COMMONWEALTH OF AUSTRALIA.

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RECORDS.

1963/51 Copy 3

THE GEOLOGY OF THE LAKE AMADEUS 1:250,000 SHEET AREA.

by

A.T.Wells, L.C.Ranford and P.J.Cook.

PART 1 of 2

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RECORDS 1963/51

CONTENTS

- - - - - - - - - - -

ILLUSTRATIONS

ILLUSTRATIONS (contd.)

FIGURE

PLATES

THE GEOLOGY OF THE LAKE AMADEUS 1:250,000 SHEET AREA

SUMMARY

Thick sections of Palaeozoic and Proterozoic sediments are exposed on the Lake Amadeus Sheet area which is near the centre of the Amadeus Basin. No older Precambrian rocks are exposed on the Sheet area Units of Upper Proterozoic, Cambrian, Ordovician, undifferentiated Palaeozoic, Mesozoic, Tertiary and Quaternary age have been mapped.

The total thickness of Proterozoic rocks in the southern part of the area probably exceeds 10,000 feet but in anticlines in the north-eastern part of the area it is only about 2600 feet. Conversely, the Palaeozoic rocks are thickest in this north-eastern area and total 12,000 feet; in the few exposures on the southern and western parts of the area they are very thinly developed, and rest unconformably on older rocks.

The basal unit of the Upper Proterozoic, the Heavitree Quartzite, has not been found on the Lake Amadeus Sheet area, even though the succeeding Bitter Springs Limestone is exposed in several places. The Heavitree Quartzite has so far been seen only at the margin of the basin.

The Bitter Springs Limestone consists of dolomite and subordinate limestone, siltstone and lenses of sandstone and is disconformably or possibly unconformably overlain by the Areyonga Formation. The Areyonga Formation is known only from the Parana Hill Anticline and comprises silty sandstone and boulder beds with erratics of many rock types, including the Bitter Springs Limestone; many of the erratics are striated and facetted and for this reason the formation is thought to be glacial in origin. The siltstone, chert, chert breccia, and sandstone of the Inindia Beds are probably laterally equivalent to the Areyonga Formation.

The Bitter Springs Limestone and Areyonga Formation are overlain with an angular unconformity by a thin sequence of sandstone and siltstone of the Pertatataka Formation in the Parana Hill Anticline. To the west and south of this area the equivalent of the Pertatataka Formation is a thick sequence of sandstone and siltstone, (Winnall Beds), which unconformably overlies the Inindia Beds.

The Cambrian siltstone, sandstone and fossiliferous limestone in the Parana Hill Anticline follows either conformably or with a slight angular unconformity on the Pertatataka Formation. The Cambrian succession has been redefined as the Pertaoorrta Formation and five members have been differentiated. The deltaic Cleland Sandstone crops out on the western part of the Lake Amadeus Sheet area and is laterally equivalent to part or all of the Pertaoorrta Formation. The Cleland Sandstone overlies the Winnall Beds with strong angular unconformity.

The richly fossiliferous sandstone, siltstone and limestone of the Larapinta Group rest conformably on the Pertaoorrta Formation and the Cleland Sandstone except on the south-eastern part of the Sheet area where the Group unconformably overlies the Winnall Beds and possibly the Pertaoorrta Formation and Bitter Springs Limestone.

The youngest Palaeozoic sediments, the unfossiliferous Mereenie Sandstone and Pertnjara Formation, were deposited in both continental and transitional environments. The Mereenie Sandstone maintains a fairly uniform thickness over a large part of the area; it conformably overlies the Larapinta Group and is overlain conformably by the Pertnjara Formation. The thickest exposed section of Pertnjara Formation is on the north-eastern part of the Sheet area. Elsewhere only two small outcrops of possible Pertnjara Formation occur.

The Mesozoic, Tertiary and Quaternary sediments are preserved as thin cappings or as unconsolidated superficial deposits.

The unconformities present in the sediments indicate two or possibly three periods of folding from Upper Proterozoic to possibly early Cambrian. The first period of folding uplifted areas of the Bitter Springs Limestone before the deposition of the Areyonga Formation; the second occurred before the deposition of the Winnall Beds and Pertatataka Formation, and the third folded the Winnall Beds before the deposition of the Cambrian Cleland Sandstone. An orogeny affected the MacDonnell Range area and uplifted large blocks of basement rocks and Amadeus Basin sediments after the deposition of the Mereenie Sandstone. The last period of major folding occurred after the deposition of the Pertnjara Formation. Only one major fault has been mapped on the Lake Amadeus Sheet area. Fold axes trend north-north-west.

Several diapiric structures, which may have originated in the Bitter Springs Limestone, are present on the Lake Amadeus Sheet area, and there is evidence from one diapir that movement of the intrusive gypsum and other evaporites occurred after the folding of the Winnall Beds. The youngest period of movement in the intrusions is not known.

Structural traps for petroleum are present on the north-west part of the Sheet area where thick marine Palaeozoic sediments are preserved in anticlines. The diapiric structures are also possible traps for oil.

Pelletal phosphate deposits occur in the Ordovician Larapinta Group, particularly in the Stairway Sandstone. The phosphate occurs in thin beds which give analyses up to 22% P_2O_5.

INTRODUCTION

General

During the period from 27th May to 9th October 1962, A.T. Wells, L.C. Ranford and P.J. Cook, geologists of the Bureau of Mineral Resources, Geology and Geophysics, mapped the Lake Amadeus (G52-4) 1:250,000 Sheet area. They also visited a few geological points on the adjacent Hermannsburg (F53-13), Mount Liebig (F52-16), Henbury (G53-1) and Ayers Rock (G52-8) Sheet areas. D.J. Forman and A. Stewart mapped part of the western side of the Lake Amadeus Sheet area.

This mapping was a continuation of that done by Wells, Forman and Ranford in 1960 and 1961 on the Rawlinson (G52-2), Macdonald (F52-14), Mount Rennie (F52-15), and Mount Liebig (F52-16) Sheet areas, and it is part of the Bureau's programme to map the Amadeus Basin at a scale of 1:250,000.

C.G. Gatehouse, palaeontologist, was attached to the field party for six weeks. M. Fetherston was draftsman with the party.

Location and Access

The area investigated is in the Northern Territory and lies between latitudes 24° and 25° south and between longitudes 130°30' and 132° east.

There are no permanent settlements within the sheet area; the nearest settlements are Wallera Ranch and Tempe Downs, Angus Downs and Curtin Springs Homesteads. The base camp at Reedy Rock Hole was approximately 200 miles from Alice Springs, the nearest town.

The only roads in the area are ungraded station tracks and a fire-ploughed track which runs from Wallera Ranch to King Canyon. Graded roads run from Alice Springs to Tempe Downs and Angus Downs.

Most of the Lake Amadeus Sheet area is a Native Reserve or Crown Land. Some fires and tracks were seen, indicating that there were some wandering natives in the area, but no natives were seen. The only stations with holdings in the Lake Amadeus Sheet area are Curtin Springs and Tempe Downs.

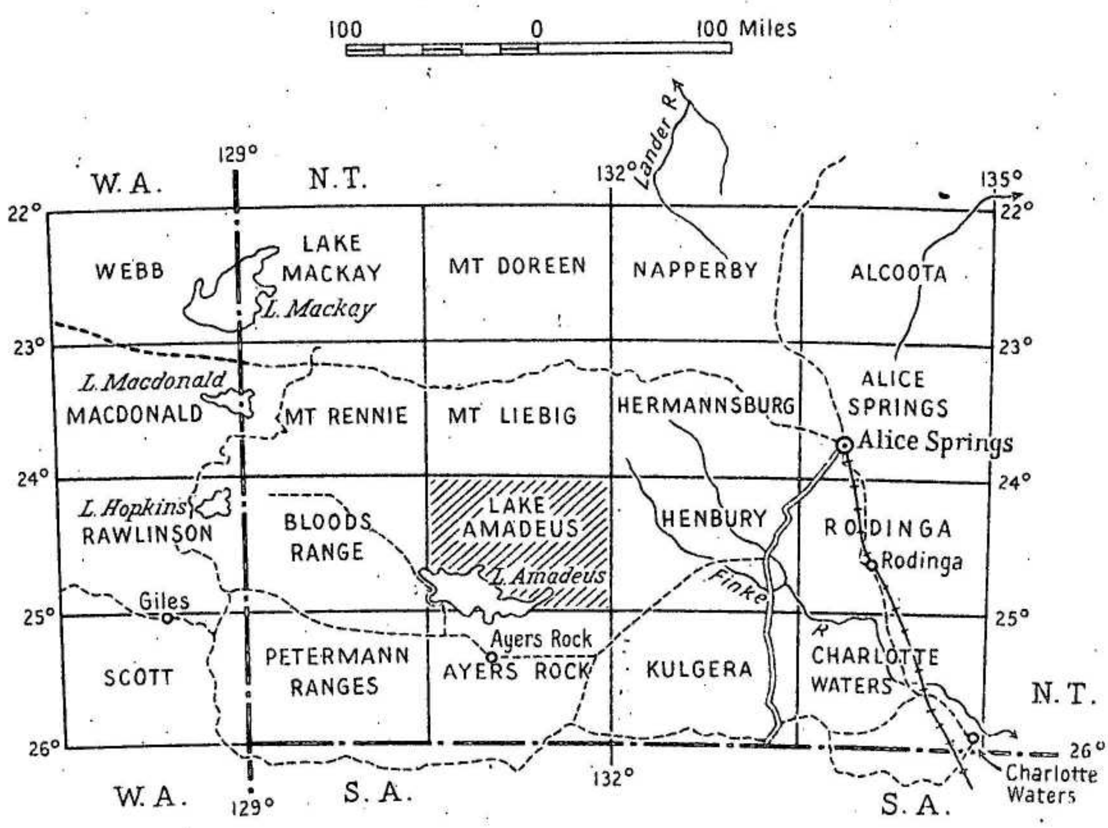
Communications with the Royal Flying Doctor base at Alice Springs were by two Traegar transceivers and a Pye transceiver.

Climate

The Lake Amadeus Sheet area receives an average rainfall of less than 10" per annum, most falling in the summer months. However, winter rains do occur and about 4" was recorded during the 1962 field season.

Fig. I

POSITION OF AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN 1:250,000 AND 1:253,440 MAP SERIES



LOCALITY MAP

Bureau of Mineral Resources, Geology and Geophysics. March, 1963.
GD 155
To accompany Record 1963/51

G52/4/13
MK

Summer temperatures are very high, with the mean daily maximum being over 100°F for many weeks. Day temperatures are very pleasant during the winter with the maximum generally not exceeding 80°F, but the nights are cold with the temperature frequently below 32°F. During the winter of 1962, several frosts were experienced in the ranges but generally the winter was considered to be mild.

The prevailing wind is from the south-east, but the wind bringing the rain is often from the north-west.

Development.

The area is almost completely undeveloped, apart from a few tracks, and there are no usable bores in the area. The only bore, Inindia Bore, is now too saline for cattle and the tank has been dismantled. All the cattle are watered from waterholes and rock holes, most of which occur in the George Gill Range and along the southern margin of Shakes Plain.

Fences have been erected around many of the water-holes, and across Shakes Plain, to restrict the movement of cattle.

The main grazing areas are in the north-east and south-east portions of the area. In the south-east, the feed is almost exclusively 'mulga', but in the north-east, in addition to the mulga, there is good grass in the Johnny Creek - Yam Creek area and on Shakes Plain. In places, Parakeelia also forms a welcome addition to the cattle's diet after rain.

In the entire area there would not be more than 500 head of cattle; numerous horses (brumbies) are found throughout the area; camels are also common, especially around the salt-lakes; kangaroos are rare, and no more than 50 were seen in the area during the field season.

The major development which has taken place in the area has been the establishment of King Canyon in the George Gill Range as a tourist attraction. The tourists now come by road from Alice Springs but it is likely that an airstrip will be constructed in the near-future so that they can be flown right to the Canyon. As a result of the tourist trade, it is possible that a graded road will eventually be constructed to the Canyon from Wallera Ranch.

Survey Method

The mapping was carried out by a series of reconnaissance traverses from the base camp established one mile south of Reedy Rock Hole, with some traverses from a subsidiary base at Inindia Bore. Two short reconnaisance traverses into the western and south-western parts of the Lake Amadeus Sheet area were made by helicopter from a base at Ayers Rock. During the field season, most outcrops on the Lake Amadeus Sheet area were visited. The geology was plotted onto air-photographs taken by the R.A.A.F. in 1950 at a height of 25,000 feet (scale 1:50,000).

The geology was transferred from air-photographs to controlled photo-scale overlay sheets in the field, which were later reduced photographically, and then redrawn at a scale of 1:250,000.

Sections were measured using a 300 ft. steel tape and an Abney level and the location of these sections indicated on the map. The sections were calculated and drawn up in columnar form using standard symbols.

PREVIOUS GEOLOGICAL INVESTIGATIONS

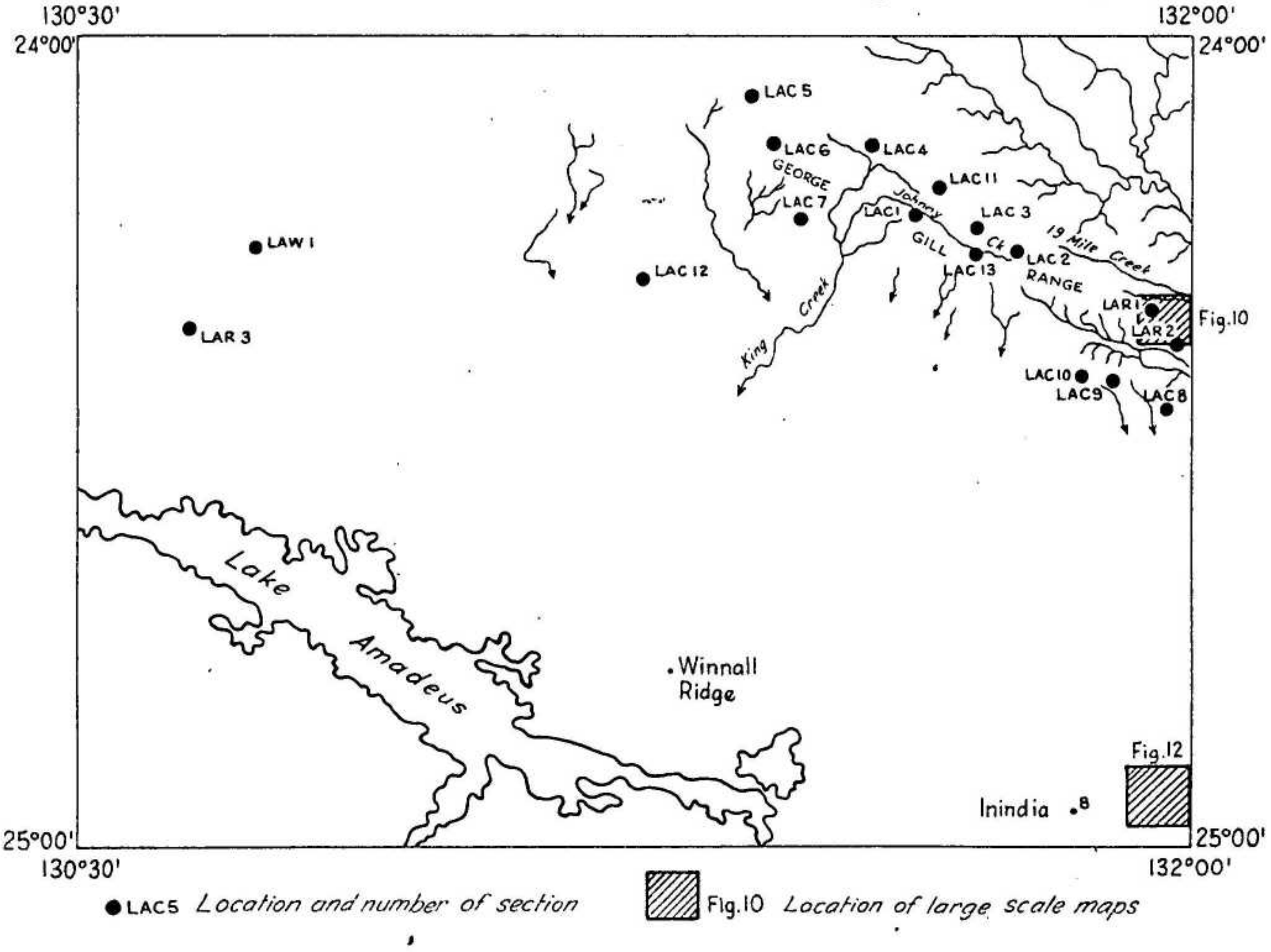
The first explorer in the area was E. Giles in 1872, (Giles 1889), who after travelling along the Western MacDonnell Ranges, turned south at Mount Udor and proceeded to the George Gill Range (named after the brother-in-law of Giles). From there he continued south, and became the first white man to see Lake Amadeus and Mount Olga (both of which he named "In honour of two enlightened royal patrons of science"). He did not, however, see Ayers Rock. Giles then returned to the George Gill Range and from there back to the Finke River.

Giles was closely followed by W.C. Gosse in 1873 (Gosse 1874). He set up a depot on Kings Creek and, like Giles, was much impressed by the good country around the George Gill Range. He journeyed south to Winnall Ridge, (briefly mentioning the sandstone ridges he encountered) and then on to discover Ayers Rock, passing around the eastern end of Lake Amadeus.

It is uncertain when Chewings first came into the area, though his first journey in 1886 (Chewings 1886) may have taken him into the eastern part whilst investigating the sources of the Finke River. He published a series of papers between 1891 and 1935 (Chewings, 1891, 1894, 1914, 1928, 1931, 1935), several of which make brief mention of the area, particularly the George Gill Range; for some time there was confusion over the correlation of the sandstone forming this range. Chewings considered that the George Gill Range was formed by what he called "the Mareeno Bluff Formation" (Chewings 1894) (now known as the Mereenie sandstone) while Brown (1892), correlated the sandstones of the George Gill Range with those of Palm Valley (which was incorrect as these are part of the Pertnjara Formation).

It is also uncertain when Brown first came into the area, but it was probably in 1889 (Brown 1890). He also mentioned the area in Brown (1891, 1892, 1895) and referred to identifications by Etheridge of Lower Silurian (later determined as Ordovician) fossils from the sandstones of the George Gill and Levi Ranges. Brown favoured a two-fold division of the sediments of the Amadeus Basin into Primary (?Cambrian) and Secondary (those forming the flat topped mountain). Chewings advocated a three-fold division of the sediments into the Glen Helen Series (?Devonian), the Mareeno Bluff Series (lower Silurian in part) and the Walker Creek Series (Cambrian).

Location of measured sections and large scale maps Fig.2



To accompany Record 1963/51

Bureau of Mineral Resources, Geology and Geophysics March 1963 G52/4/14 PB

In 1889, W.H. Tietkins travelled around the western end of Lake Amadeus and prepared a map of the extent of the lake (Tietkins 1891).

The Horn Expedition of 1892 worked mainly to the east of the area, but spent some time in the George Gill Range, where they probably collected some fossils (Tate 1896). R.T. Maurice travelled along the western margin of the Lake Amadeus Sheet area in 1902 (Murray 1904) with an expedition travelling from Fowlers Bay to Cambridge Gulf. He described the conglomerate at Mount Currie (originally named by Tietkins) and considered it to be the same as that at Mount Olga. In the north-western corner of the Lake Amadeus Sheet area he described a hill of "Dolomitic limestone with layers of chert and they present a peculiar appearance, as gypseous mounds outcrop almost to the summit, the slopes look like a hillside with snow partially melted". He was almost certainly describing the diapiric structure known as Mount Murray.

In 1906, a government prospecting party under the leadership of F.R. George (George and Murray 1907) travelled north from the Ayers Rock area across Lake Amadeus to near Winnalls Ridge. From here he travelled due north to Bagot Springs, describing some of the ridges he encountered and then across the George Gill Range and Nineteen Mile Creek to Tempe Downs Homestead. George finally returned to Alice Springs via King Creek, Deering Creek, Glen Helen, and arrived in Alice Springs on March 31st 1906.

T.E. Day led a government surveying party through the area in 1916, travelling along the eastern margin from Ayers Rock, then around the western end of the George Gill Range finally striking north, out of the area, to the Treuer Range.

Ward, Madigan and Mawson all briefly mention the Lake Amadeus Sheet area (Ward,1925, Mawson and Madigan 1930, Madigan 1931, Madigan 1932), but it is unlikely that they actually entered it.

In 1956, Prichard and Quinlan mapped the southern half of the Hermannsburg 1:250,000 Sheet area and measured the Ellery Creek section (Prichard and Quinlan 1962). Their work has since been used as a basis for geological work in the Amadeus Basin.

Gillespie and Leslie of Frome-Broken Hill Pty. Ltd. undertook reconnaissance geological work in 1959, in the eastern half of the area (Leslie 1960), and described the geology near Inindia Bore, Winnalls Ridge and the George Gill Range.

Since 1960 R.M. Hopkins together with consultant geologists C.R. Stelk and D. McNaughton have undertaken geological mapping for the Magellan Petroleum Corporation to assess the petroleum prospects of the area (Stelk and Hopkins, 1962, McNaughton, 1962).

The Lake Amadeus 1:250,000 Sheet area was photo-interpreted for the Bureau of Mineral Resources in 1960, by the Institut Francais du Petrole (Scanvic 1961), as part of a photo-interpretation programme covering the whole of the Amadeus Basin.

In 1960 the Rawlinson and Macdonald 1:250,000 Sheet area were mapped by Wells, Forman and Ranford (1961) and in 1961 the Mount Rennie and Mount Liebig 1:250,000 Sheet areas were also mapped by Wells, Forman and Ranford (1962).

In 1962, Forman and Stewart mapped the Bloods Range 1:250,000 Sheet area, which lies to the west of the Lake Amadeus Sheet area (Forman 1963).

Two aeromagnetic traverses crossing parts of the Lake Amadeus Sheet area were carried out in 1960 by the Geophysical Branch of the Bureau of Mineral Resources. A regional gravity survey of the Lake Amadeus Sheet area was also carried out by the Bureau of Mineral Resources in 1962.

PHYSIOGRAPHY

There are five main physiographic divisions in the Lake Amadeus Sheet area (see Fig. 3).

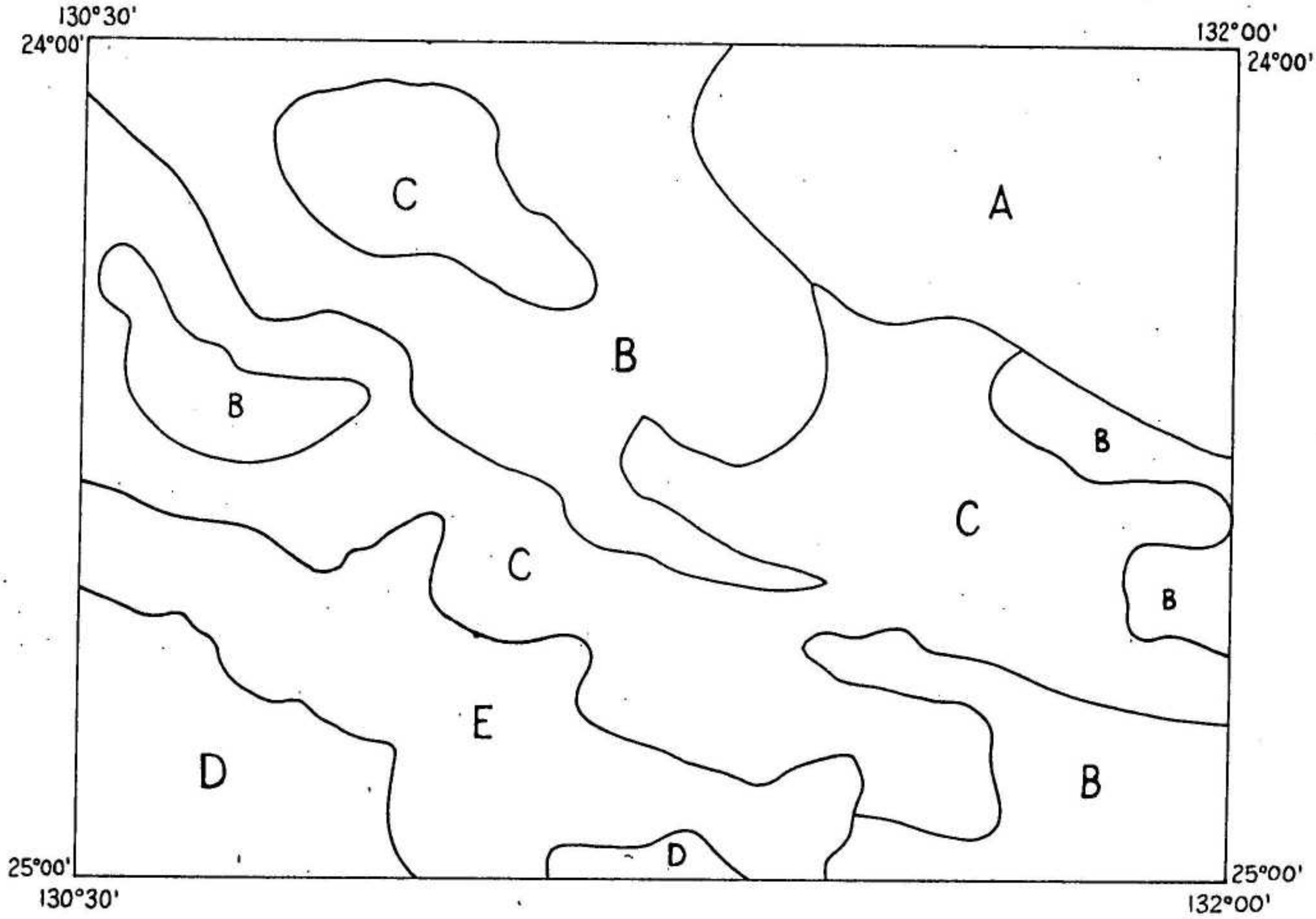
A. High Mountain ranges and hills.
B. Low ranges and hills with intervening sand dunes and sand plain.
C. Sand plain with many sand dunes, and some low outcrops.
D. Sand plain with dunes.
E. Salt lakes.

A. The high mountain ranges and hills occur entirely in the north-east corner of the Lake Amadeus Sheet area. Here the peaks rise from 200'-1000' above the general level of the plain, in many places with very steep marginal escarpments. At the base of the ranges there are alluvial fans and plains, which are in part covered with mulga. Sand dunes are generally rare in this division, but in some cases there are dunes on top of the ranges (e.g. George Gill Range).

The Mereenie Sandstone and the Pertnjara Formation form most of the hills and ranges in this division. The drainage pattern on the Mereenie Sandstone is controlled by joint planes which produce steep, straight, narrow, valleys (see Fig. 17). The drainage pattern on the Pertnjara Formation is dendritic, probably because there is no well-developed joint pattern.

The well-defined strike valleys within the ranges are underlain by recessively weathering, silty units such as the siltstone division of the Pertnjara Formation and the Stokes Formation. The major drainage pattern follows these valleys.

Physiographic divisions Fig. 3



A- High mountain ranges and hills

B- Low ranges and hills with intervening sand dunes

C- Sand plain with some dunes and low outcrops

D- Sand plain with braided dunes

E- Salt lakes

10 0 10 20 30 MILES

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PB

B. The low ranges and hills with intervening sand dunes and sand plain, cover large portions of the Sheet area in the north-west corner near Mount Oliphent and Mount Murray, in the eastern margin of the area due south of the George Gill Range, and in the south-east corner around Inindia Bore. The outcrops are generally strike ridges rising from 50-200 above the surrounding plain. The highest ridges are those in which the beds are vertically dipping. Most of the outcrops within this division are of Winnall Beds, Pacoota Sandstone, and Mereenie Sandstone. In many places, alluvium covered with Mulga flanks the higher outcrops. Most of the sand dunes are anastomosing or densely braided.

C. The division of sand plain with many sand dunes and some low outcrops, covers much of the central part of the Lake Amadeus Sheet area.

Outcrops are generally very low strike ridges, which may rise only 2 or 3 feet above the surrounding sand plain. Exposure is very poor and mostly 'rubbly'. No particular formation is limited to this division. Sand dunes are very common and are mainly of the braided type, though in some areas there are well-developed longitudinal dunes e.g. north of Winnalls Ridge.

D. The sand plain with dunes is confined to the area around Lake Amadeus, particularly in the south-west corner of the Sheet area. Outcrops are rare. The sand dunes are mainly of the braided type, though there are a few longitudinal dunes. Some of the dunes are up to 50' high and most trend south-west.

E. Salt lakes cover parts of the southern half of the Sheet area in a wide north-west trending belt. The main salt lake is Lake Amadeus which has numerous smaller salt-lakes at its margins. Sand dunes are present on some of the islands in the lake and several barkhan dunes were seen.

There is no surface water on the salt lakes. In the easterly arm of the lake, water occurs 3" - 4" below the surface. At this depth large crystals of gypsum, up to 1" in diameter are found. Six inches below the surface an extremely sticky, soft, black or grey clay is encountered.

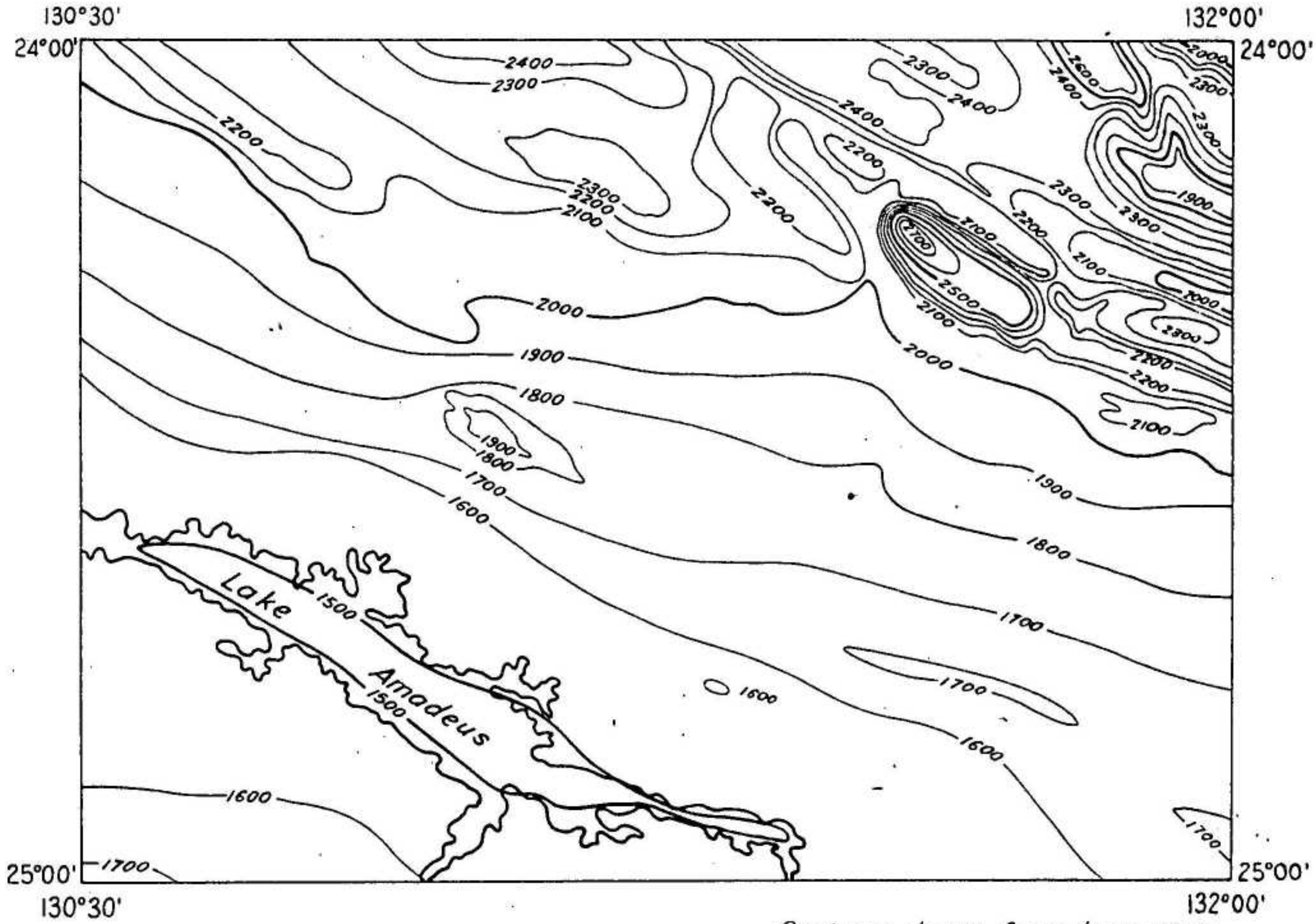
The surface of Lake Amadeus is approximately 1500' above sea-level (Fig. 4), 500' lower than the sand plain at the base of the George Gill Range, 45 miles to the north.

In the north-eastern part of the sheet area, the drainage pattern is well established, with most of the creeks following the strike valleys.

Away from the ranges, the drainage in the few well defined creeks is towards Lake Amadeus. The creeks only flow after heavy rain and the water is quickly dissipated on the sand plain.

Contour map

Fig. 4



Surface contours (100 foot interval)

Contours drawn from barometric heights taken during the helicopter gravity survey of B.M.R. 1962
Prepared in the Geological Branch

10 0 10 20 30 MILES

To accompany Record 1963/51

Bureau of Mineral Resources, Geology and Geophysics March 1963

G52/4/16 PB

STRATIGRAPHY

General

No older Precambrian rocks are present on the Lake Amadeus Sheet area and the basal sandstone of the Amadeus Basin sediments, the Heavitree Quartzite, is not exposed. The oldest exposed rocks are dolomite, siltstone and sandstone and possible glacial beds of Upper Proterozoic age which are unconformably overlain by sandstone, siltstone and minor dolomite of Upper Proterozoic to possibly Cambrian age. These are followed conformably by sandstone, siltstone and sparsely fossiliferous dolomite of Cambrian age, or in places unconformably by deltaic sand. The Cambrian sediments are followed in turn by richly fossiliferous Ordovician sediments. A thick section of undifferentiated Palaeozoic siltstone and sandstone follows conformably on the Ordovician rocks. Thin remnants of possible Mesozoic and Tertiary sediments have been mapped as well as superficial Quaternary deposits.

The relationships of the Amadeus Basin sediments is shown diagramatically in Fig. 5 and Table I and summarised in the accompanying table (Table II). Thicknesses of Proterozoic and Palaeozoic formations from measured sections are shown in Table III.

All new stratigraphic names defined in this report have been approved by the Territories Division of the Stratigraphic Nomenclature Committee.

Specimen and reference points shown on the geological map and referred to in the text are prefixed by the letters LA.

UPPER PROTEROZOIC

Bitter Springs Limestone

The Bitter Springs Limestone (Joklik, 1955) is named from the type locality at Bitter Springs Gorge, 40 miles east-north-east of Alice Springs. On the Lake Amadeus Sheet area the formation of limestone, dolomite, siltstone and sandstone which is overlian either disconformably or with a slight angular unconformity by the Areyonga Formation and conformably by the Inindia Beds and unconformably overlain by both the Pertatataka Formation and the Larapinta Group, is identified with the Bitter Springs Limestone. The base of the formation is not exposed in the Lake Amadeus Sheet area..

The Bitter Springs Limestone occurs in an inlier in the core of the Parana Hill Anticline, at Mt. Murray and at several small isolated outcrops between Lake Amadeus and the George Gill Range and near Inindia Bore on the south-eastern part of the area. Outcrops of the Bitter Springs Limestone in the core of the Parana Hill Anticline are well exposed in strike ridges. At Mt. Murray there are well exposed pinnacles and ridges of contorted Bitter Springs Limestone. Elsewhere the formation is poorly exposed in low mounds and small hillocks.

TENTATIVE CORRELATION OF ROCK UNITS

Fig. 5

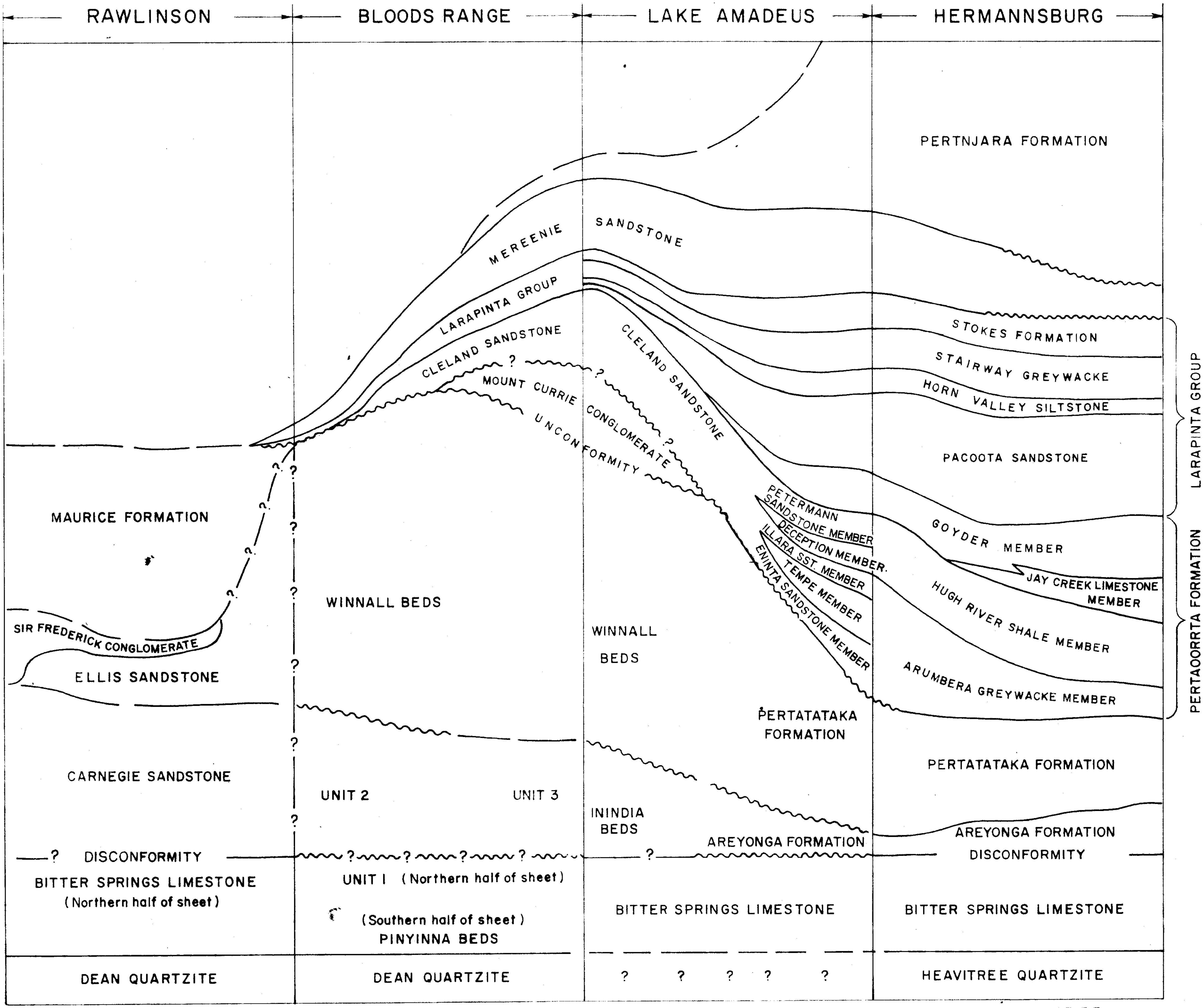


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TABLE I

STRATIGRAPHIC UNITS IN THE AMADEUS BASIN

Era	Period	Epoch	Western MacDonnell Ranges (after Prichard & Quinlan 1962)	Cleland Hills	Gardiner Range	Bloods Range 1:250,000 Sheet area.	Southern Half of Lake Amadeus 1:250,000 Sheet area.	Rawlinson - Macdonald 1:250,000 Sheet areas.
CENOZOIC	Quaternary		Alluvium, gravels.	Alluvium, aeolian sand.	Alluvium, aeolian sand.	Alluvium, gravels, aeolian sand.	Alluvium, aeolian sand.	Alluvium, gravels, aeolian sand.
CENOZOIC	Tertiary					Conglomerate		Conglomerate
MESOZOIC			Unnamed ?		Unnamed ?			
PALAEOZOIC	PERMIAN							* Buck Fm. 140' +
PALAEOZOIC	CARBONIFEROUS							
PALAEOZOIC	DEVONIAN		Pertnjara Fm. (10,000'+) (younger than Mereenie Sst and older than Permian)	Pertnjara Fm. (200'+) (younger than Mereenie Sst and older than Permian)	Pertnjara Fm. (younger than Mereenie Sst and older than Permian)	Pertnjara Fm. (younger than Mereenie Sst and older than Permian)		
PALAEOZOIC	SILURIAN		Mereenie Sst (2000') (younger than Stokes Fm. and older than Pertnjara Fm.)	Mereenie Sst (1420') (younger than Stokes Fm. and older than Pertnjara Fm.)	Mereenie Sst (3200') (younger than Stokes Fm. and older than Pertnjara Fm.)	Mereenie Sst. (younger than Stokes Fm. and older than Pertnjara Fm.	Mereenie Sst. (2000' ±) (younger than Stokes Fm. and older than Pertnjara Fm.)	
PALAEOZOIC	ORDOVICIAN	Upper	Larapinta Group: Stokes Fm. 0-2000'	Larapinta Group: Stokes Fm. 1000'	Larapinta Group: Stokes Fm. 1500'	Larapinta Group (undifferentiated)	Stokes Fm. 464'	Unnamed 10' +
PALAEOZOIC	ORDOVICIAN	Middle	Stairway Sst. 1075-1840'; Horn Valley Siltst. 440-1400'	Stairway Sst. 500'; Horn Valley Siltst. 420'	Stairway Sst. 1070'; Horn Valley Siltst. 530'		Stairway Sst. 202'; Horn Valley Siltst. 10-80'	
PALAEOZOIC	ORDOVICIAN	Lower	Pacoota Sst. 2000-3000'	Pacoota Sst. 1500'	Pacoota Sst. 2124'		Pacoota Sst. 60'	
PALAEOZOIC	CAMBRIAN	Upper	Pertaoorrta Group: Goyder Fm. 300-1600'	* Cleland Sst. 3050'	Pertaoorrta Formation: *Goyder Member 920'	* Cleland Sst.	* Cleland Sst. 1600'	* Maurice Fm. 6000'
PALAEOZOIC	CAMBRIAN	Middle	Jay Creek Lmst. 0-300'		*Petermann Sst.Mem. 840'; *Deception Member 614'; *Illara Sst.Mem. 650'			* Ellis Sst. 2000'; * Sir Frederick Conglomerate 1200'
PALAEOZOIC	CAMBRIAN	Lower	Hugh River Shale 1100-1600'	?	*Tempe Member 1300'; *Eninta Sst. Mem. 960'	* Mt. Currie Conglomerate		
PRECAMBRIAN			Arumbera Greywacke 800-2800'	?				* Board Fm. 2800'; * Carnegie Fm. 4100'
PRECAMBRIAN			Pertatataka Fm. 2200-4000'		Pertatataka Fm.	* Winnall Beds	* Winnall Beds 6000'±	
PRECAMBRIAN			Areyonga Fm. 1300'		Areyonga Fm.	Unnamed units	* Inindia Beds	
PRECAMBRIAN			Bitter Springs Lst. 2500'	Bitter Springs Lst.	Bitter Springs Lst.	* Pinyinna Beds	Bitter Springs Lst.	Bitter Springs Lst. 1200'
PRECAMBRIAN			Heavitree Quartzite 500-1500'	Heavitree Quartzite		* Dean Quartzite		Heavitree Quartzite 1200' +
PRECAMBRIAN			Arunta Complex.					

* Unpublished Names.

TABLE II STRATIGRAPHY OF THE LAKE AMADEUS SHEET AREA

AGE	FORMATION	MAP SYMBOL	MAXIMUM THICKNESS AND LOCALITY	LITHOLOGY	TOPOGRAPHIC EXPRESSION	REMARKS
QUATERNARY		Qa Qs Qt Ql Qg		Alluvium and river gravels. Aeolian sand. Evaporites Travertine Amorphous gypsum.	Stream deposits, alluvial flats and scree slopes. Dunes and sand plain. Beds of salt lakes. Low mounds Low mounds and encrustations.	
TERTIARY		Tc T	20' + Eastern George Gill Range. 20' + Near Inindia Bore.	Boulder conglomerate. Limestone.	Caps mesas. Mounds and low mesas.	Confined to area near George Gill Range. Confined to Inindia Bore area.
MESOZOIC		M	40' + Eastern George Gill Range.	Silty sandstone, poorly sorted sandstone and siltstone.	Mesas.	Most exposures in George Gill Range.
PALAEOZOIC — UNDIFFERENTIATED.	PERTNJARA FORMATION	Pzp(a) Pzp(s)	2800' + Measured on photographs on south flank of Mereenie Anticline. (Siltstone only)	Siltstone and silty limestone. Red-brown and white sandstone.	Underlies valley floor. Prominent rugged ranges.	
PALAEOZOIC — UNDIFFERENTIATED.	MEREENIE SANDSTONE	Pzm(2) Pzm(1)	2230' North flank, Johnnys Creek Anticline.	White sandstone with large cross-beds. Red-brown sandstone and some siltstone.	Rugged topography in ranges or lowridges in sand plain. Prominent scarps.	Contains single specimen of "Cruziana" and "pipe rock".
PALAEOZOIC — UNDIFFERENTIATED.	MOUNT CURRIE CONGLOMERATE	Pzc	-	Polymictic conglomerate with phenoclasts of porphyry, rhyolite basalt, quartz, quartzite and sandstone up to 24" across in matrix of coarse sand.	High rounded hills.	Possibly Cambrian in age.
PALAEOZOIC — ORDOVICIAN	LARAPINTA GROUP Є/O1 — STOKES FORMATION	Ot	1180' 8 miles S.E. of Bagot Springs.	Thin bedded limestone with marine fossils, siltstone, shale and fine silty sandstone.	Forms strike valleys.	Outcrops mostly very poor.
PALAEOZOIC — ORDOVICIAN	LARAPINTA GROUP — STAIRWAY SANDSTONE	Os	780' West part Johnnys Creek Anticline.	Sandstone, siltstone and thin beds of limestone. Marine fossils.	Resistant sandstone beds form sharp ridges.	Contains thin beds rich in phosphate.
PALAEOZOIC — ORDOVICIAN	LARAPINTA GROUP — HORN VALLEY SILTSTONE	Oh	285' Ochre Hill.	Siltstone, and blue-grey & fawn limestone. Marine fossils.	Forms strike valleys.	Outcrops very poor.
PALAEOZOIC — ORDOVICIAN	LARAPINTA GROUP — PACOOTA SANDSTONE	Є/Op	1060' South-flank Parana Hill Anticline.	Medium and coarse sandstone, in places conglomeratic. Marine fossils.	Strike ridges.	
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION Єp — GOYDER MEMBER	Єg	850' Northern-flank of Parana Hill Anticline.	Silty sandstone, silty limestone, and siltstone.	Low rounded hills.	Very poorly exposed in most places.
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION — PETERMANN SANDSTONE MEMBER	Єe	640' South-flank of Parana Hill Anticline.	Medium and thin-bedded red-brown sandstone with minor siltstone.	Strike ridges.	
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION — DECEPTION MEMBER	Єd	460' South-flank of Parana Hill Anticline.	Siltstone and shale with micaceous haematite, minor red-brown sandstone.	Underlies valley floor.	Poor outcrops.
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION — ILLARA SANDSTONE MEMBER	Єi	420' North-flank of Parana Hill Anticline.	Poorly bedded red-brown sandstone with clay pellets.	Strike ridges.	
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION — TEMPE MEMBER	Єt	400'+ North-flank of Parana Hill Anticline.	Red, blue-grey, grey-green siltstone, glauconitic sandy dolomite, glauconitic and feldspathic sandstone. Marine fossils.	Forms valleys. Dolomite usually forms small ridges or ledges on valley slopes.	
PALAEOZOIC — CAMBRIAN	PERTAOORRTA FORMATION — ENINTA SANDSTONE MEMBER	Єn	460' Parana Hill Anticline.	Red-brown sandstone with clay pellets and chert fragments. Basal part glauconitic and calcareous. Weathers massively.	Strike ridges.	
PALAEOZOIC — CAMBRIAN	CLELAND SANDSTONE	Єc	1570' 4 miles west of Kulpi Rock Hole.	Poorly sorted, pebbly, micaceous sandstone and interbedded red-brown siltstone.	Low hills, some strike ridges.	Probably lateral equivalent of Petermann Sandstone Member, Deception Member and Illara Sandstone Member.
UPPER PROTEROZOIC	WINNALL BEDS	Buw	5700'± N.E. of Inindia Bore. Measured on photographs.	Sandstone, fine conglomerate and interbedded siltstone. Some ?worm tubes and casts.	Prominent sharp ridges.	Probably lateral equivalent of Pertatataka Formation. Possibly Cambrian in part.
UPPER PROTEROZOIC	PERTATATAKA FORMATION	Bup	160' South-flank of Parana Hill Anticline.	Siltstone, sandstone and minor limestone.		
UPPER PROTEROZOIC	ININDIA BEDS	Bun	-	Interbedded siltstone, chert, chert breccia, medium and coarse sandstone. Striated cobbles in overlying scree.	Rubble covered flats and low ridges of chert and chert breccia.	Correlated with Areyonga Formation.
UPPER PROTEROZOIC	AREYONGA FORMATION	Bua	750' Core of Parana Hill Anticline.	Tillitic textured claystone, siltstone and sandstone; silty feldspathic sandstone and minor siltstone and limestone.	Poor exposures in low rounded hills.	
UPPER PROTEROZOIC	BITTER SPRINGS LIMESTONE	Bub	1660' Core of Parana Hill Anticline.	Dolomite with minor limestone siltstone and sandstone.	Low hills, strike ridges, and small pinnacles.	Formation probably contains thick evaporites and gypsum at depth.

TABLE III   THICKNESSES OF FORMATIONS ON THE LAKE AMADEUS SHEET AREA

FORMATION	MAP SYMBOL	SECTION NUMBER																		
		LAW 1	LAW 2	HYW 1	HGW 1	LAR 1	LAR 2	LAR 3	LAC 1	LAC 2	LAC 3	LAC 4	LAC 5	LAC 6	LAC 7	LAC 8	LAC 9 & 10	LAC11	LAC12	LAC13
PERTNJARA FORMATION	Pzp(a) (s)	NE	A	A	P	NM	NPS	NPS	A	NM	NM	NM	NM	A	A	A	A	NM	A	A
MEREENIE SANDSTONE	Pzm(1) (2)	1968'+ (768' measured, 1200' photo-interpreted)	P	NM		NM	NM	NPS	NM	NM	NM	NM	NM	A	A	NM	NM	2234'	NM	NM
STOKES FORMATION	Ot	464'		NM		1093'	1108'	NE	217'+	847'	NM	953'	NM	A	A	NM	1182'	NM	P	NM
STAIRWAY SANDSTONE	Os	203'		NM		588'	622'	60'+	NM	NM	553'+	784'	516'	NM	NM	NM	653'		99'+	199'+
HORN VALLEY SILTSTONE	Oh	182'		NM		198'	236'	80'	NE	NE	NE	273'	179'	280'	285'	144'	217'		160'	NE
PACOOTA SANDSTONE	Є/Op	30'+		NM		1052'	1062'	60'				NM	NM	NM	NM	516'+	NM		265'	
GOYDER MEMBER	Єg	A		NM	NM	851'	621'	A				NE	NE	NM	NM	NM	NM		293'	
PETERMANN SANDSTONE MEMBER	Єe	A		NM		499'	639'	A						NE	NE	NE	NE		A	
DECEPTION MEMBER	Єd	A		NM		318'	461'	A											A	
ILLARA SANDSTONE MEMBER	Єi	A	See Section LAR 2	NM		421'	272'	A											A	
TEMPE MEMBER	Єt	A		521'	590'	400'+	384'	A											A	
ENINTA SANDSTONE MEMBER	Єn	A		?139'	NM	NM	456'	A											A	
CLELAND SANDSTONE	Єc	NE	A	A	A	A	A	P											1568'	
WINNALL BEDS	Buw	NE	A	A	A	A	A	NE											NE	
PERTATATAKA FORMATION	Bup	A		83'+	NM	P	159'	A												
AREYONGA FORMATION	Bua	A	746'+	P	A	NPS	472'	A												
BITTER SPRINGS LIMESTONE	Bub	NE	1662'+	P	P	NPS	See LAW 2	NE												

HY - HENBURY SHEET AREA
HG - HERMANNSBURG SHEET AREA
LA - LAKE AMADEUS SHEET AREA

A - ABSENT FROM SEQUENCE
P - POOR OR INCOMPLETE OUTCROP
NE - NOT EXPOSED (MAY BE PRESENT)
NM - NOT MEASURED (GOOD OUTCROP PRESENT)
NPS - NOT PRESENT DUE TO STRUCTURE

A section (LAW2) was measured through the formation in an inlier in the core of the Parana Hill Anticline. Here the formation dips at angles generally in excess of 50° to the south and there is no evidence of repetition of beds within the formation. The base of the formation is not exposed. It is overlain either disconformably or with a slight angular unconformity by the Areyonga Formation and with an angular unconformity by the Pertatataka Formation. The section measured in the Bitter Springs Limestone gave 1670 feet of dolomite, minor limestone and dolomitic limestone, which all contain variable amounts of nodular, thin bedded and laminated chert, and interbedded siltstone and sandstone. The dolomitic and calcareous parts comprise 75% of the measured section, siltstone about 22% and sandstone about 3%. The dolomite is mostly hard, dark grey and in places purple-brown, pink or yellow, fine grained, laminated, thin or medium bedded, with variable amounts of white, grey and pink chert. Some specimens of fresh dolomite are foetid. In rare places in this section the dolomite contains about 5% angular detrital quartz up to 3 mm. across. Near the top of the formation the dolomite contains abundant rounded grains and pebbles of chert up to 1½ inches across.

Stromatolites are abundant in the lower 300 feet of the formation and form small bioherms. Some stromatolites occur in the upper few feet of the formation but they are not so abundant.

The largest thickness of siltstone occurs in the interval 400-700 feet above the base of the formation. In most places in the formation the siltstone contains thin beds of dolomite.

The occurrence of sandstone in the Bitter Springs Limestone has not been recorded previously. The sandstone is 56 feet thick in section LAW2 and its base is 200 feet from the top of the formation. It is white or pale brown, well sorted, medium and friable with very little interstitial material. The sandstone is present as discrete lenses within the formation.

An unexposed interval representing a thickness of section of about 215 feet occurs between the top of the Bitter Springs Limestone and the Areyonga Formation. No direct contacts were seen between the two formations in the Parana Hill Anticline.

No other sections were measured in the formation because of incomplete exposure or severe contortion of the beds.

In areas outside the Parana Hill Anticline the outcrops of the Bitter Springs Limestone are made up mostly of dark-grey or yellow dolomite with minor amounts of interbedded siltstone. In several places the formation contains beds of sandy dolomite which may contain a few fragments of dolomite. In some places these sandy sections have some small cross-beds. The chert in the Bitter Springs Limestone is in places oolitic and where all the dolomite and limestone has been silicified (e.g. LA235) the original oolitic nature of the rock is preserved in the siliceous material.

Many of the isolated outcrops mapped as Bitter Springs Limestone occur in diapiric structures and are associated with masses of sheared and contorted rock gypsum. The diapiric structures indicate the possibility of inclusion of thick evaporites in the formation. Öpik (pers.comm.) has suggested that because the Cambrian Period was one of widespread gypsum formation in Australia, it may be inferred that the dolomite outcrops in diapiric structures may be Cambrian in age. However the stratigraphic position of the formation (for example in the Parana Hill Anticline it occurs unconformably below Lower Cambrian fossiliferous horizons) indicates that it is Upper Proterozoic in age and can be identified with the Bitter Springs Limestone.

In the Inindia Bore area the Bitter Springs Limestone is overlain by the Larapinta Group but the nature of the contact is not known. In other areas the formation is overlain apparently conformably by the Inindia Beds and at one locality (LA525) the contact is gradational. In several places where the Bitter Springs Limestone crops out in diapiric structures the formation has probably intruded the Winnall Beds. The details of these diapiric structures are discussed elsewhere in this report. In the Parana Hill Anticline the Bitter Springs Limestone is unconformably overlain by the Pertatataka Formation. The base of the Bitter Springs Limestone is not exposed on the Lake Amadeus Sheet area.

Areyonga Formation

The Areyonga Formation was defined by Prichard and Quinlan (1962) as "...... the unit, consisting essentially of two members, a siltstone and a quartz greywacke, which disconformably overlies the Bitter Springs Limestone at Ellery Creek and is conformably overlain by the Pertatataka Formation." Prichard and Quinlan (op.cit.) say that the lower siltstone member consists of interbedded tillitic siltstone, quartz greywacke, pebble conglomerate, a boulder bed and a few thin beds of yellow limestone. The upper member is a quartz greywacke containing up to 15% feldspar.

On the Lake Amadeus Sheet area only one outcrop of the Areyonga Formation has been mapped, and this occurs in an inlier in the core of the Parana Hill Anticline. Exposures of the formation are poor with the exception of some beds of resistant silty quartz sandstone and boulder beds.

Two incomplete sections have been measured through the formation. At LAR2 470 feet of the formation is exposed. 750 feet of section was measured at LAW2 where a larger area of the unconformably overlying Pertatataka Formation has been removed. The top of the formation is concealed beneath the unconformity and there is only 12% exposure in the section. The poorly sorted pebble and boulder beds which are partly exposed in the lower 400 feet of the formation contain fragments of red-brown and grey dolomite (from the Bitter Springs Limestone), chert, siltstone, gneiss, and basic igneous rocks in a matrix is grey rock flour and calcareous sand. Some of the boulders measure 2 feet across. The upper part of the formation contains silty red-brown dolomite and poorly sorted silty sand with feldspar fragments. There is some shale scree in this part of the section. Striae are well preserved in the yellow brown partly silicified siltstone fragments. Many of the fragments are facetted.

At Section LAR2 there is 18% exposure of 470 feet of the formation. The topmost 16 feet of the formation contains well rounded to subangular boulders of sandstone, quartzite, dolomite, chert, gneiss and mica schist in a clay matrix. The only other exposed part of the formation occurs about 170 feet above its base and is made up of siltstone with subangular and subrounded erratics of chert, dolomite, sandstone and granite gneiss up to two feet in diameter. Many of the boulders are striated.

The abundance of dolomite fragments in many parts of the formation indicates considerable erosion of the underlying Bitter Springs Limestone and the disconformable or possible unconformable relationships between the two formations. The Areyonga Formation is unconformably overlain by the Pertatataka Formation.

The Areyonga Formation contains no fossils with the exception of stromatolites in the derived boulders of Bitter Springs Limestone. The formation occurs stratigraphically well below the fossiliferous Cambrian Members of the Pertaoorrta Formation and is regarded as Upper Proterozoic. It is correlated with the Inindia Beds because of their similar stratigraphic position.

Inindia Beds

The Inindia Beds is a new name applied to the sequence of siltstone, sandstone, chert, chert breccia and thin inter beds of dolomite which conformably overlies the Bitter Springs Limestone and is overlain, probably unconformably, by the Winnall Beds. The thickness of the Inindia Beds is unknown because of poor exposures and incomplete sequences. The reference area lies 36 miles south-east of Mt. Murray. The Beds are named after Inindia Bore in the south-east corner of the Lake Amadeus 1:250,000 Sheet area.

The Inindia Beds occur in isolated poor outcrops between Mt. Murray and Inindia Bore, to the north of Lake Amadeus. The Beds crop out usually in low mounds or on rubble covered flats, with low ridges of the more resistant chert beds. On the northern margin of Lake Amadeus the Inindia Beds form the beds of some salt pans.

The Inindia Beds include thick sections of white, brown, red-brown and grey, thin and medium bedded, well sorted and some sandy siltstone, white, fine and medium, in places poorly sorted sandstone, thin beds of chert and chert breccia and a few thin interbeds of silty, fine, brown dolomite. Parts of some outcrops of the Inindia Beds are overlain by scree which contains striated pebbles and boulders of dolomite, algal dolomite (probably derived from the Bitter Springs Limestone), siltstone and chert, together with boulders of metamorphic rocks (Fig.6). None of these boulders have been found in situ in the Inindia Beds.

The Winnall Beds probably overlie the Inindia Beds with an angular unconformity. The contact is not visible and the unconformity is assumed from the scanty dip information which is available in the Inindia Beds of the reference area. The conformable and gradational contact of the Inindia Beds with the Bitter Springs Limestone was seen at LA525. In the reference area, near LA235, the Inindia Beds occur near outcrops of oolitic chert which is possibly silicified Bitter Springs Limestone. The nature of the contact here is not visible.

The Inindia Beds contain no fossils. Its stratigraphic position between the Winnall Beds and Bitter Springs Limestone suggests that it is Upper Proterozoic in age and can be correlated with the Areyonga Formation.

Pertatataka Formation

The Pertatataka Formation was defined by Prichard and Quinlan (1962) as 'the sequence of siltstone which conformably overlies the Areyonga Formation and is conformably succeeded by the Arumbera Greywacke'. The name was derived from the Pertatataka Series of Madigan (1932) which was later divided into the Areyonga and Pertatataka Formations by Prichard and Quinlan (1962).

At the type section 3 miles west of Ellery Creek in the Western MacDonnell Ranges the Pertatataka Formation is 2,200 feet thick (Prichard and Quinlan, 1962).

The Pertatataka Formation is only exposed in the north-eastern part of the Lake Amadeus Sheet area, in the core of the Parana Hill Anticline. In this elongate domal structure the unit unconformably overlies the Bitter Springs Limestone and the Areyonga Formation and is disconformably or unconformably overlain by the Pertaoorrta Formation. The Pertatataka Formation is poorly exposed with the exception of some beds of sandy dolomite. The only section measured (LAR 2) gave a thickness of 159 feet.

Fig. 6. Striated and facetted pebbles and cobbles
in scree overlying the Inindia Beds.

In the Parana Hill Anticline, some pale red-brown and pink-brown, laminated, micaceous siltstone and shale crop out under a protective capping of yellow-brown and cream, sandy dolomite and similar fine sediments are thought to occupy most of the concealed interval. The sandy dolomite and calcareous sandstone interval is not more than 10 feet thick but forms a prominent ridge or escarpment around the domal structure. Thin beds of black, grey and white chert breccia crop out above the carbonate horizon in Parana Hill Anticline and in the anticlines to the East on the Henbury Sheet area. The Pertataka Formation overlies the Bitter Springs Limestone and the Areyonga Formation with a strong angular unconformity in the Parana Hill Anticline. The upper boundary of the Pertataka Formation is poorly defined in this area but it is suspected to be just above the chert breccia horizon mentioned previously. The siltstone and sandstone sequence above the chert breccia has been mapped as the Eninta Member of the Pertaoorrta Formation and appears to lie with a small angular discordance on the Pertatataka Formation at the eastern end of the Parana Hill Anticline and in the cores of anticlines to the east on the Henbury Sheet area.

The Pertatataka Formation is considered to be laterally equivalent to the Winnall Beds, which crop out on the southern half of the Lake Amadeus Sheet area. The Winnall Beds consist of a sequence of siltstone and sandstone which attain a thickness of more than 5,000 feet in the Inindia Bore area and which are unconformably overlain by the Pertaoorrta Formation, the Cleland Sandstone and Larapinta Group sediments. The Winnall Beds unconformably overlie the Inindia Beds which are considered to be laterally equivalent to the Areyonga Formation.

In the Western MacDonnell Ranges, the Pertatataka Formation is probably between 2,000 and 4,000 feet thick and lies apparently conformably between the Areyonga and Pertaoorrta Formations. In the Gardiner Range, the Pertatataka Formation is approximately 2,000 feet thick and lies apparently conformably on the Areyonga Formation and unconformably beneath the Pertaoorrta Formation. However, in the Parana Hill Anticline, the Pertatataka Formation is only 160 feet thick and lies with a marked angular unconformity above the Areyonga Formation and with a slight angular discordance beneath the Pertaoorrta Formation.

The marked thinning of the Pertatataka Formation in the Parana Hill Anticline and the relationships with the underlying and overlying units suggest that there may have been structural growth during deposition in this area. Alternatively, after the folding which followed the deposition of the Areyonga Formation this area may have remained above the level of sedimentation during most of the time in which the Pertatataka Formation was being deposited in the areas to the north.

Structural growth during deposition is favoured because of the lack of any basal conglomerate in the Pertatataka Formation in the Parana Hill Anticline.

The unconformity above the Pertatataka Formation is not very marked and there is no evidence for any great loss of section along strike.

No fossils have been found in the Pertatataka Formation and the age of the unit can only be deduced from its stratigraphic position. The overlying Pertaoorrta Formation contains fossils of a late Lower Cambrian or early Middle Cambrian age in the north-east corner of the Lake Amadeus Sheet area. The Pertatataka Formation is tentatively regarded as being of Upper Proterozoic age.

Winnall Beds (new name)

The name Winnall Beds is given to the sequence of siltstone, sandstone and pebbly sandstone which lies probably unconformably above the Inindia Beds and unconformably below the Pertaoorrta Formation, Cleland Sandstone, and Larapinta Group.

The beds are named from Winnall Ridge, a prominent feature in the southern half of the Lake Amadeus Sheet area. Winnall Ridge was originally named by Gosse (1874) after a member of his party.

The Winnall Beds crop out as prominent strike ridges throughout a 30 miles wide strip of country which extends from the south-east to the north-west corner of the Lake Amadeus Sheet area. The blocky, silicified sandstone of the Winnall Beds gives a jagged outline to the outcrops.

No section has been measured through the Winnall Beds, but it is estimated from field and photographic evidence to have a thickness of at least 5,000 feet in the south-east corner of the Lake Amadeus Sheet area. The thickness of the unit in the other areas is uncertain because of incomplete exposure.

A three-fold division of the Winnall Beds is possible from the air-photo pattern; the three divisions are a lower and upper silty unit and a middle sandstone unit.

The lower silty unit comprises red-brown and green, partly calcareous siltstone, with some interbeds of fine grained, green sandstone, two to three inches thick. Exposure of this lower unit is very poor. It only crops out in creek beds on the north side of Winnall Ridge and on the north side of the long ridge to the west of Winnall Ridge.

The middle unit consists of sandstone which is grey, white or brown, medium to coarse grained, sub-rounded, poorly sorted, and has a white silty matrix in places. There are some very coarse pebbly beds in which the pebbles are angular and consist of chert, oolitic chert, vein quartz and silicified sandstone. The bedding varies from medium to very thick; cross-bedding is very well developed (a feature which makes some parts of the Winnall Beds superficially similar to the Mereenie Sandstone) and features such as slumping, ripple marks, scour and fill structures, mud cracks, synaeresis cracks (White, 1961) and mud-pellet markings are very common. This middle unit weathers brown or grey and because it is strongly silicified forms prominent ridges.

The sandstone of the middle unit of the Winnall Beds is interbedded in places with poorly exposed, green siltstone but this only constitutes a very minor part of the total thickness of the middle unit.

The upper silty division is made up mainly of siltstone with some thin-bedded, silty sandstone. The siltstone is white and pale green, fine grained and laminate. It is soft and weathers grey-green or brown. The silty sandstone is grey and green, moderately rounded, poorly sorted, thinly bedded with some fine cross-laminations, and ripple marks. Both the siltstone and the sandstone interbeds of the upper division of the Winnall Beds are very poorly exposed, and only crop out in creek beds.

The relationship of the Winnall Beds to the overlying and underlying formations is obscured, though in the central part of the Lake Amadeus Sheet area there is evidence of an angular unconformity of about 50° between the Winnall Beds and the underlying Inindia Beds.

The contact with the overlying Pertaoorrta Formation is mostly poorly exposed but in the south-east corner of the Lake Amadeus Sheet area, where exposure is moderate, there is thought to be an angular unconformity of 20° to 30° between the two units. The boundary between the Winnall Beds and the Pertaoorrta Formation is marked by the change from the upper siltstone of the Winnall Beds to the coarse sandstone of the Pertaoorrta Formation (The sandstones are very similar to those of the middle division of the Winnall Beds). In the south-east corner of the Lake Amadeus Sheet area the Winnall Beds are also overlain by the Pacoota Sandstone with a well exposed angular unconformity of about 45° (see figs 11 and 12).

The Winnall Beds have fossil tracks and trails in some beds but the majority of these markings are indeterminate. One fossil (LA 508) found in the long strike ridge 30 miles south-east of Reedy Waterhole consists of "sandsticks", approximately one cm. in diameter and 10-15 cms. in length, lying close together and parallel to each other; they are horizontal to the bedding plane and occur in large numbers, forming colonies at this one locality (see Figure 7).

Fig. 7. "Pipe-rock" in Winnall Beds. "Pipes" (cf. Syringomorpha) parallel to the bedding.

Öpik (pers. comm.) has suggested that this trace fossil is comparable with Syringomorpha (Northorst) which is described as follows by Hass, Hantzschel, Fisher, Howell, Rhodes, Müller and Moore (1962):-

"Roller-like sticks several cm. in length and one to two mm. in thickness lying close together; slightly arched touching each other along whole length and forming complete slab; occurring in large numbers independent of bedding. (Possibly seaweed; work of gregarious worms on flat sub-stratum according to Rudolf Richter)."

Thus, the main difference between the pipes in the Winnall Beds and Syringomorpha is the larger diameter of the pipes; this prevents any certain application of the generic name. The mode of embedding of the pipes and their structure are however very similar to Syringomorpha.

On a basis of the similarities between the pipes of the Winnall Beds and Syringomorpha it is possible to speculate on a Cambrian or possibly even Lower Cambrian age for the Winnall Beds.

The Winnall Beds are tentatively correlated with the Pertatataka Formation from its stratigraphic position between the Pertaoorrta Formation and the Inindia Beds.

CAMBRIAN

Changes of Nomenclature and New Rock Units

As a result of mapping the Lake Amadeus and Mount Liebig Sheet areas together with brief reconnaissance traverses to the Western MacDonnell Ranges, it has been decided to change some of the existing nomenclature as defined by Prichard and Quinlan (1962), and to define some new units.

The changes to the existing nomenclature are:-

1. The Pertaoorrta Group has been downgraded to Pertaoorrta Formation and its constituent formations to members.

2. The Arumbera Greywacke has been downgraded to Arumbera Greywacke Member and has been included in the Pertaoorrta Formation. The reasons for these changes are:-

1. The Arumbera Greywacke is considered to be lithologically related to the Pertaoorrta Group and was originally included in the 'Pataoorrta Series' of Mawson and Madigan (1930).

2. The overall lithology of the Pertaoorrta Group (plus the Arumbera Greywacke) is recognisable away from the type area but the individual formations are not. This means that new formations (and hence a new group) must be established at localities away from the type area. It is considered preferable to downgrade the defined units;

use one name (Pertaoorrta Formation) for the sequence and to define new members for distinct rock bodies within this sequence.

The downgrading of the existing rock units is considered to be desirable at present, but a reversion to the old status may be possible on the completion of the mapping of the Amadeus Basin.

Five new members have been differentiated within the Pertaoorrta Formation. The new units have been mapped on the north-east corner of the Lake Amadeus Sheet area and have been recognised on the neighbouring Mount Liebig, Hermannsburg and Henbury Sheet areas.

Pertaoorrta Formation

The name Pertaoorrta Formation is used for the sequence of interbedded siltstone, sandstone, dolomitic limestone, shale and quartz greywacke which lies conformably beneath the Pacoota Sandstone and both conformably and unconformably above the Pertatataka Formation.

The type locality of the Pertaoorrta Formation is in the MacDonnell Ranges near Ellery Creek and the unit includes both the 'Pertaoorrta Group' and 'Arumbera Greywacke' of Prichard and Quinlan (1962).

Mawson and Madigan (1930) first used the term 'Pataoorrta Series' for 'the interval from the middle quartzite to the base of the upper or Pacoota quartzite'; i.e. the Arumbera Greywacke, Hugh River Shale, Jay Creek Limestone and Goyder Formation of Prichard and Quinlan (1962). Chewings (1931) altered the spelling to 'Pertaoorrta Series' and Madigan (1932) said 'the Pertaoorrta Series lies between Nos. 3 and 4 quartzites and includes No.3' (i.e. units Arumbera Greywacke to Goyder Formation inclusive of Prichard and Quinlan (1962). However, in the same paper, Madigan used the heading 'No.3 quartzite and Pertaoorrta Series' and Prichard and Quinlan (1962) claim by inference, that the No.3 quartzite, was not included in the 'Pertaoorrta Series'. Prichard and Quinlan (1962) then state that 'The name Pertaoorrta Series was used essentially as a rock term and is hence changed to Pertaoorrta Group, which is defined as consisting of the Goyder Formation, Jay Creek Limestone and Hugh River Shale. The Group is conformable between the Arumbera Greywacke below and the Pacoota Sandstone above'.

The name Pertaoorrta Formation is used in this report for the sequence first termed 'Pataoorrta Series' by Mawson and Madigan (1930) and this Formation contains the following members in the type area in the MacDonnell Range:- Goyder Member, Jay Creek Limestone Member, Hugh River Shale Member and Arumbera Greywacke Member. In the core of the Parana Hill Anticline on the Lake Amadeus Sheet area, the Pertaoorrta Formation has been divided into the following Members: Goyder Member, Petermann Sandstone Member (new name), Deception Member (new name), Illara Sandstone Member (new name), Tempe Member (new name) and Eninta Sandstone Member (new name). The type area for these new members is in the Gardiner Range on the Mt. Liebig and Hermannsburg Sheet areas.

The Pertaoorrta Formation crops out on the eastern half of the Lake Amadeus Sheet area as low ridges and hills. The best exposures are in the core of the Parana Hill Anticline where the more resistant units stand up as ridges approximately 300 feet high. One incomplete section and one complete section were measured through the Pertaoorrta Formation. The complete section (LAR2) was measured on the southern limb of the Parana Hill Anticline and gave a thickness of 2,833 feet, which is considerably less than that measured in the Gardiner Range (approximately 5,300 feet) or at Ellery Creek (4,175 feet). The decrease in thickness may be a reflection of the proximity of the basin margin or it may be due to structural growth during deposition.

The dominant lithology of the Pertaoorrta Formation on the Lake Amadeus Sheet area is the red-brown and purple-brown, micaceous sandstone which forms three separate ridges in areas of good exposure. These units have been mapped as Members in the Parana Hill Anticline but owing to their lithological similarity have not been differentiated in the poorer exposures elsewhere on the Sheet area. The proportion of arenites to lutites is approximately twice as great both in the Parana Hill Anticline and the Gardiner Range as in the type section of the Formation at Ellery Creek.

The sandstone members are separated by recessively weathering units of siltstone, very fine silty sandstone, carbonate and possibly shale.

The lithologies of the individual Members of the Pertaoorrta Formation will be described separately so further remarks in this section will be limited to a discussion of outcrops where division into members ~~have~~ has not been attempted.

South of the George Gill Range near Doughboy Creek the Pertaoorrta Formation is exposed in the core of a west plunging anticline. The sequence consists of sandstone with interbeds of siltstone. The sandstone is white, red-brown and purple-brown, medium to coarse grained, moderately sorted, crossbedded, micaceous and possibly feldspathic. The siltstone is red-brown and purple-brown, laminate and micaceous. Travertine at the surface suggests that there are some calcareous units in the sequence but the only exposure of limestone seen was right in the core of the structure (LA47). The pink and grey, thin bedded, fine grained, non-foetid limestone is interbedded with red-brown, laminated siltstone and shale at this locality.

A similar sequence is exposed approximately 12 miles south of Reedy Rock Hole. The lowest unit of the Pertaoorrta Formation exposed in this structure is a sequence of red-brown, micaceous siltstone and shale with interbeds of light grey, sandy limestone. This is overlain by a sequence of red-brown and purple-brown, medium to coarse grained, cross-bedded, micaceous sandstone with scattered, rounded pebbles of vein quartz, chert and silicified sandstone. This is in turn overlain by red-brown and white, thin bedded, crossbedded, fine to medium grained, micaceous sandstone and silty sandstone with interbeds of red-brown, laminated siltstone. All the sandstone units contain some clay pellets.

In the south-eastern corner of the Lake Amadeus Sheet area, sediments tentatively regarded as belonging to the Pertaoorrta Formation appear to unconformably overlie the Bitter Springs Limestone, Inindia Beds. These sediments include micaceous sandstone, siltstone, conglomeratic sandstone and conglomerate. The sandstone and siltstone are red-brown and chocolate-brown, cross bedded friable, partly calcareous and extremely micaceous. The conglomerate contains well rounded pebbles, cobbles and boulders up to 3 feet in diameter in a matrix of coarse silty sandstone. The phenoclasts are of quartzite, chert, vein quartz and sandstone. The sorting of these deposits is poor in places but the majority of the fragments are very well rounded. Many of the boulders are thought to have been derived from the underlying Winnall Beds.

The Pertaoorrta Formation is overlain conformably by the Pacoota Sandstone and has both conformable and unconformable contacts with the underlying Pertatataka Formation. In the Parana Hill Anticline the contact between the Pertaoorrta and Pertatataka Formation is apparently conformable where section LAR 2 was measured, but there is possibly a slight angular discordance at the eastern end of the structure. A similar discordance is suspected in the cores of structures to the east on the neighbouring Henbury Sheet area. If the conglomeratic unit (Fig.8) exposed in the south-eastern part of the Lake Amadeus Sheet area is part of the Pertaoorrta Formation, then the Formation lies with a very strong angular unconformity on the Winnall Beds in this area.

The sandstones of the Pertaoorrta Formation are very similar to, and probably laterally equivalent to the Cleland Sandstone, which crops out on the western half of the sheet area. More exact correlation is not possible because of the lack of continuous outcrop.

The only fossils known from the Pertaoorrta Formation in the Lake Amadeus Sheet area were found in the Tempe Member in the Parana Hill Anticline. These fossils indicate a late Lower Cambrian or early Middle Cambrian age for this Member, (Joyce G. Tomlinson, B.M.R. pers.comm.).

Fig. 8. Pebbles, cobbles and boulders mainly of quartzite, in conglomerate and conglomeratic sandstone of the Pertaoorrta Formation, LA 213.

The Pacoota Sandstone, which conformably overlies the Pertaoorrta Formation, is known to range in age from Upper Cambrian to Lower Ordovician. The Pertaoorrta Formation is considered to be mainly of Cambrian age but may extend into the Lower Ordovician in the south-eastern part of the Lake Amadeus Sheet Area.

Eninta Sandstone Member (new name)

The name Eninta Sandstone Member is given to the sequence of fine and medium grained, ferruginous, feldspathic, micaceous sandstone with interbedded micaceous siltstone which forms the basal unit of the Pertaoorrta Formation in the Gardiner Range. The Member lies unconformably on the Pertatataka Formation and is conformably overlain by the Tempe Member in the type locality 4 miles west of Katapata Gap in the Gardiner Range. The name is derived from Eninta Creek, part of which lies approximately 14 miles east-north-east of Tempe Downs Homestead on the Henbury Sheet area.

On the Lake Amadeus Sheet area, the Eninta Sandstone Member is only exposed in the flanks of the Parana Hil Anticline (Figs. 9 & 10) where it forms a discontinuous ridge around the domal structure.

The Member is 456 feet thick at LAR2 in the south flank of the Parana Hill Anticline and 1200 feet thick in the Gardiner Range on the Mount Liebig Sheet area.

The dominant rock type of the Eninta Sandstone Member is red or red-brown, thin bedded or laminated, fine and medium grained, moderately sorted, cross-bedded, feldspathic sandstone. Many of the cross-beds have slumped forming 'flow rolls' and other slump structures. The sandstone has many interbeds of laminated, micaceous siltstone and some conglomerate beds with fragments of white chert.

The Eninta Sandstone Member is the basal unit of the Pertaoorrta Formation in the Gardiner Range and Parana Hill Anticline. The Member unconformably overlies the Pertatataka Formation in the Gardiner Range and a slight angular discordance is also suspected between these units, in the Parana Hill Anticline. The Eninta Sandstone Member is overlain conformably by the Tempe Member in both the Gardiner Range and the Parana Hill Anticline and was mapped as Arumbera Greywacke by Wells et.al. (1962) on the Mount Liebig Sheet area. It is now thought that the three basal Members of the Pertaoorrta Formation in the Gardiner Range (Eninta Sandstone Member, Tempe Member and Illara Sandstone Member) are probably laterally equivalent to the Arumbera Greywacke in the Western MacDonnell Ranges (as mapped by Prichard and Quinlan, 1962).

No fossils have been found in this Member but the overlying Tempe Member contains fossils of a late Lower Cambrian or early Middle Cambrian age. The Eninta Sandstone Member is tentatively regarded as being of Lower Cambrian age.

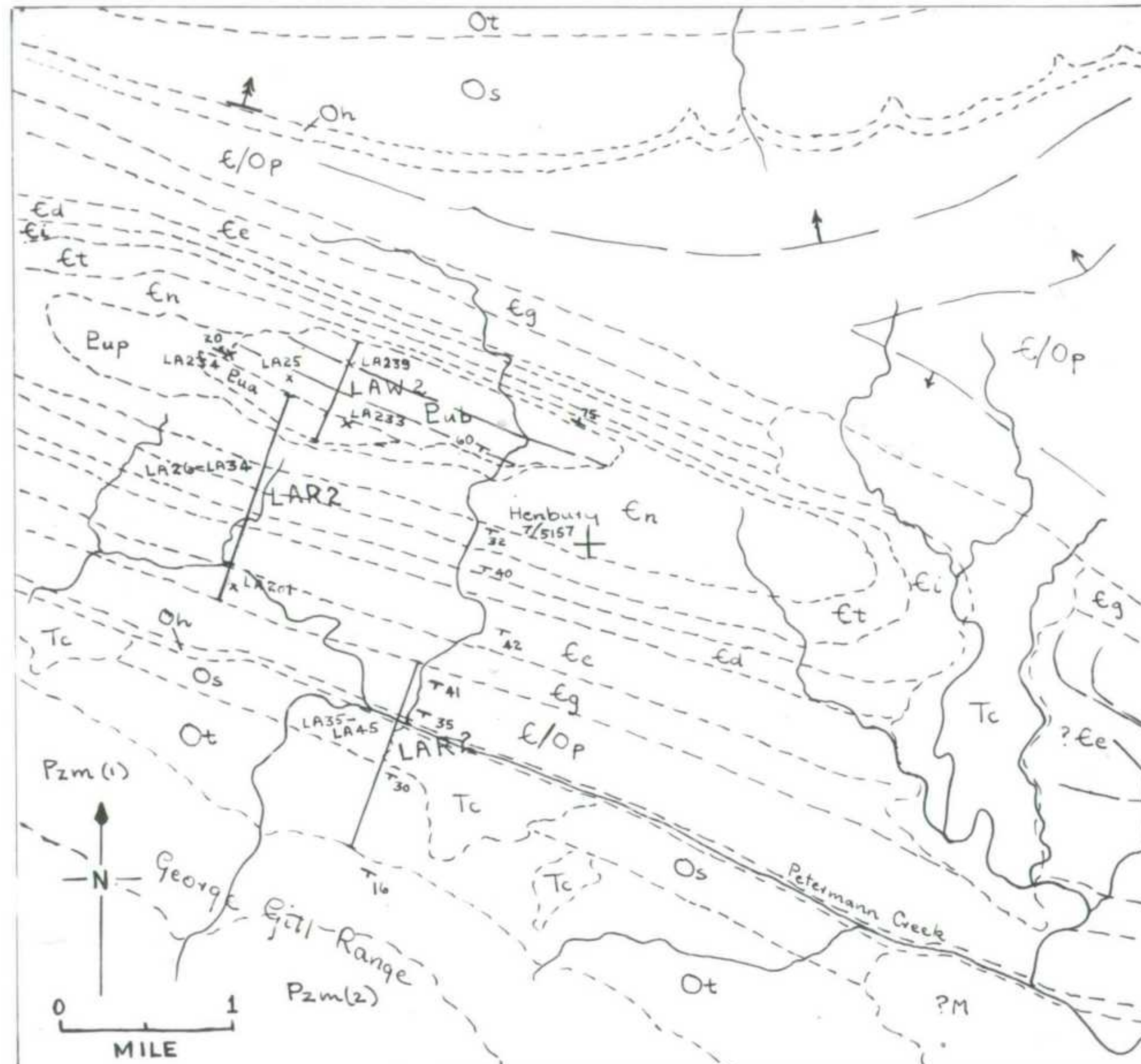


Fig. 9 Unconformity beneath the Pertatataka Formation in the core of the Parana Hill Anticline. Bitter Springs Limestone - Pub; Areyonga Formation - Pua; Pertatataka Formation - Pup; Eninta Sandstone Member - Ꞓn; Tempe Member - Ꞓt; Illara Sandstone Member - Ꞓi; Deception Member - Ꞓd; Petermann Sandstone Member - Ꞓe; Goyder Member - Ꞓg; Pacoota Sandstone - Ꞓ/Op; Horn Valley Siltstone - Oh; Stairway Sandstone - Os; Stokes Formation - Ot; Mereenie Sandstone - Pzm(1), Pzm(2); Possible Mesozoic - ?M; Tertiary Conglomerate - Tc;

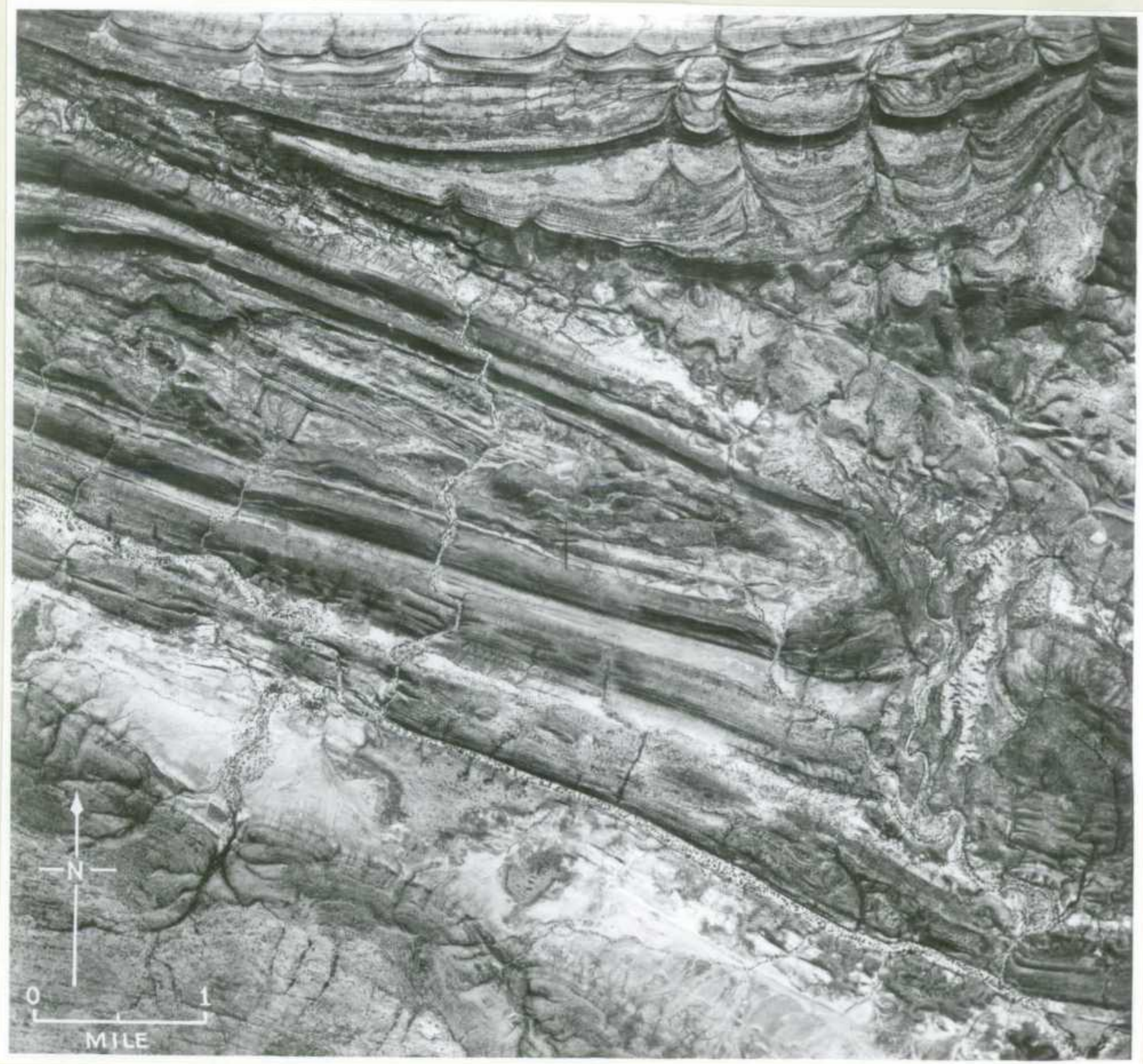


Fig.10. Air Photograph of Parana Hill Anticline. See overlay Fig.9.

Tempe Member (new name)

The name Tempe Member is given to the sequence of red and green siltstone, green-brown and grey-brown, fossiliferous, glauconitic, sandy dolomite and yellow-brown, glauconitic, feldspathic sandstone which lies conformably between the Eninta Sandstone Member below and the Illara Sandstone Member above in the Gardiner Range. The type locality is four miles west of Katapata Gap in the Gardiner Range. The bottom and the top of the unit are marked by a prominent topographic break because of the recessive weathering habit of this Member. The name of this Member is derived from Tempe Downs Station which lies on the Henbury Sheet area.

On the Lake Amadeus Sheet area, the Tempe Member has been mapped in the Parana Hill Anticline (Figs 9 and 10) and in the core of an anticline approximately 12 miles south of Reedy Water Hole. The best exposures are in the southern limb of the Parana Hill Anticline where a number of small creeks have cut into and exposed beds which are normally concealed. The Tempe Member weathers recessively but some beds of sandy dolomite and calcareous sandstone form low strike ridges.

Sections measured in both limbs of the Parana Hill Anticline indicate a thickness of about 400 feet for this Member, but a thickness of nearly 600 feet was measured at the type locality in the Gardiner Range.

The Tempe Member is dominantly red and green siltstone with beds and lenses of sandy dolomite, calcareous sandstone and sandstone. The sandstone and dolomite beds are normally rich in glauconite and some beds are richly fossiliferous.

The Tempe Member lies conformably between the Eninta Sandstone Member below and the Illara Sandstone Member above in the type area and in the Parana Hill Anticline on the Lake Amadeus Sheet area. The unit was mapped as part of the Hugh River Shale by Wells et. al. (1962) on the Mount Liebig Sheet area but it is now considered to be laterally equivalent to part of the Arumbera Greywacke as mapped in the Western MacDonnell Ranges by Prichard and Quinlan (1962).

The Tempe Member is fossiliferous and has been tentatively dated as late Lower Cambrian or early Middle Cambrian (Joyce G. Tomlinson B.M.R. Pers.comm.).

Illara Sandstone Member (new name)

The Illara Sandstone Member is the name given to the sequence of fine and medium grained, ferruginous, micaceous sandstone with minor siltstone interbeds which lies conformably above the Tempe Member and conformably beneath the Deception Member, within the Pertaoorrta Formation, in the Gardiner Range. The type locality is approximately 12 miles west-north-west of Katapata Gap in the Gardiner Range. The name is derived from Illara Creek which joins Walker Creek approximately 2 miles west-north-west of Tempe Downs Homestead.

The Illara Sandstone Member has only been mapped on the flanks of the Parana Hill Anticline (Figs. 9 & 10), in the Lake Amadeus Sheet area. The unit forms a prominent ridge up to 500 feet high and separates the recessively weathering Tempe and Deception Members.

Sections measured on both flanks of the Parana Hill Anticline give a thickness of between 300 and 400 feet for the Illara Sandstone Member whereas in the type locality in the Gardiner Range it is 650 feet thick.

The Illara Sandstone Member consists of red-brown, fine to medium grained, moderately sorted, cross-bedded, ferruginous, feldspathic, micaceous sandstone with minor interbeds of white and pale pink, medium grained, cross-bedded, calcareous sandstone and red-brown, laminated, micaceous siltstone. Many of the cross-bed sets have slumped forming 'flow rolls' and 'convolute bedding". Clay pellets are common and heavy mineral bands were seen in some sandstone beds.

The Illara Sandstone Member lies conformably between the Tempe Member below and the Deception Member above in the type area and in the Parana Hill Anticline. The unit was mapped as part of the Hugh River Shale by Wells et.al. (1962).

Fossils have not been found in the Illara Sandstone Member and it is regarded as being of Cambrian age from its stratigraphic position.

Deception Member (new name).

The name Deception Member is given to the sequence of red-brown, micaceous siltstone with minor interbeds of red-brown, fine-grained sandstone which lies conformably between the Illara Sandstone Member below and the Petermann Sandstone Member above in the Pertaoorrta Formation in the Gardiner Range. The type locality is about 12 miles west-north-west of Katapata Gap in the Gardiner Range. The upper and lower boundaries are expressed topographically because of the greater resistance to erosion of the overlying and underlying sandstone Members. The name is derived from Deception Creek which passes approximately 8 miles east of Tempe Downs Homestead on the Henbury Sheet area.

On the Lake Amadeus Sheet area, the Deception Member has only been mapped in the Parana Hill Anticline (Figs. 9 & 10), where the unit forms a major strike valley. The Member is poorly exposed except for the thin beds of fine sandstone which form low strike ridges.

The Deception Member is 461 feet thick on the south flank of the Parana Hill Anticline (LAR 2), and 318 feet thick on the northern flank (LAR 1). The unit is 614 feet thick in the type area.

The Deception Member is dominantly red-brown and purple-brown, micaceous siltstone but contains up to 20% of fine grained, micaceous sandstone. The Member also includes some thin calcareous beds and some thin beds are invariably 'slump folded' and contain many clay pellets.

The Deception Member lies conformably between the Petermann Sandstone Member above and the Illara Sandstone Member below in the Gardiner Range and in exposures in the Parana Hill Anticline. The unit was mapped by Wells et.al. (1962) as part of the Hugh River Shale in the Gardiner Range, and the new Member is still considered to be laterally equivalent to part of the Hugh River Shale (as mapped in the Western MacDonnell Ranges by Prichard and Quinlan in 1962).

Fossils have not been found in this Member and it is regarded as being of Cambrian age from its stratigraphic position.

Petermann Sandstone Member (new name)

The name Petermann Sandstone Member is given to the sequence of red-brown, pale purple-brown and white, fine and medium grained, micaceous sandstone which lies conformably between the Deception Member below and the Goyder Member above, within the Pertaoorrta Formation, in the Gardiner Range. The type locality is approximately 12 miles west-north-west of Katapata Gap in the Gardiner Range. The Petermann Sandstone Member forms a ridge so that the contact with the overlying Goyder Member is also marked by a topographic change but the boundary is more gradational and less obvious. The boundary is taken at the change from dominantly red-brown and purple-brown sandstone to dominantly yellow-brown and yellow-grey, sandy limestone and calcareous sandstone. The name is derived from the Petermann Hills which are a series of east-west trending strike ridges about 12 miles west of Tempe Downs Homestead.

On the Lake Amadeus Sheet area, the Petermann Sandstone Member has only been recognised in the flanks of the Parana Hill Anticline (Figs. 9 and 10); where it forms a prominent dark red-brown strike ridge.

The Member is 500 feet thick in the northern limb of the Parana Hill Anticline (LAR1) and 640 feet thick in the southern limb of the same structure (LAR2). The Member is 835 feet thick at the type locality in the Gardiner Range.

The dominant rock type is sandstone, which is red-brown and pale purple-brown, fine and medium grained, thin bedded, cross-bedded, ripple marked, ferruginous and micaceous. Heavy mineral bands and clay pellets are common in some beds. Slump folds, normally restricted to individual cross-bed sets, are common. The major sandstone unit has interbeds of laminated, micaceous siltstone and white, medium grained, well sorted, cross-bedded sandstone. The white sandstone occurs as thin beds and is generally silicified. The cross-bed sets in the white sandstone are thinner than those in the red-brown sandstone.

The Petermann Sandstone Member lies conformably between the Deception Member and the Goyder Member in the Gardiner Range and where mapped on the Lake Amadeus Sheet area. Both upper and lower contacts are apparently transitional. The unit was mapped by Wells et.al.(1962) as part of the Hugh River Shale, in the Gardiner Range, on the Mount Liebig Sheet area. The Petermann Sandstone Member is considered to be laterally equivalent to part of the Hugh River Shale (as mapped by Prichard and Quinlan (1962) in the Western MacDonnell Ranges).

Fossils have not been found in the Petermann Sandstone Member and it is regarded as being of Cambrian age from its stratigraphic position.

Goyder Member

The Goyder Member, as defined in this report, is the revised name for the Goyder Formation of Prichard and Quinlan (1962). Prichard and Quinlan defined the Goyder Formation as 'the quartz greywacke with interbedded limestone in the lower half, and some quartz sandstone in the upper part, which conformably overlies the Jay Creek Limestone, or where that formation is not present, the Hugh River Shale, and is conformably succeeded by the Pacoota Sandstone.' The type section is half a mile west of Ellery Creek and the name was derived from Goyder Pass, which is in the Western MacDonnell Ranges 16 miles west of the Finke River Gorge.

Outcrops of the Goyder Member are mostly confined to the north-eastern quadrant of the Lake Amadeus Sheet area. The most westerly outcrop lies approximately five miles south-south-east of Mount Tucker and the most southerly outcrop occurs about ten miles north of Winnall Ridge. The best exposures occur in the flanks of the Parana Hill Anticline (Figs 9 & 10) and in the core of the Ochre Hill Anticline.

The Goyder Member is easily eroded and in most places underlies a pediment sloping away from the overlying, more resistant, Pacoota Sandstone.

Three sections were measured through the Goyder Member on the Lake Amadeus Sheet area. Thicknesses of 851 feet (LARI) and 621 feet LAR2) were measured in the flanks of the Parana Hill Anticline and a thickness of 293 feet (LAC12) was measured 5 miles south-south-east of Mount Tucker. The Goyder Member is 1600 feet thick at the type locality (Prichard and Quinlan, 1962) and 918 feet thick 10 miles west of Katapata Gap in the Gardiner Range (Wells et al, 1962).

The dominant lithology of the Goyder Member is a pale yellow-brown, or white, thin bedded, medium grained, cross-bedded, friable, partly micaceous, kaolinitic sandstone. The sandstone is calcareous in part and contains numerous clay pellets in some beds. The Member contains interbeds of yellow, laminated, partly calcareous, micaceous siltstone and in some places, red, grey and yellow chert (LA573). Lenses of pale brown and grey-brown dolomite and sandy dolomite, with algal stromatolites, occur in the upper part of the Member in the core of the Ochre Hill Anticline and in exposures inthe northern flank of the Parana Hill Anticline (LA7). Ripple marks and 'worm' tracks and trails were seen in the lower part of the Member at some localities.

Beds of grey-black, manganese-rich rock in the upper part of the Goyder Member form a prominent strike ridge in some areas. One sample of the surface material (LA60a) and the underlying material (approximately 12 inches below ground level) (LA60b) were submitted for determination of iron, manganese and silicon. The results obtained are as follows:-

	Fe	MN	Si
LA60a	0.37%	56.2%	0.45%
LA60b	21.4%	0.43%	18.2%

The manganiferous rock is a superficial deposit and in places occurs as only a thin surface encrustation on the yellow-brown, silty sandstone. However, as the manganese is present in a number of areas, and in approximately the same stratigraphic position, it is possibly the result of surface concentration of disseminated manganese in the underlying sediments.

On the Lake Amadeus Sheet area, the Goyder Member lies conformably beneath the Pacoota Sandstone and conformably above either the Petermann Sandstone Member of the Pertaoorrta Formation or the Cleland Sandstone. The contacts with the underlying units are gradational and the thinning and gradual disappearance of the Goyder Member to the west is considered to be the result of interfingering with, and lateral transition into, the Cleland Sandstone.

Diagnostic fossils have not been found in the Goyder Member on the Lake Amadeus Sheet area and the unit is tentatively regarded as being of Cambrian age.

Cleland Sandstone

The Cleland Sandstone was defined by Wells, et. al. (1962) as, 'a sequence of fine to coarse grained and sometimes pebbly, ferruginous, partly feldspathic and partly micaceous sandstone which lies conformably beneath the Goyder Formation in the Idirriki Range and conformably beneath the Pacoota Sandstone in exposures further west'. The type locality of this Formation is in the Cleland Hills on the Mount Liebig Sheet area, where a thickness of approximately 3,000 feet was measured.

The Formation is exposed at localities scattered throughout the north-western quadrant of the Lake Amadeus Sheet area and in most places forms low strike ridges and hills. The only prominent feature consisting of Cleland Sandstone is Mount Tucker which lies about 20 miles west of King Canyon. On the Lake Amadeus Sheet area, as on the Mount Liebig Sheet Area, the Cleland Sandstone is overlain by the Goyder Member of the Pertaoorrta Formation in the east and the Pacoota Sandstone in the west. The base of the Cleland Sandstone is not exposed. The formation appears to lie unconformably above the Winnall Beds, about 20 miles south-east of Mount Murray.

Only one section was measured through the Cleland Sandstone (LAC12) on the Lake Amadeus Sheet area and this gave a minimum thickness of 1568 feet.

The Cleland Sandstone can be sub-divided into three units near Mount Tucker. The basal sandstone unit is white, pale purple-brown and red-brown, medium and thick bedded, fine to coarse grained, moderately to poorly sorted, cross-bedded, kaolinitic and feldspathic. It contains numerous clay pellets, and 'slump folds' and some beds with scattered pebbles of vein quartz and metamorphic quartzite. This unit weathers massively and forms a prominent ridge. The middle unit is poorly exposed and consists of an interbedded sequence of sandstone, silty sandstone, and siltstone. The sandstone and silty sandstone are thin to medium bedded, fine and medium grained, moderately sorted, cross-bedded, 'slump folded' and very micaceous. Clay pellets are numerous in some beds. Most of this unit is recessive but some sandstone beds form low ridges. The upper unit comprises pale red-brown and white, medium bedded, fine and medium grained, cross-bedded, slightly micaceous sandstone and silty sandstone. Clay pellets and 'slump folds' are present in some beds. This unit forms a prominent strike ridge.

The Cleland Sandstone is overlain by the Goyder Member of the Pertaoorrta Formation in outcrops to the south and east of Mount Tucker, but to the west it is conformably overlain by the Pacoota Sandstone. Where the Pacoota Sandstone-Cleland Sandstone contact is well exposed the upper part of the Cleland Sandstone consists of purple-brown and red-brown, laminated, micaceous siltstone and fine-grained, micaceous sandstone. This contact is transitional over about 10 feet of section. The contact between the Cleland Sandstone and underlying units is not exposed but there appears to be a marked angular unconformity between the intensely folded Winnall Beds and the more gently folded Cleland Sandstone. The Cleland Sandstone is laterally equivalent to part of the Pertaoorrta Formation, but until the base of the unit is better known a more exact correlation is not possible.

No fossils have been found in the Cleland Sandstone and the age of the formation can only be inferred from its stratigraphic position. It is overlain by sediments of probably Upper Cambrian age between King Creek and Mount Tucker but further west the overlying sediments are of probable Lower Ordovician age. The unit unconformably overlies possible Cambrian or Proterozoic sediments in the area approximately 20 miles south-east of Mount Murray. The Cleland Sandstone is therefore regarded as being of Cambrian Age on the Lake Amadeus Section area, although it is considered possible that the unit may be of Lower Ordovician age in the western and southern parts of the area.

CAMBRIAN-ORDOVICIAN

LARAPINTA GROUP

Brown (1890), was the first to describe the Palaeozoic rocks of the Amadeus Basin and he advocated a two-fold division of these sediments. Chewings (1894) proposed a three-fold division of the Palaeozoic sediments, with his Mareeno Bluff Series corresponding approximately to the Larapinta Group of Prichard and Quinlan (1962). Two years later, Tate and Watt (1896), gave the name Larapintine Series to what they regarded as the Ordovician rocks; the name Larapintine being derived from the Arunta name for the middle and upper reaches of the Finke River. Some confusion later arose in the nomenclature, for Madigan apparently regarded the name Pacoota as synonymous with Larapinta and stated (Madigan, 1932) "The Larapinta fauna is well known in literature, so that our former name of Pacoota is now abandoned in favour of the better known one".

The original Larapintine Series of Tate and Watt (1896), was not precisely defined and probably excluded the Pacoota Sandstone as there are no Pacoota fossils in Tate's Larapintine fossil collection (Joyce G. Tomlinson, pers. comm.). It was not until 1962 (Prichard and

Quinlan, 1962) that the Larapinta Group was formally defined; "The Larapinta Group consists of the following four formations (in ascending order); Pacoota Sandstone, Horn Valley Formation, Stairway Greywacke, and Stokes Formation. It conformably overlies the Pertaoorrta Group and is separated from the overlying Mereenie Sandstone by a regional unconformity." The Larapinta Group is composed of sandstone, siltstone and limestone and is richly fossiliferous. Its age ranges from Upper Cambrian in the lowest beds of the Pacoota Sandstone to probable Upper Ordovician in the Stokes Formation.

Pacoota Sandstone

The name Pacoota Quartzite was first given to the formation by Mawson and Madigan (1930); Pacoota being the aboriginal name for Mount Blatherskite near alice Springs (Mount Blatherskite was subsequently found to be composed of Heavitree Quartzite). The name was later changed to Pacoota Sandstone by Prichard and Quinlan (1962) who defined it as "A series of silicified quartz sandstones, conformably overlying the Goyder Formation of the Pertaoorrta Group and succeeded conformably by the Horn Valley Formation." The type section is at Ellery Creek in the Western MacDonnell Ranges.

The Pacoota Sandstone crops out sporadically throughout much of the Lake Amadeus Sheet area and especially in the north-east quadrant. It is commonly exposed in the flanks of synclines, and the cores of anticlines; it forms prominent strike ridges. Outside this north-eastern area the Pacoota Sandstone crops out mainly as low strike ridges.

The maximum recorded thickness of Pacoota Sandstone in the Amadeus Basin is 2700 feet at Ellery Creek (Prichard and Quinlan, 1962), whereas the thickest sections measured in the Lake Amadeus Sheet area are 1062 feet in section LAR2 on the southern flank of Parana Hill Anticline and 1052 feet on the northern flank (section LAR1). There is considerable thinning of the Pacoota Sandstone to the west; in section LAC 12, it is 265 feet thick, and in section LAR 3 on the western margin of the Sheet area only 60 feet thick.

The Pacoota Sandstone is a medium to coarse grained, well rounded and well sorted sandstone, with some pebble bands towards the base and some white, silty beds towards the top. The bedding varies from thin to massive; cross-bedding and ripple marks are common. The formation weathers grey or brown; superficial silicification occurs in places, though weathering has also had the effect of making the rock extremely crumbly and saccharoidal. Considerable secondary enlargement of the quartz grains can be seen in thin sections.

A "vuggy" rock of distinctive lithology crops out as a prominent bed 64 feet below the top of the Pacoota Sandstone in section LAC8. The bed is four feet thick and is composed of a medium grained, brown weathering, silicified sandstone which has a "honeycomb" appearance due to a large number of holes within the rock. In hand specimen the vughs appear to be lined with limonite or white silty material.

In thin section, (see Fig.24) the specimen (LA161, thin section No. R12424) consists of a moderately rounded sandstone showing secondary enlargement of the quartz grains. The vughs are partly filled with an opaque mineral thought to be limonite, with a rim of a phosphoritic mineral (?collophane). In places the ?collophane also occurs as a remnant core. Within the ?collophane and the limonite are scattered grains of poorly rounded quartz. It is considered that the vughs represent weathered-out phosphorite nodules or pellets.

In most places, the contacts of the Pacoota Sandstone and the overlying and underlying units are poorly exposed. Where it is exposed, the contact between the Pacoota Sandstone and the Goyder Member is conformable and often gradational, so that it is difficult to know where to place the boundary. In the Ochre Hill Anticline the only possible criteria for the boundary is that the sandstones of the Goyder Member are less well sorted and have more silty matrix than those of the overlying Pacoota Sandstone. Six miles east-north-east of the Inindia Bore, a sandstone provisionally mapped as the Pacoota Sandstone rests with an angular unconformity on possible Pertaoorrta Formation and Winnall Beds (see Fig.11). Six miles west-north-west of Inindia Bore the Pacoota Sandstone has a conglomerate near the base and rests apparently conformably on the Pertaoorrta Formation. The contact between the Pacoota Sandstone and the overlying Horn Valley Siltstone is not exposed in the Sheet area but as the Horn Valley Siltstone is characteristically a recessive formation, the top of the Pacoota Sandstone is placed at the top of the highest exposed sandstone.

Few fossils were found in the Pacoota Sandstone of the Lake Amadeus Sheet area apart from <u>Scolithus</u> ('Pipe-rock'), '<u>Cruziana</u>', <u>lingulids</u> and the cranidium of a trilobite identified by Joyce G. Tomlinson as cf. Koraipsis of Tremadocian age (see Appendix I). The most distinctive and widespread fossil of the Pacoota Sandstone is Scolithus (see Fig.18, Wells, Forman and Ranford, 1962) which first appears near the base of the formation. Various indeterminate tracks and trails were also seen, (see Fig.17 op.cit. 1962).

Fossils from other areas indicate that the Pacoota Sandstone ranges in age from Upper Cambrian to Lower Ordovician (Prichard and Quinlan, 1962).

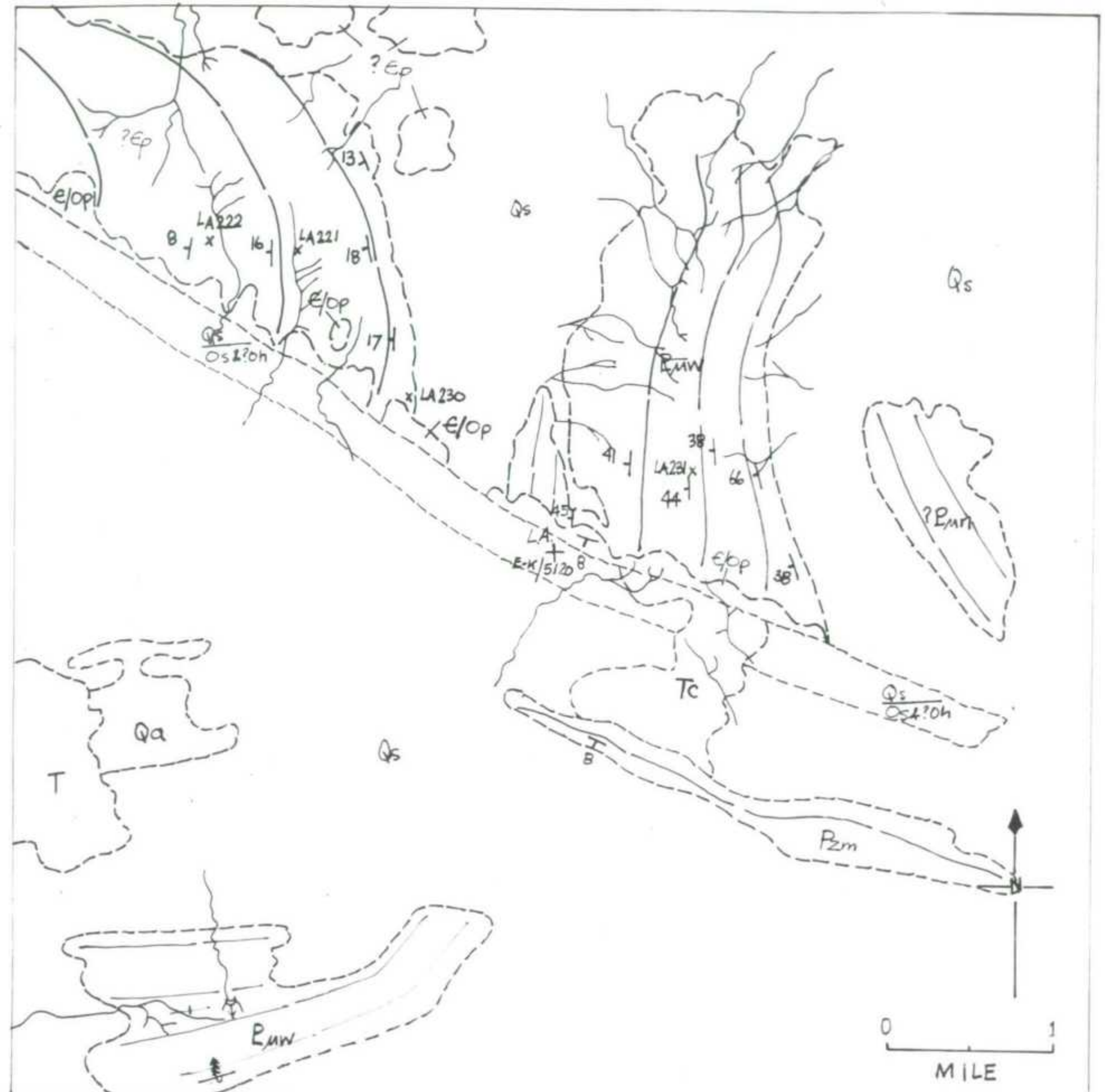


Fig. 11 Unconformity between the Larapinta Group and Winnall Beds 8 miles east of Inindia Bore. Winnall Beds - Ꝑuw, Inindia Beds - Ꝑun, Pacoota Sandstone - Є/Op, Horn Valley Siltstone - Oh, Stairway Sandstone - Os, Mereenie Sandstone - Pzm, Tertiary limestone - T, Tertiary conglomerate - Tc
Єp - Pertaoorta Formation

F

Fig. 12. Air Photo of unconformity near Inindia Bore. See overlay Fig. 11.

Horn Valley Siltstone

The geographical name Horn Valley was first given to a valley of great length in the Western MacDonnell Ranges by Tate and Watt (1896). The unit which occurs in this valley was formally defined as the Horn Valley Beds by Madigan (1932). Prichard and Quinlan (1962) define the Horn Valley Formation as "the siltstone containing thin limestone beds which conformably overlies the Pacoota Sandstone and is conformably succeeded by the Stairway Greywacke'. The type section is at Ellery Creek where the formation is 440 feet thick. Because the formation is predominantly siltstone the name is revised to Horn Valley Siltstone in this report.

The Horn Valley Siltstone is best exposed in the north-east corner of the Lake Amadeus Sheet area, where it forms strike valleys. In the remainder of the Sheet area the Horn Valley Siltstone is very poorly exposed in isolated strike valleys, cropping out as rare blocks of limestone or siltstone.

The maximum measured thickness of the Horn Valley Siltstone on the Sheet area is 285 feet at Ochre Hill (section LAC7). On the northern flank of Ochre Hill Anticline, the Horn Valley Siltstone is 280 feet thick (section LAC 6), where as in section LAC4) situated on the eastern culmination of Johnny Creek Anticline, it is 273 feet thick. Some thinning may occur on Parana Hill Anticline; the thickness of the formation on the southern flank (section LAR2) is 236 feet and on the northern flank (section LAR1), 198 feet. Similar thinning would appear to take place on the ridge south of the George Gill Range on the eastern margin of the Lake Amadeus Sheet area. At section LAC10 the Horn Valley Siltstone is 217 feet thick whereas to the east, in section LAC8 the thickness of the formation is only 144 feet. It is thought that this thinning may in part be due to growth of structures during deposition. Some thinning takes place on the western half of the Lake Amadeus Sheet area for in section LAW1 the Horn Valley Siltstone is 182 feet thick; in section LAC12 it is 160 feet thick, and in section LAR 3 a thickness of only 80 feet is recorded.

The dominant lithology of the Horn Valley Siltstone is grey-green and pale brown siltstone which is laminate to thinly bedded, calcareous in part, soft and crumbly in places, yellow weathering, and poorly exposed. The siltstone is gypsiferous in places, the gypsum (selenite) possibly being derived from the weathering of pyrite; pseudomorphs of limonite after pyrite also occur in places in the siltstone.

Limestone is commonly interbedded with the siltstone. The limestone is grey, partially recrystallised in places, with some detrital quartz. It is thinly bedded, brittle, veined with calcite, weathers yellow, ferruginized in places, and is more resistant to weathering than the siltstone of the formation.

Yellow-brown or grey-green, fine-grained, calcareous, silty sandstone is interbedded with the siltstone but is not common.

A distinctive oolitic bed crops out just below the top of the Horn Valley Siltstone (specimen LA162, thin section No.R12425). It is essentially an oolitic ironstone, with ooliths up to 1 mm in diameter. It is red-brown, thinly bedded, friable, weathers black and is poorly exposed. Because of the poor exposure, the total thickness of this oolitic ironstone is uncertain and there may be several thin oolitic beds with interbedded yellow and brown sandy siltstone.

In thin section the oolitic ironstone is seen to be made up of slightly flattened and elongate ooliths, with some alignment of the ooliths with their long axis parallel to the bedding. There is some shadowy concentric banding within the ooliths. Between the ooliths is a matrix of fine, angular, poorly rounded and sorted quartz grains. This oolitic ironstone has been found in most outcrops of the Horn Valley Siltstone.

The contacts of the Horn Valley Siltstone with the underlying Pacoota Sandstone and the overlying Stairway Sandstone are very poorly exposed but both contacts are thought to be conformable. At both contacts there is a marked lithological change from arenite to lutite of the Horn Valley Siltstone.

A very rich fauna occurs in the Horn Valley Siltstone; the localities which are especially of note are situated six miles east of Mount Olifent, one mile north of Morris Pass and in the vicinity of Ochre Hill. At these and several other localities a large number of fossils were collected. The fauna indicates a late Lower Ordovician age for the Horn Valley Siltstone (Appendix I).

Stairway Sandstone.

This formation was first named the 'Stairway Ridge Beds' by Chewings (1935) from the type locality of Stairway Ridge in the Western MacDonnell Ranges. Prichard and Quinlan (1962) renamed and formally defined the formation as the Stairway Greywacke and state that it is 'The formation of quartz greywacke and quartz sandstone which at Ellery Creek conformably overlies the Horn Valley Formation and is there followed unconformably by the Mareenie Sandstone........ It consists of about 60 percent of fine grained and medium grained quartz greywacke, usually rather silty and about 40 percent of cleaner quartz sandstone'. This unit is referred to as the Stairway Sandstone in this report in accord with Wells, Forman and Ranford (1962). In the Lake Amadeus Sheet area, the Stairway Sandstone is overlain conformably by the Stokes Formation, and underlain conformably by the Horn Valley Siltstone.

The Stairway Sandstone crops out sporadically throughout much of the Lake Amadeus Sheet area and is especially well exposed in the north-east corner, where it forms prominent escarpments, (e.g. in Johnny Creek Anticline). Away from this area, the Stairway Sandstone is poorly exposed and crops out mainly in low discontinuous strike ridges, but in the south-east corner of the sheet area, it occurs mainly as blocky scree.

The maximum measured thickness of the Stairway Sandstone in the Lake Amadeus Sheet area is 784 feet in the eastern culmination of Johnny Creek Anticline (section LAC 4). In the western culmination however (section LAC 5), the thickness is only 516 feet. At Parana Hill Anticline the thickness of Stairway Sandstone is 622 feet on the southern flank (section LAR 2) and 588 feet on the northern flank (section LAR1). In the ridge four miles due south of Parana Hill Anticline the Stairway Sandstone is 653 feet thick (section LAC10). A considerable thinning of the Stairway Sandstone takes place in the southern and western parts of the Lake Amadeus Sheet area. At section LAC12, just west of Kulpi Rock-hole, an exposed thickness of 199 feet was measured and it is unlikely that the total thickness is much in excess of this figure. At section LAW 1 on the western margin of the Sheet area a total thickness of 203 feet of Stairway Sandstone was measured. This was the minimum measured thickness within the Sheet area, but near Inindia Bore the thickness is probably less than 200 feet. The lower part of the Stairway Sandstone may be missing in parts of the Sheet area.

The best exposed beds of the Stairway Sandstone are fine to medium grained, white, quartz sandstone. The sandstone is well sorted and rounded, thin to medium bedded, commonly ripple-marked and cross-bedded, silicified in places, moderately resistant and weathers pale brown or grey. The sandstone near the base of the formation is coarse grained and in places pebbly, and contains some "pipe-rock" so that it is lithologically very similar to the Pacoota Sandstone.

Siltstone is commonly interbedded with the sandstone and may be the dominant rock type of the Stairway Sandstone in the area of Johnny Creek Anticline, assuming that the non-outcropping intervals represent siltstone. The siltstone is grey or grey-green, with some detrital quartz in places, rarely calcareous, laminate to thin bedded, weathers grey or brown and is poorly exposed.

Thin limestone and dolomite bands occur sporadically in the upper part of the Stairway Sandstone. They are generally red-brown or grey, thin bedded, sandy in places, commonly recrystallised, commonly with calcite geodes. The limestone and dolomite weather yellow or brown and form prominent bands. Phosphatic pellets are rarely in the limestone and dolomite.

Pelletal phosphorite occurs mainly in the upper part of the formation. The phosphorites are discussed more fully in the section of this report dealing with economic deposits of the Lake Amadeus Sheet area.

Throughout the Lake Amadeus Sheet area, the Stairway Sandstone is conformably overlain by the Stokes Formation and the boundary, where exposed, is gradational. The upper boundary of the Stairway Sandstone is taken at the top of the last prominent sandstone bed, which normally forms an escarpment that can be readily distinguished on air-photographs.

The Stairway Sandstone conformably overlies the Horn Valley Siltstone and the boundary is probably gradational. Exposure is however always poor and the boundary is arbitrarily placed at the base of the first prominent sandstone, which in most places forms an escarpment. In the south-east corner of the Lake Amadeus Sheet area, the Stairway Sandstone thins considerably and at LA558 rests with a marked angular unconformity on Upper Proterozoic Bitter Springs Limestone. In this south-eastern corner, a sandstone suspected to be either Pacoota Sandstone or Stairway Sandstone (provisionally mapped as Pacoota Sandstone) overlies the possible Portaoorrta Formation and the Winnall Beds with an angular unconformity (see Fig.11). A large collection of fossils was made from the Stairway Sandstone and the estimated age for the upper part of the Formation is late Middle Ordovician (Appendix I).

Stokes Formation.

The Stokes Formation was first known as the Marena Valley Shales and Mudstones (Chewings 1935). This was subsequently changed by Prichard and Quinlan (1962) to the Stokes Formation, named from the type locality at Stokes Pass in the Western MacDonnell Ranges. The Formation is defined as:- "The formation of siltstone and fine-grained silty greywacke which conformably overlies the Stairway Greywacke and is disconformably succeeded by the Mereenie Sandstone.....".

The Stokes Formation is poorly exposed in most areas and commonly forms wide strike valleys, where it is largely covered by alluvium and scree. The Stokes Formation is exposed in the George Gill Range and at one other locality (LA183).

The maximum measured thickness of the Stokes Formation in the Lake Amadeus Sheet area is 1182 feet in the ridge 8 miles south-east of Bagot Springs (section LAC9). Thicknesses recorded from Parana Hill Anticline are similar; 1108 feet on the southern flank (section LAC2) and 1093 feet on the northern flank (section LAC1). In section LAC4 on the eastern culmination of Johnny Creek Anticline the thickness is 953 feet and on the eastern extremity of the anticline the thickness is 847 feet. The Stokes Formation thins to the west and it is only 464 feet thick at LAW1.

The major rock type in the Stokes Formation is grey, grey-green and red-brown siltstone which is sandy in places. The siltstone is thin bedded or laminate, ripple marked, and is in places brittle and calcareous. It is poorly exposed and weathers red-brown or yellow. Pseudomorphs after halite are fairly common.

Limestone and sandstone are commonly interbedded with the siltstone in the lower half of the Stokes Formation. The limestone is grey or pink, sandy in places, partly recrystallised, thin bedded and commonly contains calcite geodes. It weathers yellow and is moderately resistant, forming prominent beds. The limestone is commonly crinoidal or coquinitic. The poorly exposed sandstone, which forms only a small percentage of the total thickness of Stokes Formation, is yellow or brown, moderately sorted and rounded, thin bedded and has some silty matrix which is calcareous in places.

A single phosphatic band crops out near the base of the Stokes Formation at places in the Johnny Creek Anticline; it is identical with the pelletal beds of the Stairway Sandstone and indicates that the basal part of the Stokes Formation, and the Stairway Sandstone, were deposited in a similar environment.

The boundary between the Stokes Formation and the underlying Stairway Sandstone is conformable and gradational; the base of the Stokes Formation is placed at the top of the last prominent sandstone bed of the Stairway Sandstone. The boundary between the Stokes Formation and the overlying Mereenie Sandstone is also conformable and gradational on the Lake Amadeus Sheet area. For the purposes of mapping, the boundary is arbitrarily placed at the base of the first prominent sandstone bed. This sandstone bed forms a prominent scarp four to six feet high on the otherwise scree-covered slope.

Numerous fossils were collected from the lower half of the Stokes Formation. The fauna indicates an early Upper Ordovician age for the Formation (Appendix I).

UNDIFFERENTIATED PALAEOZOIC

Mount Currie Conglomerate

The Mount Currie Conglomerate was first named and defined by Forman (1963) from the type locality at Mount Currie. He defines it as :- "A sequence of pebble, cobble and boulder conglomerate unconformably overlying probable Upper Proterozoic sediments at Mount Currie". The top of the formation is eroded.

The Mount Currie Conglomerate only crops out over a small area in the south-west corner of the Lake Amadeus Sheet area, where it gives rise to an extremely well-rounded, inselberg type of relief.

Calculations from air-photographs indicate that the Mount Currie Conglomerate is several thousand feet thick.

The formation is a poorly sorted, sub-rounded conglomerate made up of pebbles, cobbles and boulders up to 24 inches across in a matrix of coarse grained, poorly rounded and sorted sandstone (see figs 13 & 14). The phenoclasts are predominantly quartz feldspar porphyry with minor epidotised amygdaloidal basalt, vein quartz, quartzite and sandstone. The massive beds at Mount Currie dip up to 80° to the south-south-west.

The following is a description by W. Oldershaw (B.M.R.) of a sample (Reg.No.13112 thin section No.9992) of Mt. Currie Conglomerate collected at Mt. Olga on the Ayers Rock Sheet area.

'The rock is a conglomerate or agglomerate containing rounded fragments 1-5 cm across of amphibolite, basalt and granite set in a granular matrix of angular frangments 0.2-2 mm across of quartz-albite intergrowths, devitrified glass, fresh microcline orthoclase perthite, plagioclase, quartz and augite. The interstices are filled with fine-grained granular epidote. This epidote cement could be due to regional metamorphism affecting only the fine-grained cement of the rock or it could be of hydrothermal or volcanic origin. However, the surrounding feldspars show very little alteration.'

At the type locality, the conglomerate overlies interbedded sandstone and siltstone which may be Upper Proterozoic in age; the contact is not exposed. The sandstone boulders within the Mount Currie Conglomerate may be derived from the Winnall Beds whereas the epidotised basalt boulders are derived from the Mount Harris Basalt (Forman, B.M.R., pers. comm.).

The Mount Currie Conglomerate is unfossiliferous. It is younger than the Winnall Beds and is tentatively regarded as being of Cambrian age. It is possible that the Mount Currie Conglomerate is equivalent to the Sir Frederick Conglomerate of the Rawlinson-Macdonald area (Wells, Forman and Ranford 1961).

Fig. 13. Conglomerate at Mt. Currie near south-west corner of Lake Amadeus Sheet area.

Fig. 14. Phenoclasts of many rock types in Mt. Currie Conglomerate at Mt. Olga.

Mereenie Sandstone

The Mereenie Sandstone was originally defined by Madigan (1932) who described it in the MacDonnell Ranges. Prichard and Quinlan (1962) described the Mereenie Sandstone as:- "A quartz sandstone formation overlies the Larapinta Group with a regional unconformity and is succeeded again with a regional unconformity, by the Pertnjara Formation". The name "Mereenie" is derived from the Mereenie Range in the Western MacDonnell Range. The type section was measured 4½ miles west of Ellery Creek.

The Mereenie Sandstone crops out over much of the Lake Amadeus Sheet area, forming many prominent strike ridges, bold escarpments and ranges, especially in the north-east corner of the area. The unit forms the George Gill Range, which rises to over 800 feet above the general level of the plain. The steepness of the escarpments is shown in Figs.16 & 17.

Only one complete section has been measured through the Mereenie Sandstone (LAC11). This was measured six miles north-east of Carmichaels Crag and a total thickness of 2234 feet was recorded. An incomplete section (LAW1) was measured about 15 miles east-south-east of Mount Murray and a total thickness of 1968 feet recorded, of which 768 feet was measured and 1200 feet estimated from the air-photographs. Thus, it would appear that the Mereenie Sandstone maintains a fairly constant thickness throughout the area.

The Mereenie Sandstone consists of two distinct lithological units which are readily recognisable in the field, though the boundary between the two is gradational. The lower unit is a red-brown sandstone; well rounded, moderately to poorly sorted with some white silty matrix, micaceous in places and with some well-rounded grains of tourmaline; thickly bedded, cross-laminated, ripple-marked in places and weathered dark-brown or grey. There are some thin beds of green and red-brown siltstone near the base of this unit.

The upper unit is a white or pale brown sandstone which is fine grained, moderately rounded, well sorted, medium to thickly bedded, and cross-laminated. There are some slump structures (Fig. 15), and ripple marks. The unit weathers pale brown. The large cross-beds give a distinctive photo pattern to the Mereenie Sandstone. This may in part be due to joints or may be due to parting along the cross-beds at their point of emergence at the surface.

W. Oldershaw (B.M.R., pers. comm.) has examined samples of Mereenie Sandstone from boreholes in the Alice Springs area (samples originally submitted by the Resident Geologist, Alice Springs). Oldershaw found that pitting and frosting of the grains was common and some grains showed polished, flattened facets. He concludes that of the four sandstones he examined, three were deposited in a deltaic environment

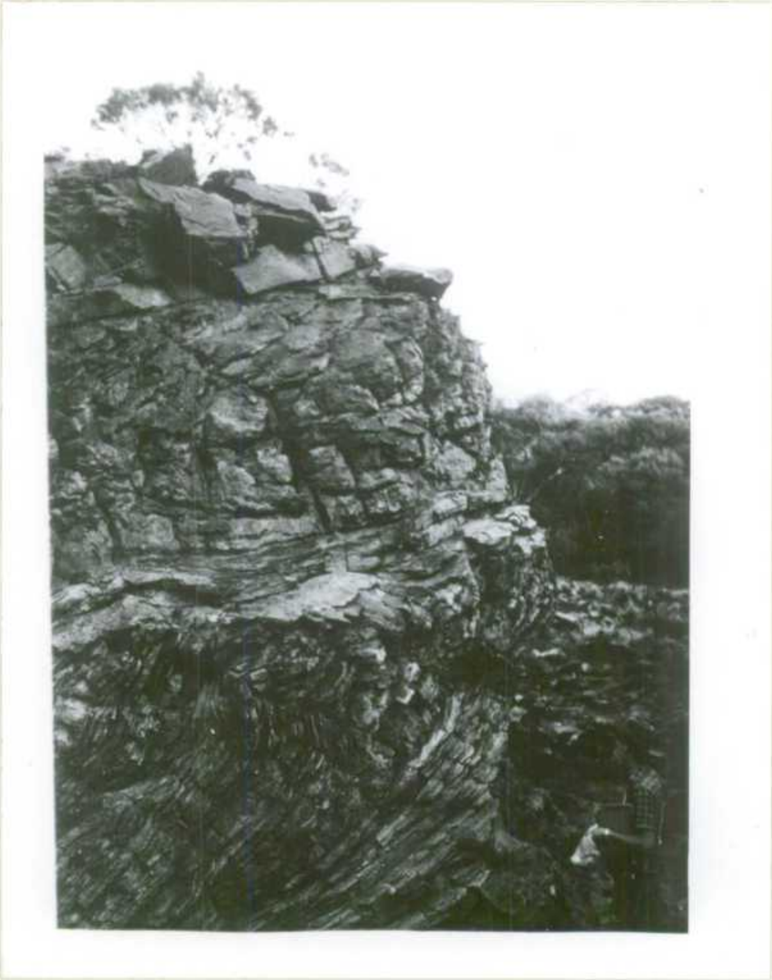


Fig. 15. Large slumped cross-beds in Mereenie Sandstone, George Gill Range.

Fig. 16. Upper cross-bedded unit of Mereenie Sandstone in south wall of King Canyon, George Gill Range.

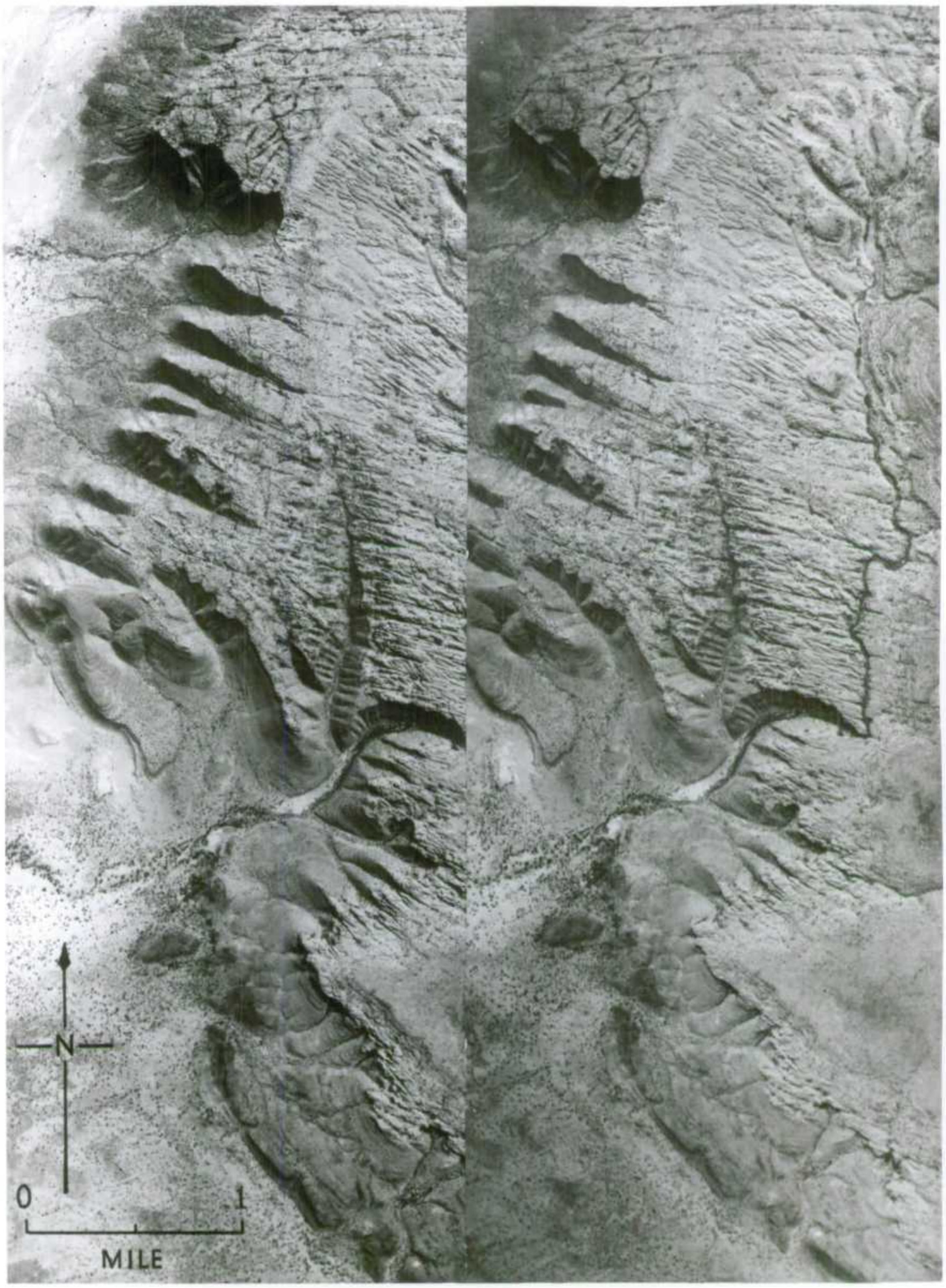


Fig.17. Stereo-pair of air photographs showing joint pattern in upper unit of the Mereenie Sandstone at King Canyon.

probably situated in or near a desert, whilst the fourth is an aeolian sandstone.

On the southern flanks of Johnny Creek Anticline, the contact of the Mereenie Sandstone with the underlying Stokes Formation is gradational with a transition zone approximately 200 feet thick. The base of the Mereenie Sandstone is taken as being the appearance of the first Mereenie - type sandstone. This bed crops out prominently, forming a useful boundary to map in the field.

The Mereenie Sandstone is overlain by siltstone of the Pertnjara Formation which is similar lithologically to the siltstone of the Stokes Formation. The boundary appears to be conformable and gradational, with a zone of interbedded Mereenie-type sandstone and Pertnjara-type siltstone. The top of the Mereenie Sandstone is placed at the first appearance of a major siltstone bed.

Few identifiable fossils have so far been found in the Mereenie Sandstone. Several problematical markings have been found in the Mount Rennie 1:250,000 Sheet area (see Figs 24 and 28. Wells, Forman and Ranford (1962)), and some similar markings have been recognised in the Lake Amadeus 1:250,000 Sheet area (Fig 18). In addition, a Cruziana was found just below the top of the lower unit of the Mereenie Sandstone, six miles north-west of Inindia Bore (specimen LA62) (Appendix I). Markings suspected to be pseudomorphs after halite have been found in scree near the base of the Mereenie Sandstone in the King Canyon area of the George Gill Range and west of Inindia Bore.

During 1962 vertical worm tubes were also recognised in the Mereenie Sandstone of the James Range, south of Areyonga Mission, which, together with the Cruziana suggest an Ordovician age. There is no other direct evidence of the age of the Mereenie Sandstone. Angular unconformities have been shown to occur at the top and bottom of the Mereenie Sandstone e.g. south of Deering Creek (Wells et.al. 1962) and in the MacDonnell Range (Prichard and Quinlan, 1962). On the Lake Amadeus Sheet area, the Mereenie Sandstone lies conformably between the Pertnjara Formation above and the Ordovician Stokes Formation below.

Pertnjara Formation.

The Pertnjara Formation was defined by Prichard and Quinlan (1962) as, 'the sequence of sandstone, quartz greywacke and conglomerate that overlies the Mereenie Sandstone with a regional unconformity.... Its upper limit is not known'.

The unit was first described by Tate and Watt (1896) and first named Pertnjara (Series) by Chewings (1931).

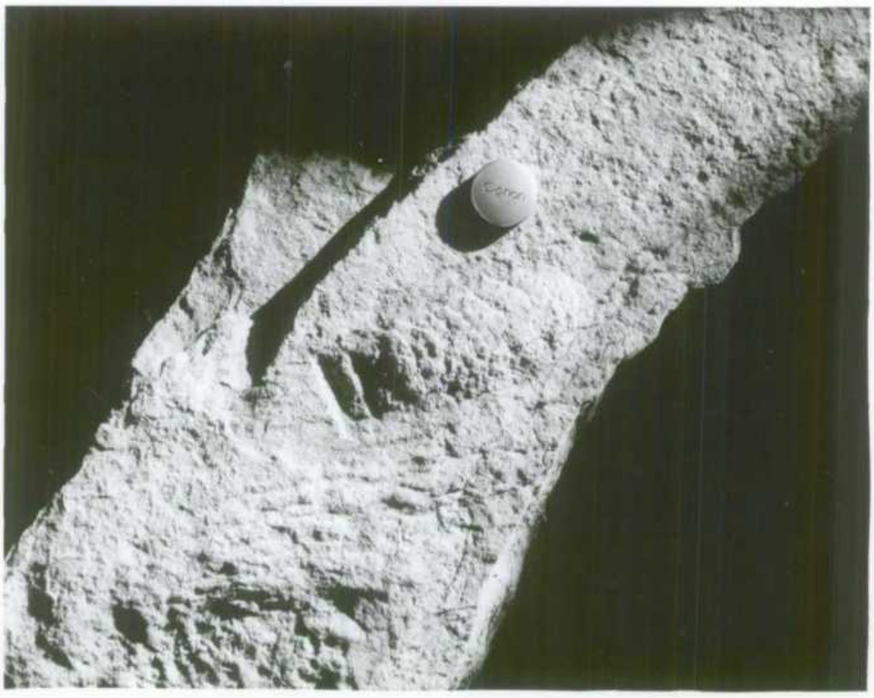


Fig. 18. Problematic bedding plane marking in Mereenie
Sandstone at top of King Canyon.

The type area is south of the MacDonnell Ranges along Ellery Creek, in the Missionary Plain Syncline.

On the Lake Amadeus Sheet area, the Pertnjara Formation lies apparently conformably above the Mereenie Sandstone. The only good exposures are in the north-east corner of the area, where the sandstone forms rugged hills and ranges which stand up approximately 500 feet above the sand plain.

No sections have been measured in the Pertnjara Formation on the Lake Amadeus Sheet area.

The Formation can be divided into two lithological units. The basal unit is dominantly siltstone and the upper unit is sandstone. Conglomerate is not present in the Lake Amadeus Sheet area.

The units are described separately.

Siltstone: The basal unit is generally very poorly exposed and forms wide alluvium-covered valleys between the ridges of underlying Mereenie Sandstone and overlying sandstone unit of the Pertnjara Formation. The siltstone is only known from the north-east corner of the Lake Amadeus Sheet area and is only well-exposed on the Dare Plain (Figure 19), where small creeks have cut deep channels into the sediments. Calculations of air-photographs with dip information, indicate a thickness of approximately 2,000 feet for the siltstone unit on Dare Plain.

The dominant lithology of the basal unit is siltstone, which varies in colour from chocolate-brown to yellow-brown, purple-brown, green, grey and orange-yellow. Much of it is micaceous and the bedding varies from laminate to massive. Some beds are slightly sandy, with scattered grains of well rounded quartz.

The contact with the underlying Mereenie Sandstone is well exposed on Dare Plain and although there is a fairly marked lithological change from the Mereenie Sandstone to the siltstone of the Pertnjara Formation, the units are apparently conformable and there are a few beds of (Mereenie type) sandstone within the siltstone sequence. These sandstone beds form strike ridges which stand approximately 50 feet higher than the surrounding plain. The sandstone is white, pinkish brown and pale purple-brown, fine to medium grained, crossbedded, ripple marked and partly calcareous. Some sandstone beds contain numerous small holes which are thought to have formed by the weathering of halite crystals. Pseudomorphs after halite were seen in some of the siltstones.

Calcareous beds occur throughout the section and are in most places lighter-coloured than the non-calcareous sediment. The limestones are pinkish brown or pale grey, fine grained and in places sandy.

No fossils have been found in this unit.

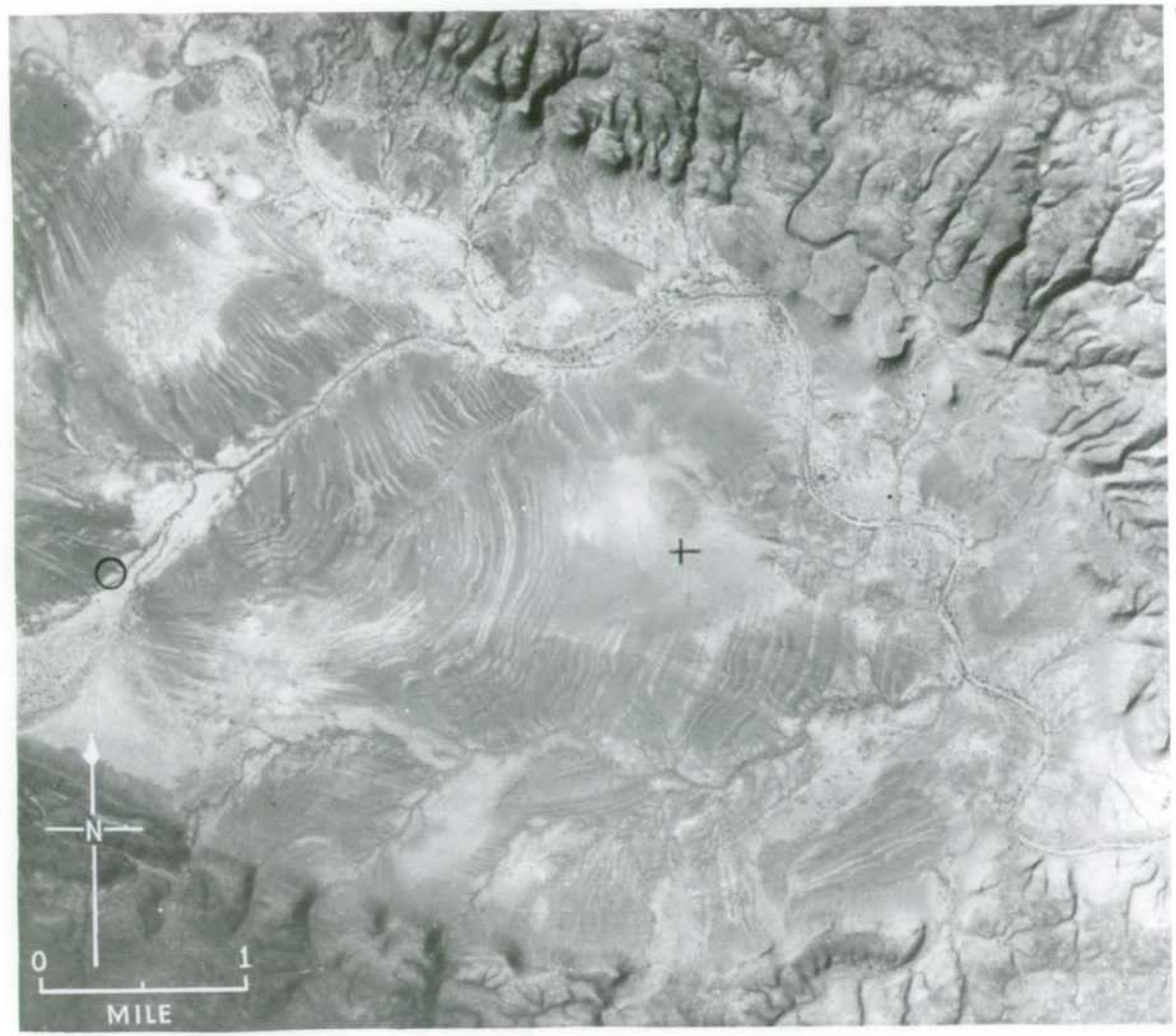


Fig. 19. Air photograph showing siltstone unit of Pertnjara Formation on Dare Plain.

Sandstone: The sandstone unit of the Pertnjara Formation was first mapped as an informal unit by Wells, Forman and Ranford (1962). This unit rests conformably on the siltstone division.

The sandstone unit is the best exposed division of the Pertnjara Formation; it crops out over a considerable part of the north-east corner of the Lake Amadeus Sheet area, where it forms prominent crags and escarpments and wide plateaux, which are deeply dissected by a dendritic type of drainage, giving a distinctive photo-pattern. Away from the north-east corner of the Sheet area the only known outcrop of the sandstone lies on the western margin of the Sheet area.

Because no section has been measured, the thickness of the sandstone unit is unknown; photo-interpretation suggests that the minimum thickness is 500 feet.

The sandstone is red-brown, medium to coarse grained, moderately rounded and poorly sorted with a silty matrix. It has thick to massive beds, cross-laminae, ripple marks and some clay pellets. It commonly weathers dark red-brown.

The contact between the sandstone unit and the underlying siltstone unit of the Pertnjara Formation is poorly exposed, but where visible, the boundary between these two units is conformable, with a transitional zone comprising interbeds of red and green siltstone and red-brown and pale brown sandstone.

Fossils have not been found in the Pertnjara Formation in the Lake Amadeus Sheet area. The Pertnjara Formation is younger than the Mereenie Sandstone and older than the Permian glacial sediments on the western side of the Amadeus Basin (Wells et.al. 1962). The unit is therefore considered to be of pre-Permian and post-Ordovician age.

MESOZOIC

Sediments tentatively regarded as being of Mesozoic age crop out at a number of localities in the north-eastern quadrant of the Lake Amadeus Sheet area, at LA203D (near the northern margin of Lake Amadeus) and in an area approximately 35 miles south-east of Mount Murray. These sediments occur as flat-lying remnants, unconformably overlying the folded Proterozoic and Palaeozoic succession. They are valley-fill deposits and in most places overlie the more easily eroded units.

No sections have been measured, but the sediments have an estimated maximum thickness of about 50 feet on the Lake Amadeus Sheet area.

The sediments are dominantly sandstone, with minor beds of siltstone and claystone. The sandstone is typically white, fine to coarse grained, moderately to poorly sorted, laminated to massively bedded, and has a kaolinitic matrix. The sequence is cross-bedded in places and large clay pellets are common. Pebbles, cobbles and boulders up to three feet in diameter occur in these sediments; these boulders could have been derived from the underlying sediments or the adjacent sandstone ridges. Boulders of sandstone from the adjacent Palaeozoic sandstone ridges occur in the sequence in the north-eastern quadrant of the Lake Amadeus Sheet area, whereas in the outcrops near Lake Amadeus, the boulders were probably derived from the underlying Inindia Beds. At LA203D the phenoclasts are of quartzite, siltstone, chert and silicified dolomite. Some of these fragments are striated and facetted.

The siltstones and claystones are white or yellow, sandy in places, and are partly gypsiferous.

Fossils have not been found in these sediments and their age can only be inferred from their stratigraphic position. They unconformably overlie the Pertnjara Formation and are overlain by unlithified Tertiary and Quaternary sediments. The presence of striated and facetted boulders in some outcrops could mean that these deposits are a continuation of the Permian glacial sediments mapped on the Mount Rennie Sheet area but it is more probable that the fragments were derived from the underlying Inindia Beds. The flat-lying valley-fill deposits are similar to those described from the Gardiner Range (Wells et.al. 1962) and on the basis of this correlation have been tentatively mapped as Mesozoic.

TERTIARY

Conglomerate

Flat-lying conglomerate, believed to be Tertiary in age is only found in the north-east corner of the Lake Amadeus Sheet area, within the ranges. They are thought to be remnants of original piedmont deposits which have now been deeply dissected, and in places thicknesses of up to 20 feet are exposed in creek banks. The conglomerate is unconsolidated, moderately to poorly rounded and poorly sorted, with fragments up to cobble size.

The conglomerate is regarded as Tertiary in age and is tentatively correlated with similar deposits described by Prichard and Quinlan (1962) from the Hermannsburg Sheet Area.

Undifferentiated Tertiary

The undifferentiated Tertiary sediments are comprised of flat-lying limestone, sandstone and siltstone, which are poorly exposed and known to crop out in the south-east corner only of the Lake Amadeus Sheet area.

The limestone is grey, fine grained and is normally strongly silicified. There is no fossil evidence for the age of the limestone, but on lithological grounds, it is correlated with Tertiary limestone exposed elsewhere in the Amadeus Basin (Prichard and Quinlan, 1962).

Sandstone of possible Tertiary age crops out only over a small area west of Inindia Bore. It is yellow, medium to fine grained, moderately rounded and sorted, with some silty matrix, calcareous in places, thinly bedded, and weathers pale brown. Siltstone is known only from a small area east of Inindia Bore where it is interbedded with flat-lying silicified limestone. The siltstone is grey, green, or brown, soft, laminated and easily weathered.

There is little evidence of Tertiary lateritization in the Lake Amadeus Sheet area, apart from ferruginization of some parts of the Mereenie Sandstone in the area around Kings Canyon and some flat-lying pisolitic ironstone which occurs about 8 miles north-west of Ochre Hill.

QUATERNARY

Alluvium.

The largest deposits of alluvial sand, gravel and clay occur in areas fringing the higher mountain ranges on the north-east part of the Lake Amadeus Sheet area. These deposits consist of a thin veneer of light-coloured sand, silt and clay, where streams are actively dissecting the country rock. Thicker deposits occur away from the ranges, where short streams have transported the alluvium into sand plain areas. The alluviated valleys in the mountain ranges have very sparse vegetation or none at all and much of the loosely consolidated alluvium is being redistributed by wind. The alluvium deposited by streams in the sand-plain areas has a thick vegetation cover. On a few areas of alluvium the mulga occurs in dense, long groves, with intergrove areas where trees are absent or sparse. The groves tend to be aligned along contours.

Aeolian Sand

Most of the Lake Amadeus Sheet area is covered with sand plain and dunes, with the exception of the north-east part of the Sheet area and Lake Amadeus. Most of the dunes trend south-west and average about 40 feet in height. The braided dunes that occupy a large area on the south-western part of the Sheet area have no preferred orientation. For the most part, the dunes are fixed by a scant growth of spinifex, desert oak and small eucalypts.

Evaporites.

Evaporites are present in the bed of Lake Amadeus. No study was made of these deposits. At one place at the eastern end of Lake Amadeus they are made up of a thin surface crust rich in halite, with underlying layers of brine saturated sand and silt containing crystals of gypsum.

Travertine.

Deposits of travertine are present in areas bordering Lake Amadeus and in some small areas between Inindia Bore and the eastern end of the George Gill Range. Many small deposits are found near outcrops of the Bitter Springs Limestone. These deposits are made up of white nodular limestone with enclosed irregular bodies of chert. They are deposits precipitated from groundwater in superficial Quaternary sediments.

Gypsum.

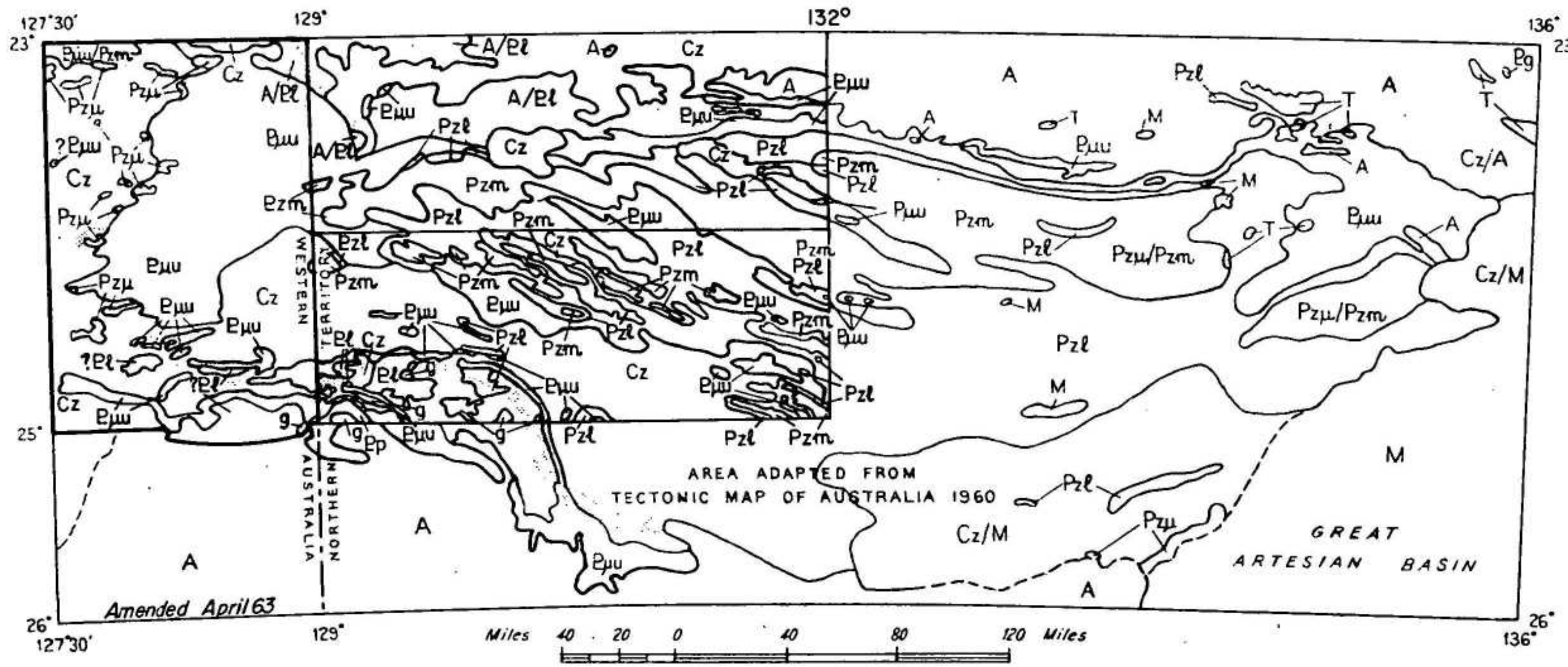
Some small areas on the south-eastern and central part of the Lake Amadeus Sheet area are covered with masses of amorphous gypsum. These deposits are either formed in a similar manner to the deposits of travertine or are possibly derived from the weathering of rock gypsum from underlying, obscured diapiric structures. The gypsum occurs in low mounds and very irregular hillocks.

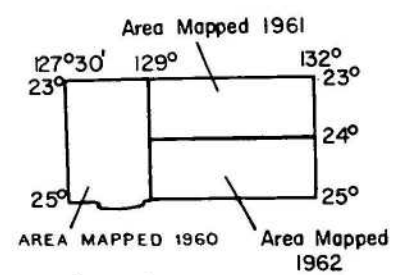
STRUCTURE

The term 'Amadeus Basin' is used in the report to refer to the downfolded and faulted area of Upper Proterozoic and Palaeozoic sediments shown in Figure 20. The Lake Amadeus Sheet area lies in the central part of the Amadeus Basin. The regional gravity contours (see Figure 21) suggest a gradual increase in the depth to basement from south to north across the Sheet area and reconnaissance aeromagnetic traverses (Goodeve, 1961) indicate a thickness of greater than 10,000 feet of sediments along the lines flown (see Figure 22 for magnetic profiles along flight lines).

Folding

There is evidence of two main periods of folding on the Lake Amadeus Sheet area (Fig.23). The earlier folding has been named the 'Lake Neale Folding' by Forman (1963) and probably took place during late Upper Proterozoic or Lower Cambrian times. This folding affected the Winnall Beds and underlying sediments but not the Cleland Sandstone. The sediments were tightly folded in most places (isoclinally in some places) and the fold axes trend west-north-west. The tight synclinal troughs and steep dips of the Winnall Beds contrast with the more open synclines and generally shallow dips of the younger sediments.





REFERENCE

Cz	*Cainozoic Undifferentiated*
T	*Tertiary*
M	*Mesozoic*
Pzμ	*Upper Palaeozoic*
Pzm	*Middle Palaeozoic*
Pzℓ	*Lower Palaeozoic*
Ꝑμu	*Upper Proterozoic*
g	*Granite*
Ꝑp	*Proterozoic Acid Porphyry*
Ꝑℓ	*Lower Proterozoic*
A	*Archaean Undifferentiated*

Amadeus Basin

Fig. 20 Sketch Map - Amadeus Basin

Bureau of Mineral Resources,
Geology and Geophysics.

To accompany Record 1963/51

N.T.-30

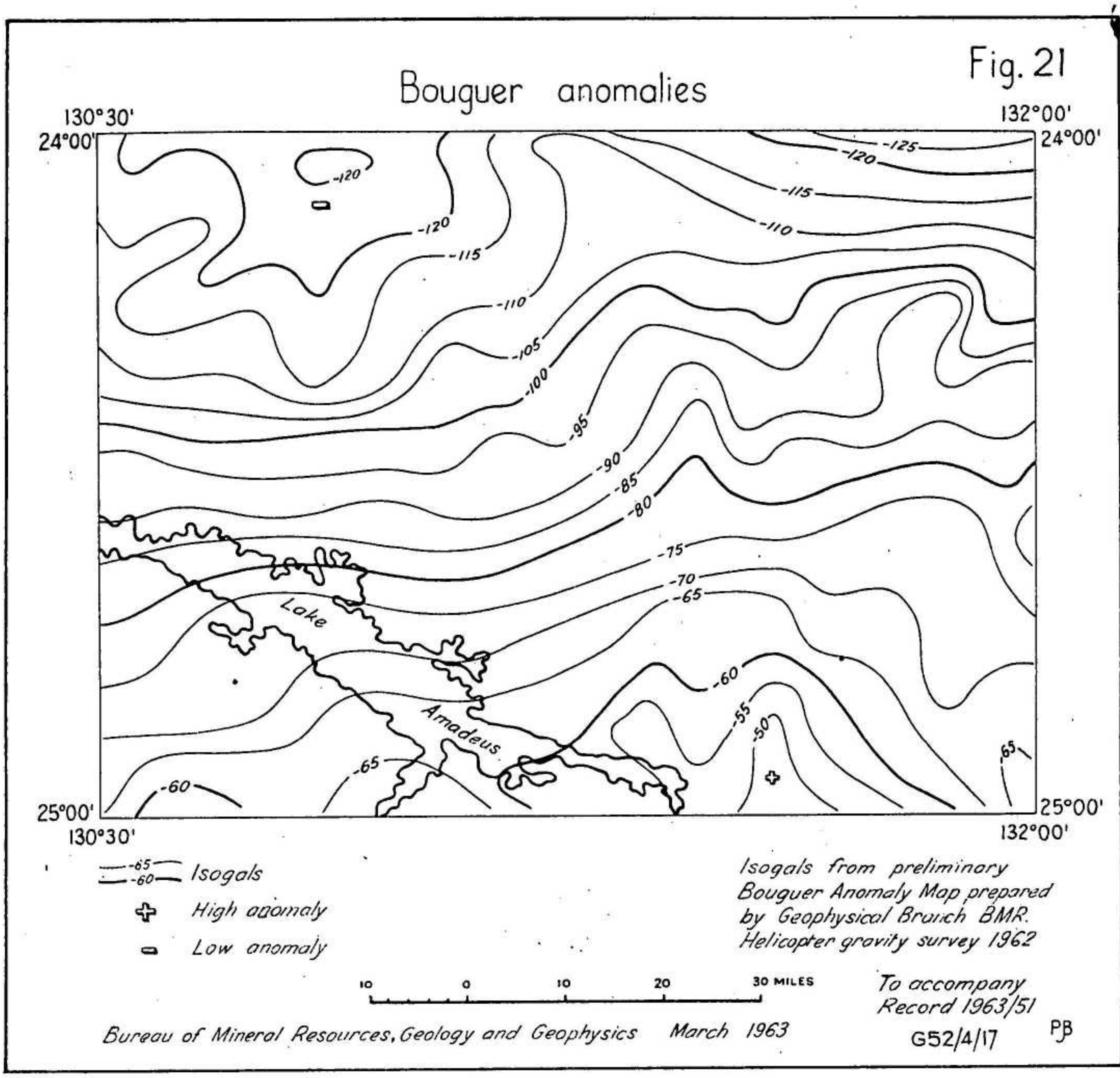
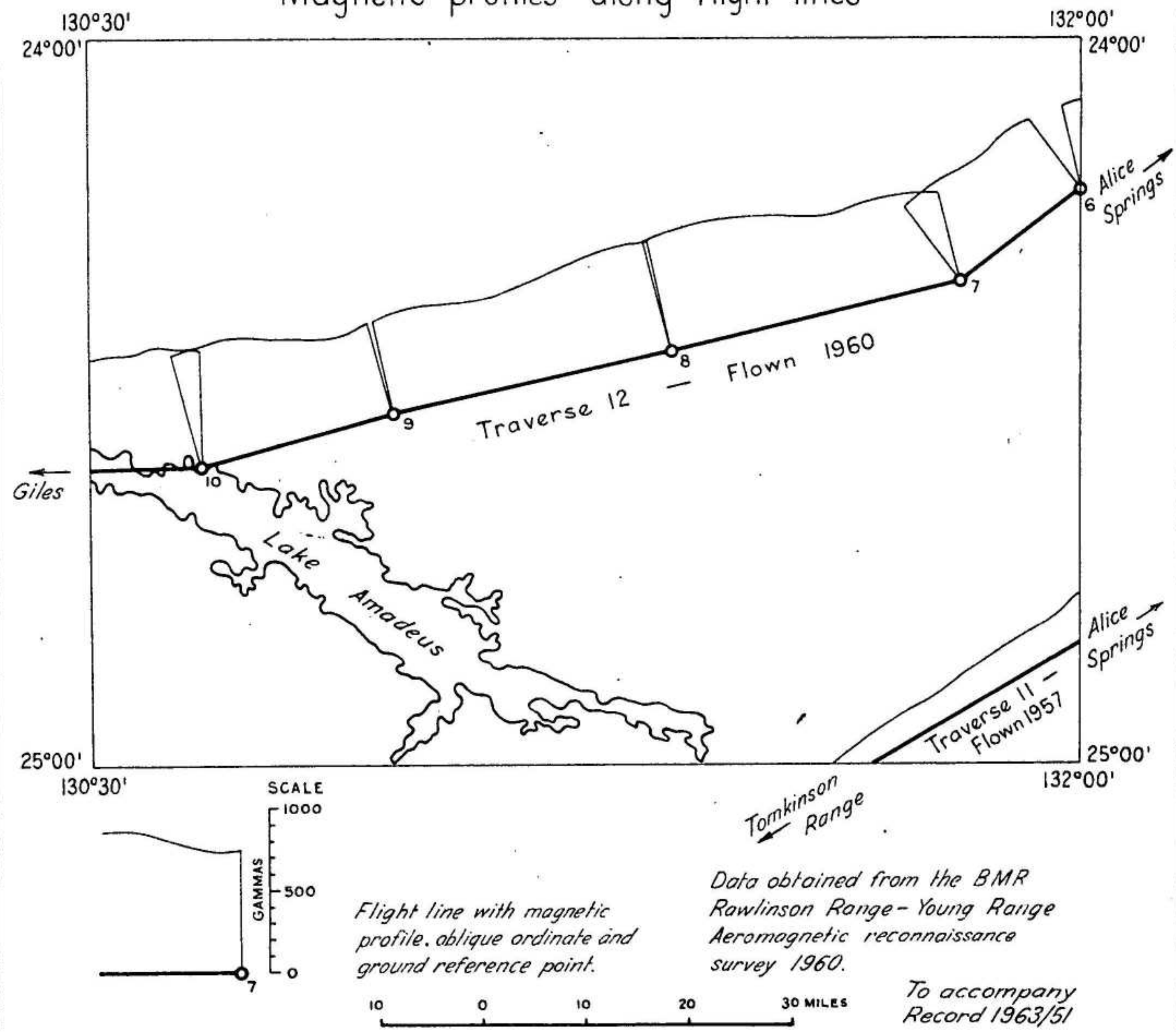


Fig. 21
Bouguer anomalies
130°30'
24°00'
132°00'
24°00'
25°00'
130°30'
25°00'
132°00'
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-65
-60
-55
-50
Lake
Amadeus
-65 -60 Isogals
High anomaly
Low anomaly
10 0 10 20 30 MILES
Isogals from preliminary Bouguer Anomaly Map prepared by Geophysical Branch BMR. Helicopter gravity survey 1962
To accompany Record 1963/51
Bureau of Mineral Resources, Geology and Geophysics March 1963
G52/4/17
PB

Fig. 22

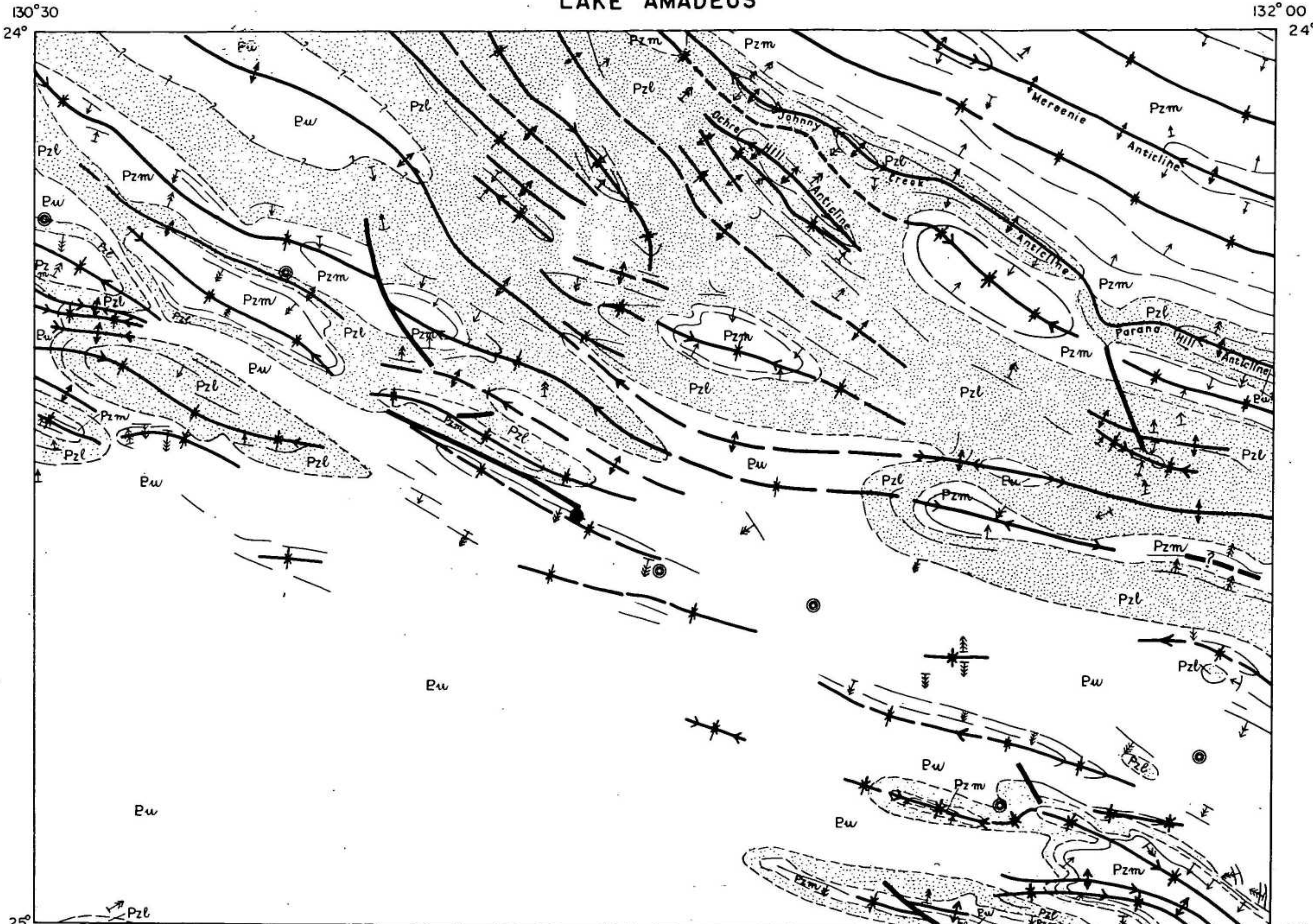
Magnetic profiles along flight lines



Bureau of Mineral Resources, Geology and Geophysics March 1963 G52/4/18 PB

STRUCTURAL INTERPRETATION
LAKE AMADEUS

FIG. 23



Bureau of Mineral Resources, Geology and Geophysics. April 1963.   To accompany Record 1963/51   G52/4/3

◎ Probable diapiric structure

The later period of folding has been called the 'Amadeus Basin Folding' by Forman (1963) because of its widespread effects within the Amadeus Basin. This folding caused most of the structures now obvious at the surface. The fold axes trend between west and north-west and the stress direction was probably much the same as during the 'Lake Neale Folding'. The 'Amadeus Basin Folding' produced a fold system with closely spaced subparallel axes and numerous reversals of plunge. Near Inindia Bore, in the south-eastern corner of the Lake Amadeus Sheet area, the structure of the Palaeozoic rocks is extremely complicated and is not, as yet, fully understood.

Faulting

The few faults that have been mapped on the Lake Amadeus Sheet area can be divided into two main types; north-north-west trending faults, and strike faults.

In general, the north-north-west trending faults have a right lateral sense of movement.

A major strike fault has been mapped 40 miles south of Mount Olifent and a south-block-up movement is indicated. The dip of the fault plane is not known. About 12 miles south of the George Gill Range on the eastern side of the Sheet area the Mereenie Sandstone is repeated and a strike fault with a north-block-up movement has been inferred.

Structural Evolution

In late Upper Proterozoic times, a thick sequence of sediments was deposited on the southern half of the Lake Amadeus Sheet area.

This southern part of the basin may have been partly separated from the rest of the basin north of the Lake Amadeus Sheet area by a ridge in the vicinity of the Parana Hill Anticline. As a result of the 'Lake Neale Folding' the southern part of the basin was probably uplifted and the main area of sedimentation moved north of the postulated ridge. The 'Lake Neale Folding' is only known in the area south of the ridge. A long period of stability and gradual subsidence followed the Lake Neale Folding.

The 'Amadeus Basin Folding' began at the northern margin of the basin after the deposition of the Mereenie Sandstone and continued intermittently during the deposition of the Pertnjara Formation. At the northern margin coarse syn-orogenic sediments were rapidly deposited adjacent to the uplifted block. This great thickness of sediment probably offered a greater resistance to the compressional forces which climaxed the 'Amadeus Basin Folding' and therefore, in this northern area, the Palaeozoic sediments are more broadly folded than in the areas further south.

Diapiric structures with cores of gypsum are known from the Amadeus Basin (Wells et.al, 1962), and six probable diapirs have been mapped on the Lake Amadeus Sheet area. However, it is not known when intrusion took place on the Lake Amadeus Sheet area. Gypsum and possibly other evaporites may be present in the cores of many of the anticlines as a result of decollement folding.

DIAPIRIC STRUCTURES ON THE LAKE AMADEUS SHEET AREA

Several possible diapiric structures were discovered on the Lake Amadeus Sheet area. The position of these structures is shown on Fig.23. In most cases the exposures in and around the diapirs are poor. The best outcrops of probable diapirs are at Mt. Murray and at a small hill 12 miles north-north-east of Inindia Bore. At both localities the core of the structure is made up of sheared gypsum partly overlain and surrounded by outcrops of dolomite and limestone which are identified with the Bitter Springs Limestone. At several other localities, there are structures which are thought to be diapiric in origin because of the outcrop of sheared gypsum or the local structure. In most places the country rock adjacent to the diapirs is not exposed.

The exposed part of the probable diapir at Mt. Murray is made up of isoclinally folded dolomite in pinnacles and ridges which overlie part of the central mound of sheared gypsum. Some isolated large blocks of dolomite are present near the centre of the dome, resting on the gypsum. The shearing in the primary gypsum is apparent in some of the small steep-sided creeks that cut through the structure. The closest outcrop to the possible diapir at Mt. Murray lies about $\frac{1}{4}$ mile to the south and consists of the Cleland Sandstone overlain by the Larapinta Group, and in turn by the Mereenie Sandstone. Part of the sequence in this outcrop is overturned.

A similar diapir is exposed 12 miles north-north-east of Inindia Bore. The dolomite present on the flanks of the structure is thin bedded and laminated, with some thin interbeds of slightly calcareous siltstone and irregular oolitic chert beds. The gypsum in the centre of the dome is well exposed in large sinkholes which are up to 35 feet deep. Shearing in the crystalline gypsum is easily discernable by tracing alternate dark and light shear planes in the rock where it is exposed in the steep walls os creeks.

Several possible diapirs occur between Inindia Bore and Mt. Murray. 18 miles east-south-east of Mt. Murray there is a small hill of sheared gypsum with sink holes and some overlying debris of dolomite and limestone. On the south-east side of the hill there are some large blocks of sandstone which are thought to be Mereenie Sandstone. The closest outcrops to the mass of gypsum are hills of Mereenie Sandstone in a syncline about a mile to the north. It is also possible that the isolated sandstone blocks near the gypsum belong to the Winnall Beds which has been folded and brought to the surface by the intrusion.

A probable diapiric intrusion is present 28 miles south-west of Reedy Rock Hole, at LA61. At this locality there is a roughly circular outcrop of steeply dipping chert (probably silicified Bitter Springs Limestone) which is partly surrounded by steeply dipping strata of the Winnall Beds. A possible stromatolite was found in the sequence of silicified chert and siltstone. The chert contains beds of oolitic chert, sandy chert and chert breccia. It is possible that some of the fragments are derived from the Inindia Beds. The Winnall Beds are brecciated near the outcrop of the silicified limestone. On the north-west side of the chert outcrop the Winnall Beds form a small syncline with an overturned south-west limb. On the south-east side of the possible intrusion part of the Winnall Beds strikes into the Bitter Springs Limestone outcrop and the other part is noticeably deflected around this outcrop. This structure has probably originated by the intrusion of gypsum and Bitter Springs Limestone into the Winnall Beds.

At LA508, about 8 miles north-west of LA62, there is a roughly circular depressed area which is covered by mounds of secondary gypsum and may be indicative of primary sheared gypsum at depth. This area is surrounded by hillocks of travertine.

At LA196 there is a semicircular rim of steeply dipping foetid grey dolomite breccia surrounding a core of gypsum. The dolomite has a few oolitic beds and possible stromatolites and contains some chert conglomerate similar to the conglomerate found near the top of the Bitter Springs Limestone in the Parana Hill Anticline.

The structure at LA525 has probably originated by diapiric intrusion. The outcrops are of pale-grey and dark grey, fine to coarse grained, laminated and in places brecciated foetid dolomite, with possible stromatolites. No primary rock gypsum was found but some of the dolomite breccia contains intergranular gypsum. Large floaters of sandstone similar to the Mereenie Sandstone, a scree of chert and rounded pebbles of coarse silicified sandstone cover the core of the structure.

A small area of poorly exposed dolomite occurs on the south side of a long strike ridge of Winnall Beds about 27 miles north-east of Inindia Bore. The anomalous position of the dolomite suggests that it may be diapiric in origin.

A circular depression about 100 yards across with a raised rim composed of mounds of secondary gypsum occurs 21 miles west-north-west of Inindia Bore. A small outcrop of steeply dipping Pacoota Sandstone occurs on the south side of the depression. This feature may be diapiric in origin.

In many of the structures described it is postulated that their roughly circular outline, the presence of a core of sheared gypsum and a roughly circular surrounding annulus of contorted and brecciated dolomite indicates that they are of diapiric origin. The intrusive gypsum (and possibly other evaporites at depth) are probably derived from the Bitter Springs Limestone. It is also possible that the incompetent Bitter Springs Limestone and associated gypsum were forced into the cores of anticlines during folding. Some of the outcrops of these rocks on the Lake Amadeus Sheet area could be the eroded remnants of the cores of the folds with the limbs of the anticline now partly obscured. A structure of this nature occurs on the south-east part of the Mt. Rennie Sheet area. Öpik (pers.comm.) has suggested that the presence of gypsum and possibly other evaporites would indicate that the dolomite and limestone in the diapirs could be Cambrian in age. This hypothesis is postulated because in many other places in the world the Cambrian is a period of salt deposition. Outside the Lake Amadeus Sheet area, particularly in the Goyder Pass area, there is some evidence that the intrusive material originated within the Bitter Springs Limestone.

The structure in the core of the Parana Hill Anticline may also be diapiric in origin but there is no evidence of any intrusive material or contortion of the dolomite. It is possible that it is a "trap-door" structure with intrusive material forcing a large block of Bitter Springs Limestone into its present position by hinging on the southern side of the outcrop. In this case, if movement of the intrusion commenced during deposition of the Pertatataka Formation it would account for the unconformity between the Pertatataka Formation and the underlying Areyonga Formation and Bitter Springs Limestone. A "trap-door" structure has been described at Goyder Pass (McNaughton, 1962).

On the Lake Amadeus Sheet area the youngest exposed sediments intruded by the gypsum and dolomite are the Winnall Beds; a possible exception occurs east-south-east of Mt. Murray where large blocks of sandstone, similar to the Mereenie Sandstone, are present at the margin of the intrusive gypsum. A load of several thousand feet of sediment is required before movement of evaporites is initiated. The sediments involved in the areas where these intrusions occur would include the thickness of Inindia Beds, Winnall Beds and any overlying section which has since been removed.

GEOLOGICAL HISTORY

The oldest known sediments preserved in the Amadeus Basin (Fig.20) are of Upper Proterozoic age and lie unconformably on Precambrian igneous and metamorphic basement. The basal Heavitree Quartzite and the overlying Bitter Springs Limestone are considered to be shallow marine sediments and were probably deposited on an epicontinental shelf, which extended well beyond the limits of the Amadeus Basin. The presence of algal dolomite and gypsum (and possibly other evaporites) in the Bitter Springs Limestone, indicates a fall-off in the amount of available detritus and suggests that the epicontinental sea was divided into areas of restricted circulation.

The deposition of the Bitter Springs Limestone was followed by uplift and erosion in some areas, and in the northern part of the basin the overlying Areyonga Formation contains fragments of the older sediments and basement rocks. The Areyonga Formation contains striated and facetted erratics up to two feet in diameter and is interpreted as a water-laid deposit formed in a glacial environment.

On the southern half of the Lake Amadeus Sheet area the Inindia Beds were deposited apparently conformably on the Bitter Springs Limestone.

It seems probable that structural growth during the later part of the Upper Proterozoic produced a ridge in the vicinity of the Parana Hill Anticline. A thick sequence of sandstone and siltstone (Winnall Beds) was deposited unconformably on the Inindia Beds south of the ridge; a thinner sequence of dominantly siltstone (Pertatataka Formation) was deposited conformably on the Areyonga Formation north of the ridge; and only a very thin veneer of siltstone and limestone (Pertatataka Formation) was deposited unconformably on the Areyonga Formation over the top of the ridge.

Sedimentation probably continued into the Lower Cambrian, after which the sediments in the southern half of the Lake Amadeus Sheet area were strongly folded and uplifted. The uplifted areas were eroded and deltaic, subgreywacke-type sediments poured into the northern part of the basin.

As the basin subsided during the Cambrian, the marine environment became more widespread and the sediments deposited in the transitional environment were gradually restricted to the south-west part of the basin. This transgression continued into the Upper Cambrian and possibly into the Lower Ordovician, with minor reversals resulting in interfingering of marine shales and limestones with the deltaic sandstones and siltstones.

During the Upper Cambrian, the basal sandstone of the marine Larapinta Group was deposited throughout much of the north-eastern part of the known basin. It is possible that the basal sandstone unit (Pacoota Sandstone) did not extend onto the southern half of the Lake Amadeus Sheet area until Lower Ordovician times. This sediment marked the beginning of a period of cyclic marine deposition of sandstone, siltstone and limestone, which continued into the Upper Ordovician with no recognizable breaks. These Larapinta Group sediments are largely, if not wholly, shallow water, marine, stable shelf deposits. The presence of extremely fossiliferous beds indicates that the Ordovician seas supported a prolific fauna. The distribution of the Larapinta Group sediments indicates that each successive unit probably transgressed the previous one and that the Ordovician seas were probably most widespread in the Upper Ordovician.

The deposition of the Larapinta sediments was interrupted in the Upper Ordovician by epeirogenic movements in the north-east part of the basin. These movements resulted in erosion of some of the sediments in the uplifted area and probably caused the retreat of the Ordovician seas. However, sedimentation was continuous on the western half of the Amadeus Basin, where the Mereenie Sandstone has a gradational contact with the underlying Stokes Formation. The Mereenie Sandstone appears to have been deposited in a combination of deltaic, aeolian, and littoral environments. The presence of worm burrows and a possible '*Cruziana*' suggest that the formation is at least partly of Ordovician age.

Following the deposition of the Mereenie Sandstone, a series of orogenic movements near the northern margin of the basin resulted in the deposition of the Pertnjara Formation. A very thick sequence of coarse, clastic sediments was deposted adjacent to the uplifted area, but farther away from the source the sediments deposited were thinner and finer grained. The Pertnjara Formation was deposited in a continental environment and is of post-Ordovician and pre-Permian age.

Orogenic movements continued after the deposition of the Pertnjara Formation and caused folding and faulting which affected the sediments throughout the basin.

The folded and uplifted Amadeus Basin sediments then underwent a long period of weathering and erosion. This erosion resulted in the more rapid removal of the siltstone and shale units, forming the strike ridge and valley topography so prevalent in the Amadeus Basin at present.

Remnants of sediments deposited during the Permian glaciation are known from the western side of the basin, but it is not known whether these deposits extended onto the Lake Amadeus Sheet area.

During the Mesozoic, a marine transgression moved over the eastern side of the Amadeus Basin. No marine, Mesozoic sediments are known from the Lake Amadeus Sheet area, but continental, valley-fill deposits of possible Mesozoic age were deposited in the north-east quadrant of the area.

After the deposition of these possible Mesozoic sediments the area was uplifted and eroded. A climatic change during the Tertiary resulted in the deposition of conglomerate immediately adjacent to the ranges, and the formation of a lake system. Remnants of possible Tertiary lacustrine sediments are still preserved in the Inindia Bore area.

An arid phase, probably during the Quaternary, resulted in the formation of sand dunes which now cover most of the Lake Amadeus Sheet area.

More recent changes to the climate have resulted in the fixing of the sand dunes by a sparse vegetational cover and the dissection of the possible Mesozoic and Tertiary deposits, producing thin sequences of alluvial sediments adjacent to the ranges.

Diapiric structures have been described from the Lake Amadeus Sheet area, but it is not possible to determine when intrusion took place. If the Parana Hill Anticline is of diapiric origin, the intrusion probably took place before the deposition of the limestones in the Pertatataka Formation which show no evidence of brecciation or any major disturbance near the core of the structure.

ECONOMIC GEOLOGY

Phosphate Deposits

Introduction

The presence of phosphorites* in the Amadeus Basin was first mentioned briefly by Wells, Forman and Ranford (1962) who found isolated outcrops of thin, phosphate-rich beds in the Ordovician Stairway Sandstone of the Mount Liebig Sheet area. During 1962 it was possible to make a more detailed study of phosphorites in the Lake Amadeus Sheet area and parts of the Henbury Sheet area.

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* The term "Phosphorite" is used in the sense of McKelvey et.al. (1959) meaning a phosphatic sedimentary rock.

The phosphorites are confined to the Cambro-Ordovician Larapinta Group. The Tempe Member of the Pertaoorrta Formation though rich in phosphatic brachiopods, has a low P_2O_5 content.

The formations of the Larapinta Group are all phosphatic to varying degrees:-

Pacoota Sandstone: At present this would appear to be the least phosphatic formation of the Larapinta Group. There are no known pelletal phosphorites in the formation, though it is suspected that a vuggy sandstone (LA161) represents an originally pelletal sandstone from which the pellets have been weathered out.

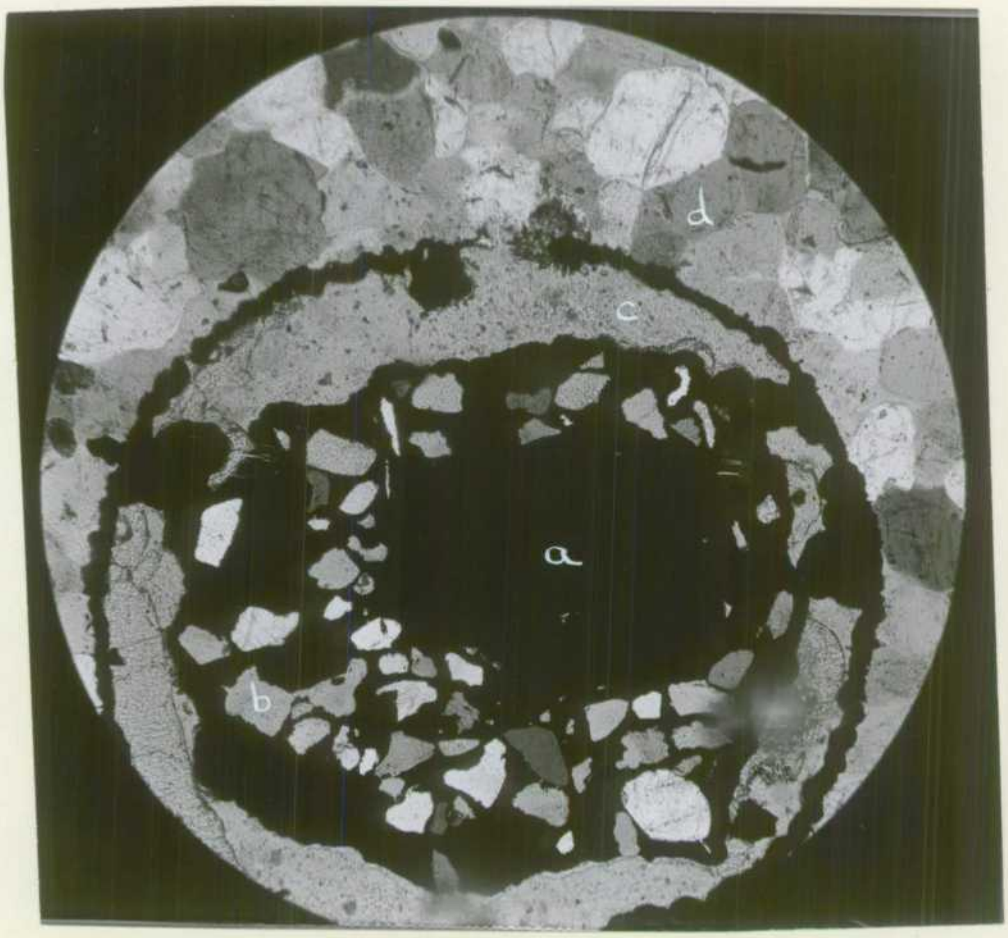
Horn Valley Siltstone: As yet, few samples have been submitted for analysis, but the majority of those submitted have very little or no phosphate; the average P_2O_5 content being about 1%. It is considered likely that the oolitic ironstone from just below the top of the Horn Valley Siltstone was an oolitic phosphorite which was subsequently ferruginized, possibly during Tertiary weathering. This is supported by the size and shape of the ooliths, which are identical with known phosphorite ooliths in the Stairway Sandstone, and by the presence of some phosphatic (probably collophane) cores surrounded by a rim of limonite.

Stairway Sandstone: This is the most phosphatic formation of the Larapinta Group and will be discussed in greater detail below.

Stokes Formation: This formation is for the most part thought to be poorly phosphatic. The only phosphatic beds occur close to the base and are identical with the phosphatic beds of the Stairway Sandstone. Two samples of this phosphatic pelletal sandstone assayed 13.9% and 8.6% P_2O_5.

Occurrence of Stairway Sandstone Phosphorites:

Phosphatic material occurs in a finely divided form throughout much of the Stairway Sandstone. The phosphorites occur most commonly as pellets or nodules which contain the highest percentage of P_2O_5; the pellets are either sparsely scattered through sandstone and limestone beds (5% to 10% of P_2O_5), or more normally, forming beds one to four inches thick composed almost entirely of phosphorite pellets in a sandy matrix. These pellet beds have the highest P_2O_5 content; generally between 10% and 22% P_2O_5. They occur irregularly throughout much of the Stairway Sandstone. In a section in the George Gill Range (section LAC13) twelve such beds, with an average thickness of about two inches, are exposed over a stratigraphic interval of 100 feet.



LA 161, Thin Section R12424 (X-Nicols), X45

Fig. 24. Thin section of coarse grained sandstone with vughs. Pacoota Sandstone.

(a) Opaque iron ore (?magnetite).
(b) Fine angular quartz .
(c) Colourless amorphous mineral (?crypto-crystalline apatite).
(d) Coarse quartz showing secondary enlargement of the grains.

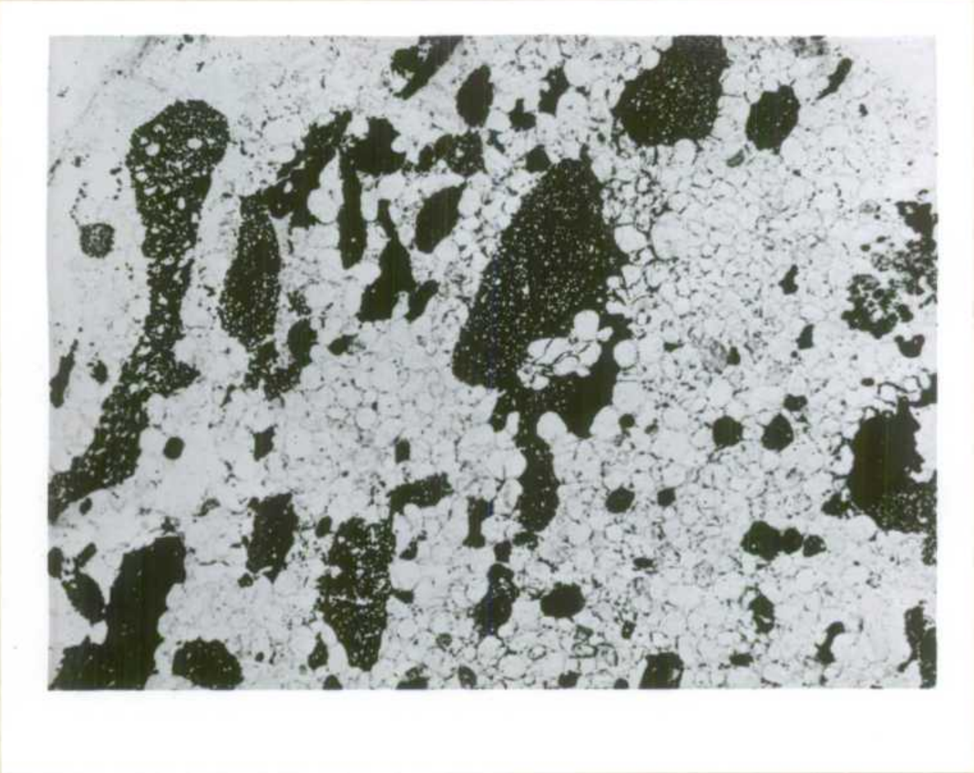
The pellets occur in two forms; brown pellets, two specimens of which contained approximately 14% and 9% P_2O_5, and grey pellets, found in two analyses to contain approximately 20% and 11% P_2O_5. Similar types are also reported from the Phosphoria Formation of the Western United States by McKelvey (1959); (Twenhofel (1950) considers that the colour depends upon the quantity of contained organic material). The pellets range in size from less than 1 mm to a maximum diameter of 5 cm. The surface of the brown pellets is generally smooth and fairly well-rounded; the grey pellets tend to be less well-rounded and concave surfaces are common. Concentric or regular banding within the pellets is rare, but in places the pellets are composed of phosphatic ooliths, 0.2 to 0.3 mm. in diameter.

In thin section, the pellets contain approximately 60% of well rounded, detrital quartz grains, with minor accessory minerals including zircon, plagioclase and tourmaline. The cement in some areas is a brown, cryptocrystalline mineral with fine, poorly rounded grains of quartz and fine mica flakes. X-ray diffraction by Greaves (B.M.R. Pers.comm.) showed that the cryptocrystalline mineral was apatite.

Results of Analyses (Tables IV and V)

46 analyses of rock from the Amadeus Basin vary in P_2O_5 content, from 21.6% in the Stairway Sandstone to .03% in the Winnall Beds. The pelletal sandstone has consistently the highest P_2O_5 content (commonly 15% and greater of P_2O_5). The highest P_2O_5 content of a phosphatic limestone is 5.3% (LA49) though other limestones from the Stairway Sandstone yielded less than 1% P_2O_5. The maximum P_2O_5 content obtained from siltstone from the Stairway Sandstone only was 1.5% but this is still well above the average P_2O_5 content for a siltstone. Few analyses have been carried out on specimens from formations other than those of the Larapinta Group; a Mesozoic siltstone assayed only 0.16% P_2O_5, and two speciiens from the Winnall Beds had a P_2O_5 content below average for sandstone. The P_2O_5 content of a limestone from the Tempe Member of the Pertaoorrta Formation is somewhat higher than that usually found in limestones, but this is explained by the presence of phosphatic brachiopods. Two analyses were carried out on Quaternary deposits; one a river gravel which had a P_2O_5 content of 1% and the other a surface gravel with 7% P_2O_5 content, suggesting these types of deposits cannot be ignored as a possible source of phosphate.

McKelvey (1959) showed that in the phosphorites of the Phosphoria Formation, there is a close association between the presence of phosphate and trace elements such as zinc, lead, rare earths, uranium, etc. 21 specimens from the Amadeus Basin were analysed spectrochemically for the elements nickel, cobalt, copper, vanadium, lead, zinc, tin, beryllium and molybdenum by E.J. Howard of the B.M.R. (See Table IV).



ML 37. X25

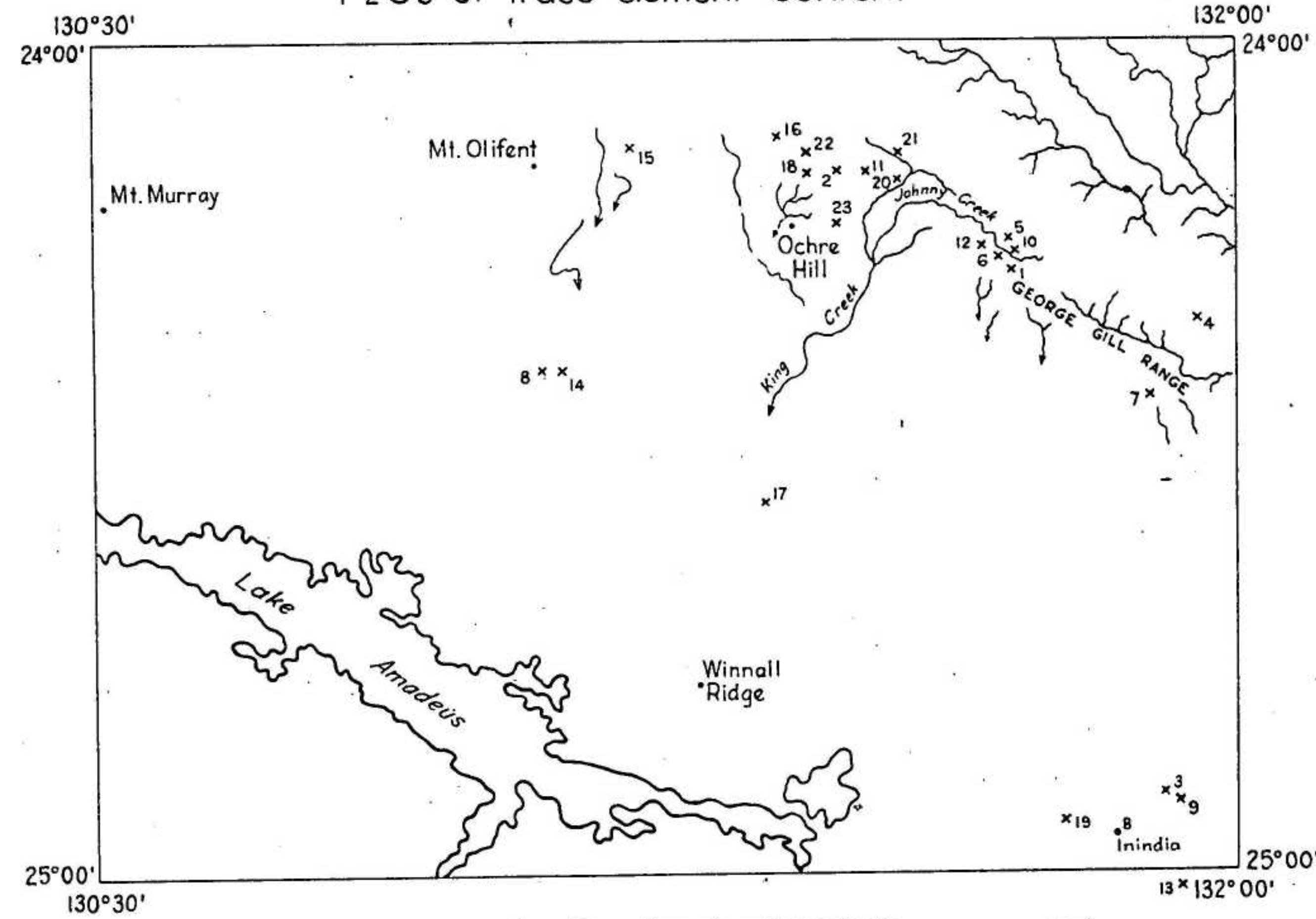
Fig. 25. Thin section of Stairway Sandstone showing cryptocrystalline apatite (black in photo) with enclosed fine angular quartz.

LA 534. X16

Fig. 26. Thin section of part of a phosphatic pellet with cryptocrystalline apatite (black in photo) and fine angular quartz.

Location of specimens analysed for P_2O_5 or trace element content

Fig. 27



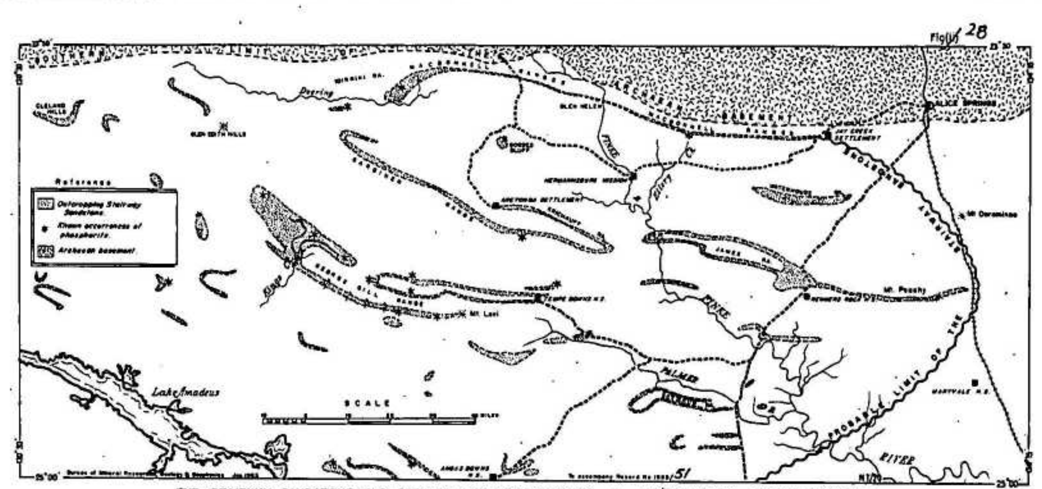
x Location of analysed specimen

10 0 10 20 30 MILES

To accompany Record 1963/51

Bureau of Mineral Resources, Geology and Geophysics March 1963

G52/4/19 PB



THE STAIRWAY SANDSTONE AND PHOSPHORITE OCCURRENCES — AMADEUS BASIN, CENTRAL AUSTRALIA.

TABLE IV SPECTROCHEMICAL ANALYSES FOR PHOSPHATE AND TRACE ELEMENTS

Map Reference No. See fig. 27	Field Reference No.	Formation	Lithology	Trace Element Content in parts per million					P_2O_5 content
				Nickel	Cobalt	Copper	Vanadium	Lead	
*	ML 37	Stairway Sandstone	Sandstone with phosphatic pellets.	10	10	100	50	400	H
5	LA 139(A)	Stokes Formation	" " " "	10	10	30	10-	150	H
14	LA 188(B)	Stairway Sandstone	" " " "	20	30	30	10	150	H
20	LA 543	" "	" " " "	10	30	10	10-	150	H
2	LA 544(B)	" "	Silty sandstone with phosphatic pellets.	5	10	10	10	150	H
1	LA 535(2)	" "	Sandstone with phosphatic pellets.	5	5-	30	10-	100	H
1	LA 534(B)	" "	Brown phosphatic pellet.	5-	20	20	10-	100	H
7	LA 168	" "	Sandstone with phosphatic pellets.	5-	5-	20	10-	70	H
1	LA 534(A)	" "	Grey phosphatic pellet.	a	a	10-	10-	50	H
14	LA 188(A)	" "	Limestone with occasional phosphatic pellets.	a	5-	10	10	10	H
1	LA 535(10)	" "	Sandstone with sponge spicules and occasional phosphate pellets.	5-	5-	10-	10-	30	L
5	LA 139(B)	Stokes Formation	Limestone.	a	a	10	10-	30	L
15	LA 114	Horn Valley Siltstone	Siltstone.	a	5-	10	10-	20	L
21	LA 141	Stairway Sandstone	Sandstone with occasional phosphatic pellets.	a	a	10-	10-	10	L
8	LA 54	" "	Sandstone.	a	5-	10-	10-	10-	L
*	ML 6	Horn Valley Siltstone	"	10	100	10	50	20	L
1	LA 535(3)	Stairway Sandstone	Siltstone.	5-	5	10	10	10	A
2	LA 544(A)	" "	"	5-	5	10	20	10	A
22	LA 154	Horn Valley Siltstone	Limestone.	a	a	10-	10-	10-	A
22	LA 153	" " "	"	a	a	10	10-	10-	A
23	LA 156	" " "	"	a	a	10-	10-	10-	A

a trace element not present in detectable amounts
H percentage of P_2O_5 is high - above 10% P_2O_5.
L percentage of P_2O_5 is low - between 1% and 10% P_2O_5.
A percentage of P_2O_5 is very low or absent - less than 1% P_2O_5.
* Specimens collected outside the Lake Amadeus 1:250,000 Sheet area (See Table V).
5- less than 5 p.p.m.

TABLE V

QUANTITATIVE PHOSPHATE ANALYSES

Map Reference No. (see Fig.27)	Field Reference No.	Formation	Lithology		Percentage of P_2O_5.
1	LA 535(9)	Stairway Sandstone	Sandstone with phosphatic pellets.	a	21.6
1	LA 535(8)	" "	" " " "	a	20.4
1	LA 534(A)	" "	Grey phosphatic pellet	b	19.5
*	ML 37	" "	Sandstone with phosphatic pellets.	b	18.0
2	LA 544(B)	" "	Silty sandstone with phosphatic pellets.	a	17.2
**	HY 9	" "	Sandstone with phosphatic pellets	a	15.9
3	LA 228	" "	" " " "	a	15.6
4	LA 18(B)	" "	" " " "	b	15.5
1	LA 103	" "	" " " "	b	14.0
1	LA 535(5)	" "	" " " "	a	14.0
5	LA 139(A)	Stokes Formation	" " " "	b	13.9
1	LA 534(B)	Stairway Sandstone	Brown phosphatic pellet.	a	13.5
6	LA 148	" "	Sandstone with coarse phosphatic pellets.	b	12.6
7	LA 168	" "	Sandstone with phosphatic pellets.	a	11.8
1	LA 534(C)	" "	Grey phosphatic pellet.	a	11.0
1	LA 535(1)	" "	Sandstone with phosphatic pellets.	a	11.0
1	LA 535(2)	" "	" " " "	a	10.6
8	LA 54	" "	" " " "	b	10.6
9	LA 229	" "	" " " "	a	10.4
5	LA 133	" "	Sandstone with coarse phosphatic pellets.	b	9.9
1	LA 535(7)	" "	Sandstone with phosphatic pellets.	a	9.2
1	LA 534(D)	" "	Brown phosphatic pellet.	a	9.0
1	LA 535(4)	" "	Sandstone with phosphatic pellets.	a	8.7
4	LA 24	Stokes Formation	Sandstone with some phosphatic pellets.	b	8.6
1	LA 535(6)	Stairway Sandstone	" " " " "	a	7.7
10	LA 106	Quaternary	Surface gravel.	b	7.0
4	LA 16	Stairway Sandstone	Sandstone with fine phosphatic pellets.	b	6.8
11	LA 49	" "	Limestone with phosphatic pellets.	b	5.3

Contd...... Sheet 2.

Map Reference No. (See Fig. 27)	Field Reference No.	Formation	Lithology		Percentage of P_2O_5.
12	LA 102	Stairway Sandstone.	Calcareous sandstone with phosphatic pellets.	b	2.6
1	LA 535(10)	" "	Sandstone with sponge spicules and some phosphatic pellets.	a	2.4
13	LA 220	" "	Sandstone with some phosphatic pellets.	a	1.7
4	LA 18(A)	" "	Siltstone.	b	1.5
1	LA 535(3)	" "	"	a	1.1
10	LA 105	Quaternary	River gravel.	b	1.0
****	HY 26-2	Tempe Member	Limestone with phosphatic brachiopods.	a	0.9
14	LA 188(B)	Stairway Sandstone.	Limestone with some phosphatic pellets.	a	0.9
15	LA 114(1)	Horn Valley Siltstone	Siltstone.	b	0.8
14	LA 189	Stairway Sandstone	"	a	0.8
***	ML 6	Horn Valley Siltstone	"	b	0.7
16	LA 107	Pacoota Sandstone	"	a	0.2
2	LA 544(A)	Stairway Sandstone	"	a	0.2
4	LA 203-D	Mesozoic	"	a	0.16
17	LA 193	Winnall Beds	Silicified sandstone.	a	0.14
18	LA 108	Pacoota Sandstone	Siltstone.	a	0.12
15	LA 114(2)	Horn Valley Siltstone.	"	a	0.10
19	LA 550(B)	Pertaoorrta Formation	Sandstone.	a	0.03

Any specimens marked with an asterisk are from a locality outside the Lake Amadeus 1:250,000 Sheet area.

* Two miles south of Deering Creek; Mount Liebig 1:250,000 Sheet area.

** Petermann Hills area; Henbury 1:250,000 Sheet area.

*** Western MacDonnell Range; Mount Liebig 1:250,000 Sheet area.

**** Three miles north of Mount Levi; Henbury 1:250,000 Sheet area.

b Analysis undertaken by the laboratory of the Bureau of Mineral Resources, Canberra.

a Analysis undertaken by the Australian Mineral Development Laboratories, S.A.

Zinc, tin, beryllium and molybdenum were absent from all the specimens and the others were detectable only in small amounts. It was found there was a general tendency for the concentration of some trace elements to rise with the P_2O_5 content e.g. the lead content increased from 30 parts per million in a sandstone containing less than 5% of P_2O_5 to 400 parts per million of lead in a pellet sandstone containing 18% P_2O_5. The table of spectrochemical analyses is arranged in order of decreasing P_2O_5 content and this corresponds approximately to decreasing lead content. A similar though less orderly decrease in copper content occurs and there is a fall from 100 parts per million of copper to less than 10 parts per million. Cobalt and nickel generally show their lowest concentrations in the specimens with the lowest P_2O_5 content but do not necessarily show their highest concentration in the specimens with the highest P_2O_5 content. Vanadium behaves similarly, though the maximum vanadium content (50 parts per million) is recorded in the specimens with high P_2O_5 content (18%) and the same vanadium content is also recorded in a specimen with a P_2O_5 content of only 0.7% (ML6). However, so few analyses have been performed as yet that it is impossible to draw any definite conclusions regarding the relation of the trace elements to the phosphate concentration.

Origin of the Phosphorites.

This discussion concerns the Stairway Sandstone type of phosphorite only, but it should be mentioned that any phosphate in the Pacoota Sandstone may be partly if not entirely formed by enormous numbers of Scolithus, for annelids commonly have a high percentage of phosphate within their bodies.

There is no evidence such as veining, or replacement textures to support an epigenetic origin for the Stairway Sandstone phosphate. The concentration, size and form of the pellets disprove any idea of excremental origin.

Blackwelder (1916) considered that the wholesale destruction of large numbers of organisms was a major factor in the formation of phosphorites. Such a factor may have been of importance in the Horn Valley Siltstone, which contains vast quantities of trilobites, brachiopods, nautiloids and (less commonly) graptolites, as to suggest destruction on a massive scale. However, it is likely to have been a much less important factor in the Stairway Sandstone.

Adams, Groot and Hiller (1961) describe many compositional differences between phosphatic pellets and their surrounding sediments in the Palaeocene Brightsea Formation, a phosphatic unit in the eastern United States. They conclude that these nodules could not have formed in situ.

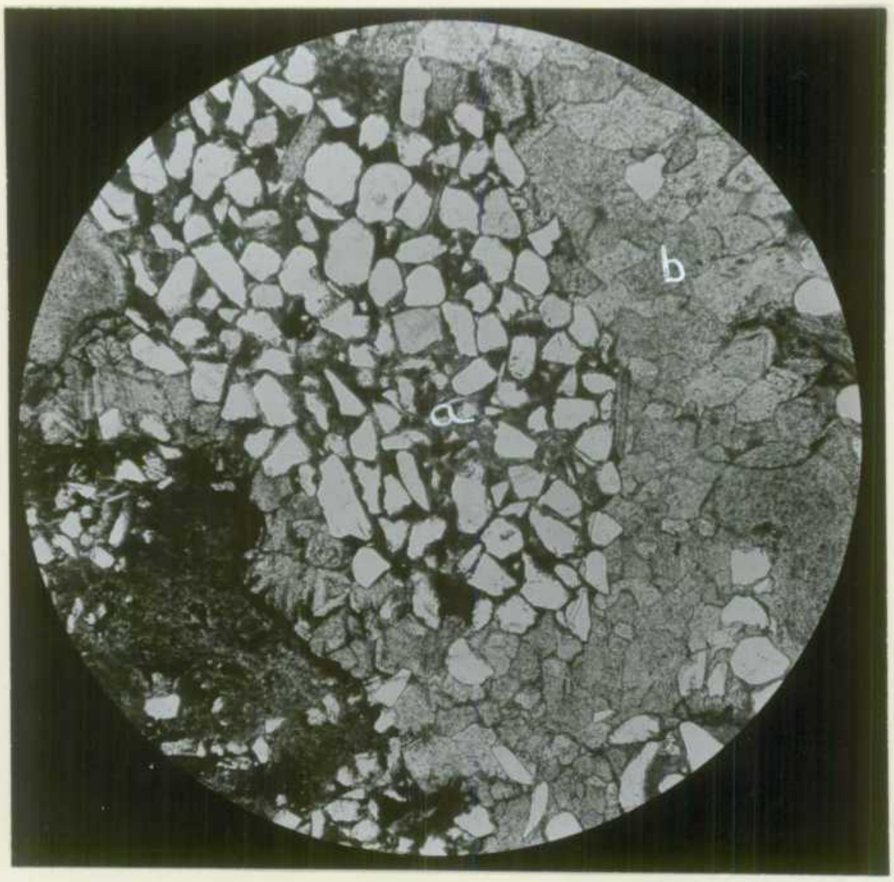
Similar differences in grain size, degree of rounding and the presence of accessory minerals, occur in the Stairway Sandstone phosphorites, suggesting that the pellets are allochthonous, but other textural evidence indicates that the pellets were probably formed in situ.

McKelvey (1959) has clearly demonstrated that the phosphorites of the miogeosynclinal facies of the Phosphoria Formation are of the bedded, platy or flagstone type; they are very rich in P_2O_5 and are associated with black bituminous shales and cherts. Such associations were not observed in outcrop in the phosphorites of the Amadeus Basin and it would seem that the Amadeus Basin deposits are not the miogeosynclinal but the shelf or platform type. Such deposits are generally considered to be distinguished (McKelvey, Swanson and Sheldon, 1953) by the nodular or pebbly habit of the phosphorites, their low to moderate P_2O_5 content, and their associations with glauconitic and arenaceous materials and limestone.

The Stairway Sandstone contains nodular phosphate and arenaceous material, but the P_2O_5 content (up to 22%) is somewhat higher than is normally expected for the shelf facies. The association of phosphorites with glauconite and limestone appears to be poorly developed in the Amadeus Basin.

Ripple marks and cross-bedding are common throughout the Stairway Sandstone, whereas they are normally absent from other phosphorites. Kazakov (1937) considered that phosphorites formed in depths of between 50 and 200 metres, whereas McKelvey et.al.(1953) put the depth of deposition of miogeosynclinal phosphorites at between 200 and 1,000 metres. The abundant ripple marks, cross-beds, and coarse sandstone in the Stairway Sandstone would suggest that in this instance, the phosphorites formed at depths very much closer to the values of Kazakov than to those of McKelvey et.al.

The variation of lithologies within the Stairway Sandstone indicates a fairly rapidly changing environment. The siltstones of the Stairway Sandstone may indicate a reducing environment, with bottom waters rich in hydrogen sulphide and anaerobic bacteria. (Baas Becking (1957) showed that the presence of hydrogen sulphide in water, solubilized phosphate.) If the hydrogen sulphide and phosphate rich bottom waters, of what where probably localized basins or depressions, were subjected to an influx of oxygenated water laden with detrital quartz, the partial pressure of hydrogen sulphide would drop, the environment become oxidizing, and pH of the water reach a value of between 7.1 and 7.8. The phosphate would then be precipitated as cryptocrystalline apatite and form the matrix for the detrital quartz grains.

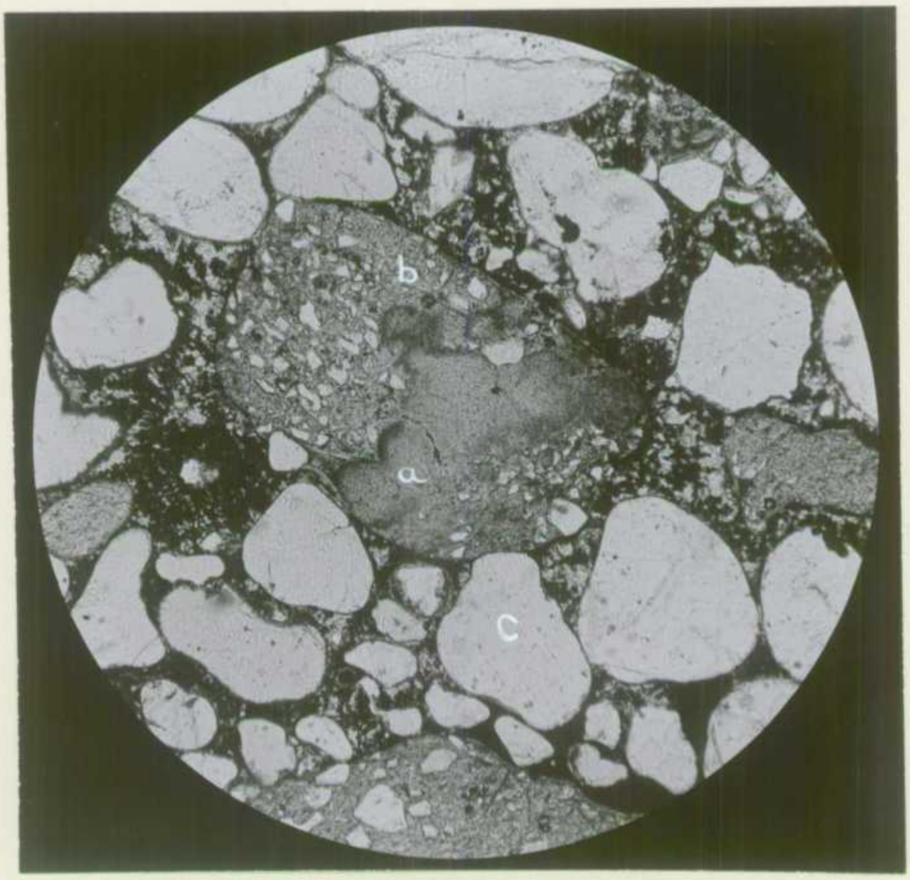


LA 54, Thin Section R13096. X45

Fig. 29. Thin section of limestone with sandy phosphatic pellets. Stairway Sandstone.

(a) Angular quartz with a dark green phosphatic (?crypto-crystalline apatite) cement.

(b) Intergrowth of calcite crystals.



LA 133. Thin section R12431. X45

Fig. 30. Thin section of coarse phosphatic sandstone. Stairway Sandstone.

(a) Crypto-crystalline apatite or collophane showing shadowy ooliths cemented together.
(b) Phosphatic groundmass and fine angular quartz.
(c) Quartz.

Further Investigations

Isopach and lithofacies maps are likely to be of considerable value in indicating possible areas for further investigation. It is very necessary initially to undertake some drilling of the Stairway Sandstone, in order to ascertain the number and thickness of phosphorite beds in an area such as Johnny Creek Anticline where even with fairly poor exposure a dozen individual phosphorite beds crop out. It is intended to carry out a diamond drilling programme in parts of the Amadeus Basin during 1963.

T. Quinlan (pers. comm. B.M.R.) reports the two holes have been drilled into the Stairway Sandstone in the Henbury Sheet area (Resident Geologist office, Alice Springs, Bore reference numbers G53/1-89 and G53/1-90). Both contain 175 parts per million nitrate and 6000 parts per million of total dissolved salts, indicating the possibility of a correlation between rocks with a high phosphate content and ground-waters with a high nitrate content. The groundwaters may therefore serve as further indicators of areas likely to be of interest in the search for phosphate.

Much work has to be done on the phosphorites of the Amadeus Basin before a fully comprehensive hypothesis can be put forward to explain their formation, for they are dissimilar in many ways to other described phosphorite deposits.

For further prospecting of these deposits, it is possible that a basic principle of Kazakov (1937) will hold; viz: that as the distance from the shoreline increases so the phosphorites become thicker and the percentage of P_2O_5 rises. If this is the case, then the area along the southern margin of the Western MacDonnell Ranges appears, at the present time, to offer the best hopes for rich phosphate deposits.(Fig 28) At this stage however, it is recommended that further investigations be first undertaken in an area such as Johnny Creek Anticline where numerous phosphate occurrences are already known, where the access is fair and where the Stairway Sandstone covers a large area within shallow drilling depth.

Petroleum Prospects

Possible source rocks for petroleum in the Amadeus Basin sediments preserved on the Lake Amadeus Sheet area include the dolomite and limestone of the Bitter Springs Limestone and the Pertatataka Formation, the limestone and shale beds in the Pertaoorrta Formation, and some of the limestone and siltstone of the Larapinta Group. One sample of soil (LA575) overlying the Stokes Formation in the Johnny Creek area gave 0.63% by weight of oil. The sample gave a strong golden colour in Xylene and a dull blue-white fluorescence in xylene. Several such small oil impregnated soil patches occur in the vicinity of LA575 but the origin of the oil and its extent with depth is not known.

A sample of sheared gypsum from the small diapiric structure south-east of Mt. Murray gave a strong yellow color in xylene and a strong fluorescence in xylene and acetone.

Suitable reservoir and cap rocks are present throughout the sedimentary section. The lenses of clean, medium sandstone (56 feet thick in section LAW2) near the top of the Bitter Springs Limestone in the Parana Hill Anticline would be an important reservoir rock for any petroleum originating in the Bitter Springs Limestone. Other possible reservoir rocks include some of the sandstones in the Areyonga Formation, the non-silty sandstone in the Pertaoorrta Formation and Cleland Sandstone, the sandier parts of the Winnall Beds, the Pacoota Sandstone and Stairway Sandstone of the Larapinta Group (provided they are not silicified at depth) and the Mereenie Sandstone. The sandstone of the Pertnjara Formation has no suitable cap rock.

The possible evaporites in the Bitter Springs Limestone and the lutites in the Pertatataka and Pertaoorrta Formations and Larapinta Group and the basal siltstone unit of the Pertnjara Formation would be suitable cap rocks where they occur in structures considered as possible traps for petroleum.

The north-eastern part of the Lake Amadeus Sheet area offers the best prospects for oil accumulation,as in this area the marine sediments of the Larapinta Group are thickest and the Pertaoorrta Formation contains sections of limestone and shale. The western and southern parts of the Sheet area are considered at this stage to have little petroleum potential. In these areas the thickness of Ordovician sediments is only a fraction of that present on the north-eastern part of the Sheet area and the Cambrian section is represented by a deltaic sandy facies.

The Cleland Sandstone is thought to be laterally equivalent to the Pertaoorrta Formation so that in favourable areas oil generated in the marine sediments of the Pertaoorrta Formation could migrate up dip to the sandy beds of the Cleland Sandstone or to sand lenses and pinch outs where the two formations interfinger.

Several anticlines on the north-eastern part of the Lake Amadeus Sheet area are closed in either the Larapinta Group rocks or the underlying Goyder Member of the Pertaoorrta Formation. The Mereenie Anticline is closed in the Mereenie Sandstone and probably offers the best prospect for a deep stratigraphic test. The eastern extension of the Johnny Creek Anticline is possibly closed in the Stairway Sandstone and could provide a structural trap for oil migrating to favourable horizons in the Larapinta Group.

The Parana Hill Anticline is breached to the Bitter Springs Limestone and offers little prospect for oil accumulation. Structures, similar to that exposed in the Parana Hill Anticline, may occur beneath other anticlines on the north-east part of the Lake Amadeus Sheet area. These structures would provide a suitable trap for any oil migrating from the Bitter Springs Limestone.

The possible diapiric structures on the Lake Amadeus Sheet area occur mainly in areas where Upper Proterozoic rocks are exposed and could form structural traps for any oil derived from the Bitter Springs Limestone. Any buried diapirs in Palaeozoic rocks could have acted as barriers to migrating oil especially if they were growing during deposition of the sediments.

<u>Water Supply</u>

Surface Water

Supplies of surface water are plentiful in rockholes and waterholes within the ranges in the north-east corner of the Lake Amadeus Sheet area. There are two lines of rockholes and waterholes within the ranges; those along the southern margin of the George Gill Range including the rockholes of King Canyon, Penny Springs, Reedy Rockhole, Kathleen Springs, and Bagot Springs; and the line of rockholes along the southern-margin of Nineteen ~~Nine~~ Mile Plain including Nineteen Mile Rockhole, Grantham Rockhole, Ukulka Rockhole, and Spur Rockhole. All of these rockholes and waterholes, which are in Mereenie Sandstone, are permanent and all contain potable water. The waterholes and rockholes have been formed either by erosion due to waterfalls, e.g. Reedy Rockhole or by the development of enlarged potholes as at Spur Rockhole.

Apart from these larger permanent rockholes there are numerous smaller rockholes and some large semi-permanent water holes within the ranges e.g. within the Vale of Tempe, along Johnny Creek, and in the Petermann Creek area. Some of the semi-permanent waterholes retain water for up to two months after rain, but the water is only suitable for drinking in an emergency.

Outside the ranges in the north-east corner of the area, there are very few rockholes; the only known ones are Nonane Rockhole, Kulpi Rockhole, and some small ones on Winnall Ridge and the long strike ridge east of Winnall Ridge. None of these rockholes are permanent.

Some of the clay-pans in the southern half of the area are known to retain freshwater for up to several weeks after rain. The only time that there is water on the surface of Lake Amadeus is shortly after rain, but this water is unsuitable for drinking because of its high salinity.

Supplies of surface water could be conserved by the construction of dams at places in the ranges. These dams would provide a useful auxiliary supply of water for stock.

Underground Water

At present, no underground water is being used in the Lake Amadeus Sheet area.

The only bore in the area, Inindia Bore, in the south-west corner, was abandoned several years ago because of its high salinity (see Table VI). The aquifer in the bore is unknown.

There are two wells in the Johnny Creek area but both have been abandoned. The westerly well, which was dry when inspected, is about 60 feet deep and is sunk in the Stairway Sandstone. The easterly well (Lang's Well) was dug in the Stokes Formation and when inspected in September 1962, the standing water level was 110 feet; the water seemed to have a low salt content and was potable; this well was probably abandoned because of a small supply of water.

Gosse (1874) describes a native well known as Kamrams Well, a few miles east of Winnall Ridge, which had sufficient supply to water stock. No trace of the well was found by the authors.

Prospects of Underground Water

In the north-east corner of the Sheet area there is likely to be considerable recharge due to presence of the high ranges. The quality of the water is likely to be moderate to good. Over the remainder of the Sheet area outcrops are low and run-off poor so that water is likely to be of stock quality only.

The Mereenie Sandstone has proved to be an excellent aquifer in other parts of the Amadeus Basin, and would probably be the best source of supply on the Lake Amadeus Sheet area.

Some of the sandstones of the Pertnjara Formation may yield a moderate supply of water, though generally these sandstones are poorly sorted and lack porosity.

Some of the sandstone in the Stairway Sandstone might be a reasonable aquifer, but Rochow (B.M.R. pers. comm.) found on the Henbury Sheet area that in two bores drilled in the Stairway Sandstone the total dissolved salt content was 6000 parts per million (nitrate content of 175 parts per million). The high salt content and especially the high nitrate content, may be associated with phosphate in the Stairway Sandstone and therefore, as phosphate was found in the Stairway Sandstone throughout the Lake Amadeus Sheet area, it is likely that the same high salt content in the water would be equally widespread.

At the surface, the Pacoota Sandstone is strongly silicified and non-porous, but at depth, below the weathering profile, is likely to be porous and constitute a reasonable aquifer.

Below the Larapinta Group, few of the formations would seem to be suitable as prospective aquifers. Some of the cleaner sandstone within the Pertaoorrta Formation, the Cleland Sandstone and the Areyonga Formation may be useful aquifers. The Winnall Beds where exposed on the

TABLE VI

Name of Bore	Inindia Bore.
Pastoral Lease	Curtin Springs.
Position of Bore	South-east corner of the Lake Amadeus 1:250,000 Sheet area.
Elevation	1704' above sea-level.
Drilled	August 1951.
Total Depth	320'.
Standing water Level	290' (1951).
Supply	800 gallons per hour (August 1951).

Analysis (results in parts per million).

Date.	17-7-57	1-8-62	1-8-62
Hardness Total	2414	2346	2582
Hardness Temporary	206	99	19
Hardness Permanent	2208	2247	2563
Free Alkali	Nil.	Nil.	Nil.
Chloride	3145	2725	3010
Sulphate	1735	1509	1748
Fluoride	4.1	3.0	3.4
Calcium	94	238	273
Bicarbonate	251	121	23
Carbonate	Nil.	Nil.	Nil.
Sodium	1600	1450	1625
Potassium	37	35	36
Magnesium	530	426	462
Nitrate	79	5	5
Total Dissolved Salts	7475	6512	7185
pH.		7.7	7.3

Analyses were performed by the Animal Industry Branch, Alice Springs, Northern Territory.

Bore data from the Resident Geologist's Office, Alice Springs, Northern Territory.

Sheet area are steeply dipping and therefore a difficult target to intersect. However, the strong jointing within the Winnall Beds make it probable that this formation would contain useful quantities of water.

The only other formation which may contain aquifers is the Bitter Springs Limestone which has yielded large quantities of water in some other parts of the basin. Water derived from the Bitter Springs Limestone is likely to be of moderate quality (suitable for stock) in areas of good recharge (the north-east corners of the sheet area) but over the remainder of the Sheet area is likely to be strongly saline.

Miscellaneous

Evaporites occur in the bed of Lake Amadeus. Some salt for local use is obtained from salt pans at the eastern end of Lake Amadeus near Curtin Springs.

Rock gypsum is in the cores of diapiric structures on the Lake Amadeus Sheet area and valuable evaporitic deposits may occur at depth in these structures. The gypsum cores of the diapirs should be prospected by augering or drilling. The gypsum is associated with outcrops of Bitter Springs Limestone. The largest exposed deposits of gypsum occur at Mt. Murray.

Thick sequences of limestone and dolomite occur in the Bitter Springs Limestone. Limestone and dolomite also occur in the Pertatataka Formation, Stokes Formation and Horn Valley Siltstone. The proportion of limestone in these formations varies from place to place and they contain variable amounts of sand and silt. Most of the deposits are difficult to reach.

No large metallic deposits were found on the Lake Amadeus Sheet area. Surface encrustations of manganese oxide were found on parts of the Goyder Formation, and thin beds of pisolitic ironstone occur in the Horn Valley Siltstone.

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APPENDIX I

CAMBRIAN AND ORDOVICIAN FOSSILS FROM THE AREAS OF HERMANNSBURG AND LAKE AMADEUS SHEET AREAS, NORTHERN TERRITORY

by
Joyce Gilbert-Tomlinson

INTRODUCTION

The material was collected by members of the Amadeus Party in 1962. Cambrian and Ordovician fossils are represented. The Cambrian fossils cannot be accurately dated at present; they were collected from the northern flank of the Gardiner Range in the south-western corner of Hermannsburg Sheet. The Ordovician fossils are similar to those of the "Larapintine" sequence of the Western MacDonnell Range on Hermannsburg Sheet. Some local peculiarities are evident, particularly the exotic *Orthis nipponica* fauna of the western part of the basin (see below, ?Stairway Sandstone). The Ordovician formation names are used in the sense established by Prichard & Quinlan (1962).

CAMBRIAN FOSSILS - HERMANNSBURG SHEET AREA, NORTHERN TERRITORY

Cambrian fossils occur in a glauconitic dolomite in the Nev's Gap area of the Gardiner Range (HG4, HG5, HG6). They consist of phosphatic brachiopods (probably belonging to several genera), a hyolithid, and a gastropod. The fossils are all very fragmentary, and no genera can be determined. The fauna cannot be matched with any from the better-known eastern end of the Amadeus Basin. The gastropod belongs to a group that is common in the early Middle Cambrian of the Northern Territory. Gastropods of similar external form are also recorded in the late Lower Cambrian of eastern Asia and North America. The age of this deposit is left open until diagnostic material can be secured.

ORDOVICIAN FOSSILS - LAKE AMADEUS SHEET AREA, NORTHERN TERRITORY

PACOOTA SANDSTONE

LA8, LA9, LA10, LA36, LA50, LA160, LA569, ?LA575.

LA 36 alone contains a diagnostic fossil, the trilobite cf. *Koraipsis*, related to a form from the Pacoota Sandstone of the Western MacDonnell Range, and indicating an upper Tremadocian age. The other samples contain fragmentary lingulid brachiopods, *Scolithus*, (pipe-rock), and *Cruziana* (trilobite trails).

<u>HORN VALLEY SILTSTONE</u> (limestone and calcareous siltstone)

Stratigraphically diagnostic: LA11, LA46, LA51, LA51a, LA66, LA111, LA112, LA113, LA140, LA156, LA157.
Inconclusive: LA47, LA155, LA207.

The stratigraphically diagnostic fossils include forms comparable with those of the "<u>Orthis</u>" <u>dichotomalis</u> fauna of the Western MacDonnell Range, which is provisionally dated as late Lower Ordovician (late Arenigian).

Brachiopods	-	lingulids (gen. indet.), orthoids (gen. indet.), "<u>Orthis</u>" <u>dichotomalis</u> Tate.
Pelecypods	-	<u>Ctenodonta</u> sp.
Gastropods	-	<u>Raphistomina</u> sp., <u>Helicotoma</u>? sp., "<u>Ophileta</u>" <u>gilesi</u> Eth.fil., <u>Lophospira</u>? sp.
Nautiloids	-	genera indet.
Trilobites	-	<u>Trinodus</u> sp., <u>Carolinites</u> sp., "<u>Asaphus</u>" <u>howchini</u> Eth.fil., "<u>Asaphus</u>" <u>illarensis</u> Eth.fil., aff. <u>Ptychopyge</u> sp., undescribed asaphid trilobites, cf. <u>Prosopiscus</u> sp.
Ostracods	-	genera indet.
Echinoderms	-	ossicles (indet.)
Graptolites	-	<u>Didymograptus</u> sp.
Conodonts	-	Not determined (being studied by P.J. Jones).

<u>STAIRWAY SANDSTONE</u>

Stratigraphically diagnostic: LA12, LA13, LA14, LA15, LA17, LA19, LA40, LA130, LA135, LA136, LA141, LA142, LA143, LA151, LA164, LA165, LA169, LA212.
Inconclusive: LA20, LA21, LA37, LA38, LA41, LA42, LA106, LA129, LA131, LA132, LA134, LA137, LA138, LA139, LA144, LA146, LA149, LA150, LA158, LA211, LA220, LA228, LA229, LA536, LA556, LA559.

The stratigraphically diagnostic fossils include forms comparable with those of the Stairway Sandstone (and particularly its upper part) in the Western MacDonnell Range. The fossils of this formation are nearly all indigenous, not only to Australia but to the Amadeus Basin; consequently, precise dating and correlation are not at present feasible. The estimated age for the upper part of the Stairway Sandstone is late Middle Ordovician (Llandeilan). The samples listed as inconclusive contain either unidentifiable fragments or fossils that are not known to occur in the typical Stairway Sandstone. (A special case of an exotic fauna is discussed below under the heading "<u>Orthis nipponica</u> fauna".)

Sponge	-	Hyalostelia australis Eth.fil.
Brachiopods	-	linguloid, strophomenacean?, orthid (all generically indeterminable), "Orthis" aff. leviensis.
Monoplacophoran	-	gen. indet.
Gastropods	-	"Euomphalus or Oriostoma" Eth.fil., Helicotoma? sp., Lophospira? sp., macluritid? (gen. indet.)
Pelecypods	-	Ctenodonta sp., Cyrtodonta sp., Goniophora? sp., ?"Isoarca" orbicularis Tate, "Isocara" easti Tate, ?"Palaearca" tortuosa Tate.
Nautiloids	-	endoceroids (gen. indet.) actinoceroids (gen. indet.).
Ribeirioid	-	Ribeiria? sp.
Trilobites	-	asaphids (undescribed genera), aff. "Asaphus" howchini Eth.fil., aff. Prosopiscus sp.2, Cruziana cf. furcifera d'Orbigny.
Worm	-	Diplocraterion spp.
Problematicum	-	undescribed genus (colloquially known as "Dingo-paws").

?STAIRWAY SANDSTONE (Orthis nipponica fauna)

?LA48, LA53, LA145, LA147.

Brachiopods	-	Orthis aff. nipponica Kobayashi, strophomenacean? (gen. indet.).
Gastropod	-	Clathrospira? sp.
Pelecypods	-	Ctenodonta (several unknown species).
Trilobite	-	aff. Prosopiscus sp.2.

The assemblage is not known to occur within the main field of the Larapintine faunas of Hermannsburg and Henbury Sheets and the adjoining parts of Mt. Liebig and Lake Amadeus Sheets. It is, however, known at one locality on Mt. Rennie Sheet (MR15) and two localities on Bloods Range Sheet (BR5 and BR12), and is apparently characteristic of the western fringes of the Amadeus Basin, where the typical Stairway faunas seem to be absent. The occurrence in the present fauna of a brachiopod close to an east Asian species is of considerable palaeogeographical interest, and, moreover, provides evidence whereby the fauna can be dated on its own merits. In South Korea, O. nipponica occurs in two formations, which are considered by the author of the name (Kobayashi, 1934) to be late Llandeilan and early Caradocian in age (late Middle and early Upper Ordovician). Correlation with the typical Stairway faunas is not yet possible. The undescribed trilobite aff. Prosopiscus sp.2 occurs at an isolated locality (LA229) in the south-eastern part of the sheet area; the associated fauna is unfamiliar, and no stratigraphic control is available. Apparently at least one element of the nipponica fauna found its way to the east, and a concentrated search may provide evidence for correlation with the Stairway faunas of the main field.

?STAIRWAY SANDSTONE ("Orthis" dichotomalis fauna).

LA56, LA65, LA110, LA115.

Brachiopods	-	orthid (gen.indet.), "Orthis" dichotomalis Tate.
Pelecypods	-	Ctenodonta spp., "Isoarca" easti Tate.
Gastropods	-	cf. "Euomphalus or Oriostoma" Eth.fil., Helicotoma? sp., Lophospira? sp.
Nautiloid	-	gen.indet.
Trilobites	-	asaphids (indet.)

The field-identification of the formation in which the samples occur is Stairway Sandstone. The brachiopod "Orthis" dichotomalis, however, is not known to occur in the typical Stairway Sandstone, and thus the preferred interpretation is that these samples represent a sandy development of the Lower Ordovician Horn Valley Siltstone. Against this is the fact that the pelecypod "Isoarca" easti has hitherto been regarded as a typical fossil of the upper part of the Stairway Sandstone, of late Middle Ordovician age, and consequently a drastic revision of ideas concerning the range of one or both of these fossils seems inevitable. An alternative explanation is that "O." dichotomalis is here a derived fossil in a normal Stairway fauna. Confirmatory evidence for this interesting possibility is not yet forthcoming.

STOKES FORMATION

Stratigraphically diagnostic: LA45, LA123, LA124, LA125, LA126, LA128, LA166, LA167.

Inconclusive: LA22, LA23, LA43, LA44, LA118, LA119, LA121, LA127, LA208.

The Stokes Formation is everywhere noted for the extremely fragmentary state of its fossils (including the conodonts). The larger fossils, as far as they can be interpreted, are indigenous, and no graptolites have been found. An early Upper Ordovician

(Caradocian) age is postulated, largely on superpositional grounds. This is the youngest marine fossiliferous sequence in the Amadeus Basin.

Brachiopod	-	"Orthis" leviensis Eth.fil.
Bryozoans	-	trepostomes (undetermined).
Monoplacophoran?	-	gen. indet.
Gastropods	-	gen. indet.
Pelecypods	-	Ctenodonta spp.
Nautiloids	-	genera indet.
Trilobite	-	asaphid (indet., probably a new genus).
Echinoderms	-	crinoid ossicles (indet.).
Problematicum	-	"Dingo-paws" (see Stairway Sandstone, above).

?MEREENIE SANDSTONE

The typical Mereenie Sandstone of Hermannsburg Sheet area is unfossiliferous except for worm-burrows. The formation rests unconformably on the fossiliferous Ordovician sequence at Ellery Creek, and no firm decision on its age is at present possible. A sample from Lake Amadeus Sheet, LA62, collected from a sandstone interpreted as Mereenie, contains a specimen of Cruziana, undoubtedly the track of an Ordovician trilobite. As no continuity of outcrop exists between this locality and the typical Mereenie, there is no certainty that they represent the same rock body, and therefore it seems injudicious at this stage to postulate an Ordovician age for the Mereenie Sandstone. It is possible that LA62 represents an Ordovician sandstone not known in the Western MacDonnell Range; perhaps a sandy bed within the Stokes Formation.

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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS

1963/51

PLATES

THE GEOLOGY OF THE LAKE AMADEUS 1:250,000 SHEET AREA.

PART 2 of 2

Plate I

LAW 2

Henbury 7/5157

G52/4/6

Bureau of Mineral Resources Geology and Geophysics April 1963 To accompany Record 1963/51

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Plate 2

Bureau of Mineral Resources, Geology & Geophysics. April 1963.

To accompany Record No. 1963/51.

G52/4/4

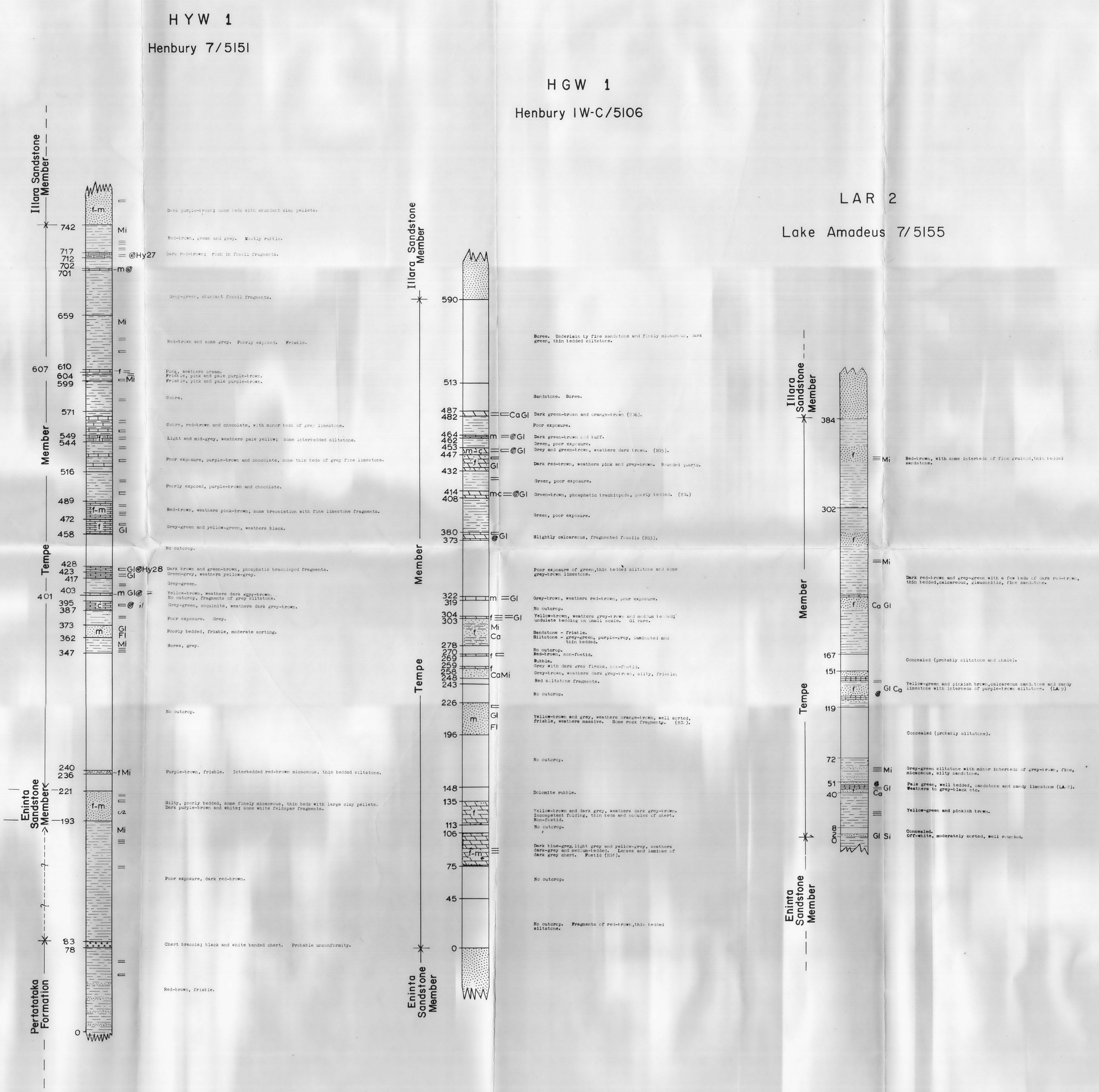

HYW 1
Henbury 7/5151
Illara Sandstone Member
Tempe Member
Eninta Sandstone Member
Pertatataka Formation
742
717
712
702
701
659
610
607
604
599
571
549
544
516
489
472
458
428
423
417
403
401
395
387
373
362
347
240
236
221
193
83
78
0
f-m
Mi
@Hy27
m@
f
Gl
@Hy28
Fl
Dark purple-brown; some beds with abundant clay pellets.
Red-brown, green and grey. Mostly rubble.
Dark red-brown; rich in fossil fragments.
Grey-green, abundant fossil fragments.
Red-brown and some grey. Poorly exposed. Friable.
Pink, weathers cream.
Friable, pink and pale purple-brown.
Friable, pink and pale purple-brown.
Ochre.
Ochre, red-brown and chocolate, with minor beds of grey limestone.
Light and mid-grey, weathers pale yellow; some interbedded siltstone.
Poor exposure, purple-brown and chocolate, some thin beds of grey fine limestone.
Poorly exposed, purple-brown and chocolate.
Red-brown, weathers pink-brown; some brecciation with fine limestone fragments.
Grey-green and yellow-green, weathers black.
No outcrop.
Dark brown and green-brown, phosphatic brachiopod fragments.
Green-grey, weathers yellow-grey.
Grey-green.
Yellow-brown, weathers dark grey-brown.
No outcrop, fragments of grey siltstone.
Grey-green, coquinite, weathers dark grey-brown.
Poor exposure. Grey.
Poorly bedded, friable, moderate sorting.
Scree, grey.
No outcrop.
Purple-brown, friable. Interbedded red-brown micaceous. thin bedded siltstone.
Silty, poorly bedded, some finely micaceous, thin beds with large clay pellets.
Dark purple-brown and white; some white feldspar fragments.
Poor exposure, dark red-brown.
Chert breccia; black and white banded chert. Probable unconformity.
Red-brown, friable.
HGW 1
Henbury 1W-C/5106
Illara Sandstone Member
Tempe Member
Eninta Sandstone Member
590
513
487
482
464
462
453
447
432
414
408
380
373
322
319
304
303
278
270
269
259
258
248
243
226
196
148
135
113
106
75
45
0
CaGl
m-c
mc
CaMi
f-m
Scree. Underlain by fine sandstone and finely micaceous, dark green, thin bedded siltstone.
Sandstone. Scree.
Dark green-brown and orange-brown (HG6).
Poor exposure.
Dark green-brown and tuff.
Green, poor exposure.
Grey and green-brown, weathers dark brown. (HG5).
Dark red-brown, weathers pink and grey-brown. Rounded quartz.
Green, poor exposure.
Green-brown, phosphatic brachiopods, poorly bedded. (HG4)
Green, poor exposure.
Slightly calcareous, fragmented fossils (HG3).
Poor exposure of green, thin bedded siltstone and some grey-brown limestone.
Grey-brown, weathers red-brown, poor exposure.
No outcrop.
Yellow-brown, weathers grey-brown and medium bedded; undulate bedding on small scale. Gl rare.
Sandstone - friable.
Siltstone - grey-green, purple-grey, laminated and thin bedded.
No outcrop.
Red-brown, non-foetid.
Rubble.
Grey with dark grey flecks. non-foetid.
Grey-brown, weathers dark grey-brown, silty, friable.
Red siltstone fragments.
No outcrop.
Yellow-brown and grey, weathers orange-brown, well sorted, friable, weathers massive. Some rock fragments.
No outcrop.
Dolomite rubble.
Yellow-brown and dark grey, weathers dark grey-brown.
Incompetent folding, thin beds and nodules of chert.
Non-foetid.
No outcrop.
Dark blue-grey, light grey and yellow-grey, weathers dark-grey and medium-bedded. Lenses and laminae of dark grey chert. Foetid (HG1).
No outcrop.
No outcrop. Fragments of red-brown, thin bedded siltstone.
LAR 2
Lake Amadeus 7/5155
Illara Sandstone Member
Tempe Member
Eninta Sandstone Member
384
302
167
151
119
72
51
40
8
2
0
Mi
Ca Gl
Gl Ca
Gl Si
Red-brown, with some interbeds of fine grained, thin bedded sandstone.
Dark red-brown and grey-green with a few beds of dark red-brown, thin bedded, calcareous, glauconitic, fine sandstone.
Concealed (probably siltstone and shale).
Yellow-green and pinkish brown, calcareous sandstone and sandy limestone with interbeds of purple-brown siltstone.
Concealed (probably siltstone).
Grey-green siltstone with minor interbeds of grey-brown, fine, micaceous, silty sandstone.
Pale green, well bedded, sandstone and sandy limestone. Weathers to grey-black etc.
Yellow-green and pinkish brown.
Concealed.
Off-white, moderately sorted, well rounded.

Plate 4

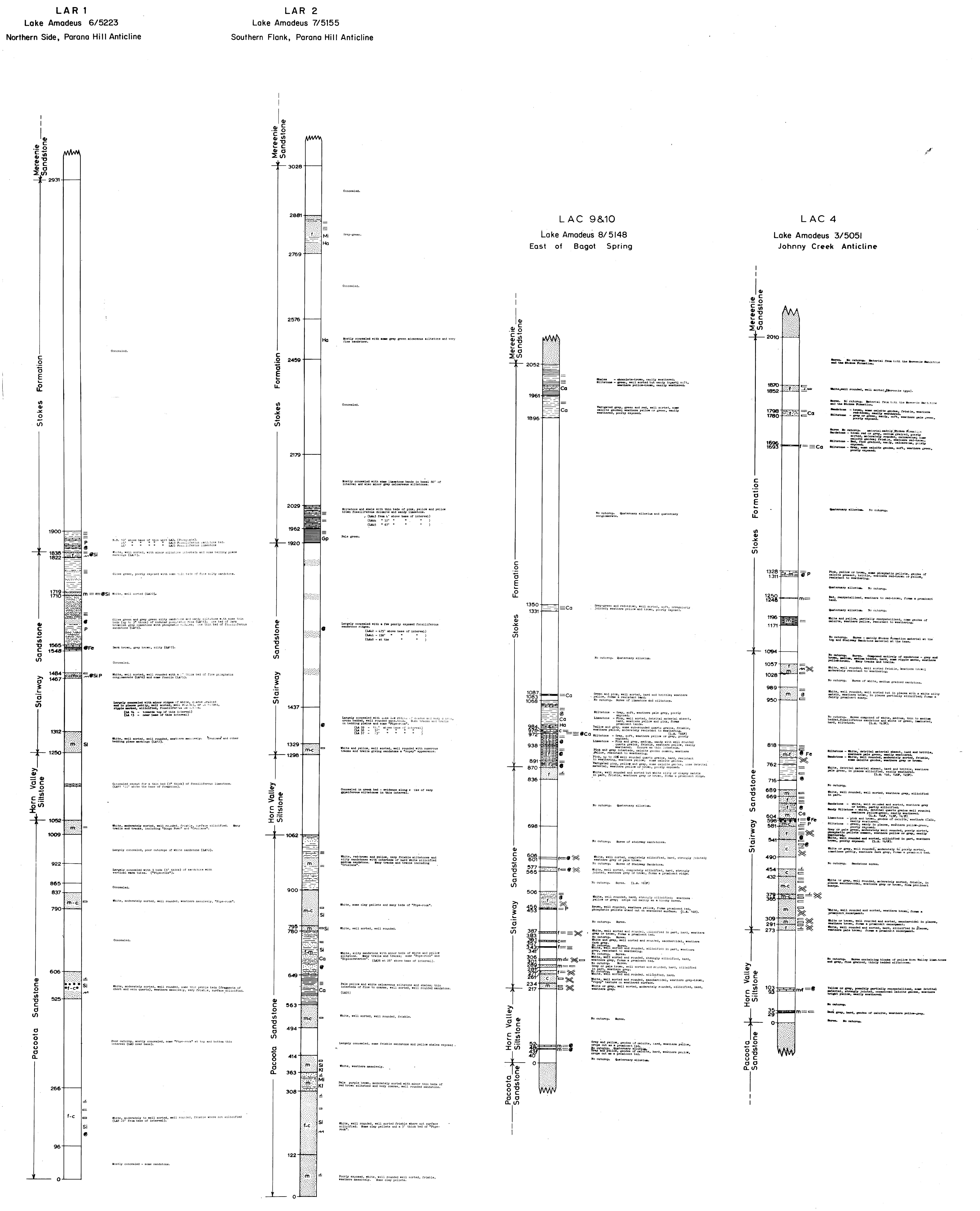
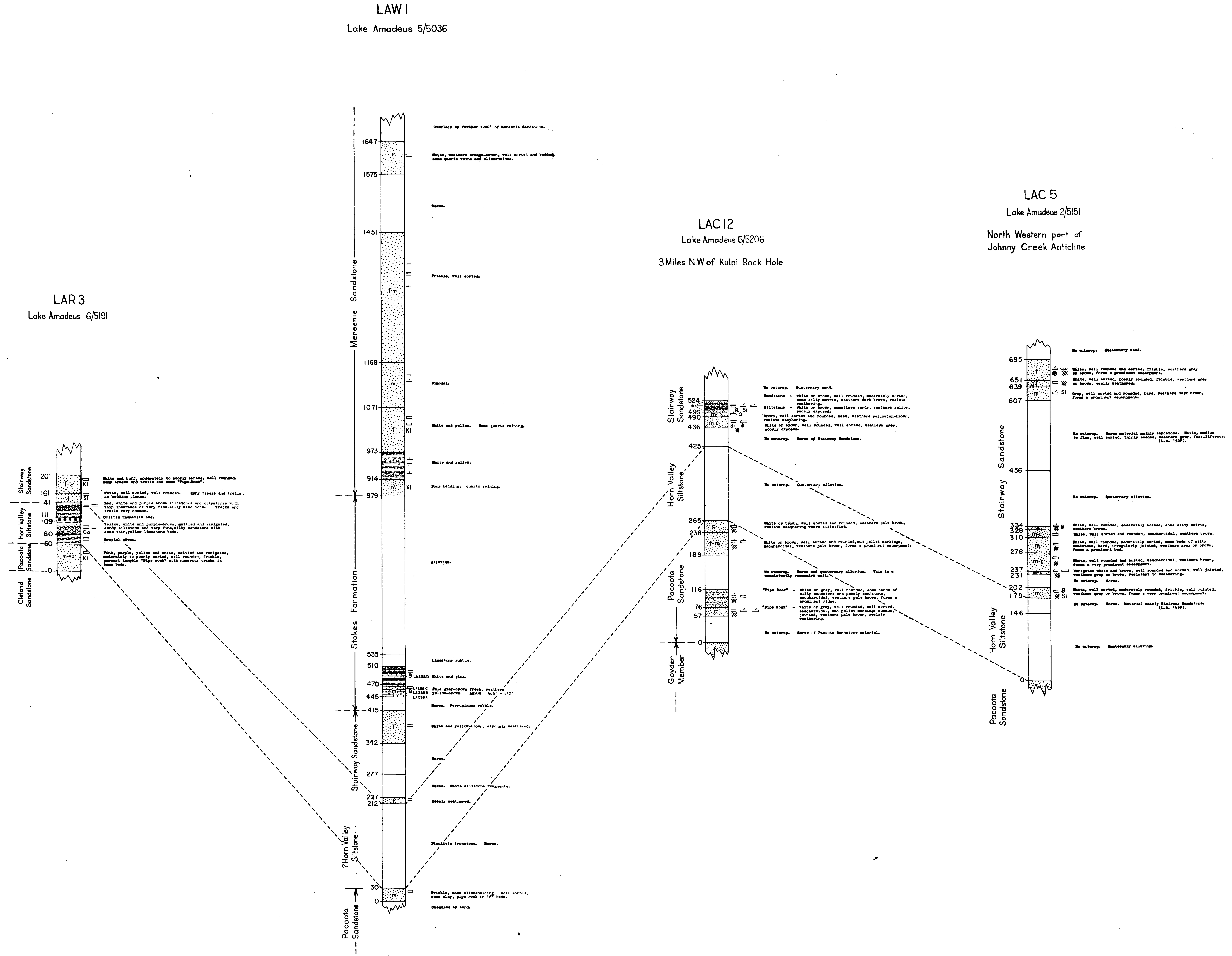
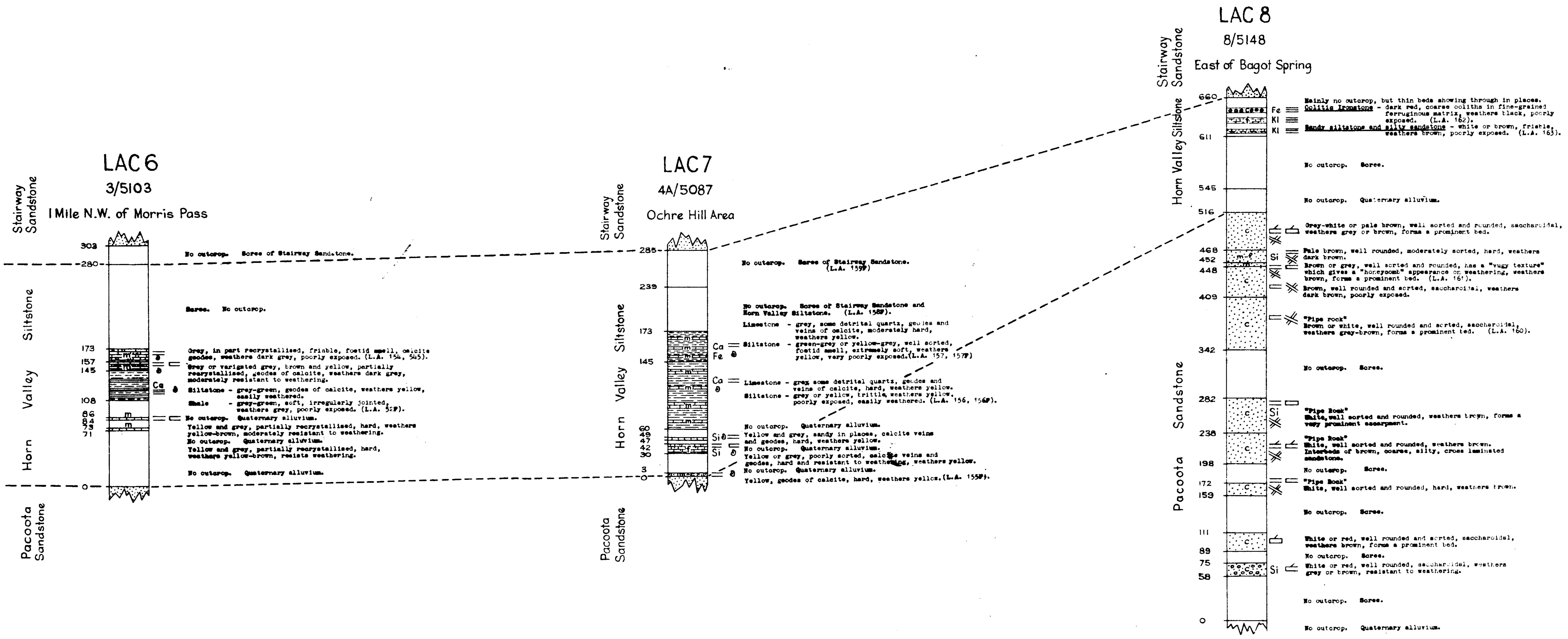

LAR 1
Lake Amadeus 6/5223
Northern Side, Parana Hill Anticline
LAR 2
Lake Amadeus 7/5155
Southern Flank, Parana Hill Anticline
LAC 9&10
Lake Amadeus 8/5148
East of Bagot Spring
LAC 4
Lake Amadeus 3/5051
Johnny Creek Anticline
Mereenie Sandstone
Stokes Formation
Stairway Sandstone
Horn Valley Siltstone
Pacoota Sandstone

Plate 5


LAR 3
Lake Amadeus 6/5191
Stairway Sandstone
Horn Valley Siltstone
Pacoota Sandstone
Cleland Sandstone
201
161
141
111
109
80
60
0
White and buff, moderately to poorly sorted, well rounded. Many tracks and trails and some "Pipe-Rock".
White, well sorted, well rounded. Many tracks and trails on bedding planes.
Red, white and purple brown siltstones and claystones with thin interbeds of very fine, silty sand tone. Tracks and trails very common.
Oolitic Haematite bed.
Yellow, white and purple-brown, mottled and varigated, sandy siltstone and very fine, silty sandstone with some thin, yellow limestone beds.
Greyish green.
Pink, purple, yellow and white, mottled and varigated, moderately to poorly sorted, well rounded, friable, porous; largely "Pipe rock" with numerous tracks in some beds.
LAW 1
Lake Amadeus 5/5036
Mereenie Sandstone
Stokes Formation
Stairway Sandstone
?Horn Valley Siltstone
Pacoota Sandstone
1647
1575
1451
1169
1071
973
914
879
535
510
470
445
415
342
277
227
212
30
0
Overlain by further 1200' of Mereenie Sandstone.
White, weathers orange-brown, well sorted and bedded; some quartz veins and slickensides.
Scree.
Friable, well sorted.
Bimodal.
White and yellow. Some quartz veining.
White and yellow.
Poor bedding; quartz veining.
Alluvium.
Limestone rubble.
LA238D White and pink.
LA238C LA238B LA238A Pale grey-brown fresh, weathers yellow-brown. LA208 445' - 510'
Scree. Ferruginous rubble.
White and yellow-brown, strongly weathered.
Scree.
Scree. White siltstone fragments.
Deeply weathered.
Pisolitic ironstone. Scree.
Friable, some slickensiding, well sorted, some clay, pipe rock in 18" beds.
Obscured by sand.
LAC 12
Lake Amadeus 6/5206
3 Miles N.W of Kulpi Rock Hole
Stairway Sandstone
Horn Valley Siltstone
Pacoota Sandstone
Goyder Member
524
499
490
466
425
265
238
189
116
76
57
0
No outcrop. Quaternary sand.
Sandstone - white or brown, well rounded, moderately sorted, some silty matrix, weathers dark brown, resists weathering.
Siltstone - white or brown, sometimes sandy, weathers yellow, poorly exposed.
Brown, well sorted and rounded, hard, weathers yellowish-brown, resists weathering.
White or brown, well rounded, well sorted, weathers grey, poorly exposed.
No outcrop. Scree of Stairway Sandstone.
No outcrop. Quaternary alluvium.
White or brown, well sorted and rounded, weathers pale brown, resists weathering where silicified.
White or brown, well sorted and rounded, mud pellet markings, saccharoidal, weathers pale brown, forms a prominent escarpment.
No outcrop. Scree and quaternary alluvium. This is a consistently recessive unit.
"Pipe Rock" - white or grey, well rounded, some bands of silty sandstone and pebbly sandstone, saccharoidal, weathers pale brown, forms a prominent ridge.
"Pipe Rock" - white or grey, well rounded, well sorted, saccharoidal, mud pellet markings common, jointed, weathers pale brown, resists weathering.
No outcrop. Scree of Pacoota Sandstone material.
LAC 5
Lake Amadeus 2/5151
North Western part of Johnny Creek Anticline
Stairway Sandstone
Horn Valley Siltstone
Pacoota Sandstone
695
651
639
607
456
334
328
310
278
237
231
202
179
146
0
No outcrop. Quaternary sand.
White, well rounded and sorted, friable, weathers grey or brown, forms a prominent escarpment.
White, well sorted, poorly rounded, friable, weathers grey or brown, easily weathered.
Grey, well sorted and rounded, hard, weathers dark brown, forms a prominent escarpment.
No outcrop. Scree material mainly sandstone. White, medium to fine, well sorted, thinly bedded, weathers grey, fossiliferous. (L.A. 152F).
No outcrop. Quaternary alluvium.
White, well rounded, moderately sorted, some silty matrix, weathers brown.
White, well sorted and rounded, saccharoidal, weathers brown.
White, well rounded, moderately sorted, some beds of silty sandstone, hard, irregularly jointed, weathers grey or brown, forms a prominent bed.
White, well rounded and sorted, saccharoidal, weathers brown, forms a very prominent escarpment.
Varigated white and brown, well rounded and sorted, well jointed, weathers grey or brown, resistant to weathering.
No outcrop. Scree.
White, well sorted, moderately rounded, friable, well jointed, weathers grey or brown, forms a very prominent escarpment.
No outcrop. Scree. Material mainly Stairway Sandstone. (L.A. 149F).
No outcrop. Quaternary alluvium.



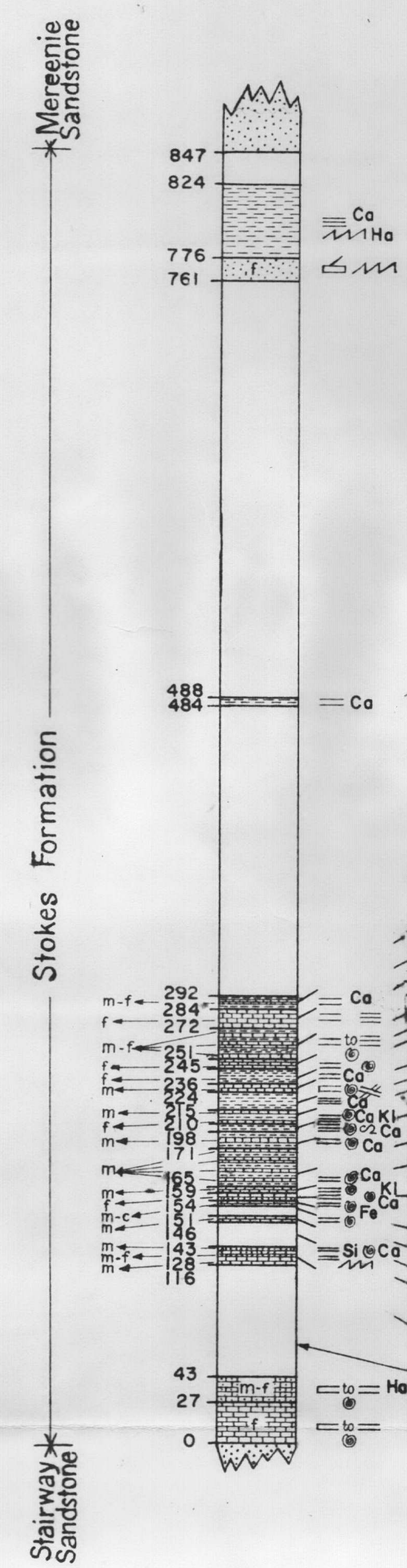
Bureau of Mineral Resources Geology and Geophysics March 1963 To accompany Record 1963/51

G52/4/1 PB

LAC 2

Lake Amadeus 5/5011

Johnny Creek Anticline



Mereenie Sandstone

Scree

Green, or red, weathers easily, forming scree.

(Mereenie Sandstone type) white, well rounded, well sorted, friable, weathers brown.

Scree underlain by siltstone:- red and green, sometimes calcareous. Thin to medium bedded, pseudomorphs of halite common, weathers red or brown, easily weathered.

Red and green, geodes of calcite common, poorly exposed, weathers to very fragmentary form.

Quaternary alluvium. No exposure.

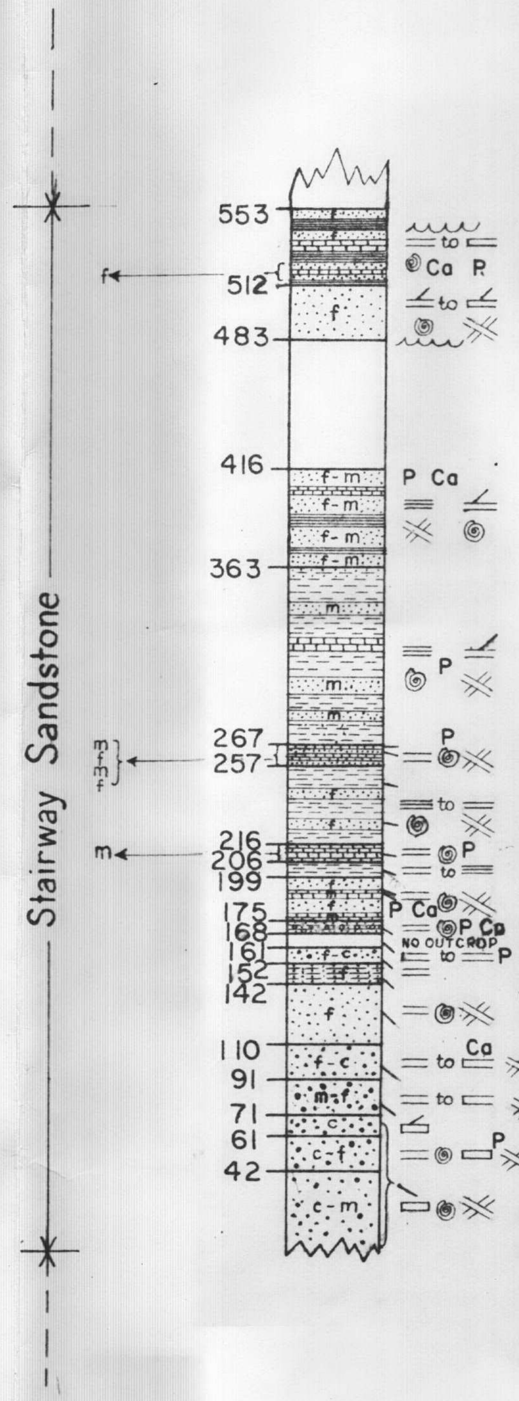
Limestone; pink, weathers buff, poorly exposed
Siltstone; grey, weathers brown, poorly exposed,
Pink and brown, irregularly jointed, weathers yellow-brown, forms an escarpment.
Limestone; Pink and grey, weathers yellow-brown, poorly exposed.
Siltstone; Pink, grey or green, weathers brown, easily weathered. fossils rare.
Pink, easily weathered.
Pink, easily weathered, weathers brown.
Varigated grey, yellow and pink, ?partially recrystallised, forms prominent band.
Pink and grey, weathers brown, forms rubbly slope.
Pink, thin interbeds, easily weathered.
Grey and pink, friable, easily weathered to yellow or brown (L.A. 127F)
Pink and grey interbedded limestones and siltstones - weathers yellow and brown.
Siltstone; grey, friable, weathers yellow.
Limestone; pink, partially recrystallised
Pink and grey, hard, partially recrystallized, weathers yellow. (L.A. 126F)
Limestone - pink and grey, weathers yellow.
Siltstone - pale grey, friable, weathers brown.
Sandstone - Grey, partially silicified. (L.A. 125F)
Grey, green and pink, partially recrystallised, weathers yellow. (L.A. 124F, 123F)
No outcrop
Grey, green and pink, partially recrystallised, hard, calcite geodes, weathers yellow.
No outcrop
Limestones - grey, green and pink, partially recrystallised, some well rounded, medium grained detrital quartz grains, calcite geodes common, weathers yellow. (L.A. 121F, L.A. 122F)
Sandstone - grey or yellow, moderately sorted, poorly rounded, weathers yellow.
No outcrop
Grey, well rounded, fine-grained detrital quartz common, weathers pale yellow-grey.

Grey and yellow, detrital quartz common, geodes of calcite common, weathers a pale yellow-grey on the surface, poorly exposed.

LAC 3

Lake Amadeus 4A/5082

Johnny Creek Anticline



No outcrop.
Sandstone - grey, well rounded, well sorted, phosphatic pellets prominent on weathered surfaces.
Siltstone - green, calcareous, phosphatic pellets rare, easily weathered.
Limestone - Dark grey, hard, some phosphatic pellets, weathers rough. (LA139)

White, well rounded, sorted and bedded, weathers grey or brown, forms a prominent scarp (LA138F)

Mainly scree, some beds of siltstone and sandstone.
Siltstone - green, calcareous in part, laminated, weathers green or brown, poorly exposed, fossiliferous.
Sandstone - white, fine, well rounded and sorted, thin to medium bedded, weathers grey or brown, fossiliferous.
Sandstone - white or grey, well rounded, well sorted, thin bedded, in places cross bedded, rarely phosphatic, weathers brown.
Siltstone - green, well sorted, in places calcareous, laminated, soft easily weathered, poorly exposed.
Limestone - Yellow or brown, fine to medium, partially recrystallised, some detrital quartz, thin bedded, weathers yellow or grey.

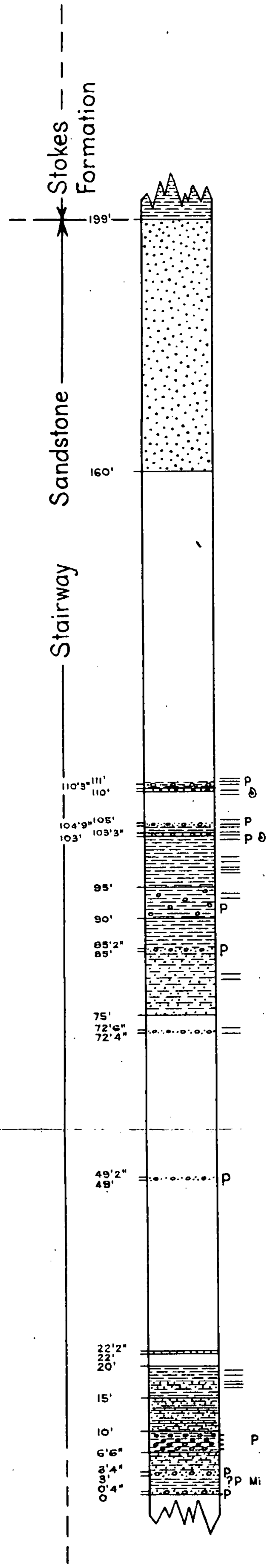
Siltstone - green, well rounded, phosphatic pellets, more sandy near top, poorly exposed weathers green or brown.
Sandstone - dark grey, well sorted, moderately well rounded with grey and brown, well-rounded phosphatic nodules, thin bedded, weathers grey or brown.
Limestone - Yellow-brown or brown, fine to medium, partially recrystallised, thin bedded, weathers yellow, forms prominent bands. (LA137F)
Limestone - Varigated yellow and brown, medium, partially recrystallised, some phosphatic nodules, thin bedded, weathers yellow or grey.
Sandstone - dark grey, fine, well rounded, well sorted, phosphatic nodules common, weathers brown.
Siltstone - green or grey, sandy, laminated or thin bedded, weathers green or brown, poorly exposed.
Sandstone - white or grey, fairly well rounded, moderately well sorted, dirty in part, thin bedded, weathers grey.
Varigated pink, yellow and brown, some detrital quartz, partially recrystallised, some geodes of calcite, pellets of phosphate common, weathers yellow or brown, forms prominent band.
Green, well sorted, in places sandy, poorly exposed, weathers brown
Sandstone - grey, well rounded, moderately well sorted, calcareous, some phosphatic pellets, weathers yellow.
Limestone - Varigated brown, yellow and grey, some detrital material, some phosphatic pellets, calcite geodes common, weathers yellow, forms prominent bands. (LA134F) (LA134F)
Grey, well rounded phosphatic pellets common, getting up to 1" in diameter, weathers dark grey, forms a prominent bed. Some thin beds of shale - grey or grey-green, calcareous, thinly bedded, irregularly jointed. (LA133)
No outcrop.
Grey, dirty, well rounded, some phosphatic pellets, saccharoidal, poorly exposed.
Green or grey-green, well rounded and sorted quartz grains, irregularly jointed, poorly exposed.
Brown or white, well rounded and sorted, friable, weathers brown or grey, poorly exposed. (LA132F)
White or grey, well rounded, well sorted, calcareous matrix in part, friable, weathers dark grey, poorly exposed.
White, well rounded and sorted, weathers brown, parts of the unit weather to give a "ropey" texture.
White, well rounded and sorted, some beds saccharoidal, may be superficially silicified, weathers grey, some beds form prominent scarps. (LA 131, 130F, 129F)

Plate 8

LAC 13

Lake Amadeus 5/5011

Johnny Creek Anticline



Typical Stairway Sandstone forming a prominent escarpment.

No outcrop. Scree made up mainly of sandstone and siltstone but some limestone and phosphatic material. (L.A. 535 (10)).

Green, some phosphatic pellets.
Dark brown, many phosphatic pellets. (L.A. 535 (9)).
No outcrop. Phosphatic scree (L.A. 535 (8)).
Grey or brown; rich in grey phosphatic pellets. (L.A. 535 (7)).
Green
Dark brown, many phosphatic pellets.
Green.
Green, occasional phosphatic pellets.
Green.
Rich in phosphatic pellets. (L.A. 534).
Green and brown.
No outcrop. Scree.
White, rich in phosphatic pellets. (L.A. 535 (6)).
No outcrop.

No outcrop.

Dark brown.
Green.
Green siltstone with dark brown coquina limestone.
(L.A. 535 (5))
(L.A. 535 (4))
(L.A. 535 (3))
(L.A. 535 (2))
Green
Well rounded, very rich in phosphatic pellets.
Green.
(L.A. 535 (1))
No outcrop. Quaternary alluvium.

To accompany Record 1963/51

Bureau of Mineral Resources Geology and Geophysics April 1963 G52/4/7 PB

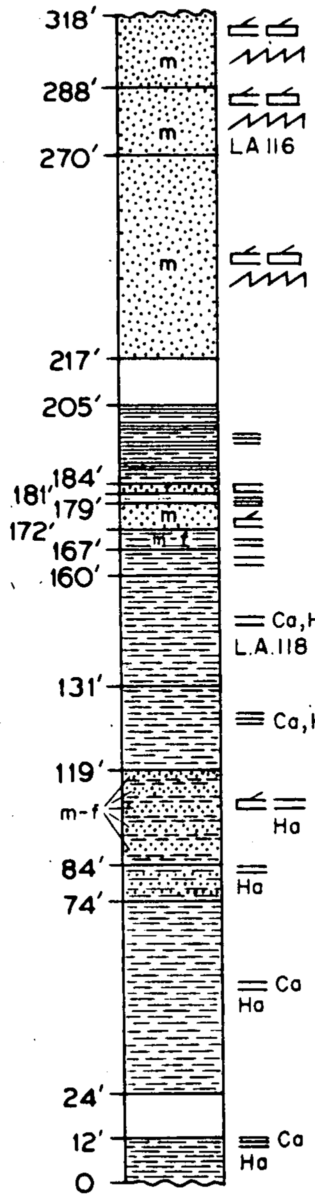
Plate 9

LAC 1

Lake Amadeus 2/5071

Western end of the George Gill Range

Transitional contact of the Mereenie Sandstone and Stokes Formation



White or brown, well rounded, well sorted, but in places with a silty matrix, friable, weathers reddish brown, forms prominent escarpment.

White and brown; with thin interbeds of varigated, finely laminated, well rounded, friable, silty sandstone .

White or brown, some thin silty beds;well rounded, sorted, friable, weathers red-brown, forms a very prominent escarpment.

Scree. No exposure.

Red-brown, weathers easily to fragmentary form.

Red-brown,moderately well sorted, well rounded, friable, (i.e. Mereenie type) weathered to a chocolate brown colour; some thin beds of brown silty sandstones.

Brown, poorly bedded, easily weathered to a fragmented form.

White, moderately to pocrly rounded,silty matrix, weathers to red-brown.

Interbedded white,silty sandstone and brown siltstone.

Brown with some green interbeds, brown easily weathers to a fragmentary form.

Green and brown

Green and red-brown

White, friable (Mereenie Sandstone type) sandstone and brown and green, fine grained, partly sandy, siltstone

Brown with subsidiary green, some very thin beds of white medium grained (Mereenie type) sandstone.. Forms prominent bed.

Series of thin alternating beds of brown and green-brown soft, easily weathered; the green brittle, more resistant. Geodes of calcite.

No outcrop.

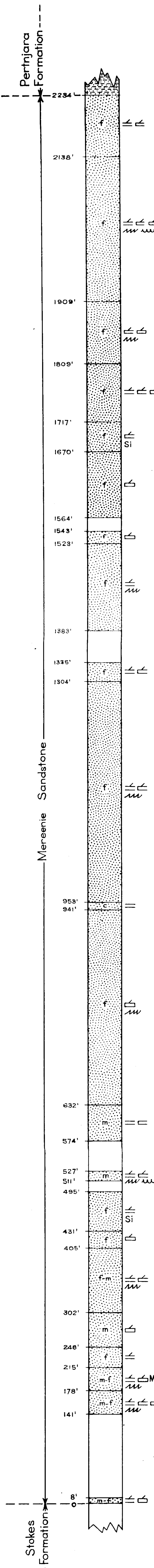
Green, occasionally red, geodes of calcite, fairly hard, moderately resistant to weathering.

G52/4/5

LAC 11

Lake Amadeus 4/5072

North side of Johnny Creek Anticline



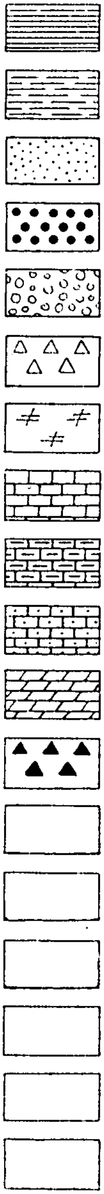
Interval	Grain size	Description
2234'–2138'	f	White, well rounded, moderately sorted, some silty matrix, cross-beds dip north, friable, weathers brown, easily weathered.
2138'–1909'	f	White, red-brown in places, well rounded and sorted, cross-beds generally dip north, friable, weathers brown.
1909'–1809'	f	White, well rounded and sorted, cross-beds dip north-west, friable, weathers brown, forms a prominent escarpment.
1809'–1717'	f	Red-brown and white, well rounded and sorted, variable dip of cross-beds, weathers brown.
1717'–1670'	f (Si)	White, well rounded and sorted, weathers brown, poorly exposed.
1670'–1564'	f	White, well rounded and sorted, friable, cross-beds dip mainly west, weathers brown.
1564'–1543'		No outcrop. Quaternary sand.
1543'–1523'	f	White, well rounded and sorted, friable, weathers brown.
1523'–1383'	f	White, well rounded, moderately sorted, some white silty matrix, some mud pellets, weathers pale brown, forms a prominent escarpment.
1383'–1335'		No outcrop.
1335'–1304'	f	White with some red-brown bands, well rounded, moderately sorted, weathers pale brown, moderately resistant to weathering.
1304'–953'	f	White, well rounded, well sorted, weathers to a "vugy" texture in parts.
953'–941'	c	Dark red-brown, well sorted and rounded, friable.
941'–632'	f	White or yellow, well sorted and rounded, friable, weathers pale brown, weathers into a series of terraces. (L.A. 540).
632'–574'	m	White, well rounded, well sorted, weathers pale brown.
574'–527'		No outcrop. Scree.
527'–511'	m	White, well rounded, well sorted, weathers brown, forms a very prominent escarpment. (L.A. 539).
511'–495'		No outcrop. Scree.
495'–431'	f (Si)	White, moderately rounded and sorted, some silty matrix, some mud-pellet markings.
431'–405'	f	White, moderately rounded and sorted, some silty matrix, weathers dark brown, forms a prominent escarpment.
405'–302'	f-m	Red-brown, moderately rounded, poorly sorted, weathers pale brown, poorly exposed.
302'–248'	m	White or pale brown, moderately rounded and sorted, silty in places, cross-beds dip north-west, weathers dark brown, forms a prominent scarp.
248'–215'	f	Varigated red-brown, yellow and purple, silty, poorly rounded and sorted, weathers dark brown, poorly exposed. (L.A. 537).
215'–178'	m-f (Mi)	Red-brown, moderately rounded and sorted, weathers dark grey; interbeds of red and purple-brown, silty, friable sandstone.
178'–141'	m-f	Red, moderately rounded and sorted, weathers dark grey, interbeds of pale brown, yellow weathering sandstone.
141'–8'		No outcrop. Scree.
8'–0	m-f	Red-brown, well sorted, moderately to poorly rounded, weathers dark grey, forms a prominent bed.
below 0		No outcrop. Scree.

G52/4/8

Bureau of Mineral Resources Geology and Geophysics April 1963 - To accompany Record 1963/51

PB

REFERENCE FOR COLUMNAR SECTIONS



- *Shale*
- *Siltstone*
- *Sandstone*
- *Coarse sandstone - Fine conglomerate*
- *Conglomerate*
- *Erratics*
- *Chert*
- *Limestone*
- *Silty limestone*
- *Sandy limestone*
- *Dolomite*
- *Breccia*

Grain Size

f	- *fine*	*0·12 - 0·25 mm*
m	- *medium*	*0·25 - 1·0 mm.*
c	- *coarse*	*1·0 - 2·0 mm.*
v.c	- *very coarse*	*2·0 - 4·0 mm.*

Fine conglomerate	*4·0 - 16·0 mm.*
Pebble conglomerate	*3/4 - 2½ inches*
Cobble conglomerate	*2½ - 10 inches*
Boulder conglomerate	*> 10 inches*

Si	*Silicified*	Gl	*Glauconitic*
Fe	*Ferruginous*	Fl	*Feldspathic*
Mi	*Micaceous*	Ha	*Pseudomorphs of halite*
Ca	*Calcareous*	P	*Phosphatic*
Kl	*Kaolinitic*		
G	*Gypsum*		

Bedding

Very thick	*> 40 inches*
Thick	*12 - 40 inches*
Medium	*4 - 12 inches*
Thin	*0·4 - 4 inches*
Laminate	*< 0·4 inches*
Cross bedded	
Cross laminated	
Graded bedding	
Undulate	
Slumped	
Ripple marks - wave	
Ripple marks - current	
Tracks and trails	
Oolites	
Macrofossil	

M6/5556 *Sheet, run and photo number*

P.P. *Principal point of photograph*

Gaps in columnar sections are concealed areas.

G52/4/12 GM

To accompany Record 1963/51

AUSTRALIA 1:250,000

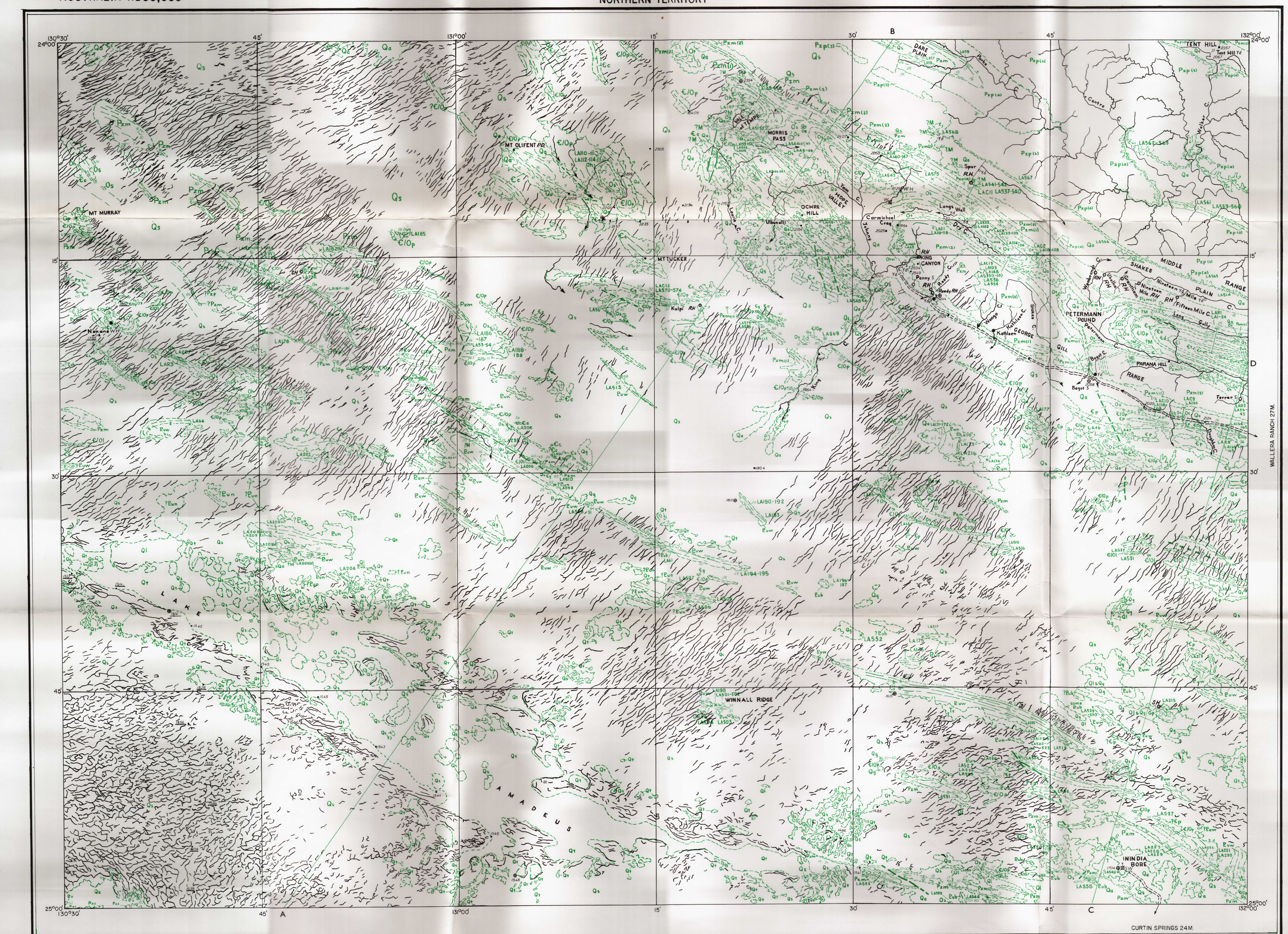
LAKE AMADEUS

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 52-4

PRELIMINARY EDITION, 1963

SUBJECT TO AMENDMENT



Reference

CAINOZOIC	QUATERNARY	Undifferentiated	Q	Alluvium, sand, travertine, evaporites, conglomerate (Section only)
			Qa	Alluvium, conglomerate
			Qs	Sand
			Ql	Travertine
			Qt	Evaporites in salt lakes
			Qg	Gypsum
	TERTIARY	Undifferentiated	T	Limestone, chert
			Tc	Conglomerate
MESOZOIC		Undifferentiated	M	Sandstone, siltstone
PALAEOZOIC	UNDIFFERENTIATED	Pertnjara Formation	Pzp	Undifferentiated
			Pzp(s)	Red-brown sandstone
			Pzp(a)	Siltstone, calcareous siltstone
		Mereenie Sandstone	Pzm(2)	White cross-bedded sandstone
			Pzm(1)	Red-brown silty sandstone, siltstone
		Mount Currie Conglomerate	Pzc	Coarse conglomerate
	ORDOVICIAN -CAMBRIAN	Larapinta Group: Undifferentiated	Є/Ol	
		Larapinta Group: Stokes Formation	Ot	Siltstone, fossiliferous limestone
		Larapinta Group: Stairway Sandstone	Os	Fossiliferous sandstone, siltstone, limestone, all in part phosphatic
		Larapinta Group: Horn Valley Siltstone	Oh	Fossiliferous siltstone, limestone
		Larapinta Group: Pacoota Sandstone	Є/Op	Fossiliferous sandstone, conglomeratic sandstone, some vertical worm-tubes
	CAMBRIAN	Pertaoorrta Formation	Єp	
		Goyder Member	Єg	Calcareous sandstone, sandy algal limestone
		Petermann Sandstone Member	Єe	Red-brown sandstone and silty sandstone
		Deception Member	Єd	Red-brown siltstone and shale
		Illara Sandstone Member	Єi	Red-brown sandstone and silty sandstone
		Tempe Member.	Єt	Siltstone, calcareous sandstone, fossiliferous glauconitic limestone
		Eninta Sandstone Member	Єn	Red-brown sandstone and silty sandstone
		Cleland Sandstone	Єc	Brown silty sandstone, pebbly sandstone
PRECAMBRIAN	UPPER PROTEROZOIC	Undifferentiated	Ꝑu	White sandstone, siltstone
		Winnall Beds	Ꝑuw	White and brown sandstone, white and green siltstone
		Pertatataka Formation	Ꝑup	Siltstone, shale, sandstone, limestone
		Areyonga Formation	Ꝑua	Siltstone, sandstone, tillite
		Inindia Beds	Ꝑun	Bedded chert, chert breccia, siltstone, thin beds of dolomite
		Bitter Springs Limestone	Ꝑub	Dolomite, dolomitic limestone, limestone, siltstone, sandstone
			Gp	Gypsum

Geological boundary

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.

Strike and dip of strata

Horizontal strata

Vertical strata

Overturned strata

Top of bed

Dip < 15° } Air-photo interpretation

Dip 15°—45°

Dip > 45°

Trend lines

Joint pattern

Macrofossil locality

×LA23 Text reference to specimen locality

LAC7 Measured section

Oc Native red ochre mine

W Well

W Abandoned well

SW Abandoned bore with windpump; saline

WH Waterhole

RH Rock hole

SH Sink hole

S Spring (permanent)

S Spring (intermittent)

Sand dunes

Vehicle track

Fence

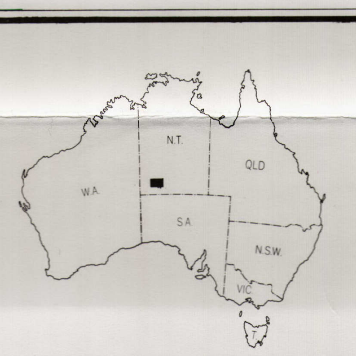
Yd Yard

Astro station

2135 Height in feet, instrument levelled } Datum, mean sea level Port Augusta

2117 Height in feet, barometric levelled

P.D. Position doubtful



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. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:46,500.

Transverse Mercator Projection.

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

WEBB SF 52-10	LAKE MACKAY SF 52-11	MT. DOREEN SF 52-12	NAPPERBY SF 53-9	ALCOOTA SF 53-10
MAC-DONALD SF 52-14	MT. RENNIE SF 52-15	MT. LIEBIG SF 52-16	HERMANNS-BURG SF 53-13	ALICE SPRINGS SF 53-14
RAW-LINSON SG 52-2	BLOODS RANGE SG 52-3	LAKE AMADEUS SG 52-4	HENBURY SG 53-1	RODINGA SG 53-2
SCOTT SG 52-6	PETER-MANN RANGES SG 52-7	AYERS ROCK SG 52-8	KULGERA SG 53-5	CHAR-LOTTE WATERS SG 53-6
COOPER SG 52-10	MANN SG 52-11	WOOD-ROFFE SG 52-12	ALBERGA SG 53-9	ABMINGA SG 53-10

3°E 5°E Annual change 1'E

Scale 1 : 250,000

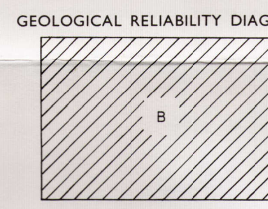
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Sections

Scale: V/H = 1

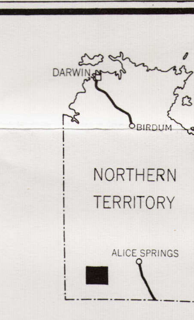
GEOLOGICAL RELIABILITY DIAGRAM

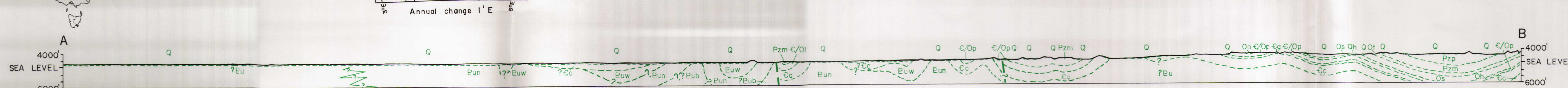


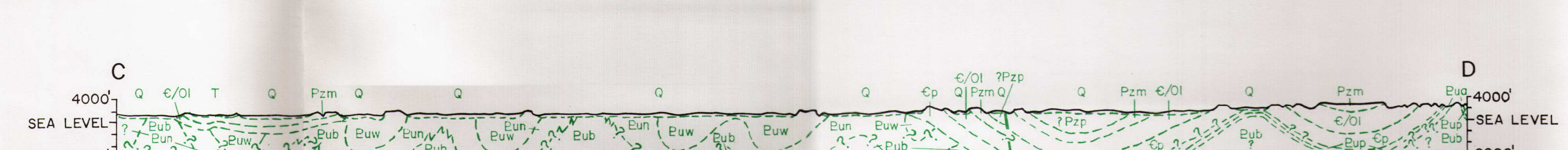
B. Detailed reconnaissance - numerous traverses with air-photo interpretation.

Geology and compilation, 1962, by: A.T. Wells, L.C. Ranford, P.J. Cook, A.J. Stewart and D.J. Forman.

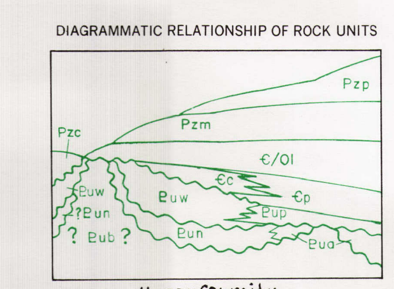
Drawn by: J.M. Fetherston.







DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



LAKE AMADEUS SG 52-4