COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 86

The Geology of the Central Part of the Amadeus Basin, Northern Territory

BY

L. C. RANFORD, P. J. COOK, and A. T. WELLS

Issued under the Authority of the Hon. David Fairbairn
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CONTENTS

CONTENTS (Cont'd)

Page

TEXT FIGURES

FIGURE

PLATES

CONTENTS (Cont'd)

SUMMARY

The oldest rocks exposed in the central part of the Amadeus Basin belong to the Upper Proterozoic Bitter Springs Formation, which is overlain in the north by at least 15,000 feet of Upper Proterozoic and Palaeozoic sediments.

The Upper Proterozoic sediments are thickest in the south and include both marine and periglacial sediments. In late Upper Proterozoic times a sequence consisting largely of arenites was deposited in the south while lutites and carbonates were deposited in the north.

The Palaeozoic sediments are thickest in the north and include marine, transitional, and continental sediments. During the Cambrian there was very little sedimentation in the south-western part of the area, but a thick sequence of transitional and continental sediments was deposited in the north-west quadrant and a thick succession of marine sediments was laid down in the east. During the Ordovician, shallow-water marine arenites and lutites with minor carbonates were deposited conformably on the Upper Cambrian sediments in the northern half of the area, while in the south a much thinner sequence of similar sediments was laid down unconformably and disconformably on the Cambrian and Upper Proterozoic rocks. In Upper Ordovician times epeirogenic movements lifted some areas (e.g. Waterhouse Range) above wave base and resulted in erosion, while elsewhere sedimentation continued without interruption. The sediments deposited indicate a continental and transitional marine environment. An orogenic episode during the Devonian resulted in the deposition of a thick continental clastic sequence and was responsible for the present shape of the basin. The final pulses of this orogeny folded the sediments of Upper Devonian and possibly Carboniferous age.

After a long period of erosion a thin sequence of Mesozoic(?) sediments was deposited unconformably on the Palaeozoic rocks. In the Tertiary, fluvial and fossiliferous lacustrine sediments were deposited in a number of small basins which were probably connected and fed by the major drainage channels in existence at present.

Two major orogenic episodes have been recognized in the central part of the Amadeus Basin. The first, the Petermann Ranges Orogeny, occurred in late Upper Proterozoic or early Lower Cambrian times, and the second, the Alice Springs Orogeny, may have begun in the Upper Ordovician, but reached a climax in the Devonian and probably continued into the Carboniferous. The main compressional force appears to have come from the south during the Petermann Ranges Orogeny and from the north during the Alice Springs Orogeny. The folds are supratenuous and have complex cores; the axes trend west-north-west. The form of the structures has been largely controlled by the presence of evaporites in the Cambrian Chandler Limestone and the Upper Proterozoic Bitter Springs Formation, and a décollement surface is suspected within or immediately beneath the Bitter Springs Formation. Major longitudinal thrusts and smaller transverse faults have been mapped in the central part of the Amadeus Basin; the major faults are probably 'break-thrusts' associated with the folding.

Four wells have been drilled in the search for oil in the central part of the Amadeus Basin at the time of writing (Feb. 1965). This and other drilling in the area to the north has shown that the Cambrian and Ordovician sediments contain considerable quantities of hydrocarbons. Potential source and reservoir rocks are known from Upper Proterozoic, Cambrian, and Ordovician sediments and there are a number of untested closed
11-3 structures as well as prospects of stratigraphic traps.

Phosphorites occur in the Ordovician Larapinta Group sediments and in 1963 four diamond drill-holes were sunk to test the deposits. The phosphorites contain pellets with up to 27 percent P_2O_5, and the P_2O_5 content of the pelletal bands ranges from 10 to 21.6 percent.

Copper mineralization was examined in the eastern half of the area, but no new deposits were found.

There are many permanent waterholes and rockholes in the northern part of the area, but very few in the south. The water table is shallower in the north than in the south and the water is much more saline in the south. Most of the bores in the area draw water from the Quaternary alluvium.

INTRODUCTION

During the periods late May to early October 1962 and late May to early October 1963, L.C. Ranford, P.J. Cook, A.T. Wells, and A.J. Stewart mapped the Lake Amadeus and Henbury Sheet areas. Ranford and Cook mapped most of the Lake Amadeus Sheet and the northern three-quarters of the Henbury Sheet, Wells mapped parts of the Lake Amadeus Sheet, and Wells and Stewart the southern quarter of the Henbury Sheet. Palaeontologists Miss J.G. Tomlinson and C.G. Gatehouse worked with the field party for part of each season.

Location and Access

The area covered by this report (Fig. 1) lies between latitudes 24° and 25° south and between longitudes 130°30' and 133°30' east. Access is by the Alice Springs-Port Augusta road, which crosses the eastern side of the area. A graded road runs west from the main highway to King Canyon via Tempe Downs homestead and Wallera ranch; a branch road runs south from Wallera ranch to Angas Downs homestead. There is also a graded road to Areyonga Mission from Alice Springs. Numerous station tracks are shown on the maps.

Climate

The area has a semi-arid climate with an average annual rainfall of less than 10 inches. Temperatures are high throughout much of the year, and a maximum in excess of 100°F is commonly recorded during the summer. The prevailing winds are from the south-east and north-west.

Development

The western half of the area is almost completely undeveloped, with only a few yards and fences along the George Gill Range. Much of the western half of the Lake Amadeus Sheet area is an Aboriginal Reserve. The eastern half of the area is moderately well developed with fencing and numerous bores and dams. There are permanent settlements at Henbury, Orange Creek, and Tempe Downs homesteads, at Wallera ranch, at the Palm Valley tourist camps, and at Areyonga Native Settlement.

The development of the area stems from the cattle industry, but added impetus is likely to be given in the future by the rapidly expanding tourist industry.

Survey Method

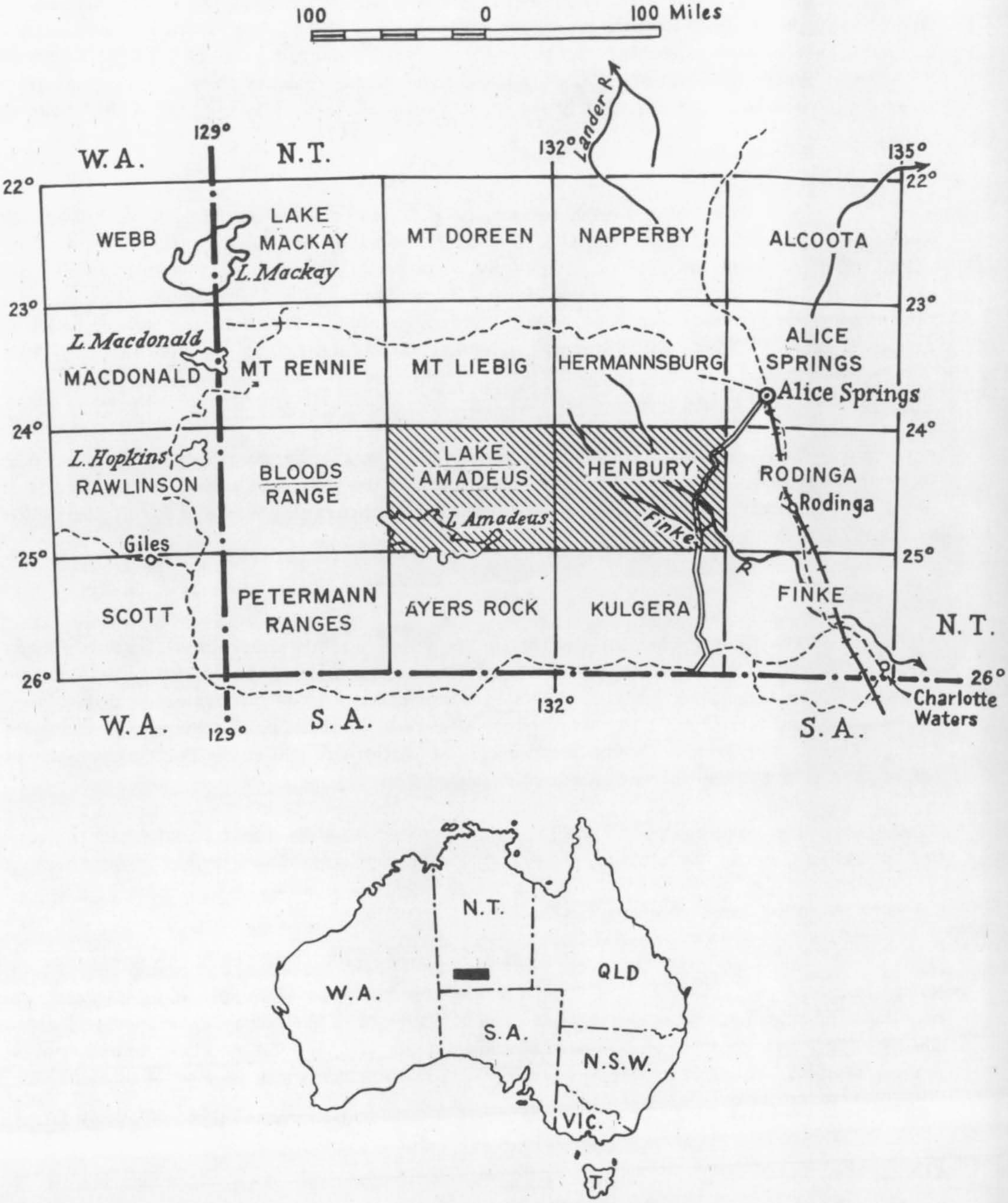
The mapping was carried out by Land-Rover traverses from base camps near Reedy Rockhole in 1962 and near Tempe Downs airstrip in 1963. A helicopter was used for two days on the Lake Amadeus Sheet area and for seven days on the Henbury Sheet area. The geology was plotted on air-photographs (scale of 1:46,500), and then transferred to slotted templet assemblies which were reduced photographically to a scale of 1:250,000.

Sections (Fig. 2) were measured with a 300-feet steel tape and Abney Level.

Previous Investigations

The first explorer to visit the area was John McDouall Stuart (1861), who travelled along the Finke and Hugh Rivers in 1860, in an attempt to reach the north coast

Fig. 1 1:250,000 SHEET INDEX AND LOCALITY MAP



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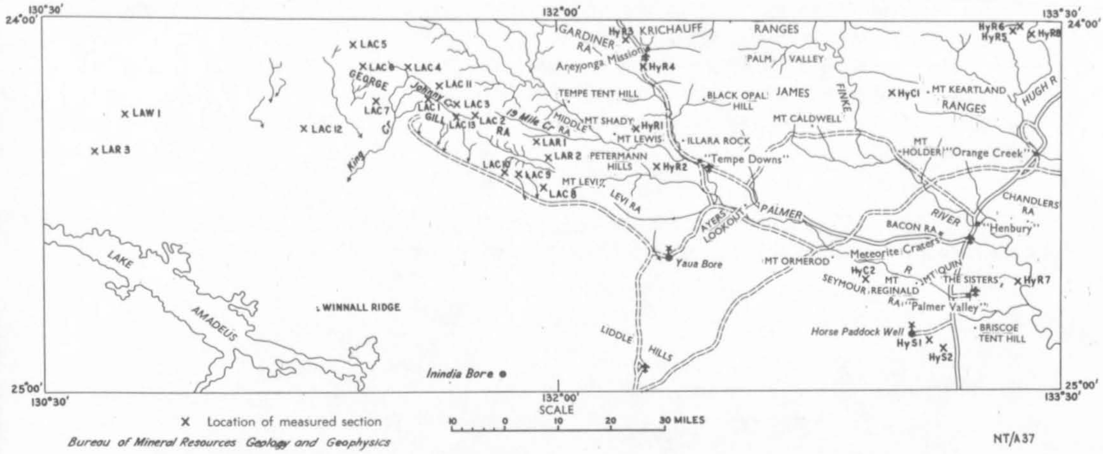


Fig.2 Location of measured sections.

of Australia. In 1864, Stuart (1865) again passed through the area on his successful journey across Australia. On both these journeys Stuart and Waterhouse (the naturalist with the expedition) made general geological observations. In 1872 E. Giles (1889) was the first explorer to travel through the western part of the area. He discovered Mount Olga and Lake Amadeus. In 1873 W.C. Gosse (1874) also travelled through the western part of the area and then travelled south, where he discovered Ayers Rock.

The first geologist to visit the area was C. Chewings (1886), who investigated the source of the Finke River in 1886. He revisited the area several times between 1891 and 1935, and several of his papers refer to the geology of the area (Chewings, 1891, 1894, 1914, 1928, 1931, 1935). H.Y.L. Brown, the South Australian Government Geologist, first visited the area in 1889 (Brown, 1890) and he mentions the area in several other reports (Brown, 1891, 1892, 1895) and refers to Etheridge's work on the Larapinta fauna from the Tempe Downs area. W.H. Tietkins (1891) travelled around the western end of Lake Amadeus in 1889 and prepared the first map of the lake. In 1892 the Horn Expedition (Tate, 1896) spent several weeks in the eastern half of the area and collected many fossils from the vicinity of Tempe Downs. In 1902 R.T. Maurice (Murray, 1904) travelled along the western margin of the area while on a journey from Fowlers Bay to Cambridge Gulf. He first described the conglomerate at Mount Currie and also the gypseous mounds at Mount Murray (a possible diapiric structure). A government prospecting party under the leadership of F.R. George (George & Murray, 1907) travelled extensively through the western half of the area in 1906. In 1916 a government surveying expedition travelled through the area (Day, 1916). L.K. Ward, C.T. Madigan, and D. Mawson worked for brief periods in the Henbury and Lake Amadeus Sheet areas (Ward, 1925; Mawson & Madigan, 1931, 1932), and it was Mawson and Madigan who pioneered the use of aeroplanes as an aid to geological mapping in Central Australia. G.F. Joklik was attached to an expedition searching for Lasseters Reef, and he made some geological observations on the Angas Downs area (Joklik, 1952).

In 1953 the National Lead Company undertook an extensive programme of drilling for copper in the Goyder Formation of the Pertaoorrta Group in the Waterhouse Range. A geochemical survey was also completed, but the results were not encouraging and the investigation was abandoned in 1955.

The Bureau of Mineral Resources sent its first field party into the Amadeus Basin in 1956 (Prichard & Quinlan, 1962) to map the southern part of the Hermannsburg 1:250,000 Sheet area. The work of Prichard and Quinlan has served as a basis for later geological work. Both before and after 1956, the geologists of the Resident Geological Office in Alice Springs have been carrying out geological work over much of the Amadeus Basin, mostly in connexion with the siting of water bores.

In 1957, Quinlan carried out reconnaissance geological mapping over a wide area of country in the Alice Springs district, as geologist with a C.S.I.R.O. field party (Perry et al., 1962).

R.O. Brunnschweiler, in 1959, made reconnaissance geological trips over a wide area in central Australia, but the area described in this Report is only briefly mentioned (Brunnschweiler, 1959, 1961).

I. Gillespie and R.B. Leslie of Frome-Broken Hill Pty Ltd (Leslie, 1960) undertook reconnaissance geological mapping on the Lake Amadeus, Henbury, and surrounding Sheet areas in 1959, and brief palaeontological studies were carried out by Taylor (1959) Frome-Broken Hill Pty Ltd relinquished their oil permits in 1960. The permits were taken over by the Magellan Petroleum Corporation and associated companies, and since 1960, R.M. Hopkins, C.R. Stelck, D.A. McNaughton, J. Banks, and B. Haites have continued geological mapping of the oil permit area (Stelck & Hopkins, 1962; McNaughton, 1962; Haites, 1963; Ranneft, 1963; Banks, 1964).

The Henbury and Lake Amadeus Sheet areas were photo-interpreted for the Bureau of Mineral Resources in 1960 by the Institut Français du Petrole (Scanvic, 1961) as part of a photo-interpretation programme covering the whole of the Amadeus Basin.

In 1960 the Geophysical Branch of the Bureau of Mineral Resources flew two aeromagnetic traverse lines across the area (Goodeve, 1961), and in 1961 a short seismic traverse was made across the Palm Valley anticline. A helicopter gravity survey was completed in 1962 (Lonsdale & Flavelle, 1963).

In 1960, the Bureau of Mineral Resources commenced a programme of reconnaissance geological mapping in the Amadeus Basin on a scale of 1:250,000. The Rawlinson and Macdonald Sheet areas were mapped in 1960 (Wells, Forman, & Ranford, 1965a), the Mount Rennie and Mount Liebig Sheet areas in 1961 (Wells, Forman, & Ranford, 1965b), the Lake Amadeus and Bloods Range Sheet areas in 1962 (this Report; Forman, 1965), the Henbury, Petermann Ranges, Ayers Rock, Kulgera, and Finke Sheet areas in 1963 (this Report; Forman, 1965; Wells, Stewart, & Skwarko, 1965, in press), and the Alice Springs, Hale River, Illogwa Creek, McDills, and Rodinga Sheet areas in 1964 (Forman & Milligan, 1965, in prep.; Wells, Ranford, Cook, Stewart, & Shaw, 1965, unpubl.).

TABLE 1 - STRATIGRAPHY OF THE CENTRAL PART OF THE AMADEUS BASIN

Age	Rock Unit	Map Symbol	Maximum Thickness (feet)	Lithology	Water Supply	Remarks
Quaternary		Qa	100+	Alluvium and river gravel.	Good potential for high-quality water	
		Qs		Aeolian sand.		
		Ql		Travertine.	Poor prospects	
		Qg		Gypsum.		
		Qc		Conglomerate (unconsolidated).		
Tertiary(?)		T Tl Tc	100	Calcareous silty sandstone, conglomerate, and limestone conglomerate.	Some beds could have potential if sequence is thicker than known from outcrop.	
		Tb		Siliceous billy.		
		Ta		Laterite, ferricrete.	No potential	
Mesozoic(?)		M	60	Kaolinitic sandstone and sandy claystone	Too thin and impermeable	Flat lying. Usually has thin capping of billy
Devonian to Carboniferous	Pertnjara Formation	Pzp(s)	1500+	Sandstone and silty sandstone with some scattered pebbles and cobbles.	Some beds could supply large quantities of moderate to good quality water	Appears to lie conformably on Pzp(a) in most areas
		Pzp(a)	About 2800	Siltstone, fine silty sandstone, some limestone.	Permeability low - prospects poor	Poorly exposed
Ordovician to Devonian	Mereenie Sandstone	Pzm(2)	2470	Sandstone with large-scale cross-bedding.	Yields large quantities of excellent water	Generally conformably on Pzm(1). Unconformably on Larapinta Group in Waterhouse Range.
		Pzm(1)		Sandstone, silty sandstone, minor siltstone. Marine fossils	Could yield moderate quantities of good-quality water	Contains Ordovician <u>Cruziana</u>. Not present in Waterhouse Range
Ordovician — Larapinta Group	Stokes Formation	Ot	About 1500	Siltstone, shale, limestone, silty sandstone. Marine fossils.	Impermeable - prospects poor	Generally poorly exposed. Some thin beds with pelletal phosphate near base
	Stairway Sandstone	Os	880	Sandstone, silty sandstone, and siltstone with minor limestone. Marine fossils.	Some porous beds but water generally saline	Contains a number of beds of pelletal phosphate
	Horn Valley Siltstone	Oh	350	Siltstone and shale with bluish grey or grey-green limestone. Marine fossils.	Prospects poor	Lenses out to south
	Pacoota Sandstone		2050	Sandstone and silty sandstone partly conglomeratic. Marine fossils.	Porosity and permeability highly variable - could provide large supply of good-quality water in some areas	Thins markedly to south; absent south of lat. 24°40' S.
Cambrian — Pertaoorta Group	Goyder Formation	Єg	1180	Silty sandstone, siltstone, shale, limestone. Some marine fossils.	Upper part may provide small supply. Poor prospects in lower part.	Generally poorly exposed. Minor copper mineralization in some areas
	Petermann Sandstone	Єe	640	Sandstone and silty sandstone with minor siltstone.	Possibly some supply from cleaner sandstone beds	
	Deception Formation	Єd	560	Siltstone and shale with minor fine sandstone.	Prospects poor	
	Illara Sandstone	Єi	About 400	Sandstone and silty sandstone with minor siltstone.	Possibly some supply from cleaner sandstone beds	
	Jay Creek Limestone	Єj	900+	Limestone, shale, siltstone, sandstone. Marine fossils and algal structures.	Porosity and permeability probably low and prospects poor	Only mapped in eastern half. Largely shallow water calcarenites and algal biolithites
	Tempe Formation	Єt	About 760	Siltstone, shale, limestone, sandstone - very rich in glauconite. Some marine fossils.	Some sandstone and limestone horizons may give small supply	Laterally equivalent to part of Jay Creek Limestone
	Chandler Limestone	Єl	About 300	Limestone and dolomite with chert laminae.	May have fracture porosity, but water probably saline	Generally highly contorted and incompetently folded. Probably includes interbedded evaporites, not seen in outcrop.
	Eninta Sandstone	Єn	310	Sandstone, silty sandstone, siltstone. Some conglomerate beds.	Porosity generally poor, prospects not good	Mapped only in Gardiner Range, where unconformable on Pertatataka Formation
	Quandong Conglomerate	Єq	About 500	Conglomeratic sandstone, conglomerate, sandstone.	Likely to have low porosity because of poor sorting. Prospects poor	Only known from area 6 miles N.E. of Tempe Downs and in core of James Range 'B' anticline
Cambrian	Cleland Sandstone	Єc	1570	Red-brown poorly sorted pebbly sandstone.	Prospects poor	Only mapped on western side of area
Cambrian	Mount Currie Conglomerate	Pzc		Polymictic conglomerate, with boulders of porphyry, rhyolite, basalt, quartz, up to 24 inches across.	No potential	Possibly Cambrian. Strongly epidotized. Only present in south-west corner of area
Upper Proterozoic	Winnall Beds	Buw	About 5000	Sandstone, siltstone, shale.	Cleaner sandstone could give good supply	Present on southern and western parts of area; grades laterally into Pertatataka Formation
	Pertatataka Formation	Bup	2000+	Siltstone and shale with minor sandstone and limestone.	Impermeable - prospects poor	Present in Gardiner Range and near Orange Creek homestead. Eroded during Lower Cambrian(?) in some areas
	Areyonga Formation	Bua	About 1000	Claystone, siltstone, sandstone, minor conglomerate and limestone.	Porous sands could give moderate supply	Partly aqueoglacial sediments; present in northern half of area
	Inindia Beds	Bun	About 3000	Siltstone, bedded chert, chert breccia, sandstone, conglomerate.	Some porous beds may give small supply	Generally poorly exposed; present in southern half of area
	Bitter Springs Formation	Bub	1662+	Dolomite with minor siltstone, limestone, and sandstone. Some chert.	Good supply in some areas but water generally very saline	Contains algal stromatolites; may contain interbedded evaporites, but not seen in outcrop

In 1963, the Bureau of Mineral Resources completed a programme of diamond drilling for phosphate in the area (Barrie, 1964) and D. Milton of the Astro Division of the United States Geological Survey mapped in detail several of the Henbury meteorite craters.

During 1964 J. Barrie made a brief visit to the area to re-appraise the phosphate potential, and K.A.W. Crook and P.J. Cook included the Stairway Sandstone in a regional sedimentary study (Crook & Cook, 1965).

PHYSIOGRAPHY

There are seven main physiographic divisions in the area (see Fig. 3).

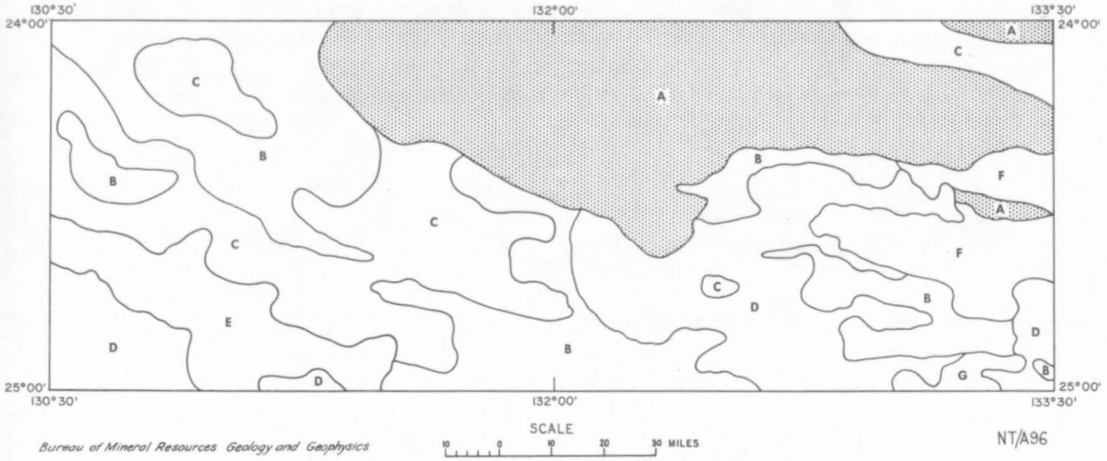


Fig. 3. Physiographic Divisions.
A: mountain ranges; B: low ridges with intervening dunes and plains; C: sand plain with many dunes; D: sand plain with dunes; E: salt lakes; F: plain with mesas; F: flood plain.

Mountain ranges and hills are restricted to the northern part of the area, with some peaks rising over 1000 feet above the general level of the sand plain. The geological units forming the ranges include the Pertnjara Formation, the Mereenie Sandstone, and to a lesser extent the Larapinta Group. The major drainage channels follow strike valleys, but the drainage in the Mereenie Sandstone is controlled by the well developed joint system, and in the Pertnjara Formation it tends to be dendritic owing to the massive nature of the sediments.

Low Ridges and Hills with intervening Sand Dunes, Sand, and Sand Plains. This physiographic division occurs mainly in the north-west corner of the Lake Amadeus Sheet area and the southern parts of the Henbury Sheet area. Hills rise from 50 to 200 feet above the level of the sand plain, and the underlying strata are generally steeply dipping Winnall Beds. The poorly defined drainage flows towards Lake Amadeus or into the Finke River.

The Sand Plain with many Sand Dunes and some Low Outcrops covers a large proportion of the western half of the area but is rare in the eastern half. Outcrops rise to only 10 feet above the sand plain. The sand dunes are generally poorly defined and there is no well-defined drainage pattern.

The Sand Plain with Braided Dunes covers a large part of the Henbury Sheet area and the southern margin of the Lake Amadeus Sheet area. Outcrops are rare. The dunes reach a maximum height of 50 feet and have a poorly defined south-westerly trend. There is no well-defined drainage pattern.

Salt Lakes occur in a wide belt, which trends in a west-north-westerly direction, in the southern half of the Lake Amadeus Sheet area. There is no surface water in the lakes, except immediately after rain, but in the western arm of Lake Amadeus the water lies only 3 to 4 inches below the surface.

Gibber or Alluvial Plain with Mesas and Low Hills. Much of the eastern part of the region is covered by gibber or alluvial plain, with mesas and hills up to 100 feet high. To the west of the main road, most of the outcrops consist of Upper Proterozoic and Palaeozoic rocks, but to the east there is a thin veneer of Mesozoic and Tertiary sediments overlying strongly folded Lower Palaeozoic and Upper Proterozoic strata. Drainage consists mainly of the Finke and Hugh Rivers and their tributaries.

Alluvial Flood Plain with some Clay Pans occupies a small area in the south-east corner where the drainage patterns are poorly defined.

STRATIGRAPHY

The oldest formation exposed in the central part of the Amadeus Basin is the Upper Proterozoic Bitter Springs Formation, which is overlain by Upper Proterozoic, Cambrian, Ordovician, Devonian, Mesozoic(?), Tertiary(?), and Quaternary deposits.

The stratigraphy of the area is summarized in Table 1 and sections are shown in Plate 9. The measured sections are given in columnar form in Plates 10 to 14.

The relationships between the Proterozoic and Palaeozoic units in the northern half of the area are as shown in Figure 4.

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

UPPER PROTEROZOIC

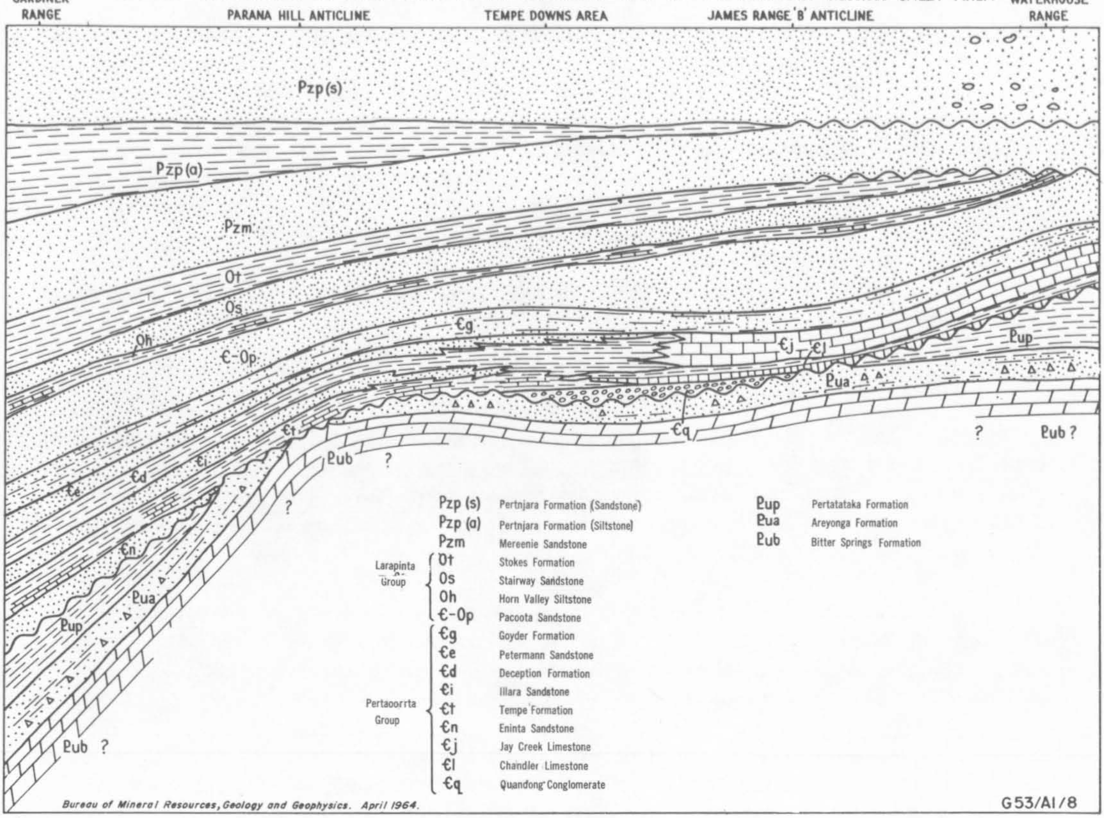
Bitter Springs Formation (Joklik, 1955)

The Bitter Springs Formation was originally defined by Joklik (1955) as the Bitter Springs Limestone, but recent mapping by geologists of the Bureau of Mineral Resources has shown that the unit is composed of siltstone, shale, dolomite, limestone, and sandstone, and the name is now amended.

In the central part of the Amadeus Basin, the Bitter Springs Formation is exposed in the cores of the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill

Fig. 4.

POSSIBLE CORRELATION OF ROCK UNITS IN THE NORTHERN PART OF THE HENBURY 1:250,000 SHEET AREA



anticlines and also in the cores of unnamed anticlines immediately south of the Liddle Hills, east of Dead Bullock Plain, 5 miles east-south-east of Orange Creek homestead, 2 miles south-east of Henbury homestead, and 4 miles north-east of Palmer Valley homestead. It also occurs at Mount Murray and several other isolated outcrops on the Lake Amadeus Sheet area. The formation is best exposed in the core of the Parana Hill anticline, where a minimum thickness of 1662 feet was measured. Good exposures are also present near Dead Bullock Plain, where Leslie (1960) measured 600 feet of Bitter Springs Formation, and in the Gardiner Range near Areyonga.

In the central part of the Amadeus Basin the outcrops of the Bitter Springs Formation consist mainly of fine-grained dolomite and dolomitic limestone which ranges from fawn to pink, or pale grey to dark grey, and generally contains numerous 'biscuits', lenses, and irregular masses of chert. The dolomite is partly sandy, and contains algal stromatolites, some of which have been replaced by chert and stand out on weathered surfaces. The dark grey dolomite emits a foetid odour when freshly broken. Interbedded with the carbonates are minor amounts of red-brown and white spotted siltstone and mudstone which weather recessively and are not normally exposed. Many of the isolated outcrops of Bitter Springs Formation ocur in association with masses of sheared and contorted gypsum, and the presence of the diapiric structures suggests that evaporites may be present.

The basal part of the Bitter Springs Formation is not exposed in the central part of the Amadeus Basin. The formation is overlain by the Areyonga Formation in the northern half of the area and by the Inindia Beds and Winnall Beds in the south. In some areas the boundary has been placed at the first appearance of tillitic siltstone, claystone, and sandstone, and in others at the change from dolomite to interbedded siltstone and chert. The presence of abundant fragments of Bitter Springs limestone in the Areyonga Formation suggests that the formations are disconformable. In the southern half of the area, the Inindia Beds generally rest apparently disconformably on the Bitter Springs Formation, but near the Liddle Hills the Winnall Beds, Pertaoorrta Group sediments, and Stairway Sandstone rest on Bitter Springs Formation with a marked angular unconformity.

The Bitter Springs Formation is considered to be Upper Proterozoic on the basis of its stratigraphical position.

Inindia Beds (new name)

The Inindia Beds consist of a sequence of siltstone, sandstone, chert, chert breccia, and thin beds of dolomite, which disconformably overlies the Bitter Springs Formation and is overlain, probably unconformably, by the Winnall Beds. The type area is 36 miles south-east of Mount Murray and the name is derived from Inindia Bore on the southern edge of the area.

The Inindia Beds usually crop out in low mounds or on rubble-covered plains. They are sparsely exposed in the cores of anticlines in the southern half of the Henbury Sheet area; in the Lake Amadeus Sheet area they are poorly exposed in isolated outcrops between Mount Murray and Inindia Bore.

No sections have been measured, but the Inindia Beds are estimated to be about 1000 feet thick in the middle of the area, and between 2000 and 3000 feet in the south-west.

The Inindia Beds comprise siltstone, shale, sandstone, chert, and rare thin beds or lenses of limestone, dolomite, and conglomerate. The siltstone and shale are predominantly pale purple-brown and red-brown, but in places they are mauve, white, or yellow. They are laminate to massive, micaceous, moderately to poorly sorted, and in some places tillitic, with angular fragments of chert averaging about a quarter of an inch in diameter but ranging up to 4 inches. The sandstone occurs as thin interbeds in the siltstone sequence and also as larger units which can be traced for several miles. Thin beds of medium-grained micaceous sandstone with halite pseudomorphs, and thin interbeds of glauconitic sandstone may also be present. The thicker sandstone units are generally white, medium to coarse-grained, cross-bedded, moderately to well sorted, and strongly fractured and jointed. The chert near the base of the formation is well bedded but strongly fractured, and tends to form lines of rubble at the surface. The chert is mostly yellow-green, white, or grey. It forms beds up to about 2 feet thick, interbedded with siltstone and shale. The oolitic texture of some of the chert suggests that it has been formed by the replacement of oolitic carbonates. Striated boulders were found at one locality 19 miles south-west of Mount Tucker in the Lake Amadeus Sheet area (Pl. 1, fig. 1).

The Inindia Beds appear to rest conformably on the Bitter Springs Formation, but the presence of pebbles of Bitter Springs limestone in the Inindia Beds indicates a disconformable relationship.

The Beds contain no fossils and are regarded as Upper Proterozoic in age. Their stratigraphical position between the Winnall Beds and Bitter Springs Formation and the presence of some tillite beds indicate that they can be correlated with the Areyonga Formation.

Areyonga Formation (Prichard & Quinlan, 1962, p.12)

The Areyonga Formation crops out in the cores of the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill anticlines. The sandstone lenses stand out as prominent strike ridges, but the softer finer-grained sediments are poorly exposed except where protected by resistant sandstone ridges, or where exposed in the banks of creeks such as near Areyonga, or in the Parana Hill anticline.

The thickness of the formation as estimated from the air-photographs is 500 feet near Areyonga and about 1000 feet near Tempe Downs. The apparent increase in thickness towards the south is accompanied by an increase in the proportion of sandstone.

The Areyonga Formation has a wide range in lithology and many of the lithological units are lenticular. Even apparently consistent sandstone horizons are found on closer examination to consist of a series of lenses. The main rock types are probably tillitic pebbly claystone and siltstone. They range from grey-green to mauve and white, and contain fragments of the underlying sediments, and of igneous and metamorphic basement rocks. Erratics up to 15 inches in diameter were seen in the claystone, and many of the phenoclasts are faceted. A few of the erratics are striated. In the Parana Hill anticline the striations were only observed on boulders of grey-green silicified sandstone, but in the exposures nearer Tempe Downs homestead the striations are restricted to pebbles of pale yellow silicified siltstone.

The sandstone beds in the Areyonga Formation are medium to coarse-grained, moderately to poorly sorted, cross-bedded, and generally silicified at the surface. The sandstone is mostly white, but in some areas the high feldspar content imparts a pale pink or fawn tint to the rocks. The blocky fracture and network of anastomosing quartz veinlets give the outcrops a characteristic appearance. In some areas a sequence of siltstone with chert interbeds is exposed towards the base of the formation. The chert is oolitic in part and ranges in colour from dark red-brown to yellow-green, grey, or white. The formation contains lenses of pebble and boulder conglomerate, as in the Parana Hill anticline, but most of the lenses appear to be of small lateral extent.

In the Gardiner Range, north-west of Areyonga Native Settlement, the typical Areyonga Formation can be traced laterally along the strike into a sequence of limestone, dolomite, chert, and sandstone. The carbonates are fawn, pink, pale grey, or white, largely oolitic or pelletal, and partly sandy. The dolomite is in part cross-laminated, and contains some possible algal stromatolites, and laminae and irregular masses of chert. The sandstone, which forms a bed about 20 feet thick, is white, medium to coarse-grained, well sorted, silicified, and thick-bedded. It contains numerous evenly spaced vertical tubes or pipes as shown in Plate 1, figure 2. The pipes are about half an inch in diameter and up to 3 feet long, and are considered to be of organic origin.

The Areyonga Formation rests disconformably on the Bitter Springs Formation. In the Western MacDonnell Ranges and Gardiner Range it is conformably overlain by the Pertatataka Formation, but to the south (e.g. in the cores of Parana Hill and Walker Creek anticlines) it is overlain unconformably by the Pertaoorrta Group. The Areyonga Formation is lithologically similar and laterally equivalent to the Inindia Beds.

The Areyonga Formation is considered to be Upper Proterozoic.

Pertatataka Formation (Prichard & Quinlan, 1962, p.13)

The Pertatataka Formation crops out in the Gardiner Range, about a mile south-south-west of Areyonga Aboriginal Settlement, and near Orange Creek homestead. The Pertatataka Formation is easily eroded and forms broad strike valleys with a few low ridges of the more resistant sandstone and carbonate members. No sections have been measured in the central part of the Amadeus Basin.

The Pertatataka Formation comprises grey-green and purple-brown laminated micaceous siltstone and shale with thin interbeds of sandstone and limestone. The sandstone is grey-green or white, laminated or thin-bedded, fine to coarse-grained, and silicified. Glauconite is a typical feature, and many thin beds contain closely spaced impressions of clay pellets. In places, there are markings on the bedding planes, some of which are probably of organic origin. The limestone is white or pale pink-brown, sandy, and oolitic. In thin section the oolites consist of both carbonate and chert, and in some bands there is evidence of selective silicification of the oolites.

The Pertatataka Formation appears to lie conformably on the Areyonga Formation, and unconformably below the Pertaoorrta Group. The unconformity is well exposed in the Gardiner Range near Areyonga Aboriginal Settlement. Theabsence of the Pertatataka Formation in the Parana Hill, Petermann Creek, and Walker Creek anticlines is considered to be the result of erosion prior to the deposition of the Pertaoorrta Group.

There is probably a gradual transition from the Pertatataka Formation to the more sandy Winnall Beds and this increase in sand content towards the south is accompanied by an increase in thickness.

No fossils have been found in the Pertatataka Formation. The formation is unconformably overlain by lower Middle Cambrian sediments and underlain conformably by sediments of possible Upper Proterozoic age. The Pertatataka Formation is tentatively regarded as Upper Proterozoic, but if the correlation with the Winnall Beds is correct, it could be of Lower Cambrian age.

Winnall Beds (new name)

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

The Winnall Beds crop out as prominent strike ridges in a strip of country 30 miles wide which extends diagonally across the Lake Amadeus Sheet area from north-west to south-east and into the southern half of the Henbury Sheet area. The blocky silicified sandstone of the Winnall Beds gives the outcrops a jagged outline. No complete section has been measured through the Winnall Beds, but it is estimated from field and photographic evidence to have a thickness of at least 5000 feet in the Inindia Bore area. In the Liddle Hills an estimated 3500 feet of sediments are exposed and in the anticline south of the Seymour Range, Stewart (pers. comm.) reports a minimum thickness of 1200 feet for the formation. Four units can be distinguished in the Winnall Beds:

(Top) Unit 4 Sandstone

Unit 3 Siltstone and silty sandstone

Unit 2 Sandstone

Unit 1 Siltstone and silty sandstone

Unit 1, at the base of the Winnall Beds, consists of thin-bedded dark siltstone and some fine slightly calcareous silty sandstone. It is poorly exposed throughout most of the area and appears to be of variable thickness. At Mount Conner on the Ayers Rock Sheet area Unit 1 is 500 feet thick, but in the Liddle Hills it is only 20 feet thick.

Unit 2 consists of two parts. The lower part comprises massive cross-bedded fine-grained silicified sandstone, and the upper part consists of thin to medium-grained coarse-grained silicified sandstone with some conglomeratic interbeds in which the fragments are composed mainly of chert. Both the upper and lower parts are strongly resistant to weathering and form prominent scarps and ridges. Unit 2 is characterized by the abundance of sedimentary structures such as load casts, slump rolls, scour-and-fill structures, possible synaeresis cracks (White, 1961), ripple marks, mud-cracks, mud-pellet markings, and a large number of other structures of unknown origin. The unit is 1800 feet thick in the Liddle Hills.

Unit 3 is a poorly exposed interval of variegated thin-bedded silty sandstone which is estimated to be 1100 feet thick in the Liddle Hills.

Unit 4 is a dark brown poorly sorted medium-bedded moderately well exposed sandstone which varies from hard to friable. The unit crops out over a wide area but is of variable thickness; in the Liddle Hills the thickness is 600 feet, but in the Bacon Range it is only 50 feet thick.

The relationship of the Winnall Beds to the underlying and overlying formations is generally obscured, but in the Liddle Hills there is a marked unconformity between the Inindia Beds dipping at 72^{o} and the overlying Winnall Beds dipping at 38^{o}. At the same locality the Winnall Beds are also unconformably on the Bitter Springs Formation.

Unit 2 of the Winnall Beds contains numerous indeterminate fossil tracks and trails. One fossil (LA508) found in the long strike ridge 30 miles south-west of Reedy Waterhole, consists of 'sandsticks', approximately 1 cm across and 10 to 15 cm long, lying close together and parallel to each other; they lie in the bedding plane and occur in large number, forming colonies at this one locality (see Pl.2, fig.1). A.A. Öpik (pers. comm.) has suggested that these fossil traces are comparable with Syringomorpha Nathorst, which is described by Haas et al. (1962) as 'Roller-like sticks several centimeters in length and one to two millimeters in thickness lying close together; slightly arched touching each other along whole length and forming complete slab; occuring in large numbers independent of bedding. (Possibly seaweed; work of gregarious worms of flat sub-stratum according to Rudolf Richter).' The main difference between the pipes in the Winnall Beds and Syringomorpha is the larger diameter of the pipes. The mode of embedding of the pipes and their structure are very similar to Syringomorpha, which suggests that the Winnall Beds may be Lower Cambrian; but an Upper Proterozoic age is thought to be more likely.

CAMBRIAN

In the central part of the Amadeus Basin the Cambrian Period is represented mainly by the Pertaoorrta Group sediments (in the eastern part of the area) and by the Cleland Sandstone and Mount Currie Conglomerate (in the western part of the area).

Mount Currie Conglomerate (Forman, 1965)

In the central part of the Amadeus Basin, the Mount Currie Conglomerate is restricted to the south-west corner. The width of the outcrop on the air-photographs indicates that the formation is several thousand feet thick.

The formation is a poorly sorted conglomerate composed of subrounded pebbles, cobbles, and boulders up to 24 inches across, set in a matrix of coarse-grained poorly rounded and sorted sandstone. The phenoclasts are predominantly quartz-feldspar porphyry with subordinate epidotized amygdaloidal basalt, vein quartz, quartzite, and sandstone. The massive beds at Mount Currie dip at 80° to the south-south-west.

The base of the Mount Currie Conglomerate is not exposed in the area, but in the type area it rests on possible Upper Proterozoic sandstone and siltstone. The sandstone boulders may be derived from the Dean Quartzite and Winnall Beds, and the basalt boulders are probably derived from the Mount Harris Basalt (Forman, 1965). Much of the formation has been strongly epidotized.

The Mount Currie Conglomerate is unfossiliferous. The field relationships indicate that it is younger than the Winnall Beds and it is tentatively regarded as Cambrian.

Cleland Sandstone (Wells et al., 1965b)

The Cleland Sandstone crops out at scattered localities only in the north-western section of the central part of the Amadeus Basin. It generally forms low strike ridges and hills, and the only prominent feature of Cleland Sandstone is Mount Tucker, which lies about 20 miles west of King Canyon. On the Lake Amadeus Sheet area, the Cleland Sandstone is overlain by the Goyder Formation in the east, and the Pacoota Sandstone in the west. The base of the Cleland Sandstone is not exposed, but the formation appears to rest unconformably on the Winnall Beds about 20 miles south-east of Mount Murray. One incomplete section (LAC12), with a minimum thickness of about 1570 feet, was measured through the Cleland Sandstone.

Near Mount Tucker, the Cleland Sandstone can be subdivided into three units. The basal sandstone 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 contain scattered pebbles of vein quartz and metamorphic quartzite. It 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 common in some beds. Most of the middle unit weathers recessively, but some of the sandstone beds form low ridges. The topmost unit, which forms a prominent strike ridge, 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.

To the south and east of Mount Tucker, the Cleland Sandstone is overlain by the Goyder Formation of the Pertaoorrta Group, but to the west it is conformably overlain by the Pacoota Sandstone. The contact with the Pacoota Sandstone is transitional over a thickness of about 10 feet. The junction between the Cleland Sandstone and underlying units is not exposed, but the degree of deformation indicates a marked angular unconformity with the Winnall Beds. The Cleland Sandstone is the lateral equivalent of part of the Pertaoorrta Group, but until its base is better known a more exact correlation is not possible.

Fossils have not been found in the Cleland Sandstone, but its stratigraphic position indicates that it may be Cambrian.

Pertaoorrta Group

(Prichard & Quinlan, 1962; Wells et al., 1965b)

The Pertaoorrta Group was originally defined by Prichard & Quinlan (1962), and the name was later revised to Pertaoorrta Formation (Wells et al., 1965b). The term Pertaoorrta Group is used in this Report for the unit referred to as the 'Pertaoorrta Formation' by Wells et al. (1965b) and is equivalent to the Pertaoorrta Group plus the Arumbera Greywacke as used by Prichard & Quinlan (1962).

In the central part of the Amadeus Basin nine Formations have been mapped within the Pertaoorrta Group. Seven of these Formations have been previously defined as Members of the Pertaoorrta Formation by Wells et al. (1965b), and two - the Chandler Limestone and Quandong Conglomerate - are defined in this Report. In the western quadrant of the area the sandstone formations form prominent strike ridges, whereas the siltstone and shale formations occur in the valleys and are mostly covered by alluvium and scree. In the east, the Pertaoorrta Group consists largely of siltstone, shale, and limestone, and generally forms broad valleys with low strike ridges of limestone and dolomite. In the region of Inindia Bore the Pertaoorrta Group is represented by a poorly sorted conglomerate and conglomeratic sandstone facies which forms a mesa near the Angas Downs airstrip. The beds are generally poorly exposed and in some places the only indication of their presence is the lines of boulders at the surface.

A complete section (LAR2) measured on the southern limb of the Parana Hill anticline gave a thickness of about 3000 feet, which is considerably less than the 5300 feet measured at Ellery Creek by Prichard & Quinlan (1962). In the Gardiner Range, in section HYR3 about 4 miles north-west of Areyonga, the measured thickness of the Group is about 3600 feet; on the northern flank of Petermann Creek anticline about 2200 feet; and on the northern and southern flanks of the anticline south of the eastern end of the Seymour Range 1390 feet and 1050 feet respectively. From these measured sections it would appear that the Pertaoorrta Group thins to the south and east. The thinning is accompanied by a change from a sandy facies in the west to a mixture of siltstone, shale, and carbonate in the east. In the south, a relatively thin sequence of about 300 feet of sandstone and conglomeratic sandstone rests unconformably on the Winnall and Inindia Beds and represents a marginal facies.

The individual formations of the Pertaoorrta Group are described later and the following remarks apply only to the outcrops which have not been divided into formations.

Near Doughboy Creek, to the south of George Gill Range, Pertaoorrta sediments are 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, cross-bedded, micaceous, and possibly feldspathic. The siltstone is red-brown and purple-brown, laminate, and micaceous. The presence of travertine at the surface suggests that there are calcareous units in the sequence, but the only exposure of limestone seen was in the core of the structure (LA47), where pink and grey thin-bedded fine-grained non-foetid limestone is interbedded with red-brown laminated siltstone and shale. A similar sequence of the Pertaoorrta Group sediments is exposed 12 miles south of Reedy Rockhole.

Near Angas Downs airstrip a number of outcrops of sandstone and conglomerate lie unconformably on the Winnall Beds and are disconformably overlain by the Stairway Sandstone. The basal unit consists of 2 to 5 feet of poorly sorted silty sandstone with angular chert fragments derived from the Inindia Beds. The basal sandstone is succeeded by red-brown and purple-brown moderately to poorly sorted silty micaceous sandstone with some conglomeratic bands, and some conglomerate. The conglomerate contains moderately rounded to well rounded pebbles, cobbles, and boulders of quartzite, sandstone, vein quartz, and chert. The boulders, which measure up to 3 feet in diameter, have been derived largely from the Winnall Beds. The matrix of the conglomerate is a dark red-brown coarse-grained poorly sorted angular sandstone.

In the Seymour Range, the Pertaoorrta Group can be traced laterally from a sequence of siltstone and sandstone with minor limestone in the west to a sequence of interbedded limestone, siltstone, and shale with very minor sandstone in the east. The interfingering of these sequences can be seen in outcrop. In the Seymour Range the Jay Creek Limestone and the Goyder Formation have been distinguished, but the rest of the sequence has not been differentiated. The siltstone is dark red-brown, purple-brown, and green, laminated, micaceous, and partly sandy. The sandstone is red-brown and fawn, laminated to thin-bedded, cross-bedded, ripple-marked, and largely silty. It contains clay pellets and cavities filled with calcite; pseudomorphs after halite were seen on some bedding planes. The limestone is fawn, cream, and pinkish brown, largely sandy, cross-laminated and partly oolitic and pelletal. It contains some algal colonies. Some of the thin interbeds contain angular to rounded granules and pebbles of chert and pink feldspar.

In the ranges to the south of the Seymour Range the Pertaoorrta Group is very poorly exposed and probably comprises mainly siltstone and shale. The exposures consist of sandstone which is red-brown, purple-brown, and yellow-brown, laminated and thin-bedded, kaolinitic, micaceous, and silty, and some siltstone which is pale purple-brown, laminated, micaceous, and partly sandy.

About 4 miles south-east of Briscoe Tent Hill the Pertaoorrta Group comprises dolomite, siltstone, silty sandstone, and one bed of arkose with pink feldspar grains.

The relationship between the various Formations of the Pertaoorrta Group is shown in Figure 4.

Fossils of early Middle Cambrian to Upper Cambrian age have been collected from the formations of the Pertaoorrta Group in the central part of the Amadeus Basin.

Quandong Conglomerate (new name)

The Quandong Conglomerate is here defined as the sequence of conglomerate, conglomeratic sandstone, and sandstone at the base of the Pertaoorrta Group which either rests unconformably on, or is thrust over, the Areyonga Formation 6 miles north-east of Tempe Downs homestead. The name is derived from Quandong Creek, about 6 miles east of the type locality.

The Quandong Conglomerate has been mapped only in the type area, where it forms a prominent strike ridge, and in the core of James Range 'B' anticline, where it forms a low ridge. No sections have been measured, but the formation is estimated to have a maximum thickness of about 500 feet in the type area, and is known to decrease to about 50 feet over a distance of 2 miles.

Because the Quandong Conglomerate is lenticular, the lithology changes markedly along strike. The sandstone is white, red-brown, or chocolate brown, thin to thick-bedded, cross-bedded, moderately to poorly sorted, with some silt and clay matrix. The conglomerate contains boulders up to 12 inches across, but the majority of the phenoclasts are less than three-quarters of an inch in diameter. The phenoclasts consist largely of chert with lesser amounts of sandstone and quartzite, and many of them have apparently been derived from the underlying Areyonga Formation.

The Quandong Conglomerate is a local conglomerate which rests on the older sediments and lies conformably below the Tempe Formation or Chandler Limestone (Fig. 4). It is considered to be the lateral equivalent of the Eninta Sandstone, which rests unconformably on the Pertatataka and Areyonga Formations in the Gardiner Range.

The Quandong Conglomerate is probably Lower Cambrian, because it lies conformably beneath sediments of lower Middle Cambrian age.

Eninta Sandstone (Wells et al., 1965b, emend.)

The Eninta Sandstone crops out only in the Gardiner Range anticline, where it forms a prominent strike ridge.

At the type locality on the Mount Liebig Sheet area the Eninta Sandstone has a thickness of about 1200 feet, but 15 miles away at HyR3 on the Henbury Sheet area the unit is only 310 feet thick.

The Eninta Sandstone comprises sandstone with minor beds of siltstone and conglomerate. The sandstone is red-brown or purple-brown, thin-bedded, cross-bedded, fine to medium-grained, moderately to poorly sorted, micaceous, feldspathic, and largely silicified. It contains some clay pellets and the cross-bed sets are characteristically slump-folded. The siltstone is red-brown, laminated, and micaceous. The conglomeratic bands occur at two main horizons: in some areas there are a few conglomerate beds up to 1 foot thick at the base of the unit, and in most places there are some conglomeratic sandstone beds about two-thirds of the way up the sequence. The phenoclasts consist predominantly of chert with minor amounts of limestone and dolomite. They range from angular to subrounded, and are up to 3 inches in diameter. In the upper part of the Eninta Sandstone the phenoclasts are accompanied by very large clay pellets.

The Eninta Sandstone lies unconformably on the Pertatataka and Areyonga Formations and is overlain by the Chandler Limestone. It is considered to be the lateral equivalent of the Quandong Conglomerate (Fig. 4) and is probably also equivalent to the Arumbera Greywacke.

Fossils have not been found in the Eninta Sandstone, but its stratigraphical position indicates that it is probably Lower Cambrian.

11-4

Chandler Limestone (new name)

The Chandler Limestone is here defined as the sequence of limestone, dolomite, and interlaminated chert which lies between the Tempe Formation above and the Quandong Conglomerate below, 6 miles north-east of Tempe Downs homestead. The name is taken from the Chandler Range, where the unit is exposed beneath the Jay Creek Limestone.

Outcrops of the Chandler Limestone extend from the type area to the eastern margin of the Henbury Sheet and from Orange Creek homestead in the north to Palmer Valley homestead in the south. Lenses of Chandler Limestone also occur in the lower part of the Tempe Formation in the Parana Hill and Petermann Creek anticlines. The formation generally crops out as low isolated ridges of contorted limestone, but in places it forms strike ridges. In other localities only lines of chert rubble at the surface indicate its presence. It is difficult to estimate the thickness of the Chandler Limestone as the contacts with the overlying and underlying units are not exposed and the beds are contorted, but it may range from about 10 to 300 feet.

The Chandler Limestone comprises pale grey to dark grey sandy limestone, dolomite, and calcareous sandstone with numerous laminae of black and white chert. It is readily distinguished from other limestones in the Pertaoorrta Group by the presence of chert laminae, the strong foetid odour, and the strong contortion of the beds. The incompetent folding is possibly due to the presence of interbedded evaporites: although evaporites do not crop out they have been recorded from the lower part of the Pertaoorrta Group in the Alice No. 1 well near Alice Springs.

In the type area the Chandler Limestone lies between the Quandong Conglomerate and the Tempe Formation, but in the Chandler Range and near Orange Creek homestead it lies between the Pertatataka Formation and the Jay Creek Limestone. South of Henbury homestead the Chandler Limestone rests on the Winnall Beds and is overlain by the Jay Creek Limestone.

The Chandler Limestone is considered to be Lower Cambrian, or possibly lower Middle Cambrian. No fossils have been found.

Tempe Formation (Wells et al., 1965b, emend.)

The Tempe Formation has been mapped in the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill anticlines and in a small anticline 12 miles south of Reedy Waterhole. The unit has not been recognized east of longitude 132°30'E. or south of latitude 24°30'S. The Tempe Formation is not a resistant unit and normally occurs in strike valleys, although the more resistant sandstone and carbonate beds tend to form low ridges.

The measured thickness in section HyR3 in the Gardiner Range, about 4 miles west of Areyonga, is 760 feet, and in section HyR2 on the northern limb of the Peterman Creek anticline the thickness is 445 feet.

The Tempe Formation consists mainly of siltstone and shale with variable amounts of sandstone, limestone, and dolomite. The siltstone and shale are red-brown, purple-brown, or grey-green , and laminated. The sandstone ranges from white to dark purple-brown. It is thin-bedded, cross-bedded, slump-folded, fine to medium-grained, moderately friable, micaceous, and glauconitic. Some beds contain clay pellets, some are calcareous, and others are rich in feldspar. The light-coloured glauconitic beds frequently contain phosphatic brachiopods. The limestone is yellow-brown, grey, and grey-green.

It is usually partly glauconitic and contains trilobites, gastropods, and phosphatic brachiopods. In the type locality, the dark grey to light grey dolomite and limestone with laminae and 'biscuits' of chert which occur towards the base of the formation are essentially a development of the Chandler Limestone. In the Parana Hill anticline this foetid carbonate sequence rests directly on the Bitter Springs and Areyonga Formations.

The Tempe Formation lies conformably beneath the Illara Sandstone. It rests conformably on the Eninta Sandstone in the Gardiner Range, and is apparently conformable on the Chandler Limestone 6 miles north-east of Tempe Downs homestead. It is unconformable with the Bitter Springs and Areyonga Formations in the western culmination of the Petermann Creek anticline, and in the Parana Hill anticline (see Figs 5 and 6). The relationships with other formations of the Pertaoorrta Group are as shown in Figure 4.

The Tempe Formation contains fossils of lower Middle Cambrian age and can probably be correlated with the lower part of the Jay Creek Limestone.

Jay Creek Limestone (Prichard & Quinlan, 1962)

The Jay Creek Limestone crops out in the middle of the Waterhouse Range anticline, the James Range 'A' and James Range 'B' anticlines, and the eastern half of the Seymour Range anticline. It also occurs to the west of Orange Creek homestead, in the Chandler Range, between the Henbury and Palmer Valley homesteads from near the main road to the eastern margin of the area. The beds are generally poorly exposed, and the unit usually forms a series of low strike ridges separated by concealed intervals. The section between the limestone ridges is composed of calcareous siltstone, fine-grained sandstone, and shale.

Incomplete sections in the middle of the Waterhouse Range (section HyR6) and about 4 miles east of The Sisters (section HyR7) have thicknesses of about 480 feet and 900 feet respectively. The Jay Creek Limestone apparently thickens to the east from where it first appears half way across the Henbury Sheet area.

The Jay Creek Limestone sequence probably consists of about 30 to 40 percent limestone, 10 percent sandstone, and from 50 to 60 percent of siltstone and shale in the concealed intervals. The siltstone and shale are pale grey, purple-brown, and grey-green, laminated, micaceous, and largely calcareous. The limestone is pale grey, fawn, cream, and grey, thin-bedded and laminated, cross-laminated, partly oolitic, partly sandy, and partly algal (see Pl. 2, fig. 2, and Pl. 3, fig.1). The sandstone is white, cream, and pale grey, thin-bedded, friable, partly micaceous, and commonly calcareous.

The Jay Creek Limestone lies conformably beneath the Goyder Formation, but in some localities the Goyder Formation is very thin (e.g. near The Sisters) or not present at all (e.g. in parts of the Seymour Range). The Jay Creek Limestone is overlain disconformably by the Stairway Sandstone or Horn Valley Siltstone. In most areas the Jay Creek Limestone rests on the Chandler Limestone, but in the most southerly exposures it may be underlain by undifferentiated siltstone and shale of the Pertaoorrta Group. Tentative correlations with other formations of the Pertaoorrta Group are shown in Figure 4.

The Jay Creek Limestone contains lower Middle Cambrian trilobites and Girvanella, and Upper Cambrian trilobites (Tomlinson, 1965). It ranges from Middle to Upper Cambrian and was probably deposited in a very shallow marine environment.

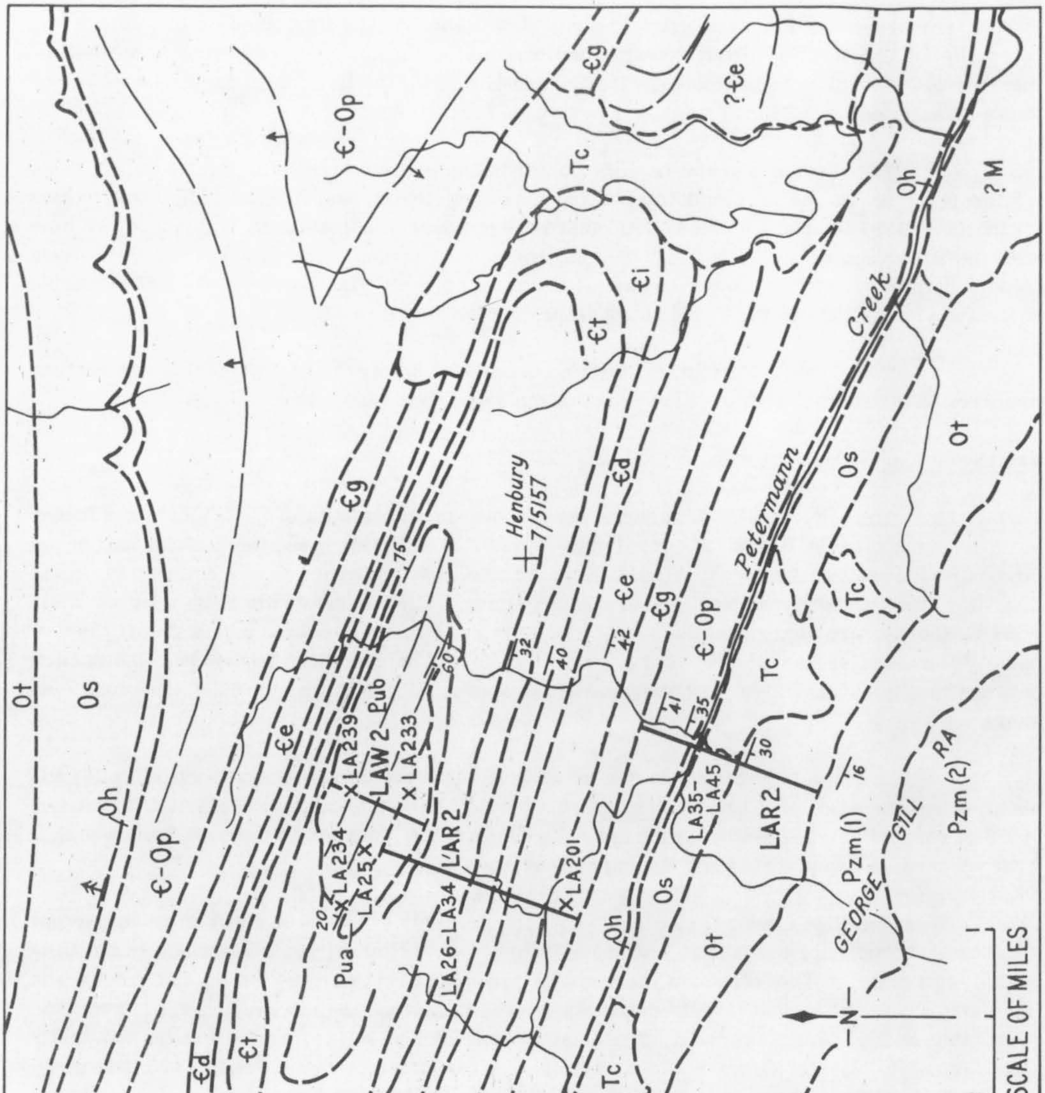


Fig. 5. Unconformity beneath Tempe Formation in core of Parana Hill anticline.

Pub-Bitter Springs Formation; Pua-Areyonga Formation; Ct - Tempe Form-Formation; Ci - Illara Sandstone; Cd - Deception Formation; Ce - Petermann Sandstone; Cg - Goyder Formation; C-Op - Pacoota Sandstone; Oh - Horn Valley Siltstone; Os - Stairway Sandstone; Ot - Stokes Formation; Pzm(1), Pzm(2) - Mereenie Sandstone; ?M - possible Mesozoic; Tc - Tertiary Conglomerate.

Fig. 6. Air photograph of Parana Hill Anticline. See Fig. 5.

Illara Sandstone (Wells et al., 1965b, emend.)

The Illara Sandstone forms prominent strike ridges in the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill anticlines.

Sections were measured in the Gardiner Range (section HyR3), where it is about 240 feet thick; in the northern limb of the Petermann Creek anticline (section HyR2), where it is 178 feet thick; and in the Parana Hill anticline, where it is 300 to 400 feet thick. The formayion thins to the east and is not present in the eastern half of the central part of the Amadeus Basin.

The Illara Sandstone comprises sandstone with some siltstone. The sandstone is pale red-brown, purple-brown, and white, laminated and thin-bedded, cross-bedded, fine to medium-grained, moderately sorted, partly silicified, and partly friable. It is slump-folded in places, and commonly micaceous and kaolinitic. Some beds are rich in clay pellets, and others have a calcareous matrix. The siltstone is red-brown and purple-brown, laminated, micaceous, and partly sandy.

The Illara Sandstone lies conformably between the Deception and Tempe Formations. It interfingers with the siltstone formations above and below and is probably the lateral equivalent of parts of the Jay Creek Limestone and Hugh River Shale in the western MacDonnell Ranges.

Fossils have not been found in the Illara Sandstone, but its stratigraphical position indicates that it is Middle Cambrian.

Deception Formation (Wells et al., 1965b, emend.)

The Deception Formation crops out in the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill anticlines. The unit is easily eroded and is generally concealed beneath alluvium in strike valleys; in some areas the more resistant sandstone beds form low strike ridges.

The thickness of the Formation is about 560 feet in the Gardiner Range (section HyR3); 430 feet on the northern limb of the Petermann Creek anticline (section HyR2); 460 feet on the southern flank of Parana Hill anticline (LAR2); and about 320 feet on the northern flank (LAR1). These thicknesses suggest that the Formation thins to the south and east from the type locality in the Gardiner Range, where it is 650 feet thick.

The Deception Formation consists mainly of siltstone and shale with minor amounts of sandstone and limestone. The siltstone and shale are red-brown, purple-brown, pale red-brown, and grey-green, laminated, micaceous, and partly calcareous or sandy. The sandstone is red-brown and purple-brown, thin-bedded, cross-bedded, fine-grained, slump-folded, micaceous, and calcareous. Some thin beds contain many clay pellets. The limestone, which occurs in scattered beds, is fawn and cream, fine-grained, and sandy.

The Formation lies conformably between the Petermann Sandstone and the Illara Sandstone. It is considered to be the lateral equivalent of part of the Jay Creek Limestone on the eastern side of the Henbury Sheet area, and of parts of the Hugh River Shale and Jay Creek Limestone in the western MacDonnell Ranges.

Fossils have not been found in the Deception Formation, but its stratigraphical position indicates that it is Middle Cambrian.

Petermann Sandstone (Wells et al., 1965b, emend.)

The Petermann Sandstone crops out in the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill anticlines. The formation thins to the east and has not been recognized east of Areyonga Aboriginal Settlement. In most places the Petermann Sandstone forms a prominent strike ridge with a steep slope at the base.

In the Gardiner Range (section HyR3) the Petermann Sandstone is 640 feet thick, and in section HyR2, on the northern limb of the Petermann Creek anticline, it is 330 feet thick; on the northern limb of the Parana Hill anticline (LAR1) it is 500 feet thick and on the southern limb (LAR2) 640 feet thick.

The Petermann Sandstone comprises sandstone with minor siltstone and sandy limestone. The sandstone is pale red-brown, cream and white, banded, fine to medium-grained, thin-bedded, cross-bedded, slump-folded, micaceous, and partly calcareous or silty. It contains some clay pellets and some silicified beds. The siltstone is red-brown, purple-brown, laminated, and micaceous. The sandy limestone, which occurs as scattered lenses only a few inches thick, is cream or pale red-brown, fine-grained, and thin-bedded.

The Petermann Sandstone lies conformably between the Deception and Goyder Formations, and both contacts are apparently gradational. The formation thins to the east, and in the Gardiner Range anticline it gradually thins until the Goyder Formation rests conformably on the Deception Formation.

Goyder Formation (Prichard & Quinlan, 1962)

The Goyder Formation crops out sporadically over the northern parts of the Henbury and Lake Amadeus Sheets. It forms low strike ridges or is concealed by alluvium and scree.

It is 850 feet thick on the northern flank of Parana Hill anticline (section LAR1) and 620 feet thick on the southern flank (section LAR2); 290 feet thick 5 miles south-south-east of Mount Tucker; 1070 feet thick in the Gardiner Range (section HyR3); 1180 feet on the northern limb of the Petermann Creek anticline (section HyR6); and 115 feet thick 4 miles east-north-east of The Sisters (section HyR7).

The Goyder Formation consists of siltstone, shale, sandstone, limestone, and dolomite. The siltstone and shale are yellow, green, fawn, red-brown, and white, micaceous, and laminated. The sandstone is yellow-brown to pale red-brown, fine to medium-grained, moderately sorted, laminated to thin-bedded, micaceous, and partly calcareous or silty. Some bedding planes show tracks and trails and others numerous pseudomorphs after halite. The limestone and dolomite are yellow-brown, grey, pink, and fawn, thin-bedded, partly sandy, and partly oolitic. Some of the sandy dolomite near the base of the unit is cross-laminated. In the Ochre Hill and Parana Hill anticlines, algal stromatolites are common in the upper part of the formation. In the Waterhouse Range the carbonate beds are included in the underlying Jay Creek Limestone. Near The Sisters the Goyder Formation consists of fawn and yellow-brown thin bedded micaceous calcareous sandstone and red-brown and grey-green laminated micaceous siltstone and shale.

In the upper part of the Goyder Formation, beds of grey-black manganese-rich rock may form prominent strike ridges. Samples of the surface material (LA60a) and the material about a foot below ground level (LA60b) from near Laurie Creek were analysed for iron, manganese, and silicon:

Sample No.	Fe (percent)	Mn (percent)	Si (percent)
LA60a	0.37	56.2	0.45
LA60b	21.4	0.43	18.2

The manganiferous rock is a superficial deposit which forms a thin encrustation on the yellow-brown silty sandstone. Since it is present in several places at about the same horizon the encrustation may have been derived from disseminated manganese in a particular sedimentary bed.

In the northern part of the area the Goyder Formation lies conformably beneath the Pacoota Sandstone, and conformably above each of the laterally equivalent Petermann Sandstone, Deception Formation, Jay Creek Limestone, and Cleland Sandstone. The basal contacts are gradational. To the south, the Goyder Formation is successively overlain by the Pacoota Sandstone, the Horn Valley Siltstone, and the Stairway Sandstone with no apparent unconformity. The formation has not been mapped in some of the southernmost areas because it is either too thin or too poorly exposed.

Fossils have been collected at a number of localities from the Goyder Formation (Tomlinson, 1965) and the age of the beds is probably Upper Cambrian.

CAMBRIAN-ORDOVICIAN

Larapinta Group
(Prichard & Quinlan, 1962, p.18)

Pacoota Sandstone (Prichard & Quinlan, 1962, p.19)

The Pacoota Sandstone crops out sporadically over the northern half of the area, but rapidly wedges out to the south and is completely absent south of the Sisters and Mount Ormerod. Measured thicknesses range from 2050 feet in section HyCl on the southern flank of the James Range 'A' anticline to 65 feet in section HyR7, 4 miles east of The Sisters; and to the south-south-west of the Liddle Hills the thickness is only 5 feet. A similar thinning occurs to the west, with a measured thickness of 1060 feet in section LAR2 on the southern flank of Parana Hill anticline, 265 feet in section LAC12, and only 60 feet in section LAR3 on the western margin of the area. The formation is locally absent in the vicinity of Illamurta Yard.

The Pacoota Sandstone is fine to coarse-grained and generally well rounded and sorted, but near The Sisters there is a high proportion of probably kaolinitic matrix, and in the Levi Range pebbles of chert and silicified sandstone, up to an inch in diameter, are common. At two localities, one near Illamurta Yard and the other on the west bank of the Finke River, where it cuts through the James Range 'A' anticline, there is a coarse basal breccia or conglomerate.

Prichard & Quinlan (1962) also describe a similar breccia at the base of the formation at Glen Helen Gorge. The similarity in stratigraphical position of the breccia over a wide area indicates that it is not a structural feature and that it was probably formed by slumping, as suggested by Prichard & Quinlan (op. cit., p.30).

Pebble bands are fairly common in the lower half of the Pacoota Sandstone. The bedding ranges from thin to massive and features such as cross-bedding and ripple marks are common. The formation weathers grey, white, or brown. The rock is partly silicified, but in places it is extremely friable.

A few pelletal phosphatic sandstones occur in the Pacoota Sandstone. They are similar in lithology to the phosphorites in the Stairway Sandstone although the pellets, which range up to 3 inches in diameter, tend to be coarser. These pellet bands are probably of very limited lateral extent and form a minor proportion of the Pacoota Sandstone sequence.

Glauconitic sandstone is fairly common in the Pacoota Sandstone and occurs mainly in the upper half of the formation. Thin sections reveal that the glauconite may be granular or intergranular. The granular type occurs as fine well-rounded discrete grains and may constitute up to 50 percent of the rock (e.g. sample Hy136(A)). The intergranular glauconite is interstitial to the quartz grains (which may show some secondary enlargement) and forms only about 15 percent of the rock (e.g. sample HY142).

In section LAC8 a prominent band of porous rock crops out 64 feet below the top of the Pacoota Sandstone. The bed is 4 feet thick and is composed of medium-grained brown silicified sandstone with a 'honeycomb' texture. In thin section (Pl. 3, fig. 2) the rock (No. R12424) is seen to consist of moderately rounded quartz sandstone showing secondary enlargement of the quartz grains. The cavities are partly filled with opaque iron oxide (magnetite(?)), with a rim of cryptocrystalline apatite(?). Scattered grains of angular quartz occur within the apatite and iron oxide. It is thought that the cavities may represent weathered-out phosphorite nodules or pellets.

The contacts between the Pacoota Sandstone and the underlying and overlying units are poorly exposed, but in the Household Range area and in the vicinity of The Sisters the contact with the Goyder Formation is conformable and gradational. In the Ochre Hill anticline the boundary is particularly difficult to define, but the sandstone of the Goyder Formation is less well sorted and has a more silty matrix than the Pacoota Sandstone. The contact between the Pacoota Sandstone and the overlying Horn Valley Siltstone is not exposed in the 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. In the western half of the Lake Amadeus Sheet area the Horn Valley Siltstone and Pacoota Sandstone are absent south of latitude 24°30'S. In the Henbury Sheet area and the eastern half of the Lake Amadeus Sheet area the same units are absent south of latitude 24°40'S. Where these units are missing the Stairway Sandstone rests directly on Cambrian or Upper Proterozoic rocks. The Pacoota Sandstone is locally absent in the vicinity of Illamurta Yard, and where present is apparently unconformably overlain by the Mereenie Sandstone.

The Pacoota Sandstone is generally poorly fossiliferous, except for Scolithus, which is very common. Other fossils found include 'Cruziana' (see Pl.4, fig. 1), pelecypods, brachiopods, trilobites, and various indeterminate tracks and trails. The fossils indicate that the Pacoota Sandstone ranges from Upper Cambrian to Lower Ordovician (Tomlinson, 1965).

Horn Valley Siltstone (Prichard & Quinlan, 1962, p.20; Wells et al., 1965b)

The Horn Valley Siltstone is a recessively weathering unit which characteristically forms strike valleys and is generally very poorly exposed. The greatest measured thickness is 350 feet in section HyR4 near Areyonga. In section LAC7 in the Ochre Hill anticline the formation is 285 feet thick. The thickness of the formation is 240 feet in section HyCl in the James Range and 235 feet and about 200 feet in sections LAR2 and LAR1 in the Parana Hill anticline. The formation thins to the west - in section LAC12 the formation is 160 feet thick, and on the western margin of the area, in section LAR3, only 80 feet thick - and also to the south: in sections LAC8, south of the George Gill Range, the formation is 145 feet thick and in section HYR7, near The Sisters, the thickness is about 80 feet. Apart from one small outcrop west of the Liddle Hills, the Horn Valley Siltstone does not crop out south of latitude $24^{o}40'$S.

The Horn Valley Siltstone consists mainly of grey-green and greenish brown siltstone which is laminated to thin-bedded, calcareous and pyritic in part, and soft and easily weathered. Thin-bedded grey brittle pyritic limestone and sandy limestone is commonly interbedded with the siltstone and forms fairly prominent bands because of its greater resistance to weathering. The formation contains minor interbeds of sandstone, silty sandstone, and calcareous sandstone, and some pelletal phosphate bands. A prominent oolitic limonite band crops out just below the top of the formation at several localities in the Levi Range and in the vicinity of the Liddle Hills. The oolite is red-brown, thinly bedded, and friable, and weathers black. Because of the poor exposures, the total thickness of the oolitic ironstone is uncertain and there may be several thin oolites interbedded with yellow and brown sandy siltstone. In thin section, the ironstone consists of slightly flattened and elongate ooliths, up to 1 mm in diameter, some of which are aligned with their long axes parallel to the bedding. The ooliths show a faint concentric banding, and the matrix consists of fine angular poorly sorted quartz grains. The same oolitic band has been intersected in diamond drill-holes API, AP2, and AP3, and a study of the cores confirmed that the limonite has been formed by the weathering of pyrite.

Rare beds of glauconitic sandstone and limestone have also been found in the Horn Valley Siltstone. In thin section the glauconitic limestone from the James Range (Hy137) is seen to contain discrete well rounded grains of glauconite and also an intergranular type. In thin section, the calcareous sandstone (Hy121a) from 10 to 20 feet below the top of the Horn Valley Siltstone, 4 miles west of Mount Holder, consists of about 80 percent quartz, which is moderately to well sorted and poorly rounded, and up to 20 percent intergranular calcite. Some of the calcite is coarsely crystalline, and the crenulated and jagged boundaries between the quartz and calcite probably indicate that both the quartz and calcite have been recrystallized. The accessory minerals include rare grains of sphene(?) and zircon(?), and laths of cryptocrystalline apatite which probably represent fossil fragments.

In the northern halves of the Lake Amadeus and Henbury Sheet areas, the Horn Valley Siltstone lies apparently conformably between the underlying Pacoota Sandstone and the overlying Stairway Sandstone, but in places in the south (e.g. Seymour Range) the formation lies disconformably on the Pertaoorrta Group, In the Waterhouse Range the Horn Valley Siltstone is directly overlain by the Mereenie Sandstone and a similar unconformable relationship may hold in the vicinity of Illamurta Yard.

The Horn Valley Siltstone contains a rich and well preserved Lower Ordovician fauna which includes trilobites, brachiopods, pelecypods, graptolites, nautiloids, ostracods, conodonts, and gastropods (Tomlinson, 1965).

Stairway Sandstone (Prichard & Quinlan, 1962, p.21; Wells et al., 1965b)

The Stairway Sandstone crops out throughout much of the central part of the Amadeus Basin, but is especially well exposed in the northern half. To the south, the Stairway Sandstone crops out as low discontinuous strike ridges.

The greatest thickness is 880 feet in section HyC1 on the southern flank of the James Range 'A' anticline. Other thicknesses measured include 825 in section HyR4 near Areyonga; 760 feet in diamond drill-hole AP3 near Running Waters; 650 feet in section LAC10, south of Parana Hill; 620 feet and 590 feet in sections LAR2 and LAR1 in the Parana Hill anticline; about 600 feet in diamond drill-hole AP1 in Johnny Creek anticline; 515 feet at the western end of Johnny Creek anticline; 520 feet in diamond drill-hole AP2 in the Mount Levi Range; 440 feet in section HyC2 in the Seymour Range; 420 feet in section HyS2 in the eastern end of the Seymour Range; 225 feet at the western end and 485 feet in section HyS1 in the middle of the range; over 315 feet in section HyR7 near The Sisters; over 100 feet in section LAC12 near Kulpi Rock-hole; 205 feet in section LAW1 on the western margin of the area; and 170 feet in diamond drill-hole AP4 near Inindia Bore. Thus, the Stairway Sandstone thins to both the west and the south, but the limit of deposition lay much farther to the south during Stairway Sandstone times than it did during the deposition of the older Larapinta Group formations.

The Stairway Sandstone can be subdivided into three main units: an upper and lower unit composed predominantly of sandstone and a middle unit consisting largely of siltstone and mudstone with only minor sandstone. These three divisions are well defined/ throughout most of the area, but less well in the marginal areas.

In the south, the lower sand is coarse to very coarse-grained, conglomeratic in places, and poorly rounded and sorted, whereas the upper sand is fine-grained and fairly well sorted. The conglomeratic lenses contain pebbles of vein quartz and quartzite up to 2 inches in diameter. The upper unit is poorly exposed in the south. It is yellow or grey in colour, and may contain abundant phosphatic material (e.g. in a small syncline 9 miles north-east of Angas Downs), and may be richly fossiliferous (e.g. in the vicinity of Briscoe Tent Hill, where pipe-rock is abundant and large gastropods are extremely common).

In the normal succession the lower sand is characterized by the presence of many tracks and trails which give the rock a 'ropy texture', and also by the presence of ooliths of limonite after pyrite. The lower sand is white or grey, thinly to massively bedded, rarely cross-laminated, and commonly silicified. It is strongly resistant to weathering and forms prominent scarps. The middle lutaceous unit consists of black, grey, and green siltstone and shaly mudstone, with subordinate grey and brown fine-grained fairly well rounded and sorted thin-bedded rarely cross-laminated sandstone. Both the lutites and the arenites of the middle unit contain a great variety of indeterminate tracks, trails, and surface markings. Pelletal phosphorites are fairly common in the middle unit of the Stairway Sandstone. Occasional bands of sandy limestone and dolomite are present; they are generally yellow, grey or brown, thin-bedded, and recrystallized in places. A few phosphatic pellets occur in the calcareous bands. The upper unit consists of fine-grained sandstone which forms prominent scarps. It is well rounded and sorted, grey or white, silty in places, thin to thick-bedded, cross-laminated in places, friable, and silicified. A few pelletal bands occur in the upper unit, and silty interbeds are much more common than in the lower sandy unit.

A thin calcareous member occurs at the base of the Stairway Sandstone in the Seymour Range and the range to the south, and near The Sisters. On the northern flank of the

Seymour Range the lowest unit consists of about 50 feet of interbedded grey and green calcareous siltstone, with grey, white, and variegated thin-bedded limestone which appears to have a characteristic faunal assemblage of phosphatic brachiopods, gastropods, and nautiloids. This sequence has been included in the Stairway Sandstone, although it is not typical. On lithological grounds it is thought to be equivalent to the middle Stairway Sandstone unit of the northern areas.

The Stairway Sandstone rests conformably on the Horn Valley Siltstone and it would appear, from poorly exposed field relationships and diamond drill-hole AP1, that the boundary between the two formations is abrupt. In the south, a major break occurs at the base of the Stairway Sandstone, which rests disconformably on conglomerate of the Pertaoorrta Group in the Liddle Hills, and unconformably on the Inindia Beds near Ten Mile Bore, north-west of Angas Downs homestead. The Stairway Sandstone is conformably overlain by the Stokes Formation in most areas, and in the Parana Hill anticline and on the southern flank of the James Range 'A' anticline the boundary appears to be gradational. However, in the vicinity of Illamurta Yard and at the western end of the Seymour Range the Stairway Sandstone is overlain by the Mereenie Sandstone.

The Stairway Sandstone is richly fossiliferous. The fossils include trilobites, brachiopods, gastropods, pelecypods, nautiloids, Cruziana (Pl.4, fig. 2), Diplocraterion, and other tracks and trails. These indicate that the formation is Middle Ordovician (Tomlinson, 1965).

Stokes Formation (Prichard & Quinlan, 1962, p.21)

The Stokes Formation is widely distributed in the central part of the Amadeus Basin, but it weathers recessively and is generally poorly exposed. The formation is moderately well exposed in Johnny Creek anticline, Parana Hill anticline, James Range 'A' and 'B' anticlines, and near Briscoe Tent Hill.

Thicknesses measured through the Stokes Formation include 1110 feet and 1090 feet in sections LAC2 and LAC1 on the southern and northern flanks of the Parana Hill anticline; 1000 feet in section HyR1 near Mount Shady; 950 feet in section LAC4 at East Johnny Creek anticline; 920 feet in section HyC1 on the southern flank of James Range 'A' anticline; 850 feet in section LAC2 at the extreme western end of Johnny Creek anticline; 630 feet in section HyC2 on the northern flank of the Seymour Range; 465 feet in section LAW1 on the western boundary of the area; 420 feet in section HyS2 at the eastern end of the range to the south of the Seymour Range; and 320 feet in section HyS1 in the middle of the same range. The formation has an estimated thickness of about 1500 feet near Areyonga.

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 in places brittle and calcareous. It is poorly exposed and weathers red-brown or yellow. Pseudomorphs after halite are fairly common. In the lower half of the formation, limestone and sandstone are commonly interbedded with the siltstone. The limestone is grey or pink, sandy in places, partly recrystallized, and thin-bedded, and commonly contains calcite geodes. It weathers yellow and is moderately resistant. The limestone is commonly crinoidal or coquinitic. Fragments of echinoderm plates are a major constituent of the coquinites. The poorly exposed sandstone, which forms only a small proportion of the formation, is yellow or brown, moderately sorted and rounded, and thin-bedded, and in places has a silty or calcareous matrix. In the Johnny Creek anticline, a single pelletal phosphatic band crops out near the base of the formation.

The Stairway Sandstone grades into the Stokes Formation; the base of the Stokes Formation is placed at the top of the last prominent sandstone bed in the Stairway Sandstone. The Stokes Formation also grades into the Mereenie Sandstone over much of the area and the boundary is arbitrarily placed at the base of the first prominent sandstone bed, which forms a band, 4 to 6 feet high, on the scree-covered slope.

In the Waterhouse Range the Stokes Formation is missing and the Mereenie Sandstone rests unconformably on the Horn Valley Siltstone and Pacoota Sandstone. The Stokes Formation is also locally absent in the Illamurta Spring area, at the western end of the Seymour Range, and in the James Ranges about 12 miles east-south-east of Areyonga Aboriginal Settlement.

Many fragmentary fossils were collected from the Stokes Formation, including brachiopods, gastropods, pelecypods, trilobites, echinoderms, and nautiloids, of late Middle or early Upper Ordovician age (Tomlinson, 1965).

ORDOVICIAN-DEVONIAN

Mereenie Sandstone (Madigan, 1932; Prichard & Quinlan, 1962)

The Mereenie Sandstone crops out as prominent strike ridges and bold escarpments, especially in the north, where it forms such featurs as the George Gill Range, Mount Levi, Mount Shady, and Illara Rock.

Sections measured through the Mereenie Sandstone give thicknesses of 2470 feet in section HyR4 in the Gardiner Range; 2230 feet in section LAC11 6 miles north-east of Carmichaels Crag; 1970 feet in section LAW1 15 miles east-south-east of Mount Murray; 1760 feet in section HyR1 near Mount Shady; 1500 feet in section HyR8 in the Waterhouse Range; 460 feet in section HyC2 in the Seymour; and 700 feet in section HyS1 in the range to the south of the Seymour Range. These thicknesses indicate a general thinning of the formation to the south.

The Mereenie Sandstone can be divided into two units; the basal unit is lithologically consistent and has been recognized in all the major outcrops, except the Waterhouse Range, the eastern end of the James Ranges, the Seymour Range, and the southern limb of the anticline to the south of the Seymour Range. The upper unit is always present but is more variable in lithology. The two units are lithologically and physiographically distinct, and the contact is invariably sharp and usually occurs in a small strike valley or gully.

The basal unit consists predominantly of red-brown and pale purple-brown sandstone which is fine and medium-grained, thin and medium-bedded, cross-bedded, and kaolinitic. The basal unit weathers massively and forms the main part of the typical Mereenie Sandstone escarpment. The basal unit is never more than 300 feet thick. It contains Cruzianas and worm tubes in the Gardiner Range, James Ranges, and near Mount Shady. Cruzianas have also been found in the Inindia Bore area, and Hopkins (pers. comm.) reports arthropod tracks in the basal Mereenie Sandstone of Johnny Creek anticline. Small worm tubes occur in the lower unit of the Mereenie Sandstone in the northern limb of the anticline south of the Seymour Range.

In the north, the upper unit of the Mereenie Sandstone has a uniform lithology. It consists of white fine to medium-grained well sorted well rounded thin-bedded ripple-marked and cross-bedded sandstone. The weathered silicified surface is a pale orange-brown, and beneath the thin surface crust the sandstone is extremely friable. This unit accounts for the major part of the Mereenie Sandstone. It contains some beds which are riddled with vertical and irregular worm burrows, and also various problematical markings (Pl.5, fig. 1).

In the south, the upper part of the Mereenie Sandstone consists of red-brown, orange-brown, and white fine to coarse-grained thin to medium-bedded cross-bedded moderately to poorly sorted friable porous sandstone. It is partly kaolinitic and some beds are strongly ferruginized. This unit is quite variable and generally a dirtier sediment than its equivalent to the north.

At locality Hy231, about 3 miles west-south-west of Tempe Downs homestead, the upper part of the Mereenie Sandstone contains a number of vertical cylindrical structures ranging from 5 to 15 inches in diameter and up to 5 feet long (Pl.5, fig.2). The large structures appear to taper slightly, some towards the top and others towards the bottom. The structures occur in sandstone, and in section they show concentric rings of well-sorted sand. The extremities of the rod-like structures are not exposed. These structures have not been seen elsewhere in the Amadeus Basin and although their origin is uncertain they are probably inorganic, and possibly represent the feed pipes to sand volcanoes.

Over most of the area, the Mereenie Sandstone is conformable over and gradational from the Stokes Formation. The transitional zone is especially well exposed on the southern flank of Johnny Creek anticline. In some areas, however, the Mereenie Sandstone is unconformable on the Larapinta Group and the basal part of the Mereenie Sandstone is absent. On the northern flank of the Waterhouse Range anticline, the upper part of the Mereenie Sandstone rests unconformably on the Pacoota Sandstone, whereas on the southern flank it rests on the Horn Valley Siltstone. In the Gardiner Range, east of Areyonga, in the James Ranges near Illamurta Spring, and at the western end of the Seymour Range, the Mereenie Sandstone rests with apparent unconformity on older units. At each of these localities there is evidence of structural disturbance, and it is possible that the surface interpreted as an unconformity is in fact a fault plane. The three localities lie approximately along a straight line, which if extended to the north would pass through Gosses Bluff and Goyder Pass. It is possible that there was structural growth along this linear belt prior to and during Mereenie sedimentation.

In the Gardiner Range area, the Mereenie Sandstone is apparently conformably overlain by siltstone and shale of the Pertnjara Formation, but in the north-eastern part of the area the sandstone of the Pertnjara Formation lies unconformably or disconformably on the Mereenie Sandstone. In the Seymour Range and in the anticlines to the south of the Seymour Range the Mereenie Sandstone is overlain by the siltstone unit of the Pertnjara Formation, but the contact is most probably unconformable.

The age of the Mereenie Sandstone is uncertain. The basal part is most likely to be Ordovician on the evidence of Cruziana, and the overlying siltstone of the Pertnjara Formation is of Upper Devonian age. The formation is partly of marine origin, but probably includes some transitional and continental sediments.

DEVONIAN-CARBONIFEROUS

Pertnjara Formation (Chewings, 1931; Prichard & Quinlan, 1962)

The Pertnjara Formation crops out over a large portion of the northern half of the area, where it forms prominent scarps and ranges which rise up to 1000 feet above the surrounding plain. The scarps are well developed in the James, Middle, and Waterhouse Ranges. The Pertnjara Formation also occurs on the flanks of the Seymour Range and the range to the south. It is estimated from the air-photographs that the Pertnjara Formation has a thickness of about 4300 feet in the north and at least 1000 feet in the south. The formation is divided into two lithological units - a lower siltstone unit (Pzp(a)) and an upper sandstone unit (Pzp(s)).

The lower unit is generally poorly exposed in broad alluvium-covered valleys, though it is well exposed on Dare Plain, where the thickness is estimated from air-photographs to be about 2800 feet. The thickness is also estimated at about 1500 feet in the Gardiner Range, and 750 feet 10 miles south of Mount Shady. A thickness of 660 feet was measured for the lower unit in section HyC2 in the Seymour Range. At the extreme western end of the James Range 'A' structure the silt unit wedges out, and it is absent over most of the north-eastern part of the area. Local thinning can be seen in the area near Illamurta Spring and near the south-western extremity of the Seymour Range. The lower unit consists primarily of red-brown and purple-brown micaceous laminated to thin-bedded siltstone, with some thin calcareous siltstone, grey limestone, and silty sandstone. Pseudomorphs after halite were seen in the siltstone.

The contact of the Pertnjara siltstone with the underlying Mereenie Sandstone is obscured by alluvium. In many places the contact is believed to be conformable, but in the range south of the Seymour Range there appears to be a marked angular unconformity between the Mereenie Sandstone and the Pertnjara siltstone.

The upper unit consists of well-exposed sandstone which forms prominent scarps and ranges and wide deeply dissected plateaux with a dendritic drainage. The thickness of the upper unit, as estimated from the air-photographs, is at least 1500 feet in the Mount Shady area.

The upper unit consists almost entirely of red-brown, pale yellow, and off-white sandstone, which is fine to coarse-grained, pebbly, poorly to well rounded, ferruginous in places and poorly sorted with a high percentage of silty matrix. The bedding is medium to thick; and cross-laminae, ripple marks, and clay-pellet markings are common. The sandstone unit, which weathers to dark brown, is commonly silicified and more resistant to erosion.

The contact between the upper sandstone and the lower siltstone is poorly exposed in most places, but near Tempe Tent Hill and in the range to the south of the Seymour Range the contact appears to be conformable. Near Tempe Tent Hill and on Dare Plain the boundary appears to be gradational, but in the south the contact is sharply defined. The presence of a regional unconformity or disconformity at the base of the upper sandstone unit can be demonstrated by following the Pertnjara Formation eastwards, where it gradually transgresses on to the Mereenie Sandstone. The upper part of the sandstone has been removed by erosion over the entire area.

Few fossils were found in the Pertnjara Formation. Leslie (1960) has reported a fossil plant (aff. Sigillaria) about 1500 feet above the base of the Pertnjara Formation in the Tempe Downs area. The plant is probably Upper Devonian or Lower Carboniferous.

R.M. Hopkins of Magellan Petroleum Corporation found the bony plate of a Devonian placoderm fossil (Tomlinson, 1965) in the siltstone near the base of the formation on the north flank of Mereenie anticline. Hodgson (1964) found early Upper Devonian spores in cuttings of the lower unit of the Pertnjara Formation from a waterbore on Mereenie anticline.

The Pertnjara Formation is therefore regarded as Devonian or Devonian-Carboniferous.

MESOZOIC(?)

Sediments tentatively regarded as Mesozoic crop out in the George Gill Range area, near the northern margin of Lake Amadeus and about 35 miles south-east of Mount Murray. Most of the outcrops lie in the south-east quadrant of the Henbury Sheet. The beds are flat-lying and rest unconformably on the folded Proterozoic and Palaeozoic rocks. In many places they form mesas capped with siliceous billy. The maximum exposed thickness of the Mesozoic sediments is about 60 feet. They comprise sandstone with interbeds of claystone and siltstone, and rarely grit and conglomerate. The sandstone is white or cream, fine to coarse-grained, moderately to poorly sorted, laminated to massively bedded, partly cross-bedded, and has a kaolinitic matrix. It contains scattered fragments of claystone, and in places the sequence is stained yellow and red as in the mottled zone of the laterite profile. The claystone and siltstone are white and generally sandy. The grit and conglomerate beds are local deposits derived from the underlying Palaeozoic and Proterozoic sediments.

No fossils have been found in the Mesozoic sediments and their age is inferred from their stratigraphical position. They rest unconformably on the Pertnjara Formation and are overlain by sediments which are probably Tertiary and Quaternary in age.

TERTIARY(?)

Superficial sediments of probable Tertiary age are common in the northern part of the area.

Tertiary sediments of limited extent occur in the Waterhouse Range, where they were first recorded by Madigan (1932); north of Dead Bullock Dam; and near Inindia Bore. The beds crop out in low mesas with a maximum height of 25 feet. The sediments comprise interbedded calcareous sandstone, calcareous sandy claystone, siltstone, and limestone. In the Waterhouse Range there are also interbedded conglomerates with boulders up to 2 feet across. The phenoclasts consist mainly of silicified sandstone, metamorphic quartzite, and minor amounts of vein quartz. The sandstone is light brown or yellow, fine to coarse-grained, and thin-bedded and cross-laminated in places. The siltstone is grey, green, or brown, soft, laminate, and poorly exposed. The limestone is grey, fine-grained, and usually strongly silicified. Silicified wood and tree roots have been recorded by Madigan (1932) and Joyce G. Tomlinson (B.M.R., pers. comm.) in the Waterhouse Range, but they are of no value in determining the age of the deposits.

Conglomerate of probable Tertiary age covers a large part of the eastern side of the area, especially along the Finke River and near some of the ranges. It is well exposed in the banks of the Finke River, in Big Stone Yard (Pl. 6, fig.1), and east of the main road where rounded hills of conglomerate rise up to 50 feet above the plain. In many places the conglomerate was redistributed during the Quaternary, as for example in the vicinity of the Henbury meteorite craters. The redistributed conglomerate has been mapped as Quaternary and the main criterion used for distinguishing between the Tertiary and Quaternary conglomerates is the degree of consolidation.

The pebbles, cobbles, and boulders consist mainly of sandstone of the Larapinta Group. The matrix is calcareous or sandy with the sand poorly sorted and rounded. The cobbles are poorly sorted but moderately well rounded.

Fossils have not been found in the conglomerate. In the vicinity of Maloney Bore and Boomerang Bore it occurs as a rim around the Tertiary(?) limestone, and it appears to have been formed on the margins of freshwater lakes in which the limestones were deposited penecontemporaneously.

Limestone of possible Tertiary age crops out between Maloney Bore and Boomerang Bore, and in the Chandler Range area. There are also minor developments 5 miles west of Running Waters, 8 miles west of Middleton Ponds homestead (abandoned), and near McRaes Yard. The beds consist of white, grey, and pale yellow limestone and silicified limestone with interbeds of purple and green siltstone and sandy siltstone, and red-brown coarse-grained poorly sorted calcareous pebbly sandstone. Individual limestone beds attain a thickness of up to 6 feet, and in places they form prominent scarps and the cappings on the mesas. The greatest known thickness of the Tertiary(?) limestone sequence (including siltstone and sandstone interbeds) is 100 feet near Maloney Bore. Elsewhere it appears to be considerably thinner, and in the Chandler Range it has a maximum thickness of about 30 feet.

The limestones in the Chandler Range area and near Running Waters contain ostracods, planorbid gastropods, and algae(?) which indicate that they are probably Tertiary (A.R. Lloyd, pers. comm.). The fossil assemblage also indicates that the beds were probably laid down in freshwater lakes.

'Billy' is the name given to hard siliceous sandstone (Dunstan, 1900) which forms part of the lateritic profile. It is most strongly developed on the Mesozoic(?) sediments, but in places is found on pre-Mesozoic sediments. 'Billy' is well developed on the eastern margin of the area, where it commonly forms the resistant cappings on the mesas. The billy has a maximum thickness of only 3 feet. It is white, grey, or pale brown, fine to coarse-grained, and partly banded.

The age of the billy is uncertain, but it is known to be post-Mesozoic and older than the Tertiary limestone sequence.

Laterite. No true laterite profiles have been recognized in the area, but some sediments have been ferruginized at the surface. The main area of ferruginization is along the southern front of the James Range between Enintatara Rockhole and Mount Holder, where ferruginized Mesozoic(?) sediments rest unconformably on the Pertnjara Formation, Mereenie Sandstone, and Stokes Formation. Parts of the Mereenie Sandstone have been ferruginized around King Canyon, and flat-lying pisolitic ironstone is present about 8 miles north-west of Ochre Hill.

A specimen of the ferruginized Goyder Formation from the Yaua Bore area of the Levi Range was found to contain 59 percent iron, and a specimen of the ferruginized Mesozoic(?) sediments from the Illamurta Spring area contained 43 percent iron. The age of the pisolitic ironstone is uncertain, but some ferruginization almost certainly took place after the deposition of the Tertiary sediments.

QUATERNARY

Aeolian Sand. A considerable proportion of the central part of the Amadeus Basin is covered by sand plain with braided dunes (Fig. 3). The dunes have a consistent trend locally, but their orientation varies considerably across the area. They are usually fixed by spinifex, desert oaks, and eucalypts, but some migrating dunes occur on the clay-rich alluvium.

Alluvium. Extensive beds of Recent alluvium occur in the eastern half of the area, especially in the physiographic divisions 'B', 'F', and 'G' (Fig. 3), or along the watercourses. The alluvium consists of orange-brown to light brown sand, silt, clay, and gravel, and in some areas it is over 100 feet thick. In places the alluvium is covered by a dense growth of mulga, especially near the ranges.

Conglomerate. Recent conglomerate is found mainly near the creeks and watercourses and on the flanks of the northern ranges and scarps. In physiographic division 'F' (Fig. 3) wide areas are covered by unconsolidated conglomerate formed by erosion and redistribution of the Tertiary(?) conglomerate.

Evaporites. Small deposits of travertine occur on and around the calcareous sediments, and around the margins of some claypans and lakes. The travertine consists of grey or white concretionary masses with a cellular texture and has been formed by the precipitation of calcium carbonate from ground-water.

At the eastern end of Lake Amadeus there is a thin surface crust rich in halite, with underlying layers of brine-saturated sand and silt containing crystals of gypsum.

Small superficial deposits of gypsum crop out in the Inindia Bore area and also to the north-west. The gypsum occurs as low mounds of amorphous gypsum, and is commonly associated with caliche or travertine. Some of the gypsum is possibly derived from the weathering of rock gypsum in concealed diapiric structures.

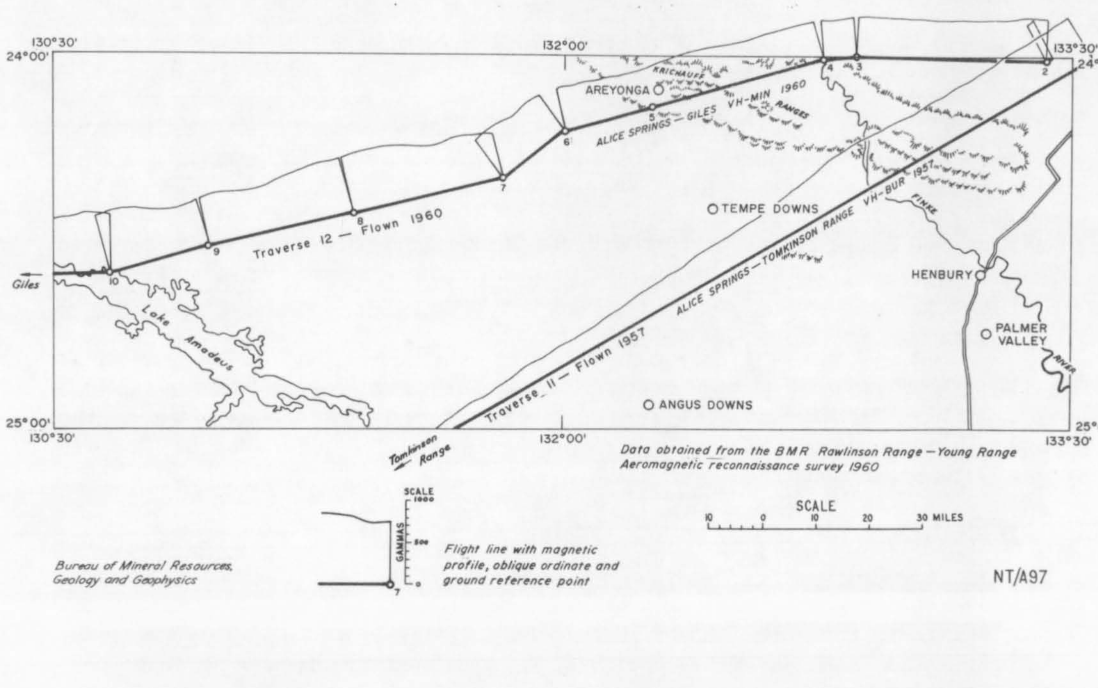


Fig. 7. Magnetic profiles along flight lines, Central part of the Amadeus Basin.

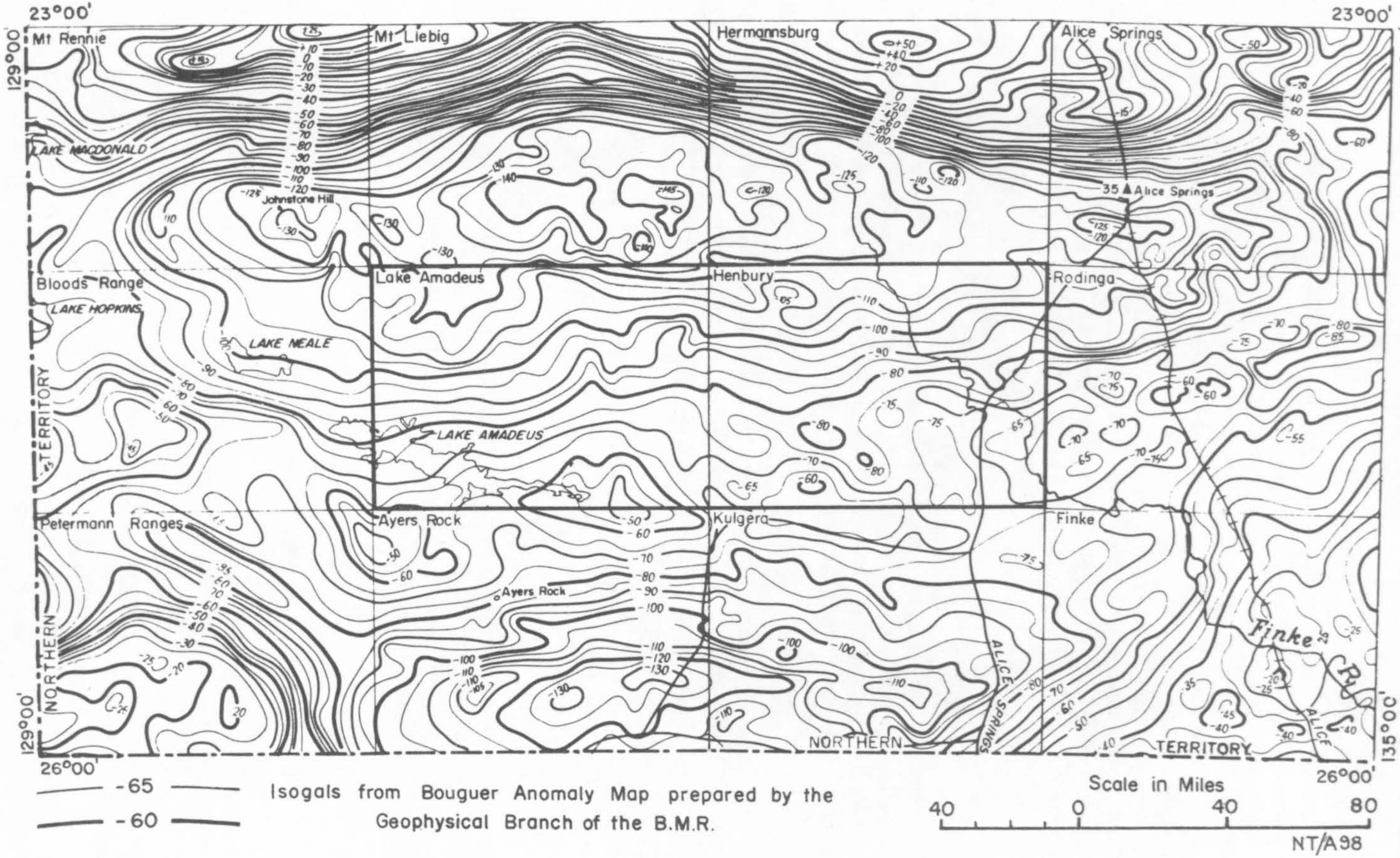


Fig. 8. Bouguer Anomaly Map

STRUCTURE

In the central part of the Amadeus Basin the igneous and metamorphic basement is not exposed, but measured sections indicate that the sedimentary succession decreases in thickness from north to south. The two reconnaissance aeromagnetic traverses across the area (Fig. 7) indicate a thickness of more than 10,000 feet of sediment along the flight lines (Goodeve, 1961). The regional gravity contours (Fig. 8) correspond closely to the known geological and structural trends, and they also indicate that the sediments thin to the south. In general, the major anticlines correspond to gravity maxima and the synclines to gravity minima. The -80 isogal divides the central part of the Amadeus Basin into two distinct provinces which have different outcrop patterns and structural elements, and possibly different sedimentational histories. The -80 isogal corresponds roughly to the southern limit of the Pacoota Sandstone, and probably marks the southern margin or hinge-line of the Amadeus Basin during the early part of the Lower Ordovician

Folding

Two major orogenic episodes have been recognized. The first period of folding occurred in late Upper Proterozoic or early Lower Cambrian times, and resulted in the tight folds found in the southern half of the area (see Fig. 9). This folding was most intense in the southern part of the Amadeus Basin and is correlated with the Petermann Ranges Orogeny of Forman (1965).

The second period of folding, known as the Alice Springs Orogeny (Forman, 1965; Forman & Milligan, 1965), probably reached a climax during the Upper Devonian. It resulted in the long narrow folds trending west-north-west in the northern part of the Amadeus Basin (see Fig. 9).

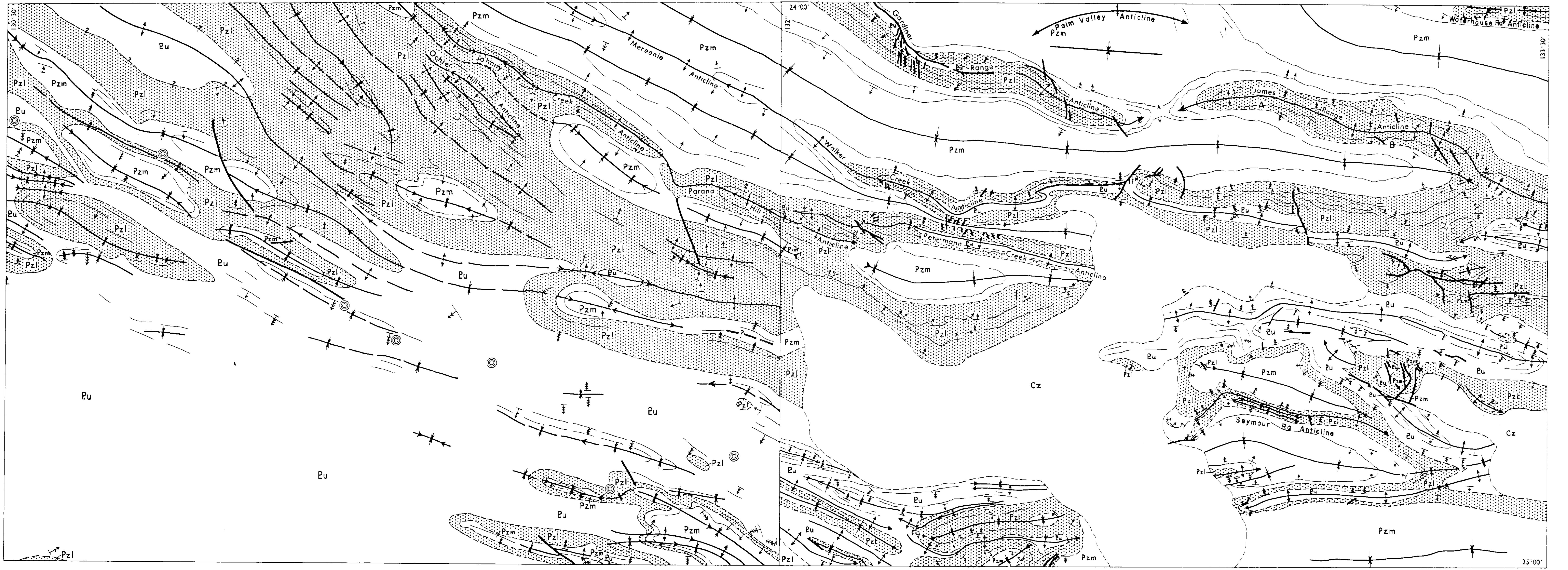
The axes of the folds formed during the two orogenies are sub-parallel, but the direction of stress was probably from the south during the earlier folding and from the north during the later folding.

The complexity of the major structures appears to increase with depth, and the relatively simple anticlines and domes in the Pertnjara Formation and Mereenie Sandstone are represented by complex folds and faults in the underlying Upper Proterozoic and Palaeozoic strata. Many of the anticlines are thought to be supratenuous folds formed by contemporaneous growth and sedimentation.

Faulting

Two main types of faults have been recognized: thrust faults and transverse faults. The largest and most prominent are longitudinal thrust-faults in the Gardiner, Chandler, Seymour, and Bacon Ranges, and in the Illamurta Spring area. These faults could be described as 'break thrusts' as defined by Billings (1942, p.172).

The main longitudinal fault in the Gardiner Range has been referred to by previous workers as the Gardiner or Areyonga fault. It extends for about 50 miles in a west-north-west to north-westerly direction and has an estimated throw of about 14,000 feet to the north-east. At the surface, the fault plane dips at 55° to 90° to the south-west. The greatest displacement occurs about midway along its length, where the Bitter Springs Formation rests against the Pertnjara Formation. The movement along the fault appears to gradually decrease laterally.



Bureau of Mineral Resources Geology and Geophysics

◎ Probable diapiric structure

SCALE

5 0 5 10 15 MILES

NT/A83

Fig. 9 Structural interpretation of the Central part of the Amadeus Basin.

The longitudinal thrusts in the Chandler Range dip steeply to the north and trend between west and north-west. The thrust zone extends for about 20 miles and the maximum throw is probably about 5000 feet. There is local overturning of the younger formations near the fault plane and in some places the Mereenie Sandstone rests against the Chandler Limestone. A feature of the thrusts in the Chandler Range is the almost ubiquitous occurrence of the highly incompetent Chandler Limestone along the line of the fault.

About 16 miles east-north-east of Tempe Downs homestead, near Illamurta Spring, the Areyonga Formation has been thrust over the Mereenie Sandstone. The thrust plane dips steeply to the south and the throw is estimated to be about 8000 feet, assuming that the displacement is due entirely to faulting. This thrust may have been folded at its western end. It is also possible that there was structural growth during deposition at this locality, in which case the movement may have been much less than 8000 feet.

At the south-western extremity of the Seymour Range the Inindia Beds have been thrust over the Mereenie Sandstone. The thrust plane dips steeply to the north and the throw could be up to 5000 feet. However, like the thrust near Illamurta Spring, it may have a much smaller throw because of structural growth during deposition.

Fifteen miles east of Areyonga Native Settlement the Pacoota Sandstone appears to have been thrust against the Mereenie Sandstone. The fault, which dips steeply to the south, has a lateral extent of about 5 miles, and a possible throw of about 2500 feet.

In the Bacon Range, and in the area about 10 miles to the south, several steeply dipping thrusts can be traced for up to 15 miles. The thrusts trend between west and west-north-west, and the larger faults have a south-block-up movement.

Transverse faults are more numerous, but most of them are short and show very little displacement. A large number of the transverse faults, trending between north-north-west and north-north-east, radiate from the large longitudinal fault in the core of the Gardiner Range anticline.

Diapiric Structures

The distribution of possible diapiric structures in the area is shown on Figure 9. The exposures in and around most of the diapirs are poor; the best outcrops are at Mount Murray and at a small hill 12 miles north-north-east of Inindia Bore. At both localities the core of the structure consists of sheared gypsum, which is partly overlain and surrounded by outcrops of Bitter Springs dolomite and limestone. At several other localities, diapirs are suspected because of either the attitude of the beds or the presence of sheared gypsum. In most of the structures the surrounding country rock is not exposed.

At Mount Murray isoclinally folded dolomite pinnacles and ridges, and isolated blocks of dolomite, partly overlie a large central mound of sheared gypsum. The closest outcrop to the Mount Murray diapir is about a quarter of a mile to the south; it consists of a partly overturned sequence of Cleland Sandstone overlain by Larapinta Group and Mereenie Sandstone.

In the structure 12 miles north-north-east of Inindia Bore, the dolomite on the flanks is thin-bedded and laminated, with thin interbeds of slightly calcareous siltstone and irregular oolitic chert. The gypsum in the centre of the dome is exposed in creeks and large sink-holes up to 35 feet deep.

Several other possible diapirs occur between Inindia Bore and Mount Murray. Eighteen miles to the east-south-east of Mount Murray there is a small hill of sheared gypsum, with sink-holes, which is overlain by dolomite and limestone debris. On the south-east side of the hill there are large blocks of sandstone derived from the Mereenie Sandstone or the Winnall Beds. Another possible diapir occurs 28 miles south-west of Reedy Rockhole, where a roughly circular outcrop of steeply dipping chert (probably silicified Bitter Springs Formation) is partly surrounded by steeply dipping Winnall Beds. The chert contains beds of oolitic chert, sandy chert, chert breccia, and a possible stromatolite. The Winnall Beds are brecciated near the outcrop of the silicified limestone. The structure may have been formed by the intrusion of the Bitter Springs Formation into the Winnall Beds, which are brecciated near the outcrop. About 30 miles west-south-west of Reedy Rockhole there is a circular depression covered by mounds of secondary gypsum with associated travertine which may indicate the presence of an underlying gypsum plug. A similar structure about 100 yards across occurs 21 miles west-north-west of Inindia Bore.

Twenty-five miles south of Reedy Rockhole a semicircular rim of steeply dipping foetid grey dolomite breccia surrounds a core of gypsum. The dolomite contains occasional oolitic beds and possible stromatolites, and chert conglomerate similar to that found near the top of the Bitter Springs Formation. A similar structure crops out 13 miles north-west of Inindia Bore. No rock gypsum was found, but some of the dolomite breccia contains intergranular gypsum. Large blocks of sandstone similar to Mereenie Sandstone, and scree of chert and rounded pebbles of coarse silicified sandstone, cover the core of the structure. Another structure of possible diapiric origin occurs on the south side of a long strike ridge of Winnall Beds about 27 miles north-east of Inindia Bore.

The roughly circular outline, the presence of a core of sheared gypsum, and the surrounding annular zone of contorted and brecciated dolomite, strongly suggest that these structures are of diapiric origin. The intrusive rock was probably derived from the Bitter Springs Formation. Alternatively it is possible that the incompetent Bitter Springs Formation was forced into the cores of anticlines during folding, and some of the structures described could be eroded remnants of the cores of the folds with the limbs of the anticlines partly obscured.

GEOLOGICAL HISTORY

The oldest exposed rocks in the central part of the Amadeus Basin (Bitter Springs Formation) were deposited in a widespread Upper Proterozoic sea during a period of tectonic stability. The presence of evaporites and algal stromatolites suggests a shallow marine environment with periods of restricted circulation.

The deposition of the Bitter Springs Formation was terminated by uplift, and the overlying Areyonga Formation and Inindia Beds were deposited in a glacial environment. These formations are at least partly marine, and contain thin algal and oolitic carbonate beds which were deposited during the warmer interglacial or interstadial periods.

The glacial sediments were followed by marine lutites in the north (Pertatataka Formation) and a much thicker sequence of coarser transitional sediments (Winnall Beds) in the south. The presence of oolitic and pelletal carbonate beds in the upper part of the Pertatataka Formation suggests shallow seas in late Upper Proterozoic times prior to the Petermann Ranges Orogeny. This orogenic episode was centred along the present southern margin of the Amadeus Basin, and resulted in isoclinal folding and uplift of much of the Winnall Beds, and minor folding and warping of the Pertatataka Formation in some areas. Although sedimentation may have continued along the northern margin of the Amadeus Basin it is probable that much of the central part of the basin remained above sea level for most of the Lower Cambrian.

As the basin subsided the Cambrian seas spread to the south and the west leaving lenses of a locally derived conglomerate on the unconformity surface.

Migration of the shoreline resulted in a corresponding shift in the sedimentary facies, so that the carbonates which first appeared in the Lower Cambrian in the north-east part of the basin reached the eastern margin of the Henbury Sheet area by the early Middle Cambrian. The sea level fluctuated sufficiently for thin marine beds and lenses to be deposited as far west as longitude 131°31'E., but the typical Jay Creek Limestone facies is not known west of longitude 132°50'E. Subsidence continued into the Upper Cambrian, and both the marine carbonates in the east and the continental and transitional red sandstones in the west were followed by a widespread marine sequence of sandstone, siltstone, and sandy limestone (Goyder Formation). This sequence was followed in late Upper Cambrian times, in the northern part of the area, by the basal sandstone of the Larapinta Group (Pacoota Sandstone). During the period from the late Upper Cambrian until at least the early part of the Upper Ordovician, stable shelf marine sediments were deposited in the north. However, the sea may not have encroached on the southern half of the area until late in the Lower Ordovician.

In Upper Ordovician times some sediments in the Waterhouse Range area were lifted above wave-base and eroded, but marine sedimentation continued into Mereenie Sandstone times over the remainder of the central part of the Amadeus Basin. The sea gradually receded and the environment became continental during the deposition of the Mereenie Sandstone. In Upper Devonian times orogenic movements in the northern and eastern parts of the Basin resulted in erosion in some areas and the deposition of a thick sequence of continental clastic sediments (Pertnjara Formation). The final pulse of the orogeny folded the Pertnjara Formation and initiated a period of active erosion.

The erosion has continued up to the present except for minor interruptions during the Permian, Jurassic or Cretaceous, and Tertiary periods.

During the Permian, thin sequences of glacial sediments were deposited on the western margin of the Amadeus Basin, and during the Mesozoic, the seas transgressed the eastern part of the Basin. The sediments mapped as Mesozoic(?) in the central part of the Basin are considered to be the continental facies deposited on the margins of the Mesozoic seas.

In the Tertiary(?) an extensive lake system formed and fossiliferous lacustrine sediments were deposited in numerous small basins in the eastern half of the Basin. The deposition of these sediments was followed by further dissection and erosion. Sand dunes formed during an arid phase of the Quaternary, and a more recent improvement in the climate has resulted in the fixing of the dunes by a sparse cover of vegetation and the deposition of thin alluvial sequences in the rivers, on the flood plains, and adjacent to the ranges.

ECONOMIC GEOLOGY

Petroleum Prospects

Ten wells have been or are being drilled in the Amadeus Basin in the search for oil. Four are sited in the central part of the Basin and three a short distance to the north. All the wells completed so far have had some indication of hydrocarbons and all four wells drilled on the Mereenie anticline have encountered substantial quantities of gas. Shows of hydrocarbons have been recorded in Upper Proterozoic, Cambrian, and Ordovician units, but the most encouraging finds have been in the Ordovician Larapinta Group sediments.

During the search for phosphate deposits in 1963, a diamond drill-hole (AP1) was drilled for the Bureau of Mineral Resources on the southern flank of Johnny Creek anticline. At a depth of 652 to 661 feet, 9 feet of oil-saturated and patchy oil-saturated core was recovered in the Stairway Sandstone. Oil was also seen in numerous fractures and vugs below 661 feet in both the Stairway Sandstone and Horn Valley Siltstone. In addition, the 11 feet of Pacoota Sandstone penetrated showed slight fluorescence. The Petroleum Technology Section of the Bureau of Mineral Resources established that the oil-bearing core had an effective porosity of 9 percent, an absolute horizontal permeability of 21 millidarcys, and an oil saturation in the pore space of 40 percent. The extracted oil, which was a highly mobile black fluid with a strong naphthenic odour, had a density of about 15^{o} API. The core was exposed to the atmosphere for several days before analysis and some of the more volatile fractions were probably lost.

Possible source rocks in the central part of the Amadeus Basin include the lutites of the Larapinta Group and the Pertatataka Formation and the carbonates in the Pertaoorrta Group, Pertatataka Formation, and Bitter Springs Formation.

Possible reservoir rocks include thin sand lenses near the top of the Bitter Springs Formation; sandstone beds and lenses in the Areyonga Formation; the cleaner sandstone units in the Pertaoorrta Group; the calcarenites and fractured carbonates in the Pertaoorrta Group, Pertatataka Formation, and Bitter Springs Formation; the sandstone units in the Larapinta Group; and the Mereenie Sandstone.

The lutites in the Pertaoorrta and Larapinta Groups and in the Areyonga, Pertatataka, and Pertnjara Formations could act as suitable cap-rocks. Evaporites in the Bitter Springs Formation and the Pertaoorrta Group could also form a cap in some areas.

Most of the anticlinal structures in the central part of the Amadeus Basin have been breached down to the Upper Proterozoic rocks. However, the James Range 'A' and Waterhouse Range anticlines are closed in the Cambrian Jay Creek Limestone, the James Range 'B' anticline is closed in the Cambrian Quandong Conglomerate, the Palm Valley anticline is probably closed in the Pertnjara Formation, the western and central culminations of Johnny Creek anticline are closed in the Pacoota Sandstone, and the eastern culmination of Johnny Creek anticline is closed in the Stairway Sandstone.

The best prospects for oil accumulation in the area are in the Palm Valley, James Range 'C' (if there is closure), and Johnny Creek anticlines, and in stratigraphic traps due to the pinchout and partial silicification of porous sands which are common features in the Pertaoorrta and Larapinta Groups.

Phosphate Deposits

Phosphorites were first reported from the north-western part of the Amadeus Basin in 1961 by Wells et al. (1965b). In 1962 and 1963 the phosphorites were studied in more detail in the Lake Amadeus (Cook, 1963) and Henbury Sheet areas, and the Bureau of Mineral Resources carried out a programme of diamond drilling in the Stairway Sandstone at four localities (AP1, 2, 3, and 4) in the central part of the Amadeus Basin (Barrie, 1964). Except for minor occurrences in the Tempe Formation of the Pertaoorrta Group and at the base of the Areyonga Formation, the pelletal phosphorites are restricted to the Cambro-Ordovician Larapinta Group, especially the Stairway Sandstone.

Pacoota Sandstone: Some samples of the Pacoota Sandstone were found to contain up to 16 percent P_2O_5, but these richly phosphatic bands are unusual, and the average P_2O_5 content of the phosphatic bands is generally less than 1 percent.

Horn Valley Siltstone: A maximum of 7 percent P_2O_5 was recorded from a calcareous sandstone about 20 feet below the top of the Horn Valley Siltstone near Mount Holder. The bed contains fine phosphatic pellets and is about 12 inches thick. The phosphatic content of some of the beds is partly due to the presence of abundant fragments of trilobites and brachiopods, but the formation probably generally contains less than 1 percent P_2O_5.

Stairway Sandstone: The pelletal phosphorite bands in the Stairway Sandstone are well exposed in Johnny Creek anticline, the Mount Shady area, in the vicinity of Mount Holder, in the Chandler Range, 9 miles north-east of August Downs homestead, and near The Sisters.

The only beds in the Stairway Sandstone of potential economic value are the pelletal bands in which the P_2O_5 content ranges from about 10 to 21.6 percent. Individual pellets contain up to 27 percent P_2O_5, and the pelletal bands range from 1 to 12 inches thick. The proportion of pellets ranges up to 50 percent in some bands. There is some correlation between the proportion of pellets and the average P_2O_5 content of the bands, but the correlation is only approximate as the amount of detrital quartz in the pellets is extremely variable. Scattered pellets are also found in the calcareous sandstones and limestones, in which the average P_2O_5 content is 5 percent or less. The pelletal bands occur at all horizons in the Stairway Sandstone, but they are especially common in the middle silty unit (Pl. 6, fig. 2; Pl. 7, fig. 1).

In the southern part of the central area of the Amadeus Basin an unusual green pelletal band up to 1 foot thick was found. It is especially well developed at the western end of the range to the south of the Seymour Range and near the site of AP4. X-ray analysis has shown that the green mineral is corkite (a lead phosphate), which has not previously been recorded in Australia. As corkite has not been recorded in the cores from AP4 it appears that the mineral may be a secondary weathering product.

In thin section the phosphorites are seen to consist predominantly of medium to very fine-grained detrital quartz and areas of cryptocrystalline apatite. The apatite generally forms the intergranular cement in the pellets, but some apatite is also present in the matrix of the sandstone (Pl. 7, fig. 2).

Twenty-one specimens from the Amadeus Basin were analysed spectrochemically for nickel, cobalt, copper, vanadium, lead, zinc, tin, beryllium, and molybdenum. Zinc, tin, beryllium, and molybdenum were not detected in the specimens examined, but it was found that the concentrations of some trace elements, notably lead, rises appreciably with increasing P_2O_5 content. The lead content varies from 30 parts per million in a pelletal sandstone containing less than 5 percent P_2O_5 to 400 parts per million in a similar sample with 18 percent P_2O_5. The variations in the content of copper, cobalt, nickel, and vanadium are less orderly, and no definite trends could be established.

Stokes Formation: In the Stokes Formation pelletal phosphorite has been found in one bed near the base of the formation in the Walker Creek and Johnny Creek anticlines. The bed contains up to 13.9 percent P_2O_5 and is identical with the pelletal phosphorites found in the underlying Stairway Sandstone.

Water Supply

Surface Water: Surface water is relatively abundant in the northern and eastern ranges of the central part of the Amadeus Basin, with large waterholes in the many creeks and rivers. The numerous waterholes along the northern part of the Finke River are permanent and contain abundant supplies of fresh water. Downstream there are fewer, and most of them are saline. Permanent waterholes also occur in the Hugh and Palmer Rivers, and in the Petermann, Walker, Illara, and Palm Creeks.

Permanent rockholes are found at many places in the ranges. They are especially common in the Mereenie Sandstone and to a lesser extent in the sandstone of the Pertnjara Formation. The waterholes tend to be concentrated in specific areas and along certain scarps. The main concentrations occur south of Areyonga Mission, along the George Gill Range, along the southern side of Nineteen Mile Plain, east and west of Illamurta Spring, and Palm Valley. In addition, isolated permanent rockholes occur in the Levi Range (Antaia Rockhole) and the Chandler Range (Antiarra Rockhole).

Semi-permanent waterholes and rockholes are found throughout the area. They may retain water for several months after rain, but cannot be relied upon. Numerous dams have been constructed for the storage of surface water.

Underground Water: Details of the water-supply potential of the various formations in the central part of the Amadeus Basin are summarized in Table 1. The formation with the greatest potential is undoubtedly the Mereenie Sandstone. In many areas, the most accessible aquifers occur in the Quaternary alluvium, and this is probably the most widely used source of underground water in the area.

Parts of the Pertnjara Formation, the Larapinta Group, the Pertaoorrta Group, the Winnall Beds, the Areyonga Formation, and the Bitter Springs Formation are possible sources of moderate to poor-quality water.

There are many bores and wells in the eastern half of the area, but the data are incomplete. The deepest is the Hugh River Stock Route No. 3 Bore, which reached a depth of 500 feet, but the average depth of the bores is about 200 feet. The standing water-level varies considerably within a small area, but there is a regional variation from about 100 feet in the northern part of the area to 200 to 300 feet in the south. The salinity is also very variable, but in general it increases towards the south. The maximum salinity recorded is 20,285 parts per million of dissolved salts in a bore in the Stairway Sandstone.

Copper

Copper mineralization is known in four localities in the north-eastern part of the area. No new mineralized areas were located during the survey and much of the information given below is based on an unpublished report by A.D.M. Bell (1953) on copper deposits in the Alice Springs district.

Waterhouse Range (Owen Springs prospect): Malachite and cuprite occur in the Goyder Formation of the Pertaoorrta Group on the northern flank of the Waterhouse Range anticline. Some nickel is also present. The copper appears to be stratigraphically controlled and as no veins or intrusives of any type are known from this area, it is thought most likely to be of syngenetic origin. Five diamond drill-holes were drilled by the Titanium Alloy Manufacturing Company in 1954 to investigate the deposit, but the results were disappointing and the project was abandoned.

Areyonga (Namatjira's prospect): Malachite, azurite, chalcocite, digenite, chrvsocolla, and covellite occur in a crush zone or fault breccia in the Eninta Sandstone about 10 miles east-south-east of Areyonga Aboriginal Settlement. There is evidence of possible syngenetic copper in the Eninta Sandstone nearby and it is considered probable that this has been concentrated in the fault breccia. One mineralized specimen from the fault breccia (Hy402) was found to contain, as well as the minerals listed above, some possible enargite and gold. The major constituent of the sample was a fine-grained steel-grey admixture of chalcocite and digenite.

Alalgara Yard (Lalgra prospect): Copper showings have been reported from the Pertaoorrta Group near Alalgara Yard, about 22 miles north-west of Henbury homestead. The copper occurs as pellets of malachite in a micaceous sandstone of the Goyder Formation.

Boggy Hole: Malachite has been reported from a 'ferruginous oolite grit' in the Larapinta Group exposed in the banks of the Finke River about 42 miles north-north-west of Henbury homestead. Bell (1953) reports that the oolite grit is variable in character and from 5 to 10 feet thick.

Miscellaneous

Evaporites occur in the bed of Lake Amadeus, and salt for local use is obtained from salt pans near Curtin Springs at the eastern end of the Lake. Halite has also been found in Ooraminna No. 1 and Alice No. 1 wells.

Rock gypsum occurs in the cores of the diapiric structures. It is associated with outcrops of Bitter Springs Formation, and the largest exposed deposits occur at Mount Murray.

Thin beds of pisolitic ironstone occur in the Horn Valley Siltstone. In the vicinity of Running Waters, on the Finke River, flat-lying ferruginized sediments crop out over an area of about 20 square miles. A specimen of the ferruginized sediment was found to contain 43.5 percent iron and 10 percent silicon. Ferruginous and manganiferous surface encrustations are found above the Goyder Formation, and up to 59 percent iron has been recorded from a selected sample from the Levi Range (Hy106).

HENBURY METEORITE CRATERS

The Henbury meteorite craters are situated 7 miles west-south-west of Henbury homestead. They were first reported by Alderman (1933), and have since been investigated by Rayner (1939), who carried out a geophysical survey of the craters, and by many other geologists. In 1963, Dr D.J. Milton of the U.S.G.S. investigated the structure of some of the larger craters. There are at least 12 craters to the north of the Bacon Range, and Alderman (1933) reported 13. The largest crater (Pl. 8, fig. 1) is about 600 feet in diameter and 40 to 50 feet deep. The craters are partly filled with alluvium, and contain a thicker growth of trees than the surrounding plains. They occur in the Winnall Beds and an unconsolidated Quaternary(?) conglomerate.

Fragments of meteoritic iron up to 170 pounds in weight, meteoric glass, and fused rock fragments were common when the area was first visited, but most of the material has since been collected. Taylor & Kolbe (1964) have investigated the geochemistry of impacted material in and around the craters.

The age of the Henbury meteorite craters is uncertain, but they are known to be younger than the unconsolidated conglomerate and older than the fully grown acacia and mulga trees in and around the craters. Although a search has been made for charcoal formed as the result of the burning of trees ignited by the meteorite none has been found. There are no records of the meteorites in the aboriginal lore of the area, but the well preserved form of the craters suggests that they are of Recent origin. Alderman (1933) has suggested the age should be reckoned in terms of thousands of years, but Milton (pers. comm.) considers that the impact may have occurred several hundred years ago.

Dr D.J. Milton has made the following resumé of his recent study of the Henbury craters:

'A geologically Recent meteorite shower at Henbury, Northern Territory, Australia, formed twelve craters in shale and sandstone dipping homoclinally about 35^{o} and in overlying alluvium. The largest crater, formed by the impact of two objects, is an oval 660 feet long, 500 feet wide, with the floor 30 feet below and the crest 5 to 20 feet above the surrounding surface. Bedrock units in the walls are markedly displaced outward. Folds formed in both the lower and upper portions of the wall. Many are overturned outward and break thrusts are associated with some anticlines. One such nappe overrides the pre-crater surface for sixty feet or more.

'Elsewhere on the rim are overturned flaps of the Meteor Crater type [Pl.8, fig.2], some thrust outward as well as overturned. In some segments of the lower wall outward displacement increases downward, so that these segments appear as if they had been hinged at the top. Structural blocks separated by faults characteristically are interlocking, even where the displacement between them is considerable. Apparently dilation accompanied impact, so that structural blocks moved more or less independently of their neighbours.

'At two of the smaller craters ejected fragments from thin sandstone beds lie in straight lines radial to the crater. One pair of such rays emanating from the two intersections of a bed with the rim have their outer ends connected by a loop, in a pattern similar to that of rays and ray loops around some lunar craters.'

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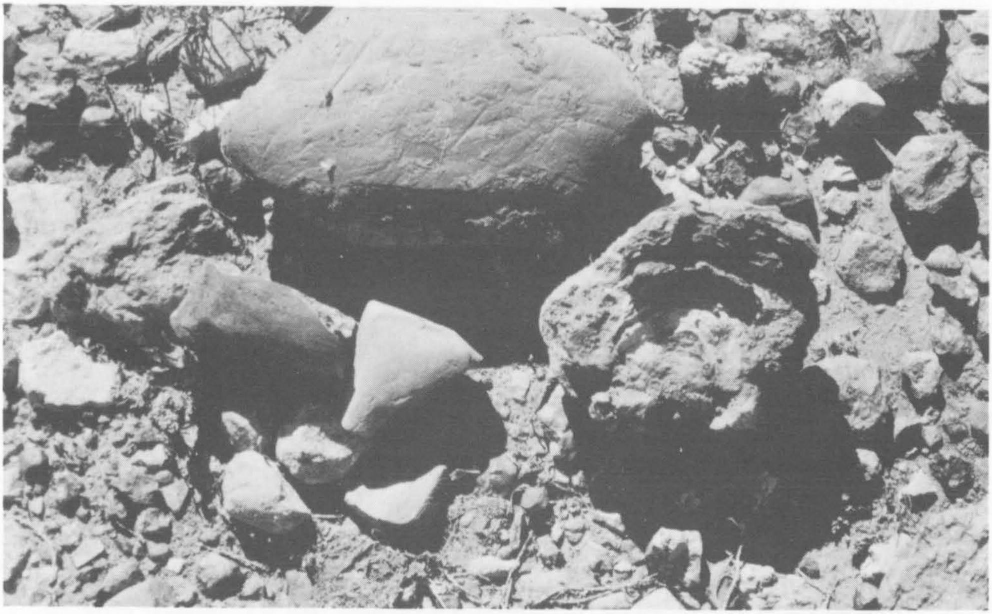


Fig. 1. Striated and faceted pebbles and cobbles in scree overlying the Inindia Beds, 19 miles south-west of Mount Tucker.

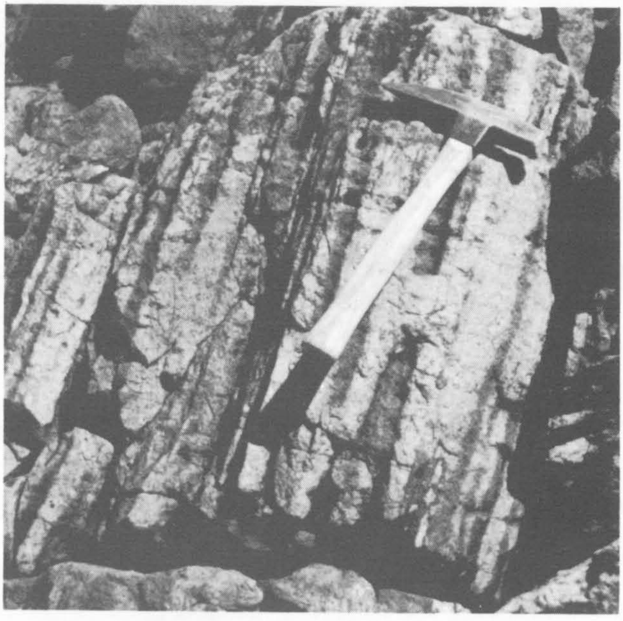


Fig. 2. Pipe-rock in the Areyonga Formation, Gardner Range.

Plate 2:

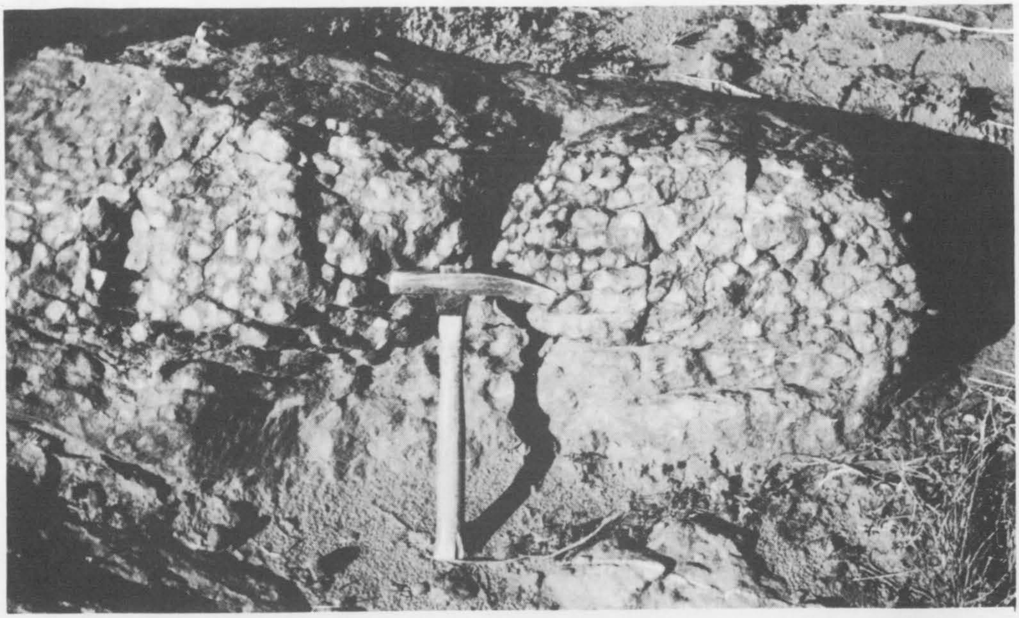


Fig. 1. Pipe-rock in Winnall Beds. The pipes (cf. Syringomorpha) are parallel to the bedding.

Fig. 2. Girvanella from the basal part of the Jay Creek Limestone in the Waterhouse Range.

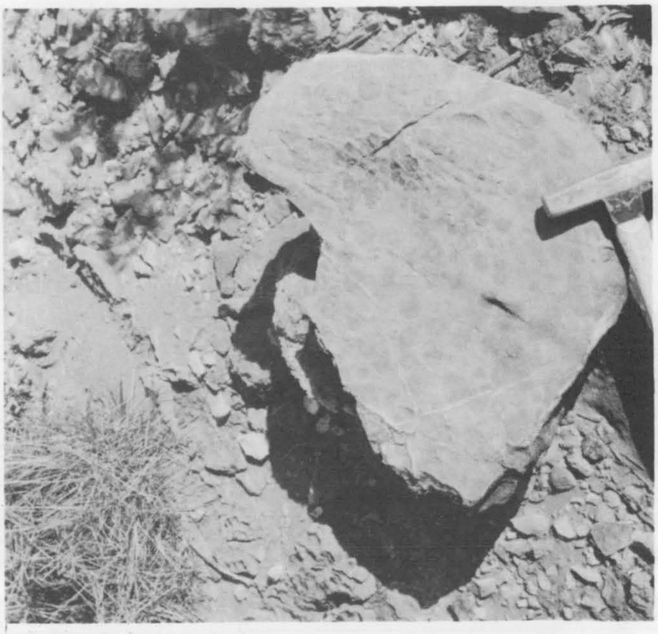


Fig. 1. Algal structure in the Jay Creek Limestone in the Waterhouse Range.

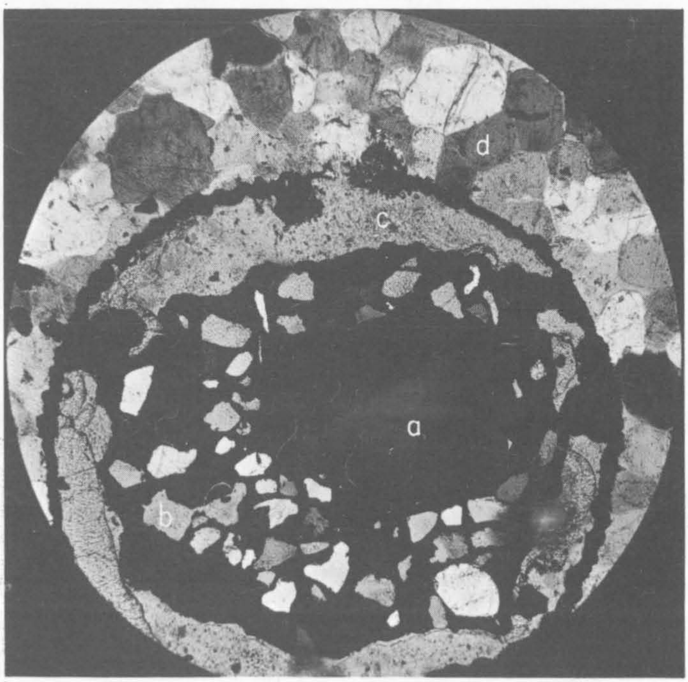


Plate 3: Fig. 2. Thin section of coarse-grained Pacoota sandstone with vugs; thin section R12424, crossed nicols, x5. (a) Iron oxide (magnetite?); (b) fine angular quartz; (c) colourless amorphous mineral (crypto crystalline apatite?); (d) coarse quartz showing secondary enlargement of grains.

Plate 4:

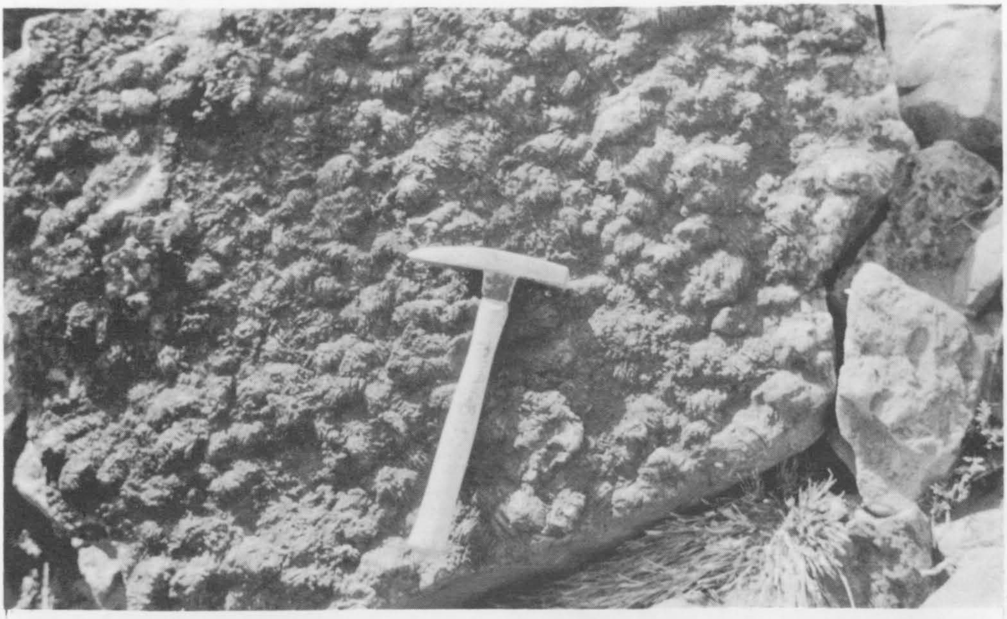


Fig. 1. Cruziana from the Pacoota Sandstone, Waterhouse Range.

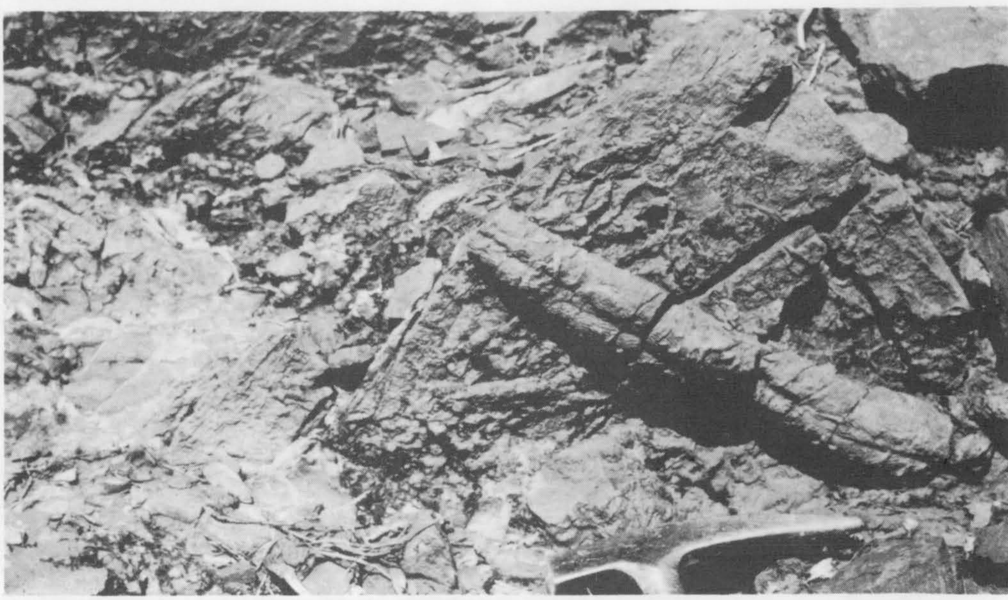


Fig. 2. Cruziana from the Stairway Sandstone, unnamed range south of the Seymour Range.

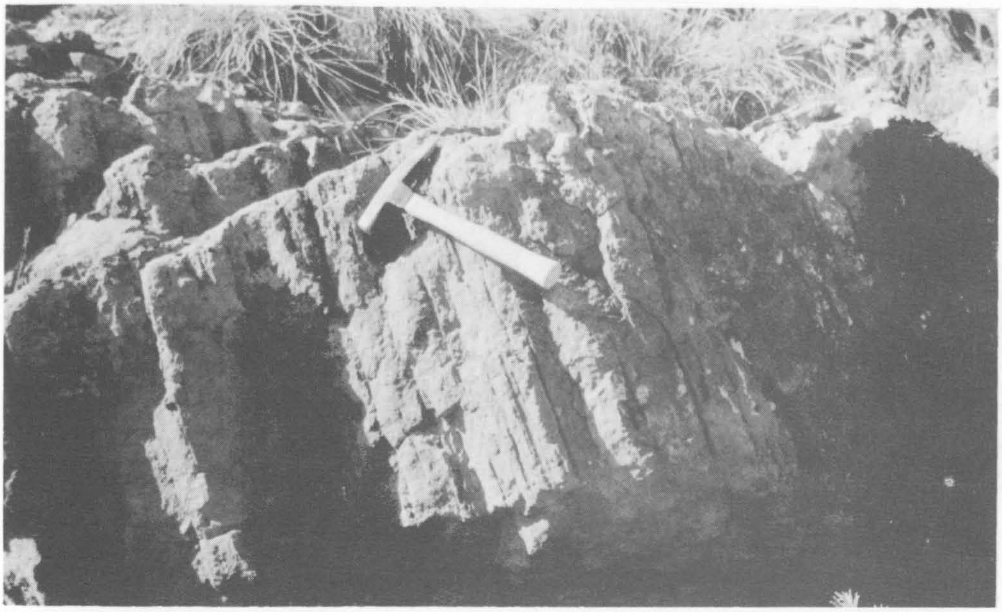


Fig.1. Pipe-rock in the Mereenie Sandstone (Pzm(2)) near Mount Shady.

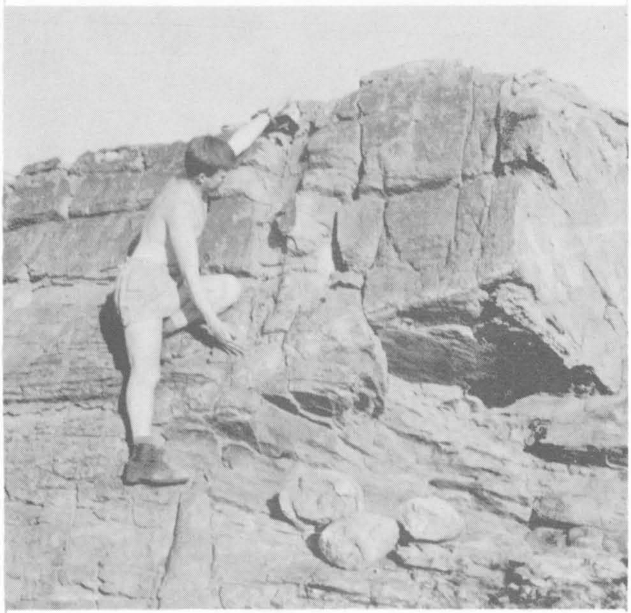


Fig. 2. Large cylindrical rod-like structures in Mereenie Sandstone (Pzm(2)) about 3 miles south-west of Tempe Downs homestead.

Plate 6.

Fig. 1. Tertiary conglomerate near No. 5 Bore on Big Stone Plain.

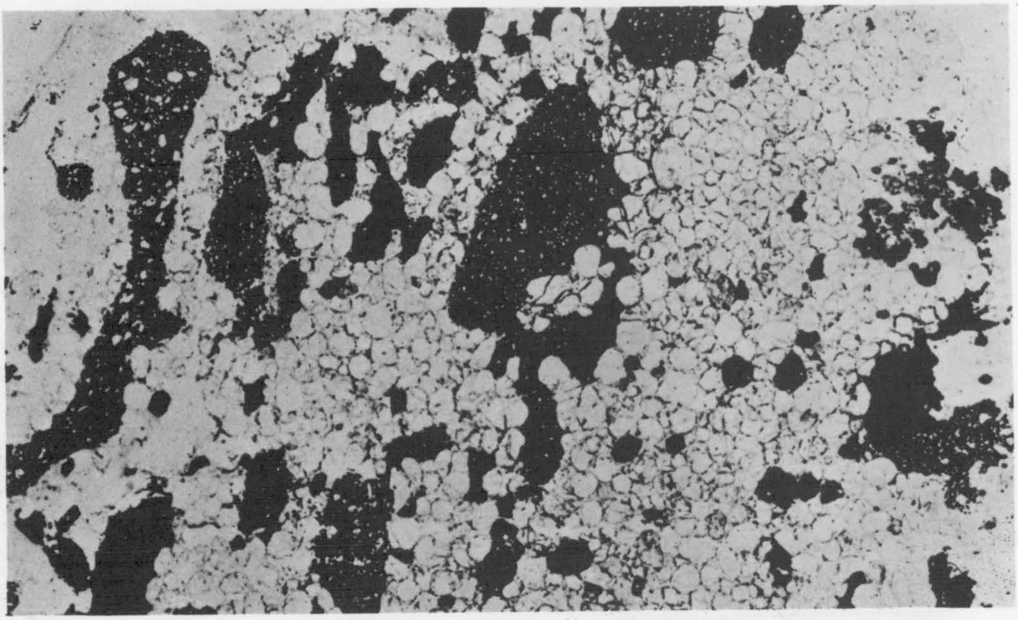


Fig. 2. Thin section of Stairway Sandstone showing cryptocrystalline apatite (black) with enclosed fine angular quartz. x25.

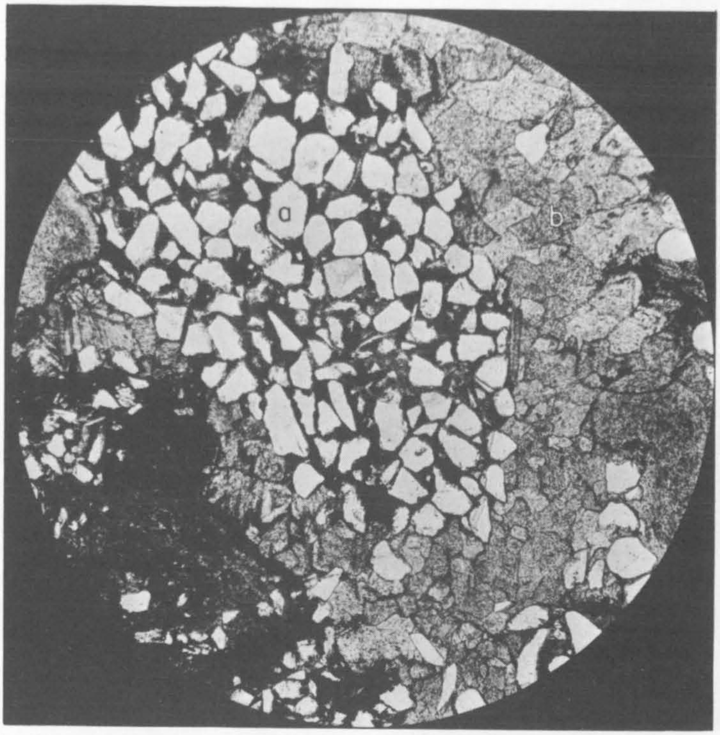


Plate 7: Fig. 1. Thin section of limestone with sandy phosphatic pellets; Stairway Sandstone. (a) angular quartz with dark green phosphatic cement (cryptocrystalline apatite?); (b) intergrowth of calcite crystals. LA54, thin section R13096x45.

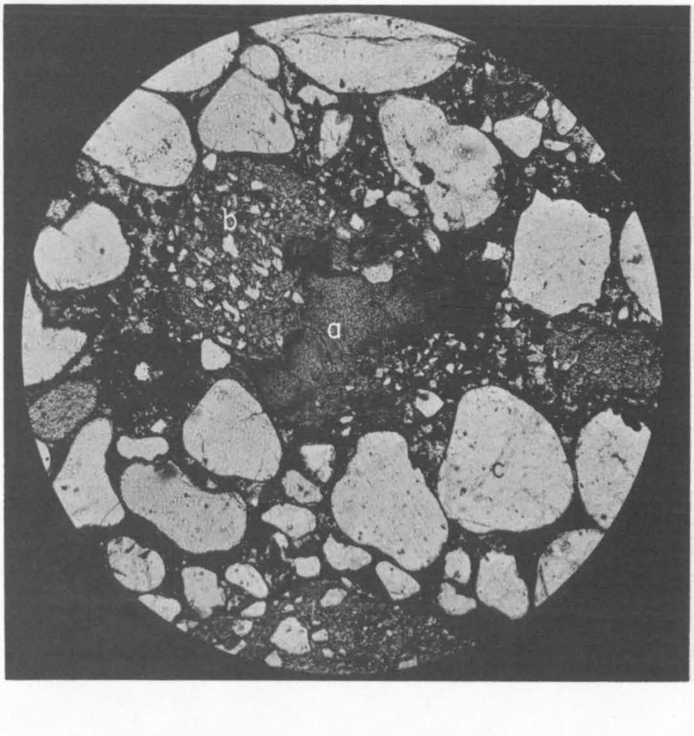


Fig. 2. Thin section of coarse phosphatic sandstone; Stairway Sandstone. (a) cryptocrystalline apatite or collophane showing shodowy ooliths cemented together; (b) phosphatic groundmass and fine angular quartz; (c) quarts. LA133, thin section R12431. x 45.

Plate 8:

Fig. 1. Aerial view of the largest of the Henbury meteorite craters.

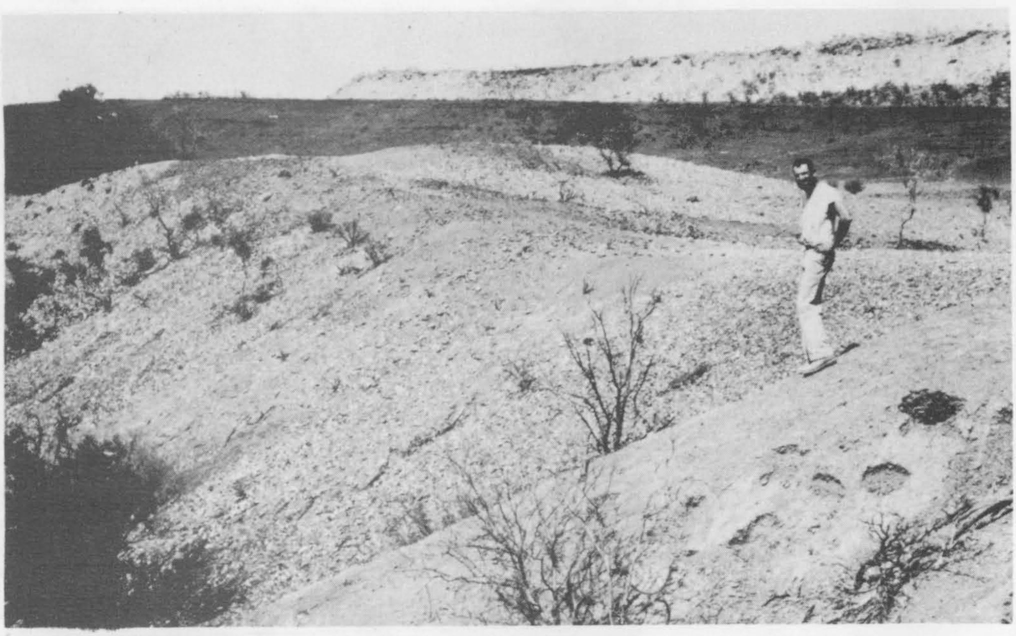
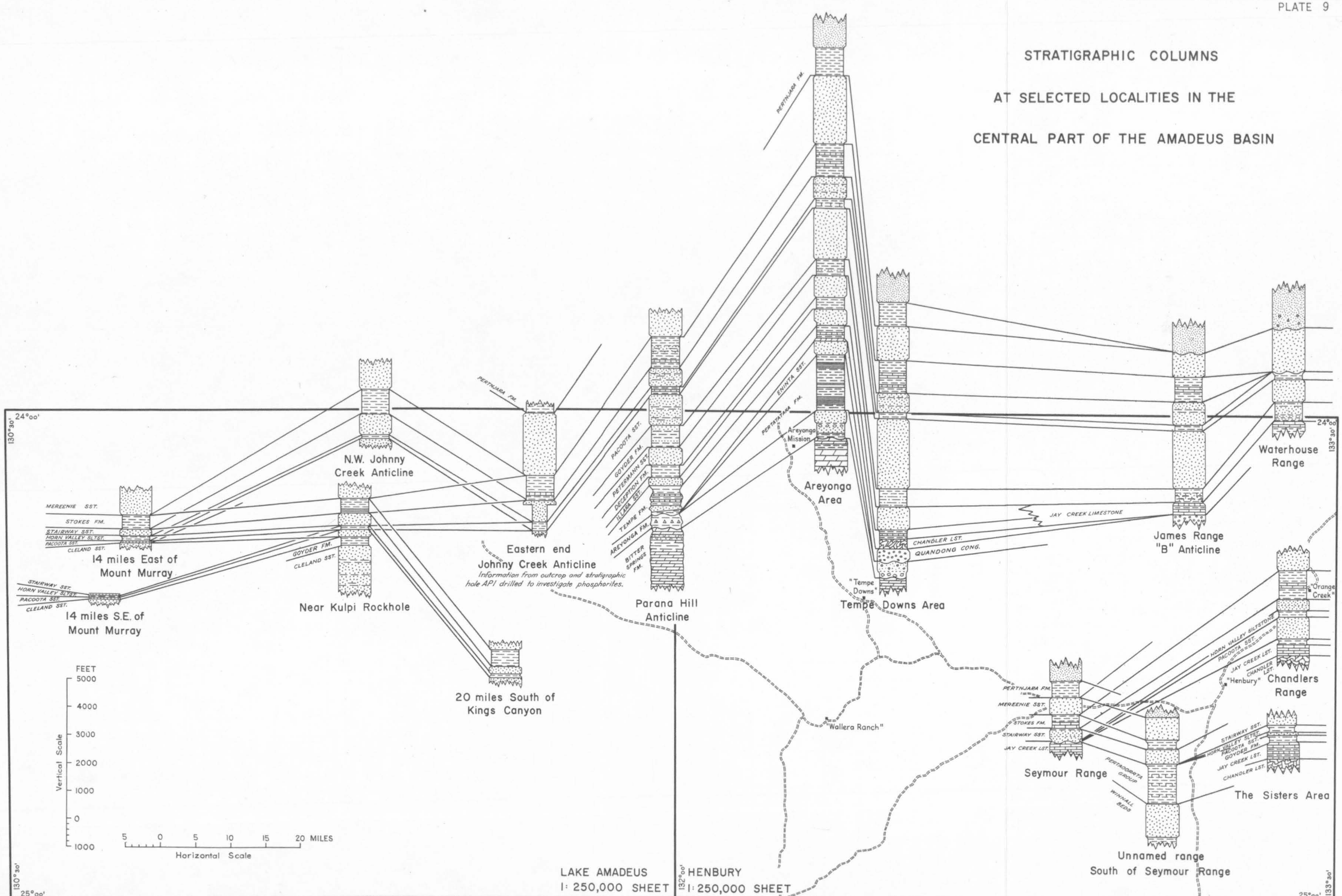


Fig. 2. Margin of main crater, showing siltstone and shale of the Winnall Beds forced out and over Quaternary scree by the impact.

PLATE 9

STRATIGRAPHIC COLUMNS AT SELECTED LOCALITIES IN THE CENTRAL PART OF THE AMADEUS BASIN



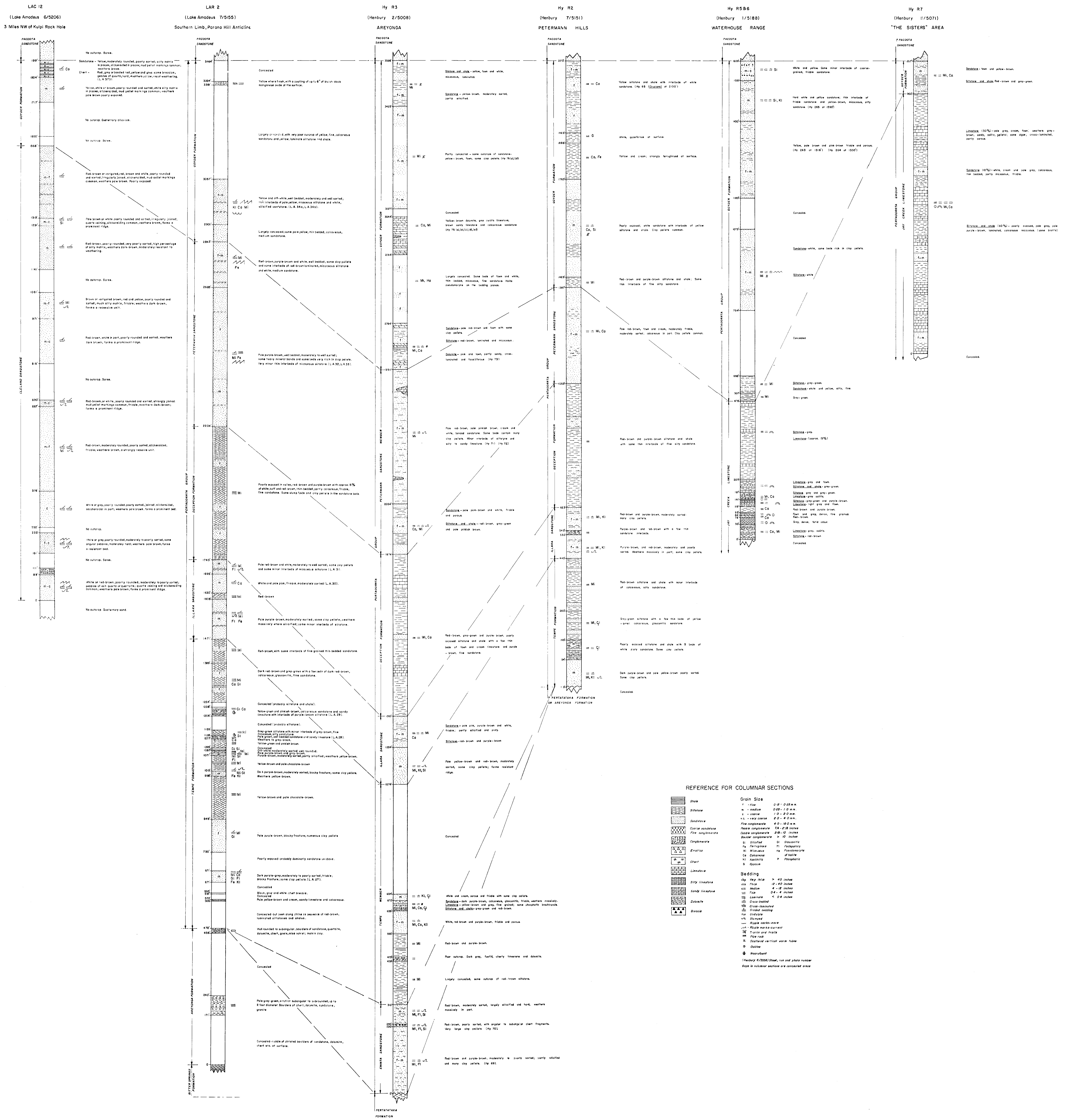
Bureau of Mineral Resources Geology and Geophysics March 1965

NT/A95

MEASURED SECTIONS OF PERTAOORRTA GROUP, CLELAND SANDSTONE AND AREYONGA FORMATION

CENTRAL PART OF THE AMADEUS BASIN

Scale 1" = 150 Feet



MEASURED SECTIONS OF LARAPINTA GROUP UNITS
CENTRAL PART OF THE AMADEUS BASIN

SCALE 1" = 150Feet

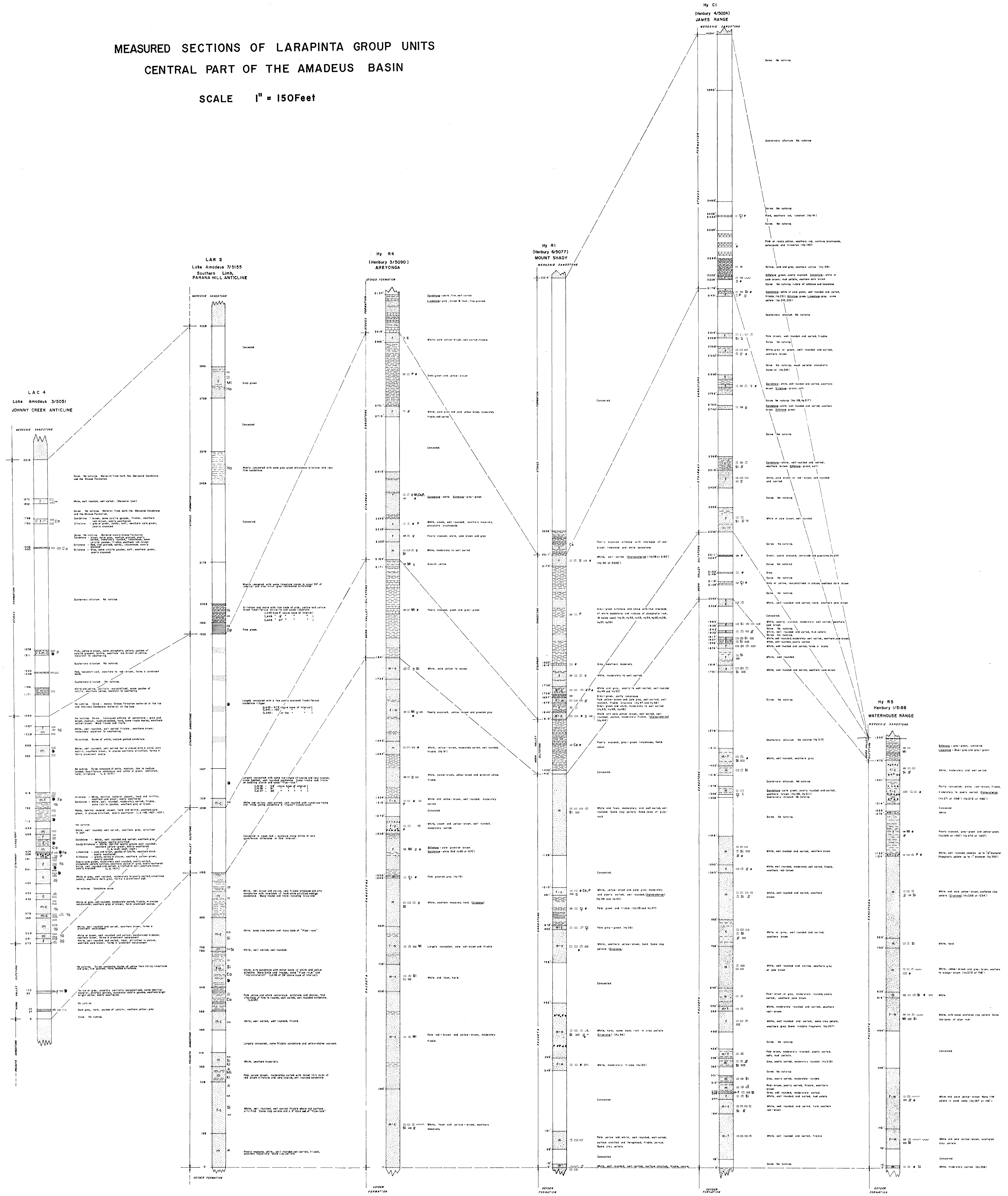


Plate 12

MEASURED SECTIONS OF LARAPINTA GROUP UNITS

SOUTHERN HALF OF THE HENBURY SHEET AREA

Scale 1" = 100 Feet

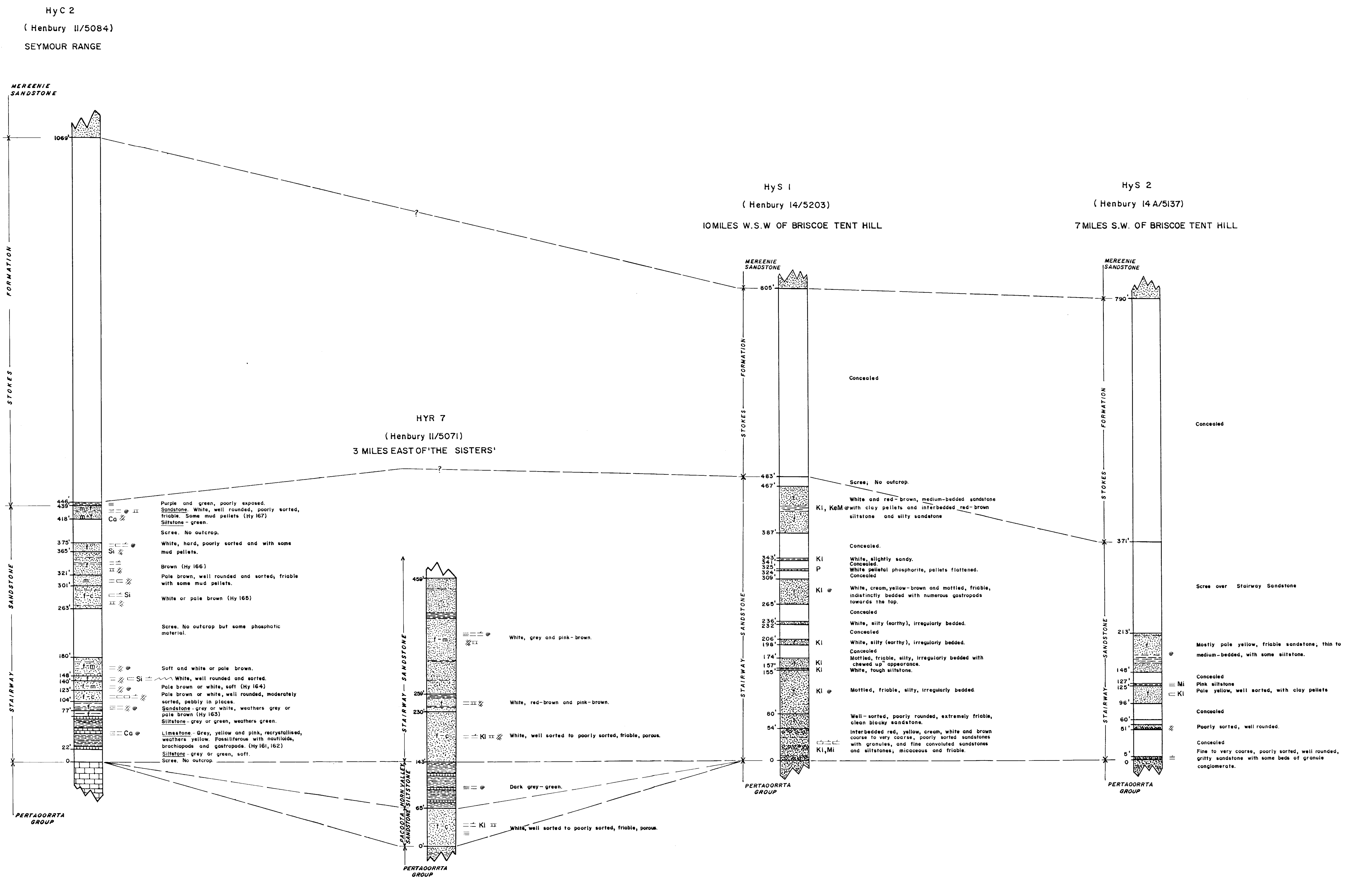
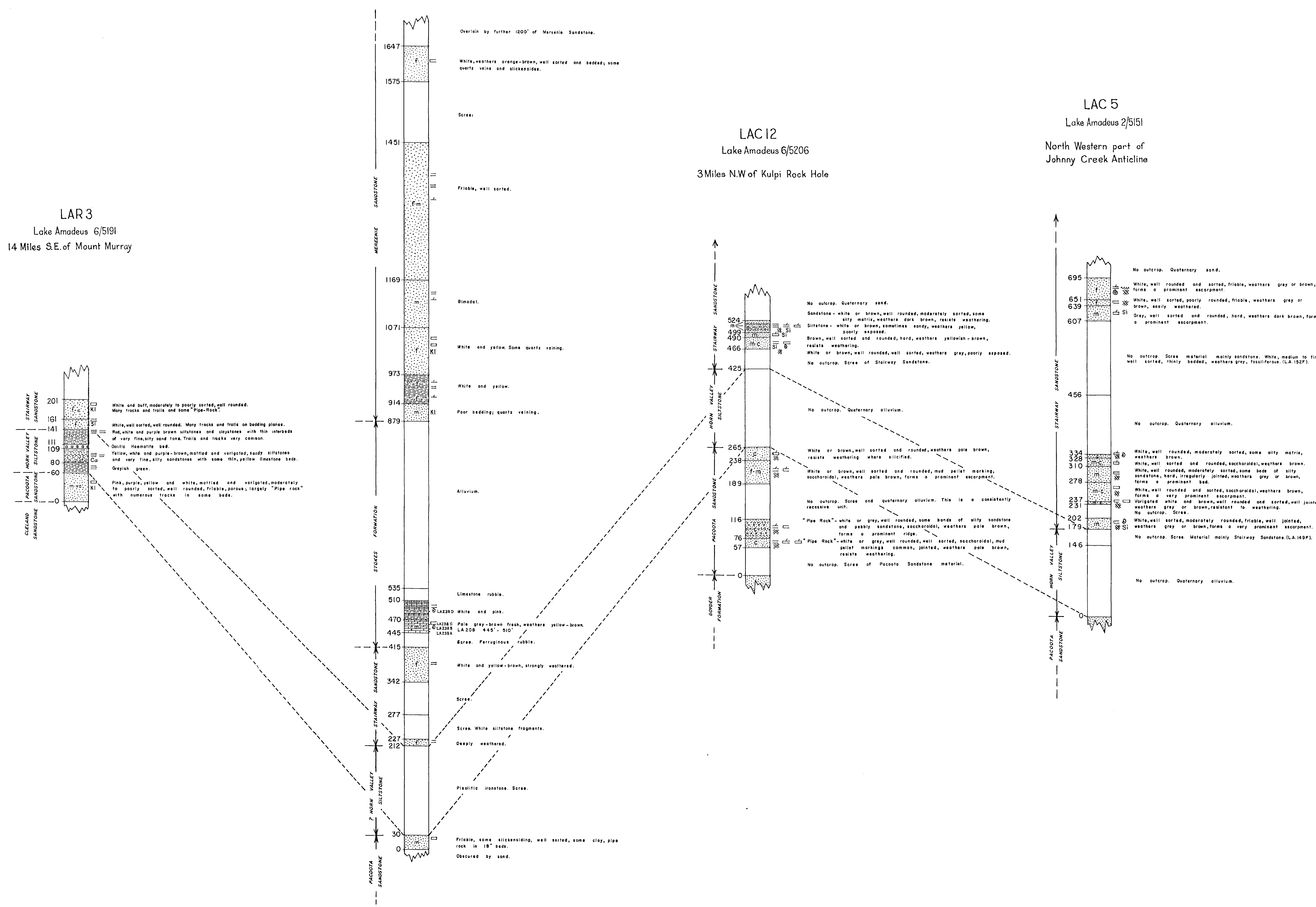


Plate 13

MEASURED SECTIONS OF LARAPINTA GROUP UNITS AND MEREENIE SANDSTONE

NORTHWESTERN PART OF THE LAKE AMADEUS SHEET AREA



Bureau of Mineral Resources Geology and Geophysics April 1963

G52/4/9

MEASURED SECTIONS OF MEREENIE SANDSTONE
CENTRAL PART OF THE AMADEUS BASIN

SCALE 1" = 400

AUSTRALIA 1:250,000

LAKE AMADEUS

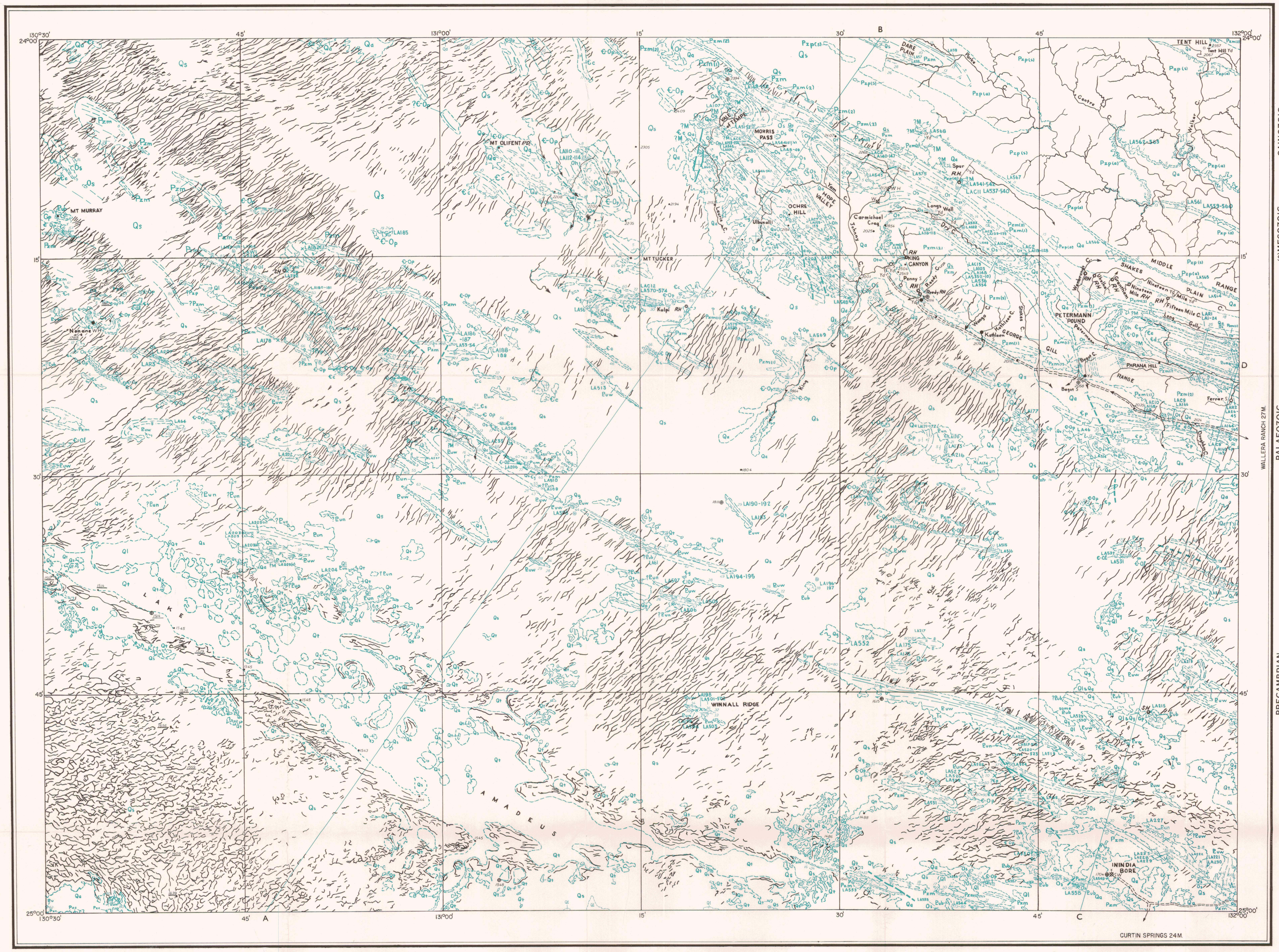
NORTHERN TERRITORY

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

PRELIMINARY EDITION, 1965

SUBJECT TO AMENDMENT

PLATE 15



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	DEVONIAN CARBONIFEROUS	Pertnjara Formation	Pzp	Undifferentiated
			Pzp(s)	Red-brown sandstone
			Pzp(a)	Siltstone, calcareous siltstone
	ORDOVICIAN TO DEVONIAN	Mereenie Sandstone	Pzm	Undifferentiated
			Pzm(2)	White cross-bedded sandstone
			Pzm(1)	Red-brown silty sandstone, siltstone
	CAMBRIAN TO ORDOVICIAN	Larapinta Group: Undifferentiated	€-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	€-Op	Fossiliferous sandstone, conglomeratic sandstone, some vertical worm-tubes
	CAMBRIAN	Pertaoorrta Group: Undifferentiated	€p	
		Pertaoorrta Group: Goyder Formation	€g	Calcareous sandstone, sandy algal limestone
		Pertaoorrta Group: Petermann Sandstone	€e	Red-brown sandstone and silty sandstone
		Pertaoorrta Group: Deception Formation	€d	Red-brown siltstone and shale
		Pertaoorrta Group: Illara Sandstone	€l	Red-brown sandstone and silty sandstone
		Pertaoorrta Group: Tempe Formation	€t	Siltstone, calcareous sandstone, fossiliferous glauconitic limestone
		Cleland Sandstone	€c	Brown silty sandstone, pebbly sandstone
		Mount Currie Conglomerate	Pzc	Coarse conglomerate
PRECAMBRIAN	UPPER PROTEROZOIC	Undifferentiated	Ꝑu	Section only
		Winnall Beds	Ꝑuw	White and brown sandstone, white and green siltstone
		Pertatataka Formation	Ꝑup	Section only
		Areyonga Formation	Ꝑua	Siltstone, sandstone, tillite
		Inindia Beds	Ꝑun	Bedded chert, chert breccia, siltstone, thin beds of dolomite
		Bitter Springs Formation	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° }

Dip 15°—45° }

Dip > 45° } Air-photo interpretation

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

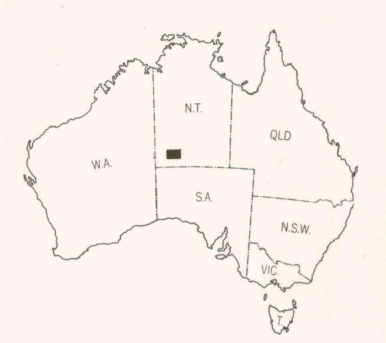
Yd Yard

Astro station

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

2117 Height in feet, barometric levelled } Port Augusta

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

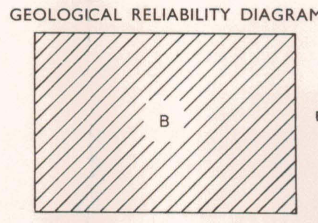
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Sections

Scale: V/H = 1

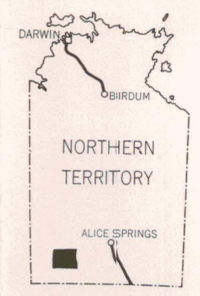
GEOLOGICAL RELIABILITY DIAGRAM

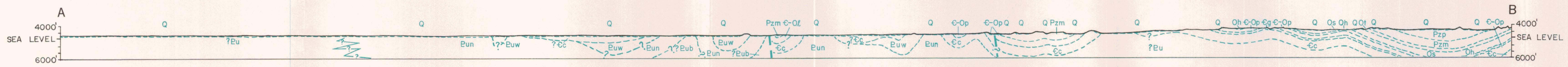


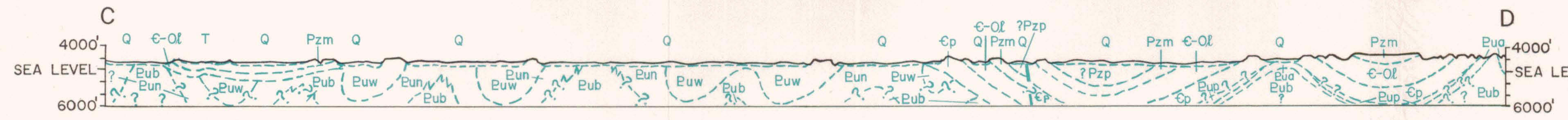
B. Detailed reconnaissance - numerous traverses with air-photo interpretation.

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

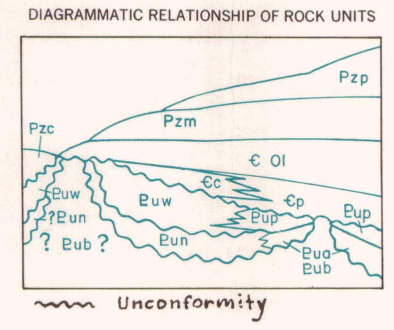
Drawn by: J.M. Fetherston.







DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



LAKE AMADEUS SG 52-4

PRELIMINARY EDITION, 1965
SUBJECT TO AMENDMENT

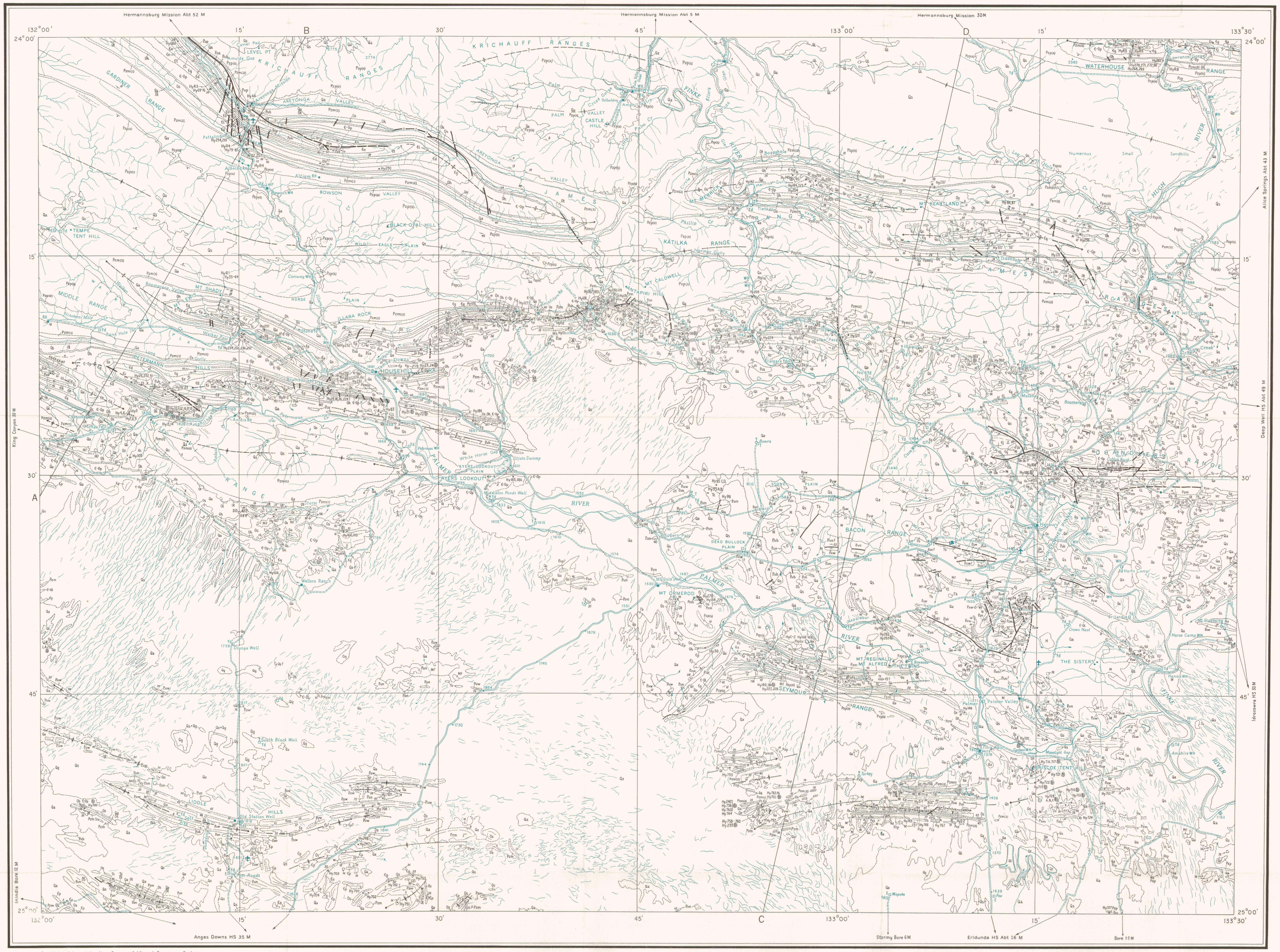
PLATE 16

AUSTRALIA 1:250,000

HENBURY

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 53-1



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 scale.
Transverse Mercator Projection.

Geology and compilation, 1963, by: L.C. Ranford, P.J. Cook, A.T. Wells, A.J. Stewart and A.S. Mikolajczak
Drawn, 1964, by: A.S. Mikollajczak

Reference

CAINOZOIC	QUATERNARY		Q	Alluvium, sand, travertine, gypsum, conglomerate (section only)
			Qa	Alluvium, river gravel
			Qs	Aeolian sand
			Ql	Travertine
			Qg	Gypsum
			Qc	Conglomerate
	(?)TERTIARY	Undifferentiated	T	Calcareous, silty sandstone, conglomerate, limestone
			Tl	Limestone containing freshwater gastropods
			Tc	Conglomerate
			Tb	"Grey Billy"
			Ta	Laterite, ferricrete
(?)MESOZOIC			M	Kaolinitic sandstone, sandy claystone
PALAEOZOIC	DEVONIAN TO CARBONIFEROUS	Pertnjara Formation	Pzp	Sandstone, pebbly sandstone, siltstone
			Pzp(s)	Sandstone, pebbly sandstone
			Pzp(a)	Siltstone, fine silty sandstone
	ORDOVICIAN TO DEVONIAN	Mereenie Sandstone	Pzm	Red-brown and white, cross-bedded sandstone
			Pzm(2)	White, cross-bedded sandstone
			Pzm(1)	Red-brown, silty sandstone
	CAMBRIAN TO ORDOVICIAN	Larapinta Group: Undifferentiated	€-Ol	Fossiliferous sandstone, siltstone and limestone
		Stokes Formation	Ot	Siltstone, shale, fossiliferous limestone
		Stairway Sandstone	Os	Fossiliferous sandstone, silty sandstone, siltstone, limestone
		Horn Valley Siltstone	Oh	Fossiliferous siltstone, limestone
		Pacoota Sandstone	€-Op	Fossiliferous sandstone, silty sandstone
	CAMBRIAN	Pertaoorrta Group: Undifferentiated	€p	Sandstone, siltstone, shale, limestone
		Goyder Formation	€g	Silty sandstone, sandstone, siltstone, limestone
		Petermann Sandstone	€e	Red-brown sandstone, silty sandstone
		Deception Formation	€d	Red-brown siltstone, shale
		Illara Sandstone	€i	Red-brown sandstone, silty sandstone
		Jay Creek Limestone	€j	Limestone, shale, dolomite
		Tempe Formation	€t	Siltstone, calcareous sandstone, fossiliferous glauconitic limestone
		Chandler Limestone	€l	Limestone and dolomite with chert laminae
		Eninta Sandstone	€n	Red-brown sandstone, silty sandstone, siltstone
		Quandong Conglomerate	€q	Conglomerate, conglomeratic sandstone
PRECAMBRIAN	UPPER PROTEROZOIC	Winnall Beds	Puw	Sandstone, siltstone
		Pertatataka Formation	Pup	Siltstone, shale, sandstone, limestone
		Areyonga Formation	Pua	Sandstone, claystone, siltstone, minor conglomerate and limestone
		Inindia Beds	Pun	Siltstone, bedded chert, chert breccia, sandstone
		Bitter Springs Formation	Pub	Dolomite, dolomitic limestone, limestone, siltstone

Geological boundary
Anticline, showing plunge
Syncline, showing plunge
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
Strike and dip of strata, facing not known
Vertical strata
Horizontal strata
Overturned strata
Top of bed
Dip < 15° } air-photo interpretation
Dip 15° — 45°
Dip > 45°
Trend lines
Joint pattern

Macrofossil locality
x Hy23 Text reference to specimen locality
HyR-2 Measured section
DD APZ 388'6" Diamond drill hole, showing depth
•Cu Minor mineral occurrence (Cu copper, Pb lead)

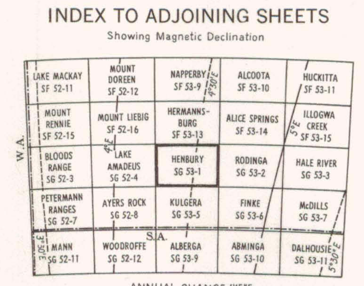
Bore with windpump
Abandoned bore
Well
Spring
T Tank
E Earth tank
WH Waterhole
RH Rockhole

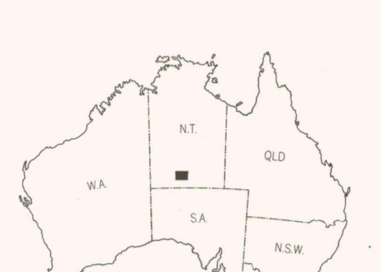
Swamp
Sand dunes

Road
Vehicle track
Fence
"Henbury" Homestead
Landing ground
Yd Yard
Astronomical station
•1193 Height in feet, instrument levelled. Datum, mean sea level Port Augusta

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

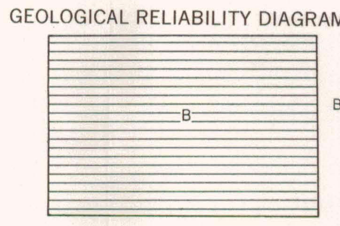




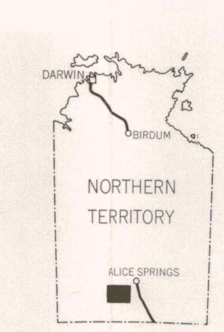
Scale 1 : 250,000

5	0	5	10	15 MILES			
5	0	5	10	15	20	25 KILOMETRES	

GEOLOGICAL RELIABILITY DIAGRAM

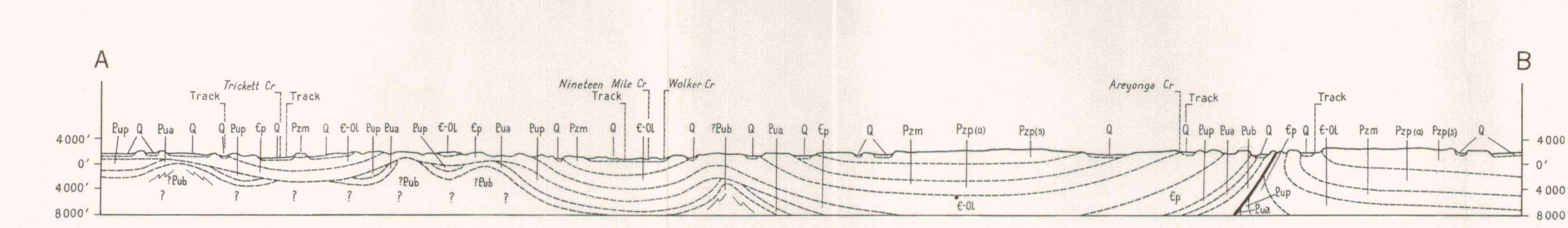


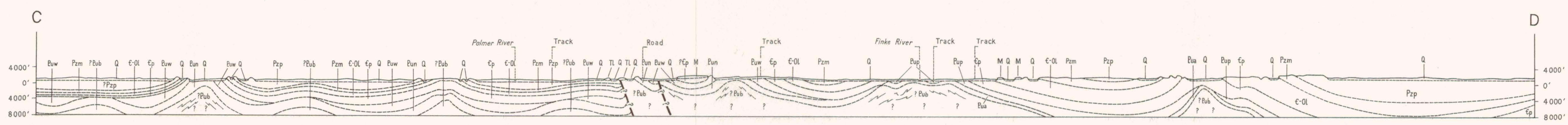
B *Detailed reconnaissance - numerous traverses with air-photo interpretation*



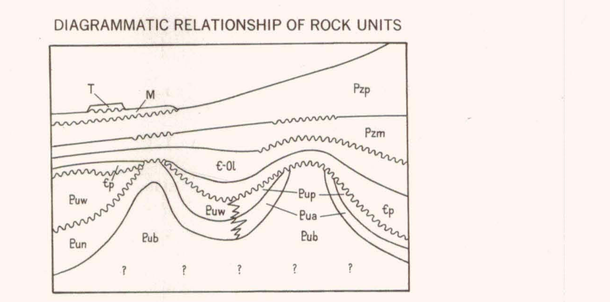
Sections

Scale: $\frac{V}{H} = 1$





DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Unconformity

HENBURY

SHEET SG 53-1

✓

DATE DUE

~~2-[illegible]-88~~			
~~12-7-88~~			
~~19-10-98~~			