably overlie the Arunta Complex and Precambrian intrusive rocks, and are overlain conformably by the Grant Bluff Formation near Barrow Creek settlement. The thickness of the Beds is variable, depending in part on the basement configuration; it ranges from 240 to 450 feet south of Barrow Creek settlement, but increases south-eastwards, on the Alcoota Sheet area, to about 1000 feet.

The Central Mount Stuart Beds dip generally at low angles to the south-west, away from the Georgina Basin; however, the exposures may be on the upthrown side of a major fault trending north-west, and therefore they could form basement to the Georgina Basin north-east of the postulated fault, but there is no subsurface evidence to support or negate their presence there.

The Helen Springs Volcanics, named by Noakes and Traves (1954), crop out in small areas of the Tennant Creek Sheet area (Ivanac, 1954; Crohn and Oldershaw, 1964, unpubl.) as well as in the Helen Springs Sheet area where Randal, Brown and Doutch (1966, unpubl.) have mapped them on a regional scale. They consist of deeply weathered amygdaloidal basalt, tuff, agglomerate and rhyolite, and include thin sandstone and siltstone interbeds in the Helen

Springs Sheet area. The maximum thickness in the Tennant Creek area is 50 feet, and in the Helen Springs area 120 feet.

The Volcanics unconformably overlie both the Warramunga Group and the Tomkinson Creek Beds, and are overlain unconformably by the Middle Cambrian Gum Ridge Formation. The Lower Cambrian age of the Volcanics has not been proven by radioactive dating methods.

(2) The North-Western Margin. No Precambrian or Lower Cambrian rocks crop out along this margin, which is tentatively drawn on a boundary between Mesozoic and Cambrian sediments.

(3) The Northern Margin. For the purposes of this report, the northern margin of the Georgina Basin is considered to extend from a locality about 18°S and 10m west of longitude 136°30'E in the Northern Territory, to about 18°30'S and longitude 138°30'E approximately in Queensland. The margin is defined thus for convenience in stratigraphy, and is in fact mostly the southern margin of the South Nicholson Basin (G.S.A. 1962, Smith and Roberts, 1963) which contains a thick sequence of Adelaidean rocks named the South Nicholson Group. Older rocks, which unconformably underlie the South Nicholson Group also form part of the Georgina Basin margin. These Precambrian rocks are sometimes overlapped by the Georgina Basin sediments, but in places about 8 miles of sand separates the Precambrian from Cambrian outcrops and/or pedocalcic soils which indicate Cambrian sediments at shallow depth.

The oldest Precambrian rocks, which form basement to the South Nicholson Group, are Lower Proterozoic in age and these are succeeded by Carpentarian rocks. They have not been differentiated on Plate 2, but Smith and Roberts (1963) have described and named several units in the Mount Drummond Sheet area, and of these the Murphy Metamorphics, Carrara Range Formation and Bluff Range Beds are either in contact, or near contact, with Georgina Basin sediments. A summary description of these units is given in Table 9 which is an extract of pertinent parts of Smith and Roberts' (1963, op cit.) Table 1, facing p. 6 of their publication, with alterations to Carpentarian age on the advice of Roberts (pers. comm.).

The Nicholson Granite, which intrudes the Murphy Metamorphics has been dated by K-Ar methods at 1815 m.y. (McDougall, Dunn, Compston, Webb, Richards

TABLE 9

STRATIGRAPHY OF LOWER PROTEROZOIC AND CARPENTARIAN ON THE NORTHERN MARGIN OF THE GEORGINA BASIN, (AFTER SMITH & ROBERTS, 1963, TABLE 1)

Period	Rock Unit	Known Maximum Thickness in feet	Lithology	Structure
			UNCONFORMITY	
Carpentarian	Bluff Range Beds	9000	Quartz sandstone, dolomitic sandstone, limestone, dolomite, siltstone, shale, dolomitic siltstone.	Dips generally N, 0-80°. Strongly strike-faulted.
Carpentarian	Carrara Range Formation	7650	Porphyritic rhyolite, trachyte, vesicular basalt, trachyte tuff, agglomerate, conglomerate quartz sandstone, minor shale.	Dips generally N, 0-80°. Very strongly faulted (mainly strike faults).
			UNCONFORMITY	
Lower Proterozoic	Murphy Metamorphics	?	Quartz-sericite schist, sheared siltstone, greywacke, ashstone, intermediate feldspar porphyry, minor sheared calcareous siltstone, metamorphosed ashstone; ?monzonite.	Near-vertical dips.

and Bofinger, 1965) and this indicates the Lower Proterozoic age of the metamorphics.

The extent of the Lower Proterozoic and Carpentarian rocks under the Georgina Basin is unknown. In general, the Carpentarian rocks dip away from the Basin margin, but Wells, Tipper and Milsom (1964, unpubl.) ascribe some magnetic anomalies in the western part of the Mount Drummond Sheet area to the Murphy Metamorphics. Several anomalies in the Carrara Range area are associated with fault zones, but the sources of the anomalies could not be related to any geological horizon. The Murphy Metamorphics may extend eastwards into Queensland, but if so the aeromagnetic results on the Lawn Hill and Camooweal Sheet areas indicate that this would be at a considerable depth, and far too deep to be basement to the Georgina Basin.

The South Nicholson Group, named by Smith and Roberts (1963 op cit.) consists of four formations of Adelaidean age - the Maloney Formation, Constance Sandstone, Mullera Formation and Mittiebah Sandstone. The Maloney Formation is a local facies variation of the Constance Sandstone (Smith and Roberts, 1963, op cit.) and for convenience it has been included with the Constance Sandstone on Plate 2 of this Bulletin.

Carter et al. (1961, op cit.; p. 117, 119) named the Constance Sandstone from the Constance Range area (Lawn Hill Sheet). The type section is at 18°27'35"S, 138°17'00"E. The unit borders the Georgina Basin for 90 miles and extends westward into the Northern Territory where Smith and Roberts mapped it on the Mount Drummond Sheet area. The unit consists mainly of medium-grained, cross-bedded, ripple-marked quartz sandstone, with extensive pebble beds and some siltstone lenses. Carter et al. (1961) recorded thicknesses ranging from 1000 to 3600 feet, and Smith and Roberts (1963 op cit.) recorded a maximum thickness of 5500 feet in the south-western part of the South Nicholson Basin. The Constance Sandstone has been gently folded into basins and domes, where dips exceeding 40° are rare except near faults. The Formation has been extensively faulted, and some Precambrian faults, notably the Mitchiebo Fault and Little Range Fault, have been reactivated and have affected Cambrian sediments of the Georgina Basin.

The Mullera Formation has been named by Carter et al. (1961) in the Lawn Hill Sheet area of Queensland, and it extends into the Northern Territory across the central part of the Mount Drummond Sheet area. The Mullera Formation conformably overlies the Constance Sandstone, and is conformably overlain by the Mittiebah Sandstone in the western outcrop area, and unconformably overlain by Cambrian sediments of the Georgina Basin in both Queensland and the Northern Territory.

The Mullera Formation is dominantly thin-bedded, micaceous, pink and white siltstone, shale and fine-grained sandstone. Elsewhere, north of the margin, the formation contains extensive sedimentary oolitic ironstone, (mainly hematite, siderite and chamosite) and glauconitic sandstone. Carter et al., (1961 op cit.) report that the thickness of the Mullera Formation in north-west Queensland ranges from 3600 to 7000 feet, and Smith and Roberts (1963) state that the thickness in the Northern Territory ranges from 1250 feet to 8000 feet, and the formation thins northwards. Folding and faulting in the Mullera Formation is similar to that of the Constance Sandstone. McDougall et al. (1965 op cit.) report a K-Ar date of 1040 m.y., and a Rb-Sr date of 1160 m.y., from glauconite of the Mullera Formation. The older date is considered the more reliable, and on this basis the whole of the South Nicholson Group is considered to be of Adelaidean age.

The <u>Mittiebah Sandstone</u> crops out only in the Northern Territory, along the western exposed margin of the South Nicholson Basin in the Mount Drummond, Ranken and Brunette Downs Sheet areas; its westernmost outcrop is about 10 miles west of longitude 136°30', at roughly latitude 18°S. Smith and Roberts (1963 op cit.) named the formation in the Mittiebah Range, where an incomplete section of the sandstone is about 9000 feet thick; these authors believe that the unit thins northwards. The Mittiebah Sandstone usually consists of fine to medium-grained, cross-bedded quartz sandstone, with some glauconitic sandstone near the base, and lenses of pebble and boulder conglomerate. Randal and Brown (1962a, unpubl.) report poor outcrops in the Ranken Sheet area.

The extent of the South Nicholson Group beneath the Georgina Basin is unknown. Alexandria No. 1 Bore (latitude 19°03'S, longitude 136°47'E) terminated at 1760 feet in sandstone which Randal and Brown (1962a, unpubl.) interpret as the Mittiebah Sandstone, after passing through a carbonate sequence (Cambrian) from surface to the top of the sandstone at 1750 feet.

Brunette Downs No. 1 Well (Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.), 10 miles north-east of Brunette Downs homestead (Plate 1), drilled through Cambrian sediments to 1050 feet, then penetrated sandstone to 1410 feet, and a siltstone sequence from 1410 to T.D. at 2060 feet. From the siltstone sequence Evans (B.M.R., pers. comm.) has obtained Hystericophirids which are identical with those from outcrop samples of the Mullera Formation, and therefore the sequence below the Cambrian in Brunette Downs No. 1 can be interpreted as 360 feet of Mittiebah Sandstone, underlain by 650+ feet of the Mullera Formation.

Aeromagnetic surveys, both by B.M.R. (Wells, Tipper and Milson, 1964 unpubl.) and Papuan Apinaipi Petroleum Company Limited (1965 unpubl.), indicate that the South Nicholson Group is either non-magnetic or weakly magnetic; basement is shallow over most of Brunette Downs Sheet area, but many of the magnetic anomalies are ascribed to intra-basement features, and therefore no great thickness of the South Nicholson Group is expected. On the other hand, deep magnetic basement is shown over much of Ranken, Mount Drummond, Lawn Hill and Camooweal Sheet areas, and since Cambrian sediments are expected to be thin, on evidence from Morstone No. 1 and BMR11 Wells, some or all of the sequence between magnetic basement and the base of the Cambrian could be the South Nicholson Group. However, the pre-Cambrian basement sediments in BMR11 and Morstone No. 1 cannot be identified with outcropping formations.

The Colless Volcanics crop out in small areas in the Lawn Hill Sheet area (Plate 2). Carter et al. (1961 op cit.) named this unit, which unconformably overlies the Mullera Formation and is overlain by Middle Cambrian sediments. The contact with the Camooweal Dolomite is obscured, but Carter et al., 1961 (op cit.) report an unconformity between the Volcanics and the Thorntonia Limestone.

The Colless Volcanics consist of basalt, commonly vesicular, and are thought to be about 200 feet thick. Their age is probably Adelaidean, but may be Cambrian.

(4) The Eastern Margin. This margin consists mainly of the Cloncurry Complex, whose outcrop extends in a near-meridional belt from about latitude

18°30'S to about latitude 22°S, where the width of the belt is about 120 miles. Gravity surveys (Gibb, 1966, unpubl.) indicate that this belt extends in the subsurface to about latitude 25°S, and Gibb (op cit.) has named the positive gravity feature over the belt the Cloncurry Regional Gravity High. Part of the eastern margin consists of the Pilpah Sandstone, of ?Adelaidean age, and of three ?Lower Cambrian units - the Riversdale Formation, the Makbat Sandstone and the Mount Birnie Beds.

Carter et al., (1961) have described the geology of the Cloncurry Complex, and the brief descriptions which follow are taken from their work. The Cloncurry Complex consists of 31 formations and 9 granite masses. For convenience, most of the formations and granite masses have been grouped as "Undifferentiated Proterozoic" on Plates 2 and 4, but a few units have been delineated to show regional structure.

The Cloncurry Complex was deposited in two geosynclinal basins separated by a narrow basement belt of metamorphic rocks; Carter et al., (1961 op.cit., p. 40) figure this basement belt as a narrow, near-meridional zone, whose western boundary lay east of Mount Isa and Dajarra and the eastern boundary generally west of 140°E longitude. The meridional belt is now occupied by the Leichhardt Metamorphics and the Kalkadoon Granite. Therefore all the rocks of the Complex on Plate 2 were deposited in the western basin, and those shown on Plate 4 include some deposited in both basins; the Marraba Volcanics belong to the eastern basin.

Sedimentation in both basins was essentially arenaceous and dolomitic, with great thicknesses (20,000 feet) of basic lavas accumulating at some stages. Five separate periods of granite intrusion have been recorded, and at least five different ages of dolerite intrusion. The eastern basin suffered two major diastrophisms, but the western basin was affected by only one; during the first, folding and extensive faulting took place in the eastern basin, and during the second, strata of both basins were folded and faulted.

The Precambrian strata have a wide range of metamorphic grade. The rocks deposited in the eastern basin display fracture cleavage, slaty cleavage, schistosity, gneissose foliation and migmatisation. The overall grade appears to be that of the green-schist facies, but the amphibolite facies is evident over large areas. Metasomatism on a regional scale has affected a large part of the eastern geosynclinal belt. In the western basin the Proterozoic rocks show much lower metamorphic grade; they show, at most, slaty cleavage, and contact metamorphic effects are confined to narrow aureoles around intrusive granite.

In the eastern basin, faults are of the strike-slip type, striking 030° -045°, and $130^{\circ}-150^{\circ}$; the faults striking $030^{\circ}-045^{\circ}$ are the best developed. Strike faults are also common, and east-dipping high-angle reverse faults occur south of Cloncurry. Folded beds on near-meridional axes generally dip steeply.

In the western basin, strike-slip faults strike 045° and 130°, east-west normal faults are common. Strike faults are also important, and the Mount Isa Fault is a high-angle west-dipping reverse fault. Folding is linear but open, with dips up to 80°, and occasionally overturned in the eastern part, but in the west folding is commonly of the basin and dome type, with axes in many directions.

Brief descriptions of the units separated on Plates 2 and 4 are:
Eastern Creek Volcanics. These were named by Carter et al., (1961, p.73) from Eastern Creek, a tributary of Gunpowder Creek. The sequence is essentially of interbedded metabasalt and metasediments, with some intermediate and acid lavas near the top; the basic lavas are remarkably uniform throughout, and they give a most intense pattern of magnetic disturbance (Wells, Tipper and Milsom, 1964, unpubl.). Rocks of the formation crop out in a wide area, and they have been subjected in different places to regional, thermal and dislocation metamorphism, or combinations of these. Intense fracturing west and north-west of Mount Isa has produced schists, and some thermal effects from the intrusion of Sybella Granite have produced high-grade metamorphic rocks west of Mount Isa and throughout the outcrop of the Eastern Creek Volcanics on the Urandangi Sheet area. Schists and gneisses have been produced south of Ardmore homestead but may belong to an older sequence although they are included in the Eastern Creek Volcanics.

The thickness ranges from 15,000 to 20,000 feet, but in many places poor outcrop prevents measurement. The Eastern Creek Volcanics are younger than the Ewen Granite (Carter et al., 1961, p. 145-146), which has been dated by Rb-Sr at 1780 m.y. (McDougall et al., 1965) and this, together with the regional stratigraphy, indicates a Carpentarian age for the Eastern Creek Volcanics.

The Marraba Volcanics (Plate 4) consist essentially of metabasalt, quartzite and tuffs; arenaceous rocks are most abundant at the base of the succession, and tuffs predominate towards the top. Metabasalt is abundant throughout but predominates in the middle of the succession. The Marraba Volcanics have not been intensely metamorphosed; mica schist, slate and sericite schist are known, and much of the metabasalt is schistose. The maximum thickness is probably not less than 10,000 feet, but intricate folding prevents reliable determination. The outcrops on Plate 4 are part of a large north-pitching anticline.

Carter et al., (1961, p. 72-73) correlate the Marraba Volcanics with part of the Eastern Creek Volcanics, and therefore here they are assigned a similar Carpentarian age.

The Sybella Granite is exposed in a belt trending north for about 110 miles along the eastern margin of the Cloncurry Complex, and in places is overlapped by Cambrian sediments. The Sybella Granite contains four distinct types - a weathered core, a foliated porphyritic granite, a massive porphyritic granite, and a microgranite. Richards et al., (1963, op cit.) dated several samples of the Sybella Granite, by K-Ar methods, and the results showed its age to be about 1400 m.y. Tentatively, this age is regarded as Carpentarian.

The Kalkadoon Granite crops out in a meridional belt about 160 miles long, and attains a maximum width of about 25 miles near Dajarra. The granite is a composite mass, consisting mainly of granodiorite which is overlain by sediments of the Cloncurry Complex, but with minor granite and adamellite which intrude the Cloncurry Complex. All of these igneous rocks are grouped in the Kalkadoon Granite. Carter et al., (1961, p. 157) believe that the Kalkadoon Granite may be as old, or even older, than the Ewen Granite, which is the earliest granite established by incontrovertible field evidence. However, K-Ar ages (Richards, et al., 1963) for the Kalkadoon granite are about 1400 m.y., and considerably younger than field evidence would suggest. Because of the uncertainty, it is shown on Plate 4 as Proterozoic.

The extent of the Cloncurry Complex beneath the Georgina Basin is shown in outline by aeromagnetic and gravity surveys. Across the strike, on the western margin of the Complex, magnetic basement drops steeply and regularly, and Wells, Tipper and Milsom (1964, unpubl.) state that in the Camooweal Sheet area the 2000-10,000 feet contours cross the area at an average separation of about one mile. The trend of the edge of the Complex is meridional, and has been followed across Mount Isa, Urandangi Sheets to Glenormistion Sheet area where a basement ridge, probably caused by Eastern Creek Volcanics, persists at least as far south as 22°30' (Wells and Milsom, 1965, unpubl.). Low amplitude anomalies are similar to those over outcrops of Sybella Granite.

The eastern boundary of the Cloncurry Complex probably coincides with the eastern margin of the Cloncurry Regional Gravity High, but the eastern margin of the preserved Georgina Basin lies west of longitude 141°E, and is formed by a subsurface mass of granite (which may or may not belong to the Cloncurry Complex). Casey et al., (1960, unpubl.) have recorded this granite in several water bores in the eastern part of the Boulia Sheet area, and Reynolds (1965) has recorded it in one water bore in the north-east of the Springvale Sheet area.

(a) ?Adelaidean

The Pilpah Sandstone crops out over an area of about 650 square miles along and adjacent to part of the eastern margin of the Georgina Basin. Noakes and Traves (1954, p.36) named the unit and Carter et al., (1961, p.121) defined it. The Pilpah Sandstone unconformably overlies several stratigraphic units of the Cloncurry Complex and is itself overlain by several Middle Cambrian units of the Georgina Basin succession.

The Pilpah Sandstone consists of fine to medium-grained well-sorted, light brown to white sandstone, with some coarse-grained sandstone and pebble and cobble conglomerate. Ripple marking and cross-bedding are abundant throughout the formation, whose maximum thickness is about 1000 feet. The Sandstone has been folded into domes and basins with axes trending generally north-west. Dips of beds rarely exceed 30°. The formation is faulted in a few places.

The Pilpah Sandstone has many features in common with the Constance Sandstone, and correlation appears reasonable but speculative. For this reason the age of the Pilpah Sandstone is referred to ?Adelaidean.

The subsurface extension of Pilpah Sandstone as basement to Georgina Basin sediments is unknown, and is not evident from gravity and aeromagnetic surveys; e.g. Wells and Milsom (1965, unpubl.) report magnetic basement at 8000 feet (sub-sea) beneath outcrops of Pilpah Sandstone.

(b) Adelaidean-Lower Cambrian

The Makbat Sandstone, named by Carter et al., (1961, p. 122) crops out over less than 20 square miles in each of the Duchess and Boulia Sheet areas. The formation consists predominantly of sandstone, poorly-sorted and commonly feldspathic, which grades upwards into yellow sandy siltstone. Brown shale, and 50 feet of conglomerate, also occur in the sequence; the minimum thickness is 1000 feet.

The Makbat Sandstone is moderately folded, well-compacted and indurated, but not metamorphosed, although cut by quartz veins. The Sandstone is underlain by the Kalkadoon Granite and by other sequences of the Cloncurry Complex; no contact has been observed in the field, but a metamorphic discordance between Cloncurry Complex and Makbat Sandstone indicates that an angular unconformity separates them. Carter et al., (1961, p.122) believed the age of the Makbat Sandstone to be Upper Proterozoic (Adelaidean) but expressed doubt that it could be correlated with nearby Lower Cambrian Mount Birnie Beds because of differences in thickness, lithology and degree of folding.

(c) Lower Cambrian

The Mount Birnie Beds, named by Opik (1960) consist of a sequence of conglomerate, sandstone, green shale and arkose, which rest unconformably on the Cloncurry Complex, and are overlain unconformably by lower Middle Cambrian formations. Diplocraterion and Crossochorda found in the beds prove a Lower Cambrian age (Opik, 1960). The Mount Birnie Beds have small areal distribution along the margin of the Cloncurry Complex in each of the Boulia and Duchess Sheet areas, and the maximum exposed thickness is 250 feet.

The Riversdale Formation, named by Noakes, Carter and Opik (1959) crops out only in an outlier near Ardmore homestead in the Urandangi Sheet area. The unit consists of red sandstone with several bands of conglomerate, succeeded by red, sandy dolomite; it rests on Precambrian basement and forms erosional residuals beneath lower Middle Cambrian sediments. The preserved thickness of the formation ranges from 10 to 100 feet. Dips do not exceed 5 degrees. No fossils have been found in the formation and its age may be either Adelaidean or Lower Cambrian, but on the basis of correlation with the Mount Birnie Beds a Lower Cambrian age is preferred.

(5) The South-eastern Margin

This is not exposed and it has been drawn partly from geophysical information on the extent of the Toko Syncline and partly from geological information from wells and water bores. This margin coincides only in part with the Diamantina Gravity Gradient figured by Gibb (1966, unpubl.), because this gravity feature defines the southern limit of the Cloncurry Complex, whereas Adelaidean/Lower Cambrian basement rocks are known well to the north of the Gravity Gradient.

The most important geological information on the south-eastern margin comes from the following four wells:

Phillips Petroleum Company Limited Canary No. 1 Well (23°15'30"S, 140°22'43"E) drilled the base of the Mesozoic sequence at 504 feet, then shale to 2688 feet and arkose from 2688 to total depth of 3218 feet. The shale and arkose are apparently unfossiliferous, and at present are considered to be of Adelaidean age. Harding (1966, unpubl.) has quoted an age of 710 ± 250 m.y. for shale below the Mesozoic sequence.

Phillips Petroleum Company Limited Elizabeth Springs No. 1 Well (23°20'44"S, 140°34'12"E) drilled the base of the Mesozoic sequence at 383 feet and penetrated shale of probable Adelaidean age from 383 feet to total depth of 1410 feet. Harding (op cit.) has reported an age of 710 ± 250 m.y. for samples of the shale.

French Petroleum Company (Aust.) Pty Ltd Marduroo No. 1 Well (24°02'20"S, 139°54'15"E) drilled the base of the Mesozoic at 1242 feet and from there to total depth of 3861 feet the well penetrated a sequence of sandstone and shale, with some boulder beds indicative of glacial sediments. The sequence below 1242 feet is referred to the Adelaidean Field River Beds, and Harding (op cit.) has reported an age of 720 ± 130 m.y. for shale obtained from the well.

French Petroleum Company (Aust.) Pty Ltd The Brothers No. 1 Well ($24^{\circ}15'40''$S, $139^{\circ}20'30''$E) was drilled slightly west of Marduroo No. 1 and penetrated ?Ordovician and Cambrian sediments at 1153 feet, beneath Mesozoic cover.

The ?Adelaidean sediments in three of these wells probably belong to the Field River Beds, which are expected to be widespread beneath the south-eastern Georgina Basin; one indication of this is the occurrence of the Sun Hill Arkose and the Sylvester Sandstone in the Mount Whelan Sheet area (Plate 4). Although these outcrops are well within the Basin margins as known at present, for convenience they are described in this section of the basement rocks.

The Sun Hill Arkose, named by Casey (1959), crops out only in the Mount Whelan Sheet area (Plate 4). The name is taken from Sun Hill, 12 miles south-east of Glenormiston homestead, and the type area is partly at that locality and partly in low hills one mile to the north.

The formation consists of arkose, arkosic sandstone, micaceous grey-wacke, siltstone, dolomitic siltstone, conglomerate and some lenses of dolomite. The only fossils known are worm trails and ?trilobite tracks. The base of the formation is not exposed, but in some places it overlies probable varves of the Field River Beds, in exposures too small to show on the 1:500,000 scale map.

Casey (1959, op cit.) remarked on the lithological similarity between the Sun Hill Arkose and arkosic beds in the Hay River Sheet area of the Northern Territory; these beds have now been mapped as the Field River Beds, and the present author agress with Casey's correlation and regards the Sun Hill Arkose as a correlate of arkosic beds above the basal glacial sequence of the Field River Beds.

The maximum exposed thickness of the Sun Hill Arkose is 150 feet.

The Sylvester Sandstone has been named by Casey (1959) from outcrops along Sylvester Creek on Marion Downs Station (Plate 4), about 35 miles west of the homestead. The type area is 8 miles north-north-east of Watchee Bore and 4 miles south-east of Rocky Yard, on Marion Downs Station.

The formation consists of silicified sandstone with many slump rolls and balls, and green siltstone. The base of the sequence is not exposed, and the top is either eroded or overlain unconformably by Mesozoic sediments. The maximum thickness is 1200 feet in the type area.

The Sylvester Sandstone probably overlies the Sun Hill Arkose conformably, but the contact has not been seen (Casey, 1959, op cit.). The present author believes that the Sylvester Sandstone is a correlate of units high in the Field River Beds. No fossils have been found in the formation, and its age is either Adelaidean or Lower Cambrian, and is dependent at present on the identification of the ?trilobite tracks in the underlying Sun Hill Arkose.

The extent of the Sun Hill Arkose, Sylvester Sandstone and/or Field River Beds in the concealed south-eastern part of the Georgina Basin is unknown, but it is assumed that they underlie much of the Toko Syncline, and they probably underlie much of the Basin east of this Syncline.

THE PALAEOZOIC SEDIMENTS

MIDDLE CAMBRIAN

NORTHERN TERRITORY

Gum Ridge Formation

Definition: Derivation of Name: From Gum Ridge, a trigonometrical station about 16 miles east-north-east of Tennant Creek, Northern Territory. Opik (*in* Ivanac, 1954, op cit.) named the formation, and (1956, b op cit.) published additional notes on it.

Distribution: In a discontinuous belt extending from about 30 miles north-east of Tennant Creek south-east for a distance of about 120 miles. The south-eastern exposures are in and around the north-eastern margins of the Davenport Range. The outcrops are all on or near the margins of Lower Proterozoic rocks; in the subsurface the formation may extend north and east, and some evidence of this is found in water bores on the Frew River Sheet area (Smith, 1964b).

Map Reference: Plate 1 (Tennant Creek and Frew River 1:250,000 Sheet areas).

Lithology: Shale, limestone, sandy limestone, chert and fine-grained sandstone at Gum Ridge; shale, chert, sandstone, and conglomerate in the margins of the Davenport Range.

Thickness: 45 feet at Gum Ridge Trigonometrical Station; 10-75 feet on and around the margins of the Davenport Range, 500 feet in subsurface (Frew River Sheet area).

Contacts: The Gum Ridge Formation unconformably overlies the Lower Proterozoic Warramunga and Hatches Creek Groups, and the Precambrian igneous rocks intruding these Groups: the Formation also unconformably overlies the Lower Cambrian Helen Springs Volcanics. The top of the Formation has been eroded.

Fossils: The following fossils have been reported by Opik (*in* Ivanac, 1954 op cit., and 1957):

Brachiopoda - *Wimanella* sp., *Billingsella* cf. *humboldti* Walcott, *Lingulella* sp., *Obolus*.

Trilobita - *Redlichia*, 2 sp., *Xystridura* aff. *browni*, *Pagetia* cf. *significans* (Etheridge), *Peronopsis* *elkedraensis* (Etheridge).

Hyolithidae - *Hyolithes*, 2 sp., *Biconulites* cf. *humboldti* (Walcott).

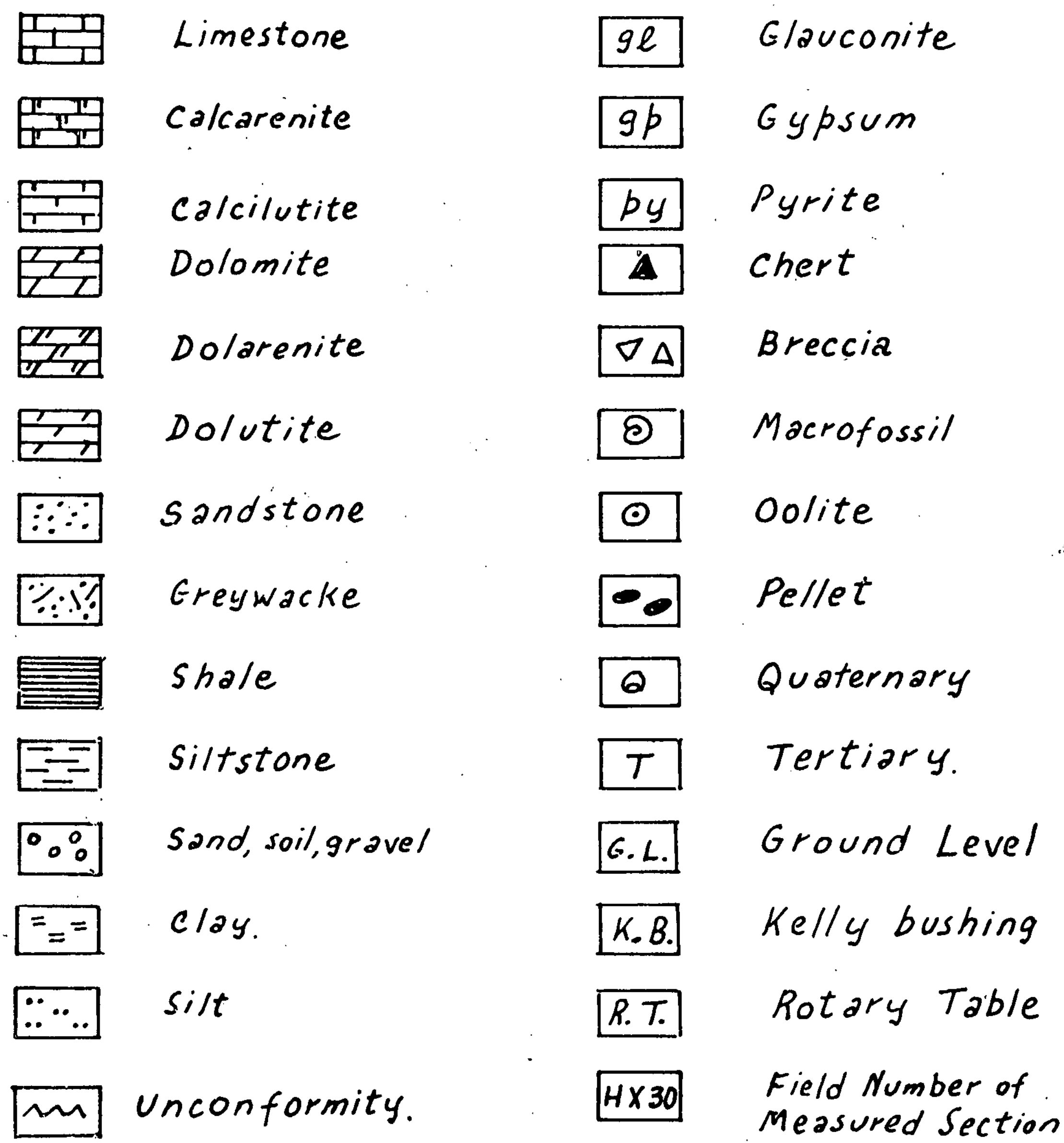
Spongia - *Chancelloria*, *Eiffelia*.

Age: lower Middle Cambrian

Description and Comment: The Gum Ridge Formation is part of an extensive sheet of Middle Cambrian sediments in the northern part of the Georgina Basin, and is one of the basal units of the Georgina Basin sequence. Before 1956 most, if not all, of the *Redlichia*-bearing sediments in Australia were regarded as late Lower Cambrian in age, but Opik (1956b, op cit.) showed that in northern Australia *Redlichia* was associated with Middle Cambrian fossils, and that the sequences containing these faunas were actually Middle Cambrian.

Fig 22

REFERENCE FOR ALL FIGURES WITHOUT LITHOLOGICAL DESCRIPTIONS

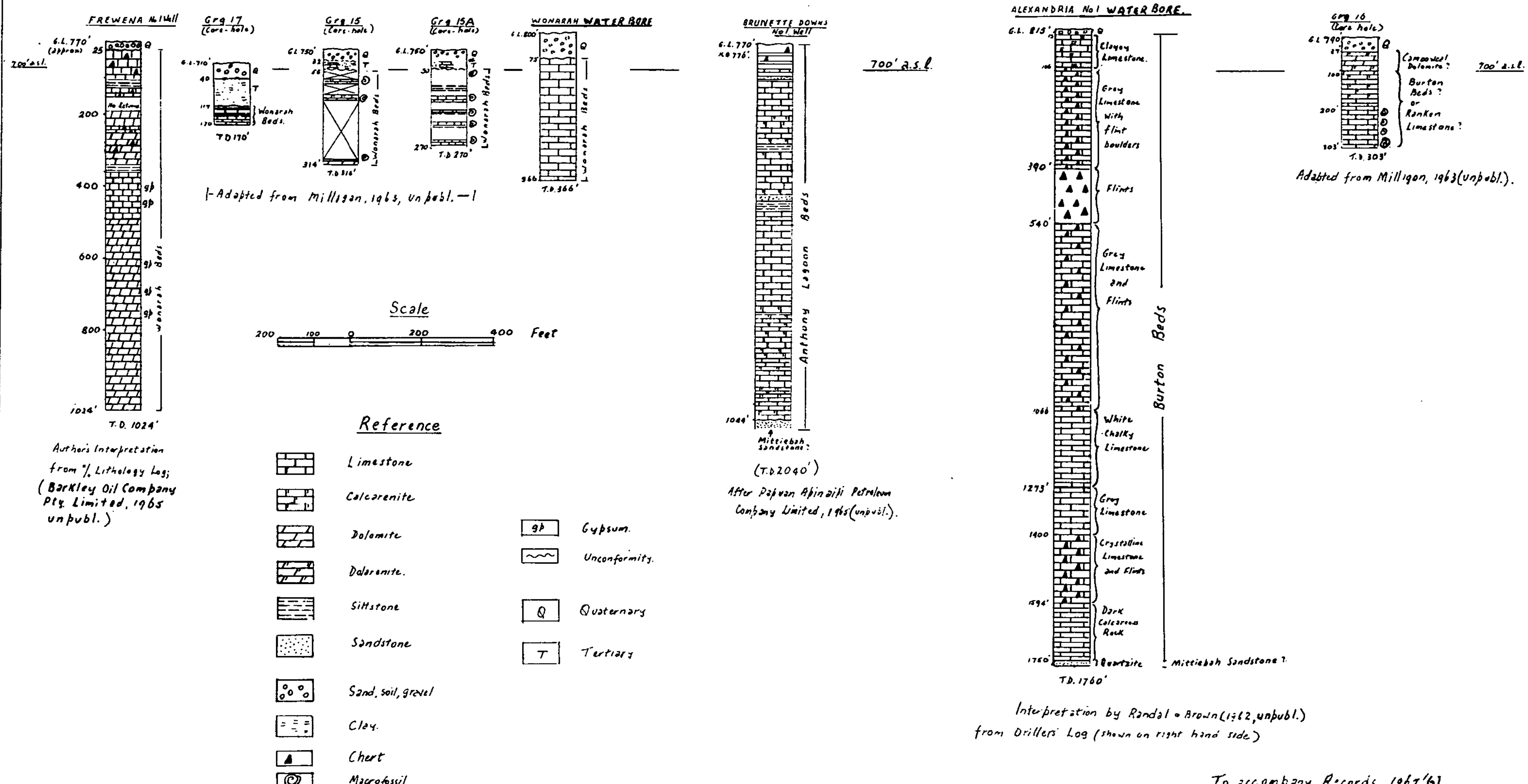


To accompany Records 1967/61

GEORGINA BASIN

Fig 23.

Middle Cambrian sediments in wells, core-holes and water bores, Barkly Tableland area, Northern Territory.



To accompany Records 1967/61

The Gum Ridge Formation usually crops out poorly, often as rubble-covered rises; the rubble usually consists of angular fragments of chert and silicified shale, and some of the fragments are rich in fossils. In many localities, rubble has been re-cemented to form pavements and large blocks. Occasionally the rubble has been transported and is strewn on the surface of depressions and plains which may, or may not, be underlain by the Gum Ridge Formation.

The subsurface extent and thickness of the Gum Ridge Formation is unknown, but it probably extends at shallow depth under much of the Frew River, Tennant Creek and Alroy Sheet areas (Plate 1). Reliable logs of three water bores on Epenarra Station (Frew River Sheet area) show dolomite, limestone, chert and sandstone lithologies which are believed to belong to the Gum Ridge Formation (Smith 1964b). However, no fossils have been found in this subsurface material, and the rocks could belong to a younger Middle Cambrian sequence. Two of the bores reached total depths of 289 and 360 feet in the Gum Ridge Formation, but the third (Section A-B, Plate 1) drilled through the formation into granite at 505 feet below the surface. In this bore the Quaternary was 50 feet thick, and the Cambrian sequence had a thickness of 455 feet.

The Gum Ridge Formation has not been metamorphosed or intruded by igneous rocks and no folding or faulting movements have affected it.

<u>Wonarah Beds</u>

<u>Definition</u>: Derivation of Name: From Wonarah Telegraph Repeater Station, on the Barkly Highway, at latitude 19°55'S, longitude 136°21'E, and about 170 miles by road from Tennant Creek township. Opik (1956b, op cit.) named the Beds from outcrops along the Barkly Highway. They are synonomous with the Alroy Downs Beds (David, 1932), and formed part of the Barkly Group of Noakes and Traves (1954, op cit.).

<u>Distribution</u>: In a discontinuous belt extending from Frewena (Plate 1) to Barrys Caves (Plate 2) approximately, and on both sides of the Barkly Highway.

Map Reference: Alroy, Frew River (Plate 1), Avon Downs and Ranken (Plate 2) 1:250,000 Sheet areas.

Lithology: Shale, oolitic limestone, coquinite, dolutite, (all deeply weathered on the surface); dolomite, limestone siltstone and sandstone are known in the subsurface.

Thickness: Outcrop seldom exceeds 50 feet; in the subsurface, at least 450 feet is known in water bores, and 1024 ± feet in Frewean No. 1 Well. No well or water bore has penetrated the whole sequence, but it is unlikely that the average thickness exceeds 1500 feet; mostly it is expected to be less than 1000 feet.

Contacts: The base is not exposed, the top has been eroded, and no subsurface data on basal contacts are available. It is reasonable to assume that the Wonarah Beds rest unconformably on Precambrian basement.

Fossils: The Wonarah Beds contain a rich fauna, from which Opik (1956b, op cit., p. 41) has named the following:

Trilobita - "Xystridura" browni, Xystridura aff. browni, Xystridura sp., Pagetia significans, Oryctocephalus, Peronopsis, spp., Pytchoparids (several species).

Brachiopoda - Several species.

Spongia - Helcionella.

Age: lower Middle Cambrian. The Wonarah Beds are slightly younger than the Gum Ridge Formation, but since all of the fossils are from surface samples and there is adequate subsurface evidence that each locality is underlain by several hundreds of feet of near-horizontal Cambrian sediments, it is likely that lower parts of the Wonarah Beds are equivalent to, and perhaps contiguous with, the Gum Ridge Formation, as suggested by Opik (1957, op cit., Fig. 2, p. 6).

Correlates: The Burton Beds (Alexandria Beds of Opik, 1956b, op cit.) and the Sandover Beds. The Wonarah Beds may intertongue with the Ranken Limestone (Opik 1956b, Fig. 2, p. 6), but no contacts are evident.

Description and Comment: Surface exposures are always low, and the beds are deeply weathered, often to chert rubble which usually covers the low rises. Randal and Nichols (1963, unpubl.) record laterite cappings, up to 30 feet thick, on the Wonarah Beds. Outcrops are rare, but some are known near Barrys Caves (Plate 2), where Randal and Brown (1962b, unpubl.) recorded the following sequence:

Thickness (feet)	
12	silicified, brecciated billy
1	quartz pebble conglomerate
20	ferruginous, red and white, fine-grained quartz sandstone, and siltstone
35	rubble
Total 68 feet;	the base is not exposed.

Fossils are abundant in chert scree from the Wonarah Beds.

In the subsurface, the Wonarah Beds usually consist of carbonate rocks, with minor siltstone and sandstone. The logs of Barkley Oil Company Pty Limited Frewena No. 1 Well, three Bureau core-holes, and one water bore (at Wonarah Telegraph Repeater Station),are summarized on Fig. 23. Barkley Oil Company Pty Limited (1965, unpubl.) record limestone and dolomite, with some red and purple shale, to 490 feet, and dolomite from 490 feet to 1024 feet (T.D.) in Frewena No. 1 Well. Gypsum is abundant in the interval 360 to 490 feet and also in the upper half of the interval 490-1024 feet. All of the carbonate beds are vuggy.

In Grg 17, Milligan (1963, unpubl.) recorded red, chocolate and green siltstone and sandstone interbedded with dolomitic limestone and he considered that the lithologies resembled those of the Anthony Lagoon Beds rather than the Wonarah Beds. This correlation may be correct, but there is no proof of either alternative and for the present the sequences in Grg 17 and in Frewena No. 1 are here placed in the Wonarah Beds.

Grg 15 had poor core recovery, and Grg 15A was drilled ½ mile to the south; it is not shown on Plate 1 because of scale limitations. In addition to the lithologies from cores (Fig. 23), Milligan (1963, unpubl.) summarized the sequence in both core holes:

Grg 15
(feet)

0-50	Quaternary and Tertiary
50-133	Chiefly shaly siltstone, with a rich fauna of *Xystridura*, agnostids; thin beds of calcarenite, calcareous sandstone and silicified bioclastic limestone.
133-304	No cuttings, and no core (too soft)
304-310	Brownish dolomite, with grey fossiliferous chert lenses

Grg 15A
(feet)

0-50	Quaternary and Tertiary
50-250	Chiefly shaly siltstone, with rich fauna - *Xystridura*; thin beds of calcarenite, calcareous sandstone and silicified limestone.
250-270	Brownish, fossiliferous, crystalline limestone with grey chert lenses.

The log of the water bore at Wonarah Telegraph Repeater Station shows the typical lithologies reported by drillers from many water bores in the areas. The subsurface carbonates are often vuggy and cavernous and yield good supplies of sub-artesian water, which is usually suitable for both stock and domestic use.

Anthony Lagoon Beds

Definition: Derivation of Name: From Anthony Lagoon homestead (latitude 17°59'S, longitude 135°32'E) in the Walhallow 1:250,000 Sheet area (Plate 1). Plumb and Rhodes (1963) named the Anthony Lagoon Beds from rubble and boulders of dolomite and limestone, with calcareous sandstone and chert, on the black soil plains around Anthony Lagoon and Creswell Downs homesteads. Randal and Nichols (1963, unpubl.) extended the definition to include outcrops in the Brunette Downs Sheet area.

Map Reference: Plate 1 (Brunette Downs and Walhallow Sheet areas).

Distribution: In low, well-defined ridges in the north-west of Brunette Downs Sheet area, and in low rises of lateritised rocks in the central part; there is a wide distribution of slabs on grassy, black-soil downs, and information from water bores suggests that much of the downs country on both Brunette Downs and Walhallow Sheet areas may be underlain by the Anthony Lagoon Beds.

Lithology: Yellow-brown to buff interbedded coarse-grained dolomite and fine-grained limestone, grey, fine-grained calcareous sandstone, chert and silicified limestone occur in blocks; silicified coquinites, silicified oolitic limestone and oolitic chert are found in scree on black soil downs. In outcrop, dolomite, limestone, ripple-marked quartz sandstone and siltstone. The surface rocks have been extensively lateritised.

In the subsurface, limestone, dolomitic limestone, chert, calcarenite, calcilutite,sandstone and shale, in Brunette Downs No. 1 Well (Fig. 23); dolomite, limestone, sandstone and shale in drillers' logs of water bores. Geologists' examinations of chips from water bores show silty, micaceous limestone and dolomite, and grey, tan and red-brown quartz sandstone.

Thickness: 1044 feet in Brunette Downs No. 1 Well; up to 700 feet are known in water bores, but less than 50 feet in outcrop.

Contacts: The top has been eroded, and the base is known only in Brunette Downs No. 1 Well, where the Anthony Lagoon Beds rest on a weathered surface of Adelaidean Mittiebah Sandstone. The only rocks known to overlie the Anthony Lagoon Beds are of Mesozoic and Cainozoic ages.

Fossils: No diagnostic fossils have been found. Algae, fragments of trilobites and Echinodermata(?) are known in surface blocks, and indeterminate brachiopods below 670 feet in Brunette Downs No. 1 Well.

Age: lower Middle Cambrian(?).

Correlates: The Anthony Lagoon Beds may be an extension of the Wonarah Beds from the south, and the Burton Beds from the east.

Description and Comment: Due to poor outcrop, deep weathering and the lack of diagnostic fossils, very little is known of this stratigraphic unit. In accordance with normal practice in the northern part of the Georgina Basin, the predominantly carbonate sequence beneath outcrop, rubble, and black soil plains in the surrounding area is referred to the Anthony Lagoon Beds. It is reasonable to assume that the Anthony Lagoon Beds are a local "block" in a predominantly carbonate sequence which extends continuously over much of the northern part of the Georgina Basin. As such, the Anthony Lagoon Beds are probably equivalent in age to many of the other named lower Middle Cambrian sequences in this area, with the age of the oldest beds in the sequence varying in accord with local basement topography.

The uncertainty of the northern limits of the Anthony Lagoon Beds restricts delineation of part of the north-western margin of the Georgina Basin. The black-soil plains may give a reasonable indication of underlying Cambrian carbonate rocks but Tertiary carbonate sequences may also develop soils which are superficially similar and consequently this method of delineation must be treated with caution when subsurface information is not available.

The Anthony Lagoon Beds have not been metamorphosed and no structural trends are evident. In the subsurface, the carbonate rocks are usually vuggy, cavernous in part, and yield good supplies of water (Randal, 1966, unpubl.).

Peaker Piker Volcanics

Definition: Derivation of Name: From Peaker Piker Creek, in the south-west of the Mount Drummond 1:250,000 Sheet area (Plate 2). This creek flows near outcrops of the Volcanics and drains areas probably underlain by them. Smith and Roberts (1963, p. 10-11) named and described the unit, but did not designate a type section.

Distribution: In the Mount Drummond Sheet area only; the Volcanics crop out in mesas and low hills in the west (mainly north of Fish Hole Creek) and south-west, near Peaker Piker Creek. The distribution in the subsurface is unknown, but Smith and Roberts (1963, op cit.) have reported that weathering of the Volcanics has produced areas of black soil contiguous with outcrop.

Map Reference: Mount Drummond 1:250,000 Sheet; Plate 2.

Lithology: Strongly-weathered vesicular and non-vesicular basalt, with some ?trachyte and minor dolerite flows. Sandstone lenses occur near the base, south of Peaker Piker Creek.

Thickness: 120 feet.

Contacts: Unconformably overlies both the Mullera Formation and the Mittiebah Sandstone; conformably overlain by the Burton Beds, and at one locality Smith and Roberts (1963, op cit.) report a lens of lava in a siltstone - shale sequence of the Burton Beds.

Fossils: Sandstone near the base is apparently unfossiliferous; the lens of lava in the siltstone-shale sequence of the Burton Beds (referred to above) is only 20 feet below beds containing lower Middle Cambrian fossils.

Age: lower Middle Cambrian.

Description and Comment: The Peaker Piker Volcanics are particularly susceptible to lateritization and weathering, and their petrology is therefore difficult to determine. In outcrop, their distribution is closely allied to that of the overlying Middle Cambrian Burton Beds, but in the subsurface they have not been recorded in water bores; this could be because adequate supplies were obtained from overlying carbonate rocks or because unsuccessful bores terminated above them. Wells, Tipper and Milsom (1964, unpubl.) recorded a few scattered, low amplitude, short wavelength anomalies which disturb the normally smooth magnetic profiles in the north-western part of the Mount Drummond Sheet area, and they considered the majority of these anomalies were due to shallow sources in the Peaker Piker Volcanics.

The Peaker Piker Volcanics have not been folded, but in some places they have been faulted; the age of the faulting is unknown, since the various Cambrian units affected have no younger Palaeozoic cover.

Smith and Roberts (1963, op cit.) regard the age of the Peaker Piker Volcanics as lower Middle Cambrian because a lens of lava, which may represent the last phase of extrusion, occurs in a siltstone-shale sequence which they place in the Burton Beds; Middle Cambrian fossils have been found 20 feet above the top of the lava. This is the only record of probable Middle Cambrian vulcanicity around the margins of the Georgina Basin, but many volcanics in the

Northern Territory, including the Helen Springs Volcanics on the basin's north-western margin, underlie fossiliferous Middle Cambrian sequences and are regarded as Lower Cambrian in age. However, there is no palaeontological evidence to support the Lower Cambrian designation and all, or some, of the occurrences could be of early Middle Cambrian age.

The Burton Beds

Definition: Derivation of Name: From Burton Creek, which drains some of the outcrop area of the Beds in the western part of the Mount Drummond 1:250,000 Sheet area (Plate 2). Smith and Roberts (1963, p. 11, op cit.) named the Beds, and Randal and Brown (1962a, unpubl.) traced them southwards to Alexandria homestead and other areas in the Ranken 1:250,000 Sheet area. The name Burton Beds supersedes the "Alexandria Beds" of Opik (1956b, p. 40, op cit.). Smith and Roberts do not give a reference section for the Burton Beds, but Opik (1956b, p.40, op cit.) stated that the best exposure of the sequence was at the "old well" on Alexandria Station, 7 miles north-west of the homestead, where 120 feet of Cambrian sediments rest on Precambrian sandstone (Mittiebah Sandstone).

Distribution: In rounded hills, often with lateritic caps, in the western part of the Mount Drummond Sheet area, and in low rises in the Ranken Sheet area. Outcrop is usually poor and the presence of the Burton Beds is often inferred from loose fragments and blocks of sedimentary rock strewn on the surface of the plains and from chert rubble on low rises.

Map Reference: Plate 2; Mount Drummond and Ranken 1:250,000 Sheet areas.

Lithology: White and cream siltstone and shale, occasionally silicified, chert, and red, friable, medium-grained sandstone in the Mount Drummond Sheet area; limestone, oolitic limestone, coquinite, mudstone, shale, siltstone and chert in the Ranken Sheet area; grey and green dolomite has been recorded in a water well east of Alexandria homestead. Randal and Brown (1962a, unpubl.) report that shale predominates in Burton Beds flanking a prominent ridge of Mittiebah Sandstone, south-east of Alexandria homestead, with limestone predominating north-west and south-east of the ridge. All of the rocks of the Burton Beds are usually strongly lateritised and very few outcrops of original rock are preserved.

Thickness: 75 feet in the Mount Drummond Sheet area; the maximum known thickness is 1750 feet in Alexandria No. 1 Bore (Fig. 19).

Contacts: The Burton Beds unconformably overlie the Mittiebah Sandstone and conformably overlie the Peaker Piker Volcanics. Their top is eroded.

Fossils: The Burton Beds contain a rich fauna, described by Opik (1956b, op cit.); the fossils include:

Trilobita - Xystridura browni, Xystridura, 2 sp., Lyriaspis alroyensis, Pagetia significans, Peronopsis elkedraensis, Peronopsis, Kootenia, Redlichia, Oryctocephalus, Beyrichona.

Brachiopoda - Stenotheca, Obulv, Acrotreta, Lingulella, Acrothele.

Spongia - Eurostina, Archaeocyathus.

Hyolithidae - Hyolithes, Biconulites.

Age: lower Middle Cambrian

Correlates: Probably the Wonarah Beds and the Anthony Lagoon Beds.

Description and Comment: Much of the limestone in the Burton Beds has been recrystallized, but the recrystallization has not completely obliterated fossils and oolites, and complete fossils and large fragments of fossils are often found. Coquinites are common; one type contains trilobites and hyolithids cemented by sparry calcite and other coquinites, containing brachiopods and echinoids, have a matrix of fine-grained brown calcite. Silicification is common in the scree occurrences, but has not completely destroyed original limestone textures. In oolitic limestones, silicification has resulted in replacement of oolites by a fine mosaic of chert, with coarser chert mosaics occupying the former voids between the oolites.

The thickness of the Burton Beds is variable; a few water bores have penetrated the full sequence and have indicated a range of thickness from 300 to 1750 feet. The sediments are generally horizontal or have very low dips. Faulting has affected the Beds in some parts of the Mount Drummond Sheet area, but in the Ranken Sheet area the beds are undisturbed.

Ranken Limestone

Definition: Derivation of Name: From the Ranken River (Plate 2), a tributary of the Georgina River; Opik (1956b, p. 41, op cit.) applied the name "Ranken Limestone" to outcrops of oolitic and crystalline limestone in the valley of the Ranken River. Randal and Brown (1962a, unpubl.) included chert and dolomite in their description of the Ranken Limestone. No type section has been described.

Distribution: Surface distribution is limited to a narrow meridional belt extending from Soudan, on the Barkly Highway, north-north-west for about 20 miles. Most of the outcrops are west of the Ranken River.

Map Reference: Ranken and Avon Downs 1:250,000 Sheet areas (Plate 2).

Lithology: Thin and medium-bedded, oolitic and crystalline limestone, silicified limestone, coquinite, chert and minor dolomite. Ripple marks occur and shell-in-shell structure is common in accumulations of brachiopods and *Biconulites*.

Thickness: Not recorded; the surface thickness does not exceed 20 feet in any outcrop.

Contacts: The base is not exposed and has not been recorded in the sub-surface; the top has been eroded. Several miles of black soil plains separate outcrops of the Ranken Limestone from outcrops of Wonarah Beds to the west. To the east, extensive "float" of dolomite (the Camooweal Dolomite) occurs in black soil plains. Opik (1956b, op cit.) considered that on fossil evidence the top of the Ranken Limestone cannot be older than the Wonarah Beds, and that these two units probably intertongue. Opik (1956b, p. 41, op cit.) stated "The Ranken limestone rests on the Camooweal Dolomite"; Condon (1961, unpubl.) considered that the exposures of Ranken Limestone dip east at 1-2°, and that the Ranken Limestone appeared to grade upward into the Camooweal Dolomite on the east bank of the Ranken River. The facts are that no contacts of Ranken Limestone with either the Wonarah Beds on the Ranken Limestone have been observed and more recent work, summarised by Smith (1965), shows that most of the Camooweal Dolomite is of Middle Cambrian age.

Fossils: Opik (1956b, p. 41, op cit.) has named a rich fauna from the Ranken Limestone.

Trilobita - Kootenia, Asaphiscus, Peronopsis.

Brachiopoda - Lingulella, Acrothele, Bohemiella?, Nisuia?, one new Orthoid.

Cystids - Cymbionites, Peridionites, Eocystis.

Hyolithidae - Biconulites, Hyolithes, Helcionella.

Archaeocyathids - Archaeocyathus.

Age: lower Middle Cambrian

Description and Comment: Outcrop of the Ranken Limestone is poor; the rocks occur as scattered slabs, large blocks and gravel on black soil downs. Limestone predominates in the sequence; Randal and Brown (1962a, unpubl.) describe some of the limestone beds as consisting of pellets and fossil fragments in a matrix of optically dense, fine-grained calcite; terrigenous material, consisting of quartz, feldspar and mica is present in the pellets. The sediments indicate shallow-water deposition, probably along a shore line.

In addition to the fossils listed above, Opik (1956b, p. 41, op cit.) records the presence of the upper Middle Cambrian trilobites Asthenopsis and Papyriaspis at the top of the Ranken Limestone in one locality, but states (p. 41) that these fossils occured "in the fragmented and re-cemented top of the Ranken Limestone", and he considered this as evidence of re-working of the upper part of the Ranken Limestone. Opik cited as supporting evidence the occurrence of an upper Middle Cambrian fauna in a few limestone and chert boulders on the surface of the Camooweal Dolomite east of the Ranken River, and a boulder containing Amphoton on a bank of the Ranken River south of the Barkly Highway; an alternative explanation is that they belong to the Camooweal Dolomite and show that in this locality its age is upper Middle Cambrian. These residuals have not been mapped as a separate stratigraphic unit.

Undifferentiated Middle Cambrian

Several outcrops on Plates 1 and 2 are shown as "undifferentiated Middle Cambrian". Those on Plate 1 have since been mapped (Randal, Brown and Doutch, 1966, unpubl.) and the westernmost outcrop, near Brunchilly homestead, includes both Precambrian Tomkinson Creek Beds and Middle Cambrian Gum Ridge Formation, whilst the other two are placed in the Anthony Lagoon Beds. The outcrops on Plate 2 have not been remapped; they occur in the north-central part of the Ranken Sheet area (Randal and Brown, 1962a, unpubl.) and consist of blocks of coarsely crystalline dolomite with chert nodules which contain abundant hyolithids and fragments of trilobites and brachiopods. The lithology does not resemble the other Middle Cambrian units in the northern part of the Georgina Basin, and the relationship between the undifferentiated Middle Cambrian sediments and the surrounding Camooweal Dolomite is unknown. Since the Camooweal Dolomite is regarded as Middle Cambrian in age, the undifferentiated Middle Cambrian sediments may be lenses in it.

In the subsurface, a sequence of 266 feet of carbonate rocks was cored in Grg 16 (136°51'23"E, 19°45'50"S), below 37 feet of Quaternary gravel and soil (Milligan 1963, unpubl.). A summary of the log (Fig. 23) is:

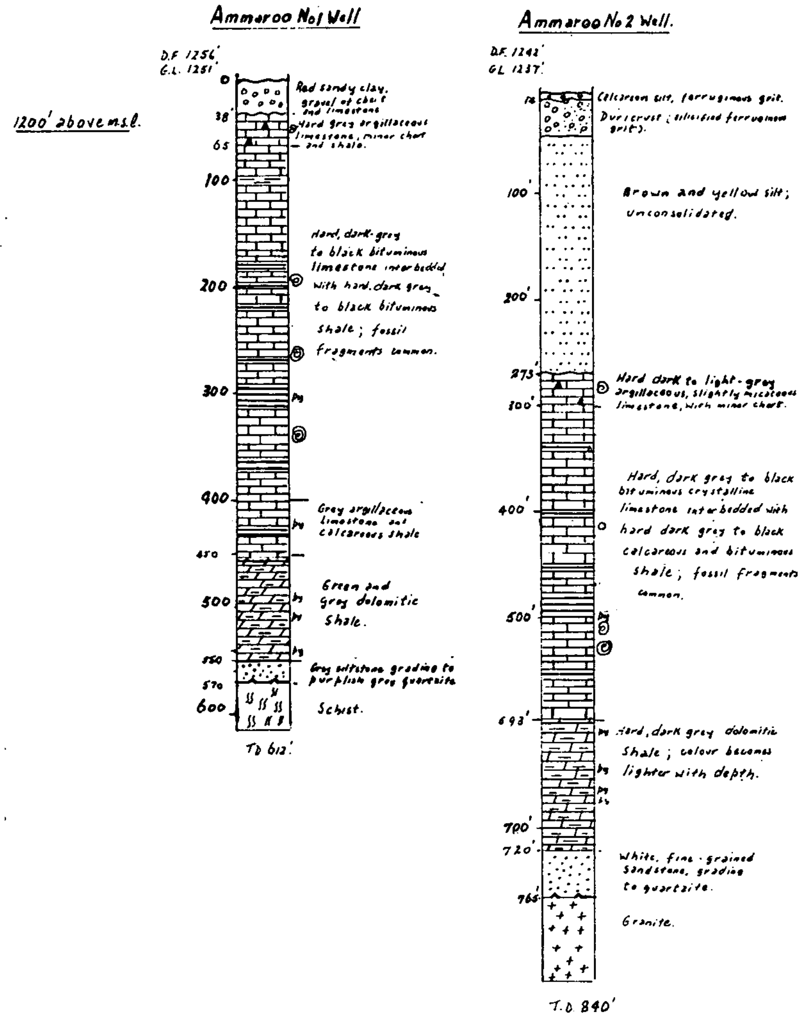
Feet	
37	Soil and gravel
37-100	Dolomite and dolutite
100-200	Calcilute, calcarenite and crystalline limestone, in approximately equal amounts
200-303	Oolitic and bioclastic limestone (coquinite) which is silicified near the bottom, and interbedded calcilutite.

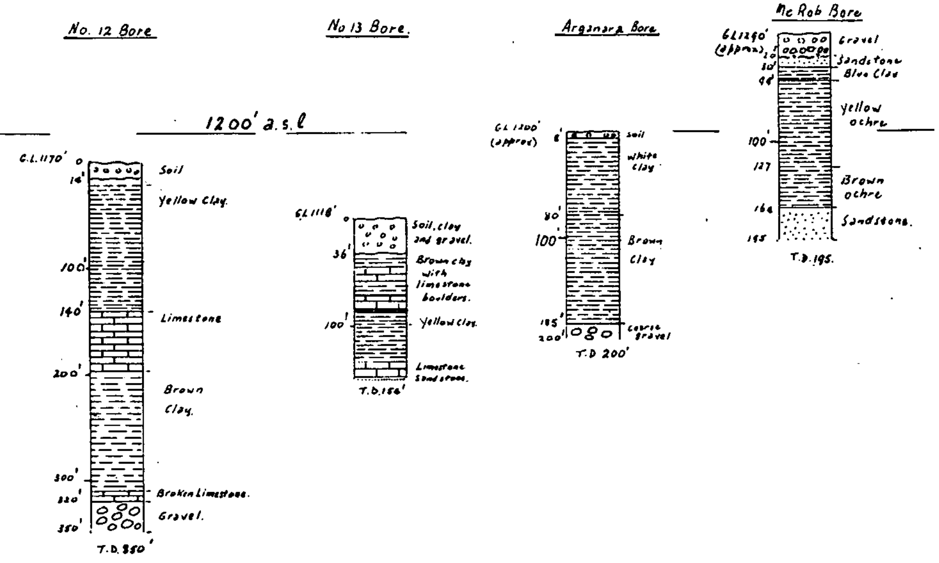
The sequence below 200 feet has lithological similarities with both the Ranken Limestone and the Burton Beds, and a gentle dip could bring either of these units to the correct stratigraphic position in the core-hole. Gatehouse (pers. comm.) has examined the cores and has found Biconulites in Core No. 27 (220'9"-230'2"), Biconulites and Ptychoparid trilobites in Core No. 29 (240'-250'1"), and lithistid sponge spiclues in Core No. 35 (290'5"-299'2") and Core No. 36 (299'2"-303'); the fauna is not diagnostic but is probably of early Middle Cambrian age.

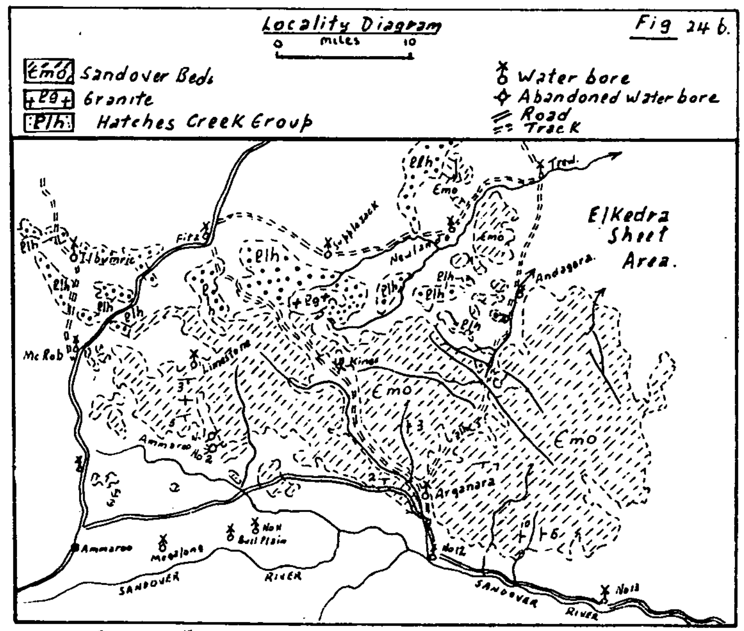
Although the identity of the formations in the core-hole cannot be satisfactorily established, an important result is that a Middle Cambrian sequence has been determined in an area which Opik (1956b, Fig. 2) believed is underlain by Camooweal Dolomite (of Adelaidean or Lower Cambrian age). The sequence between 37 and 100 feet in the core-hole may be Camooweal Dolomite,

SANDOVER BEDS.

Logs of Exploratory Wells, and Interpreted Logs of Water Bores.







To accompany Records 1967/61

but at present the probable boundary of this unit (Plate 2) is east of Grg 16.

Sandover Beds

Definition: Derivation of Name: From the Sandover River (Plate 3); outcrop of the Beds extends from near the river northwards to the south-eastern foothills of the Davenport Range. Opik (1956b, p. 42-44, op cit.) named the Beds, described some units, and gave a brief account of the rich fauna in them. Smith, Stewart and Smith (1961) extended the name to include unfossiliferous sandstone and conglomerate below Opik's sequence, at the base of the section; Smith and Milligan (1963, unpubl.) made an additional modification by including fossiliferous limestone which crops out west of the area examined by Opik and which was not included in his lithologies of "friable mudstone, laminated fine-grained sandstone, shale and chert". The sequence cannot be defined as a formation because the contact with younger formations is not exposed. Poor outcrop and the geographical distribution of units of the Sandover Beds prevents the nomination of a reference section; good sections of the basal sandstone and conglomerate can be seen west of Andagera Bore (Fig. 24b), the limestone is exposed between Limestone Bore and Ammaroo No. 1 Well (Fig. 24b) and the remainder of the sequence can be seen along tracks leading from Arganara Bore to Fitz and Andagera Bores (Fig. 20b).

Distribution: The main outcrop area is between the southern foothills of the Davenport Range, at about latitude 21°30'S, and the Sandover River; some outcrops are known in the south-eastern foothills of the Davenport Range and also in valleys within the Range. The subsurface extent is unknown, and information away from main outcrop areas is limited to interpretations of the logs of a few water bores.

Map Reference: Elkedra 1:250,000 Sheet area (Plate 3).

Lithology: The Sandover Beds consist of a basal sandstone, with local developments of conglomerate, succeeded by siltstone with minor shale, limestone and sandstone bands; in the western part of the outcrop area, limestone crops out and is interbedded with, and grades laterally into, the siltstone unit.

The sandstone is brown and pink, thin to medium-bedded, medium to coarse-grained, ripple-marked, with local development of thick-bedded, pebble, cobble and boulder conglomerate. Siltstone is usually buff and white, silicified, thin to medium-bedded, richly fossiliferous, with shale, buff and white, fossiliferous, and minor limestone, sandstone and chert bands. The limestone is grey and blue, thin bedded to massive, algal in part, fossiliferous, with chert nodules and minor shale and siltstone bands.

In Farmout Place Ammaroo No. 1 and No. 2 wells, lithologies include hard, grey, argillaceous limestone; hard, dark grey and black, bituminous, crystalline limestone with interbedded grey to black bituminous shale; dark-grey, blue-grey and green-grey dolomitic shale; sandstone and quartzite (Fig. 24a).

Thickness: Reliable thicknesses of the exposed sequence are difficult to obtain because of the poor exposure of limestone beds, and the gently-undulating and slumped nature of the siltstone beds, which are often obscured by blocky scree. The thickness of the basal sandstone-conglomerate sequence ranges from 5 to 120 feet, and the siltstone unit is estimated to have a maximum thickness of at least 500 feet; the limestone is at least 175 feet thick at the surface. The maximum thickness of Sandover Beds is estimated at 750 feet.

In Farmout Place Ammaroo No. 1 Well the thickness of the Sandover Beds is 532 feet, and in No. 2 Well, 492 feet (Fig. 24a). Both wells began about 100 feet below the top of the exposed sequence, and the thickness in each approximates true thickness, because of low dips. In the south-eastern foothills of the Davenport Range, and in valleys within the Range, the thickness of the eroded Sandover Beds seldom exceeds 100 feet.

Contacts: The basal sandstone-conglomerate unit rests unconformably on the Arunta Complex, the Hatches Creek Group, and on igneous rocks which intrude the Group; in both Ammaroo No. 1 and No. 2 Wells a basal sandstone rests unconformably on Precambrian rocks. The basal sandstone-conglomerate is not everywhere present, and in some outcrops siltstone of the Sandover Beds is unconformable on the Hatches Creek Group. The outcropping Sandover Beds are overlain by Cainozoic sediments.

Fossils: The Sandover Beds contain a rich, well-preserved fauna; Etheridge (1902) described the trilobites Pagetia significans and Peronopsis elkedraensis in a collection made by the explorer Davidson (1905) in 1898.

Traves (1947, unpubl.) collected fossiliferous pebbles shed from the Sandover Beds and transported to the flood plain of the Sandover River near Argadargada homestead (Sandover River Sheet area; Plate 4); Opik described this fauna, but the descriptions and the fossils were destroyed by fire in 1953. After collecting fauna from outcrop of the Sandover Beds, Opik (1956b, op cit., p. 43) described the following trilobites:

"Xystridura browni"; Xystridura aff. browni; Xystridura (sensu strictu), sp.; Lyriaspis; Elrathina; Oryctocephalus, cf. reynoldsi and other species; Oryctocara aff. geikei (Walcott); Oryctocephalites cf. typicalis; Ptychagnostus (Triplagnostus) several species; Ptychagnostus (Tr.) cf. gibbus; Peronopsis elkedraensis (Eth.); Peronopsis significans (Eth.); Peronopsis sentalis (Salter).

Opik (1956b, op cit., p.43) states that the fossils have no species, except Peronopsis sentalis, in common with fauna from early Middle Cambrian sediments in north-west Queensland, but that the genera in the Sandover Beds and the Inca Formation (north-west Queensland) are the same.

In addition to the fauna listed above, Opik (1956b, op cit., p.43) mentions an occurrence of Bathynotus cf. holopyge (Hall)in the Sandover Beds, and Tomlinson (in Farmout Drillers, 1963, unpubl.) named fauna from localities in the vicinity of Farmout Place Ammaroo No. 1 and No. 2. This fauna contained several of the trilobites listed previously by Opik, and in addition the brachiopods Lingulella sp., Nisusia sp., and Acrothele sp. Also, hyolithids have been found by several workers in the area.

Age: lower Middle Cambrian

Correlates: The Wonarah Beds (Opik, 1956b, op cit., p. 43), the lower part of the Arthur Creek Beds, and the Inca Formation in north-west Queensland (Opik, 1956a).

Description and Comment: The sandstone-conglomerate unit of the Sandover Beds (which is not everywhere present at the base of the sequence) crops out well in mesas and in the scarps of low plateaux. The boulders, cobbles and pebbles in the conglomerate consist of silicified sandstone similar to that of the Hatches Creek Group, and in some localities a sedimentary breccia is present and consists of large angular blocks of the underlying Hatches Creek Group and of igneous rocks. Smith, Stewart and Smith (1961, p. 16) record a thickness of 10 feet of angular boulders of quartz sandstone and acid volcanic rocks in the base of the Sandover Beds 7 miles north of Supplejack Bore (Fig. 24b). Another variation is the presence of grey siltstone near the base in Ammaroo No. 1 Well (Farmout Drillers, 1963, unpubl.).

The thickness of the sandstone-conglomerate unit ranges from 5 to 120 feet in outcrop, but thicknesses exceeding 100 feet are rare and most exposures are between 30 and 60 feet thick. The gravel reported by drillers in No. 12 and Arganara Bores, and the sandstone in McRob Bore (Fig. 24a), are here interpreted as belonging to the basal unit of the Sandover Beds, but specimens of these lithologies have not been seen by geologists and none of the bores penetrated basement rock (unless the sandstone in McRob Bore belongs to the Hatches Creek Group).

No fossils have been found in the sandstone-conglomerate unit, but it is overlain conformably by fossiliferous siltstone.

The siltstone unit comprises the bulk of the outcrop of the Sandover Beds. It crops out in low rounded hills which have been deeply incised by creeks with fairly straight courses (presumably following major joints) and less deeply-incised by numerous, parallel, short streams at right angles to the major direction. The siltstone unit is usually buff or white and, together with its drainage pattern, is clearly defined on air photographs.

The siltstone beds are often silicified, and in some localities silicification has completely obliterated bedding planes. The beds roll gently, with dips in several directions, but east of Arganara Bore the regional dip is to the south-east, and west of it the regional dip is to the south or south-west. The absence of marker beds, and rolling dips and scree cover, make measurement of a complete outcrop section difficult; several sections of about 200 feet can be measured, and an estimate of the thickness of outcropping siltstone in the south-east is 500 feet. To this can be added about 175 feet in Arganara Bore to give a total of about 675 feet for the unit. The author has examined the spoil drains at several bores, and has found chips of brown, white and yellow siltstone in several of them; this has enabled the interpretation of drillers' logs for bores shown on Fig. 24a. The logs shown are those with more reliable data, but in addition, mention should be made that King's Bore (Fig. 24b) is reported to have penetrated granite at 316 feet, and the author has observed chips of Sandover Beds siltstone with agnostid trilobites from each of Ilbumric, No. 12 and No. 13 Bores. Grey to black shale and limestone have been reported in both Ammaroo No. 1 and No. 2 Wells, and this shale, in particular, is probably the unweathered equivalent of some of the light-coloured siltstone-shale sequence seen on the surface, and regarded by Condon (1961, unpubl.) as leached dolutite. The dolomitic shale recorded in both Ammaroo Wells further supports the theory. However, the presence of outcropping limestone indicates that the weathering and leaching processes in the Sandover Beds are complex.

The siltstone unit of the Sandover Beds contains a rich fauna, which is usually present in beautifully preserved specimens on bedding planes. Fossils are less abundant in higher stratigraphic horizons, but are extremely common in the lower parts of the sequence.

The limestone unit is poorly exposed; it occurs in an area bounded approximately by McRob and Limestone Bores and Ammaroo No. 1 Well. The older beds are usually lateritised and silicified and their thickness is unknown; younger beds are better exposed south of Limestone Bore and consist of blue and grey algal, thin-bedded to massive limestone, with a rich fauna of trilobites, brachiopods and hyolithids. This sequence is 175 feet thick, and includes some concealed intervals where shale could be interbedded. The limestone appears to grade eastward into the siltstone unit, and 2 miles west of Ammaroo No. 1 Well it is overlain by 50 feet of white, micaceous, siltstone, with chert and thin bands of silicified coquinite. In Ammaroo No. 1 Well, the limestone unit is 412 feet thick and it is 320 feet thick in Ammaroo No. 2 Well (Fig. 24a).

The Sandover Beds have been neither metamorphosed nor intruded by granite and they have not been folded. A few weak faults affect them between Arganara and Andagera Bores, and these faults are probably pre-existing faults in the Hatches Creek Group, which have been rejuvenated during an orogeny which affected sediments of the southern Georgina Basin in late Devonian or Carboniferous time. The faults mark the approximate northern-most extent of the orogeny. The

Sandover Beds have been strongly jointed, which probably accounts for the availability of water in the otherwise unpromising siltstone unit of the Beds.

The subsurface extent of the Sandover Beds is unknown. South of the outcrop area they have not been identified beneath the Quaternary plains stretching from the Sandover River to the northern foothills of the Dulcie Range (Plate 3); there is no information available on strata penetrated by Megalong, Bull Plain and No. 11 Bores (Fig. 24b). To the west, they are not known in outcrop between the Ammaroo-Elkedra road and the Stuart Highway (Plate 3), although some unfossiliferous sandstone referred to the Upper Cambrian-Lower Ordovician Tomahawk Beds could belong to the Sandover Beds. In the east and north-east, the Sandover Beds may be extensive in the subsurface and continuous with the Wonarah Beds and Gum Ridge Formation. Early Middle Cambrian sediments, equivalent in age to the Sandover Beds, have been drilled in BMR 13 Well (Smith et al., 1966), and Trew Bore (Fig. 24b) was drilling in green shale, which could be either Sandover Beds or Hatches Creek Group, at total depth (678 feet). The Bureau's core-holes Grg3 and 3A (Plate 3) were sited with the object of penetrating Sandover Beds, or their equivalents, but both were abandoned for technical reasons without providing conclusive proof; Grg3 was abandoned in ?Tertiary sediments at 206 feet, and Grg3A passed from ?Tertiary sediments to probable Upper Cambrian dolomite at 220 feet, and was abandoned at 243 feet.

The richly-fossiliferous black bituminous limestone and shale are probably good source beds for petroleum, and an early impetus to petroleum exploration in the Georgina Basin was provided by the accidental discovery of natural gas in a water bore on Ammaroo Station in 1956 (Mackay and Jones 1956, unpubl., Sprigg, 1958). This bore, named Discovery Bore, was drilled 50 yards south-west of the site of the subsequently-drilled Farmout Place Ammaroo No. 1 Well, and small quantities of methane and ethane were detected in samples collected by Mackay and Jones (1956, op cit.). Fluorescence was noted in cuttings and cores between 65 and 550 feet in Ammaroo No. 1 Well, and between 310-380 feet and 600-660 feet in Ammaroo No. 2. Cores of some bituminous beds gave a petroliferous odour when freshly-broken and a small flow of gas was encountered at 406 feet in Ammaroo No. 2 Well (Farmout Drillers, 1963, unpubl.). These occurrences indicate the source-bed potential of the

Sandover Beds, but porosity was very low and restricted to caverns in the limestone; no other exploratory tests have been made in the Sandover Beds.

Arthur Creek Beds

Definition: Derivation of Name: From Arthur Creek, a prominent stream which drains part of the outcrop area of the Beds in the Huckitta Sheet area (Plate 3). Smith (1964a) named the Arthur Creek Beds and defined them as a sequence of fossiliferous shale, limestone, dolomite and sandstone of Middle Cambrian age, which lies between the Lower Cambrian Mount Baldwin Formation and the upper Cambrian Arrinthrunga Formation. The term 'Beds' is used because poor outcrop prevents the precise definition of formations and because preliminary examination of the fauna suggest breaks in the sedimentary sequence which are not evident in the field (Opik and Tomlinson, pers. comm.). Because of poor outcrop, no reliable reference section can be given, but sections representative of the lithology can be seen on and near the road from Lucy Creek homestead to the Jervois mines and on the plains south-south-west of Lucy Creek homestead, and also west and south-west of the old Huckitta homestead (Plate 3).

Distribution: In a discontinuous belt from the north-eastern flank of the Jervois Range to the south-eastern foothills of the Dulcie Range, and in a smaller belt extending west and south-west of the old Huckitta homestead.

Map Reference: Huckitta 1:250,000 Sheet; Plate 3.

Lithology and Thickness: In the eastern belt, three units can be recognised in the Arthur Creek Beds, and Smith (1964a) recorded them, in descending order, as:

	Thickness (feet)	Lithology
Unit 3	160 (measured)	Sandstone; buff, white and brown, with Asthenopsis sp., in part lensing into brown dolomite and blue limestone; minor siltstone
Unit 2	250 (estimated)	Limestone; blue, black and grey, flaggy with trilobites and brachiopods

	Thickness (feet)	Lithology
Unit 1	600 (estimated)	Shale and siltstone, white and buff, with numerous trilobites; thin blue coquinite, and thin, medium-grained, pebbly sandstone sometimes at the base of the sequence.

In the western belt, the lithology consists of dolomite and limestone, sandstone, siltstone, chert and weathered carbonate rocks; many of the beds have been strongly lateritised. The thickness of the Arthur Creek Beds in this western belt is about 750 feet, but the location of the upper boundary may be inexact and the thickness could be either 500 or 1000 feet.

Contacts: In the eastern and western belts the Arthur Creek Beds appear to be conformable on the Mount Baldwin Formation, but fossil evidence indicates a disconformity between the sequences. In the eastern belt the Arrinthrunga Formation conformably overlies the Arthur Creek Beds, but in the western belt the contact between these units is either concealed or occurs in an apparently-conformable sequence of carbonate rocks where the boundary is not precisely determined.

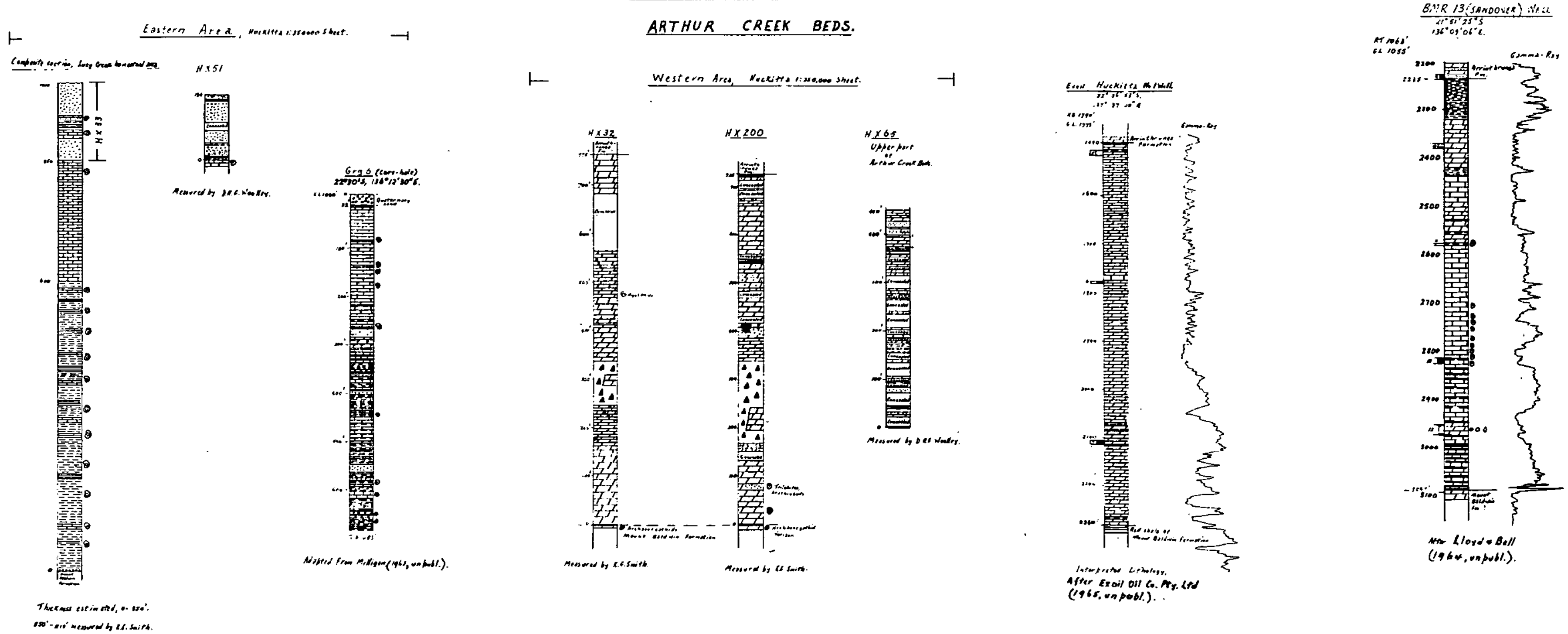
Fossils: The rich fauna of the Arthur Creek Beds has not been fully examined; from fauna collected in the eastern outcrop belt Tomlinson (in Casey and Tomlinson, 1956, pp. 62-66) identified fossils representative of each of the three zones Dinesus - Xystridura, Ptychagnostus atanus and Leiopyge laevigata; rocks of Unit 1, above, contained Xystriduna aff. browni (Eth.), and Pagetia cf. significans, of lower Middle Cambrian age; Unit 2 contained the trilobite Fouchouia and an undescribed genus of Nepeidae Whitehouse, together with Ptychagnostus atanus, Peronopsis spp. and the brachiopod Lingulella, of middle Middle Cambrian age. In sandstone of unit 3, the trilobites Asthenopsis and Crepicephalina establish an upper Middle Cambrian age ("time of Leiopyge Laevigata") for the top of the unit. Additional support for this age came from the identification of the trilobite Dorypyge (Opik and Tomlinson, pers. comm.) which was collected later from the sandstone of unit 3.

Very few fossils have been found in the western outcrop belt. Tomlinson (in Casey and Tomlinson, 1956, op cit.) identified Hyolithes and undescribed

F+ 25

GEORGINA BASIN

ARTHUR CREEK BEDS.



To accompany Records 1967/

billingseloid brachiopods in a sandstone bed about 7 miles south-south-west of old Huckitta homestead, and Smith (1964a, p. 39) reported another horizon of trilobites and brachiopods in the Arthur Creek Beds, 85 feet stratigraphically above Lower Cambrian archaeocyathid-bearing beds of the Mount Baldwin Formation. The zonal age of the Middle Cambrian fauna in this western belt has not been determined.

Age: lower-uppermost Middle Cambrian in the eastern belt; Middle Cambrian in the western belt.

Correlates: The lower part of the Sandover Beds, and the Marqua Beds.

Description and Comment: In the eastern belt, unit 1 usually crops out in isolated, low mesas, with shallow dips except in fault blocks; the beds are usually silicified and in some places have been replaced entirely by chert. A basal sandstone, up to 20 feet thick, is present in some localities, but in others the shale and siltstone lithologies rest on quartz sandstone of the Mount Baldwin Formation with apparent conformity. The fossils in unit 1 are of lower Middle Cambrian age, but the underlying Mount Baldwin Formation does not contain fossils and there is no palaeontological evidence to suggest a break in sedimentation except that the fossils in unit 1 are not of earliest Middle Cambrian age. Contacts between unit 1 and the overlying unit 2 have not been observed.

Unit 2 occurs mainly in the area between Jervois Range and Arthur Creek, where it underlies open, grassy plains. Some beds of gently-dipping limestone crop out, but usually the presence of the unit is evident only by chips of limestone excavated from rabbits' burrows. Further west, the limestone is exposed in fault blocks and has steep to overturned dips. Many beds of limestone emit petroligerous odours when freshly broken. The fauna from this unit is of middle Middle Cambrian age, but the base is not exposed. The outcrop thickness is estimated at 250 feet, but poor outcrop and gently-rolling dips give this figure a low reliability. The Bureau's core hole Grg 6 penetrated most, but not all, of unit 2, and examination of the log (Milligan, 1963, unpubl., and Fig. 25, this Bulletin) shows mainly limestone, calcarenite and calcilutite from 23 to 333 feet, and mainly siltstone from 333 to 683 feet (total depth). On lithological grounds the author interprets the sequence to 333 feet as unit 2, and the interval 333-683 feet as unit 1. However, the fauna in the cores has not been examined and the likely gradation from siltstone and shale to limestone in unit 1 would further complicate the lithological identification of either unit.

The trends of limestone beds in unit 2 show clearly on air photographs and gentle domes and basins can be traced on the north-western flank of the Jervois Range. These gentle structures are difficult to map on the ground.

Unit 3 crops out in a few prominent, dark brown mesas and low rises in the eastern area, but not west of 136°E. Sandstone is the dominant lithology, but lateral gradation into limestone and dolomite is common and it is considered probable that the sandstone represents large lenses in carbonate rocks rather than a continuous sandstone unit. The lithologies of the unit are shown in the following sections:

HX33, measured by the author, about 3 miles south of Grg6 (Plate 3, and Fig. 25) in descending order consists of:

Thickness (feet)	Top of mesa
70	Sandstone; buff and yellow, calcareous, medium-bedded, medium-grained
1	Limestone; grey, dense, with brachiopods and trilobites
8	Sandstone; calcareous, buff and yellow, medium-bedded, fine-grained; (about 350 yards north of the section line, this unit contains the trilobite Asthenopsis)
17	Calcilutite; grey and pink, laminated to thin-bedded; and limestone, grey, medium-bedded
20	Limestone; dark grey, thin-bedded, cross-bedded, sandy, with brachiopods
43	Sandstone; calcareous, yellow, soft, thin-bedded, micaceous
159,	thickness of part of sequence. The base is not exposed, but is underlain by limestone of unit 2.

About ½ mile west of section line HX33, flaggy blue limestone grades laterally, within a very short distance, into yellow-brown, medium-grained sandstone which contains the upper Middle Cambrian trilobite Dorypyge.

Section HX51 (Fig. 25), measured by D.R.G. Woolley in a prominent mesa about 5 miles north-west of Lucy Creek homestead, consists of:

Thickness (feet)	Top of mesa
11	Quartz sandstone; yellow, flaggy, medium-grained, well-sorted
1	Limonite; botyroidal (weathered shale)
44	Quartz sandstone; yellow brown, medium-grained, medium-bedded, with 5%-10% argillaceous matrix
18	Concealed
2	Quartz sandstone; cream, medium-grained, massive, poorly-sorted
12	Quartz sandstone; white, fine-grained, thin-bedded, friable
12	Quartz sandstone; dazzling white, fine-grained
3	Dolomite; brown, laminated
7	Quartz sandstone; white, fine-grained, laminated
7	Quartz sandstone; grey, fine-grained, medium-bedded, friable, with small brachiopods
6	Sandstone; calcareous, greenish white, laminated to thin-bedded, with small brachiopods
11	Sandstone; calcareous, friable, greenish-grey, fine-grained, with thin interbeds of blue limestone
134,	thickness of part section, which is underlain by 14 feet (exposed) of fossiliferous blue limestone of unit 2.

In a mesa two miles north-west of HX51, Woolley has measured a thickness of 104 feet of Unit 3 (In Smith, 1964a), consisting of calcareous sandstone and quartz sandstone, with lenses and interbeds of limestone. Trilobites and brachiopods were collected 44 feet above the base of the sequence, and Opik (pers. comm.) states that their age is uppermost Middle Cambrian.

Lithologies in the western belt of outcrop bear little resemblance to those in the eastern belt (Fig. 25); fresh rock consists mainly of dolomite, but most of the sequence is lateritised and weathered and is composed of weathered carbonate rocks, chert, and ferruginous sandstone and siltstone, all of which crop out poorly. Some soft yellow dolomitic siltstone is known but outcrop is poor. Fossils are uncommon and those which have been found (all near the base of the sequence) have not been examined completely. The precise dating of fossils just above the base of the Arthur Creek Beds, and those in the top of the Mount Baldwin Formation will be extremely important in determining if a significant break in deposition occurs between the two units.

The lithologies of measured sections of outcrop in the western area, are shown in Fig. 25, and the interpreted lithology logs of both Exoil Oil Company Pty Limited Huckitta No. 1 Well and the Bureau's stratigraphic well BMR13 (Sandover) are shown on the same figure. Dolomite constitutes most of the outcrop in the localities of HX32 and HX200, but towards the north-western extremity of the outcrop area sandy dolomite, leached and ferruginised siltstone and red-brown sandstone comprise most of the outcrop. HX65 was measured in the area and shows some of this lithology but it is only part of the sequence, and no reliable section is available in the lower beds.

Both the base and top of the Arthur Creek Beds are difficult to determine in the western area, because the top of the underlying Mount Baldwin Formation is often dolomitic, and the overlying Arrinthrunga Formation consists largely of dolomite. The base of the Arthur Creek Beds is placed immediately above a prominent bed of archaeocyathid-bearing dolomite of the Mount Baldwin Formation; this bed forms a prominent marker which can be traced for about 20 miles, and it is 40 feet stratigraphically below Middle Cambrian fossils reported by Casey and Tomlinson (1956, op cit.). The upper boundary of the Arthur Creek Beds is placed at the change from yellow dolomite below to a sequence of purple, buff and blue dolomite and red sandy siltstone above, which contains trilobites of lower Upper Cambrian age (Opik, pers. comm.). The lithology in the basal part of the Arrinthrunga Formation is variable but an approximate boundary with the Arthur Creek Beds can be drawn by tracing beds on air photographs.

The Middle Cambrian sequence in the Huckitta No. 1 Well is the first record of subsurface lithology of the Arthur Creek Beds in the western area. No fossils were recorded in cores and cuttings, and whilst the base of the sequence is clearly defined, the present author has some doubt about the upper boundary. The gamma-ray log to about 1900 feet shows little if any difference from that recorded in the Arrinthrunga Formation, but the lower part of this log has an entirely different character. Two alternatives are possible:

(1) that the boundaries selected are correct, and that the change in gamma-ray characteristics is due to increasing "shale" content below 1900 feet; this is supported by the occurrence of black, micaceous siltstone in Core No. 7.

(2) that the boundary between the Arrinthrunga Formation and the Arthur Creek Beds is at 1900 feet approximately; this is supported by a decreased thickness of Arrinthrunga Formation in the well, but only partly supported by similar gamma-ray log characteristics, because the lithologies in the well are equally difficult to distinguish as on the surface.

The correct interpretation of the boundary may be resolved if fossils are found and determined in cores and cuttings. If the second alternative quoted above is correct, the inference is that the Huckitta Anticline may be a "draped" structure, with a thin sequence of Middle Cambrian sediments over its crest. This raises the possibility of flank tests for oil and gas. But if the log is correct as it stands, the Arrinthrunga Formation is 800 feet thinner than in outcrop a few miles away, and this probably indicates a disconformity between the Arthur Creek Beds and the Arrinthrunga Formation, at the locality of the well.

The Arthur Creek Beds are not known in outcrop west of the Bundey River, although they may be present and covered by sediments deposited in a late Upper Cambrian transgressive sea. To the east of the Jervois Range the Beds do not crop out, but they are probably continuous in that direction with the Marqua Beds. In the north, the Arthur Creek Beds do not crop out, but they may be continuous under the Arrinthrunga Formation, and a Middle Cambrian sequence penetrated in BMR13 (Sandover) Well is tentatively correlated with the Arthur Creek Beds.

The lithology and gamma-ray log of the Middle Cambrian sequence in BMR13 (Sandover) Well is shown on Fig. 25. The section consists of a mixed limestone-siltstone-dolomite lithology which is not easily subdivided into units similar to those of the eastern outcrop area of the Arthur Creek Beds, but there is an increasing proportion of "shale" in the lower part of the sequence. Gatehouse (In Smith, 1967) has made a preliminary examination of the fossils obtained in cores and cuttings, and considers that the occurrence of Pagetia significans (Etheridge) and Xystridura sp. indicates an age high in the lower Middle Cambrian for the rocks in the interval 2750-2830 feet. Fossils higher in the well (2574 feet) are not diagnostic, but are assumed to be of Middle Cambrian age.

Marqua Beds

Definition: Derivation of Name: From Marqua homestead (latitude 22°49'S, longitude 137°21'E), which is about 4 miles north-west of outcrops of limestone and sandstone belonging to the sequence. Smith and Vine (1960, unpubl.) applied the name to a sequence of fossiliferous blue chert, silicified shale and siltstone, limestone and calcareous sandstone which lies between the Field River Beds below, and the Arrinthrunga Formation above, in the Tobermory Sheet area (Plate 4). Smith (1963a) reported the same sequence in the Hay River Sheet area, and Reynolds (1964, unpubl.) noted outcrops in the western part of the Mount Whelan Sheet area of Queensland. A complete study of fossils from the sequence has not been made, but a preliminary study indicates that there may be breaks in the sequence which are not otherwise discernable and accordingly the term "Beds" is preferred to "Formation".

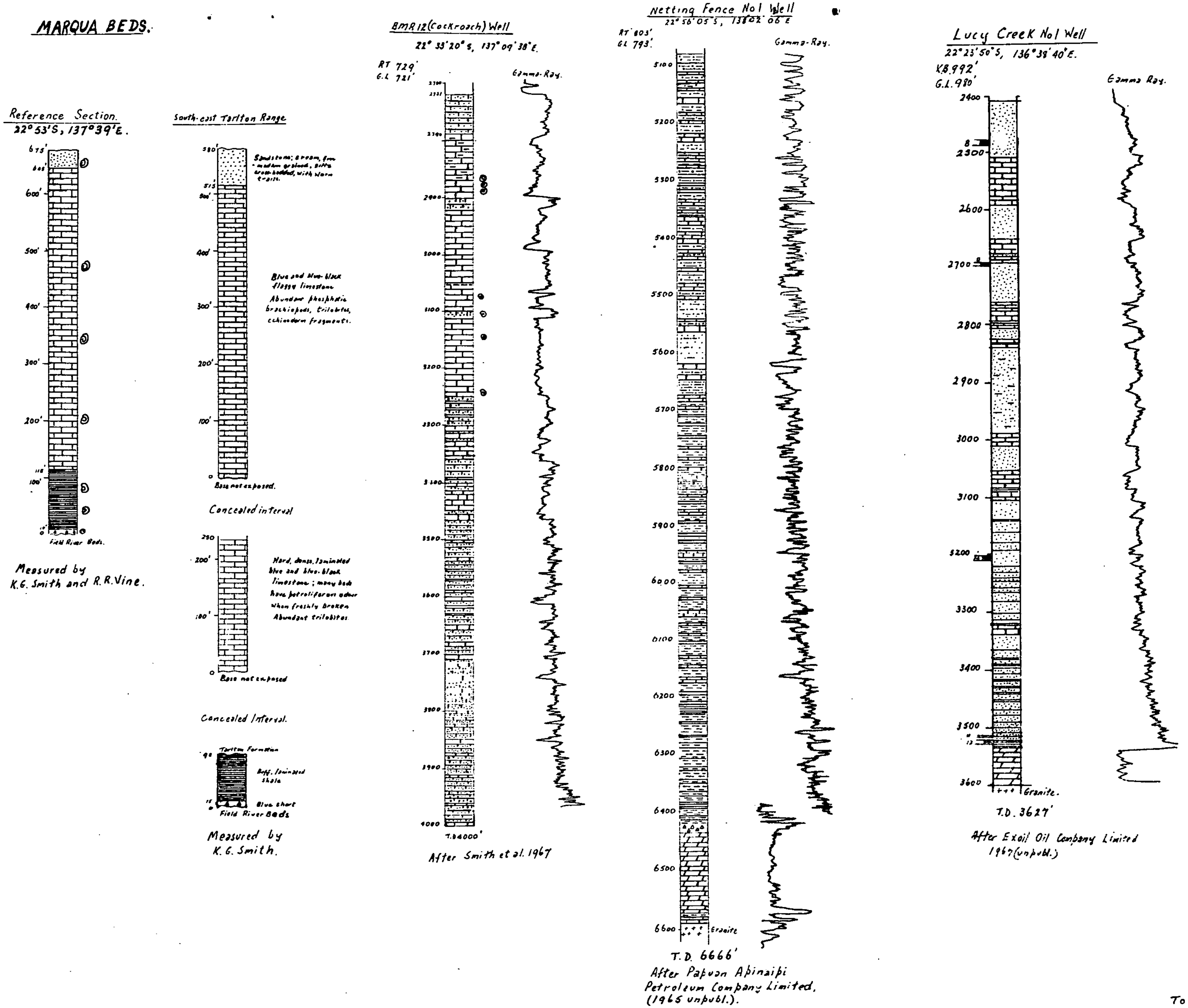
The reference section for the Marqua Beds is on Marqua station at about latitude 22°53'S, longitude 137°39'E, and about ½ mile north of the junction of station tracks leading to Noakes Bore and to Craigie Dam. The section is about 50 yards west of an old track which leads north from this junction. Although the sequence is structurally disturbed in this locality, and the thickness measurements are not considered reliable, the reference section has been chosen there because all of the lithological units comprising the Marqua Beds are present, and because the location is easily accessible.

Distribution: In the Northern Territory the Beds crop out in several small, isolated areas south-east of the Tarlton Range and east and south-east

Georgina Basin.

MARQUA BEDS.

Fig 26



To accompany Records 1967/61

of Mount Ewing, and in larger areas east of Marqua homestead. In Queensland, they occur in a small area on the western flank of the Toomba Range. In the subsurface they occur in BMR 12 (Cockroach) Well, in the Northern Territory, and in Papuan Apinaipi's Netting Fence No. 1 Well in Queensland.

Map Reference: Tobermory, Hay River and Mount Whelan 1:250,000 Sheet areas, and, (subsurface only), Glenormiston 1:250,000 Sheet area; all are on Plate 4.

Lithology: Blue and white chert, buff and white silicified shale and siltstone, blue, grey and black fine-grained flaggy limestone, grey sandy limestone, brown and cream medium-grained calcareous sandstone. In the subsurface, light grey calcareous sandstone, light grey micro-crystalline, argillaceous limestone, and minor dark grey and black pyritic siltstone (BMR 12); light grey to dark grey siltstone, grey and fawn limestone, black micaceous shale, dolomitic limestone and sandstone (Netting Fence No. 1 Well).

Thickness: Outcrop thicknesses are unreliable, because of poor outcrop and structural complexity. The reference section is 675 feet thick; south-east of the Tarlton Range, several reliable measurements of part sections, totalling 925 feet, have been made but structural complexity precludes estimation of thickness in concealed intervals between the measured sequences. The Marqua Beds exceed 1279 feet in BMR12 (Cockroach) Well, and Netting Fence No. 1 Well penetrated at least 1500 feet of the sequence; since the dips in this sequence range from 3^{o} to 2^{o}, the true thickness is about 1300 feet, but it is not known whether the full sequence of Marqua Beds is present in the well.

Contacts: In outcrop, the Marqua Beds rest unconformably on various stratigraphic units of the Field River Beds, and some fault contacts with the Field River Beds are known; in Netting Fence No. 1 Well the Marqua Beds rest on a granite which has been dated at 1643 m.y. The Marqua Beds are overlain by the Arrinthrunga Formation in outcrop and in BMR12 (Cockroach) Well; no evidence of an unconformity is known, but a disconformity may separate the two units. In Netting Fence No. 1 Well the dip evidence suggests unconformity between the Marqua Beds and overlying Upper Cambrian sequences, but deviation of the hole may account for angular differences, which are slight and less than 5^{o}.

Fossils: Tomlinson (_in_ Casey and Tomlinson, 1956, op cit., p. 67) has identified the trilobites _Pagetia_ cf. _significans_ and _Xystridura_ aff. _browni_ collected in white, siliceous shale of the Marqua Beds, and also mentioned _Acrotreta_ and other phosphatic brachiopods in grey limestone which has now been mapped as high in the Marqua Beds. The trilobite species were identical with those of the Sandover Beds, but distinct from those of north-west Queensland.

Many new collections of trilobites and brachiopods were made when the Tobermory Sheet was mapped; palaeontological work is incomplete, but Opik has made preliminary examinations, both in the field and in the office, and considers (pers. comm.) that the fauna indicates a range of ages from lower to upper Middle Cambrian.

Gatehouse (_in_ Papuan Apinaipi Petroleum Company Ltd, 1965, unpubl.) has examined part of Core No. 19 (6414-6424 feet) in Netting Fence No. 1 Well, and from core at 6418 feet has reported conodonts and the following phosphatic brachiopods: _Lingulella_, _Acrothele_, _Acrotreta_, _Chancelloria_.

An accurate zonal date cannot be applied because of the absence of trilobites in this fauna, but the fossil assemblage suggests a middle Middle Cambrian age.

Age: lower to upper Middle Cambrian.

Correlates: The Arthur Creek Beds.

Description and Comment: Usually, lower units of the Marqua Beds do not crop out strongly, but a band of blue chert at the base of the sequence is sometimes prominent; in some localities white leached and brown-red-ferruginised siltstone crops out in mesas, but the beds are usually obscured by scree, and the lithology is sometimes difficult to distinguish from the Triassic Tarlton Formation. Higher units consist mainly of limestone, which sometimes forms prominent ridges but often is poorly-exposed, although the pattern is evident on air-photographs; the limestone usually supports a dense vegetation of gidyea, which is also evident on air photographs but which grows also on Adelaidean, Upper Cambrian and Ordovician sediments of the general area. Lenses of sandstone in the top of the unit crop out in isolated mesas.

In outcrop, the Marqua Beds resemble the Arthur Creek Beds in the eastern part of the adjoining Huckitta Sheet area. In the reference section, the Marqua Beds, in descending order, consist of:

	Thickness (feet)	Top of mesa
Unit 3	30	Sandstone; calcareous, brown and buff, medium-grained, flaggy, with fragments of trilobites
Unit 2	530	Limestone; blue, fine-grained, poorly-outcropping, medium and thin-bedded, with trilobite fragments; some strongly-outcropping thin-bedded, grey, sandy medium-grained limestone
Unit 1	105	Shale; buff and white, hard, silicified, thin-bedded, with abundant trilobites including *Xystridura* sp. (Opik pers. comm.); some white chert
	10	Chert; blue, with fragments of trilobites; forms a prominent band
Total	675,	thickness of part section, unconformably overlying dolomite of the Field River Beds.

This sequence is shown on Fig. 26 and the units 3, 2 and 1 correspond lithologically with similarly-numbered units in the Arthur Creek Beds (Fig. 25). The basal blue chert has not been observed in the Arthur Creek Beds, but its equivalent could be present. It is not always present in the Marqua Beds.

A sequence measured south-east of the Tarlton Range (Fig. 26) contains four lithological units which are similar to those of the reference section of the Marqua Beds, but the 250-foot section of blue and blue-black laminated limestone has not been observed in the reference section.

The lithologies in BMR12 (Cockroach) Well and in Netting Fence No. 1 Well are shown in Fig. 26; the sandstone of unit 3 has been interpreted in BMR12 (Cockroach) Well, in the interval 2721-2790 feet, and much of the lithology consists of calcareous sandstone and sandy and argillaceous limestone. Fossils are few and only fragments have been recovered. The beds are horizontal and the thickness in the well represents the true thickness.

Netting Fence No. 1 Well penetrated the Marqua Beds from 5080 feet to 6590 feet, where the Beds rest unconformably on Precambrian granite. The upper boundary in the well is not precisely determined, but Core No. 14 contains Upper Cambrian fossils (Gatehouse, in Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.), and the boundary is placed at a lithological break between essentially limestone above the greywacke with limestone interbeds below, as determined by the operator. The Marqua Beds in Netting Fence No. 1 Well consist mainly of greywacke and interbedded limestone from 5080 to 5680 feet, limestone and interbedded siltstone from 5080 to 6420 feet, and essentially dolomite from 6420 to 6590 feet. The Papuan Apinaipi Petroleum Company Limited (1965, unpubl.) has used the names Netting Fence Formation and Thorntonia Limestone for the upper and lower parts respectively of the sequence, but the author prefers the term Marqua Beds for the whole sequence.

The subsurface extent of the Marqua Beds is unknown; they are assumed to be present on the eastern (downthrown) side of the Toomba Fault, but have not been identified east of Netting Fence No. 1 Well. Likewise they are unknown north of BMR12 (Cockroach) Well, but are assumed to extend northwards and to be contiguous with a thin Middle Cambrian sequence reported in Mulga No. 1 Well (Alliance Petroleum Australia N.L., 1965, unpubl.).

The Marqua Beds have been neither metamorphosed nor intruded by granite, but they have been affected by strong faulting movements during the Alice Springs Orogeny, and in many places have been faulted against some of the older units in the Field River Beds.

QUEENSLAND

Opik (1956a, 1960 and 1961) has published descriptions of all of the Middle Cambrian outcrops in the Queensland part of the Georgina Basin and the descriptions which follow are substantially from his work, with minor additional material obtained from published Explanatory Notes (in which Opik has often been responsible for sections dealing with Palaeozoic geology), from unpublished material of later workers in the Camooweal area, and from exploratory and stratigraphic wells. Opik (1956a and 1960) formally named all of the units.

Beetle Creek Formation

Definition: Derivation of Name: From Beetle Creek, a small tributary of the Templeton River, at 139°18'E, 20°36'S approximately (Mount Isa 4-mile Sheet). This is one of the best-known localities for Middle Cambrian rocks in Queensland. The lower part of the Formation is known as the Yelvertoft Bed (David, 1932) which takes its name from Yelvertoft Station, and has its type area at Halls Memorial (latitude 20°11'S, longitude 138°53'E) on the Barkly Highway about 14 miles north-west of Yelvertoft Station.

Distribution: As erosional residuals near the eastern margin of the Georgina Basin and as outliers on basement rocks; the formation occurs on each of the Camooweal, Mount Isa, Urandangi (Plate 2) and Duchess (Plate 4) Sheet areas.

Lithology: Siliceous shale, chert, siltstone, fine-grained sandstone, and thin, silicified limestone interbeds; a basal conglomerate is sometimes present and bituminous flaggy limestone is reported in the Duchess Sheet area (Carter and Opik, 1963). The complete lithology of the formation is unknown because of its preservation only as residuals.

Thickness: 50 feet at Beetle Creek (Opik, Carter and Noakes, 1961); these authors state that the thickness of the Yelvertoft Bed is 15 feet. Opik (1960, op cit., p. 100) states that the thickness of the Beetle Creek Formation ranges from 10 to 60 feet; however, Carter and Opik (1963) have estimated a thickness of "several hundred feet" in the Duchess Sheet area. In Black Mountain No. 1 Well, Phillips Petroleum Company (1963, unpubl.) reported 487 feet of sediments which, although un-named, were regarded as probably equivalent to the Beetle Creek Formation.

Contacts: The Beetle Creek Formation rests unconformably on Precambrian metamorphic rocks and on the Pilpah Sandstone. Opik (1956a, op cit., p. 14) reported that at Beetle Creek silicified Collenia and Cryptozoon-like bodies, probably attached to the basement, occur at the base of the Formation and may belong to it or may represent residuals of an otherwise completely-eroded "sub-Cambrian" sequence.

The Beetle Creek Formation is overlain both conformably and disconformably by the Inca Formation in some localities, but in others it is either overlain disconformably by other younger Middle Cambrian units, or occurs as residuals.

Fossils: Whitehouse (1936 and 1939) described the fauna, and Opik (1956, op cit., p. 17-18) lists the trilobites Redlichia idonea (Whitehouse) and Redlichia chinensis (Walcott) in the lower part of the Formation, whilst the upper part contains several species of both Xystridura and Lyriaspis, Pagetia cf. significans (Etheridge), Peronopsis normata Whitehouse, and, less common, Kootenia modica (Whitehouse) and Dinesus ida (Etheridge). The fauna also includes some ptychoparid trilobites, two bathyuriscids, (Fuchouia), Eodiscus?, Elathrina and Oryctocephalus. Opik (1960, op cit., p. 103) reported Biconulites, brachiopods and several general of Archaeostraca in the Yelvertoft Bed.

Age: lower Middle Cambrian.

Correlates: The Sandover Beds, Wonarah Beds and Thorntonia Limestone.

Description and Comment: Opik (1960, op cit.) regarded the Beetle Creek Formation as one of regional extent; it has a wide distribution, in disconnected areas, around the eastern margin of the Georgina Basin, but has not been identified in the subsurface. The Formation is contemporaneous with the Thorntonia Limestone, and the two units interfinger.

The beds of the Inca Creek Formation are often horizontal or gently dipping, but they have been folded in the Duchess area (Plate 4), and faulted in areas near the Pilpah Range (Plate 2).

Border Waterhole Formation

Defintion: Derivation of Name: From the Border Waterhole, which is about 1½ miles north-west of Highland Plains homestead, on the Northern Territory-Queensland border, at latitude 18°37'S, approximately. Opik (1960) named the Formation and briefly described it; Carter and Opik (1961, op cit.) gave a more complete description, and Smith and Roberts (1963) described the formation's Northern Territory outcrops. None of these authors has designated a type section for the Border Waterhole Formation.

Distribution: In a fault zone on the downthrown (southern) side of the Littles Range Fault, which extends from Queensland into the Northern Territory (Plate 2). Outcrops of the Formation are restricted to a segment of the fault zone, about 30 miles long, and occur in low, rubbly ridges which are sometimes capped by laterite.

<u>Map Reference</u>: Mount Drummond and Lawn Hill Sheet areas (Plate 2).

<u>Lithology</u>: Siliceous shale, with chert rubble on the surface, overlain by dolomitic limestone with 50 per cent or more chert in some places, and interbeds of chert and siliceous shale (Carter and Opik, 1961, op cit.). Smith and Roberts (1963, op cit.) described the lithology in the Northern Territory as white and cream siltstone, shale and chert with minor limestone and they also reported an occurrence of pebble conglomerate at the base of the formation in a locality north of Lancewood Creek (not shown on Plate 2).

<u>Thickness</u>: About 100 feet (estimated) in Queensland (Carter and Opik 1961, op cit.); a maximum of about 150 feet in the Northern Territory (Smith and Roberts, 1963, op cit.).

<u>Contacts</u>: The Border Waterhole Formation rests unconformably on Precambrian rocks, and is overlain conformably by the Currant Bush Limestone. Carter and Opik (1961, op cit., Table 1, facing p. 7) state that the Border Waterhole Formation rests on Camooweal Dolomite immediately west of the Northern Territory-Queensland border; Smith and Roberts (1963, op cit., Table 1, facing p. 6, and p. 12) state that in some places the Currant Bush Limestone (which overlies the Border Waterhole Formation) dips south under the Camooweal Dolomite; elsewhere in Northern Territory the contact is faulted.

<u>Fossils</u>: <u>Xystridura</u>, <u>Lyriaspis</u>, <u>Peronopsis</u>, <u>Helcionella</u> (Carter and Opik, 1961, op cit.).

<u>Age</u>: lower Middle Cambrian.

<u>Correlates</u>: The Beetle Creek Formation, and the Burton Beds.

<u>Comment</u>: This is another occurrence of early Middle Cambrian sediments, containing a <u>Xystridura</u> fauna, which form the basal Georgina Basin sequence. The beds are either horizontal or gently-dipping, except near faults, and they are probably continuous in the subsurface with the Burton Beds, and may grade laterally into part of the Camooweal Dolomite. In outcrop there are two interpretations of the relationship between the Border Waterhole Formation and the Camooweal Dolomite; on the evidence from field work and stratigraphic wells in the Camooweal area, it would seem that the interpretation of Smith and Roberts (1963, op cit.) is correct.

Thorntonia Limestone

Definition: Derivation of Name: From Thorntonia homestead (latitude 138°56'20"E, longitude 19°30'00"S) which is situated near outcrops of limestone of the formation. Opik (1956a, op cit.) named the formation, and has mapped it in all its known occurrences. No type section has been proposed.

Distribution: From near Lawn Hill (latitude 18°35'S, longitude 138°24' 40"E) in the north, south along the eastern margin of the Georgina Basin and thence via the Quita Creek area eastwards to Mount Birnie (latitude 21° 38'S, longitude 139°56'E). The main outcrop area lies between Lawn Hill and Thorntonia homestead, approximately, and here the formation has been shown separately on Plate 2. Elsewhere, the outcrop areas are discontinuous and much smaller, and for convenience they are included in the Єm1 group of units. The previously-published 4-mile and 1:250,000 Sheets show the Thorntonia Limestone as an individual formation.

Map Reference: Lawn Hill, Camooweal (Plate 2), Urandangi, Glenormiston, Duchess (Plate 4) 1:250,000 Sheet areas.

Lithology: Thick-bedded dolomitic limestone, dolomite, and limestone with chert layers and nodules; in some places these lithologies are replaced by the siliceous shale, chert, siltstone, fine-grained sandstone and silicified limestone of the Beetle Creek Formation.

Thickness: The maximum outcrop thickness is estimated at 200 feet (Opik, 1956a, op cit.) but usually much less is preserved - Carter and Opik (1963) record 60 feet in the Duchess Sheet area, and Noakes, Carter and Opik (1959) reported thicknesses ranging from 30-70 feet in the Urandangi Sheet area. Amalgamated Petroleum Exploration Pty Limited (1963, unpubl.) reported 340 feet of Thorntonia Limestone in the interval 760 to 1100 feet in Morstone No. 1 Well, and here, at least, the formation is thicker than the surface evidence suggests.

Contacts: The Thorntonia Limestone rests unconformably on Precambrian basement and on Lower Cambrian(?) rocks, and is overlain conformably by the Inca Creek Formation and by the Currant Bush Limestone.

Fossils: Redlichia idonea Whitehouse, several species of Xystridura and Lyriaspis, Pagetia cf. significans (Etheridge), Ptychopariidae and Girvanella are common.

Age: lower Middle Cambrian.

Correlates: The Beetle Creek Formation and lower part of the Age Creek Formation.

Comment: This formation crops out over a wide area in the Lawn Hill-Camooweal Sheet areas, and as small residuals in many other areas marginal to the Georgina Basin. Opik (1956a, op cit.) regards it as a formation of regional extent and has used the name Thorntonia Limestone for discontinuous outcrops separated by great distances from the Thorntonia homestead area where the formation was named. The unit is usually richly fossiliferous, and is one of the basal Georgina Basin sequences. It is also the basal sequence of the succession in the former "Undilla Basin", where Opik (1960) believes that it rests disconformably on the Camooweal Dolomite; however, in Morstone No. 1 Well the Thorntonia Limestone rests directly on Precambrian basement and no Camooweal Dolomite was identified in the well (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.).

Inca Creek Formation

Definition: Derivation of Name: From Inca Creek, a tributary of the Buckley River. The Creek drains large outcrop areas of the formation in the Camooweal and Mount Isa Sheet areas. Opik (1956a, op cit.) named the formation.

Distribution: In low rolling hills, mesas and cliffs and creek banks in the Camooweal and Mount Isa Sheet areas (Plate 2); as mesa cappings, and in cuestas and low rises in the Duchess Sheet area (Plate 4).

Lithology: Laminated siliceous shale and siltstone (bituminous when fresh), chert bands and large lenses of impure flaggy and ellipsoidal limestone in the west; in the Duchess Sheet area, the lower part of the formation consists of siliceous shale with chert, siltstone, sandstone and bituminous limestone, whilst the upper part consists of bituminous, shaly limestone.

Thickness: This increases southwards, from 10 feet near Thorntonia homestead to 500 feet in the Mount Isa Sheet area, but the thickest sequences are near Mount Merlin (Duchess Sheet area) where 2000 feet is estimated (Carter and Opik, 1963, op cit.). In Black Mountain No. 1 Well, an un-named sequence correlated with the Inca Formation has a thickness of 1772 feet (Phillips Petroleum Company Limited, 1963, unpubl.).

Contacts: The Inca Creek Formation is conformable on the Thorntonia Limestone, in the western outcrop areas, but unconformable on the Pilpah Sandstone and on the Riversdale Formation. In the Duchess Sheet area, the formation is unconformable on Precambrian basement and on the Mount Birnie Beds and disconformable on residuals of the Beetle Creek Formation.

Fossils: The fauna consists dominantly of agnostid trilobites and sponge spicules. Whitehouse described the fauna and Opik (1956a) listed Ptychagnostus Gibbus, Ptychagnostus atavus, Agnostus seminula Whitehouse, Goniagnostus purus, Hypagnostus vortex.

Age: Middle Cambrian.

Correlates: The Currant Bush Limestone.

Comment: The Inca Creek Formation is contemporaneous with the Currant Bush Limestone. Opik (1956a, op cit.) reported that the "rising" contact between the two formations "dips" north, and therefore the outcrops of the lower part of the Inca Creek Formation are more abundant than those of the upper part.

The Inca Creek Formation is a stratigraphical unit of regional extent and although many miles separate the eastern and western outcrops the same formation name has been used. The fossiliferous bituminous sediments may be source beds for petroleum, and Noakes (pers. comm.) considers that a relatively high percentage of phosphate minerals in shales of the formation may indicate phosphate deposits in it.

The western outcrops of the Inca Creek Formation are either horizontal or gently-dipping, but the eastern outcrops have been moderately folded and dips of 20 degrees are common (Carter and Opik, 1963, op cit.).

Currant Bush Limestone

Definition: Derivation of Name: From Currant Bush Creek, a tributary of Harris Creek, about 10 miles south-west of Thorntonia homestead.

Map Reference: Camooweal 1:250,000 Sheet area (Plate 2).

Distribution: Along the northern margin of the Georgina Basin in the Mount Drummond and Lawn Hill Sheet areas (Plate 2); outcrops here are of small extent, in fault blocks. The main outcrops are near the eastern margin of the Georgina Basin, in the Thorntonia area, and extend south to, but not beyond, the Barkly Highway.

Lithology: In the Northern Territory, thin-bedded, cream to grey limestone with some sandy limestone, occasionally cross-bedded, and minor friable medium-grained sandstone (Smith and Roberts, 1963, op cit.). These authors also included leached siltstone and shale at Lancewood Waterhole which Opik (1960, op cit.) named as a separate unit, the Lancewood Shale. Further east along the Georgina Basin's northern margin, Carter and Opik (1961, op cit.) described the Currant Bush Limestone lithology as variable, consisting of dark, bituminous limestone, soft, grey, flaggy limestone, hard, nodular limestone, massive, thick-bedded dolomitic limestone and dolomite, in the upper parts of the formation. In the Thorntonia area and to the south, the lithology consists of bituminous, flaggy limestone with oolitic, shaly and marly interbeds.

Thickness: About 100 feet in the Northern Territory and perhaps 500 feet in the Lawn Hill Sheet area, but this figure is regarded as doubtful (Carter and Opik, 1961, op cit.) because of structural complexities. There are no published figures for outcrop thickness in the Camooweal and Mount Isa Sheet areas, but Morstone No. 1 Well drilled through 380 feet of the Currant Bush Limestone, in the interval 380-760 feet (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.).

Contacts: In the Northern Territory, the Currant Bush Limestone is underlain conformably by the Border Waterhole Formation and is overlain by dolomite regarded by Smith and Roberts (1963, op cit.) as the Camooweal Dolomite. Carter and Opik (1961, op cit.) state that the Currant Bush Limestone conformably overlies the Border Waterhole Formation in the Lawn Hill Sheet area, and that it is overlain by Mesozoic plant-bearing sandstone. In the main outcrop areas, the

Currant Bush Limestone rests conformably on, and grades into, the Inca Formation, and is overlain conformably by the V-Creek Limestone.

Fossils: The fauna consists predominantly of abundant, undescribed agnostid trilobites. Numerous polymerid trilobites also are found in the Currant Bush Limestone. Opik (1956a, op cit.) lists *Paterina* cf. *superba* (near the base); *Koptura*; *Anomocare* cf. *confertum* Whitehouse, and *Mapania*, in the upper half, and *Doryagnostus incentus* and *Ptychagnostus punctuosus* near the top.

Age: Middle Cambrian.

Correlates: The Inca Creek and Quita Formations, and the greater part of the Age Creek Formation.

Lancewood Shale

This name is included here for completeness only; Opik (1960, op cit.) named it in the Border Waterhole area of the Northern Territory, and described the lithology as deeply-lateritized, indistinctly-laminated sandy shale and siltstone; Opik also stated that the Lancewood Shale rested apparently conformably on the Currant Bush Limestone. Carter and Opik (1961, op cit., Table 1) included the Lancewood Shale in a stratigraphic table of the Lawn Hill Sheet area, but stated that it occurred in the Northern Territory only; they gave the thickness as 70 feet, listed the fauna as *Fouchouia*, *Peronopsis*, *Ptychagnostus* and cystids, and described the Lancewood Shale as "apparently equivalent of part of Currant Bush Limestone".

Smith and Roberts (1963, op cit.) included the Lancewood Shale in the Currant Bush Limestone. Since the Lancewood Shale, as named and described by Opik (1960, op cit.), occurs only in the Mount Drummond Sheet area of the Northern Territory and has not been mapped as a separate unit there, it is not shown on Plate 2.

V-Creek Limestone

Definition: Derivation of Name: From V Creek, a small tributary of Harris Creek, about 8 miles east of Undilla homestead (latitude 19°37'S, longitude 138°38'E), Plate 2.

Map Reference: Camooweal 1:250,000 Sheet area, Plate 2.

Distribution: In a belt trending south-east from Old Morstone to latitude 19°52'S approximately, in the Camooweal Sheet area, and in discontinuous outcrops between the Barkly Highway and the Bukley River, in the Mount Isa Sheet area (Plate 2). Outcrops are usually poor in the south, in low rises and in creek banks, but are better developed in the Undilla area in the north.

Lithology: Blue and grey laminated sandy and marly limestone, with widely spaced interbeds of silicified limestone, cherty in the upper part; the lower part contains interbeds of calcilutite.

Thickness: 100-120 feet in the Undilla area, but only a maximum of 10 feet in any one outcrop in the southern part, where Opik, Carter and Noakes (1961, op cit.) estimate the total thickness at 100 feet. The thickness in Morestone No. 1 Well is 325 feet, in the interval 55-380 feet (Amalgamated Petroleum Exploration Pty Limited, 1963 unpubl.).

Contacts: Conformably overlies the Currant Bush Limestone in the northern outcrop area, and is conformably overlain there by the Mail Change Limestone. It grades laterally into the upper part of the Age Creek Formation. In the southern area, it conformably overlies the Inca Creek Formation, and is overlain conformably by the Mail Change Limestone and the Split Rock Sandstone.

Fossils: Agnostids are abundant, and Whitehouse (1936, 1939) has described many of them, which Opik (1956a, op cit.) considers to belong to an Acado-Baltic fauna. The fauna includes Solenopleura (Asthenopsis) levior, Mapania angusta (Whitehouse), Amphoton serotinum, Papyriaspis lanceola, Goniagnostus scarabaeus, Goniagnostus nathorsti, Ptychagnostus punctuosus, Phalacroma and many undescribed agnostids (Opik, 1956a, op cit., p. 19). In addition, Koptura cf. lisani (Walcott) and Leiopyge laevigata rugifera Westergaard occur in the upper parts of the V-Creek Limestone, and are important fossils for dating and correlation.

Age: Middle Cambrian.

Correlates: The upper part of the Age Creek Formation and lower part of the Split Rock Sandstone.

Comment: The V-Creek Limestone is a unit of small areal extent which has been deposited conformably on older units. Opik (1960, op cit., p. 101) states that several thin interbeds in the V-Creek Limestone have lithological similarities with the overlying Mail Change Limestone but are distinguished on the grounds that the Mail Change Limestone is thick-bedded. The available information on subsurface thickness shows that the V-Creek Limestone is considerably thicker than indicated in outcrop.

Mail Change Limestone

Definition: Derivation of Name: From an abandoned hut (in ruins) known as Mail Change, at latitude 19°35'S, longitude 138°30'E, approximately, and about 10 miles south of Old Morstone homestead.

Map Reference: Camooweal Sheet area (Plate 2).

Distribution: Similar to that of the V-Creek Limestone, with a northern belt trending south from Old Morstone homestead, and a southern belt between the Barkly Highway and the Buckley River; outcrops are small and of limited extent in the southern area. In both areas the Mail Change Limestone forms low, terraced hills.

Lithology: Blue and yellow, mottled, fine-grained, thick-bedded limestone.

Thickness: This seldom exceeds 20 feet; in Morstone No. 1 Well the thickness is 15 feet (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.).

Contacts: Rests conformably on the V-Creek Limestone and is overlain conformably by the Split Rock Sandstone.

Fossils: Trilobites are rare, but brachiopods are common. Opik (1956a, op cit., p. 19) states that the Mail Change Limestone contains a fauna similar to that of the V-Creek Limestone, and that Crepicephalina also occurs in the Mail Change Limestone fauna.

Age: Middle Cambrian.

Comment: The Mail Change Limestone is contemporaneous with the upper part of the Age Creek Formation and grades laterally into part of the Split Rock Sandstone.

Split Rock Sandstone

Definition: Derivation of Name: From Split Rock Waterhole (latitude 19°58'S, longitude 138°29'E) about 2 miles north of the Barkly Highway.

Map Reference: Camooweal 1:250,000 Sheet area, Plate 2.

Distribution: Crops out in residuals, discontinuously between Undilla homestead area and the Buckley River; the outcrops are included in the Єm3 group of units on Plate 2.

Lithology: Fine-grained quartz sandstone, with siltstone interbeds. The sandstone is commonly cross-bedded, and most outcrops are strongly weathered.

Thickness: The maximum thickness in any residual is 70 feet; thicknesses of about 50 feet are common. A thickness of 30 feet is reported in Morstone No. 1 Well (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.).

Contacts: Conformably overlies the V-Creek Limestone and the Mail Change Limestone in some localities; the Split Rock Sandstone grades laterally into the lower part of the Mail Change Limestone. The Lower Cretaceous Polland Waterhole Shale unconformably overlies the Split Rock Sandstone.

Fossils: Opik (1960, op cit.) states that some beds are richly fossiliferous and he lists the following: Nepea narinosa Whitehouse, Amphoton spinigerum Whitehouse, Dorypyge, Anomocarella, Lisania, Crepicephalina(?), and numerous agnostids. Opik (1956a, op cit.) recorded Goniagnostus nathorsti at the base of the Split Rock Sandstone and agnostids of the Leiopyge laevigata assemblage in higher levels.

Age: Middle Cambrian, low in the Leiopyge laevigata zone.

Comment: The Split Rock Sandstone has a "rising" contact against both the Mail Change and V-Creek Limestones, and therefore has a wide stratigraphical range. It is one of the youngest Middle Cambrian sequences exposed on the eastern margin of the Georgina Basin. Dips in the formation are usually near-horizontal, but some mild faults have affected it.

Age Creek Formation

Definition: Derivation of Name: From Age Creek, a short tributary of the O'Shanassy River. The type locality is at the junction of Age Creek and the O'Shanassy River, about four miles downstream from Old Morstone homestead. Opik (1954b, unpubl.) designated the type locality, and he published the name (1956a) and defined the formation (1960). Condon (1961, unpubl.) made additional observations on the Age Creek Formation and Randal and Brown (1962c, unpubl.) gave full descriptions of the formation and described its relationship with other units, particularly with the Camooweal Dolomite.

Map Reference: Camooweal 1:250,000 Sheet area, Plate 2.

Distribution: The Formation is restricted to the Morstone-Thorntonia area, but Opik, Carter and Noakes (1961, op cit.) reported a single small outcrop (at latitude 20°11'S, longitude 138°21'E) within a lateritic plain in the Mount Isa Sheet area; these authors regarded the outcrop as probably, but not definitely, belonging to the Age Creek Formation and they showed it as such on the Mount Isa 4-mile map but did not include it in the accompanying stratigraphic table. On Plate 2 the Age Creek Formation has been shown as a separate unit and the small outcrop in the Mount Isa Sheet area is also shown.

Lithology: Opik (1960, op cit.) described the Age Creek Formation as "A calcareous formation consisting of sandy clastic dolomite and limestone with interbeds of calcareous sandstone". Randal and Brown (1962c, unpubl.) and Brown (1962, unpubl.) give fuller descriptions of the lithology of the Age Creek Formation, and Randal and Brown (1962, op cit., unpubl.) summarise the lithology as pellet dolomite, dolomite with pellets, crystalline two-tone dolomite, dolomitic limestone, and minor calcarenite; chert nodules and bands occur, but are uncommon. These authors also describe the common cross-bedding in the formation, which Condon (1961, unpubl.) had noted.

Thickness: Opik (1960, op cit.) quoted a thickness of 4000 feet; on the published Camooweal 4-mile Sheet a thickness of about 2700 feet is shown in one cross-section and about 1700 feet in another. Randal and Brown (1962c, op cit.) consider that total thicknesses of part sections exceeded 4000 feet in Ada Creek (this creek is named Marion Creek on published topographic base maps of the Camooweal Sheet and is named accordingly on Plate 2).

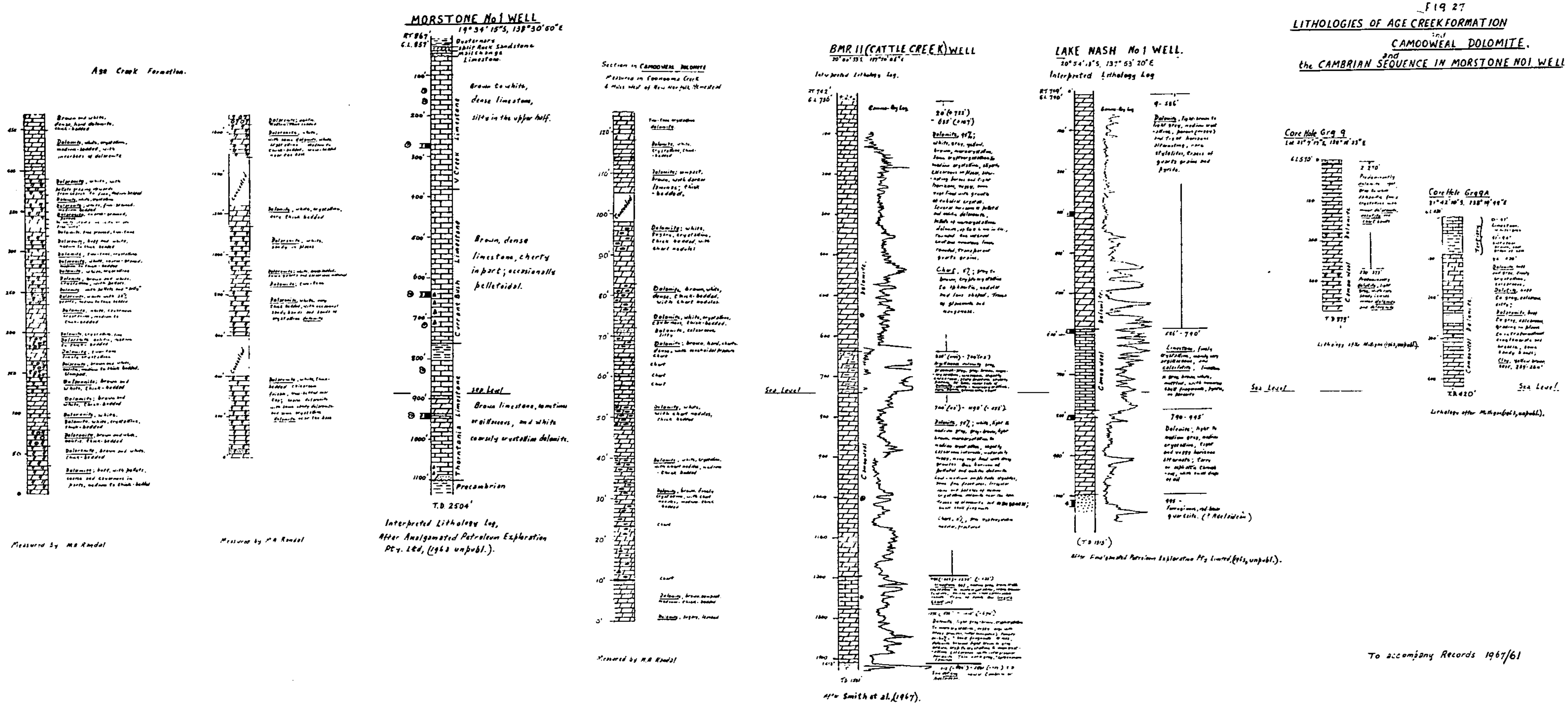


FIG 27
LITHOLOGIES OF AGE CREEK FORMATION and CAMOOWEAL DOLOMITE, and the CAMBRIAN SEQUENCE IN MORSTONE NO1 WELL

To accompany Records 1967/61

Contacts: Opik (1956, op cit., and Camooweal 4-mile Geological Sheet, First Edition, 1961) considered that the Age Creek Formation disconformably overlies the Camooweal Dolomite, and that the formation was contemporaneous with, and interfingered with, parts of the Thorntonia Limestone, the Currant Bush Limestone, the Inca Creek Formation, and V-Creek Limestone and the Mail Change Limestone. There is adequate palaeontological evidence to support the contemporaneity, and field evidence supports the interfingering relationships. However, Randal and Brown, 1962c, op cit.) believe that there is adequate field evidence of interfingering of the Age Creek Formation and the Camooweal Dolomite along the western boundary of the Age Creek Formation, and that these two units are contemporaneous, at least in part. Mesozoic sediments unconformably overlie the Age Creek Formation is some localities.

Fossils: Phosphatic brachiopods are common, and trilobites occur in some limestone interbeds. Opik (1960, op cit.) listed the following fauna: Acrothele, Acrotreta, Micrometra, Lingulella, Peronopsis, and Fuchouia.

Age: Middle Cambrian, ranging from the Xystridura to the Ptychagnostus nathorsti zones as defined by Opik (1960, op cit.).

Correlates: The upper part of the Thorntonia Limestone, the Currant Bush Limestone, the Inca Creek Formation, the V-Creek Limestone, the lower part of the Mail Change Limestone, and part, at least, of the Camooweal Dolomite.

Description and Comment: The Age Creek Formation crops out mainly in rough karst structures, deeply-incised by steep-sided creeks and rivers. Typical outcrops are blocky and separated by irregular joints up to 20 feet deep. Away from watercourses the formation is less dissected and forms plateaux where black soil often obscures outcrops. The formation is mainly thick and medium-bedded, but some massive beds and some thin beds are known. The formation is usually cross-bedded, and some foresets are 50 feet thick; the foresets are thin to thick-bedded, and dip at angles up to 30 degrees, but mainly less than 10 degrees. The cross-beds are developed strongly in coarser lithologies of the Age Creek Formation and their presence, together with slumping and collapse of beds towards sink holes, makes dip measurements on isolated outcrops unreliable.

In outcrop the Age Creek Formation is usually white or buff, with large pellets visible on weathered and fresh surfaces. The lithology is mainly a dolomite composed of large pellets, oolites, terrigenous material, fossil fragments and algal material. The rock often shows intergranular porosity because fragments generally are cemented only at points of contact. Brown (1962, unpubl.) reported on the petrology of the formation; he stated that the carbonate grains consist of pellets, oolites and algal fragments, with the pellets well-rounded, and oolites usually recrystallised. Pellets usually exceed 0.1 mm. in diameter, and some exceed 2.0 mm.; they are composed of dark, microcrystalline dolomite and paler, more coarsely crystalline dolomite. Composite pellets, consisting of small pellets, oolites and fossils in a dark matrix, are known. Oolites are common, but few retain their structure and in thin section they are identified by a cricular arrangement of dolomite crystals, which may be slightly darker and finer-grained than the surrounding dolomite cement. The oolites have an average grain-size of 0.3 mm., are well-sorted and are remarkably even in size.

Brown (1962, op cit.) states that terrigenous material is almost universal in the pellet dolomites of the Age Creek Formation, but is less common in fine-grained, thin-bedded, fossiliferous limestone interbeds. Two distinct grain-size groups of terrigenous material occur; the smaller, with grain-sizes of 0.05 mm. or less, is common throughout the formation, but the larger (greater than 0.1 mm. in diameter) is restricted to the western margin of the formation near Old Morstone homestead; further south it spreads eastwards. The coarser terrigenous material consists of quartz grains, some of which contain ?silliamanite needles, and they show signs of strain in thin section; chert grains are common in the Ada Creek area. The finer terrigenous material consists of unstrained quartz, plagioclase, microcline, tourmaline, zircon, hypersthene and garnet or spinel.

The pellet dolomites have a dolomite matrix; the only rocks of the Age Creek Formation with a lime-mud matrix are limestone layers composed of algal grains. Lenses of thin-bedded, fossiliferous dolomite and dolomitic limestone occur within foresets of the formation and represent very fine-grained carbonate mud deposits.

The structure of the Age Creek Formation is obscured by the abundance of cross-beds; the validity of high dips measured on isolated outcrops is suspect, and some high dips (15 to 20 degrees) shown on the Camooweal 4-mile Sheet, south-west of Old Morestone homestead, have been measured on large foresets.

The regional dip of the Age Creek Formation usually ranges from 2-5 degrees, but the beds are apparently gently-rolling, and the direction of regional dip is difficult to determine. Randal and Brown (1962c, op cit.) have found several areas along the western outcrop belt where beds dip either south or south-east, i.e. towards the Undilla Basin postulated by Opik (1956, op cit., and 1960, op cit.). However, some low south-west dips have been observed by Randal and Brown (1962c, op cit.) and by the present author, near the boundary of the Age Creek Formation and the Camooweal Dolomite. Morstone No. 1 Well did not penetrate any beds of the Age Creek Formation before reaching the base of the Middle Cambrian sequence at 1115 feet (Amalgamated Petroleum Exploration Pty Ltd, 1963, unpubl.). This suggests that either there is no basin in the Undilla area, and that the regional dip of Middle Cambrian sequences is south-west, away from Precambrian basement into the Georgina Basin, or that there is a minor 'deep' in the Undilla area, developed on an uneven Precambrian surface, but not worthy of a separate basin name, and with thickness considerably reduced from that shown on cross-sections on the Camooweal 4-mile Geological Map.

The thickness of 4000 feet for the Age Creek Formation may not be reliable, because of the foreset beds. Some sections measured by Randal and Brown (1962c, op cit.) are shown on Fig. 27, together with the interpreted lithology log of Morstone No. 1 Well.

The contact between the Age Creek Formation and the Camooweal Dolomite has been interpreted in several different ways. Opik (1956, op cit.) considered that the Camooweal Dolomite was of Lower Cambrian or Upper Proterozoic (Adelaidean) age, and that this dolomite formed an older meridional divide between Middle Cambrian sequences in Queensland and the Northern Territory. Opik clearly showed the stratigraphic position of the Camooweal Dolomite in his 1960 correlation chart. Subsequent to the identification by Condon (1961, unpubl.) of cross-beds in the Age Creek Formation near Old Morstone homestead, Randal and Brown (1962c, op cit.) studies the Age Creek Formation/Camooweal Dolomite boundary and the lithologies on both sides of it. They concluded that:

(1) a lithological boundary is traceable from Morstone homestead to Labortion Creek and its position approximates that of the boundary shown on the Camooweal 4-mile Geological Map (1961). East of the boundary the rocks

consist of pellet dolomite; near the boundary, pellet dolomite forms lenses within a crystalline dolomite and west of the boundary the rocks consist of cross-laminated, white and mottled porous crystalline dolomite.

(2) the boundary extends northwards along the eastern side of the watershed between Nankivel Creek and Ada Creek, i.e. to the west of the approximate boundary shown on the Camooweal 4-mile Geological Sheet.

(3) along the boundary, large tongues of detrital pellet dolomite (Age Creek Formation) are interbedded with lenses of crystalline dolomite (Camooweal Dolomite); immediately north of the northern boundary of Morstone Station, interbeds of pellet dolomite commonly occur in crystalline dolomite (Camooweal Dolomite) and form characteristic rugged black outcrops which are easily distinguished on air photographs from the lighter-coloured crystalline dolomite.

(4) interbeds of pellet dolomite in Camooweal Dolomite lithology were observed in Frith and Labortion Creeks, in small tributaries of Goonooma Creek (Plate 2), and north of Norfolk homestead (Plate 2).

Despite the slight westwards shift of part of the boundary the basic facts are that there are two distinct rock bodies, one a pelletal dolomite (Age Creek Formation) and the other a crystalline dolomite (Camooweal Dolomite); these two rock bodies intertongue along the boundary line shown on Plate 2. Therefore, the age of the Camooweal Dolomite in this locality is Middle Cambrian, and supporting evidence for this age is given in the description of the Camooweal Dolomite, which follows.

Camooweal Dolomite

Definition: Derivation of Name: From Camooweal Township (latitude 19° 55'15"S, 138°07'10"E) which is close to outcrops of the formation in the Georgina River. Opik (1954b, unpubl.) designated the type area along the Georgina River between Lake Mary (about 5 miles north-north-west of Camooweal) and Lake Francis (about 2 miles south-south-west of Camooweal). Both lakes are large waterholes in the Georgina River. Opik (1956a, op cit.) published the name of the formation and described its lithology, extent and stratigraphical relationships.

Map Reference: Camooweal 1:250,000 Sheet area, Plate 2.

Distribution: In a meridional belt extending along both sides of the Northern Territory-Queensland Border, from 18°35'S approximately to latitude 21°S approximately, whence it swings south-east into Queensland and extends almost to latitude 22°S. In the west it is bounded approximately by the Ranken River and Georgina River, and in the east by longitude 138°30' from the northern extremity to the Buckley River, where it swings south-east along the margins of the Pilpah Range and then south along longitude 139°E approximately until it reaches latitude 22° approximately.

The distribution is shown on Plates 2 and 4; the boundaries are approximate and are drawn to include the main outcrop areas and areas where the Camooweal Dolomite is assumed to underlie black soil plains because of the sporadic occurrence of outcrops, both large and small, of the formation in the plains. The distribution in the Northern Territory differs from that shown by Opik (1956b, op cit., in Fig. 2, facing p. 30) because later work has shown a need for revision and reduction of the outcrop area. The distribution shown for Queensland is substantially that delineated on the Geological Map of North-west Queensland, compiled by Carter and Opik (1961).

Lithology: Opik (1956a, op cit.) described the lithology as "bedded dolarenite with nodules, stringers, and small lenticles of chert; some admixed fine quartz sand and interbeds of quartz sandstone occur at its base and locally thin beds of limestone and dolomitic limestone occur at various horizons". The Camooweal Dolomite is buff, light-brown, cream and white in colour, with the white rocks predominating. Randal and Brown (1962c, unpubl.) reported pellet dolomite interbeds and lenses in the Morstone area, and intraformational conglomerates in the eastern part of the Ranken Sheet area. The lithology of outcrops of Camooweal Dolomite is fairly uniform everywhere. Bedding ranges from thin to very thick, but thick and medium types are more common. Small-scale cross-bedding is also common.

Thickness: Measurable sections seldom crop out and the complete sequence is nowhere exposed, therefore published figures are estimates; Carter and Opik (1961) quote a thickness of about 500 feet in the Lawn Hill Sheet area, and Smith and Roberts (1963) quote "several hundred" feet in the Mount Drummond Sheet area. Opik (1956a, op cit.) quoted a thickness of 800-1000 feet, which was an interpretation of bore data. Randal and Brown (1962c, unpubl.) measured a part section of 125 feet (Fig. 27). In wells which penetrated sequences tentatively referred to the Camooweal Dolomite the thickness is 1412 feet in BMR11 (Cattle Creek) and 987 feet in Lake Nash No. 1.

Contacts: The formation interfingers with the Age Creek Formation in the Morstone area (Randal and Brown, 1962c, unpubl.); it overlies, and is faulted against, the Middle Cambrian Currant Bush Limestone in the Border Waterhole area (Smith and Roberts, 1963); it overlies Lower Cambrian or Adelaidean basement in Lake Nash No. 1 Well (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.) and overlies fossiliferous Middle Cambrian limestone in BMR11 Well (Smith, 1967). These contacts, together with other supporting information given below, indicate a Middle Cambrian or younger age for the Camooweal Dolomite; an opposing view is expressed by Opik (1956a, 1960) and Carter and Opik (1961), who state that the Camooweal Dolomite underlies Middle Cambrian sequences and is separated from them by a disconformity.

Fossils: None are known in outcrop. Trilobites and brachiopods have been obtained in stratigraphic wells, core-holes and water bores which spudded in the Camooweal Dolomite.

Age: Middle Cambrian and may range into the Upper Cambrian.

Discussion: The Camooweal Dolomite is a stratigraphic unit of regional extent and of reasonably constant lithology. Outcrop is generally poor except in the Camooweal Sheet area, where some cliff sections are known; elsewhere, outcrops consist of low benches and terraces. In much of the area, dolomite blocks and boulders protrude through black soil plains, and in some of these localities it is difficult to distinguish cherty Camooweal Dolomite from silicified dolomite and limestone of ?Tertiary age. In the southern part of the "outcrop" area it is also difficult to distinguish between the Camooweal Dolomite and the Upper Cambrian-Lower Ordovician Ninmaroo Formation.

Brown (1962, unpubl.) has reported on the petrology of the Camooweal Dolomite in the Camooweal Sheet area and found that in thin section the lithology varies considerably from a dolomite with pellets and intraformational pebbles to a dense, fine-grained crystalline dolomite. The pellets are usually small, about 0.05 mm. in diameter, and are about the same size as grains of terrigenous material (quartz, feldspar and, rarely, heavy minerals) which are often present in the rock. The size of pellets increases towards the boundary of the Camooweal Dolomite with the Age Creek Formation.

The Camooweal Dolomite is often cavernous, with sink holes on the surface; many caverns have been encountered in drilling operations, and most cores are vuggy. For this reason the Camooweal Dolomite yields abundant supplies of water suitable for stock and usually also fit for human consumption. The potential of the formation has not been tested; most stock bores are terminated at reasonably shallow depths when supplies of 1000-2000 gallons per hour are obtained. The best deep test to date has been BMR11 (Cattle Creek) Well, which yielded supplies ranging to 6000 gallons per hour by air lifting. The tests were of short duration and therefore not exhaustive.

The age of the Camooweal Dolomite has been the subject of much debate, because different workers have interpreted field relationships between Camooweal Dolomite and fossiliferous Middle Cambrian rocks in exactly opposite senses. Since 1962 a series of widely-separated wells have spudded in the Camooweal Dolomite (as mapped by Opik) and many have recovered Middle Cambrian fossils in the subsurface. On the other hand, no well or core-hole which has spudded in Middle Cambrian sequences has penetrated Camooweal Dolomite below. Therefore on this evidence alone, the Camooweal Dolomite is here regarded as Middle Cambrian in age, and the possibility of its ranging to Upper Cambrian and Lower Ordovician cannot be ignored. (Nichols, 1966, unpubl.) has made detailed petrological studies of core hole Grg9A (latitude 21°42'10", longitude 138°19'48"E, approximately; Plate 4) and he considers that some parameters allow a correlation with core-hole Grg14 (latitude 21°10'32"S, longitude 137° 21'46"E) which spudded in rocks mapped as Upper Cambrian.

The logs of two wells which spudded in Camooweal Dolomite and which penetrated fossiliferous Middle Cambrian sequences below are shown in Fig. 27. These wells are BMR11 (Cattle Creek) and Amalgamated Petroleum's Lake Nash No. 1. For BMR11, Gatehouse (in Smith, 1967) considers that the presence of Biconulites in Core No. 2 (547-560 feet) and in Core No. 9 (1006-1016 feet), together with associated phosphatic brachiopods and sponge spicules, indicates an early Middle Cambrian age for the interval to 547-1016 feet. He also reported that fragmentary fossils in Core No. 12 (1202-1205 feet) may be Middle Cambrian in age. The lowest fossil found was a free cheek of an unidentifiable trilobite in Core No. 14 (1308-1318 feet).

No palaeontological report has been published on the fossils in Lake Nash No. 1 Well (Amalgamated Petroleum Exploration Pty Limited, 1963, unpubl.) but Opik (pers. comm.) has identified early Middle Cambrian fossils from Core No. 2 (586-596 feet) and from cuttings in the interval 670-680 feet.

Core-hole Grg16 (Fig. 23; Plate 2) spudded in an area which Opik (1956b, op cit.) considered is underlain by Camooweal Dolomite, but after penetrating dolomite near the top, the drill cored sections of richly-fossiliferous Middle Cambrian limestone. Other evidence comes from a water-bore drilled for Rocklands Station (near Camooweal), in 1963; this bore, known as Rocklands No. 33, was drilled about 14 miles north-north-east of Camooweal and trilobites were recovered in the interval 410-420 feet. These fossils are held at the Bureau of Mineral Resources, Canberra.

There is no published account of an observed contact between the Camooweal Dolomite and Precambrian or Lower Cambrian rocks, and there is no account of the lithology of the whole unit. Therefore the selection of the lower boundary of the Camooweal Dolomite in BMR11 (Cattle Creek) and Lake Nash No. 1 Wells is open to several interpretations: on lithological grounds the base would be placed at the base of the lowest beds above limestone units in each well, but the whole sequence above Precambrian in each well could be placed in the Camooweal Dolomite, with the limestone units representing parts of the original rock body which have not been dolomitised.

Blazan Shale

Definition: Derivation of Name: From Blazan Creek, a tributary in the headwaters of St Ronans Creek (Plate 4). No type section has been published.

Map Reference: Urandangi 1:250,000 Sheet area, Plate 4.

Distribution: The unit limited to a small area in the south-eastern part of the Urandangi Sheet area; on Plate 4 the Blazan Shale is included in the Ꞓm3 group of units.

Lithology: Siliceous shale with sandstone interbeds, and conglomerate at the base.

Thickness: 200 feet (Noakes, Carter and Opik, 1959); 120 feet (Opik, 1960).

Contacts: The Blazan Shale lies disconformably on the eroded surface of the Thorntonia Limestone and fills canyons and gullies in the limestone; it is unconformable on the Eastern Creek Volcanics and Sybella Granite, and conformably overlain by the Quita Formation.

Fossils: Brachiopods and indeterminate agnostids.

Age: upper Middle Cambrian (Noakes, Carter and Opik, 1959, op cit.).

Comment: This is the basal unit of an upper Middle Cambrian sequence which disconformably overlies early Middle Cambrian formations on part of the eastern margin of the Georgina Basin. According to Opik, beds representing the time of Ptychagnostus atavus and Hypagnostus parvifrons are missing, below the base of the Blazan Shale.

Quita Formation

Definition: Derivation of Name: From Quita Creek, a large tributary of St Ronans Creek.

Map Reference: Urandangi 1:250,000 Sheet area; Plate 4.

Distribution: Restricted to small areas in the south-eastern part of the Urandangi Sheet area. Noakes, Carter and Opik (1959, op cit.) state that the formation extends south from this area, but Reynolds (1965a) has not mapped it in the Glenormiston Sheet area.

Lithology: Siliceous shale and limestone, overlain by impure flaggy, marly and sandy limestone with chert nodules.

Thickness: 180 feet maximum.

Contacts: The formation rests conformably on the Blazan Shale and disconformably on the Thorntonia Limestone and the Beetle Creek Formation. It is overlain disconformably by the Steamboat Sandstone (Opik, 1960).

Fossils: Ptychagnostus punctuosus (Opik, 1960, op cit.)

Age: upper Middle Cambrian.

Time Correlates: Upper levels of the Currant Bush Limestone and the Inca Creek Formation.

Comment: The Quita Formation crops out in low terraced hills, and dips at low angles, seldom exceeding 3 degrees, to the south-south-west. In places it has been strongly faulted by crescentic-shaped faults but the age of this faulting is not known. The formation is faulted against the Eastern Creek Volcanics in the south-eastern part of its ourcrop area. Additional comment on the Quita Formation is included in comment on the Steamboat Sandstone, in following pages of this Bulletin.

Steamboat Sandstone

Definition: Derivation of Name: From 'The Steamboat', a prominent mesa (latitude 21°55'S, longitude 139°04'E, Plate 4) which is capped by sandstone of the formation. The type locality is stated to be "Quita Creek area, east of Urandangi, north-western Queensland" (Lexicon, 1962). No type section has been published.

Map Reference: Urandangi 1:250,000 Sheet area, Plate 4.

Distribution: The south-eastern part of the Urandangi Sheet area, extending south into the northern part of the Glenormiston Sheet area.

Lithology: Calcareous sandstone and quartz sandstone, with interbeds of sandy limestone and dolomite, in the Urandangi Sheet area (Noakes, Carter and Opik, 1959). Reynolds and Pritchard (1964, unpubl.) reported the lithology in the Glenormiston Sheet area as calcarenite, dolarenite, calcareous sandstone, calcilutite and sandy calcilutite in the lower part of the formation, and sandstone with minor siltstone beds in the upper 90 feet, which is leached and weathered.

Thickness: 200 feet (Opik, 1960); 270+ feet (Reynolds and Pritchard, 1964, unpubl.).

Contacts: The Steamboat Sandstone rests disconformably on the Quita Formation (Opik, 1960, op cit.) and interfingers with the lower parts of the Mungerebar Limestone in the Glenormiston Sheet area. The top is eroded.

Fossils: The formation is richly fossiliferous, but the fauna has not been described. Agnostids of the Leiopyge laevigata assemblage (laevigata zones II and III) abound. The fauna includes Goniagnostus nathorsti near the base, and Leiopyge laevigata above. Dorypyge, Mapania and Nepea aff. marinosa are common.

Age: upper Middle Cambrian.

Comment: Noakes, Carter and Opik (1959, op cit.) state that the Steamboat Sandstone is "visibly calcareous when fresh"; Reynolds and Pritchard (1964, unpubl.) consider that the predominance of sandstone in the upper beds may be a weathering effect, and they report lateral changes from "comparatively fresh sandy carbonate rock to weathered red, slightly ferruginous and kaolinitic? porous sandstone". The changes from sandy limestone to sandstone could also reflect transgression and regression of the shoreline.

The sandstone in the upper part of the sequence is usually fine-grained, laminated or thin-bedded, well-sorted, and silicified. The formation has been faulted in pre-Mesozoic time, but has not been folded.

Noakes, Carter and Opik (1959) mapped the Quita Formation to latitude 22°S, i.e. the boundary of the Urandangi and Glenormiston Sheet areas, but Reynolds and Pritchard (1964, unpubl.) did not map the Quita Formation south of this latitude and included the extensions from Urandangi Sheet area in the Steamboat Sandstone. The lower part of the Steamboat Sandstone is considered indistinguishable lithologically from the Quita Formation, and the validity of one of these two units as a formation is therefore in doubt. The matter has not been resolved.

Roaring Bore Siltstone

Definition: Derivation of Name: From Roaring Bore (latitude 20°17'S, longitude 140°05'E). The type locality is the Selwyn Range area (Lexicon, 1962, p. 125) but no type section has been published.

Map Reference: Duchess 1:250,000 Sheet area, Plate 4.

Distribution: In small, discontinuous outcrops in the Selwyn Range area only.

Lithology: Light grey, friable, laminated siltstone when fresh; on the surface, mottled siliceous siltstone and shale and interbedded sandstone (Carter and Opik, 1963).

Thickness: 200-250 feet maximum.

Contacts: The formation rests unconformably on Precambrian rocks of the Cloncurry Complex, and on the Lower Cambrian Mount Birnie Beds. It is overlain conformably by the Devoncourt Limestone.

Fossils: Centropleura (two species), Ptychagnostus aculeatus (Westergaard), Hypagnostus brevifrons (Angelin), and Leiopyge laevigata (Dalman), Opik (1960, op cit.); and Acontheus cf. acutangulus (Angelin), Opik (1956a, op cit.).

Age: Middle Cambrian.

Comment: The Roaring Bore Siltstone is the basal unit of three upper Middle Cambrian formations in the Bourke River Outlier of the Selwyn Range area, and shown as Ꞓm4 on Plate 4. It has been faulted along several major faults, but away from these regions dips are gentle. In common with other Cambrian formations near the eastern margin of the Georgina Basin, the outcrops are silicified and ferruginised and surface lithologies therefore are quite different from fresh rock.

Devoncourt Limestone

Definition: Derivation of Name: From Devoncourt railway siding, at latitude 21°09'25"S, longitude 140°11'55"E, about 6 miles north-west of Devoncourt Station. The type locality is given as "Selwyn Range area" (Lexicon, 1962, Vol. VI, 19, p. 57), but no type section has been proposed.

Map Reference: Duchess 1:250,000 Sheet area, Plate 4.

Distribution: In the Selwyn Range area only.

Lithology: Grey, sandy, bituminous, laminated and bedded limestone, with thin-bedded, soft limestone interbeds (Carter and Opik, 1963).

Thickness: 350 feet in the Selwyn Range and about 600 feet farther north (Carter and Opik, 1963, op cit.).

Contacts: The unit conformably overlies the Roaring Bore Siltstone, is faulted against Precambrian rocks of the Cloncurry Complex, and is overlain conformably by the Selwyn Range Limestone.

Fossils: The formation contains about 40 species of trilobites, but not all have been described. Descriptions of Diplagnostus humilis (Whitehouse), Leiopyge exilis Whitehouse, Phoidagnostus limbatus Whitehouse and Phalacroma? dubium Whitehouse have been given by Whitehouse (1936), and Opik (1956a, op cit., p. 20) reported Centropleura aff. loveni Angelin, Leiopyge laevigata laevigata, Leiopyge laevigata cf. armata, Mapania, Amphoton, Agraulos cf. difformis Angelin, Papyriaspis aff. lanceola Whitehouse, and Holteria Walcott.

Age: upper Middle Cambrian.

Comment: The Devoncourt Limestone usually crops out poorly in pediments, and in terraced low hills in the north. It has been gently folded (Carter and Opik, 1963, op cit.) and dips steeply near faults. The formation has numerous slickensided fractures which dip 10 degrees east and apparently reflect thrusting and compression from the east, after faulting movements had ended.

Selwyn Range Limestone

Definition: Derivation of Name: From the Selwyn Range, north-western Queensland. The type locality is the Selwyn Range, east of Duchess; no type section has been published.

Map Reference: Duchess 1:250,000 Sheet area; Plate 4.

Distribution: In the Selwyn Range area only; the formation does not crop out north of the latitude of Devoncourt homestead, nor south of the latitude of Selwyn railway siding.

Lithology: Light-coloured flaggy calcilutite with chert nodules, and regular interbeds of soft, marly limestone.

Thickness: 120 feet maximum.

Contacts: The formation rests conformably on the Devoncourt Limestone and is overlain disconformably by the Upper Cambrian O'Hara Shale.

Fossils: None have been found.

Age: upper Middle Cambrian but the unit may range into lower Upper Cambrian.

Comment: The Selwyn Range Limestone has a restricted surface distribution, in low terraces, and as rubble on low rises. Dips are steep near faults, but are low elsewhere. The formation exhibits numerous slickensided fractures, dipping east at 10 degrees, which are similar to those in the underlying Devoncourt Limestone.

Mungerebar Limestone

Definition: Derivation of Name: Not given in principal reference (Casey, 1959). The type area is described thus (with latitudes and longitudes supplied by the author): "From Chummy Tank north-west for 6 miles towards Andy (latitude 22°18'S, longitude 138°55'E) and Chummy dry bores; this is across the strike of the beds which dip low to the south-east".

Map Reference: Glenormiston 1:250,000 Sheet area; Plate 4.

Distribution: In north-central part of the Glenormiston Sheet area only; it crops out in a belt from McCabe Knob (latitude 22°23'S, longitude 138°54'E) in the west to Smoky Creek in the east, with a few outcrops further east near Cottonbush Creek.

Lithology: Mainly grey and dark grey, well-bedded sandy limestone, and limestone beds which contain many chert biscuits; Casey (1959, op cit.) reported dolomitic limestone and oolitic limestone are known in some outcrops.

Thickness: An estimated maximum of 100 feet; a maximum of 60 feet has been measured in continuous sequence.

Contacts: The formation overlies the Steamboat Sandstone, and lower beds of the Mungerebar Limestone interfinger with the Steamboat Sandstone. It is overlain disconformably by the Ninmaroo Formation, and also by Mesozoic and Cainozoic units.

Fossils: A rich but undescribed fauna of trilobites, brachiopods, gastropods, ?pelecypods and small ?sponges. Ostracods have also been identified (P.J. Jones, pers. comm.).

Age: Uppermost Middle Cambrian to lowermost Upper Cambrian, with the major part Upper Cambrian (Opik, 1960, op cit.).

Description and Comment: This formation ranges in age from Middle to Upper Cambrian and is included here in the Middle Cambrian stratigraphy for completeness.

The outcrops are discontinuous and low and this makes measurement of thickness difficult. Reynolds and Pritchard (1964, unpubl.) report the following section, just west of McCabe's Knob, which is representative of the upper beds of the formation:

Thickness (feet)	
10	Calcilutite; two-coloured grey, blue-grey, thin to medium-bedded, poor outcrop;
4	Limestone-breccia, intraformational, altering to two-coloured calcilutite; partly dolomitic, fossils near the base;
1	Calcilutite; grey, with irregular ?burrows filled with crystalline calcite;
6	Calcarenite; coarse-grained, oolitic, and intraformational limestone-breccia, very sandy, cross-bedded; lenses of sandstone, fine-grained, calcareous, oolitic;
12	Calcilutite, grey, laminated, friable, mostly soft, sandy in part; poor outcrop; fossils 6 feet above the base.

Total 33 feet, thickness of part-section of Mungerebar Limestone.

The Mungerebar Limestone is overlain disconformably by red and white sandstone and siltstone, up to 30 feet thick, which are mapped as the leached, local basal beds of the Ninmaroo Formation, but Reynolds and Pritchard (1964, unpubl.) point out that these beds could belong to a separate formation between the Mungerebar Limestone and the Ninmaroo Formation.

In Netting Fence No. 1 Well, which drilled almost a complete sequence of the Georgina Basin Cambrian and Ordovician sediments, Papuan Apinaipi Petroleum Company Limited (1965, unpubl.) reported 265 feet of Mungerebar Limestone in the interval 4090 to 4355 feet. The sediments were described as calcarenite and calcilutite, with traces of oolites. No fossils were recorded in this unit; on lithological grounds, Casey (pers. comm.) has expressed some doubt on its identification with the Mungerebar Limestone. Nevertheless, the gamma-ray log shows a distinctive unit in the interval 4090-4355 feet and this may or may not be the Mungerebar Limestone. The well is about 70 miles south-west of outcrops of the formation, whose presence is unknown in the subsurface between the two localities.

UN-NAMED MIDDLE CAMBRIAN IN THE SUBSURFACE

Phillips Petroleum Company Limited (1963, unpubl.) drilled Middle Cambrian rocks in Black Mountain No. 1 and Beantree No. 1 Wells, and the French Petroleum Co. (Aust.) Pty Ltd (1965, unpubl.) drilled Middle Cambrian in The Brothers No. 1 Well. None of these sequences has been named, but brief descriptions of the lithologies are given below.

Black Mountain No. 1 Well, 1569-3828 feet (After Phillips Petroleum Comapny, 1963):
Pomegranate Limestone (Upper Cambrian) overlying:
1569-3341 feet (thickness 1772 feet); Limestone; light grey, buff to dark brownish grey, cryptocrystalline, argillaceous, silty in part; interbedded with shale, grey to dark grey to black, calcareous, micro-micaceous in part, pyritic and glauconitic in part; calcite veining in varying amounts is common.
3341-3828 feet (thickness 487 feet). Limestone, argillaceous, and shale, calcareous, grading down into siltstone, brownish grey to red, siliceous, sandy in part, calcareous between 3790-3828 feet; abundant black chert, 3360-3776 feet. Cores show bituminous limestone. Mount Birnie Sandstone (Lower Cambrian) underlying.

The total thickness of Middle Cambrian in the well is 2259 feet, but dips in cores are about 10 degrees and the true thickness is therefore less than the footage drilled. Details of fossils (examined by Tomlinson) are:

Core No. 6, 1704-1714 feet,
About 1708 feet, Stenotheca sp.; trilobite (indeterminate fragment)
1710 feet, phosphatic brachiopod (indeterminate fragment)

Core No. 7, 1931-1941 feet,
1935 feet, phosphatic brachiopod, (indeterminate fragment)
1941 feet, " " " "

Core No. 8, 2280-2290 feet,
About 2280 feet, trilobite (indeterminate fragment)

Core No. 9, 2611-2621 feet,
About 2618 feet, phosphatic brachiopod (indeterminate fragment)

Core No. 10, 2956-2966 feet, no fossils

Core No. 11, 3288-3298 feet, " "

Core No. 12, 3355-3357 feet
Upper 8 inches of recovery, Aluta, trilobite (immature, indeterminate); conodonts?

Core No. 13, 3637-3639 feet,
Lower part of recovery, ?Xystridura sp.

No other fossils were recovered in the well below Core No. 13. Core No. 5, (1427-1437 feet) contains trilobites of early Upper Cambrian age, but apart from the questionable Xystridura in core No. 13, there are no diagnostic Middle Cambrian fossils in Black Mountain No. 1 Well. Therefore the determination of Middle Cambrian age comes mainly from the position of the interval, 1569-3828 feet, below known Upper Cambrian rocks and above a sequence identified on lithological grounds as Lower Cambrian.

Within the interval 1569-3828 feet, the sequence 1569-3341 feet is lithologically identified with the Inca Creek Formation, and the sequence 3341-3828 feet, which in cores resembles the interval 1569-3341, is identified with the Beetle Creek Formation because of the presence of ?Xystridura. However, the identifications are tentative and no formal names are given to the sequences.

Beantree No. 1 Well, (After Phillips Petroleum Company, 1963, unpubl.):

1604-1740 feet (136 feet); limestone, grey, hard, dense, shaly and silty; and limestone, brown, hard coarsely crystalline (1620-1644 feet); phosphatic brachiopods.

Adamellite underlying, at 1740 feet.

Fossils found in the interval 1604-1740 feet are *Xystridura* sp., *Peronopsis* sp., and *Achotreta* sp., in core No. 3 (1635-1645 feet). Thus there is proof of Middle Cambrian age for the interval, and McKellar (*In* Phillips Petroleum Co. Limited, 1963, unpubl.) has identified lower Upper Cambrian fossils in core No. 2 (983-993 feet); the well completion report states that part of the sequence above 1604 feet may be of upper Middle Cambrian age. In any event, if the sequences assigned to Middle Cambrian in both Beantree No. 1 and Black Mountain No. 1 Wells are even approximately correct, the results show a considerable thinning from Black Mountain No. 1 Well westward to Beantree No. 1 Well, which was drilled on a Precambrian "high" presumably extending south from the Cloncurry Complex.

The Brothers No. 1 Well (After French Petroleum Company (Aust.) Pty Ltd, 1965, unpubl.).

This well penetrated a probable Cambrian sequence from 1153 feet to 4173 feet (T.D.), although part of the sequence above 1227 feet at least may be Lower Ordovician. Late Upper Cambrian or early Lower Ordovician conodonts were found in core No. 2 (1222-1245 feet), late Upper Cambrian conodonts in core No. 3 (1406-1426 feet), and early Middle Cambrian *Biconulites* in core No. 10 (4153-4173 feet). Jones (*In* French Petroleum Co. (Aust.) Pty Ltd, 1965, unpubl.). No fossils were found in cores and cuttings between 1426 feet and 4153 feet, and therefore there is no information on the Middle-Upper Cambrian boundary in this well. The sequence 1153-4173 feet has been divided on lithological grounds and electric log characteristics into 5 units; brief lithological descriptions of each unit are given below, regardless of age, to obviate repetition in a later section of this Bulletin:

Unit 5 (1153 to 1292 feet): mainly limestone, grey to grey brown, non-porous but fractured and water-bearing; stylolitic; minor interbeds of grey, plastic clay.

Unit 4 (1292-2152 feet): interbedded limestone and shale. Limestone is grey to grey-brown, fine-grained, contorted and fractured; shale is grey, fissile, micaceous.

Unit 3 (2152-2490 feet): dominantly shale, grey, compact, fissile, slightly calcareous, with thin interbeds of limestone, grey, impure.

Unit 2 (2490-3980 feet): interbedded limestone and shale, 2490-3662 feet; limestone is grey, fine-grained, compact, contorted; shale is grey, fissile, micaceous. 3662-3980 feet, dominantly shale with minor interbeds of limestone, grey, pyritic. The top of Unit 2 is at the main break in the Cambrian sequence in the well, marked by resistivity change and an increase in velocity on the sonic log.

Unit 1 (3980-4173 feet): interbedded limestone and shale at the top, becoming massive limestone at the base. Grey to dark grey, fossiliferous at the base (*Biconulites*).

The total thickness of probable Cambrian in this well is 3003 feet. The sequence is mainly flat-lying, or gently-dipping, but some thin intervals above 1600 feet are contorted.

UPPER CAMBRIAN

This section of the Bulletin is confined to Upper Cambrian stratigraphy but excludes late Upper Cambrian sequences which are continuous with the Lower Ordovician. These are described later under the headings of "Cambro-Ordovician".

NORTHERN TERRITORY

Arrinthrunga Formation

Definition: Derivation of Name: From Arrinthrunga Creek, a prominent tributary of Arthur Creek, rising in the south-eastern flank of the Dulcie Range and flowing through outcrops of beds high in the sequence. The type section is at 22°41'15"S, 135°40'E, approximately, near the north-western end of the Elyuah Range.

Map Reference: Huckitta 1:250,000 Sheet area; Plate 3.

Principal Reference: Smith, 1964a.

Distribution: The formation occurs in a narrow belt in the south-western foothills of the Dulcie Range, and in a broad belt between the south-eastern tip of the Dulcie Range and longitude 136°30'E, approximately, extending north almost to Ooratippra homestead. The formation has not been identified either in outcrop or in the subsurface west of Ooratippra Creek and west of Mount Ultim. East of the Huckitta Sheet area, the formation crops out discontinuously in an arcuate belt extending from south-east of the Tarlton Range to Marqua homestead (Plate 4), and continues south-east in narrow belts, on the eastern side of the Craigie Fault; a few discontinuous outcrops extend into Queensland, along the eastern side of the Toomba Fault.

In the subsurface, the formation has been identified in BMR13 (Sandover) Well, and in BMR12 (Cockroach) Well, and is probably present in Netting Fence No. 1 Well.

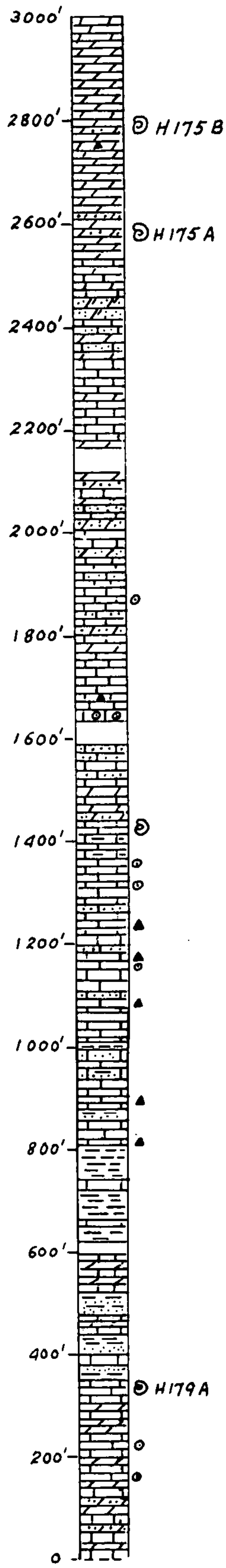
Lithology: The sequence consists of dominantly carbonate rocks, with interbeds of siltstone and sandstone; the main lithologies are crystalline dolomite, algal dolomite, oolitic and pelletal limestone and dolomite. Red and green siltstone is common in the middle part of the sequence, and thin quartz sandstone interbeds are common throughout, but usually crop out poorly. One quartz sandstone has been delineated as a separate member - the Eurowie Sandstone Member.

Thickness: The maximum measured thickness is 3200 feet, east of Yam Creek (Huckitta Sheet area); the sequence is estimated to be about 3000 feet thick, when fully developed, in much of the Huckitta Sheet area; it thins

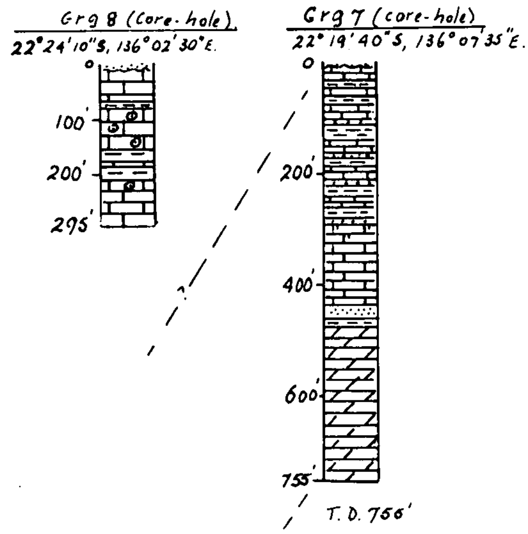
Fig 28

Composite Section

8 miles south of old Huckitta Homestead.



Measured by RR Vine.



Adapted from Milligan (1963 unpubl.).

The Arrinthrunga Formation

Composite Section and Core hole Logs.

To accompany Records 1967/61

eastward to about 2000 feet in the Tarlton Range - Toko Range area, e.g., 2236 feet in BMR12 (Cockroach) Well.

Contacts: Conformably overlies the Middle Cambrian Arthur Creek Beds in the Lucy Creek station area, but elsewhere the lower contacts are not definitive and are between carbonate rocks in both stratigraphic units; the formation may be unconformable on the Mount Baldwin Formation in the Elyuah Range; in the east, it is apparently conformable on the Marqua Beds, and in many places is faulted against the Adelaidean Field River Beds. In the west, it is overlain disconformably by the Tomahawk Beds in some places, and apparently conformably in others; in the east it is overlain apparently conformably by the Ninmaroo Formation.

Fossils: These are rare and are known only in outcrops east of Yam Creek, about 7 miles south-east of Huckitta homestead, and in another locality about 8 miles south-west of Huckitta homestead, west of Yam Creek. The stratigraphic position of these fossils is shown in the measured section in Fig. 28; the lowest fossils are trilobites of lower Upper Cambrian age (Opik, pers. comm.), the fossils in the approximate middle of the formation are brachiopods and hyolithids which could not be removed undamaged from the rock, and those near the top of the formation are trilobites which have not been positively identified. No fossils have been obtained from stratigraphic and exploratory wells.

Age: Upper Cambrian; this is known from the stratigraphic position of the Arrinthrunga Formation between the Middle Cambrian Arthur Creek Beds and Marqua Beds below, and the late Upper Cambrian-Lower Ordovician Tomahawk Beds and Ninmaroo Formation above. The range of the formation within Upper Cambrian time has not been established.

Correlates: Part of the Meeta Beds, and the Georgina Limestone of western Queensland.

Description and Comment: The type section of the Arrinthrunga Formation includes only about one third of the sequence but it adequately demonstrates the lithology of carbonate rocks and interbedded siltstone and sandstone which are typical of the formation in the western and central parts of the Huckitta Sheet area. The type section was selected also because it is not possible to measure the sequence in any locality (in the Huckitta Sheet area) where the top and bottom beds are clearly exposed, nor one where the Eurowie Sandstone member can be included in a measurable sequence. Since the selection of the type section (in 1958), new pastoral development and the drilling of stratigraphic wells have provided better access to good sections of the formation in the Huckitta homestead-Elyuah Range area, and these sections, which are thicker than the type section, also amply illustrate the lithology.

In the type section of the Arrinthrunga Formation, the sequence is steeply-dipping and overturned, but outcrop is good; the sequence, in descending order, consists of:

Thickness (feet)	
	Grey, fossiliferous quartz sandstone, with interbedded green siltstone of the Tomahawk Beds conformably overlying:
15	Sandstone, grey, calcareous, medium-grained, with lenses of sandy limestone and poorly outcropping interbeds of siltstone, green and white
116	Dolomite, poorly-outcropping, grey and brown, sandy, medium-bedded, cross-bedded, with a few thin interbeds of sandstone, brown, medium-grained
44	Sandstone, grey, ?calcareous, coarse-grained, thin-bedded, with some thin interbeds of dolomite; brown, coarsely crystalline
8	Limestone, grey, sandy, medium-bedded
25	Dolomite, brown, medium-bedded, finely crystalline, with interbeds of siltstone, grey, micaceous
7	Dolomite, brown, hard, thin-bedded, finely crystalline
9	Dolomite, brown, hard, medium-bedded, finely crystalline
8	Sandstone; poorly-outcropping, hard, fine-grained, cross-laminated, micaceous
21	Limestone, grey, thin-bedded
7	Siltstone, grey, soft
10	Limestone, grey, thin-bedded, crystalline
71	Limestone, blue and buff, massive-weathering, thick-bedded, with some interbeds of buff laminated limestone

Thickness (feet)	
3½	Limestone, blue, massive-weathering, with chert fragments
½	Quartz sandstone, brown, coarse-grained
3	Quartz sandstone, brown, coarse-grained, cross-laminated;
3	Limestone, blue, dense, massive-weathering
1½	Sandstone, brown, coarse-grained, micaceous
18½	Limestone, blue and brown, thick-bedded, oolitic, with some oolitic dolomitic limestone
10	Dolomite, yellow, purple and blue, flaggy
1	Limestone, blue flaggy, oolitic
5	Dolomite, purple and yellow, flaggy
54	Limestone, blue, massive-weathering, oolitic oolites are in lenses and range to 2mm in diameter, numerous random calcite veins
4	Dolomite, purple, thick-bedded
19	Limestone and dolomite, purple, massive-weathering, thick-bedded, oolitic
18	Sandstone, poorly-outcropping, brown, coarse-grained, micaceous
1	Dolomite, dark brown, flaggy
29	Quartz sandstone, brown, coarse-grained, cross-laminated, with numerous mud pellets
5	Sandstone, brown, hard, coarse-grained, with lenses of dolomite, yellow, crystalline
12	Dolomite, yellow, sandy, soft, fine-grained
7	Dolomite, yellow, hard, laminated
21	Dolomite, poorly-outcropping, buff, oolitic
3	Limestone, blue, oolitic, with oolites ranging to 4mm in diameter
1½	Dolomite, buff, finely crystalline
4½	Sandstone, cream, fine-grained, flaggy
3	Limestone, blue, medium-bedded
3	Limestone, two-tone, massive-weathering, with algae

Thickness (feet)	
12	Limestone, blue-grey, oolitic, with some interbeds of flaggy blue-grey limestone without oolites
17	Limestone, blue-grey, medium-bedded with lenses of oolites
7	Limestone, blue-grey, medium-bedded, with abundant oolites
18	Limestone, blue-black, medium-bedded, fine-grained, with one 6-inch band of oolites 9 feet above the base of the interval
2	Limestone, buff, sandy
4	Limestone, blue-black, massive-weathering, with abundant oolites
7	Limestone, buff, sandy, with one foot of blue-black limestone 4 feet above the base of the interval
10	Limestone, brown, flaggy, sandy
21	Limestone, blue-black, thin-bedded, with a few oolites and numerous random calcite veins
8	Dolomite, buff, hard, thick-bedded
8	Limestone, blue-grey, medium-bedded
12	Limestone, blue and purple, medium-bedded, coarsely-crystalline
17	Limestone, blue, thin-bedded, oolitic, with oolites ranging to 1mm in diameter; numerous silica fragments on weathered surfaces; random calcite veins
36	Dolomite, poorly-outcropping, blue and brown, medium-bedded
6	Concealed
2	Limestone, blue, oolitic
8	Limestone, blue-grey, medium-bedded, oolitic
1	Dolomite, brown, oolitic
6	Limestone, blue, coarsely crystalline
6	Concealed
2	Limestone, grey, oolitic (oolites 1mm in diameter)
8	Limestone, blue-grey, laminated, oolitic
5	Limestone, poorly-outcropping, blue, flaggy

Thickness (feet)	
5	Limestone, blue-grey, with sporadic oolites, and abundant silica fragments on weathered surfaces
10	Limestone, blue-grey, medium-bedded
5	Limestone, mottled, with numerous silica fragments on weathered surfaces
17	Dolomite, poorly outcropping, grey and purple, medium-bedded
7	Limestone, purple, massive-weathering, coarsely crystalline, with abundant random calcite veins
12	Limestone, blue, flaggy, with abundant silica fragments on weathered surfaces
7	Limestone, blue, flaggy, with 1 foot of chocolate-coloured dolomite 3 feet above the base of the interval
9	Limestone, blue, massive-weathering, with numerous random calcite veins and abundant silica fragments on weathered surfaces
13	Limestone, two-tone, flaggy
16	Dolomite, yellow, medium-bedded
35	Dolomite, two-tone, medium-bedded, with 2 feet of grey limestone, with numerous chert fragments, 16 feet above the base of the interval
29	Limestone, dark-grey, medium-bedded, with numerous chert nodules on weathered surfaces
2	Dolomite, yellow, flaggy
17	Sandstone, yellow, coarse-grained, poorly-outcropping, with lenses of hard, yellow dolomite
1007,	thickness of type section of the Arrinthrunga Formation, which here is faulted against the Mount Baldwin Formation.

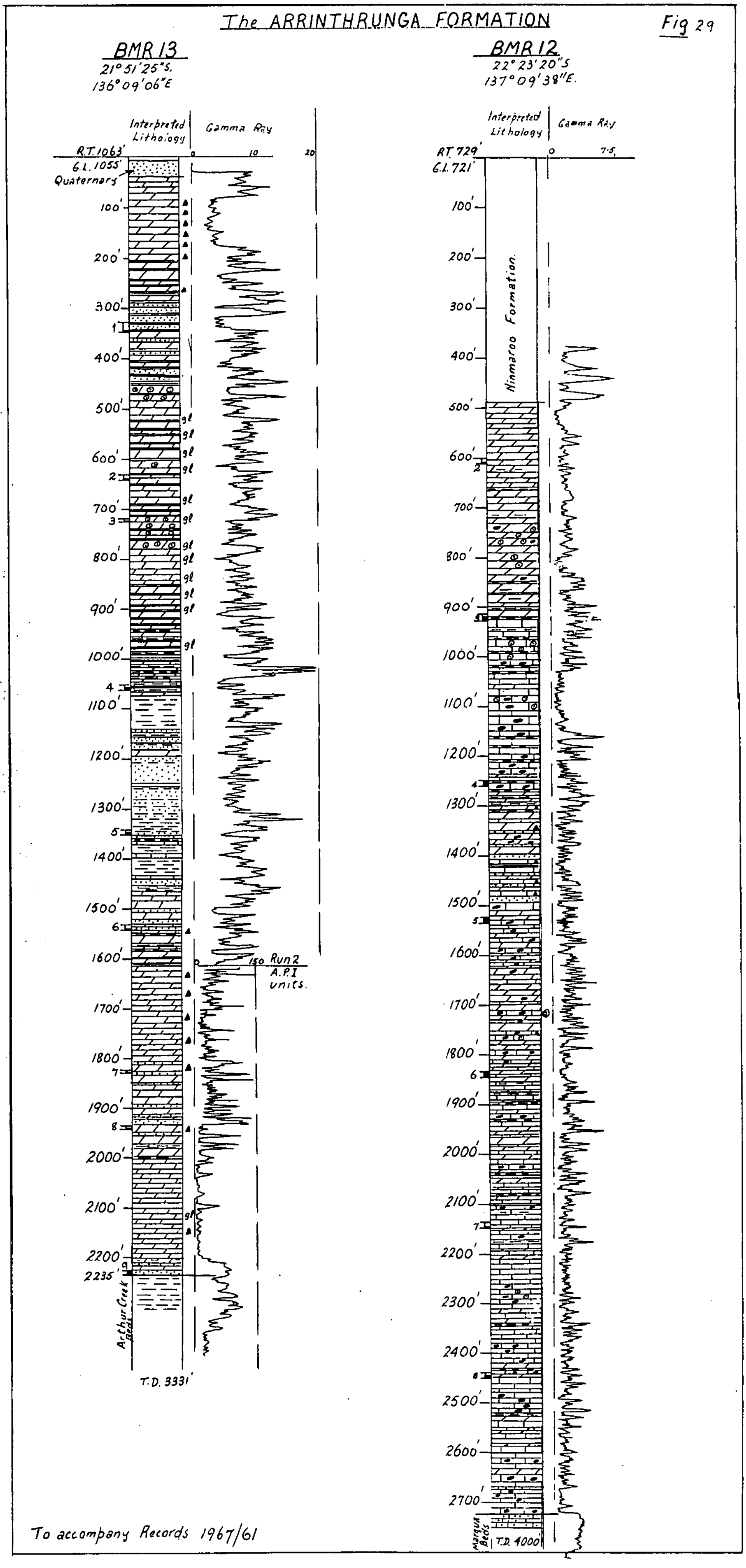
In the eastern part of the Huckitta Sheet area, the Arrinthrunga Formation may be subdivided into four units, which in descending order are:

Unit 4. Hard, brown dolomite, some prominent interbeds of blue and blue-black oolitic and algal limestone, minor interbeds of thin quartz sandstone, red and green siltstone, buff, soft, fine-grained dolomite;
Unit 3. Brown quartz sandstone with ripple-marks and halite casts - the Eurowie Sandstone Member.
Unit 2. Poorly-outcropping blue oolitic limestone, blue algal limestone, buff dolomite, thin quartz sandstone, minor red and green siltstone; numerous concealed beds, probably consisting of siltstone (on evidence from water bores).
Unit 1. Hard, thick and medium-bedded, brown and dark brown dolomite with chert nodules, and minor quartz sandstone. This unit crops out strongly.

Although there are many changes along the strike from limestone to dolomite and from dolomite to quartz sandstone, particularly in unit 4, the broad division of units is easily recognisable in the eastern Huckitta Sheet area, and can also be recognised, in part, in outcrops in the eastern part of the Tobermory Sheet area. However, unit 3 is not known in the western part of the Huckitta Sheet area, nor is it known in the Tobermory Sheet area where, in general, outcrops contain more limestone and less dolomite than the sequence in the Huckitta Sheet area; however, this is not borne out by the interpreted lithology log of BMR12 (Cockroach) Well, which shows a preponderance of dolomite (Fig. 29).

An important lithological variation from unit 1 occurs in the western part of the Huckitta Sheet area, in the localities of the composite section; here the base is not exposed, but lower beds of the formation consist of platy blue limestone with interbeds of red siltstone and sandstone. This part of the sequence may be older than the normal basal dolomite of unit 1, or it may be low in unit 2 which does not crop out well. In either case, its presence may indicate disconformity between the Arrinthrunga Formation and underlying sequences.

The total thickness of units 1-4 in the eastern part of the Huckitta Sheet area has not been measured, because of the poor outcrop of unit 2; however the thickness there is estimated at 3000 feet. The lithologies of surface sections and well sections of the Arrinthrunga Formation are shown on Fig. 28 and 29. The only well which has penetrated the complete sequence is BMR12 (Cockroach), but BMR13 (Sandover) Well provided a good record of unit 2, as outlined in the


The ARRINTHRUNGA FORMATION
Fig 29
BMR 13
21°51'25"S.
136°09'06"E
Interpreted Lithology
Gamma Ray
R.T. 1063'
G.L. 1055'
Quaternary
Run 2
A.P.I units.
Arthur Creek Beds
T.D. 3331'
BMR 12
22°23'20"S
137°09'38"E.
R.T. 729'
G.L. 721'
Ninmaroo Formation
T.D. 4000'
To accompany Records 1967/61

eastern part of the Huckitta Sheet area, and the Bureau's core hole Grg7 provided valuable lithological information on the lower part of unit 2 and the upper part of unit 1, whilst Grg8 cored a higher part of unit 2. Exoil's Huckitta No. 1 Well spudded 820 feet stratigraphically below the top of the Arrinthrunga Formation and provided a record of subsurface lithology in the western part of the Huckitta Sheet area. The Arrinthrunga Formation has not been recorded in Netting Fence No. 1 Well but the present author believes that a dominantly carbonate sequence in the interval 2381-5080 feet, below the Ninmaroo Formation, is best placed in the Arrinthrunga Formation.

The contacts of the Arrinthrunga Formation with underlying and overlying sequences are seldom definitive, because of structural complexity, poor outcrop, or the inability to select an accurate boundary between units with carbonate rocks predominating. At the lower boundary the formation is, in most places, apparently conformable on Middle Cambrian units, but in the Elyuah Range the Arrinthrunga Formation may be disconformable either on the Mount Baldwin Formation or on Arthur Creek Beds. In this locality, the Arthur Creek Beds have not been mapped, but in some places rubble of unfossiliferous chert and soft, yellow sandstone, which might belong to the Arthur Creek Beds, lies on the surface between the Mount Baldwin Formation and the Arrinthrunga Formation. In other places, towards the north-western end of the Range, but south-east of Grant Bluff, there is little room for sediments between the two formations. The evidence for disconformity in the Elyuah Range is, of course, dependent on the correct identification of the Arrinthrunga Formation there; but the sequence is lithologically similar to the lower part of the Arrinthrunga Formation to the north-east.

There is ample evidence north-west of Huckitta homestead that the Cambro-Ordovician Tomahawk Beds have transgressed several older units, but in the Huckitta area itself, i.e., in a deeper part of the Georgina Basin, the Arrinthrunga Formation and the Tomahawk Beds appear conformable and gradational, although the sandstone at the base of the Tomahawk Beds could indicate a new set of environmental conditions. Further east in the Lucy Creek area, the top unit of the Arrinthrunga Formation is thinner than normal; this may indicate erosion, and another erosional break is indicated in the region of BMR13 (Sandover) Well, where the Tomahawk Beds overlie beds high in unit 2 of the Arrinthrunga Formation. In the Tobermory, Hay River and Mount Whelan Sheet areas the Arrinthrunga Formation is succeeded by other carbonate formations, and the boundary is difficult to determine. In all areas, there is unsufficient palaeontological information on the Arrinthrunga Formation to assist in determining time breaks at either its base or its top.

In the subsurface, the Arrinthrunga Formation has a wide extent and is almost certainly contiguous with the Meeta Beds, which are correlated lithologically with lower parts of the formation. However, the extent of the formation west of Ooratippra Creek and a continuation of this south-west "line" to Mount Ultim, is highly speculative. The formation has not been positively identified in outcrop west of this line, nor has it been identified in the subsurface, although it may be concealed beneath Cambro-Ordovician sediments or beneath Quaternary sand and alluvium. There is no aeromagnetic data available to indicate depth to basement in the Barrow Creek and Alcoota Sheet areas, but aeromagnetic contours in the Huckitta Sheet area (Fig. 36) show regular north-west trends, generally in conformity with surface outline of the Dulcie Syncline, for the 8000 and 6000 foot contours which are not closed near Ooratippra Creek. The complete removal of about 3000 feet of Arrinthrunga Formation would have a marked effect on these contours; the Dulcie Sandstone and the Tomahawk Beds continue north-west without much reduction in thickness, so the closing of the 6000 foot contour and the convergence of the 4000 foot contour may indicate reduction in thickness of the Arrinthrunga Formation towards the north-west. Nevertheless, the available geological information is:

(1) Core hole Grg1, which was cited to penetrate either the Arrinthrunga Formation or the Arthur Creek Beds, cored Cainozoic sediments from surface to 116 feet, and a sequence of sandstone with interbedded siltstone and oolitic limestone from 116 to 210 feet (total depth). A brachiopod recovered at 208 feet is "not older than Upper Cambrian" (Opik, pers. comm.). The sequence bears some lithological resemblance to both the Tomahawk Beds and the Arrinthrunga Formation, but the one fossil recovered is not diagnostic.

(2) A water bore about 5 miles south-east of Mount Ultim penetrated about 220 feet of soft yellow siltstone, with some sandstone interbeds. This lithology belongs almost certainly to the Arthur Creek Beds, and consequently there is little room for the Arrinthrunga Formation unless its strike is transverse to that of the Dulcie Syncline. The bore was re-drilled in 1962

(approx.) and logged by D.R.G. Woolley, of the Bureau's Resident Geologist Staff in Alice Springs. The new bore was located 50 yards north of the first bore; it penetrated 30 feet of Cainozoic sediments and then 220 feet of quartz sandstone, claystone and siltstone which has not been positively identified but certainly does not fit known lithologies of the Arrinthrunga Formation, but may be the Arthur Creek Beds.

(3) Core hole Grg2, on the north side of the Dulcie Syncline, penetrated friable quartz sandstone, lithologically identical with the Devonian Dulcie Sandstone, and was abandoned at 354 feet.

(4) Core hole Grg5, also on the north-side of the Dulcie Syncline, penetrated Quaternary sand from surface to 173 feet, and then a sequence of limestone, oolitic limestone, sandstone and siltstone from 173 to 450 feet (total depth). This sequence has some lithological similarities to both the Tomahawk Beds and the Arrinthrunga Formation; trilobites found at 174'6"-175'6", and at 177'3" are "not older than Upper Cambrian" (Gilbert-Tomlinson, in Milligan, 1963, unpubl.), and therefore are not sufficiently diagnostic of either the Tomahawk Beds or the Arrinthrunga Formation.

(5) About 16 miles north-west of core hole Grg2, low outcrops of oolitic unfossiliferous limestone underlie, in part, fossiliferous Upper Cambrian sandstone of the Tomahawk Beds, and have tentatively been included in the Tomahawk Beds; these are the only known outcrops which might be part of the Arrinthrunga Formation.

(6) The north-western limit of the Arrinthrunga Formation trends between Ooratippra homestead and Mount Ultim, and parallel to a major Precambrian fault trend. It may mark a fault, active in post Arrinthrunga-pre Tomahawk Bed time, with the downthrown side to the south-east; subsequent erosion may have caused some thinning of the formation on the uplifted north-western before late Upper Cambrian transgressive seas covered the area.

However, there is no known evidence of such a fault affecting the Adelaidean and Lower Cambrian sediments and Precambrian rocks on the southern flank of the Dulcie Range.

(7) There is no core hole which spudded in the Tomahawk Bed sequence, nor has any stratigraphic or exploratory well penetrated them; therefore we cannot adequately compare sequences in Grg1 and 5, and outcrops 16 miles north-west of Grg2, with lithologies of known outcrops of the Beds. However, the known transgression of Tomahawk Beds over older rocks, particularly north-west of Huckitta homestead, indicates that the main probability is that the sequences in Grg1 and Grg5 belong to the Tomahawk Beds. This does not negate the possibility of the Arrinthrunga Formation occurring beneath them, but merely indicates that the core holes were not deep enough to penetrate the formation, if present.

A striking feature of the lithology of the Arrinthrunga Formation is the abundance of oolites and algae, particularly in the upper parts of unit 2 and the lower parts of unit 4. The algae are usually in dome shaped colonies, each dome consisting of many individual "rods" of Collenia. One easily-accessible locality where algae are well displayed is about 4 miles south-east of Lucy Creek homestead, near the track leading from this homestead to the Tarlton Downs-Jervois road. At this locality, low but prominent mounds of algal limestone crop out in the right hand side of the track in the bed of a shallow stream. Larger algal colonies about 9 feet in diameter are exposed in Eurowie Creek, but access to this locality is difficult. An interesting occurrence of syngenetic lead was found by a prospector in the upper part of the Arrinthrunga Formation in 1960, and was subsequently tested and abandoned by the Consolidated Zinc Pty Ltd (1962, unpubl.). Woolley and Rochow (1961, unpubl.) examined the deposit for the Bureau. Additional information in the occurrence, about 8 miles east of Arapunyah homestead, is given in the section on Economic Geology.

The main structural features in the Arrinthrunga Formation are faults trending north-west, with the eastern blocks downthrown. In the Dulcie and Toomba Range areas these can be dated as post-Upper Devonian and it is assumed that most, if not all, of the other faults are of the same age. Some of the faults are up to 60 miles long and the throws are of the order of several thousands of feet but cannot be determined more accurately because of lack of knowledge of eroded thicknesses of Adelaidean rocks, e.g., along the Toomba Fault near the Queensland-Northern Territory border. Associated with the faults are several small drag folds, both anticlines and synclines; however, folding movements have not affected the Arrinthrunga Formation to a marked extent. The most prominent surface folds are the Huckitta Anticline and an un-named dome about 8 miles east of it, but the results of Exoil Co. Ltd Huckitta No. 1 Well, on the Huckitta Anticline, indicate a reasonable suspicion that the beds may be compacted over an Adelaidean "high".

Eurowie Sandstone Member

Definition: Derivation of Name: From Eurowie Yard (latitude 22°29'S, longitude 135°54'50"E, approximately), on the western bank of the southern branch of Eurowie Creek. The type locality is in the Eurowie Yard area, but no type section has been measured in the member because of irregular dip readings and incomplete sequences.

Map Reference: Huckitta 1:250,000 Sheet area; Plate 3.

Author of Name: Smith (1964a, op cit.).

Distribution: By definition, the Eurowie Sandstone Member is restricted to an almost continuous belt extending from latitude 22°10'S, longitude 136° approximately southward for 30 miles to about 5 miles east of Picton Spring, at latitude 22°35'S, approximately.

Lithology: Quartz sandstone, red-brown, medium-grained, laminated to thin-bedded, with some beds of fine-grained quartz sandstone and siltstone near the base; some sandstone is dolomitic and grades vertically and laterally to dolomite in its upper levels. Abundant ripple-marks, small-scale cross-beds, halite casts, mud cracks and mud pellets are features of the member.

Thickness: Ranges from 50 to 100 feet.

Contacts: The base usually shows a sharp, conformable contact with underlying limestone and dolomite, but the top usually grades vertically, and sometimes laterally, into dolomite.

Fossils: None found.

Age: Upper Cambrian, because the unit is part of the Arrinthrunga Formation.

Description and Comment: The weathered red-brown colour of the Eurowie Sandstone Member gives a dark, easily-followed pattern on air photographs. Fresh sandstone samples are white. The halite casts are well-developed and consist of hollow cubes of dolomitic sandstone and dolomite. The member crops out in low rises and as low outcrops and scree on the surface of carbonate rocks. Many beds are slumped and dips are often very irregular.

The Eurowie Sandstone Member has no known equivalent in the western and central parts of the Huckitta Sheet area, nor is any known in the Tobermory, Hay River, Mount Whelan Sheet areas. In the north-eastern part of the Huckitta Sheet area the Arrinthrunga Formation contains many lenses of ripple-marked quartz sandstone, many of which grade laterally to dolomite, but they are not all confined to one stratigraphical horizon, and none is at the same stratigraphical level as the Eurowie Sandstone Member. Accordingly, the member is restricted to the area of distribution shown on Plate 3.

Meeta Beds

Definition: Derivation of Name: From Meeta Bore, at latitude 21°27'S, longitude 137°15'E, on the main road between Argadargada and Lake Nash homesteads. No reference section is available, because of poor and discontinuous outcrop, but a reference area for the Meeta Beds is an arcuate belt extending from about 4 miles west of Meeta bore to about 4 miles north of it. Neither the base nor the top of the sequence is exposed and therefore the term "Beds" is preferred to the formal naming of a formation.

Map Reference: Sandover River Sheet area; Plate 4.

Author of Name: Nichols (1966).

Distribution: The north-eastern part of the Elkedra Sheet area (Plate 3), most of the northern half of the Sandover River Sheet area, and part of its southern half (Plate 4); the southern part of the Avons Downs Sheet area (Plate 2), and perhaps the central-eastern part of the Frew River Sheet area (Plate 1).

Lithology: Predominantly dolomite in the surface, with interbeds of quartz sandstone and siltstone. Fragmentary secondary chert is very common on the surface and much of it is oolitic and pelletal; some oolitic limestone beds are known.

Thickness: A complete sequence is unknown but thickness probably exceeds 1000 feet in most localities; the Bureau's core holes Grg4 and Grg14 have total depths of 739 feet and 720 feet respectively, and water bore G2 on Lake Nash Station, about 10 miles north-west of Meeta Bore, penetrated 902 feet of the Beds; an unsuccessful water bore, about 10 miles south-west of Meeta Bore, was abandoned in the Meeta Beds at a depth of 1036 feet. None of these core holes or water bores reached the base of the sequence.

Fossils: Nichols (1964, unpubl.) found recrystallised gastropods of probable Upper Cambrian age, 13 miles west-south-west of Georgina Downs homestead, but these fossils could not be dated definitely. The only other fossils known are algae from some dolomite beds in the Argadargada station area.

Age: Upper Cambrian (based on lithological correlation with part of the Arrinthrunga Formation); part of the Meeta Beds in the north could be Middle Cambrian, but the only supporting evidence for this is the occurrence of Middle Cambrian limestone in Lake Nash No. 1 Well, and the uncertainty of the age of overlying dolomite which dips south towards, if not under, the Meeta Beds.

Correlates: Part of the Arrinthrunga Formation (unit 2 and below) and perhaps part of the Camooweal Dolomite (based on correlations of detailed lithology of core holes Grg14 and Grg9A; Nichols, 1966, unpubl.).

Description and Comment: The Meeta Beds usually crop out poorly in low rises, often covered with chert scree. These rises are separated by expanses of black soil plains with protruding dolomite blocks and thin layers of quartz sandstone rubble, in the east; in the west, on the Elkedra Sheet area, outcrops are mainly confined to a series of ridges trending south-west from Annitowa homestead and surrounded by spinifex-vegetated sand plain, except for small areas north and west of the homestead, where dolomite blocks protrude through brown soil plains. Outcrops of sandstone occur in small rises and also in low benches. The outcrops in the Avon Downs Sheet area are continuous with those on the Sandover River Sheet area in very low rises and ridges, and they are tentatively included in the Meeta Beds because their lithologies - buff and white dolomite, and oolitic and pelletal chert - resemble those of the Meeta Beds rather than the fossiliferous Wonarah Beds to the north.

Dips in the Meeta Beds are usually very irregular, due to slumping, particularly in quartz sandstone. However, some reliable, low south dips have been observed in the ridges south-west of Annitowa. The low, irregular dips and discontinuous outcrops make the determination of stratigraphy and thickness difficult.

Nichols (1964, unpubl.) reported the lithology of the Meeta Beds in the Sandover River Sheet area as buff, microcrystalline and medium to coarse crystalline dolomite, buff, microcrystalline and cryptocrystalline dolutite, buff pelletal and intraclastic, medium to well-sorted, medium to thick-bedded dolarenite, buff, oolitic and quartzose dolarenite, buff algal dolomite, buff intraclastic dolarenite, with large intraclastics 2-3 cms long, and brown, medium to coarse-grained, ripple-marked, cross-bedded, medium to well-sorted quartz sandstone, and some dolomitic sandstone. Nichols (1965, unpubl.) described the lithologies in more detail. In the Elkedra Sheet area, Smith and Milligan (1963, unpubl.) described the lithology in ridges east of Annitowa homestead as dolomite, chert, and brown, friable quartz sandstone, overlain by buff and light-grey finely-crystalline limestone and oolitic limestone, with interbeds of soft, grey calcareous sandstone; blocks of brown dolomite occur on plains north and west of the homestead. In the ridges south-west of the homestead, buff and white dolomite predominates, but near the south-western extremity of the ridges there are numerous beds of green and purple siltstone and some interbeds and lenses of quartz sandstone. One prominent lens of quartz sandstone is 75 feet thick and is white (when fresh), medium coarse-grained, friable, clean and ripple-marked.

In outcrop, the boundary between the Meeta Beds and the overlying Tomahawk Beds is not seen, but the lithologies of the two units are reasonably distinctive and an approximate boundary can be drawn between the Meeta Beds and the darker brown, thick-bedded coarsely crystalline dolomite and dolarenite, with fossiliferous interbeds of sandy dolomite, quartz sandstone and siltstone, of the Tomahawk Beds. The boundary between the Meeta Beds and the Ninmaroo Formation, in the western part of Sandover River Sheet area, is more difficult to select; here no clear cut boundary is exposed and it is drawn approximately, between two dolomite lithologies one of which (the Ninmaroo Formation) grades laterally into fossiliferous sandstone of the Tomahawk Beds.

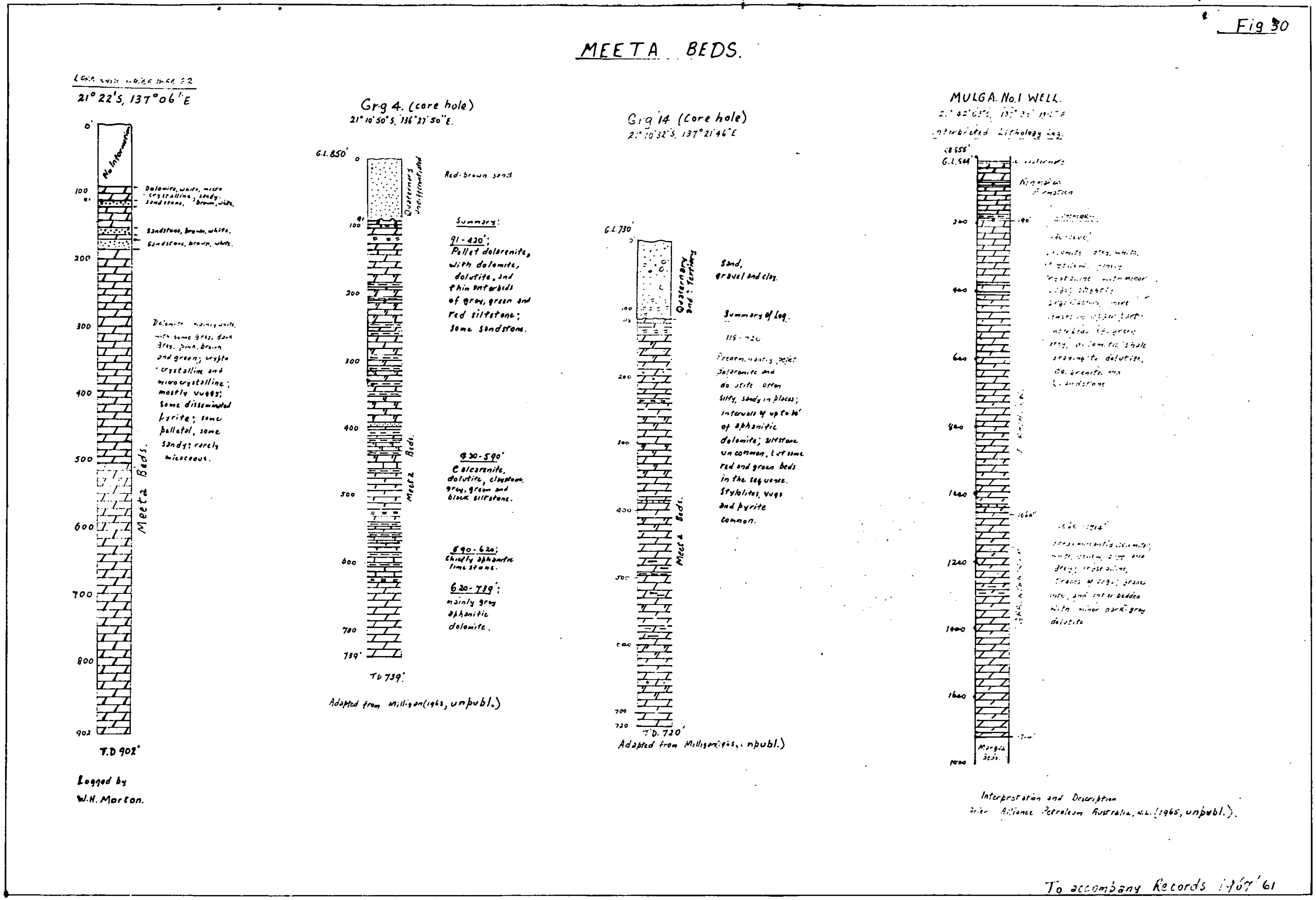


Fig 30
MEETA BEDS.
21° 22'S, 137° 06' E
No Information
Dolomite, white, micro-crystalline, sandy.
Sandstone, brown, white.
Sandstone, brown, white.
Sandstone, brown, white.
Dolomite mainly white, with some grey, dark grey, pink, brown and green; crypto-crystalline and microcrystalline; mostly vuggy; some disseminated pyrite; some pelletal, some sandy; rarely micaceous.
Meeta Beds.
T.D 902'
Logged by
W.H. Morton.
Grg 4. (core hole)
21° 10' 50" S, 136° 27' 50" E.
G.L. 850'
Red-brown sand
Quaternary Unconsolidated
Summary:
91 - 420';
Pellet dolarenite, with dolomite, dolutite, and thin interbeds of grey, green and red siltstone; some sandstone.
420 - 590'
Calcarenite, dolutite, claystone, grey, green and black siltstone.
590 - 620';
Chiefly aphanitic limestone.
620 - 739';
mainly grey aphanitic dolomite.
Meeta Beds.
TD 739'
Adapted from Milligan (1963, unpubl.)
Grg 14 (Core hole)
G.L. 730'
Sand, gravel and clay.
Quaternary and Tertiary
Summary of Log.
Meeta Beds.
T.D. 720'
MULGA No. 1 WELL.
Interpreted Lithology Log.
Mangza Beds.
Interpretation and Description
after Alliance Petroleum Australia, N.L. (1965, unpubl.).
To accompany Records 1967/61

167.

Subsurface information on the Meeta Beds has been obtained in Bureau core holes Grg4 and Grg14 (Milligan, 1963, unpubl.) and presumably also in Alliance Petroleum Australia N.L. Mulga No. 1 Well, although the sequence below the Ninmaroo Formation is named the Arrinthrunga Formation in the completion report (Alliance Petroleum N.L., 1965, unpubl.). Valuable supporting information on subsurface lithologies has been obtained from the Bureau's Resident Geologist staff at Alice Springs, who logged several water bores drilled in 1963 and made the unpublished results available to the author. Detailed petrological examination on core from Grg4 has been made by Fehr (1963, unpubl.) and on Grg14 by Nichols and Fehr (1964, unpubl.). The logs of Grg4, Grg14 and the appropriate part of Mulga No. 1 Well, together with the log of water bore G2 drilled on Lake Nash Station, are shown on Fig. 30.

QUEENSLAND

Pomegranate Limestone

Definition: Derivation of Name: From Pomegranate Creek, a tributary of the Burke River, with a source about 20 miles south-west of Selwyn. The type locality is "Pomegranate Creek, Chatsworth Station, south of Cloncurry, north-western Queensland" (Lexicon, 1962, Fascicule 52, p. 117). No type section has been published.

Map Reference: Duchess 1:250,000 Sheet area; Plate 4.

Author of Name: Opik (1960, p. 101-102).

Distribution: The main outcrops are in the Duchess Sheet area, where the formation occupies a surface area of about 350 square miles; outcrops of a few square miles in extent are known in the De Little Range in the Boulia Sheet area. In the subsurface, the formation has been identified in the interval 752-1569 feet in Black Mountain No. 1 Well, and in the interval 303-1604 feet in Beantree No. 1 Well (Phillips Petroleum Company, 1963, unpubl.).

Lithology: Light-coloured, crystalline, bituminous flaggy and laminated limestone, grey sandy limestone, intraformational breccia, some chert nodules; in the subsurface, light grey, hard, dense microcrystalline and cryptocrystalline limestone, silty and argillaceous, with thin interbeds and laminae of grey-black, calcareous, micaceous shale.

Thickness: 100 feet estimated in the Pomegranate Creek area, but the base is not exposed (Carter and Opik, 1963); 50 feet in outcrop and probably 300 feet in water bores in the De Little Range area (Casey et al., 1960, unpubl.); 817 feet in Black Mountain No. 1 Well and 1301 feet in Beantree No. 1 Well (Phillips Petroleum Company, 1963, unpubl., op cit.).

Contacts: The base of the formation is not exposed; it is overlain by, and interfingers with, the O'Hara Shale; in both Black Mountain No. 1 and Beantree No. 1 Wells it rests on un-named sequences of probable lower Middle Cambrian age.

Fossils: Glyptagnostus reticulatus, Olenus sp. nov. in the lower beds; Eugonocare tesselatum Whitehouse, Proceratopyge, Lotagnostus and Pseudagnostus (several species) in succeeding beds, and Irvingella and Iddingsia in the highest beds (Opik, 1960). Brachiopods are also common (Casey et al., 1960, unpubl.).

Tomlinson (in Phillips Petroleum Company, 1963, op cit.) has identified the following fossils in cores of Pomegranate Limestone from Black Mountain No. 1 Well:

Core No. 3, 830-840 feet - hydroids, phosphatic brachiopod (indet.) and trilobite fragment (indet.).
Core No. 4, 1033-1043 feet - agnostids (undescribed); Proceratopyge sp.
Core No. 5, 1427-1437 feet - agnostids (indet.); trilobite (undescribed), Pseudagnostus sp., Clavagnostus sp.

Mackellar (in Phillips Petroleum Company, 1963, op cit.) has identified the following fossils in Beantree No. 1 Well:

Cuttings, at 700 feet - Lingulella sp.
Core No. 2, 983-993 feet - Pseudagnostus sp.; Proceratopyge sp.; ?Dicellomus sp.

Age: lower Upper Cambrian.

Correlates: Lower part of the O'Hara Shale and perhaps the Georgina Limestone.

Description and Comment: The outcrops of the Pomegranate Limestone in the Duchess Sheet area are low, discontinuous, gently undulating and probably repeated by small-scale faulting; only the upper part of the sequence is exposed and all of these factors preclude the definition of a type section. In the Boulia Sheet area, outcrop is also poor. In both Sheet areas, the O'Hara Shale conformably overlies the Pomegranate Limestone and in some localities the two formations interfinger. The Pomegranate Limestone has been named formally from outcrops, but surface sections are very thin when compared with the thicknesses of 817 and 1301 feet identified as Pomegranate Limestone in Black Mountain No. 1 Well and Beantree No. 1 Well respectively.

In Beantree No. 1 Well, the Cretaceous Wilgunya Formation unconformably overlies the Pomegranate Limestone and an unnamed lower Middle Cambrian limestone underlies it at 1604 feet. The selection of the base of the Pomegranate Limestone is presumably based on electric log characteristics, which show a marked change at 1604 feet and are supported in part by the presence of coarsely crystalline limestone below that depth. Lower Middle Cambrian fossils have been identified in Core No. 3, 1635-1645 feet (Mackellar, in Phillips Petroleum Company, 1963, op cit.). The sequence in Beantree No. 1 Well is the thickest known in the Pomegranate Limestone and it shows a thickening from Black Mountain No. 1 to Beantree No. 1, which is an opposite case to Middle Cambrian sedimentation between these two localities.

O'Hara Shale

Definition: Derivation of Name: From O'Hara Gap Station, latitude 21°25'S, longitude 140°05'E, approximately, in north-western Queensland.

Map Reference: Duchess 1:250,000 Sheet area.

Author of Name: Opik (1956a, op cit.).

Distribution: In the Duchess Sheet area the unit is confined to small, discontinuous areas in the Burke River valley, between Devoncourt and Chatsworth homesteads. The formation occurs also in the north-western part of the Boulia Sheet area.

Lithology: Micaceous laminated well-bedded pink and red shale and siltstone, with thin sandstone interbeds and some chert interbeds (Opik 1960, op cit.). Carter and Opik (1963, op cit.) record conglomerate in the sequence; Casey et al., (1960, op cit.) also reported conglomerate interbeds.

Thickness: Up to 200 feet preserved (Carter and Opik, 1963, op cit.).

Contacts: Conformably overlain by the Chatsworth Limestone (in Black Mountain No. 1 Well), but most outcrops are overlain by Cretaceous or Cainozoic sequences; in some places the O'Hara Shale conformably overlies the Pomegranate Limestone and also interfingers with it.

Fossils: *Cartillicephala*, *Blountia*, *Meteoraspis*, *Brassicicephalus*, Norwoodiidae, and *Liostracina*, *Drepanura*, *Stephanocare*, *Blackweldaria*; *Rhodonaspis longula* Whitehouse, *Stephanocare richthofeni* Monke and *Glyptagnostus stolidotus* Opik. All of these trilobites are found in a chert bed low in the O'Hara Shale (Opik, 1961); Opik (1956a), op cit., stated that a chert bed, (presumed to be the same as the one mentioned in the 1961 publication) about 10 feet above the base of the O'Hara Shale contained a fauna of essentially Upper Cambrian, but included some upper Middle Cambrian forms. Opik (1961) later made no mention of the Middle Cambrian fossils and assigned a lower Dresbachian age to the fauna listed above.

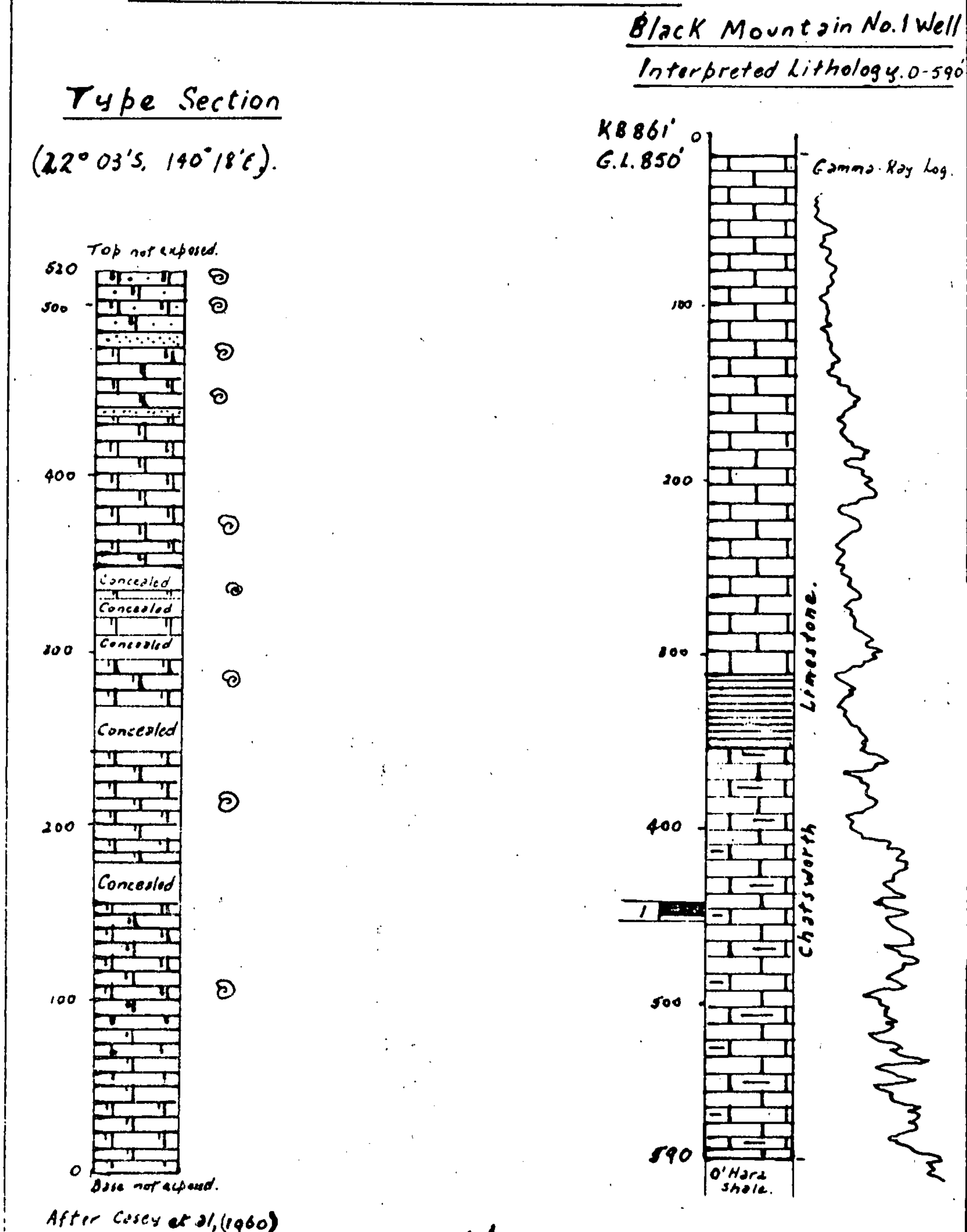
Other trilobites in the O'Hara Shale, above the chert bed, include *Eugoncare*, *Proceratopyge*, *Olenus*, *Pseudagnostus*, *Litagnostus*, *Clavagnostus* and *Idamea*.

Age: lower Upper Cambrian.

Description and Comment: The O'Hara Shale crops out as cappings to mesas and plateaux and is usually weathered red, brown or pink. The shale and siltstone are well-laminated. It has been tectonically disturbed along with other Palaeozoic formations in the Burke River Structural Belt, but dips are always gentle except near faults.

The subsurface extent of the O'Hara Shale is unknown; it has been identified in Black Mountain No. 1 Well, but in Beantree No. 1 Well the Pome-

Sections in Chatsworth Limestone. Fig 31



To accompany Records 1967/61

granate Limestone is overlain by Mesozoic sediments and the O'Hara Shale is not present, although the upper part of the Pomegranate Limestone may be laterally equivalent to it. The O'Hara Shale is 162 feet thick in Black Mountain No. 1 Well and consists of dark grey, micaceous, silty, slightly calcareous shale with laminae of brownish-grey calcareous siltstone (Phillips Petroleum Company, 1963, op cit.). No diagnostic fossils were obtained.

Chatsworth Limestone

Definition: Derivation of Name: Chatsworth Station, which extends from Duchess Sheet area to Boulia Sheet area. The homestead is at latitude 21°59'S, longitude 140°17'E. The type area is at latitude 22°03'S, longitude 140°18'E.

Map Reference: Duchess and Boulia 1:250,000 Sheet areas; Plate 4.

Author of Name: Casey (1959).

Distribution: In the Duchess Sheet area, north, north-west and east of Chatsworth homestead; in the Boulia Sheet area, 16 miles east-north-east of Digby Peaks, and at Black Mountain, Mount Ninmaroo, and near Dribbling Bore.

Lithology: Grey and dark grey calcarenite and calcilutite, with minor calcareous sandstone, coquinite beds and intraformational breccia. The rocks are dominantly thin-bedded and laminated, with minor cross-bedding. Opik (1960) reported dolomite in the sequence, but Carter and Opik (1963) do not mention dolomite.

Thickness: 520 feet in the type section, where neither the base nor the top is exposed (Casey 1959, op cit.). Casey, et al. (1960, unpubl.) report other thicknesses as follows: Near Dribbling Bore, 200 feet; at Mount Datson, 650 feet; at Mount Ninmaroo, 375 feet; at Black Mountain, 1050 feet. The base is not exposed at these localities, but Black Mountain No. 1 Well penetrated the contact of the Chatsworth Limestone with the underlying O'Hara Shale at 590 feet (Phillips Petroleum Company Ltd, 1963, unpubl.). The dip of the Chatsworth Limestone in this well is not stated, but shale laminae in Core No. 1 (440-451 feet) were almost horizontal. By combining surface and subsurface sections at Black Mountain the complete thickness of the formation there is 1500 feet. Opik (1960, op cit.) gives total thickness of the order of 2000 feet.

Contacts: Rests conformably on the O'Hara Shale and is conformably overlain by the Ninmaroo Formation (Casey, 1959); disconformably overlies the Middle Cambrian Inca Formation.

Fossils: Abundant trilobites and brachiopods; the fauna is mainly undescribed, but Opik (1960, op cit.) lists the following from the lower part of the Chatsworth Limestone: Eoorthis, Billingsella, Paramansuyella, Maladiodella, Proceratopyge?.

Age: Upper Cambrian (Franconian and Trempealeauan); Opik (1960, op. cit.).

Description and Comment: Outcrops in the Duchess Sheet area are generally poor, but the formation crops out better in a chain of isolated peaks in the Boulia Sheet area. Casey et al., (1960, unpubl.) have described the type section (Fig. 31) of the Chatsworth Limestone as follows:

Thickness (feet)	
35	Calcarenite, sandy, laminated, with brachiopods; (15 feet of the interval is concealed);
10	Sandstone, calcareous;
20	Calcarenite, sandy, thin and medium-bedded; agnostids at 475 feet;
15	Calcarenite, coarse grained, with some sandy calcarenite; brachiopods at 446 feet, trilobites at 442 feet;
5	Calcarenite, fine-grained, laminated, and calcilutite, laminated;
5	Sandstone, calcareous, cross-bedded, slumped;
130	Calcarenite, sandy, fine-grained; trilobites and brachiopods at 425 feet and 430 feet; trilobites, brachiopods, gastropods, blastoids in a coquinite at 370 feet; trilobites at 345 feet; about 40 feet of the interval are concealed;
55	Calcarenite, laminated and thin-bedded, and calcilutite, medium and thin bedded; trilobites, blastoids and brachiopods at 280 feet;

Thickness (feet)	
35	Calcarenite, thin-bedded; some sandy and some "two-tone" calcarenite; trilobites;
210	Calcarenite, coarse-grained, with calcilutite, laminated; trilobites and shells at 110 feet.

520, thickness of part of the Chatsworth Limestone; the base is not exposed.

In Black Mountain No. 1 Well, Phillips Petroleum Company (1963, unpubl.) describe the Chatsworth Limestone as follows:

"0-590'	Limestone, light-grey, grey to buff, crypto to microcrystalline, argillaceous, silty in part, glauconitic in part; with interbedded grey to dark grey, micaceous, calcareous shale.
Core No. 1	
440-451' Recovered 8'7"	Interlaminated limestone, buff, microcrystalline, argillaceous, with traces of glauconite; and silty shale, dark grey, calcareous. Shale laminations vary in thickness from 1/10 to 10mm., making up 20-50 per cent of core by volume; laminations near-horizontal for the most part but occasionally in wavy bands".

Casey et al., (1960, unpubl.) have summarized the lithology of the Chatsworth Limestone cropping out in the base of Black Mountain; the sequence, in descending order, consists of:

Thickness (feet)	
	Dolomite beds at the base of the Ninmaroo Formation overlying
450	Calcarenite, fine-grained, medium to thick-bedded, laminated in part, with some sandy laminae, pyritic in part; brachiopods and trilobites

Thickness (feet)	
600	Calcarenite, fine-grained, some coarse-grained, some sandstone, friable, and calcilutite. Grey to blue grey, thin-bedded and laminated, and with bituminous smell when struck. Agnostid trilobites.
Total 1050, of part of the sequence, whose base is not exposed.	

There is some overlap between this section, measured by Casey et al., (1960, unpubl.) and the sequence penetrated in the well (Fig. 31); this is the most complete surface sequence available in the Chatsworth Limestone.

The Chatsworth Limestone has been folded and faulted along the Black Mountain-Mount Ninmaroo-Mount Datson line of outcrops; the downthrown side is on the east, and the throw is at least 1000 feet.

Gola Beds

Definition: Derivation of Name: County of Gola, 6 miles north of St Lucia homestead (latitude 22°38'S, longitude 140°30'E).

Map Reference: Boulia 1:250,000 Sheet area; Plate 4.

Author of Name: Casey (1959, op cit.).

Distribution: In two small inliers in the Momedah Anticline, east of Black Mountain.

Type Area: The inliers; a type section has not been designated.

Lithology: Calcarenite and calcilutite.

Thickness: An estimated maximum of 150 feet is exposed.

Contacts: The base is not exposed; the eroded top is overlain unconformably by the Lower Cretaceous Longsight Sandstone.

Fossils: Brachiopods and trilobites including a rich agnostid fauna. The fauna has not been examined completely, but Opik (1960, op cit.) named Richardsonellidae, Kaolishania, Koldinioidia, Pagedia, Pseudagnostus and Sinosaukia?.

Age: Upper Cambrian.

Description and Comment: The Gola Beds crop out poorly in low, vegetated rises in two elongated inliers; the beds protrude sporadically through soil cover, but crop out reasonably well where dips are steep, near the axis of the asymmetrical Momedah Anticline. This anticline is a post-Cretaceous structure and Casey et al., (1960, unpubl.) state that there is field evidence, at the northern end of the northernmost outlier of Gola Beds, of an earlier anticlinal structure.

The Gola Beds are probably time-equivalents of part of the Chatsworth Limestone (Opik, 1960, op cit.) but this has not been clarified, and the fauna of the Gola Beds has not been found in the Chatsworth Limestone.

Georgina Limestone

Definition: Derivation of Name: From the Georgina River. Neither a type area nor a type section has been designated.

Map Reference: Glenormiston and Mount Whelan 1:250,000 Sheet areas; Plate 4.

Author of Name: Opik (1960, op cit.) used the name in its present context, but Ogilvie (in Whitehouse, 1931) first proposed the name for a sequence of fossiliferous limestone "in and around the basin of the Georgina River"; Whitehouse (1936) used "Georgina Series", for limestone in this area and his usage was continued by David and Brown (1950, Vol. 1, pp. 115-118) and by the compilers of both the Geological Map of Queensland (1953) and the Geological Map of Australia (1953). Opik (1956a)objected to the usage on the grounds that the term Georgina Series was too broad and indistinct and that it included both Middle and Upper Cambrian rocks together with unfossiliferous dolomite - the Camooweal Dolomite. He stated that it should be restricted to either Upper Cambrian limestone in the Glenormiston Station area, or the Camooweal Dolomite.

Subsequently Opik (1960, op cit.) restricted the name Georgina Limestone to a thin limestone sequence south of Glenormiston homestead and he stated (1963) that fossiliferous Middle Cambrian inliers could not be distinguished lithologically from the Georgina Limestone; Reynolds (1964b, unpubl.) mapped the formation southwards to the Mount Whelan Sheet area.

Distribution: Small areas south of Glenormiston homestead, in the Glenormiston Sheet area, and larger, adjoining areas to the south in the Mount Whelan Sheet area.

Lithology: Flaggy, grey, sandy limestone with several breccia interbeds Opik (1960, op cit.) in the upper part; dark, bituminous limestone with shale partings, and light grey aphanitic limestone, in the lower part, which crops out in the Glenormiston Sheet area only (Opik, 1963). Reynolds, 1964a (unpubl.) described the lithology in the Glenormiston Sheet area as hard, laminated and thin-bedded, blue-grey and brown calcilutite and sandy calcilutite, with cross-beds and ripple marks, soft white marl, oolitic limestone, intraformational breccia, two-tone limestone, sandy limestone and calcareous sandstone. Reynolds (1964b, unpubl.) believed that two lithologically-distinct units of the formation were also present in the Mount Whelan Sheet area, and that outcrops of the older (sandy) beds occurred along anticlinal crests.

Thickness: Maximum of 100 feet (Reynolds, 1964a, unpubl.) exposed in the Glenormiston Sheet area, and a similar thickness in the Mount Whelan Sheet area.

Contacts: Disconformably overlain by the Ninmaroo Formation; the base of the Georgina Limestone is not exposed.

Fossils: *Hypagnostus hippalus* Opik (*Leiopyge laevigata* zone of late Middle Cambrian); fossils of *Glyptagnostus stolidotus* zone (Mindyallan Stage) in the Glenormiston Sheet area, fossils of the *Glyptagnostus reticulatus*, *Corynexochus plumula* and *Erixantium sentum* zones (all of Idamean Stage) in the Mount Whelan Sheet area (Opik, 1963, op cit.).

Age: Late Middle Cambrian to early Upper Cambrian.

Description and Comment: The outcrops and fossils of the Georgina Limestone indicate a pre-Ninmaroo erosional period. Opik's 1963 work is the latest available on the Georgina Limestone, and he has now included Middle Cambrian beds in it but this information has not been incorporated on Plate 4, where the unit is shown as Upper Cambrian.

The subsurface extent of the Georgina Limestone is unknown, but it crops out in the eastern limb of the Toko Syncline and probably continues into the trough; on the western limb of the syncline the Georgina Limestone has not been recognised, but part of the Arrinthrunga Formation and perhaps the upper part of the Marqua Beds are regarded as time equivalents. The thickness of the Georgina Limestone is unknown; Tyson's No. 1 bore (9 miles south of Glenormiston homestead) spudded in the formation and penetrated 1810 feet of limestone (Opik, 1960). Reynolds (1964b, unpubl.) re-interpreted a report of Jack (1895), which presumably referred to Tyson's No. 1 bore, and suggested that the Georgina Limestone could be about 1100 feet thick. Papuan Apinaipi Petroleum Company Limited (1965, unpubl.) reported 1709 feet of Georgina Limestone in the interval 2381-4090 feet, in Netting Fence No. 1 Well; here the formation lies between the Ninmaroo Formation above and the Mungerebar Limestone below, with dips suggesting an unconformable relationship between the Georgina and Mungerebar Limestones. However, Core No. 14 (4910-4920 feet) contains early Upper Cambrian fossils of the Idamena Stage (possibly in the zone of Glyptagnostus reticulatus) in a bituminous limestone with black shale laminae (Gatehouse, in Papuan Apinaipi Petroleum Company Limited 1965, op cit.) which is shown on the well logs as the Steamboat Sandstone. Therefore the stratigraphic interpretations of parts of Netting Fence No. 1 Well may be incorrect. The author has included the sequence in the interval 2381-5080 feet in the Arrinthrunga Formation.

Mungerebar Limestone

This formation, which ranges in age from Middle to Upper Cambrian, has already been described in the Middle Cambrian section of this Bulletin.

CAMBRO-ORDOVICIAN

This section of the Bulletin describes the stratigraphy of the Tomahawk Beds and the Ninmaroo and Kelly Creek Formations. The Tomahawk Beds range in age from Upper Cambrian to Lower Ordovician, and contain equivalents of both the Ninmaroo and Kelly Creek Formations. The three units are best treated in a section separate from other Upper Cambrian and Lower Ordovician sequences.

Tomahawk Beds

Definition: Derivation of Name: From Tomahawk Yard, latitude 22°26'S, longitude 135°48'45".

Author of Name: Smith (1964a).

Map Reference: Huckitta 1:250,000 Sheet area; Plate 3.

Reference Section: In the Point Spring area (latitude 22°37'30"S, longitude 135°50'E) at the south-eastern end of the Dulcie Range.

Distribution: On the Huckitta, Alcoota, Barrow Creek, Elkedra, Sandover River and Tobermory Sheet areas. Outcrops extend along the south-western flank of the Dulcie Range, in a narrow belt with (usually) moderately steep dips; in most of the north-eastern flank of the Range dips are very low and the Beds extend northwards discontinuously from the Dulcie Range towards Davenport Range; in the north-east of the Huckitta Sheet area, and on the Elkedra, Sandover River and Tobermory Sheet areas, the Beds form an extensive sheet of sediments which are always gently dipping except near faults and on the limbs of sharp folds.

Lithology: In the Huckitta Sheet area, essentially a basal sandstone with interbeds of siltstone grading laterally and vertically into dark brown and grey-brown dolomite, grey limestone, grey and brown sandstone, and green siltstone; this is succeeded by grey and brown sandstone with brown, sandy dolomite. This sequence is generally similar to those on Elkedra, Sandover River and Tobermory Sheet areas, but north-west of the Bundey River outcrops usually contain much more sandstone and less carbonate rock, and siltstone is usually white and leached. In the foothills of the Davenport Range, on both the Barrow Creek and Elkedra Sheet areas, some beds of sandstone and conglomerate are tentatively included in the Tomahawk Beds.

Contacts: In the central part of the Huckitta Sheet area the Tomahawk Beds are conformable on the Arrinthrunga Formation, but in other parts they are either faulted against that formation or are disconformable on it. North-west of the Bundey River, the Tomahawk Beds transgress several units of Precambrian rocks; on the Sandover River Sheet area they are probably disconformable on the Meeta Beds, and grade into the Ninmaroo Formation in the eastern part of that Sheet area; on Tobermory Sheet area the Beds are equivalent to the Kelly Creek and Ninmaroo Formations.

The Nora Formation conformably overlies the Tomahawk Beds in part of the Dulcie Range, but for most of the Huckitta-Alcoota-Barrow Creek Sheet areas, the Devonian Dulcie Sandstone unconformably overlies the Beds.

Fossils: The Tomahawk Beds contain abundant trilobites, pelecypods, brachiopods and ribeirioids, but the fauna is undescribed. Öpik and Tomlinson have made preliminary examinations of the fauna and Tomlinson (in Casey and Tomlinson, 1956) examined a few early collections from the Huckitta-Marqua area and reported the brachiopods Eoorthis and Huenella?, and the following trilobites: Litagnostus, Prosaukia (2 spp.) Sinosaukia, Sankia?. Pagodia cf. buda Resser and Endo, "Quadraticephalus" aff. teres Resser and Endo, Tsinania? Kingstonia, Shirakiella?. Three genera of ribeirioids were also present. All of these fossils came from the lower part of the sequence subsequently mapped as the Tomahawk Beds, and one Eoorthis? from a sequence (on the Tobermory Sheet area) which is now mapped as the Ninmaroo Formation. Tomlinson (op cit.) regarded all of these as middle Upper Cambrian (Franconian) in age, but considered one other trilobite resembling Tellerina, from a downfaulted block on the south-western side of Arthur Creek and north of Mount Playford (Huckitta Sheet area), to be of Upper Cambrian (Trempealeauian) age.

Age: Upper Cambrian-Lower Ordovician (Opik and Tomlinson, pers. comm.).

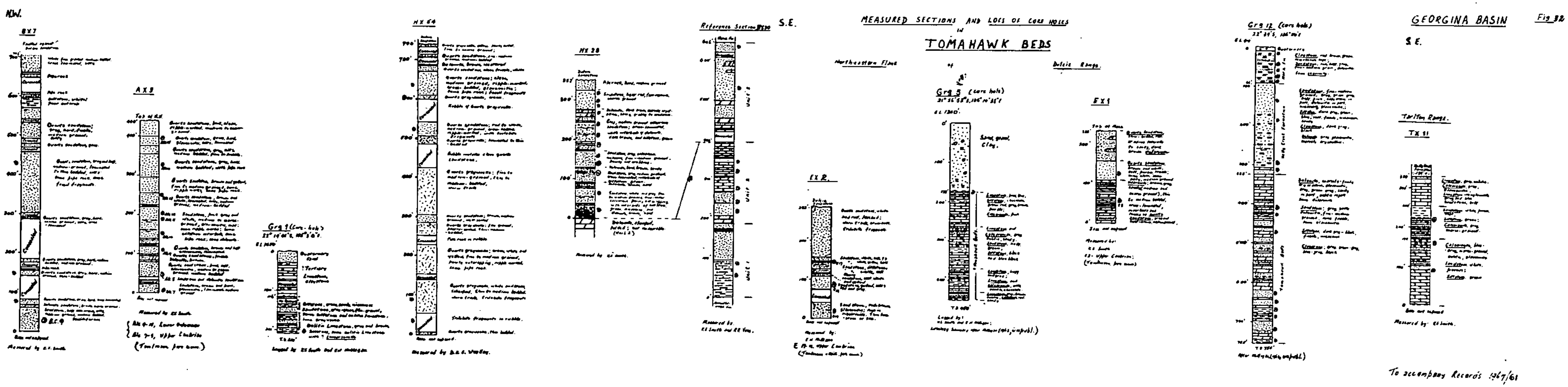
Correlates: Parts of each of the Ninmaroo and Kelly Creek Formations.

Description and Comment: The type of outcrop changes considerably over the large outcrop area; some changes are due to lithological variations, principally between dolomite and sandstone, and some are due to tectonics. Along the south-western flank and part of the north-eastern flank of the Dulcie Range, the beds crop out in low rounded hills and in cuestas, which are often covered with rubble. North-west of the Bundey River, the Beds crop out in low peaked hills, low terraces and mesas. In the north-eastern Huckitta and south-eastern Elkedra, Sandover River, and the northern part of Tobermory Sheet areas the Tomahawk Beds crop out in a plateau dissected and eroded into mesas and sharp peaks. In the remainder of the Tombermory Sheet area, outcrop is often poor in low hills with some strong benches of carbonate rock.

The Tomahawk Beds usually have low dips, but along much of the south-western flank of the Dulcie Range and along some of its north-eastern flank, the Beds are intricately folded, mainly by slumping; it is common to have the sequence repeated as many as four times in one hill. Beds of prominent dark-brown dolomite enable the order of succession to be established, and reliable thickness measurements.

In the reference section (HX30), measured and described by the author and R.R. Vine (in Smith 1964a, op cit.) the sequence, in descending order, consists of:

Thickness (feet)	
	Green siltstone of the Nora Formation overlying:
26	Sandstone, grey, medium-grained, soft, porous, calcareous, glauconitic, fossiliferous
13	Concealed
15	Quartz sandstone, coarse-grained, friable, cross-folded, grading laterally to light brown dolarenite
8	Sandstone, brown and grey, poorly outcropping, with pelecypods
1	Dolomite, dark brown, coarsely crystalline
15	Quartz sandstone, grey, medium-grained, thin to medium-bedded, cross-bedded, with worm trails
1	Dolomite, grey-brown, coarsely crystalline
5	Sandstone, medium-grained, friable, well-sorted, thin to medium-bedded, cross-bedded



N.W.
S.E.
MEASURED SECTIONS AND LOGS OF CORE HOLES
TOMAHAWK BEDS
GEORGINA BASIN
Fig 32
S.E.
Grg 1 (Core hole)
Grg 5 (core hole)
Grg 12 (core hole)
Reference Section
To accompany Records 1967/61

Thickness (feet)	
17	Quartz sandstone, medium-grained, thin to medium-bedded, cross-bedded, with mud pellets, ripple marks and worm trails, abundant "pipe-rock".
55	Sandstone, white and grey, medium-grained, friable, thin-bedded, poorly-sorted
10	Dolomite, grey, medium-bedded to massive, cross-bedded in part
2	Sandstone; medium-bedded, cross-bedded, dolomitic
31	Sandstone, white, medium-grained, friable, well-sorted
10	Dolomite, brown, coarsely crystalline, medium-bedded to massive
4	Dolomite, dark brown, medium-bedded, coarsely crystalline
1	Sandstone, fine-grained, laminated, glauconitic, micaceous
1	Dolomite, brown, sandy, coarsely crystalline
1	Sandstone, white, fine-grained, laminated, poorly outcropping
1	Dolomite, grey-brown, thin-bedded, cross-laminated, sandy
2	Dolomite-breccia, medium-bedded, sandy
3	Sandstone, medium-grained, friable, poorly-outcropping
1	Dolomite-breccia, sandy
3	Sandstone, calcareous, thin to medium-bedded, poorly outcropping
6	Dolomite, dark-brown, thick-bedded, coarsely crystalline
27	Concealed
1	Siltstone, soft, glauconitic, micaceous
9	Dolomite, dark-brown, corss-laminated, sandy, massive weathering
26	Calcarenite, grey, sideritic, poorly outcropping
2	Limestone, grey, coarsely crystalline, fossiliferous
11	Sandstone, grey, medium-grained, thin-bedded, poorly outcropping, with thin bands of laminated green siltstone

Thickness (feet)	
1	Limestone, grey, with abundant brachiopods
6	Limestone, grey, flaggy, cross-laminated
9	Limestone, grey, poorly outcropping
4	Calcarenite, grey-brown, medium-grained, thin-bedded
4	Limestone, grey, coarsely crystalline, with numerous brachiopods
15	Calcarenite, grey, poorly outcropping
5	Dolomite, brown and grey, sandy, cross-laminated
28	Calcarenite, grey, medium-bedded, cross-laminated
3	Limestone, grey, sandy, cross-laminated, with abundant brachiopods
21	Sandstone, grey, medium-grained, thin-bedded, poorly outcropping
4	Limestone, grey-brown, hard, sandy, with abundant brachiopods
36	Sandstone, grey, glauconitic, medium-grained, cross-laminated, fossiliferous
14	Dolomite, dark brown, thin-bedded, poorly-outcropping
3	Dolomite, brown, sandy, thin-bedded
83	Sandstone, grey, medium-grained, glauconitic, poorly-outcropping, with thin interbeds of sandy, glauconitic limestone
11	Sandstone, grey, soft, porous, medium-grained, glauconitic
13	Siltstone, green, micaceous, laminated, with thin interbeds of grey, medium-grained, glauconitic, fossiliferous sandstone
12	Sandstone, grey, firm, medium-grained, thin-bedded, glauconitic, fossiliferous, with interbedded green, micaceous siltstone
14	Siltstone, green, laminated, with interbeds of grey, glauconitic, fossiliferous, thin-bedded, medium-brained sandstone
53	Siltstone, green, poorly outcropping

Total 646, of Tomahawk Beds, ?disconformably overlying dolomite of the Arrinthrunga Formation.

This sequence is shown on Fig. 32; Smith (1964a, op cit.) divided the sequence into the following units:

Unit 3. 260 feet of sandstone, grey and brown, with dolomite, sandy brown
Unit 2. 200 feet of dolomite, dark-brown and limestone, grey, with some sandstone, grey glauconitic
Unit 1. 186 feet of sandstone, grey, with interbeds of green siltstone.

The lithology of several representative sections and the logs of three core holes, are shown on Fig. 32. Features common to most outcrop sections and core hole Grg 12, are the high fossil content and abundant glauconite.

Unit 2 of the reference section is prominent near the south-eastern tip of the Dulcie Range and can be traced on the south-western flank of the Range, north-west to measured section HX28, and almost to the Bundey River. West of the river, the unit does not crop out and the exposed sequence consists mainly of quartz sandstone or quartz-greywacke, with a few beds of weathered dolomite; these lithologies are shown in measured sections HX54, AX3 and BX7. Palaeontological examination of fossils in HX54 and BX7 is incomplete and consequently it is not known whether the sequences in these sections represent:

(a) almost the complete sequence of Tomahawk Beds, ranging from Upper Cambrian to Lower Ordovician, with the carbonates of unit 2 grading laterally to psammites;

or (b) a thick development of psammites of unit 3;

or (c) a thick development of psammites of unit 1, or alternatively a thicker development of units 1 and 2 combined.

The erosion surface beneath the Devonian Dulcie Sandstone, and the steeper dips and probably concealed structural complexity, make it necessary to rely on palaeontological evidence to elucidate the problem. If (a) or (c) above are correct, then the sequence in Grg 1 may represent a new unit in the Tomahawk Beds; if (b) is correct, it could represent a subsurface continuation of unit 2. The sequence in this well and that in Grg 5 has some lithological similarity to both the Arrinthrunga Formation and the Tomahawk Beds, and also to some poorly outcropping oolitic limestone beneath sandstone of the Tomahawk Beds in the north-eastern flank of the Dulcie Syncline in the Barrow Creek Sheet area. Grg 1 contains a fossil of Upper Cambrian age at 208 feet (Opik, pers. comm.) and Grg 5 contains fossils "not older than Upper Cambrian" at 173-175 feet (Tomlinson, pers. comm.); P.J. Jones has examined the cores of both wells for conodonts, without success. At present, the sequences in both wells are regarded tentatively as belonging to the Tomahawk Beds.

From the eastern side of the Spring Range to the north-western tip of the Dulcie Syncline and south-eastwards along the north-eastern flank of the syncline, the Tomahawk Beds consist mainly of sandstone and siltstone (with oolitic limestone already mentioned in one locality in Barrow Creek Sheet area) and the fossils are all of Upper Cambrian age (Opik and Tomlinson, pers. comm.). Section EX5 is representative of most of the outcrops, although the exposures there are thicker than usual - often less than 100 feet crop out, and the beds are strongly slumped, making thickness measurements unreliable. Towards the south-eastern end of the Dulcie Syncline, the sequences resemble those of the reference section, and include Lower Ordovician sediments.

Some poorly-outcropping sequences in the northern parts of Elkedra and Barrow Creek Sheet areas are referred tentatively to the Tomahawk Beds; they consist of sandstone and interbedded siltstone and a few outcrops of green-grey limestone. The sediments are apparently unfossiliferous, but on lithological grounds they are included in the Tomahawk Beds. Generally they have low regional dips, but are strongly slumped at many localities. At a few localities where the beds are not slumped and where siltstone is absent, the sequence resembles the basal sandstone of the Middle Cambrian Sandover Beds, (e.g., 70 feet of medium-coarse grained, red-brown, silicified, laminated-thin-bedded, cross-laminated silty sandstone about 20 miles south of Murray Downs homestead) and it is possible that units of both the Tomahawk Beds and the Sandover Beds crop out in close prcximity. Other sequences tentatively referred to the Tomahawk Beds consist of cobble, pebble and boulder conglomerate in the foothills of the Davenport Range. These are unfossiliferous, but in a few instances they are topographically above, and almost certainly stratigraphically above, Middle Cambrian Sandover Beds in water bores. They do not contain boulders, cobbles, pebbles or fragments of Sandover Beds, and all of the inclusions consist of well-rounded quartz sandstone similar to types found in the Hatches Creek Group. These outcrops are unlikely to be Middle Cambrian, but probably represent the basal Upper Cambrian transgression; on this basis they have been mapped tentatively as Tomahawk Beds. The possibility that the beds are of Mesozoic age cannot be discounted because there are conglomerates in Mesozoic sediments to the east.

Section EX1 is representative of much of the Tomahawk Bed outcrop in the north-eastern Huckitta, south-eastern Elkedra, southern Sandover River and northern Tobermory Sheet areas. Lateral gradations between sandstone and dolomite are common and very rapid in these areas and equivalent outcrops in close proximity often appear red-brown (sandstone) and dark brown or black (dolomite and dolarenite) when viewed from a distance and on air photographs. Generally, regional dips are low, but the beds, particularly sandstone and sandy siltstone, are strongly slumped. The Beds contain a rich fauna, mainly trilobites and ribeirioids, but all are of Upper Cambrian age (Opik, Tomlinson and Jones, pers. comm.) and no Lower Ordovician sediments are known.

In some places, unit 3 of the Reference Section is identical lithologically with the Kelly Creek Formation, but it is not a mappable unit, on regional-scale mapping, because of contortions. In some parts of the Tarlton Range on the Tobermory Sheet area it is possible to separate the Kelly Creek Formation from the Tomahawk Beds; in other places it is possible to separate the Ninmaroo Formation from the lower part of the Tomahawk Beds. In the Tarlton Range area, the Upper Cambrian-Lower Ordovician sequence consists of carbonate rocks, sandstone and siltstone; many of the beds in sequences where all three rock types are present have been leached and lateritised; one effect of the leaching of sandy carbonate rocks is the apparent presence of more "sandstone" in the sequence than is originally present and this effect, together with the rapid lateral gradations normal in the sequence, is reflected in the outcrop pattern of carbonate rocks dotted with lenses and interbeds of weathered, leached sandstone and siltstone.

The approximate boundary between the Tomahawk Beds and the Ninmaroo Formation marks essentially a broad division between a fossiliferous sandy formation in the west, and a less fossiliferous carbonate formation (Ninmaroo Formation) on the east. This is not a simple lateral change and many tongues and members of each unit occur in the other.

The Kelly Creek Formation can be mapped around the Tarlton Range, but north-west of the Range the effects of weathering and the gradations between carbonate rocks and sandstone have made mapping of the formation impossible, and the whole sequence is then mapped as Tomahawk Beds.

Within the Georgina Basin the Tomahawk Beds have a wide regional extent - from Barrow Creek to the Tarlton Range, and their distribution clearly indicates their transgressive nature; the transgression is even more evident if the non-outcropping sequences tentatively included in the Tomahawk Beds are considered. In the south-east, in Tobermory Sheet area, the Tomahawk Beds lens into mappable units, but to the north-west they may continue in the subsurface and provide a link between the Georgina and Wiso Basins. Such a connection is only inferred at present; an Upper Cambrian fossil was recovered from dolomite at 310 feet in Grg 18 (Milligan, 1963, unpubl.) and Lower and Middle Ordovician sediments are known in the Lander River Sheet area of the Wiso Basin (Milligan, Smith, Nichols and Doutch, 1966, unpubl.). However, no Upper Cambrian rocks are known there, although some sediments are lithologically similar to the sequences tentatively included in the Tomahawk Beds in the north-eastern part of the Barrow Creek Sheet area.

<u>Ninmaroo Formation</u>

<u>Definition</u>: Derivation of Name: From Mount Ninmaroo (latitude 22°31'S, longitude 140°17'E); Whitehouse (1936, p. 69) used the name "Ninmaroo Limestone" for the thick sequence of limestone exposed at Black Mountain, Mount Ninmaroo and Mount Datson. Casey subsequently (1959) named the lower part at Black Mountain the Chatsworth Limestone, and renamed the remainder the Ninmaroo Formation because mapping to the west, towards the Queensland Border, showed that the unit contained roughly equal amounts of dolomite and limestone, as well as some sandstone.

<u>Author of Name</u>: Casey (1959).

<u>Map Reference</u>: Boulia 1:250,000 Sheet area; Plate 4.

<u>Distribution</u>: Boulia, Glenormiston, Mount Whelan, Urandangi, Duchess, Sandover River, Tobermory and Hay River Sheet areas; Plate 4.

Type Section: This is at Black Mountain, in the Boulia Sheet area ($22^{\circ}32'S$, $140^{\circ}18'E$).

Lithology: Calcarenite, often dolomitic and sandy, dolarenite, calcilutite, intraformation breccia, dolomite, limestone, calcareous sandstone, in the Boulia area (Casey et al., 1960 unpubl.); dolomite, sandy dolomite, limestone, calcilutite, dolomitic sandstone, oolitic limestone, algal limestone, calcarenite, marl, in the Glenormiston-Mount Whelan area (Pritchard, 1960); calcarenite, quartz sandstone, siltstone, dolarenite, limestone, oolitic limestone in the Tobermory Sheet area (Smith 1965b); dolomite, dolarenite and dolutite on the Sandover River Sheet area (Nichols, 1964, unpubl.); marl, sandstone, shale, limestone, dolomite in Urandangi Sheet area, (Noakes, Carter and Opik, 1959) and limestone, dolomite and marl in the Duchess Sheet area (Carter and Opik, 1963). In general, the outcrops are mainly calcarenite and dolarenite in the Boulia-Duchess Sheet areas, and dolomite, dolarenite and calcarenite in the western outcrop areas (Fig. 33).

Thickness: 2200 feet at Mount Ninmaroo, 1950 feet at Black Mountain, 1200 feet at Mount Datson (Casey et al., 1960, op cit.); 1200+ feet in the Glenormiston Sheet area (Reynolds and Pritchard, 1964, unpubl.); 1120 feet in Netting Fence No. 1 Well (Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.), about 900 feet in western flank of Toko Syncline (Smith and Vine, 1960, unpubl.); 425 feet+ in Sandover River Sheet area (Nichols, 1964, op cit.).

Contacts: The Ninmaroo Formation is conformable on the Chatsworth Limestone, unconformable on the Mount Birnie Beds, disconformable on the Mungerebar and Georgina Limestones, and ?disconformable on the Arrinthrunga Formation and the Meeta Beds; it grades laterally into the lower part of the Tomahawk Beds and is overlain unconformably by the Swift Formation, and conformably by the Kelly Creek Formation. Along the Toomba Fault the Ninmaroo Formation is down-faulted against the Adelaidean Field River Beds.

Fossils: The Ninmaroo Formation contains a rich fauna of nautiloids, gastropods, brachiopods, ribeirioids, trilobites and echinoderms, and algae are abundant. The fauna has not been described, but Opik (1960, p. 101) reported the ribeirioids Eopteria Billings, Euchasma Billings and cf. Ribeiria Sharpe, as well as syntrophioid brachiopods, the orthoid Finkelnburgia, gastropods including Ceratopea, and two genera of Monoplacophora - Archinacella Ulrich and

Schofield and Proplina Kobayashi. These are Tremadocian fossils from the upper part of the Ninmaroo Formation. From lower horizons in the Glenormiston Sheet area Opik (1960, op cit.) reported fossils including Saukia, Sinosaukia, Pagodia and Tellerina?, of Trempealeauian age, and Tomlinson (1956) reported Upper Cambrian fossils including Kingstonia? and other trilobites, and a ribeirioid genus at locality T5, 9 miles north-east of Southern Cross Bore, Marqua Station, and Eoorthis? at locality T6, 3 miles south-east of the same bore. The beds containing the T5 fossils were mapped as the Ninmaroo Formation, and those of T6 as Tomahawk Beds, by Smith, Vine and Milligan (1961, unpubl.).

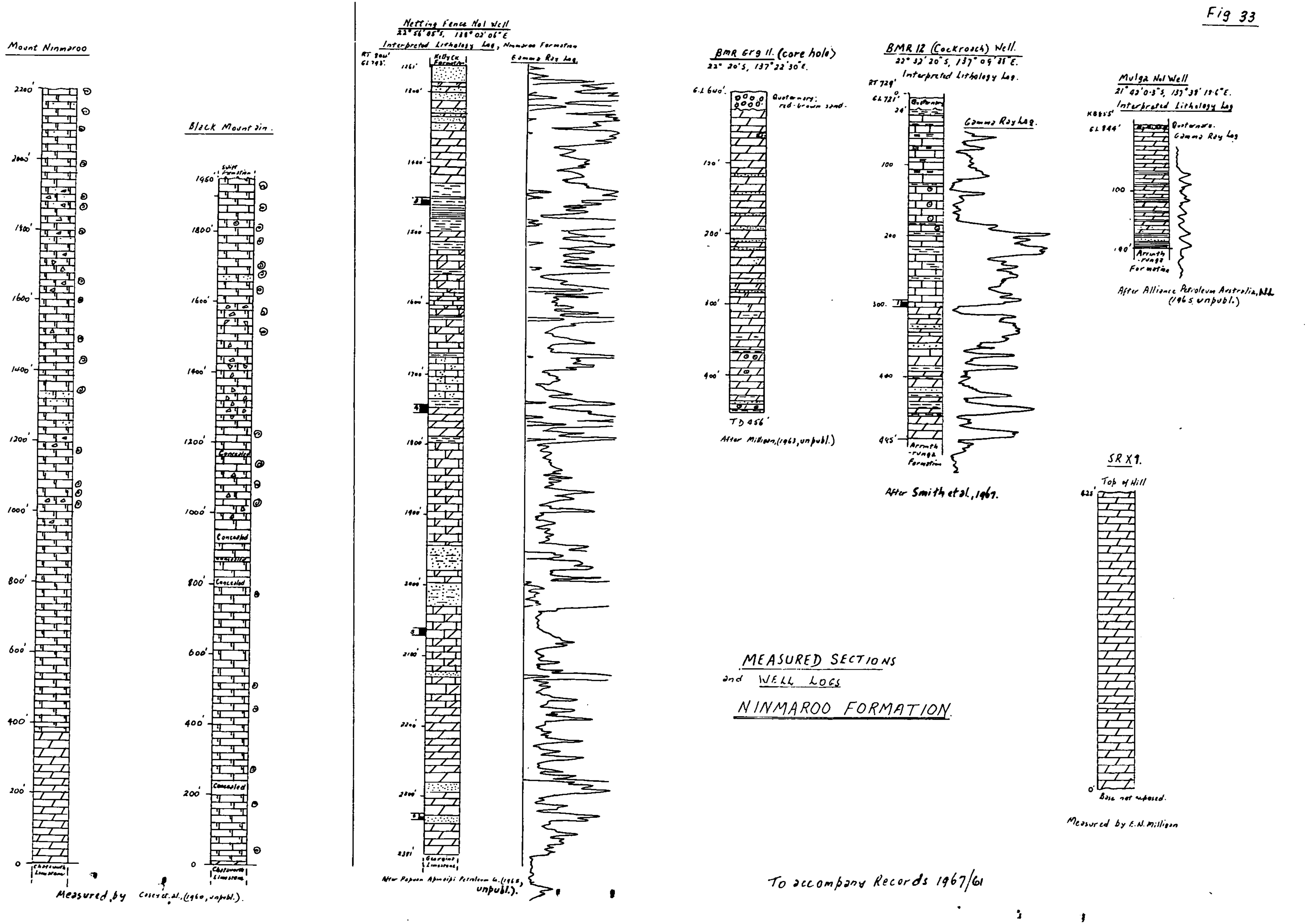
Age: Late Upper Cambrian-Lower Ordovician (Trempealeauian-Tremadocian).

Description and Comment: The Ninmaroo Formation is a stratigraphic unit of regional extent in the south-eastern part of the Georgina Basin. It is preserved in two separate belts of outcrop: a narrow belt along the Burke River Structural Belt in the east, and a broad belt west of longitude 139°30'E, approximately. Casey (1959, op cit.) re-named the formation in the eastern belt and the name has been extended to the outcrops in the western belt, but there is no proven subsurface continuity of beds, e.g., Beantree No. 1 Well penetrated early Upper Cambrian sediments (Pomegranate Limestone) beneath Mesozoic cover. Nevertheless, the belts have the same general lithology and it seems reasonable for the name to be extended from east to west.

In the eastern belt the Ninmaroo Formation forms large hills in some places and low benches in others; often it crops out sporadically in grey soil plains. The major outcrops are in faulted asymmetrical anticlines. Casey et al., (1960, unpubl.) describe the sequences at Black Mountain and Mount Ninmaroo as follows (in descending order):

Mount Ninmaroo

Thickness (feet)	
20	Limestone, white, massive, fine-grained, with nautiloids and brachiopods
260	Calcarenite, coarse and medium-grained, with sandy laminae; medium bedded, minor cross-bedding; subordinate intraformational breccia; chert biscuits



MEASURED SECTIONS and WELL LOGS

NINMAROO FORMATION

To accompany Records 1967/61

Thickness (feet)	
	and plates, many styolites, ribeirioids, brachiopods, echinoderm ossicles
300	Intraformational breccia, with interbedded calcarenite, "two-tone", medium-grained, with some sandy laminae; medium-bedded, minor cross-bedding
250	Calcarenite, two-tone, medium-grained, some fine-grained, thin to medium-bedded, slumped in part; minor intraformational breccia; nautiloids common
750	Calcarenite, fine-grained and "two-tone", and minor intraformational breccia; thin-bedded and laminated; minor sand, and chert nodules and biscuits; nautiloids fairly common in top 350 feet; ribeirioids and echinoderm fragments
250	Calcarenite, fine-grained, with minor calcilutite; medium-bedded and laminated, minor cross-bedding
375	Dolomite, thick-bedded, minor cross-bedding

Total 2200, conformably overlying calcarenite of the Chatsworth Limestone.

Black Mountain

Thickness (feet)	
	Leached silicified carbonate rocks of the Swift Formation unconformably overlying:
75	Calcarenite, medium-grained, sandy, some chert biscuits and silica blebs; brachiopods, gastropods, echinoderm ossicles, coprolites
20	Limestone, white, fine-grained, massive; nautiloids, crinoids, brachiopods, gastropods(?), algae(?), 'coral-like' structures
250	Calcarenite, fine and coarse-grained, some medium-grained, minor cross-bedding, chert biscuits; brachiopods and echinoderm plates

Thickness (feet)	
350	Intraformational breccia with calcarenite interbeds, minor amounts of sand, some slumping, some cross-bedding and chert biscuits; nautiloids, brachiopods, and echinoderm plates
300	Calcarenite, fine-grained, calcilutite and intraformational breccia, silica blebs common; nautiloids, brachiopods, gastropods, trilobites, and algae
945	Calcarenite, fine-grained, and minor intraformational breccia, thin and thick-bedded, laminated in part, some slumping and chert rolls; a few nautiloids in upper 800 feet
5	Dolomite
1950, Conformably overlying 1050 feet of Chatsworth Limestone	

The intraformational breccias recorded in the sequence at Black Mountain and Mount Ninmaroo are common in the upper half of most sequences in the eastern belt of the Ninmaroo Formation; they consist of angular and sub-angular fragments of calcarenite or calcilutite, elongated along the bedding, and set in a matrix of calcarenite or marl which is frequently oolitic. The fragments appear to be derived from underlying beds (Casey et al., 1960, op cit.).

In the eastern outcrop belt the Ninmaroo Formation has been folded into asymmetrical anticlines with steeper eastern flanks. Later faults along or near the crests of these anticlines have blocks downthrown to the east, and at Black Mountain and Mount Ninmaroo the faults cut the fold axes. To the east and west of the structural zones, the Ninmaroo Formation is generally horizontal.

In the western belt, the Ninmaroo Formation crops out in low rises, terraced hills and plains; the dip is usually low, except in slump structures and near the Craigie and Toomba Faults. A combination of gentle dip, strong joint patterns and alternating hard and soft lithologies give much of the formation an outcrop form of low, stepped hills with a pronounced bastion aspect.

In general in the western belt, the Ninmaroo Formation dips towards the Toko Syncline, but the combination of poor outcrop, low rolling dips and repetition of lithological types prevents the determination of relative stratigraphic position of most outcrops; only adequate palaeontological control will resolve these problems. East of the Georgina River, outcrop is very poor and discontinuous, and the local base of the sequence is seldom exposed. However, the contact with the Mungerebar Limestone is exposed, and Reynolds and Pritchard (1964, unpubl.) regard the rim of leached and weathered sandy and silty beds, up to 30 feet thick, around the southern margin of the Mungerebar Limestone, as the (local) base of the Ninmaroo Formation.

West of the Georgina River in the Toko Range area, Pritchard (1960) subdivided the Ninmaroo Formation into five members; one of these is now mapped as the Kelly Creek Formation and the others are retained in the Ninmaroo Formation. Opik (1963) states that the Ninmaroo Formation rests on the eroded surface of lower beds of the Georgina Limestone, north of the 23rd parallel, and Reynolds and Pritchard (1964, op cit.) state that these outcrops of Ninmaroo Formation are the oldest in the area. They are exposed only around a core of Georgina Limestone, in an anticline 8 miles west of Glenormiston homestead, and in scarps below Mesozoic sediments at the eastern end of the Ten Mile Hills.

Four members (units Cu-2, Cu-3, Cu/O14 and O15) have been described by Pritchard (1960, op cit.) and Reynolds and Pritchard (1964, op cit.) have given slightly expanded descriptions; the following descriptions are combined from both works, with members in ascending order.

<u>Member 1</u> consists of thick to massive sets of white, grey brown and brown, fine to medium-grained, laminated, thin and medium-bedded dolarenite, with minor amounts of fine and medium-grained dolomitic sandstone and sandy dolomite. Blue, thin-bedded calcilutite occurs as interbeds in the top and bottom of the member. The thickness is estimated at 200 feet, and algae are the only fossils.

<u>Member 2</u> consists mainly of hard calcilutite; it is estimated to be 350 feet thick, and algae are the only fossils. The lithology consists of roughly-bedded two-tone (grey-brown and grey-blue) calcilutite, in sets up to 10 feet thick; thin-bedded grey brown and grey-blue calcilutite, white marl, thin-bedded, medium-grained calcarenite, intraformational calcilutite conglomerate, and algal colonies.

Member 3 extends from the west and north of the Ten Mile Hills to Linda Downs homestead and around to the western side of the Toko Range. It consists mainly of alternating hard and soft sediments, but only the hard hands crop out. They consist of laminated, thin and medium-bedded brown and white, fine to coarse-grained dolarenite, and laminated to thin-bedded fine-grained, well sorted, well rounded dolomitic quartz sandstone, in sets up to 15 feet thick. Thickness of the member is estimated to be 200 feet. Nautiloids and trilobites occur, and Opik (1960) has assigned them a late Upper Cambrian age.

Member 4 flanks both sides of the Toko Range and consists of sets up to 10 feet thick of laminated and thin to medium-bedded two-tone limestone, laminated and thin-bedded brown calcilutite and sandy calcilutite, fine-grained calcarenite and sandy calcarenite, and calcareous sandstone. The thickness is estimated to be 400 feet and it contains nautiloids, ribeirioids and gastropods similar to those in the Tremadocian part of the Ninmaroo Formation in the Boulia area. Algal colonies are abundant. The total thickness of members 1-4 is estimated at 1150 feet. On the western flank of the Toko Syncline, Smith and Vine (1960, unpubl.) measured a thickness of 840 feet, which they do not regard as reliable because of structural complexity in the Ninmaroo Formation. The lithology of the Ninmaroo Formation, west of the Toko Syncline, has been discussed previously in the description of the Tomahawk Beds, and its main difference from Pritchard's (1960) description occurs in lower units, where tongues and lenses of quartz sandstone and dolomitic sandstone are common. The boundary between the Ninmaroo and Arrinthrunga Formations is not easy to select in the Tobermory Sheet area unless these lenses of sandstone are present. Likewise, the boundary between the Ninmaroo Formation and the Meeta Beds in the Sandover River Sheet area is not easily mappable, but the units are identified by the general presence of oolitic chert in the Meeta Beds and the lack of it in the Ninmaroo Formation. Both units consist of dolomite and dolarenite, but the Meeta Beds contain numerous beds of quartz sandstone.

The subsurface extent of the Ninmaroo Formation is unknown in Queensland, but is known reasonably well in the Northern Territory. In Queensland, continuity of outcrop has not been established between the eastern and western belts of outcrop. However, the Ninmaroo Formation almost certainly occurs in the south-eastern extension of the Toko Syncline, as evidenced by results obtained by a Bureau seismic party (Robertson, 1965, unpubl.); these results showed a strong reflector, with a velocity 18,000 feet per second, at a depth of about 11,000 feet in the syncline near Pulchera Waterhole (latitude 22°56'S, longitude 138°35'E) and the party traced this west-dipping reflector north-eastward to shot-point 247, near Yarandilla Yard (latitude 23°43'S, longitude 138°56'E) where it was at shallow depth beneath Cretaceous sediments. A hole drilled at shot point 247 penetrated about 300 feet of Cretaceous sediments above dolomite-siltstone sequence from which P.J. Jones identified Lower Ordovician conodonts similar to those in the Ninmaroo Formation. It is reasonable to identify this reflector with the Ninmaroo Formation; its thickness is unknown, but the seismic data indicate that the Palaeozoic section in the Toko Syncline may be about 14,000 feet thick, which is much thicker than the 6000 feet in outcrop on the flanks of the syncline in the Tobermory Sheet area. Reynolds (1964, unpubl.) estimated the thickness of the Ninmaroo Formation in the western limb of the Toko Syncline, near the southernmost outcrops, as 2400 feet, but did not regard his estimate as reliable.

Eastward from Yarandilla Yard, the extent of the Ninmaroo Formation is unknown in the subsurface, and south-east of this yard it has not been encountered in either The Brothers No. 1 Well or Marduroo No. 1 (French Petroleum Co. (Aust.) Pty Ltd, 1965, unpubl.).

Kelly Creek Formation

Definition: Derivation of Name: From Kelly Creek, which rises in the foothills of the Toko Range in the Northern Territory, and flows east to join Pituri Creek.

Author of Name: Casey (in Smith 1965b).

Map Reference: Tobermory 1:250,000 Sheet area; Plate 4.

Type Area: The hills on both sides of Bloodwood Creek, 8 miles north of No. 8 Dam on Tobermory Station (latitude 22°45'S, longitude 137°45'E).

Type Section: On Gaphole Creek, at latitude 22°58'S, longitude 137°54'22"E, on the western flank of the Toko Syncline.

Distribution: The formation crops out in the Tarlton, Toko and Toomba Ranges; most of the outcrop is on the flanks of the Toko Syncline.

Lithology: Quartz sandstone, calcareous sandstone, siltstone, dolomite, calcarenite, coquinite with lenses of white chert.

Thickness: 550 feet in the type section, 400+ feet in the Toomba Range, 250 feet in the Tarlton Range and 361 feet in Netting Fence No. 1 Well (Fig. 34).

Contacts: The Kelly Creek Formation conformably overlies the Ninmaroo Formation and is overlain disconformably by the Coolibah Formation in the Toko Range, and disconformably by the Nora Formation in the Tarlton Range.

Fossils: The formation contains abundant nautiloids, trilobites, brachiopods, ribeirioids and gastropods; this fauna has not been described, but its age is Lower Ordovician (Tomlinson, pers. comm.).

Correlates: The upper part of the Tomahawk Beds in the Tarlton Range-Dulcie Range area of the Northern Territory, and the Swift Formation in the Boulia area of Queensland.

Description and Comment: The Kelly Creek Formation is restricted to the south-western part of the Georgina Basin, and apart from a small area in and near the Tarlton Range, all of the outcrops are in the limbs of the Toko Syncline. On the north-western and north-eastern part of this syncline, outcrop is usually poor in low, rubble-covered hills, but some good exposures are available in mesas. On the south-western side of the Toko Syncline outcrop is better because dips are steeper, and good outcrops are also available in the scarp on the eastern side of the Tarlton Range, and in isolated mesas near the south-eastern end of this Range.

In the Toko Range, the lower part of the Kelly Creek Formation is dominantly sandstone and higher beds usually consist of carbonate rocks. In the type section, measured by Pritchard (in Reynolds and Pritchard, 1964, unpubl.) the sequence in descending order consists of:

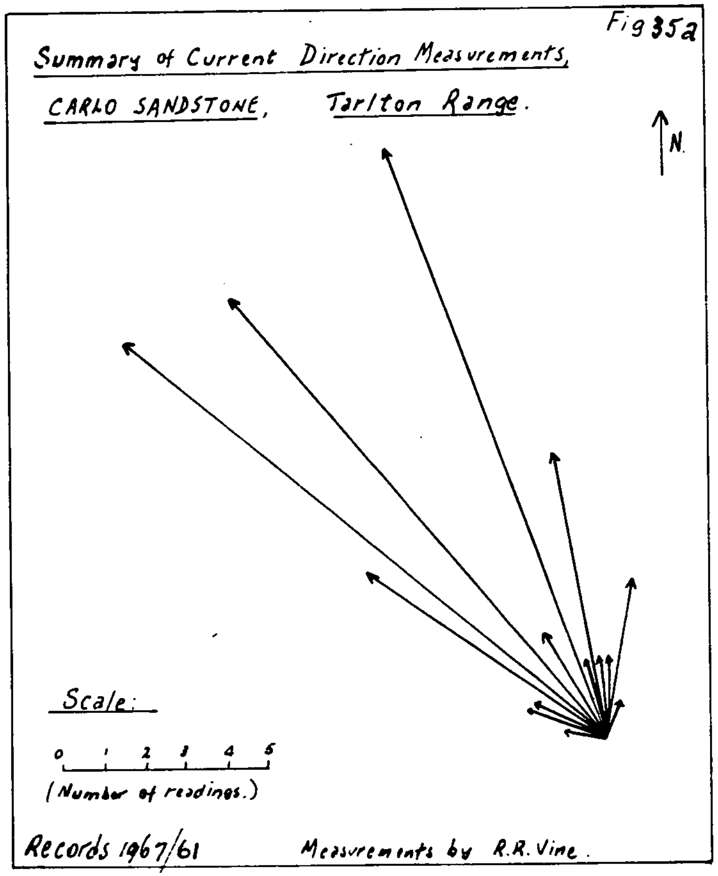


Fig 35a
Summary of Current Direction Measurements,
CARLO SANDSTONE, Tarlton Range.
N.
Scale:
0 1 2 3 4 5
(Number of readings.)
Records 1967/61
Measurements by R.R. Vine.

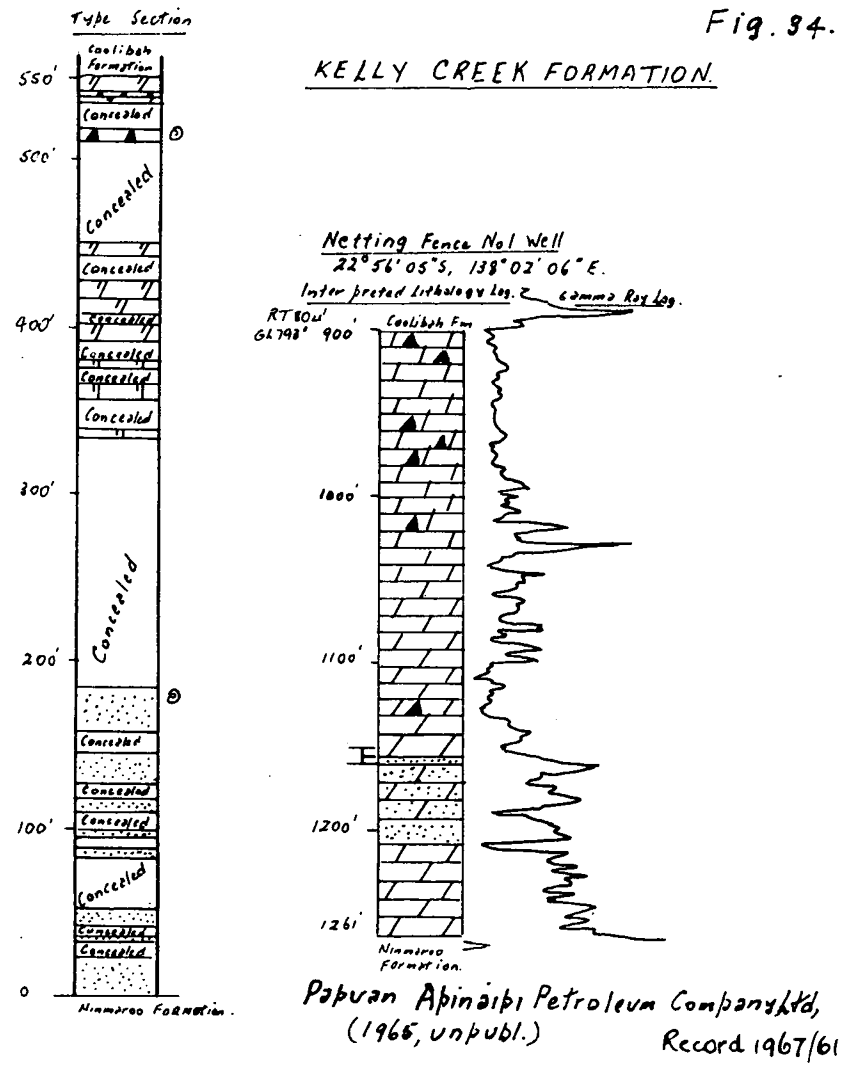


Fig. 34.
KELLY CREEK FORMATION.
Type Section
Coolibah Formation
550'
500'
400'
300'
200'
100'
0
Concealed
Ninmaroo Formation.
Netting Fence No1 Well
22°56'05"S, 138°02'06"E.
Interpreted Lithology Log.
Gamma Ray Log.
RT 800'
GL 798'
900'
Coolibah Fm
1000'
1100'
1200'
1261'
Ninmaroo Formation.
Papuan Apinaipi Petroleum Company Ltd, (1965, unpubl.)
Record 1967/61

Thickness (feet)	
	Coolibah Formation overlying disconformably(?)
10	Dolarenite, grey-brown, fine-grained, thin and medium-bedded
2	Chert, white, thin-bedded
2	Dolarenite, grey-brown, fine to medium-grained
17	Concealed
7	Chert, white, thin and medium-bedded, fossiliferous; one interbed of dolarenite, fine-grained, thin-bedded and laminated
60	Concealed
10	Dolarenite, grey-brown, fine-grained, thin-bedded and laminated, alternating hard and soft in thick sets
13	Concealed
20	Dolarenite, fine-grained, thin-bedded and laminated, alternating hard and soft, in thick sets
7	Concealed
10	Dolarenite and alternating calcarenite; fawn fine-grained, thin-bedded and laminated
12	Concealed
3	Calcarenite, fawn, fine-grained, thin-bedded, with sandy lenses
11	Concealed
11	Calcarenite, fawn, fine-grained, thin-bedded, with sandy lenses
16	Concealed
5	Calcarenite, fawn, fine-grained, thin-bedded, with sandy lenses
150	Concealed
26	Quartz sandstone; white, fine to very fine-grained, laminated, thin and medium-bedded, well-rounded, well-sorted, with worm trails on the bedding planes, and brachiopod coquina towards the top of the interval
14	Concealed

Thickness (feet)	
18	Quartz sandstone, white, fine to very fine-grained, thin to very medium-bedded, well-rounded, well-sorted, with worm trails on bedding planes
9	Concealed
7	Quartz sandstone, white, very fine-grained, thin-bedded well-rounded, well-sorted
11	Concealed
4	Quartz sandstone, white, very fine-grained, thin-bedded, well-rounded, well-sorted
6	Concealed
7	Quartz sandstone, white, very fine-grained, laminated, well-rounded, well-sorted
31	Concealed
10	Quartz sandstone, white, very fine-grained, laminated, cross-laminated, well-rounded, well-sorted
6	Concealed
3	Quartz sandstone, white, very fine-grained, silicified, thin and medium-bedded, well-rounded, well-sorted
8	Concealed
24	Rubble of white silicified quartz sandstone, which observes the contact with the underlying Ninmaroo Formation

550, thickness of type section.

Netting Fence No. 1 Well and core hole Grg 12 are the only sources of information on the subsurface lithology of the Kelly Creek Formation. In Netting Fence No. 1 Well, about 8 miles east of the type section, the Kelly Creek Formation is 361 feet thick (900-1261 feet) and consists of dolomitic limestone, dolomite and quartz sandstone (Papuan Apinaipi Petroleum Co. Ltd, 1965, unpubl.). The composite log records sandstone and dolomitic sandstone in the top of the Ninmaroo Formation, and this part may belong to the Kelly Creek Formation. The author considers that on lithological grounds the base of the Kelly Creek Formation could be placed at 1480 feet; however, there is no palaeontological evidence to favour one interpretation more than the other.

South-east from the type section, in the Hay River Sheet area, the Kelly Creek Formation consists of dolomite and calcarenite, without the basal sandstone units. These outcrops are in an area of structural complexity, which prevents reliable section measurement, and the lower part of the sequence may have been faulted out. Further south-east, in the Mount Whelan Sheet area, the Kelly Creek Formation has sandstone in its lower beds and dolomite in its upper part; the thickness there is estimated at 270 feet (Reynolds 1964, unpubl.).

On the eastern limb of the Toko Syncline, Pritchard (1960, op cit.) described the lithology of the Kelly Creek Formation (Unit 01-6 of Pritchard) as "thin-bedded and laminated, fine-grained dolomitic quartz sandstone which is in places glauconitic; and laminated to medium-bedded grey-brown dolomite and white marl". He estimated the thickness to be 250 feet along the Mulligan River (Mount Whelan Sheet area). In the eastern outcrop area Reynolds (1964, op cit.) reported that the Kelly Creek Formation appeared disconformable on older parts of the Ninmaroo Formation, and a disconformity between the two units in this area is also supported by an occurrence of Kelly Creek Formation resting on the Georgina Limestone. Therefore, although the Ninmaroo and Kelly Creek Formations appear conformable in the Northern Territory and parts of Queensland, a disconformity may separate the two units near the eastern extremity of outcrop of the Kelly Creek Formation.

In the Talrton Range the Kelly Creek Formation consists mostly of calcareous micaceous sandstone, with interbeds of dolomite, sandy dolomite, green siltstone, and some calcarenite. Glauconite is common in many beds, and fossils are abundant although less numerous than in the Toko Range. The beds of the Formation are gently dipping, except near the Tarlton Fault, and north-west of the Range the formation grades laterally into the Tomahawk Beds. Part of the formation crops out well in several benches, which can be followed for several miles along the scarp of the Tarlton Range. The sequence is considerably thinner than in the Toko Range, and most sections are about 250 feet thick.

West of the Tarlton Range the Kelly Creek Formation has been identified in core hole Grg 12 (Milligan, 1963, unpubl.); here it is preserved in a down-faulted block, whose westward extent beneath soil cover is unknown.

LOWER ORDOVICIAN

Swift Formation

Definition: Derivation of Name: From the Swift Hills, latitude 22°00' 00"S, longitude 140°01'E. Casey (1959) named the formation.

Map Reference: Boulia 1:250,000 Sheet, Plate 4.

Type Area: The Swift Hills.

Distribution: The unit extends from the western side of Black Mountain, north-west in a narrow belt to a few miles beyond the Swift Hills on the Duchess Sheet area.

Lithology: Bedded chert with interbeds of siltstone, sandstone, silicified coquinite, and limestone.

Thickness: About 60 feet; 20-30 feet is exposed in the Duchess Sheet area.

Fossils: Trilobites, brachiopods and graptolites.

Age: Lower Ordovician (Carter and Opik, 1963; Casey, 1959).

Correlates: The Kelly Creek Formation.

Contacts: The formation unconformably overlies the Ninmaroo Formation in the north of the Boulia Sheet area and probably in the Black Mountain area also (Casey, 1959, op cit.); it is unconformable on the Middle Cambrian Beetle Creek Formation in the Duchess Sheet area (Carter and Opik, 1963, op cit.). The formation is overlain unconformably by Mesozoic and Cainozoic sequences.

Description and Comment: Carter and Opik (1963, op cit.) used the name "Swift Beds" for outcrops which are shown on Plate 4 as the Swift Formation; the terms are synonomous but Swift Formation has priority.

Casey et al., (1960, unpubl.) have described the outcrop of the formation in the type area as forming low rounded hills with a small scarp on the eastern side, and they state that south of Digby Peaks it forms a broad divide with dendritic streams deeply incised in steep-sided valleys. West of Black Mountain it forms low rounded foothills cut by steep-sided, flat-floored valleys. Carter and Opik (1963, op cit.) describe the topographic expression of the formation in the Duchess Sheet area as "plain with pediments".

In the type area, Casey et al. (op cit.) record the following sequence:

Thickness (feet)	
10	Chert breccia, of unknown age, resting unconformably on:
20	Chert; white and grey, thin-bedded and laminated; with some silicified coquinite
25	Concealed
12	Sandstone, red and white, laminated, fine-grained; and siltstone, red and white, laminated
Total 67,	of Swift Formation overlying the Ninmaroo Formation, but the contact is not exposed here.

The contact between the Swift Formation and the Ninmaroo Formation is exposed at localities between two and four miles south-east of Digby Peaks; in these places, beds of the Swift Formation transgress truncated beds of the Ninmaroo Formation, with an angle of unconformity of about 1 degree. Other contacts are exposed at localities one, four and eight miles south-east of Digby Peaks, where chert of the Swift Formation rests on old karst topography in the Ninmaroo Formation, with maximum relief of about 15 feet. Carter and Opik (1963, op cit.) deduce that the main tectonic movement in the Burke River Structural Belt preceded deposition of the Swift Formation, but Casey et al., (1960, op cit.) regard the folding or tilting which preceded the deposition of the Swift Formation as a minor event.

The thickest known sequences of the Swift Formation are at the Swift Hills and Digby Peaks; at Digby Peaks the unit is about 60 feet thick and the lower half of the formation consists of chert and coquinite bands, interbedded with graptolite-bearing siltstone, and the upper half contains predominantly thin-bedded chert. There is a marked decrease in the amount of detrital quartz in the Swift Formation from north to south.

LOWER-MIDDLE ORDOVICIAN

The Toko Group

The name "Toko" has been used as the geographical component of several names for Ordovician rocks in western Queensland, but its present usage dates only from 1966. Whitehouse (1936) used the name "Toko Series" for Ordovician sediments west of Boulia; this was a modification of his earlier (1930) "Glenormiston Series", because most of the Glenormiston area was underlain by Cambrian sediments and he wished to denote Ordovician rocks only. The Geological Map of Queensland (1953) records "Toko Group" for Ordovician rocks south-west of a line joining Linda Downs homestead and Mount Idamea, i.e., for rocks above the Ninmaroo Formation as delineated on Plate 4 of this Bulletin. The sequence above the Ninmaroo Formation had not been divided into formations, and Casey (1959) proposed the name "Toko Beds" for this sequence, pending subdivision by the mapping then in progress. Pritchard (1960) followed Casey's usage, and described five units (017-8, Om9-11) in the Toko Beds, but he did not name them.

Casey (in Smith, 1963a) stated "The name Toko will be used as Toko Group, which will consist of the Kelly Creek, Coolibah, Nora, Carlo, and Mithaka Formations; the base of the group (i.e., base of Kelly Creek Formation) overlies the Ninmaroo Formation with an unconformity". The formations are equivalent to units 016-8 and Om9-10 of Pritchard (1960, op cit.); Pritchard's unit Om11 was deleted (it is now named the Craven's Peak Beds) and his unit 016 was included, although Pritchard had excluded it from the Toko Beds.

After further field checks, Casey (in Smith, 1965b) deleted the Kelly Creek Formation from the Toko Group, because palaeontological evidence indicated a break between this formation and the overlying Coolibah Formation. Casey's 1965 amendment means that the Toko Group consists of four units - in ascending order, the Coolibah Formation, the Nora Formation, the Carlo Sandstone and the Mithaka Formation. This definition is followed in this Bulletin and on the accompanying plates and figures. The age of the Group ranges from Lower to Middle Ordovician; it is underlain disconformably by the Kelly Creek Formation and overlain unconformably by the ?Silurian-Devonian Craven's Peak Beds. Formations of the Group have been mapped west from the Toko Range to the Talrton and Dulcie Ranges.

The stratigraphy of formations in the Toko Group follows.

Coolibah Formation

Definition: Derivation of Name: From Coolibah Dam, on Tobermory Station, Northern Territory; latitude 22°49'S, longitude 137°44'E.

Author of Name: Casey (In Smith, 1965b).

Map Reference: Tobermory 1:250,000 Sheet area.

Type Area: From four to six miles north of No. 8 Dam, Tobermory Station (latitude 22°45'S, longitude 137°45'E), on the road from Tobermory homestead to Craigie Dam.

Distribution: In a belt parallel to the scarp of the Toko Range, at distances ranging from ½ to 2 miles from the scarp; also in south-eastern extensions of the Toko Range, but the formation has not been recognised in the Tarlton Range.

Lithology: Grey and white limestone, sandy limestone, calcilutite, dolomite and marl, with lenses of white chert.

Thickness: 25 to 50 feet in the type area, 175 feet at Gaphole Creek and about 360 feet in the Mount Whelan Sheet area of Queensland; 117 feet in Netting Fence No. 1 Well (Papuan Apinaipi Petroleum Co., 1965, unpubl.).

Contacts: The formation is probably disconformable on Kelly Creek Formation and is overlain conformably by the Nora Formation.

Fossils: Nautiloids, gastropods, sponges, ribeirioids and 'horn-shaped ?corals'. The fauna has not been described.

Age: Lower Ordovician (Opik and Tomlinson, pers. comm.).

Description and Comment: The Coolibah Formation is the basal unit of the Toko Group. It usually crops out poorly in low hills and strike ridges parallel to the Toko Range, and continues along strike to the south-east in the Toomba Range on the south-western limb of the Toko Syncline, and in un-named hills and ridges on the south-eastern limb. Dips are low, except along the Toomba Fault where they range from 45° to 90° and are sometimes overturned.

The limestone and chert of the Coolibah Formation usually crop out better than other lithologies and are represented on air photographs by a white or light-coloured pattern. The chert often contains fossils, mainly gastropods. The general poor outcrop of the formation precludes measurements of reliable sections, although most of the sequence can be observed at Gaphole Creek (Tobermory Sheet area) and Reynolds (pers. comm.) has measured 360 feet of the formation in the Toomba Range (Mount Whelan Sheet area). The following sequence, measured by Pritchard in the upper part of the formation, near the north-western end of the Toko Syncline, shows some of the lithology and also demonstrates the oolitic nature of some of the beds of limestone and calcilutite.

Thickness (feet)	Top not exposed;
½	Limestone, brown-grey, fine-grained, thin-bedded, oolitic, with fragments, up to 1 cm across, of the same material
6	Concealed
1	Limestone, similar to the top ½ foot
3	Concealed
½	Limestone, brown-grey, fine-grained, thin-bedded, oolitic, silicified, with fragments of white calcilutite, and gastropods
3	Concealed
½	Limestone, brown-grey, fine-grained, thin-bedded, oolitic, with fragments up to 1 cm across, of the same material
11	Concealed
½	Dolomite, brown, medium-grained
3	Calcilutite, brown-grey, medium-bedded, with stringers and blebs of brown, medium-grained carbonate rocks

Total 29, for part of section, whose base is not exposed.

The only available subsurface information on the Coolibah Limestone is in Netting Fence No. 1 Well, which drilled the unit in the interval 783 to 900 feet. Here the lithology is mainly white and grey, fine-grained styolitic limestone, with chert bands; three thin shale bands were also recorded (Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.).

Nora Formation

Definition: Derivation of Name: From Nora Gap in the Northern Territory, at latitude 22°43'S, longitude 137°56'E. Casey (In Smith, 1963a) named the formation.

Map Reference: Tobermory 1:250,000 Sheet area.

Type Area: On the western side of the Toko Range, for two miles north and south of Halfway Dam (latitude 22°53'S, longitude 137°49'E).

Distribution: In the slope of the scarp, the Toko, Toomba and Tarlton Ranges, and in the south-eastern part of the Dulcie Range.

Lithology: Olive-brown and dark brown dolomite and coquinite near the base, succeeded by olive, yellow, grey and purple siltstone and sandy siltstone, and green and brown fine-grained glauconitic sandstone.

Thickness: About 200 feet in the north and north-east of the Toko Range, thickening to about 400 feet in the south-western limb of the Toko Syncline. In Netting Fence No. 1 Well, the formation is 373 feet thick, and the low dips indicate that this will be approximately the true thickness. The thickness in the Tarlton Range is 200 feet, and 370+ feet in the Dulcie Range.

Contacts: The Nora Formation is apparently conformable on the Coolibah Formation and is conformably overlain by the Carlo Sandstone in the Toko Syncline; in the Tarlton Range the Nora Formation rests with apparent conformity on the Kelly Creek Formation (a disconformity should be present, on preliminary palaeontological evidence), but there is evidence of a disconformity between the Nora Formation and the Carlo Sandstone at The Pinnacles, near Tarlton Downs homestead (Smith, Vine and Milligan, 1961, unpubl.). In the Dulcie Range, the formation is overlain unconformably by the Devonian Dulcie Sandstone and overlies the Tomahawk Beds with apparent conformity.

Fossils: The lower part of the Nora Formation contains a rich but undescribed fauna of pelecypods, brachiopods, nautiloids, trilobites, gastropods and bryozoa; shelly fossils are uncommon in the upper part of the formation, but tracks and trails are abundant.

Age: Middle Ordovician (Opik and Tomlinson, pers. comm.).

Description and Comment: In the scarps of the ranges, much of the Nora Formation is covered by scree from the overlying Carlo Sandstone, and good exposures are found only in steep gullies draining the scarps. Older beds crop out better in the base of the Toko Range, where the dolomite and coquinites are often well exposed, and also in the Tarlton Range. Exposures in the Dulcie Range are generally poor.

The Nora Formation is Pritchard's (1960, op cit.) unit 01-8; Pritchard (In Reynolds and Pritchard, 1964, op cit.) has described the following sequence in the Toko Range at a locality 2 miles north of Linda Creek, in the north-eastern side of the Range.

Thickness (feet)	Carlo Sandstone conformably overlying:
30	Quartz siltstone; yellow-brown and purple, laminated and thin-bedded, with blebs and stringers of siltstone containing very fine sand grains
20	Concealed
6	Quartz sandstone, purple, fine-grained, laminated and thin-bedded, micaceous, with a few clay pellets; interbeds of siltstone, sandy in part
20	Siltstone, yellow-brown, white and purple, sandy in part, with tracks and trails
85	Concealed; a few plates of brown coquinite 40 feet from the top of the interval
35	Quartz sandstone, brown, grey-brown and tan, fine-grained, laminated and thin-bedded, friable, well-sorted, well-rounded; with thin interbeds of grey-brown and tan coquinite

Total 196, thickness of part section (to base of scarp); the base of the formation is not exposed.

In Netting Fence No. 1 Well the Nora Formation is 373 feet thick (interval 410-783 feet) and Papuan Apinaipi Petroleum Company Limited (1965, unpubl.) has reported the following sequence (summarised by the present author).

410-650 feet, (240 feet),	- Sandstone, grey, grey-green, fine-grained, very shaley in places, and transitional to sandy shale; pyritic and glauconitic; yellow, hard, tight, very fine-grained quartz sandstone predominates in the interval 500-600 feet; shale, grey-green, grey-brown, chocolate and grey, silty and sandy, micaceous (biotite and muscovite);
650-783 feet (133 feet)	- Quartz sandstone, grey, micaceous, glauconitic and calcareous in places, bituminous and shaley in places, interbedded with shale, blue grey, grey, green, fissile, very micaceous (biotite and sericite), pyritic; and coquinite.

In the Tarlton Range the slope of the scarp is formed of a dominantly siltstone-claystone lithology which grades upwards into fine-grained sandstone; coquinite are common in the basal part and they persist as thin interbeds throughout most of the formation. Vine (*in* Smith and Vine, 1960, unpubl.) has measured the following complete section in the southern part of the Tarlton Range:

Thickness (feet)	
	Carlo Sandstone overlying:
49	Concealed; scree of siltstone and quartz sandstone
28	Quartz sandstone, fine-grained, porous, friable, highly gypsiferous in part
25	Concealed
56	Claystone and siltstone, brown and green, gypsiferous in part, with numerous thin interbeds of coquinite, brown, pelletal, and sandstone, pale brown, fine-grained, indurated

Thickness (feet)	
27	Siltstone, green, micaceous, with thin interbeds of coquinite, ferruginous, pelletal, and quartz sandstone and glauconitic sandstone
17	Coquinite, ferruginous, pelletal, and shelly dolomite; all poorly-outcropping

Total 202, of Nora Formation, overlying the Kelly Creek Formation.

In the Dulcie Range the Nora Formation is mostly concealed by scree. Smith (1964a) reported the following sequence as a continuation of HX30, the reference section of the Tomahawk Beds:

Thickness (feet)	Dulcie Sandstone unconformably overlying:
185	Mainly concealed; debris of Dulcie Sandstone and of conglomerate with fragments of fossiliferous Ordovician sandstone; "near outcrop" of red siltstone and of purple quartz sandstone 135 feet above the base of the interval
65	Concealed; debris of dark-brown fossiliferous dolomite, green, fossiliferous mudstone and grey fossiliferous sandstone
½	Sandstone, dark red, ferruginous, coarse-grained, with small lenses of brown dolomite
49	Concealed
1	Mudstone, green, fossiliferous
2	Ironstone, dark-red, oolitic, coarse-grained
20	Mudstone, poorly-outcropping, green, with some lenses of sandstone, coarse-grained, fossiliferous
2	Mudstone, greenish-brown, with some lenses of sandstone, medium and coarse-grained
1	Ironstone, dark red, coarse-grained
4½	Siltstone, green
3	Sandstone, dark red, ferruginous, coarse-grained (Sample Ha 248A)

Thickness (feet)	
2½	Mudstone, green, fossiliferous
2½	Sandstone, light-green, with some lenses of dark-red ferruginous sandstone
4	Mudstone, green, with some thin (2-inch) bands of dark red, ferruginous sandstone
28	Mainly concealed; some poor outcrops of green siltstone

Total 370, of Nora Formation, conformably overlying the Tomahawk Beds.

Towards the north-western part of its outcrop in the Dulcie Range the Nora Formation is only about 75 feet thick.

Some of the beds of the Nora Formation in the Dulcie Range contain iron, and some in the Toko Range contain phosphatic nodules; these occurrences are discussed on pages 51 and 57 .

Carlo Sandstone

Definition: Derivation of Name: From Carlo Station, which extends west from the netting fence near the Mulligan River into the sand dunes of the Simpson Desert. The homestead is situated at latitude 23°30'S, longitude 138° 40'E. Casey (In Smith, 1963a) named the formation.

Map Reference: Mount Whelan 1:250,000 Sheet area, Plate 4.

Type Area: Two miles south of Carlo homestead; here the sandstone is exposed in four parallel ridges, trending north-west, and dips to the south-west.

Distribution: Forms the top 20 feet of the Toko Range scarp, and continues south-east on both limbs of the Toko Syncline; also forms the rim of the scarp in the Tarlton Range.

Lithology: Thick and medium-bedded, fine to medium-grained quartz sandstone, with ripple marks and flute casts; in the Tarlton Range clay pellets are common in the lower half of the unit, and a prominent clay pellet bed occurs at the base in the Toko Range area. A few thin beds of siltstone occur in the lower part of the sequence.

Thickness: About 200 feet in the type area; and a similar thickness for much of the north-eastern and northern part of the Toko Syncline; on the south-western limb of this structure the Carlo Sandstone thickens to the south-east; it is about 250 feet thick near Gaphole Creek, 300 feet at the Queensland-Northern Territory Border and increasing to 500+ feet in the south-east; 60-120 feet in the Tarlton Range, where the top is eroded.

Contacts: The Carlo Sandstone conformably overlies the Nora Formation and is conformably overlain by the Mithaka Formation in the Toko Syncline. In the Tarlton Range, the sandstone is apparently conformable on the Nora Formation except in one location on the northernmost hill of The Pinnacles near Tarlton Downs homestead, where a probable disconformity is indicated by scour and fill structures. The top of the formation is eroded in most places on the Tarlton Range, but the Mithaka Formation conformably overlies the Carlo Sandstone at a few localities.

Fossils: Nautiloids, brachiopods, pelecypods, and worm tracks and trails; fossils are not abundant and most of those found in the Carlo Sandstone are in its upper half. The fauna is undescribed.

Age: Middle Ordovician (Opik and Tomlinson, pers. comm.).

Description and Comment: Despite the apparently-resistant nature of the Carlo Sandstone, outcrops in the scarp rims are often poor and much of the formation is covered by sandstone scree. South-east of Gaphole Creek the formation crops out well where streams have cut across steeply-dipping beds, but apart from those localities the beds are seldom seen on the bevelled surface of the Toomba Range. It is difficult to measure reliable, complete sections of the Carlo Sandstone because the upper part is seldom available in strong outcrops.

The Carlo Sandstone is Pritchard's (1960) Unit Om-9, which he described as "medium to thick-bedded, brown and white, fine to medium-grained quartz sandstone, with cross-bedded sandstone containing clay-pellets at the base. The upper part of the unit is massive". Pritchard (in Reynolds and Pritchard, 1964, unpubl.) measured the following sequence in the lower part of the Carlo Sandstone, in section G261 which is a continuation of his section in the Nora Formation:

Thickness (feet)	Lateritised Carlo Sandstone overlying:
20	Quartz sandstone, brown, laminated to thin and medium-bedded, medium-grained, well-sorted, well rounded, with irregularly distributed clay pellets, and interbeds of medium-bedded quartz siltstone; bedding planes show tracks and trails
10	Quartz sandstone, brown, laminated and thin-bedded, fine to very fine-grained, well-sorted, well-rounded, and interbeds of laminated siltstone; bedding planes show tracks and trails
5	Quartz sandstone, brown, thick-bedded, cross-bedded, medium-grained, well-sorted, well-rounded, with clay pellets and clay breccia
30	Quartz sandstone, mottled white, yellow-brown and purple, thin and medium-bedded, medium-grained, well-sorted, well rounded, with clay pellets; interbeds of thin-bedded and laminated siltstone
Total 65,	thickness of part section of the Carlo Sandstone, resting conformably on the Nora Formation.

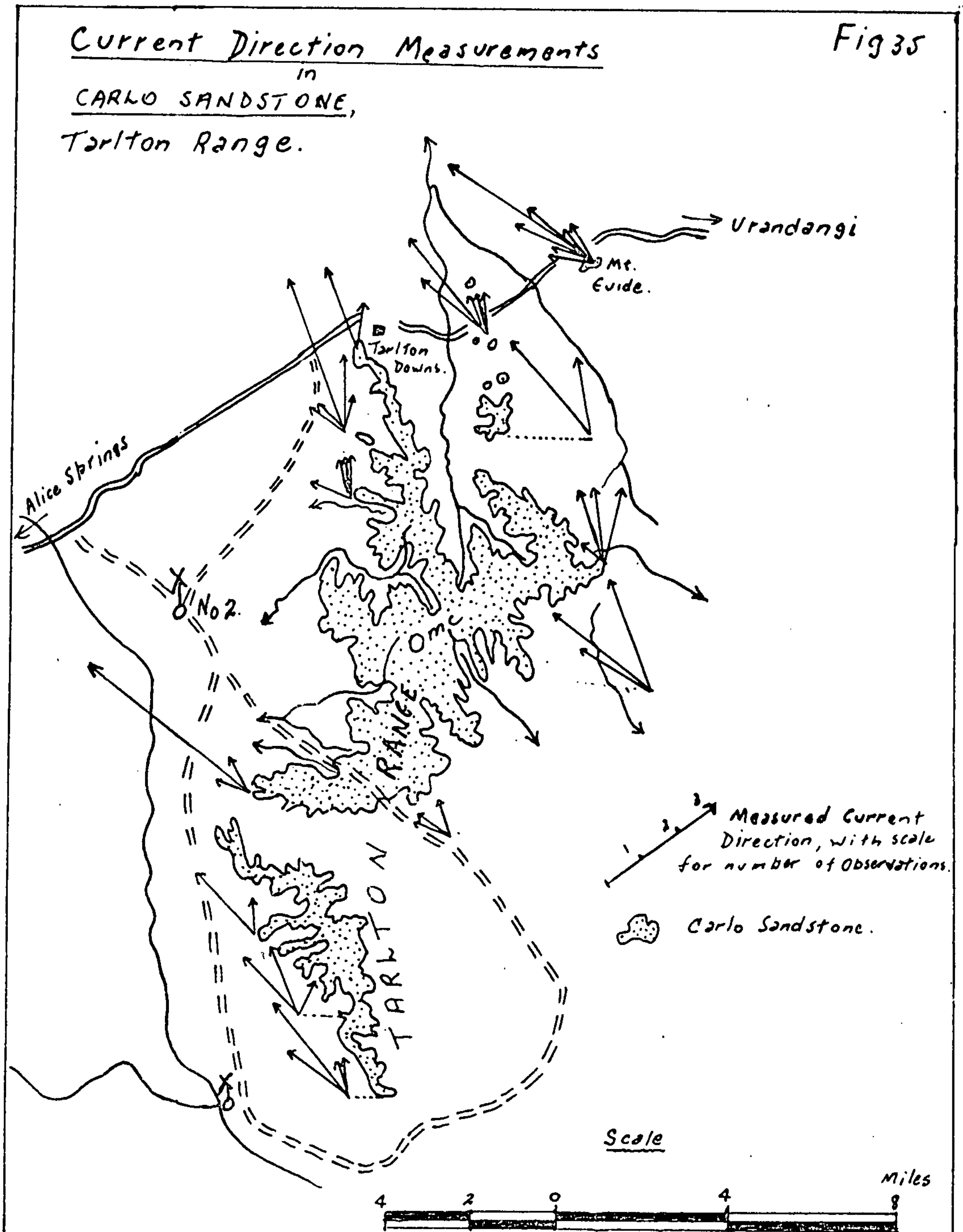
A more complete section, 280 feet thick, has been measured by the author in a prominent gap in the Toomba Range near the Northern Territory-Queensland Border. At this locality neither the base nor the top of the formation is exposed and the sequence consists of quartz sandstone, with clay pellets prominent in the lower 50 feet. Some beds of red, clean, friable sandstone are present, and most of the sequence is cross-bedded.

The only well which has penetrated the Carlo Sandstone is Netting Fence No. 1, where the thickness is given as 410+ feet (surface to 410 feet) and the lithology is described as "mostly medium-grained, well-sorted quartz sandstone, generally clean and porous but also with yellow ferruginous or white clay matrix in some beds" (Papuan Apinaipi Petroleum Company Limited, 1965, unpubl.).

R.R. Vine has measured a complete sequence of the Carlo Sandstone in the Tarlton Range, six miles south of Tarlton Downs homestead; here the formation is 120 feet thick and consists of:

Thickness (feet)	Mithaka Formation conformably overlying:
½	Quartz sandstone, red and brown, fine to medium-grained, rounded, well-sorted, medium-bedded, cross-laminated, with flute casts, mud pellets and interference ripple-marks
16½	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, friable, thin-bedded to laminated; rubbly outcrop
5	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, strongly cross-bedded
30	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, friable, laminated to thin-bedded, rubbly outcrop
4	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, strongly cross-bedded
12	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, friable, laminated to thin-bedded; rubbly outcrop
2	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, strongly cross-bedded
50	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted, friable, laminated to thin-bedded, with flute casts ripple marks and cross-laminations on harder beds; rubbly outcrop
2	Quartz sandstone, red-brown and buff, fine to medium-grained, rounded, well-sorted strongly cross-laminated, with mud pellets and interference ripple marks

Total 122, of Carlo Sandstone, overlying the Nora Formation.



To accompany Records 1967/61

Smith, Vine and Milligan (1961, unpubl.) examined the Carlo Sandstone in the Talton Range for indications of current directions during deposition. Although the study was hampered by lack of material, sufficient exposures to give reliable indications were found, and the results show that the currents come from the south-east, although local variations occur. The measurements were made on festoon bedding and lamination, flute casts, current ripple marks and current lineations, and the directions observed at each locality are shown on Fig. 35 with a rose diagram of all measurements on Fig. 35a.

Mithaka Formation

Definition: Derivation of Name: From Mithaka Waterhole, located 200 yards west of the Queensland-Northern Territory Border, at latitude 22°53'S, longitude 138°E. Casey (In Smith, 1963a) named the formation.

Map Reference: Tobermory 1:250,000 Sheet area, Plate 4.

Type Area: On the track from Wheelaman Bore (latitude 22°52'S, longitude 138°16'30"E) to Craven's Peak (dud) bore (22°57'S, 138°7'E) and extending from one mile north-east of this bore to the top of the scarp to the south.

Distribution: In a relatively broad belt in the centre of the Toko Syncline (south-eastern corner of Tobermory Sheet area and south-western corner of Glenormiston Sheet area) and intermittently to the south-east, along both limbs of the Toko Syncline; residuals occur on the Tarlton Range.

Lithology: Brown and grey gypsiferous siltstone and sandstone, white glauconitic quartz sandstone, gypsiferous green shale, calcareous siltstone and some thin coquinites.

Thickness: 200-400+ feet in the Toko Syncline, 60+ feet in the Tarlton Range; no reliable, complete sequences are available for measurement.

Contacts: Conformable on the Carlo Sandstone and overlain unconformably by the Craven's Peak Beds in the Toko Syncline; in the Tarlton Range, the formation is conformable on the Carlo Sandstone but the top is eroded.

Fossils: Trilobites, nautiloids, and sponges (Receptaculites) are common, pelecypods and brachiopods less abundant; conodonts are reported by P.J. Jones (In Reynolds and Pritchard, 1964) from more than 80 shot-hole samples collected during the Phillips Petroleum Company Ltd's (1961, unpubl.) subsidized Springvale-Toko seismic survey; tracks and trails are common.

Age: Middle Ordovician (Opik and Tomlinson, pers. comm.).

Description and Comment: The Mithaka Formation is Pritchard's (1960) Unit Om-10, which he described as "sets up to 30 feet thick of thin-bedded brown and white quartz sandstone which in places is glauconitic, interbedded with gypsiferous green shale". A complete sequence of the Mithaka Formation has not been observed; in the Toomba Range the formation often is almost completely concealed in valleys up to 1000 feet wide, separating ridges of Carlo Sandstone and Craven's Peak Beds; the only evidence of the unit in the subsurface is afforded by blue-grey siltstone drilled in a few water bores. The best available exposures are in the Tobermory-Glenormiston Sheet areas, where the most common rock type is soft, brown gypsiferous siltstone interbedded with brown and white, laminated and thin-bedded quartz sandstone, and green shale. The proportion of sandstone increases towards the top, and some coquinite also occurs in the upper part of the formation. In all cases, thicknesses are based on small percentages of measurable sequence, together with estimates of the concealed remainder. There is no reliable subsurface information on the Mithaka Formation.

A few residuals of the Mithaka Formation on the top of the Tarlton Range consist of strongly lateritised, fossiliferous siltstone with a few sandy laminae; the thickness ranges from 5 to 60 feet.

SILURIAN-DEVONIAN

No fossiliferous Silurian rocks are known in the Northern Territory, and the only sediments which may be of Silurian age in western Queensland occur in the south-western part of the Glenormiston Sheet area, and may extend south-east under the Mesozoic and Cainozoic sediments which conceal the south-eastern part of the Toko Syncline. These rocks are the Craven's Peak Beds and Jones (In Reynolds and Pritchard, 1964) reported coelolepidid fish scales indicative of an

Upper Silurian-Lower Devonian age in five shot hole samples, at latitude 23°00'S, longitude 138°07'E, obtained during the subsidized Springvale-Toko seismic survey of Phillips Petroleum Company Ltd (1961, unpubl.).

Cravens Peak Beds

Definition: Derivation of Name: From Craven's Peak Holding (Queensland Lands Department Map No. 68) which includes most of the northern part of the area between the Northern Territory Border and the Toko Range in western Queensland, and extends from just north of latitude 23°00'S to latitude 23°22'S. Reynolds (In Smith, 1965b) named the Craven's Peak Beds.

Map Reference: Glenormiston and Mount Whelan 1:250,000 Sheet areas, Plate 4.

Reference Section: This is about ¼ mile east of Toomba Bore (latitude 23°05'S, longitude 137°59'E) on the Hay River Sheet, Northern Territory. The top of the reference section is within a few yards of the Queensland-Northern Territory Border, which is unfenced at that locality.

Distribution: Outcrops are confined mainly to the area of Craven's Peak Holding, but a narrow belt extends along the eastern edge of the Toomba Range into the Northern Territory, and small outcrops occur near the Queensland-Northern Territory Border, south of Mithaka Waterhole.

Lithology: Red-brown quartz sandstone, with mud pellets in some beds and some pebble, cobble and boulder conglomerate.

Thickness: 460+ feet in the reference section where neither the base nor the top is exposed, and 300+ feet near the south-eastern end of the Toomba Range (Reynolds, 1964, unpubl.).

Contacts: Unconformable on the Mithaka Formation in the Toomba Range; unconformable on Toko Group and on the Kelly Creek Formation near the Mulligan River north-west of Carlo homestead; overlain unconformably by ?Permian, Mesozoic and Cainozoic rocks.

Fossils: Placoderms on the surface, coelolepidid fish scales in the subsurface.

<u>Age</u>: Silurian(?) - Devonian.

<u>Description and Comment</u>: The Craven's Peak Beds constitute the sequence designated Om-11 by Pritchard (1960) and "Middle Ordovician Undifferentiated" by Smith (1963a). Mapping of the sequence has now been completed, and the fossils found disprove an Ordovician age.

In the northernmost outcrops, and on the eastern side of the Toko Syncline and in its centre, the Craven's Peak Beds crop out poorly in low rises which are often rubble-covered where the sequence has gentle dips. In the Toomba Range the beds crop out well where dips are steep, although structural complexities caused by cross-faults and by suspected strike faults make determination of stratigraphy sometimes difficult in a sequence of sandstone without prominent marker beds.

In some localities north-west from Toomba Bore, the Craven's Peak Beds rest on sandstone of the upper part of the Mithaka Formation, and the actual boundary between the two stratigraphic units is difficult to place accurately, particularly when both sandstones are brown. However, some of the sandstone of the Mithaka Beds contains large pelecypods and the presence of the fossils enables delineation of an approximate boundary. South-east of Toomba Bore the Mithaka Formation crops out poorly, if at all, and the base of the Craven's Peak Beds is placed at the base of the oldest sandstone bed on the eastern side of the valleys which separate ridges of Carlo Sandstone and Craven's Peak Beds and which are assumed to be underlain by the Mithaka Formation.

In the reference section, the author has measured the following sequence (described in Smith, Vine and Milligan, 1961, unpubl.).

Thickness (feet)	
	Top of ridge
20	<u>Quartz sandstone</u>, red-brown, medium-grained, medium-bedded, cross-bedded, hard, with numerous narrow silica veins
25	<u>Quartz sandstone</u>, red and brown, medium-grained, medium-bedded, hard, with some narrow silica veins in the upper 10 feet

Thickness (feet)	
35	Quartz sandstone, red, medium-grained, hard, poorly-outcropping
45	Quartz sandstone, red, medium-grained, medium-bedded, cross-bedded, clean, friable
15	Concealed
45	Quartz sandstone, red, medium-grained, poorly-outcropping
35	Quartz sandstone, red, medium-grained, medium-bedded, cross-bedded, silty in part, with some mud pellets
65	Quartz sandstone, red, medium-grained, thin to medium-bedded, cross-bedded
125	Quartz sandstone, red, medium-grained, medium-bedded, cross-bedded, friable, with numerous large mud pellets
25	Quartz sandstone, red, coarse-grained, medium-bedded, cross-bedded, friable, with thin interbeds of cream medium-grained, silty quartz sandstone
25	Quartz sandstone, red, medium to coarse-grained, thin-bedded, and laminated, clean
Total 460,	thickness of reference section of Craven's Peak Beds, whose base is not exposed.

The age and sequence of the Craven's Peak Beds are incompletely known at present, and there is some conflict in ages of the few fossils which have been found. The available evidence is:

(a) Jones (In Reynolds and Pritchard, 1964, unpubl.) discovered coelolepidid fish scales in samples from five seismic shot holes, at latitude 23°00'S, longitude 138°07'E; the fish scales occured in quartz sandstone overlying conodont-bearing beds of the Mithaka Formation; Jones (op cit.) stated that the scales indicated an Upper Silurian-Lower Devonian age.

(b) Alliance Petroleum Australia, N.L. (1963, unpubl.) found well-preserved fossil fish in loose blocks of quartz sandstone at the base of a low mesa of red and cream medium and coarse-grained cross-bedded quartz sandstone, with pebble and boulder conglomerate, in the south-eastern part of the Tobermory

Sheet area. This occurrence is about 8 miles north-east of the shot holes where Jones found the fish scales mentioned in (a). The specimens of fish have been dated as Upper Devonian (Fletcher, in Alliance Petroleum Australia, N.L., op cit.).

(c) Mulder (1961) found a specimen of an indeterminate Arthrodire (regarded by Tomlinson, 1966, as Upper Devonian) about 1 mile north-east of the reference section of the Craven's Peak Beds. The specimen was not in situ and was lying on the surface of the Craven's Peak Beds.

(d) The French Petroleum Co. (Aust.) Pty Ltd found specimens of fragmentary *Phyllolepis*, indeterminate Arthrodires and ?*Lycopod* bark about 12 miles south-east of Toomba Bore (Tomlinson, 1966). These specimens were not in situ but were in fact near a former aboriginal tribal ground on top of the Carlo Sandstone, a few hundred yards from outcrops of the Craven's Peak Beds.

Tomlinson (1966) regards the fossils (b), (c) and (d) as Upper Devonian; therefore the Craven's Peak Beds may consist of two sequences, separated by a disconformity. Most, if not all, of the outcrop probably consists of the upper sequence. The lower sequence may have either been eroded or in some places it may underlie areas which, at present, are believed underlain by the Mithaka Formation. Because of these uncertainties, the term 'Beds' is preferred for the whole sequence.

DEVONIAN

Dulcie Sandstone

Definition: Derivation of Name: From the Dulcie Range, which is capped by prominent outcrops of the sandstone. Smith (1964a) named the formation.

Map Reference: Huckitta 1:250,000 Sheet area, Plate 3.

Type Section: At latitude 22°35'S, longitude 135°41'E, about 8 miles south-east of old Huckitta homestead.

<u>Distribution</u>: In a broad belt extending from the south-eastern tip of the Dulcie Range north-west for about 130 miles; this belt has been folded into an asymmetric syncline named the Dulcie Syncline and outcrops of the sandstone are restricted to that structure.

<u>Lithology</u>: Cream, white and brown, medium-coarse-grained, medium to thick-bedded, cross bedded clean to silty quartz sandstone with sporadic beds of pebble conglomerate, calcareous silty sandstone and white siltstone.

<u>Thickness</u>: 2040 feet in the type section, 1700 feet north-west of Picton Spring, 1475+ feet north-east of Grg 1, 1475+ feet in the southern part of the Barrow Creek Sheet area; about 300 feet in the north-western end of the Dulcie Syncline, and usually less than 140 feet along most of the north-eastern limb of that structure.

<u>Contacts</u>: Unconformable on Middle and Lower Ordovician and Upper Cambrian sequences, and overlain unconformably by Cainozoic sediments. Often the base of the sequence is concealed beneath Cainozoic sand.

<u>Fossils</u>: Placoderms; Hills (1959) described <u>Bothrolepis</u> sp. and <u>Phyllolepsis</u> sp. collected from the type section area; other fossils, from the Barrow Creek Sheet area are arthrodires (Opik, pers. comm.) but they are undescribed.

<u>Age</u>: Upper Devonian; Opik (pers. comm.) considers that the specimens from the Barrow Creek Sheet area may be Lower Devonian, and Tomlinson (1966) concurs.

<u>Description and Comment</u>: The Dulcie Sandstone is an easily recognised lithological unit, although its contact with sandstone of the underlying Tomahawk Beds is sometimes difficult to determine, particularly on the north-eastern side of the Dulcie Syncline, where dips are usually low in both units. At many other places in the scarp of the Dulcie Range, scree conceals the contact between the Dulcie Sandstone and the underlying Nora Formation and Tomahawk Beds. However, where reasonable exposures occur, the contact can be determined by walking along beds of older rocks to observe scour and fill effects in them. There is no readily-discernible angular unconformity at any locality and the contact may be best described as a disconformity of regional extent.

In the type section, the Dulcie Sandstone consists of:

Thickness (feet)	Top of mesa
18	Quartz sandstone, white, medium-grained
5	Pebble conglomerate; poorly-sorted, sub-angular to sub-rounded pebbles, in a matrix of soft, white mudstone
16	Concealed
6	Sandstone, white, medium-grained, with abundant kaolin
23	Sandstone, white, medium-grained, cross-bedded, with abundant interstitial kaolin, and sporadic pebbles
46	Concealed
22	Sandstone, white, medium-grained, strongly cross-bedded, with abundant interstitial kaolin
113	Concealed
115	Quartz sandstone, poorly-outcropping, friable, with sporadic pebbles
81	Concealed
92	Sandstone, white, medium-grained, strongly cross-bedded, kaolinitic, with *Bothriolepis* sp. between 30 and 55 feet above the base of the interval
11	Siltstone, white, micaceous, with some soft, compact, light-grey mudstone
62	Concealed
23	Sandstone, medium-grained, kaolinitic
37	Concealed
29	Pebble conglomerate, poorly-outcropping, soft, kaolinitic
69	Sandstone, medium-grained, cross-bedded, very kaolinitic, with stringers of pebble conglomerate
196	Quartz sandstone, white, medium-grained, sub-angular, friable, cross-bedded
23	Sandstone, light-grey, medium-grained, kaolinitic
127	Sandstone, white, poorly-outcropping, medium-grained, with abundant kaolin
12	Quartz sandstone, white, medium-grained, cross-bedded
178	Mainly concealed; a few small outcrops of sandstone

Thickness (feet)	
63	Sandstone, white, fine-grained, strongly cross-bedded, with abundant kaolin
140	Mainly concealed; a few small outcrops of fine conglomerate
115	Sandstone, white, medium-grained, cross-bedded, sub-angular, with interstitial kaolin; some stringers of fine conglomerate
40	Quartz sandstone; white, medium-grained, strongly cross-bedded, some thin stringers of coarse, well-rounded quartz grains
138	Concealed
34	Sandstone, white, medium-grained, strongly cross-bedded, with abundant interstitial kaolin; some thin bands of pebble conglomerate
164	Quartz sandstone, white, friable, medium-grained, strongly cross-bedded
40	Quartz sandstone, white, well-sorted, medium-grained, firm, porous, strongly cross-bedded

Total 2038, thickness of type section of Dulcie Sandstone; the contact with the underlying Nora Formation is not exposed.

The specimens of the placoderm Phyllolepis sp. were discovered by geologists of Frome-Broken Hill Pty Ltd, near the type section, but higher in the sequence than the Bothriolepis sp. which was discovered by Bureau geologists. Hills (1959) described the fossils, which were thefirst Devonian fossils found in Central Australia, and which are of considerable importance in dating the major orogeny which affected the southern part of the Georgina Basin. Tomlinson (1966) has described fragmentary fossil fish 1640 feet above the base of Section HX93, 5 miles north-north-west of Picton Spring and on the same stratigraphic level as the Bothriolepis sp. locality.

The best and thickest outcrops of the sandstone are on the south-western limb of the Dulcie Syncline. Good exposures occur also on the north-eastern side between HX93 locality and the south-eastern extremity of the Dulcie Range.

In these localities the dips are steep in lower beds, but flatten out rapidly to less than 5 degrees across the remainder of the outcrop belt. The thickest sequence, on air photograph interpretation, is in the type section area, and light-coloured beds below the Bothriolepis sp. horizon can be traced around several outcrops north-westwards to the headwaters of Mistake Creek. Further north-west, most of the sequence is probably below the horizon where Bothriolepis sp. has been found, although measurement is difficult in cross-bedded and poorly-outcropping sediments when the dip flattens out a short distance from the base. 1475 feet has been measured in section BX8, in the south-eastern part of the Barrow Creek Sheet area.

Along most of the north-eastern edge of the Dulcie Syncline the measurable thickness is less than 100 feet in low scarps. In the north-western end of the Syncline, the Dulcie Sandstone is less than 300 feet thick, and fossil fish obtained there may be Lower Devonian in age (Opik, pers. comm.), but this determination is a preliminary one. If it is correct, there may be two disconformable sequences within the Dulcie Sandstone but these cannot be distinguished on the present scale of mapping.

The Dulcie Sandstone may be present under soil-covered plains north of its outcrop area on the Elkedra and Barrow Creek Sheet areas. If so, it would fill hollows in the Tomahawk Beds. The only evidence of this is in core hole Grg 2; here the sequence consists of 280 feet of Quaternary sand overlying soft, white, clean quartz sandstone, and silty quartz sandstone with some pebbly sandy siltstone and white siltstone. On lithological grounds this sequence is regarded as part of the Dulcie Sandstone, but there is no fossil evidence to support the identification. Core recovery was poor, and the hole was abandoned at 354 feet (Milligan, 1963, unpubl.).

The north-westward continuation of the Dulcie Sandstone is unknown; it was not recorded in core hole Grg 18, which recovered Upper Cambrian sediments at 310 feet, but further north-west on the Lander River Sheet area Milligan, Smith, Nichols and Doutch (1966, unpubl.) have mapped an apparently unfossiliferous sandstone, lithologically similar to the Dulcie Sandstone, unconformably overlying fossiliferous Middle Ordovician sediments.

PERMIAN?

There are no proven Permian sediments cropping out in the Georgina Basin, but Reynolds and Pritchard (1964, unpubl.) regarded some small outcrops beneath ?Mesozoic rocks, 11 miles west of Roxborough Downs homestead as probably Permian in age. Reynolds (1964, unpubl.) regarded similar outcrops of larger areal extent in the Mount Whelan Sheet area also as probably Permian. The sequences are un-named.

The outcrops west of Roxborough Downs homestead consist of a few feet of unconsolidated boulder to pebble-sized gravel which have weathered from the slopes of small rounded hills capped by weathered sediments typical of the Mesozoic of the Glenormiston Sheet area. One small outcrop of green-brown, laminated siliceous shale appeared to be associated with the gravel, which consisted mainly of silicified sandstone resembling that of the Ordovician sequences in the Toko Range; some blocks were fossiliferous, and Tomlinson (1959, unpubl.) identified boulders of the Kelly Creek and Nora Formations. Some cobbles and pebbles have flat-iron shapes, some have "chatter" or impact structures, and a few pebbles show striations. These features, together with the post-Ordovician and probable pre-Mesozoic age and the fact that pebble beds are rare in the basal Mesozoic of the region led Reynolds and Pritchard (op cit.) to regard the sequence as probable glacial deposits of Permian age.

Reynolds (1964, unpubl.) described the occurrences in the Mount Whelan Sheet area as pebble deposits, mostly unconsolidated, which are widespread in hollows of the Toomba Range and over its eastern slopes, and as scree over low hills in the western trough of the Toko Syncline, and in the area between Sun Hill and Polly's Lookout. The pebbles are mainly silicified quartz sandstone and appear to be derived locally from older Palaeozoic rocks of the Toomba Range. Leslie (1959, unpubl.) found some pebbles in unconsolidated boulder clay.

In general, the features of the pebbles were similar to those of the Glenormiston Sheet area and Reynolds regarded the occurrences as probable glacial sequences of Permian age.

The author has not seen any of these ?Permian occurrences, but their description is very similar to that of the Tarlton Formation of Condon and Smith

(1959, unpubl.) which those authors regarded as Permian glacials. Later, White (1959) identified Upper Triassic-Lower Jurassic plant fossils from the upper (non-pebbly) part of the Tarlton Formation, and the whole sequence is now tentatively regarded as Mesozoic.

THE POST-PALAEOZOIC SEDIMENTS ON THE GEORGINA BASIN

Mesozoic sediments obscure the north-western and south-eastern margins, and Mesozoic and Cainozoic rocks occur within the Basin and near some marginal areas. These sediments are described below:

1. The north-western margin

The Mesozoic sediments are a southern extension of the Mullaman Beds (Randal, Brown and Doutch, 1966, unpubl.); Noakes (1949) named the Mullaman Group in the Katherine-Darwin area, and Walpole et al., 1967 re-named the sediments the Mullaman Beds.

The Mullaman Beds are not shown on Plate 1, because the mapping of Helen Springs and Beetaloo Sheet areas had not been completed before the 1:500,000 scale maps of the Georgina Basin were compiled, and because no reasonable-sized outcrops of Mesozoic are known in the southern part of the Walhallow Sheet area, although Plumb and Rhodes (1963) reported Mesozoic sediments in gullies and small scarps.

Randal, Brown and Doutch (1966, unpubl.) state that outcrop of Mesozoic sediments is low, usually less than 10 feet, in the Helen Springs Sheet area. The sediments of the Mullaman Beds consist of horizontally-bedded quartz sandstone, pebble conglomerate, siltstone and calystone. The thickest known sequence in this area is 10 miles east of Beetaloo homestead, where a water bore penetrated 285 feet of Mullaman Beds without reaching the base of the sequence. The sediments in the bore contain radiolaria and plant impressions.

Noakes and Traves (1954) collected fossils from scattered blocks of sandstone 7 miles south-east of Creswell Downs homestead, and Brunschweiller (1950, unpubl.) examined this collection and reported *Ptilophyllum* sp. nov., *Cycadites* sp. ind., and *Elatocladus* cf. *planus*; he gave a Lower Cretaceous age to the flora. Randal and Nichols (1963, unpubl.) collected additional material from the same locality, and Mary White (In Randal and Nichols, 1963, op cit.) listed the following forms in numbered specimens held in the official collections of the Bureau of Mineral Resources:

F22310	Pterophyllum fissum Feist.
F22311	Thinnfeldia pinnata Walk.
F22312	Otozamites bechei Brong.
F22313	Pterophyllum fissum Feist.
F22314	Pterophyllum fissum Feist.
	?Otozamites bengalensis (Morr.)
F22315	Otozamites bengalensis (Morr.)
F22316	Taeniopteris spatulata McClell
F22317	Pterophyllum fissum Feist.
F22318	Ptilophyllum pecten (Phil.)
F22319	Pterophyllum fissum Feist.
F22320	Otozamites bengalensis (Morr.)

White stated that the age of the flora is probably Lower Cretaceous, but as the range of the Otozamites-Pterophyllum flora was unknown, a Jurassic age may be possible.

(2) The south-eastern margin and south-eastern Basin

A large part of this area is covered by Mesozoic sediments of the Great Artesian Basin. These are widespread on each of the Glenormiston, Boulia, Mount Whelan and Springvale Sheet areas, and extend south and east into the deeper parts of the Great Artesian Basin. Minor occurrences of Mesozoic sediments belonging to these sequences occur also in the Hay River, Urandangi and Duchess Sheet areas.

Most of the Mesozoic sediments are of Lower Cretaceous age, and consist of three formations - the Longsight Sandstone, the Wilgunya Formation with its Toolebuc Member, and the Mackunda Formation - which form part of the Rolling Downs Group as defined by Vine and Day (1965). Some of the Mesozoic sediments of the Duchess Sheet area have been mapped by Carter and Opik (1963), and are shown as "Undifferentiated Mesozoic"; most of these overlie Precambrian rocks, and are described in a later section.

Casey (1959) named the Longsight Sandstone and the Wilgunya Formation and its Toolebuc Member. Vine (1964) named the Mackunda Formation, and Vine and Day (1965) modified the Rolling Downs Group in the light of evidence available from deeper parts of the Great Artesian Basin to the east; this modification divided the Wilgunya Formation into five members. However, this modification post-dated the mapping of the Mesozoic cover of the Georgina Basin, where the Wilgunya Formation has not been subdivided except for the delineation of the Toolebuc Member; Casey's 1959 definitions are followed in this Bulletin.

Table 10 gives the stratigraphy of the Mesozoic sediments on the south-eastern part of the Georgina Basin, and brief descriptions of the units follow.

In the Lower Cretaceous sediments, the Longsight Sandstone ranges from marine to non-marine (probably lagoonal); it is succeeded by the Wilgunya Formation, of dominantly argillaceous marine sediments, which is overlain by the Mackunda Formation, which is composed of argillaceous and arenaceous marine and paralic sediments which are transitional between the marine Wilgunya Formation and a freshwater sequence named the Winton Formation by Vine and Day (1965).

The Longsight Sandstone is named from Longsight Peak, a prominent hill at latitude 22°30'S, longitude 139°32'E, 8 miles south-east of Alderley Station (Plate 4). Its distribution is shown in Table 10 and on Plate 4. Casey et al., (1960, unpubl.) reported that bore records show that the formation extends over much of the eastern part of the Boulia Sheet area; east of the Hamilton River the sandstone forms the main local aquifer of the Great Artesian Basin. The Longsight Sandstone is thin both in outcrop and in the subsurface over the south-east Georgina Basin (Table 10).

The Wilgunya Formation has been named from its outcrops near Wilgunya Creek, a tributary of the Hamilton River in the eastern part of the Boulia Sheet area (Casey, 1959). The type section is 8 miles north-north-east of Dover homestead (22°32'S, 140°50'E). At this location the sequence (Casey et al., 1960, unpubl.) in descending order is:

TABLE 10: STRATIGRAPHY OF MESOZOIC SEDIMENTS, SOUTH-EASTERN GEORGINA BASIN

Formation	Map Symbol	Age	Distribution (Surface)	Lithology	Thickness (feet); S-surface sub-subsurface								Topography	Fossils	Stratigraphic Relationships
					Boulia		Glenor-miston		Mount Whelan		Spring-vale				
					S	Sub	S	Sub	S	Sub	S	Sub			
Mackunda Formation	Klm	Lower Cretaceous	Springvale Sheet.	Fine grained felds-pathic sandstone, commonly calcareous and grading to sandy limestone; blue-grey claystone and siltstone, minor conglomerate.							50		Rolling Downs; and low duricrust -capped hills.		Conformably overlies the Wilgunya Formation.
Wilgunya Formation	Klw	Lower Cretaceous	Boulia, Glen-ormiston, Springvale, with minor occurrences on Mt Whelan, Duchess and Urandangi Sheet areas.	Siltstone, sandy siltstone, blue claystone, glau-conitic sandstone; these sediments are usually deeply weathered, and sili-cified in top part.	120	Up to 1140 in water bores; 303 in Bean-tree No.1 Well.	100					472 in Canary No. 1 Well; 134 in Eliza-beth Springs No. 1 Well.	Mesas and plateaux; some rolling plains, some low hills.	Gastropods, foraminifera, ?radiolaria, ammonites, pelecypods.	Conformable on Long-sight Sandstone; unconformable on Palaeozoic and Precambrian rocks in some places, both surface and subsurface; conformably overlain by Mackunda Beds; unconformably overlain by Tertiary sediments in some localities.
Toolebuc Member	Klo	Lower Cretaceous	Boulia, Spring-vale, Mount Whelan Sheet area.	Calcareous sandstone and siltstone, lime-stone; concretions rich in fossils.	30	Not recor-ded in bores	-		10		30	1-54?	Rolling grassy plains; some out-crops in mesa slopes.	Pelecypods (<u>Inoceramus</u> and <u>Aucellina</u>), ammonites Myloceras, Labeceras, Falciferella, (Appurdiceras) gastropods, foraminifera, radiolaria, fish scales.	Member of Wilgunya Formation, about 400 feet above its base.
Longsight Sandstone	Kll	Lower Cretaceous	Boulia, Mount Whelan, Glen-ormiston; minor occurrences in Urandangi and Duchess Sheet areas.	Quartz sandstone, minor conglomerate and sandy siltstone, shale, lignite, glauconitic sandstone.	100	200; miss-ing in Bean-tree No.1 Well	110			Up to 550		32 in Canary No. 1 Well, 149 in Eliza-beth Springs No.1 Well.	Ferruginised rubble plains, or as benches below overlyign silt-stone in diss-ected plateau.	Plants, pele-cypods, rare gastropods, heleminites, worm burrows and <u>Rhizocorallium</u>	Conformably overlain by Wilgunya Formation; rests unconformably on Precambrian and Palaeozoic rocks.
Undiffere-ntiated	M	Mesozoic	Hay River, Tobermory, Glenormiston, Mount Whelan, Duchess	Silty, sandstone, with conglomerate and silt-stone.			20-70		30				Low mesas	Fossil wood and plant remains. <u>Rhizocorallium</u>	Unconformable on Palaeozoic and Precambrian rocks.

Thickness (feet)	
8	Ferruginous laterite cap
20	Claystone and siltstone, silicified and mottled
5	Claystone, red-brown, hard
15	Claystone, white, massive
20	Claystone, white and grey, greasy, with limonite disc-shaped concretions up to 18 inches in daimeter
½	Limonite
25	Siltstone, massive, white, with barytes and irregular limonite veins
20	Concealed; clay and siltstone rubble
10	Concealed
	The base of this section ended at the 10-mile Bore (latitude 22°27'S, longitude 140°52'E) whose log gives the following section of the remainder of the Wilgunya Formation:
10	Soil and clay
70	Clay, yellow; (may include the Toolebuc Member)
20	Shale, blue
530	Shale, black
Total 753½,	of Wilgunya Formation, underlain by 60 feet + of Longsight Sandstone.

The Toolebuc Member forms a thin but resistant sequence which crops out extensively and forms a good marker. The Toolebuc Member has been named from Toolebuc homestead, in the north-eastern part of the Boulia Sheet area. In this region the member crops out in a belt one to four miles wide along the eastern bank of the Hamilton River. The member consists of laminated and thin-bedded sandy calcarenite, calcareous siltstone, limestone and coquinite. A prominent feature of the limestone is the spherical boulders which weather out at the surface and always show traces of the original bedding. In addition, many concretions of the Toolebuc Member weather out, and contain fossils. The member is generally rich in fossils; Dickins (1960, unpubl.) described some of them, and Casey et al., (1960, unpubl.) considered that the presence of a uranium mineral on fish scales in the member should provide the basis for detection by gamma-ray logging. A programme of logging has since been carried out successfully by the Bureau in Western Queensland, but has not extended to any of the Sheet areas shown on Plate 4 of this Bulletin.

Vine and Day (1965) and Casey et al., (1960, unpubl.) state that the member is seldom identified as limestone in water bore logs, but may be recorded as sandy shale, or by a colour change. Vine and Day (1965) also state that a limestone interval is not recorded in most exploration wells, but the member is identified by shale with limestone cuttings, or by an increase in calcareous content. This is accompanied by a strong increase in gamma-ray count, and forms a useful sub-surface marker.

The Mackunda Formation has been named by Vine (1964) from Mackunda Creek in the Mackunda Sheet area, which adjoins Springvale on the east. The type area is in the headwaters of Mackunda Creek on Cnalta Station. The formation consists of sandstone, commonly calcareous and grading to limestone, claystone, siltstone and minor intraformational conglomerate. The subsurface thickness is estimated at 300-800 feet, and the formation contains a rich marine fauna of pelecypods, gastropods and ammonites.

In the Springvale Sheet area, Reynolds (1965b) mapped the Winton Formation on the basis of Whitehouse's (1954) definition, but this unit on the Springvale Sheet area is now included in the Mackunda Formation. Surface thickness is generally less than 50 feet, and in the subsurface the formation has proved difficult to identify from water bore logs. Olgers (1964) recognised the Mackunda Beds in the subsurface of the Machattie Sheet area but did not specify thickness because the nomenclature was in state of flux; however, he recorded a total thickness of 2575 feet for the Wilgunya Formation, "Mackunda Beds" and "Winton Formation".

Undifferentiated Mesozoic

The distribution of thin sandstone, siltstone and conglomerate beds around the south-eastern margin is shown in Table 10. On the Mount Whelan Sheet area, *Rhizocorallium*, which is probably of Lower Cretaceous age, (Veevers, 1962) has been found. The sediments have not been named and, because they may not all be of the same age, they are referred to Mesozoic undifferentiated.

Other subsurface occurrences of Mesozoic sediments are known in French Petroleum Company (Aust.) Pty Ltd's Marduroo No. 1 and The Brothers No. 1 Wells. Because of different usages of nomenclature, the formations penetrated cannot be equated accurately with those shown in Table 10. A summary of the section penetrated in the well is as follows:

Marduroo No. 1

Sfc - 95 feet - Quaternary
95 - 542 (447') Tambo Formation including 10 feet Toolebuc at the base.
542-914' (372') Roma Formation.
914-940' (26') Transition Beds
940-1180' (240') Jurassic
1180-1242' (62') Lower Jurassic
1242-TD (2619'+) Proterozoic

The Brothers No. 1

Sfc - 40 feet, Quaternary
40 - 397 feet (357'), Tambo Formation,
397-882' (485') Roma Formation.
882-904' (22') Transition Beds.
904-1153' (249') Jurassic.
1153-4156' (TD), (3003'), Cambrian.

To the south and east, older Mesozoic units are known in the subsurface, beneath the Longsight Sandstone, but they are not considered here, except to mention that Reynolds (1964a, unpubl.) recorded 380+ feet of unfossiliferous ?Jurassic red claystone and minor sandstone below Lower Cretaceous sediments in Montara Bore on Sandringham station (Bedourie Sheet area).

(3) The South-western and western margins

Along these margins, Mesozoic rocks seldom obscure the actual margin, but Triassic rocks occur extensively in and near the south-western marginal areas. Condon and Smith (1959, unpubl.) named the Tarlton Formation near the southern tip of the Tarlton Range, and White (1961, unpubl.) described Upper Jurassic plant fossils collected from outcrops which cap the Palaeozoic sequence of the Range.

The type section is 11 miles south of Tarlton Downs homestead ($22^{o}36'$E, $136^{o}51'$E, on Plate 4), and is exposed in a scour on the south-western scarp of a mesa. At this locality, the sequence in descending order, consists of:

3 feet of billy, at top surface of the mesa

Thickness (feet)	
17	Sandstone, silty, coarse and medium-grained; siltstone (Mottled zone)
30	Sandstone, white, thin-bedded, silty, medium-grained; and Siltstone Pallid Zone.
20	Sandstone, white, scour-and-fill cross-laminated, very coarse, coarse, coarse and medium-grained, silty; Conglomerate, silty, small pebbles; and siltstone, thin laminated; (Pallid zone).
3	Claystone, pale grey, pebbly, with a few boulders. (Pallid zone).

Overlying lateritized Ordovician siltstone.

Many of the boulders in this and other sequences in the same area exhibited features attributable to glaciation, and consequently Condon and Smith (1959, op cit.) considered that the formation was a Permian fluvio-glacial deposit. Subsequently, the dating of plant fossils (White, 1961, unpubl.) showed that at least the upper part of the formation was of Triassic age, and now the whole of the sequence is placed in the Triassic.

The Tarlton Formation crops out extensively in mesas and small plateau in the Tobermory and Hay River Sheet areas, and two small outcrops correlated with these occur in the Huckitta Sheet area. The base is seldom exposed, but the formation overlies Palaeozoic and Precambrian rocks. The maximum thickness (of 140 feet) observed is at Mount Ewing (latitude 22°59'S, longitude 137°10'E; Plate 4).

Mesozoic sediments may occur beneath Quaternary sand of the Simpson Desert, but there is no subsurface evidence of this near the south-western margin. Lower Cretaceous forams have been obtained at a depth of 186 feet in a water bore on the Plenty River, and Smith and Vine (1960, unpubl.) have described 50 feet of sandstone and siltstone, of probable Lower Cretaceous age from Lake Caroline and near the Hay River. Both occurrences are in the Hay River Sheet area.

(4) The Eastern Margin

Flat-lying residuals of Mesozoic sediments occur extensively on the Cloncurry Complex near the Georgina Basin margins, and in places encroach extensively onto the Complex. Both marine and fresh-water sediments are known; the marine sediments are of established Lower Cretaceous age, but the fresh-water sequence has not been precisely dated and may range in age from Jurassic to Lower Cretaceous (Opik, Carter and Noakes, 1961); most of this sequence and some of the marine sediments have not been formally named, and on Plate 4 they are shown as Undifferentiated Mesozoic.

The fresh-water sequence consists of conglomerate, and sandstone, arkose siltstone, sandstone and shale. Opik, Carter and Noakes (1961, op cit.) report two small outcrops of sandstone containing plant fossils (Otozamites flora) in the Mount Isa Sheet area. These have been referred to an Upper Jurassic or Lower Cretaceous age; similar sandstone crops out on the Lawn Hill and Camooweal Sheet areas, and the conglomerates are believed to be of the same age as the plant-bearing sandstone. Thickness is usually less than 20 feet.

The Polland Waterhole Shale is a marine formation which crops out extensively on each of the Mount Isa and Camooweal Sheet areas. It is a sequence of uniform lithology, occurring in plateaux and mesas, and consisting of white, grey and blue-grey, siliceous friable shale which is lateritized at the surface. The maximum preserved thickness is 100 feet, and the formation rests unconformably on Precambrian and Cambrian rocks, and disconformably on the Mesozoic fresh-water sequence. Opik, Carter and Noakes (1961, op cit.) assign a Lower Cretaceous age to the Polland Waterhole Shale.

(5) The Northern Margin

A few outcrops of fresh-water Mesozoic sediments have been reported near the margin on Lawn Hill (Carter and Opik, 1961) and Mount Drummond (Smith and Roberts, 1963) Sheet areas. These outcrops consist of conglomerate, mudstone, siltstone, sandstone and shale, and they lie unconformably on Cambrian sequences.

(6) Mesozoic Sediments within the Georgina Basin

There are several outcrops of Mesozoic in the Sandover River Sheet area and on the Avon Downs and Ranken Sheet areas. All are referred to "undifferentiated

Mesozoic".

The outcrops on Sandover River consist of brown, coarse-grained, current-bedded sandstone, with pebble, cobble and boulder conglomerate (Nichols, 1964 unpubl.). No fossils have been found in these beds, which lithologically resemble the Tarlton Formation and rest unconformably on several Palaeozoic carbonate sequences.

Randal and Brown (1962a and b, unpubl.) have described Mesozoic sediments in the Ranken and Avon Downs Sheet areas as quartz sandstone and pebble conglomerate boulders in rubble-covered areas. No fossils have been found, and the rocks are assigned to the Mesozoic on the basis of lithological similarity to fresh-water Mesozoic sequences of the Camooweal Sheet area. Randal (pers. comm.) has identified Mesozoic sediments in only one water bore log in the Barkly Tableland area.

(7) Cainozoic on the margins and within the Basin

Thin Tertiary sediments crop out discontinuously but extensively on the Barkly Tableland, in the valleys of the Georgina River, Pituri Creek and the Burke River and at several other localities within the Georgina Basin. Evidence from water bores and core holes indicates that Tertiary sediments may be extensive in the subsurface. On plates 1-2-3-4, the Tertiary sediments are shown as undifferentiated, because they are of no great concern to the geology of the Georgina Basin. However, formations have been named in various parts of the Basin and a brief description of these units follows.

The Arltunga Beds [re-defined by Smith (1964a) as a modification of Arltunga Beds named by Madigan (1932b)] crop out on the Huckitta Sheet area. They consist mainly of vuggy chalcedony, with relict patches of silicified limestone; the chalcedony grades downwards into limestone with layers, nodules and veins of chalcedony and into grey or white limestone. In some localities, beds of sandstone and siltstone occur in the sequence. The outcropping thickness ranges from 35 to 90 feet; in the Bureau's core hole Grg 1, 86 feet of the unit was recorded (Milligan 1963, unpubl.).

The only fossils found in the Arltunga Beds are fresh-water gastropods, reported by Madigan (1932b, p. 98) and which are regarded as being either of

Pliocene or Pleistocene age.

The Austral Downs Limestone, named by Noakes and Traves (1954), crops out in the valley of the Georgina River and its tributaries and rests unconformably on many Precambrian, Palaeozoic and Mesozoic units. This is a silicified limestone and chalcedonic limestone with some calcilutite and siltstone interbeds, which crops out in mesas and also as pavements; often the surface is strewn with loose boulders of chalcedonic limestone. Thickness ranges from 5 to 100 feet. Ostracods and Foraminifera have been reported from outcrops in the Glenormiston Sheet area(Reynolds and Pritchard, 1964) and Lloyd (1966) reports gastropods from many localities.

The Marion Formation, named by Casey (1959), consists of silicified sandy quartz siltstone which rests unconformably on lateritized Wilgunya Formation. The reference section is 5 miles north-west of Strathelbiss homestead (14 miles north of Boulia) at 22°44'S, 139°47'E. The formation weathers into rounded pebbles which form most of the gibbers on plains extending south for long distances. The maximum thickness is 20 feet; conifer wood has been found in the reference section. The formation is considered to be of fresh-water and aeolian origin, deposited in a large Tertiary lake.

Reynolds (1960, unpubl.) reports the formation on the western part of the Springvale Sheet area and the eastern part of Mount Whelan Sheet area.

The Noranside Limestone, named by Casey (1959), consists of limestone and chalcedonic limestone resting unconformably on Palaeozoic and Cretaceous sediments in the Boulia Sheet area. Because no single section contains all of the lithologies observed, Casey et al., (1960, unpubl.) listed sequences in two reference areas:

1. White siliceous limestone in a gully crossing the Boulia-Selwyn road, 1.2m south of Old Noranside Well, at latitude 22°12'S, longitude 140°04'E.

2. Pink, red and white banded impure limestone, 1.4m south-south-west of Six Mile Bore on Fort William Station; 0.4m south of an east-west dog proof fence, at latitude 22°27'S, 140°12'E.

The limestone usually occurs as numerous flat plates and scattered outcrops on brown or black soil plains. The basal 10 feet often contains ferruginous material from a redistributed soil. An irregular zone of siliceous limestone caps the sequence.

Ostracods, diatoms and gastropods are common and Casey et al., (1960, unpubl.) consider algae responsible for structures such as aggregation of lime pellets and laminated structure around nuclei.

The Noranside Limestone overlies the Marion Formation, at least in part, but the relationship between the two is not fully resolved. Both are lake deposits, perhaps deposited in the same lake, but no lithological gradation between the two units has been observed.

The Noranside Limestone formed in a lake trending south-south-east from Digby Peaks to the Hamilton River, and springs issuing from the unconformity between Palaeozoic and Mesozoic sediments, or from fractured limestone in the Burke River structural belt, probably supplied lime-rich water to the lake. Casey et al., (1960, unpubl.) consider that very slight southward tilting, combined with gentle meridional warping, drained the lake and destroyed the springs, probably in late Tertiary or early Quaternary time.

The Mount Coley Sinter (Reynolds, 1964, unpubl.) consists of 170 feet of chalcedony, siliceous sinter, and fine-grained sandstone, in the Mount Whelan Sheet area. It contains silicified wood.

The Brunette Limestone, named by Noakes and Traves (1954), covers a large area in the Ranken, Brunette Downs, Alroy and Helen Springs Sheet areas. Good exposures are rare and the limestone occurs often as scattered blocks and boulders in black soil.

The rock consists of white to brown, fine-grained to coarsely crystalline limestone and dolomite, often siliceous with chert and opaline nodules and smears. Boulders of sandstone and siltstone found on the surface probably are in the sequence, and some sandy limestone is known.

Fossils found in blocks of conglomeratic limestone (Randal and Nichols, 1963, unpubl.), which occur on the surface but have not been found in situ, include fresh-water gastropods similar to Planorbina, and some similar to the marine forms Lanistes and Daistoma (Lloyd, 1966). Lloyd also recorded numerous specimens of the Foraminifera Ammonia beccarii (Linne) and one ostracod; he considers the age "not older than Middle Miocene and possibly not younger than Pliocene". The fossils indicate marine or brackish-water environment in addition to the fresh-water lake environment which is usually postulated for the Brunette Limestone.

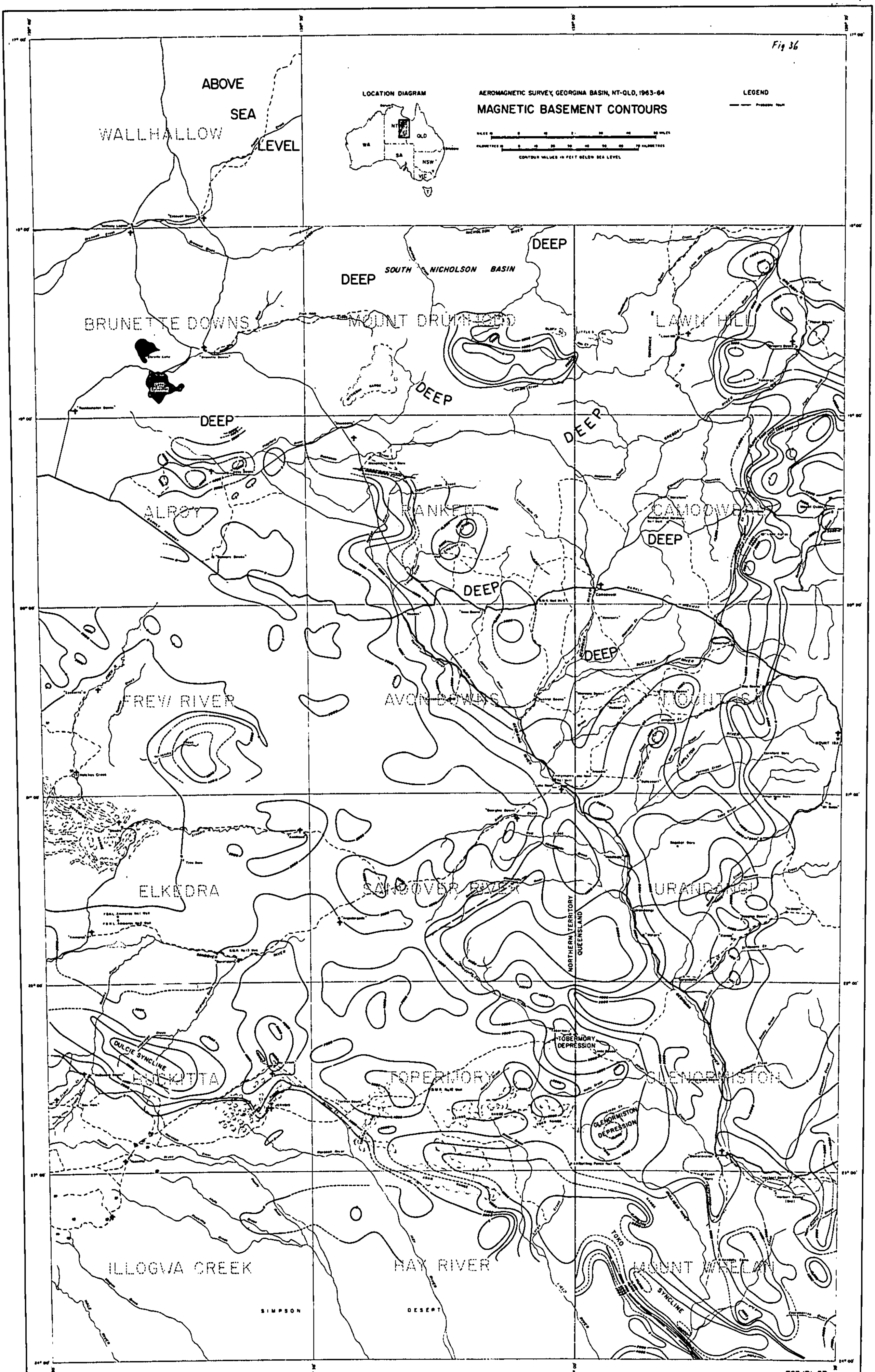
Quaternary sand, soil, alluvium, gravel and kunkar is widespread within the Basin and along its margins. Within the northern half of the Basin, pedocalcic grey soils are widespread, and developed on the Palaeozoic carbonate rocks of that area. Often this soil is admixed with sand and debris of chert and gravel from break-down of Tertiary laterite. The depth of the Quaternary is variable, but generally less than 30 feet, e.g., 25 feet in Frewena No. 1 Well, 15 feet in Brunette Downs No. 1 Well, and 20 feet in BMR11 (Cattle Creek) Well. Similar thicknesses occur in many water bores in the area.

Within the northern half of the Georgina Basin one desert area occurs, east and north-east of the Davenport Range. This desert is un-named, and consists mainly of sand plain, with low, fixed dune-fields trending north-west in some places on the Elkedra and Frew River Sheet area. The desert is uninhabited and there is no information available on the thickness of the sand.

In the southern half of the Georgina Basin, soils are mainly of the red-earth residual type, but there are patches, e.g. on Tobermory Station, where grey pedocalcic soils are developed on Cambro-Ordovician carbonate rocks. The depths of the pedocalcic soils is variable but usually does not exceed 20 feet. On the other hand, depths of the red earth soils is as much as 33 feet in Ammaroo No. 1 Well, and considerable thicknesses of unconsolidated sand have been recorded in some of the Bureau's core holes - 173 feet of sand in Grg 5, and 280 feet in Grg 2 (Milligan, 1963, unpubl.). Active dune fields occur east of Barrow Creek settlement; the dunes trend north-west, and their height ranges from 20 to 90 feet.

The most prominent sand deposits are in the Simpson Desert, which borders the south-western part of the Georgina Basin and encroaches onto the south-eastern extension. This desert consists of parallel active dunes, tending north-west and spaced from $\frac{1}{4}$ to $\frac{1}{2}$ mile apart. The dunes are asymmetric, with the steeper side on the east, and they reach a height of 100 feet in many places, although the average height is probably about 50 feet. Madigan (1946), Crocker (1946) and Carroll (1946) have reported on various facets of the desert, and the overall conclusion, stated by Madigan (op cit.) is that it was formed by south-easterly wind action on unconsolidated fluviatile sands. The heavy mineral content (studied by Carroll, op cit.) indicated that the dunes had originated near the sources of the heavy minerals, and had not all grown north-westwards from the southern edge of the desert.

The only known fossils in the Simpson Desert area are reported by Reynolds (1964, unpubl.), who records the discovery of a reptilian tooth and diprotodon bones by Mr R. Larter (Bureau of Mineral Resources) in gypsiferous deposits near Pulchera Waterhole. Officials of the Queensland Museum identified these fossils and assigned an Upper Cainozoic age.



TO ACCOMPANY RECORD No 1969/142

BIBLIOGRAPHY

PUBLISHED REFERENCES

ALLEN, R.J., 1962 - 62 years search for oil in Queensland still unavailing ...but...Oil & Gas Journal (America) Aug. 27, 1962, pp. 87-89.

ANONYMOUS, 1964 - Australian code of stratigraphic nomenclature, Fourth Edition Revised. J. geol. Soc. Aust. 11(1), 165-171.

ANDREWS, E.C., 1937 - The structural history of Australia during the Palaeozoic. J. Roy. Soc. N.S.W., 71, 118-187.

BALL, L.C., 1911 - The Burketown Mineral Field (silver-lead and zinc mines). Geol. Surv. Qld Publ. 232.

BALL, L.C., 1931 - The Lawn Hill Mineral Field. Qld Govt Min. J. 32, 263.

BARCLAY, H., Vere, 1878 - Journal of Mr Barclay's explorations 1878. S. Aust. parl. Pap. 209.

BLANCHARD, R., and HALL, E., 1942 - Rock deformation and mineralization at Mount Isa. Proc. Aust. Inst. Min. Metall. n.s. 125, 1-60.

B.M.R., 1958 - Summary of Oil Search Activities in Australia and New Guinea to end of 1957. Bur. Min. Resour. Aust. Rept. 41.

B.M.R., 1960 - Summary of Oil Search Activities in Australia and New Guinea to 15th June, 1959. Bur. Min. Resour. Aust. Rept. 41A.

BROWN, H.Y.L., 1895 - Report of Northern Territory Explorations. S. Aust. Parl.Pap. 82.

BROWN, H.Y.L., 1897 - Reports on the Arltunga Goldfield and Harts Range Mica Field. S. Aust. parl. Pap. 127.

BROWN, H.Y.L., 1903 - Report on country recently examined in the Davenport and Murchison Ranges along the Frew River and eastwards of Tennant Creek. S. Aust. parl. Pap. Adelaide.

BRYAN, W.H., and JONES, O.A., 1946 - The Geological History of Queensland. A Stratigraphical Outline. Pap. Univ. Qld Dept Geol. 2 (N.S.), 12.

CAMERON, W.E., 1900 - On the Lawn Hill Silver-lead Company's Properties, Mended Hill. Geol. Surv. Qld Publ. 138.

CAMERON, W.E., 1901 - Geological Observations in north-western Queensland. Geol. Surv. Qld Publ. 159.

CARROLL, D., 1944 - The Simpson Desert Expedition, 1939. Scientific Reports: No. 2, Geology - Desert Sands. Trans. Roy. Soc. S. Aust. 68 (1), pp. 49-59.

CARTER, E.K., BROOKS, J.H., and WALKER, K.R., 1961 - The Precambrian Mineral Belt of North-western Queensland. Bur. Min. Resour. Aust. Bull. 51.

CARTER, E.K., and OPIK, A.A., 1961 - Lawn Hill - 4 mile Geological Series. Bur. Min. Resour. Aust. explan. Notes. No. 21.

CARTER, E.K., and OPIK, A.A., 1963 - Duchess, Qld - 4-mile Geological Series, Bur. Min. Resour. Aust. explan. Notes No. 23.

CASEY, J.N., 1959 - New names in Queensland Stratigraphy North-West Qld. Austr. O. & G.J., 5 (12), 31-36.

CASEY, J.N., and GILBERT-TOMLINSON, Joyce, 1956 - Cambrian Geology of the Huckitta-Marqua region, Northern Territory. In EL SISTEMA CAMBRICO, SU PALEOGEOGRAFIA Y EL PROBLEMA DE SU BASE 20th int. geol. Cong. Mexico. Also in Bur. Min. Resour. Aust. Bull. 49.

C.S.I.R.O., 1954 - Survey of Barkly Region 1947 - 48. Comm. sci. ind. Res. Org., Land. Res. Ser 3.

C.S.I.R.O., 1962 - Lands of the Alice Springs area, Northern Territory. Comm. sci. ind. Res. Org. Land. Res. Ser 6.

COMMONWEALTH CENSUS, 1961.

CHAPMAN, F., 1929 - On some trilobites and brachipods from the Mount Isa district, N.W. Queensland. Proc. Roy. Soc. Vic., 41 (2), 206-216.

CHEWINGS, C., 1928 - Further notes on the stratigraphy of Central Australia. Trans. Roy. Soc. S. Aust., 52, 62-81.

CONDON, M.A., 1956 - Geological occurrences of oil and gas in Australia. Oil and Gas Symposium, 20th int. Geol. Cong., Mexico.

CROCKER, R.L., 1946 - The Simpson Desert Expedition 1939. Scientific Reports: No. 8 - The soils and vegetation of the Simpson Desert and its borders. Trans. Roy. Soc. S. Aust., 70(2), 235-258.

CUNDILL, J., and MEYERS, N.A., 1964 - A summary of the Geology and Petroleum Prospects of the Queensland Sedimentary Basins. Qld Dep. Min. Rep.

DAINTREE, R., 1872 - Notes on the geology of the Colony of Queensland. Quart. J. Geol. Soc. Lond., 28 (3), 271-360.

DALY, J., 1957 - Magnetic Prospecting at Tennant Creek, Northern Territory, 1935-1937. Bur. Min. Resour. Aust. Bull. 44.

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

DAVID, T.W.E., 1950 - Ed. BROWN, W.R., - The Geology of the Commonwealth of Australia. London, Arnold.

DAVIDSON, A.A., 1905 - Journal of Exploration in Central Australia, 1898-1900. S. Aust. parl. Pap. Adelaide.

DUNN, P.R., PLUMB, K.A., and ROBERTS, H.G., 1966 - A proposal for Time - stratigraphic Subdivision of the Australian Precambrian. J. geol. Soc. Aust., 13(2), 593-608.

DUNSTAN, B., 1913 - Queensland mineral index. Geol. Surv. Qld Publ. 241.

DUNSTAN, B., 1920 - North-western Queensland. Geological notes on the Cloncurry-Camooweal-Burketown-Boulia area. Geol. Surv. Qld Publ. 265.

ETHERIDGE, R. Jr. 1897 - Official contributions to the palaeontology of South Australia. No. 9, on the occurrence of Olenellus in the Northern Territory. S. Aust. parl. Pap.

ETHERIDGE, R. Jr. 1902 - Official contributions to the palaeontology of South Australia. No. 13, Evidence of further Cambrian trilobites. S. Aust. parl. Pap.

ETHERIDGE, R. Jr., 1917 - Girvanella in the Cambrian rocks of north-western Australia. Geol. Surv. W. Aust. Bull. 72, p. 89.

ETHERIDGE, R., and JACK, R.L., 1881 - CATALOGUE OF WORKS, PAPERS REPORTS AND MAPS ON THE GEOLOGY, PALAEONTOLOGY, MINERALOGY, MINING, METALLURGY ETC., OF THE AUSTRALIAN CONTINENT AND TASMANIA. London. Stanford.

EVERNDEN, J.F., and RICHARDS, J.R., 1962 - Potassium-argon ages in eastern Australia. J. geol. Soc. Aust., 9(1), 1-49.

FORMAN, D.J., MILLIGAN, E.N., and McCARTHY, R.C., 1967 - Structure of the north-eastern margin of the Amadeus Basin, Northern Territory. Bur. Min. Resour. Aust. Rept. 103.

G.S.A., 1962 - Tectonic Map of Australia.

G.S.A., 1962 - Geological Notes in Explanation of the Tectonic Map of Australia. Bur. Min. Resour. Aust., 1962.

GUILLEMOT, J. et TISSOT, B., 1965 - La Geologie des Principaux Basins Sedimentaires Australians. In Revu de l'institut francais du Petrole. Vol. XX, No. 3.

GREGORY, A.C., 1861 - North Australian expedition. S. Aust. parl. Pap. 3. (No. 170).

HETHERINGTON, C.R., 1964 - Energy resources of Queensland and their use. Report to the Honourable, The Premier of Queensland, Brisbane. by Authority.

HILL, Dorothy, 1951 - Geology. In Handbook of Queensland. Aust. Ass. Adv. Sci., 13-24.

HILL, Dorothy, and DENMEAD, A.K., 1960 - The Geology of Queensland. J. Geol. Soc. Aust., 7, 474.

HILL, Dorothy, and MAXWELL, W.G.H., 1962 - Elements of the Stratigraphy of Queensland. University of Queensland Press.

HILLS, E.S., 1959 - Record of Bothriolepis and Phyllolepis from the Northern Territory of Australia. Proc. Roy. Soc. N.S.W. 92, 174-5.

HODGKINSON, W.O., 1877 - Exploration in north-western Queensland 1875-76. V. & P. legis. Ass. Qld Sess. 1876. 3, 352-386.

HODGE-SMITH, T., 1932 - Geological and Mineralogical Observations in Central Australia. Rec. Aust. Mus., 18, (8), p. 415.

HONMAN, C.S., 1937 - Report for Queensland. In. Ann. Rep. aer. Surv. N. Aust. 26-30, 52-67.

HOSSFELD, P.S., 1937 - The Home of Bullion Mine, Central Australia. Aer. Surv. N. Aust., N.T. Rep. 29.

HOSSFELD, P.S., 1954 - Stratigraphy and structure of the Northern Territory of Australia. Trans. Roy. Soc. S. Aust. 77, 103-161.

HURLEY, P.M., FISHER, N.H., FAIRBAIRN, H.W., and PINSON, W.H., 1961 - Geochronology of Proterozoic granites in Northern Territory, Australia. Bull. geol. Soc. Amer. 72 (V), 653-662.

IVANAC, J.F., 1954 - The Geology and Mineral Deposits of the Tennant Creek Goldfield, Northern Territory. Bur. Min. Resour. Aust. Bull. 22.

JACK, R.L., and ETHERIDGE, R. Jr., 1892 - Geology and Palaeontology of Queensland and New Guinea. Brisbane, Govt Printer, and London, Dulau.

JACK, R.L., 1885 - Report on the geological features of part of the district to be traversed by the proposed trans-continental railway. Brisbane, by Authority.

JACK, R.L., 1895 - Stratigraphical notes on the Georgina Basin, with reference to the question of artesian water. Proc. Roy. Soc. Qld 11(2), 70-74.

JACK, R.L., 1897 - Note on the discovery of organic remains in the Cairns Range, Western Queensland. Proc. Roy. Soc. Qld 12, 47-48.

JACK, R.L., 1898 - Geological features of part of the district to be traversed by the proposed trans-continental railway with amending footnotes. Bull. Geol. Surv. Qld. 10.

JACKSON, A., 1862 - ROBERT O'HARA BOURKE AND THE AUSTRALIAN EXPLORING EXPEDITION OF 1860. London. Smith, Elder.

JENSEN, H.I., 1914 - Geological Report on the Darwin Mining District, McArthur River District and the Barkly Tableland. Bull. N. Terr. Aust. 10.

JENSEN, H.I., 1925 - Palaeogeography of Queensland, Q.G.M.J., 26, 379-382.

JENSEN, H.I., 1926 - Oil Possibilities in Qld (pt. 1). Q.G.M.J., 12-19.

JENSEN, H.I., 1941a - The Lawn Hill silver-lead-zinc field, Lawn Hill, Wollogorang District, Aer. Surv. N. Aust. Qld Rep. 46.

JENSEN, H.I., 1941b - The Lochness area, Cloncurry district. Aer. Surv. N. Aust. Qld Rep. 37.

JENSEN, H.I., 1944 - The geology of Central Australia. Proc. Roy. Soc. Qld, 56(10), 85-94.

JOKLIK, G.F., 1955 - The geology and mica fields of the Harts Range, Central Australia. Bur. Min. Resour. Aust. Bull. 26.

JONES, O.A., 1953 - The structural Geology of the Precambrian in Queensland in relation to mineralization. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS. Fifth Emp. Min. metall. Cong. 1. 344-351.

JONES, N.O., and QUINLAN, T., 1962 - An Outline of the Water Resources of the Alice Springs Area. In LANDS OF THE ALICE SPRINGS AREA, NORTHERN TERRITORY, 1956. Comm. sci. ind. Res. Org. Aust., Land. Res. Ser. No. 6, 150-162.

LANDSBOROUGH, W., 1862 - Journal of Landsborough's Expedition from Carpentaria, in search of Burke and Wills. Melbourne, Wilson and MacKinnon.

LINDSAY, D., 1889 - Expedition across Australia. Proc. J. Roy. Geol. Soc. Vol. ii. p. 650.

LLOYD, A.R., 1966 - An outline of the Tertiary geology of northern Australia. In PALAEONTOLOGICAL PAPERS, VOL. 1. Bur. Min. Resour. Aust. Bull. 80.

McDOUGALL, I., DUNN, P.R., COMPSTON, W., WEBB, A.W., RICHARDS, J.R., and BOFINGER, V.M., 1965 - Isotopic age determinations on Precambrian rocks of the Carpentaria Region, Northern Territory, Australia. J. geol. Soc. Aust. 12(1), 67-90.

McKINLAY, J., Circa, 1863 - McKINLAY'S JOURNAL OF EXPLORATION IN THE INTERIOR OF AUSTRALIA, Melbourne, Bailliere.

MABBUTT, J.A., 1962 - Geomorphology of the Alice Springs area. Comm. sci. ind. Res. Org. Land. Res. Ser. 6, 163-178.

MADIGAN, C.T., 1929 - An aerial reconnaissance into the south-eastern portion of Central Australia. Proc. Roy. Geogr. Soc. Aust. (S. Aust. Branch), Session 1929-29.

MADIGAN, C.T., 1932a - The geology of the Western MacDonnell Ranges, Central Australia. Quart. J. geol. Soc. Lond., 88(4), 672-716.

MADIGAN, C.T., 1932b - The geology of the Eastern MacDonnell Ranges. Trans. Roy. Soc. S. Aust. 56, 71-117.

MADIGAN, C.T., 1938 - The Simpson Desert and its Borders. Proc. Roy. Soc. N.S.W., 71, 503-535.

MADIGAN, C.T., 1937 - Additions to the geology of Central Australia; the region north of the MacDonnell Ranges and eastward from the telegraph line to the Queensland border. Rep. Aust. Ass. Adv. Sci., 23, p.89.

MADIGAN, C.T., 1945 - Simpson Desert Expedition, 1939. Scientific reports: Introduction, Narrative, Physiography and Meteorology. Trans. Roy. Soc. S. Aust., 69(1), 118-139.

MARSHALL, C.E., and NARAIN, H., 1954 - Regional gravity investigations in the eastern and central Commonwealth. Univ. Sydney, Dep. Geol. Geophys., Mem. 1954/2.

MAWSON, D., and MADIGAN, C.T., 1930 - Pre-Ordovician rocks of the MacDonnell Ranges (Central Australia). Quart. J. geol. Soc. Lond. 86, 415-429.

MOTT, W.D., 1952 - Oil in Queensland. Qld Govt Min. J., 53, 848-861.

MOTT, W.D., et al., 1961 - Occurrence Petroleum and Natural Gas in Queensland. Geol. Surv. Qld Publ. 299.

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 in relation to mineralization. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS. Fifth Emp. Min. metall. Cong. 1, pp. 284-296.

NOAKES, L.C., 1956 - Upper Proterozoic and Sub-Cambrian rocks in Australia. Inst. Geol. Cong. 20th Sess. Mexico, 2, 213-238. (Also in Bur. Min. Resour. Aust. Bull. No. 49, 1957).

NOAKES, L.C., and TRAVES, D.M., 1954 - Outline of the geology of the Barkly Region. In Survey of the Barkly Region, 1947-48. Land. Res. Ser. 3. Comm. sci. ind. Res. Org. Melbourne. 34-41.

NOAKES, L.C., CARTER, E.K., and OPIK, A.A., 1959 - Urandangi - 4 mile Geological Series. Bur. Min. Resour. Aust. explan. Notes No. 1, 2nd ed.

OIL AND GAS JOURNAL (AMERICA), 1962 - Generalized Formation correlators in Australia and New Guinea, August, 1962.

OLGERS, F., 1964 - Machattie Qld 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes., SG/54-2.

OPIK, A.A., 1956a - Cambrian Geology of Queensland. Int. Geol. Cong., 20th Sess. Mexico, 2, 1-24. (Also in Bur. Min. Resour. Aust. Bull. 49.).

OPIK, A.A., 1956b - Cambrian Geology of the Northern Territory. Ibid. 2, 25-84. (Also in Bur. Min. Resour. Aust. Bull. 49).

OPIK, A.A., 1961 - The Geology and Palaeontology of the headwaters of the Burke River, Queensland. Bur. Min. Resour. Aust. Bull. 53.

OPIK, A.A., 1963 - Early Upper Cambrian Fossils from Queensland. Bur. Min. Resour. Aust. Bull. 64.

OPIK, A.A., 1966 - The Early Upper Cambrian Crisis and its Correlation. Proc. Roy. Soc. N.S.W., 100(1), 9-14.

OPIK, A.A., and PRITCHARD, P.W., 1960 - Cambrian and Ordovician. In The Geology of Queensland. Jour. Geol. Soc. Aust. Vol. 7, 89-114.

OPIK, A.A., CARTER, E.K., and NOAKES, L.C., 1961 - Mount Isa - 4-mile Geological Series. Bur. Min. Resour. Aust. explan. Notes. No. 20.

OGILVIE, C., 1954 - The hydrology of the Queensland portion of the Great Artesian Basin. Appendix H to Artesian water supplies in Queensland. Brisbane. by Authority.

PAPUAN APINAIPI PETROLEUM COMPANY LIMITED, 1962 - Boulia Area Gravity Survey, Queensland 1959. P.S.S.A. Rept., 37.

PATEN, R.J., 1964 - Tertiary Geology of the Boulia Region, western Queensland. Bur. Min. Resour. Aust. Rept. 77.

PERRY, R.A., 1960 - Pasture Lands of the Northern Territory, Australia. Comm. sci. ind. Res. Org., Land. Res. Ser., 5.

PERRY, R.A., QUINLAN, T., JONES, N.O., and BASINSKI, J.J., 1963 - Preliminary assessment of groundwater suitable for irrigation in the Alice Springs area, and its agricultural significance. Comm. sci. ind. Res. Org., Land. Res. Tech. pap. No. 21.

PLAYFORD, P.E., and JOHNSTONE, M.H., 1959 - Oil Exploration in Australia. Bull. Amer. Assoc. Pet. Geol. 43 (2), 397-433.

PLUMB, K.A., and RHODES, J.A., 1963 - Walhallow, N.T. Bur. Min. Resour. Aust. explan. Notes. E.53/7.

PRICHARD, C.E., and QUINLAN, T., 1962 - The geology of the southern half of the Hermannsburg 1:250,000 Sheet. Bur. Min. Resour. Aust. Rept. 61.

PRITCHARD, P.W., 1960 - The Ordovician section in the Toko Range. In The Geology of Queensland. J. geol. Soc. Aust., 7, 110-114.

RAGGATT, H.G., 1954 - The Search for oil in Australia and New Guinea. Aust. Inst. Min. metall. Suppl. to Bull. 172 (1954 review lecture).

REEVES, F., 1951 - Australian oil possibilities. Bull. Amer. Ass. Pet. Geol. 35, 2479-2525.

REYNOLDS, M.A., 1960 - The Eromanga Sub. Basin. The western margin. In The Geology of Queensland. Jour. Geol. Soc. Aust. Vol. 7, pp. 318-323.

REYNOLDS, M.A., 1965a - Glenormiston, Qld - 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF/54-9.

REYNOLDS, M.A., 1965b - Springvale, Qld 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF/54-14.

RICHARDS, J.R., 1963 - Isotopic composition of Australian leads - III, northwestern Queensland and the Northern Territory - a reconnaissance. Geochim. Cosmochim. Acta. 27, pp. 217-240.

RICHARDS, J.R., BERRY, H., and RHODES, J.M., 1966 - Isotopic and lead-alpha ages of some Australian zircons. J. geol. Soc. Aust. 13(1), 69-96.

RUDD, E.A., 1961 - Petroleum Developments in South-west Pacific Region during 1960. Ibid. 46(10).

RUDD, E.A., 1962 - Petroleum Developments in south-west Pacific Region during 1961. Ibid. 46(7), 1298-1302.

SAINT-SMITH, E.C., 1924 - Note on the occurrence of Cambrian strata near Mount Isa, Cloncurry Gold and Mineral Field. Qld Govt Min. J. 25, 411.

SHEPHERD, S.R.L., 1945a - Cambrian Oil Shale, Camooweal. Qld Govt Min. J. 46, 75-77.

SHEPHERD, S.R.L., 1945b - Cloncurry water supplies. Qld Govt Min. J. 46, 267-9.

SMITH, K.G., 1963a - Hay River, N.T. 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF53/16.

SMITH, K.G., 1963b - Huckitta N.T. 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF53/11.

SMITH, K.G., 1964a - Progress Report on the Geology of the Huckitta 1:250,000 Sheet, N.T. Bur. Min. Resour. Aust. Rept. 67.

SMITH, K.G., 1964b - Frew River, N.T. - 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF/53-3.

SMITH, K.G., 1965a - The Geology of the Georgina Basin. J. Aust. Pet. Ex. Assn. 111-112.

SMITH, K.G., 1965b - Tobermory, N.T. 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF/53-12.

SMITH, K.G., STEWART, J.R., and SMITH, J.W., 1961 - The Regional Geology of the Davenport and Murchison Ranges, N.T. Bur. Min. Resour. Aust. Rept. 58.

SMITH, K.G., and MILLIGAN, E.N., 1964 - Barrow Creek, N.T. 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF53/6.

SMITH, K.G., and others, 1967 - Stratigraphic drilling in the Georgina Basin. Bur. Min. Resour. Aust. Rept. 124.

SMITH, J.W., and ROBERTS, H.G., 1963 - Mount Drummond, N.T. 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SE53/12.

SPRIGG, R.C., 1958 - Petroleum prospects of western parts of Great Artesian Basin. Bull. Amer. Ass. Petrol. Geol. 42 (10) 2465-2491.

SPRIGG, R.C., 1959 - The Central Great Artesian Basin of Australia; A Bright Oil Prospect. Austr. Oil & Gas Jour., 5(4), 19-23.

SPRIGG, R.C., 1963 - Geology and petroleum prospects of the Simpson Desert. Trans. Roy. Soc. S. Aust., 86, 35-65.

STEWART, G.A., 1954 - GEOMORPHOLOGY OF THE BARKLY REGION. Comm. sci. ind. Res. Org., Land Res. Ser 3, 42-58.

SYVRET, B.A., 1966 - Copper mining in the Cloncurry and Mt Isa Fields, 1965. Geol. Surv. Qld Rept No. 14.

TINDALE, N.B., 1931 - Geological Notes on the Iliaura country north-east of the MacDonnell Range, Central Australia. Trans. Roy. Soc. S. Aust., 55, p. 32.

TOMLINSON, Joyce G., 1966 - A new discovery of Bothriolepis in the Northern Territory. In Bur. Min. Resour. Aust. Bull. 80.

TRAVES, D.M., and STEWART, G.A., 1954 - HYDROLOGY OF THE BARKLY REGION. Comm. sci. ind. Res. Org. Land Res. Ser. 3, 59-64.

TRUMPY, D. et al., (I.F.P.), 1961 - Petroleum Prospects in Australia - Preliminary Review of Main Sedimentary Basins. Institute Francais du Petrole, Rept. 5414.

VEEVERS, J.J., 1962 - Rhizocorallium in the Lower Cretaceous rocks of Australia. Bur. Min. Resour. Aust. Bull. 62.

VOISEY, A.H., 1939 - A contribution to the Geology of the eastern MacDonnell Ranges, Central Australia. Proc. Roy. Soc. N.S.W., 72, 663-668.

VINE, R.R., 1964 - Mackunda Q'ld - 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes. SF/54-11.

VINE, R.R., and DAY, R.W., 1965 - Nomenclature of the Rolling Downs Group, Northern Eromanga Basin, Queensland. Q. Govt Min. J. September, 1965.

WALPOLE, B.P., and SMITH, K.G., 1961 - Geochronology of Proterozoic granites in Northern Territory, Australia. Part 2. Stratigraphy and structure. Bull. geol. Soc. Amer., 72 (5), 663-668.

WALPOLE, B.P., DUNN, P.R., and RANDAL, M.A., 1967 - Geology of the Katherine-Darwin Region, Northern Territory. Bur. Min. Resour. Aust. Bull. 82.

WARD, K.L., 1925 - Geological Structure of Central Australia. Roy. Soc. S. Aust. Vol. 49, p. 61.

WELLS, A.T., RANFORD, L.C., COOK, P.J., STEWART, A.J., and SHAW, R.D., 1967 - Geology of the north-east Amadeus Basin, Northern Territory.

WHITEHOUSE, F.W., 1930 - The Geology of Queensland. In Handbook for Queensland. Aust. Ass. Adv. Sci.

WHITEHOUSE, F.W., 1931 - Report of the Palaeontologist. Ann. Rep. Dep. Min. Qld, 1930, 141-142.

WHITEHOUSE, F.W., 1936 - The Cambrian faunas of north-eastern Australia, Part 1: Stratigraphical Outline. Part 2: Trilobita. Mem. Qld Mus., 11 (1), 59-112.

WHITEHOUSE, F.W., 1939 - The Cambrian faunas of north-eastern Australia. Part 3: The Polymerid Trilobites. Mem. Qld Mus., 11, 179-280.

WHITEHOUSE, F.W., 1940 - Studies in the late geological history of Queensland. Pap. Univ. Qld Dep. Geol. 2 (N.S.) (1).

WHITEHOUSE, F.W., 1941 - The Cambrian faunas of north-eastern Australia. Part 4: Early Cambrian echinoderms similar to the Parval stages of Recent forms. Mem. Qld Mus. 12, 1-28.

WHITEHOUSE, F.W., 1945a - The Cambrian faunas of north-eastern Australia. Part 5: The trilobite genus Dorypyge. Mem. Qld Mus., 12, 117-123.

WHITEHOUSE, F.W., 1945b - Geological work upon the Great Artesian Basin and additional notes on the geology of the Basin. Appendices C and D to Artesian water supplies in Queensland. First Interim Report. Brisbane, by Authority.

WHITEHOUSE, F.W., 1954 - The geology of the Queensland portion of the Great Artesian Basin. Appendix C to Artesian Basin water supplies in Queensland. Brisbane, by Authority.

WILLIAMS, W.W., 1928 - Pastoral Settlement in the Barkly Tableland. Geog. Journal 71, 61, 1928.

WILSON, A.F., COMPSTON, W., JEFFERY, P.M., and RILEY, G.H., 1960 - Radioactive ages from the Precambrian rocks in Australia. J. geol. Soc. Aust., 6 (2) 179-195.

WINNECKE, C., 1884 - Central Australian Exploration during 1883. S. Aust. Parl. Pap. 39.

WOOLNOUGH, W.G., 1912 - Report on the geology of the Northern Territory. Bull N. Terr. Aust. 4, Nov. 1912, p. 36-37.

WOOLNOUGH, W.G., 1933 - Report on Aerial Survey Operations in Australia during 1932. Commonwealth of Australia. By Authority, 1933.

UNPUBLISHED COMPANY REPORTS

ALLIANCE PETROLEUM AUSTRALIA N.L., 1963 - The Geology and Oil Prospects of O.P. 77, Northern Territory, by R.B. Wilson.

" The Geology and Oil Prospects of O.P. 63, Northern Territory by R.B. Wilson.

" Tarlton Downs Gravity Survey, Completion Report. Tobermory Area, Northern Territory, Australia.

" Re-interpretation of Gravity and Aeromagnetic Surveys O.P. 63, by L.J. Starkey.

" 1965, Mulga No. 1 Well Completion Report, by A.C.M. Laing.

AMALGAMATED PETROLEUM EXPLORATION PTY LIMITED, 1963 - Lake Nash No. 1 Well, Completion Report.

" Morstone No. 1 Well, Completion Report.

" Interpretation Report on an Aeromagnetic Survey of O.P. 53, Sandover River, N.T. (by Wongala Geophysical Pty Ltd).

AUSTRALIAN AQUITAINE PETROLEUM LIMITED, 1964 - Survey of core samples from wells in the neighbourhood of Concession A.T.P. 86P, Queensland, Australia. Compiled by Centre de Recherches, S.N.P.A. Pau.

" (1965) "Etude Micrographique du Proterozoique et du Palaeozoique de la Region de Toko" S.N.P.A. Pau. Report No. R/ST 16045.

" (1964) "Etude Micrographique du Palaeozoique de la region de Huckitta, S.N.P.A., Pau. Report No. R/ST 11823.

AUSTRALIAN OIL CORPORATION, 1963 - Photogeologic evaulation of part of Oil Permit 61 N.T., by Doeringsfeld, Amuedo & Evey.

" (1964) The Geology of Oil Permit 61, by R. Grasso.

BARKLEY OIL COMPANY PTY LIMITED, 1965 - Frewena No. 1 Well Completion Report, by R.L. Pemberton & E.A. Webb.

" Alroy-Wallhallow Aeromagnetic Survey, Completion Report, by Adastra-Hunting Geophysics.

" Review of the geology of O.P. 73, N.T. by B.F. Fitzpatrick.

COMPAGNIE FRANCAIS DU PETROLE, DIRECTION EXPLORATION, 1963 - Etude de laboratoire des materiaux recoltes par la mission de Reconnaissance en Australia, 1962.

CONTINENTAL OIL & GAS LIMITED. Progress Report on the Oil and Gas possibilities of O.P. 44, N.T.

CONSOLIDATED ZINC PTY LIMITED - Huckitta Lead-Zinc Prospect, N.T. Report No. N.T. 219, by K.M. Phillips.

DELHI-SANTOS-F.P.C. (A) - Cooper's Creek Aeromagnetic Survey. Completion Report.

EXOIL OIL CO. PTY LIMITED, 1965 - Photogeological Interpretation of the Huckitta area, O.P. 136. N.T., by Aero Service Limited.

" (1965) Huckitta No. 1 Well. Completion Report, by R.L. Pemberton.

" (1966) Lucy Creek No. Well. Completion Report, by R.L. Pemberton.

FARMOUT DRILLERS, N.L. - Ammaroo No. 1 and No. 2 Wells. Completion Report, by H.J. Newton.

FRENCH PETROLEUM COMPANY (AUST.) PTY LIMITED, 1965 - Bedourie Seismic and Gravity Survey. January-November, 1964. Final Report by C.G.G.

" (1964) Bedourie Scout Hole No. 1. Final Report, by P. Magnier.

" (1965) Marduroo No. 1 Well. Completion Report, by P. Magnier.

FRENCH PETROLEUM COMPANY (AUST.) PTY LIMITED, 1964 - Etude Geologique de la partie sud de Bassin de Georgina. Report No. R.G. 304, by R. Cooper.

" (1965) - The Brothers No. 1 Well. Completion Report by P. Magnier and P. Sweeney.

" (1965) - Bedourie Seismic and Gravity Survey, 1964. Final Report, by C.G.G.

" (1965) - Sandringham Seismic and Gravity Survey, April-May, 1965. Final Report, by C.G.G.

" (1964) Mission geologique sur les bordiures occidentales su Grand Bassin Artesian. Report No. R.G. 301.

FROME-BROKEN HILL CO. PTY LTD, 1954 - Review of the Georgina Basin, Report No. 4400-G-1, by H.J. Evans.

" (1957) - Review of the geology of the Georgina River Basin, by N.M. Thomas.

" (1959) - Report on the examination of fossils collected from the Georgina Basin, Queensland and Northern Territory, 1958, Report No. 4400-G-12, by D.J. Taylor.

" (1959) - Geology of the Southern Georgina Area, Queensland and Northern Territory. Report 4400-G 13, by R.B. Leslie.

" (1959) - Photo-geologic maps of the Georgina Basin, by A. Weegar.

MERCURE INTERNATIONAL PETROLEUM PTY LTD - Northern Simpson Desert Seismic Survey. Final Report, by C.G.G.

MINES EXPLORATION PROPRIETORY LIMITED, 1966 - Examination of well samples for sedimentary phosphate, Georgina Basin. Northern Territory and Queensland. Report No. 1966/6 by R.T. Russell.

OIL SEARCH LIMITED, 1932 - Geology and oil prospects of western Queensland, by F.A. Moss.

PAPUAN APINAIPI PETROLEUM COMPANY LIMITED, 1965 - Brunette Downs No. 1 Well, Completion Report, by Minad (NT.67/213).

" (1965) Netting Fence No. 1 Well Completion Report. No. Q/54P/214, by Minad.

" (1964) An Airborne Magnetometer Survey of Brunette Downs, N.T. Final Report, by Adastra-Hunting Geophysics.

PHILLIPS PETROLEUM COMPANY, 1961 - Seismograph Survey of the Boulia Area, A.T.P., 54P, Queensland. Boulia 106C/21/19; Springvale-Toko, 106G/21/31, by C.D. Hier.

" (1963) Phillips-Sunray Stratigraphic Drilling A.T.P., 54P, Queensland.

SHELL COMPANY, 1962 - Report on Geology and Photo-interpretation of the Georgina Basin, by C. Mulder.

SMITH AUSTRALIAN OIL CO. PTY LTD, 1962 - Report on Georgina Basin area, by R.C. Sprigg and B.P. Webb.

" (1963) Recommended Test Drilling Sites O.P. 41, Georgina Basin, N.T., by B.P. Webb.

THREE STATES AUST. PETROLEUM PTY LIMITED, 1960 - Report on a Geological Reconnaissance of Petroleum Permit 28, N.T., by B.F. Fitzpatrick and R.B. Wilson.

UNITED AUSTRALIAN OIL INC., - The Oil and Gas Possibilities of the Georgina and Barkly Basins with respect to Permit No. 48, by Ted B. Lacaff.

" (1962) O.P. 53, N.T. Petroleum possibilities of the Georgina Barkly Basins with respect to O.P. 53, by Red B. Lacaff

" O.P. 53 N.T. Report for United Australian Oil Inc., by K.A. Riggs.

UNITED AUSTRALIAN OIL INC. 1953, - Photo Geologic Evaluation Report O.P. 53, N.T., by Doeringsfeld, Amuedo & Ivey.

I.F.P. REPORTS (UNPUBLISHED)

FEHR, A., 1963 - Report on Well Grg 4 (Georgina Basin), I.F.P. Report Aus/85.

SOUTH AUSTRALIAN MINES DEPARTMENT REPORT (UNPUBLISHED)

MILTON, B.E., and SEEDMAN, K.R., 1961 - Seismic Survey, 1960. Great Artesian Basin, South Australia and Queensland. Prelim. Rep. S. Aust. Min. Dept., 1961/60.

B.M.R. RECORDS (UNPUBLISHED)

BARLOW, B.C., 1965 - Georgina Basin reconnaissance gravity survey, N.T. and Qld, 1959. Bur. Min. Resour. Aust. Rec. 1965/96.

BARLOW, B.C., 1966 - Georgina Basin reconnaissance gravity surveys using helicopters, Northern Territory and Queensland, 1960-61. Bur. Min. Resour. Aust. Rec. 1966/147.

B.M.R., 1963, 1964, 1965 - Sedimentary Basins Section, Summary of Activities. Bur. Min. Resour. Aust. Rec. 1963/142, 1964/151, 1965/216.

BROWN, G.A., 1962 - The petrology of the carbonate rocks of the western Undilla Basin. Bur. Min. Resour. Aust. Rec. 1962/43.

BROWN, M., 1965 - Report on main carbonate sequence of Well Lake Nash No. 1 (Amalgamated Petroleum N.L.). Bur. Min. Resour. Aust. Rec. 1965/149.

BRUNSCHWEILLER, R.O., 1950 - Macropalaeontological report on Northern Australia Regional Survey Rock samples. Bur. Min. Resour. Aust. Rec. 1950/13.

CASEY, J.N., et al., 1960 - The Geology of the Boulia Area Western Queensland. Bur. Min. Resour. Aust. Rec. 1960/12.

CONDON, M.A., 1958 - Geological Notes, Inspection Trip 1958. Bur. Min. Resour. Aust. Rec. 1958/106.

CONDON, M.A., 1961 - Notes on Field Trips, 1960. Bur. Min. Resour. Aust. Rec. 1961/46.

CONDON, M.A., and SMITH, K.G., 1959 - Permian Glacials in Central Australia. Bur. Min. Resour. Aust. Rec. 1959/29.

CRESPIN, Irene, and EVANS, P.R., 1962 - Cretaceous Microfossils from the Hay River Area, N.T. Bur. Min. Resour. Aust. Rec. 1962/19.

CROHN, P.W., and OLDERSHAW, W., 1964 - The Geology of the Tennant Creek 1-mile Sheet area. Bur. Min. Resour. Aust. Rec. 1964/79.

DUNNET, D., 1965 - Report on the Mount Woodcock one-mile Sheet area. Bur. Min. Resour. Aust. Rec. 1965/228.

FORMAN, D.J., and SMITH, K.G., 1960 - Pegmatites in the Hay River Sheet area. Bur. Min. Resour. Aust. Rec. 1960/54.

FLAVELLE, A.J., 1965 - Helicopter Gravity Survey by Contract, Northern Territory and Queensland, 1965. Part 1. Bur. Min. Resour. Aust. Rec. 1965/212.

GATEHOUSE, C.G., 1966 - Summary of the Palaeontology of the Barkly Tableland Region. Bur. Min. Resour. Aust. Rec. 1966/216.

GIBB, R.A., 1966 - Western Queensland Reconnaissance Gravity Surveys, 1957-1961. Bur. Min. Resour. Aust. Rec. 1966/13.

HARDING, R.R., 1966 - Catalogue of Age Determinations carried out by the K-Ar, Rb-Sr, Re-Os and Pb-α Methods on Australian Rocks between June 1962 and December 1965. Bur. Min. Resour. Aust. Rec. 1966/22.

IRVING, S., SMITH, E., and WALKER, J., 1958 - Sedimentary Basins of Australia. A Glossary of Nomenclature. Bur. Min. Resour. Aust. Rec. 1958/80.

JEWELL, F., 1960 - Great Artesian Basin aeromagnetic reconnaissance survey, 1958. Bur. Min. Resour. Aust. Rec. 1960/14.

JOHNSON, N.E.A., NICHOLS, R.A.H., and BELL, M.D., 1964 - Completion Report B.M.R. 11 Well, Cattle Creek, Northern Territory. Bur. Min. Resour. Aust. Rec. 1964/45.

JONES, P., 1965 - South-eastern Georgina Basin Seismic Survey, Queensland, 1964. Bur. Min. Resour. Aust. Rec. 1965/39.

LONSDALE, G.F., 1962 - Great Artesian Basin reconnaissance gravity survey using Helicopters, Queensland, 1961. Bur. Min. Resour. Aust. Rec. 1962/14.

LLOYD, A.R., and BELL, M.D., 1964 - Completion Report, B.M.R. 13 Well, Sandover, Northern Territory. Bur. Min. Resour. Aust. Rec. 1964/127.

MACKAY, N.J., and JONES, N.O., 1956 - Report on a gas occurrence in a bore on Ammaroo Station, N.T. Bur. Min. Resour. Aust. Rec. 1956/67.

MILLIGAN, E.N., 1963 - The Bureau of Mineral Resources Georgina Basin core drilling programme. Bur. Min. Resour. Aust. Rec. 1963/86.

MILLIGAN, E.N., 1964 - The Regional Geology of the northern half of the Alcoota 1:250,000 Sheet, Northern Territory. Bur. Min. Resour. Aust. Rec. 1964/43.

MILLIGAN, E.N., SMITH, K.G., NICHOLS, R.A.H., and DOUTCH, H.F., 1966 - Geology of the Wiso Basin, Northern Territory. Bur. Min. Resour. Aust. Rec. 1966/47.

MONTECCHI, P., and ROBERTSON, C.S., 1966 - Southern Georgina Basin Seismic Survey, Northern Territory and Queensland, 1965. Bur. Min. Resour. Aust. Rec. 1966/28.

MORGAN, W.R., 1959 - The petrology of the Jervois Range mining area. Bur. Min. Resour. Aust. Rec. 1959/109.

NEUMANN, F.J., 1959a - Preliminary report on a reconnaissance gravity survey in the Georgina Basin area, Queensland. Bur. Min. Resour. Aust. Rec. 1959/8.

NEUMANN, F.J., 1959b - Preliminary report on a reconnaissance gravity survey in the Toko Range area, Western Queensland. Bur. Min. Resour. Aust. Rec. 1959/51.

NICHOLS, R.A.H., 1963 - The sedimentary petrology of the Alroy and Brunette Downs Sheets, Northern Territory. Bur. Min. Resour. Aust. Rec. 1963/69.

NICHOLS, R.A.H., 1964 - The Regional Geology of the Sandover River, 1:250,000 Sheet area. Bur. Min. Resour. Aust. Rec. 1964/63.

NICHOLS, R.A.H., 1965 - Sedimentary Petrology of some units from the Sandover River Sheet area, N.T. Bur. Min. Resour. Aust. Rec. 1965/211.

NICHOLS, R.A.H., 1966a - Report on core-hole Grg 9A, Georgina Basin, and comparison with Grg 14. Bur. Min. Resour. Aust. Rec. 1966/2.

NICHOLS, R.A.H., 1966b - Petrology of some carbonates in the Georgina Basin. Bur. Min. Resour. Aust. Rec. 1966/145.

NICHOLS, R.A.H., 1966c - Mulga No. 1 Well and its stratigraphic implications, Georgina Basin, N.T. Bur. Min. Resour. Aust. Rec. 1966/155.

NICHOLS, R.A.H., and FEHR, A.E., 1964 - Report on core-hole Grg 14, Georgina Basin, and correlation with Grg 4. Bur. Min. Resour. Aust. Rec. 1964/69.

NICHOLS, R.A.H., and BELL, M.D., 1965 - Completion Report for B.M.R. 12 (Cockroach) Northern Territory. Bur. Min. Resour. Aust. Rec. 1965/60.

NOAKES, L.C., 1952 - Subsurface water supply in the Barkly Tableland. Bur. Min. Resour. Aust. Rec. 1952/67.

OPIK, A.A., 1949 - Geological Observations during a journey to Eastern Jervois Ranges. Bur. Min. Resour. Aust. Rec. 1949/52.

OPIK, A.A., 1951 - Progress in the study of Cambrian fossils from the Northern Territory and north-west Queensland. Bur. Min. Resour. Aust. Rec. 1951/26.

OPIK, A.A., 1952 - Discovery of fossiliferous Upper Cambrian in Central Australia. Bur. Min. Resour. Aust. Rec. 1952/17.

OPIK, A.A., 1954 - Cambrian stratigraphy of the Camooweal Region (Progress Report). Bur. Min. Resour. Aust. Rec. 1954/31.

OPIK, A.A., 1954 - Dolomite Problems. Bur. Min. Resour. Aust. Rec. 1954/51.

OPIK, A.A., 1959 - Correlation Chart of Cambrian and Ordovician in Australia. Bur. Min. Resour. Aust. Rec. 1959/52.

OPIK, A.A., 1966 - Cambrian. Bur. Min. Resour. Aust. Rec. 1966/6.

RANDAL, M.A., and BROWN, G.A., 1962a - The Geology of the Ranken 1:250,000 Sheet area. Bur. Min. Resour. Aust. Rec. 1962/55.

RANDAL, M.A., and BROWN, G.A., 1962b - The Geology of the Avon Downs 1:250,000 Sheet area. Bur. Min. Resour. Aust. Rec. 1962/56.

RANDAL, M.A., and BROWN, G.A., 1962c - Additional Notes on the Geology of the Cammoweal 4-mile Sheet area. Bur. Min. Resour. Aust. Rec. 1962/49.

RANDAL, MA., 1962 - The Hydrology of the eastern Barkly Tablelands. Bur. Min. Resour. Aust. Rec. 1962/61.

RANDAL, M.A., 1966 - Groundwater in the Barkly Tableland, Northern Territory. Bur. Min. Resour. Aust. Rec. 1966/11.

RANDAL, M.A., and NICHOLS, R.A.H., 1963 - The Geology of the Alroy and Brunette Downs 1:250,000 Sheet areas, Northern Territory. Bur. Min. Resour. Aust. Rec. 1963/72.

RANDAL, M.A., BROWN, M.C., and DOUTCH, H.F., 1966 - The Geology of the Helen Springs and Beetaloo 1:250,000 Sheet areas, Northern Territory. Bur. Min. Resour. Aust. Rec. 1966/110.

REYNOLDS, M.A., 1960 - Geology of the Springvale 4-mile Sheet area Queensland. Bur. Min. Resour. Aust. Rec. 1960/92.

REYNOLDS, M.A., 1964a - Explanatory Notes on the Bedourie Geological Sheet, Bur. Min. Resour. Aust. Rec. 1964/123.

REYNOLDS, M.A., 1964b - Explanatory Notes on the Mount Whelan Geological Sheet. Bur. Min. Resour. Aust. Rec. 1964/138.

REYNOLDS, M.A., 1965 - The Sedimentary Basins of Australia and the Stratigraphic Occurrence of Hydrocarbon. Bur. Min. Resour. Aust. Rec. 1965/196.

REYNOLDS, M.A., and PRITCHARD, P.W., 1964 - The Geology of the Glenormiston 1:250,000 Sheet area. Bur. Min. Resour. Aust. Rec. 1964/28.

REYNOLDS, M.A., and others, 1963 - The Sedimentary Basins of Australia nd New Guinea. Bur. Min. Resour. Aust. Rec. 1963/159.

ROBERTSON, C.S., 1963 - Undilla Basin Seismic Survey, Queensland, 1961. Bur. Min. Resour. Aust. Rec. 1963/63.

ROBERTSON, C.S., 1965 - South-eastern Georgina Basin seismic survey, Queensland, 1963. Bur. Min. Resour. Aust. Rec. 1965/75.

ROBERTSON, C.S., 1967 - Seismic Record in prep.

SMITH, J.W., 1962 - Explanatory notes on the Mount Drummond 1:250,000 Sheet. Bur. Min. Resour. Aust. Rec. 1962/113.

SMITH, K.G., VINE, R.R., and WOOLLEY, D.R.G., 1960 - The geology of the Huckitta Sheet area. Second Progress Report. Bur. Min. Resour. Aust. Rec. 1960/66.

SMITH, K.G., and VINE, R.R., 1960a - Summary of the geology of the Tobermory 4-mile Sheet, Northern Territory. Bur. Min. Resour. Aust. Rec. 1960/71.

SMITH, K.G., and VINE, R.R., 1960b - Traverses down the Hay and Plenty Rivers. Bur. Min. Resour. Aust. Rec. 1960/20.

SMITH, K.G., 1960 - Summary of the geology of the Hay River 4-mile Sheet Northern Territory. Bur. Min. Resour. Aust. Rec. 1960/73.

SMITH, K.G., 1964 - Explanatory notes to accompany the Frew River 1:250,000 Geological Sheet, Northern Territory. Bur. Min. Resour. Aust. Rec. 1964/49.

SMITH, K.G., VINE, R.R., and MILLIGAN, E.N., 1961 - Revisions to the Stratigraphy of Hay River, Huckitta and Tobermory 4-mile Sheets, Northern Territory. Bur. Min. Resour. Aust. Rec. 1961/65.

SMITH, K.G., VINE, R.R., and MILLIGAN, E.N., 1961 - Progress Report on the Palaeozoic geology of the Elkedra 4-mile Sheet. Northern Territory. Bur. Min. Resour. Aust. Rec. 1961/50.

SMITH, K.G., and MILLIGAN, E.N., 1963 - The geology of the Elkedra 1:250,000 Sheet, Northern Territory. Bur. Min. Resour. Aust. Rec. 1963/46.

SMITH, K.G., and CONDON, M.A., 1959 - An aerial reconnaissance over portion of the Frew River Sheet, Northern Territory. Bur. Min. Resour. Aust. Rec. 1959/28.

SPENCE, A.G., 1962 -Tennant Creek Airborne Magnetic and Radiometric Survey, Northern Territory. Bur. Min. Resour. Aust. Rec. 1962/99.

TOMLINSON, Joyce G., - 1956 - Cambrian fossils from Huckitta and Elkedra 4-mile Sheets, Northern Territory. Bur. Min. Resour. Aust. Rec. 1956/89.

TOMLINSON, Joyce G., 1959 - Lower Ordovician fossils in the area of Boulia 4-mile Sheet, Queensland. Bur. Min. Resour. Aust. Rec. 1959/37.

TOWNLEY, K.A., BENNETT, E.M., and GATES, D.J., 1952 - Cambrian stratigraphy at Cammoweal. Bur. Min. Resour. Aust. Rec. 1952/47.

TRAVES, D.M., 1947 - Field Summary of Geology of Barkly Tablelands. Bur. Min. Resour. Aust. Rec. 1947/63.

VINE, R.R., 1959 - Sedimentary Iron in the Dulcie Range, Northern Territory. Bur. Min. Resour. Aust. Rec. 1959/102.

VALE, K.R., 1962 - Reconnaissance gravity surveys using helicopters, for oil search in Australia. Bur. Min. Resour. Aust. Rec. 1962/130.

VALE, K.R., 1965 - Progress of the reconnaissance gravity survey of Australia. Bur. Min. Resour. Aust. Rec. 1965/197.

WOOLLEY, D.R.G., 1959 - Pegmatites in the Huckitta Sheet area. Bur. Min. Resour. Aust. Rec. 1959/88.

WOOLLEY, D.R.G., 1961 - The occurrence of sedimentary lead at Box Hole, Northern Territory. Bur. Min. Resour. Aust. Rec. 1961/42.

WHITE, Mary E., 1961 - Mesozoic Plant Fossils from the Tarlton Range, Northern Territory. Bur. Min. Resour. Aust. Rec. 1961/32.

WELLS, R., and MILSOM, J.S., 1965 - Georgina Basin Aeromagnetic Survey, Queensland, and Northern Territory, 1963. Bur. Min. Resour. Aust. Rec. 1965/52.

WELLS, R., TIPPER, D.B., and MILSOM, J.S., 1964 - Georgina Basin Aeromagnetic Survey, Queensland and Northern Territory, 1964. Bur. Min. Resour. Aust. Rec. 1964/172.

WELLS, R., MILSOM, J.S., and TIPPER, D.B., 1966 - Georgina Basin Aeromagnetic Survey, Queensland and Northern Territory, 1963-1964. Bur. Min. Resour. Aust. Rec. 1966/142.

PRELIMINARY MAP ONLY

GEOLOGICAL MAP

NORTH EAST GEORGINA BASIN

QUEENSLAND
NORTHERN TERRITORY
AUSTRALIA

Scale 1:500,000

10 0 10 20 30 MILES

10 0 10 20 30 40 50 KILOMETRES

Geology to 1965 by: Officers of the Bureau of Mineral Resources and G.S.Q.

Compiled 1965 by: K.G. Smith

Drawn by: G. Matveev

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Transverse Mercator Projection

Reference

CAINOZOIC	QUATERNARY	Undifferentiated	Q	*Sand, soil, alluvium, gravel*
	TERTIARY	Undifferentiated	T	*Chalcedonic limestone, dolomite, chert, siltstone, gypsum*
MESOZOIC	LOWER CRETACEOUS	Polland Waterhole Shale	Klp	*Shale*
	UNDIFFERENTIATED	Undifferentiated	M	*Sandstone, conglomerate, mudstone, siltstone*
PALAEOZOIC	UPPER CAMBRIAN	Meeta Beds	€um	*Dolomite, chert, sandstone*
	MIDDLE CAMBRIAN	Undifferentiated	€m	*Dolomite, chert*
		Ranken Limestone	€mk	*Limestone, chert*
		Wonarah Beds	€mw	*Limestone, shale, siltstone, chert*
		Peaker Piker Volcanics	€mp	*Basalt, trachyte, sandstone*
		Burton Beds	€mr	*Siltstone, chert, limestone, coquinite, calcarenite*
		Age Creek Formation	€mb	*Calcarenite, dolarenite*
		Thorntonia Limestone	€mt	*Limestone, dolomitic limestone*
		Split Rock Sandstone	$€m_4$	*Sandstone, siltstone, shale*
		Mail Change Limestone V-Creek Limestone Currant Bush Limestone	$€m_3$	*Limestone*
		Inca Creek Formation	$€m_2$	*Shale, chert, limestone*
		Border Waterhole Formation Beetle Creek Formation	$€m_1$	*Shale, chert, conglomerate, limestone, siltstone*
	UNDIFFERENTIATED	Camooweal Dolomite	€d	*Dolomite, chert*
	LOWER CAMBRIAN	Bukalara Sandstone	€lk	*Sandstone, conglomerate*
PRECAMBRIAN	UPPER PROTEROZOIC	Colless Volcanics	Puo	*Basalt*
		Mittiebah Sandstone	Psi	*Sandstone*
		Mullera Formation	Psl	*Siltstone, shale, sandstone*
		Constance Sandstone	Psa	*Sandstone, conglomerate, siltstone*
		Pilpah Sandstone	Pui	*Sandstone, conglomerate*
	LOWER PROTEROZOIC	Undifferentiated	Pg	*Granite*
		Sybella Granite	Pgs	*Granite*
		Eastern Creek Volcanics	Ple	*Basalt*
	ARCHAEAN ? – LOWER PROTEROZOIC	Undifferentiated	p€	*Migmatite, gneiss, schist, metaquartzite, rhyolite, dacite, basalt, quartz sandstone, conglomerate, limestone, dolomite shale, slate, calc-silicate, tuff and agglomerate*

Geological boundary

Anticline showing the plunge

Syncline

Fault

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

15 *Strike and dip of strata*

Horizontal strata

Dip < 15°

Trend lines } *air-photo interpretation*

Joint pattern } *air-photo interpretation*

Macrofossil locality

Abandoned dry hole; St- *stratigraphic hole*

Abandoned well with show of gas

Bore

Abandoned bore

Windpump

Highway or road

Vehicle track

Railway

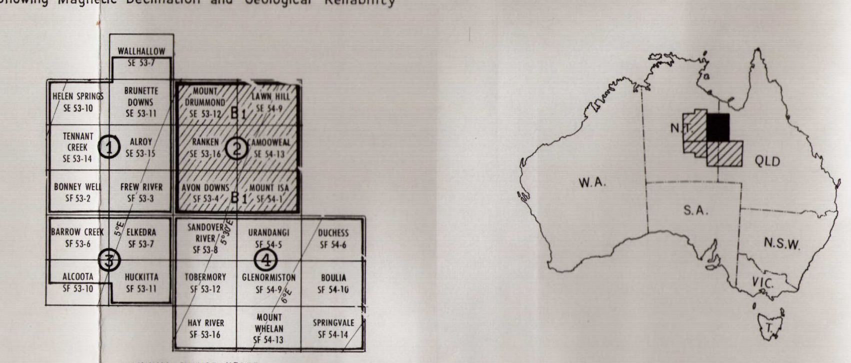
"Ranken" *Homestead*

Airport

Landing ground

• 720 *Height in feet, instrument levelled*

INDEX TO
GEORGINA BASIN 1:500,000 SHEETS
AND AUSTRALIAN 1:250,000 SERIES
Showing Magnetic Declination and Geological Reliability



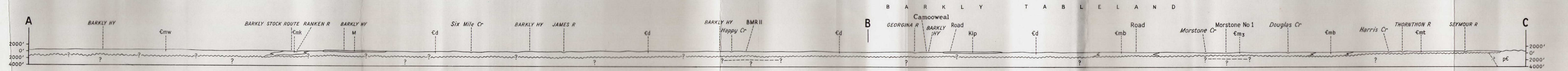
ANNUAL CHANGE 1'30"E

B1 Detailed reconnaissance - numerous cross traverses and air-photo interpretation

Section

Quaternary omitted from section

Scale : $\frac{V}{H} = 2$



PRELIMINARY MAP ONLY

GEOLOGICAL MAP

NORTH WEST GEORGINA BASIN

NORTHERN TERRITORY

AUSTRALIA

Scale 1:500,000

Reference

CAINOZOIC	QUATERNARY	Undifferentiated	Q	Alluvium, gravel, soil, sand
	TERTIARY	Undifferentiated	T	Limestone, dolomite
PALAEOZOIC	UPPER CAMBRIAN – LOWER ORDOVICIAN	Tomahawk Beds	Є-Ot	Sandstone, conglomerate
	UPPER CAMBRIAN	Meeta Beds	Єum	Dolomite, chert
	MIDDLE CAMBRIAN	Undifferentiated	Єm	Dolomite, chert, limestone
		Anthony Lagoon Beds	Єmn	Dolomite, limestone, chert, sandstone, siltstone
		Wonarah Beds	Єmw	Limestone, chert, dolomite, sandstone, shale
		Gum Ridge Formation	Єmg	Shale, limestone, chert
	LOWER CAMBRIAN	Helen Springs Volcanics	Єlh	Basalt, sandstone
PRECAMBRIAN	UPPER PROTEROZOIC	Rising Sun Conglomerate	Pur	Boulder conglomerate, sanstone
		Mittiebah Sandstone	Psi	Sandstone
	LOWER PROTEROZOIC	Undifferentiated	Pg	Granite
			Pp	Porphyry
			Pd	Gabbro, dolerite
		Ashburton Sandstone	Plt	Sandstone, greywacke, siltstone, shale, acid and basic lavas
		Hatches Creek Group	Plh	Sandstone, greywacke, siltstone, shale, acid lavas
			Pb	Basic lavas
		Warramunga Group	Plw	Siltstone, greywacke, shale

Geological boundary

Anticline

Syncline

Fault

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

75 Strike and dip of strata

Dip > 45°, Trend lines: air-photo interpretation

15 Dip slope

Macrofossil locality

Dyke; q – quartz

Dry hole, abandoned; St – Stratigraphic hole

Bore

Abandoned bore

Windpump

Highway or road

Vehicle track

"Alroy Downs" Homestead

Landing ground

•745 Height in feet, instrument levelled

Geology to 1965 by: Officers of the Bureau of Mineral Resources

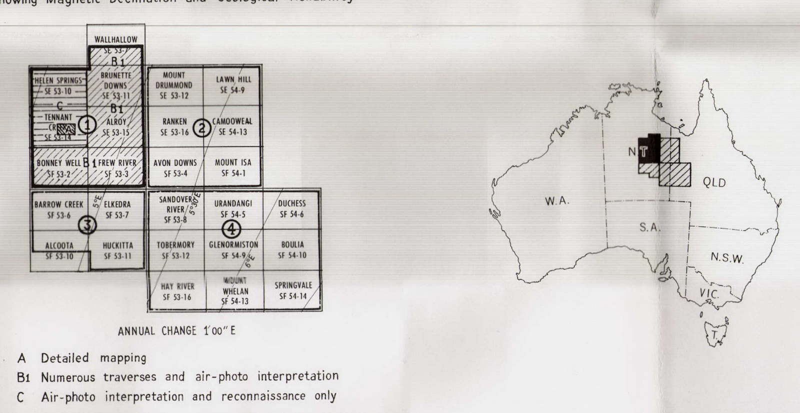
Compiled 1965 by: K.G. Smith

Drawn by: G. Matveev

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Transverse Mercator Projection

INDEX TO
GEORGINA BASIN 1:500,000 SHEETS
AND AUSTRALIAN 1:250,000 SERIES

Showing Magnetic Declination and Geological Reliability

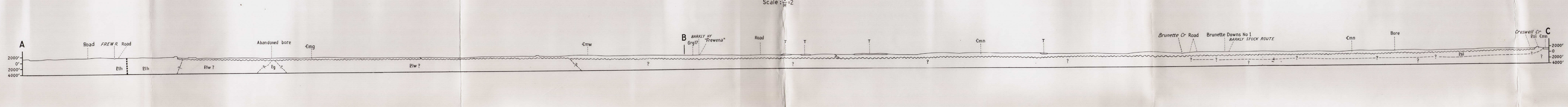


ANNUAL CHANGE 1'00" E

A Detailed mapping
B1 Numerous traverses and air-photo interpretation
C Air-photo interpretation and reconnaissance only

Section

Quaternary omitted from section



GEOLOGICAL MAP
SOUTH WEST GEORGINA BASIN
NORTHERN TERRITORY
AUSTRALIA

Reference

MESOZOIC CAINOZOIC	QUATERNARY	Undifferentiated	Q	Sand, soil, alluvium, gravel
	TERTIARY	Undifferentiated	T	Chalcedonic limestone, siltstone, sandstone
	TRIASSIC	Tarlton Formation	Rt	Conglomerate, sandstone
PALAEOZOIC	UPPER DEVONIAN	Dulcie Sandstone	Dud	Quartz sandstone, pebble conglomerate
	MIDDLE ORDOVICIAN	Nora Formation	Omn	Siltstone, sandstone
	UPPER CAMBRIAN – LOWER ORDOVICIAN	Tomahawk Beds	€-Ot	Sandstone, siltstone, limestone, dolomite
	UPPER CAMBRIAN	Meeta Beds	€um	Dolomite, limestone, chert, sandstone
		Arrinthrunga Formation	€ua	Dolomite, limestone, siltstone, sandstone
		Eurowie Sandstone Member	€ue	Sandstone
	MIDDLE CAMBRIAN	Arthur Creek Beds	€ma	Shale, limestone, dolomite, quartz sandstone
		Sandover Beds	€mo	Siltstone, shale, limestone, dolomite, sandstone, conglomerate
	UPPER PROTEROZOIC – LOWER CAMBRIAN	Mopunga Group: Mount Baldwin Formation	€lb	Sandstone, greywacke, shale, siltstone, dolomite
		Mopunga Group: Grant Bluff Formation	P-€g	Sandstone, shale, siltstone, dolomite
PRECAMBRIAN		Mopunga Group: Elyuah Formation	Pue	Shale, siltstone, arkose
	UPPER PROTEROZOIC	Central Mount Stuart Beds	Pus	Greywacke, arkose, siltstone, sandstone
		Mount Cornish Formation	Puc	Boulder beds, siltstone, arkose, dolomite
	LOWER PROTEROZOIC		Pg	Granite
			Pp	Porphyry
			Pd	Gabbro, dolerite
		Hatches Creek Group	Plh	Sandstone, greywacke, siltstone, shale, acid lavas
		Hatches Creek Group	Pb	Basic lavas
	? ARCHAEAN	Arunta Complex	Aa	Gneiss, schist, amphibolite, meta quartzite

Geological boundary
Anticline
Syncline
Monocline
Overturned syncline
Fault

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

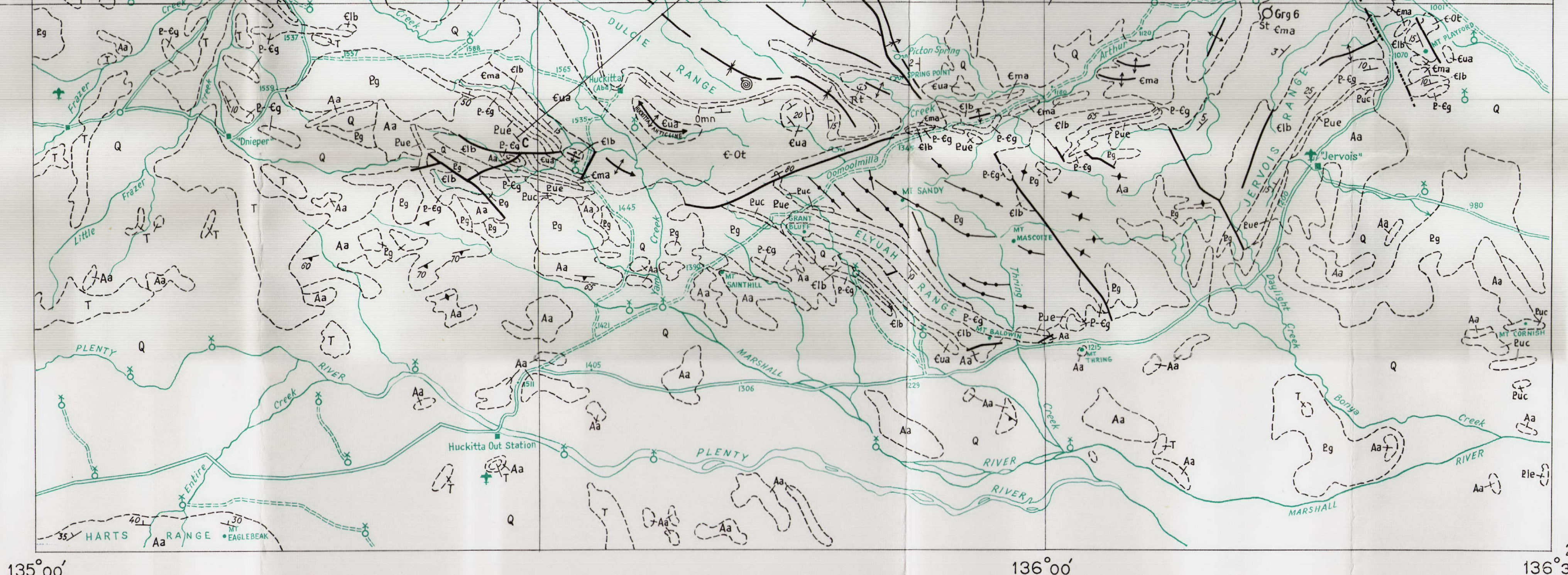
20 Strike and dip of strata
Horizontal strata
75 Overturned strata
Dip < 15° (air-photo interpretation)
Dip 15°–45° (air-photo interpretation)
Dip > 45° (air-photo interpretation)
Trend lines (air-photo interpretation)
Joint pattern (air-photo interpretation)
75 Strike and dip of foliation
Vertical foliation

Macrofossil locality
Dyke or vein

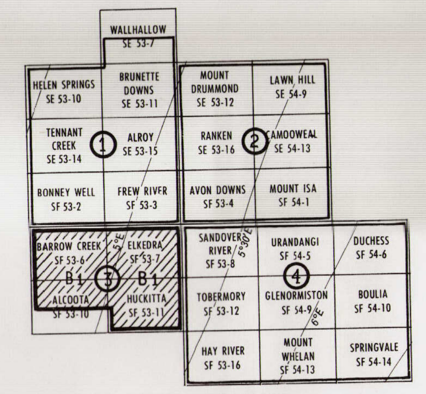
Dry hole (abandoned)
St Stratigraphic hole (abandoned)
Well with show of gas (abandoned)
Well with show of oil and gas (abandoned)

Bore
Bore with windpump
Spring

Highway or road
Vehicle track
"Utopia" Homestead
Landing ground
1405 Height in feet, instrument levelled

INDEX TO GEORGINA BASIN 1:500,000 SHEETS and AUSTRALIAN 1:250,000 SERIES
Showing Magnetic Declination and
GEOLOGICAL RELIABILITY



ANNUAL CHANGE 1'30" E

B1 Detailed reconnaissance - numerous cross traverses and air-photo interpretation

Scale 1:500,000

10 0 10 20 30 MILES

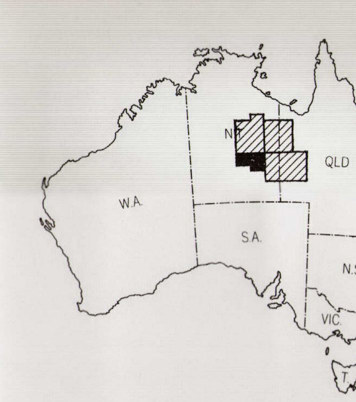
10 0 10 20 30 40 50 KILOMETRES

Geology to 1965 by: Officers of the Bureau of Mineral Resources

Compiled 1965 by: K.G. Smith

Drawn by: G. Matveev

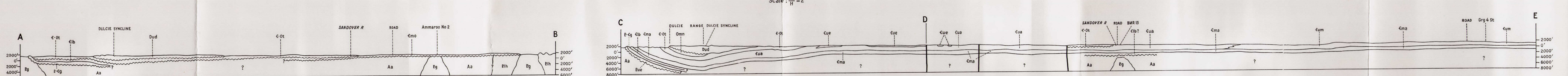
Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Transverse Mercator Projection



Sections

Cainozoic omitted from sections

Scale: V/H = 2




PRELIMINARY MAP ONLY
GEOLOGICAL MAP
SOUTH EAST GEORGINA BASIN
QUEENSLAND
NORTHERN TERRITORY
AUSTRALIA
Scale 1:500,000
10 0 10 20 30 MILES
10 0 10 20 30 40 50 KILOMETRES
Geology to 1965 by: Officers of the Bureau of Mineral Resources and G.S.Q.
Compiled 1965 by: K.G. Smith
Drawn by: G. Matveev
Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Transverse Mercator Projection
Reference
CAINOZOIC
QUATERNARY Undifferentiated Q Sand, soil, alluvium, kunkar, gravel
TERTIARY Undifferentiated T Limestone, chalcedony, sandstone, siltstone, conglomerate
MESOZOIC
CRETACEOUS
Mackunda Formation Klm Arkose, siltstone
Wilgunya Formation Klw Claystone, siltstone
Toolebuc Member Klo Calcareous siltstone
Longsight Sandstone Kll Sandstone
TRIASSIC Tarlton Formation Rt Conglomerate, siltstone, sandstone
UNDIFFERENTIATED M Sandstone
PALAEOZOIC
PERMIAN ? Undifferentiated P? Conglomerate, shale
SILURIAN - DEVONIAN ? Cravens Peak Beds S-Dc Sandstone
MIDDLE ORDOVICIAN
Toko Group
Mithaka Beds Omm Siltstone, sandstone
Carlo Sandstone Omc Sandstone
Nora Formation Omn Siltstone, sandstone
LOWER ORDOVICIAN
Coolibah Formation Olc Limestone, dolomite, chert
Kelly Creek Formation Olk
Swift Formation Ols Sandstone, dolomite, siltstone, coquinite
UPPER CAMBRIAN - LOWER ORDOVICIAN
Tomahawk Beds €-Ot Sandstone, dolomite, limestone, siltstone
Ninmaroo Formation €-On Dolomite, limestone, siltstone, sandstone
UPPER CAMBRIAN
Georgina Limestone €ug Limestone
Chatsworth Limestone €uc Limestone, dolomite
Gola Beds €uo Limestone
O'Hara Shale €uh Shale, chert, sandstone
Pomegranate Limestone €up Limestone
Meeta Beds €um Dolomite, chert, sandstone
Arrinthrunga Formation €ua Dolomite, limestone, siltstone, sandstone
MIDDLE - UPPER CAMBRIAN Mungerebar Limestone €m-u Limestone
MIDDLE CAMBRIAN
Selwyn Range Limestone
Devoncourt Limestone
Roaring Bore Siltstone
Steamboat Sandstone €m4 Limestone, sandstone, shale, siltsone
Quita Formation
Blazan Shale €m3 Limestone, shale, sandstone, conglomerate
Inca Creek Formation €m2 Shale, chert, limestone, siltstone
Beetle Creek Formation
Thorntonia Limestone €m1 Shale, chert, siltsone, sandstone, limestone, dolomite
Marqua Beds €mf Limestone, siltstone, calcareous sandstone, shale
Camooweal Dolomite €d Dolomite with chert lenses
LOWER CAMBRIAN
Mount Birnie Beds €li Arkose, sandstone, shale
Riversdale Formation €lr Conglomerate, sandstone, dolomite
PRECAMBRIAN
UPPER PROTEROZOIC - LOWER CAMBRIAN
Grant Bluff Formation P-€g Quartz sandstone
Makbat Sandstone P-€m Quartz sandstone, conglomerate
UPPER PROTEROZOIC
Sylvester Sandstone Puy Sandstone, siltstone
Sun Hill Arkose Puh Arkose, conglomerate, sandstone, siltstone, dolomite
Field River Beds Puf Boulder beds, siltstone, arkose, dolomite, quartz sandstone
LOWER PROTEROZOIC
Undifferentiated Pg Granite
Sybella Granite Pgs Granite
Kalkadoon Granite p€k Granite
Eastern Creek Volcanics Ple Metabasalt and metasediments; some schist and gneiss
Marraba Volcanics Pla Metabasalt, tuff; metaquartzite, slate, schist, limestone
ARCHAEAN ? - LOWER PROTEROZOIC Undifferentiated p€ Migmatite, gneiss, schist, metaquartzite, rhyolite, dacite, basalt, quartz sandstone, conglomerate, limestone, dolomite, siltstone, shale, slate, calc-silicates, tuff, and agglomerate
ARCHAEAN ? Arunta Complex Aa Gneiss, schist, metaquartzite
Geological bounday
Anticline showing the plunge
Syncline
Monocline
Fault
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Dry hole
Stratigraphic hole
abandoned
Bore
Abandoned bore
Well
Windpump
Sections
INDEX TO GEORGINA BASIN 1:500,000 SHEETS AND AUSTRALIAN 1:250,000 SERIES
NORTHERN TERRITORY
QUEENSLAND