COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

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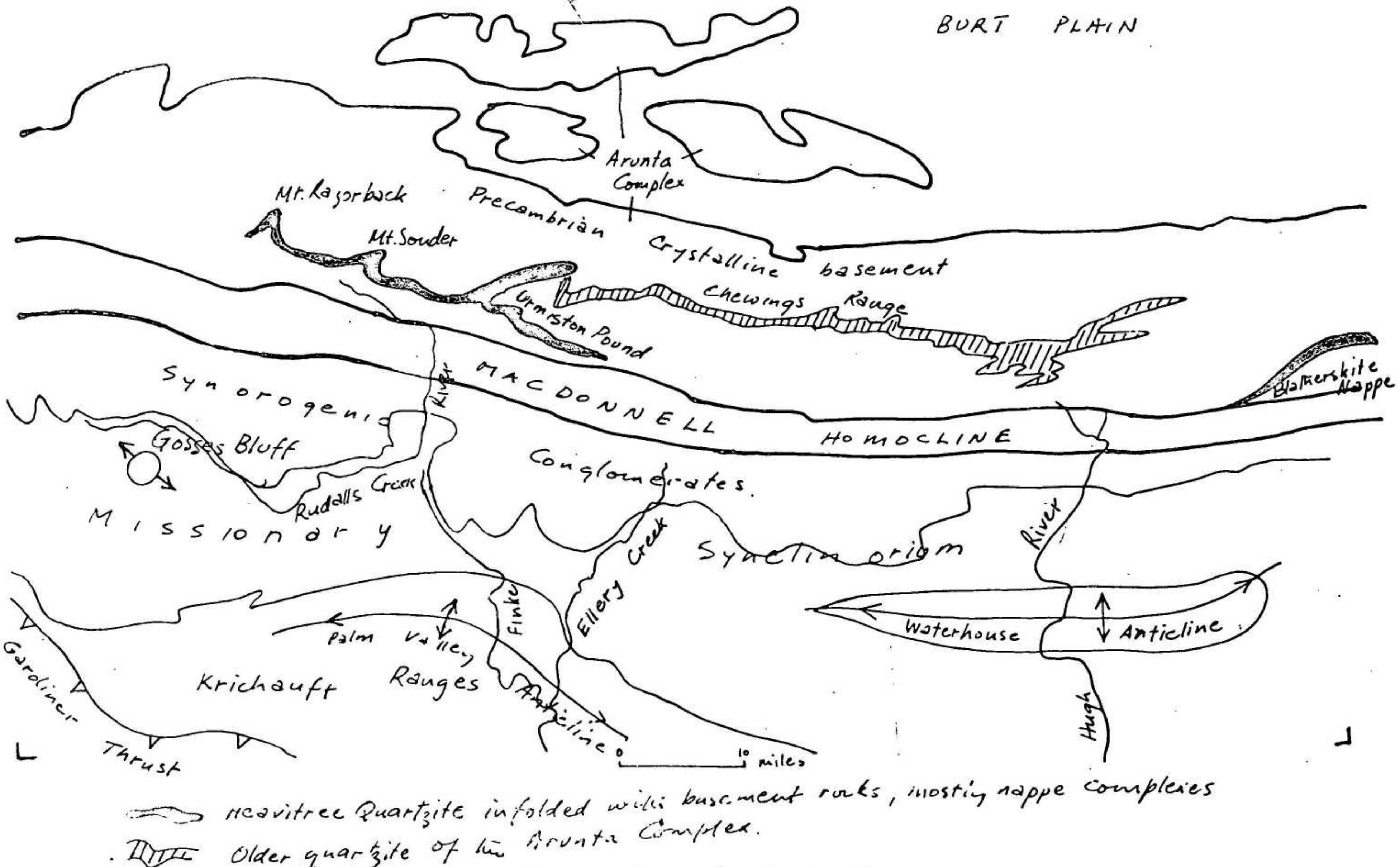
THE GEOLOGY OF THE AMADEUS BASIN, CENTRAL AUSTRALIA

by

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

5928/65

Frontispiece - Satellite photo of the northern margin of the Amadeus Basin with the MacDonnell Range trending east-west across the centre of the photograph. Gosses Bluff on the left and Waterhouse Range on the right. (National Aeronautics and Space Administration, U.S.A., Photo).
G/9267



Overlay to frontispiece

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CONTENTS

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ILLUSTRATIONS

INTRODUCTION

STRATIGRAPHY

PRECAMBRIAN

BASEMENT COMPLEX

BC-1 - Arunta Complex metamorphics in foreground near Blanche Tower and Precambrian quartzite in the background.

BC-2 - Precambrian crystalline rocks in foreground and basalt unconformably beneath Mount Strickland in the Kintore Range.

BC-3 - Dixon Range Beds in the Dixon Range, Western Australia. Dean Quartzite in the Robert Range on the horizon.

BC-4 - Precambrian quartzite at Mount Udor, looking west from Mount Putardi

PROTEROZOIC

PROTEROZOIC (Cont.)

PG - 18	-	Heavitree Quartzite at Mount Gillen dipping southwards and unconformably overlying Arunta Complex exposed on lower slopes and low hills.
PG - 19	-	Irregular stromatolites in the Bitter Springs Formation at Ellery Creek.
PG - 20	-	Polygonal joints in thin phosphate beds at the base of the Areyonga Formation, 2 miles north of Pulya-Pulya Dam.
PG - 21	-	Interbedded shale and siltstone and prominent beds of fine sandstone in the Pertatataka Formation near Areyonga.
PG - 22	-	Julie Member of the Pertatataka Formation, east of Loves Creek homestead.
PG - 23	-	Bed of dolomite pebble and boulder conglomerate in the Carnegie Formation, north-western Amadeus Basin.
PG - 24	-	Lensoid beds in dolomite of the Julie Member of the Pertatataka Formation, 4 miles south east of Box Hole Bore.
PG - 25	-	Fragmental limestone of the Julie Member of the Pertatataka Formation exposed in the Gardiner Range.
PG - 26	-	Ringwood Member of the Pertatataka Formation near Limbla Homestead.
PG - 27	-	Ringwood Member of the Pertatataka Formation near Limbla Homestead.
PG - 28	-	Edgewise conglomerate of dolomite plates in matrix of coarse angular sand. Olympic Member of the Pertatataka Formation.
PG - 29	-	Rounded boulder of granite in conglomerate of the Olympic Member, Pertatataka Formation.
PG - 30	-	Stromatolite colony in the Bitter Springs Formation.
PG - 31	-	Slump structure in the upper sandstone of the Limbla Member, Pertatataka Formation.
PG - 32	-	Olympic Member - Pertatataka Formation.

CAMBRIAN

PERTAOORRTA GROUP

PERTAOORRTA GROUP (Cont.)

C15	-	Interbedded shale and limestone of the Giles Creek Dolomite on the north flank of the Ooraminna Anticline.
C16	-	Shannon Formation in the Ross River Syncline.
C17	-	Stromatolite colony in the Shannon Formation.
C18	-	Stromatolite colony in the Shannon Formation.
C19	-	Shannon Formation of the Pertaoorrta Group on the south flank of the Ross River Syncline.
C20	-	Flow casts in the upper part of the Arumbera Sandstone, Alice Springs Sheet area.
C21	-	Invertebrate tracks in the Arumbera Sandstone, near the middle of the formation.
C22	-	Pseudomorphs after halite in the Goyder Formation near the contact with the Petermann Sandstone, western Petermann Creek Anticline.
C23	-	Formations of the Pertaoorrta Group.
C24	-	Upper beds of Arumbera Sandstone on the south-side of the Ross River Syncline.

CAMBRIAN - ORDOVICIAN

LARAPINTA GROUP

LARAPINTA GROUP (Cont.)

LARAPINTA GROUP (Cont.)

L41 - 'Ropey' textured sandstone in the lower unit of the Stairway Sandstone.

L42 - Diplocraterwin in the Stairway Sandstone.

L43 - Orthis leviensis in limestone of the Stokes Siltstone.

L44 - Halite pseudomorphs in the Stokes Siltstone.

L45 - Western end of the Walker Creek Anticline.

L46 - Western MacDonnell Ranges looking east towards the Finke Gorge.

L47 - Formations of the Larapinta Group in the western nose of the James Range 'A' anticline.

L48 - Formations of the Larapinta Group in the western MacDonnell Range.

L49 - Palaeozoic sediments exposed in the Walker Creek Anticline, viewed north-westwards from south flank of fold.

L50 - Overlay for the photograph above (L49).

?SILURIAN - DEVONIAN

MEREENIE SANDSTONE

DEVONIAN - ?CARBONIFEROUS

PERTNJARA AND FINKE GROUPS

PERTNJARA AND FINKE GROUPS (Cont.)

LIGERTWOOD BEDS

LB1 - Ligertwood Beds at Ligertwood Cliffs.

PERMIAN

PE-1	-	Conglomerate of the Buck Formation, Buck Hills. Phenoclasts of quartz feldspar porphyry.
PE-2	-	Permian boulder beds of the Buck Formation, north of Lake Macdonald, Western Australia.
PE-3	-	Erratic in the Buck Formation showing deformation of the underlying sediments. Macdonald Sheet area, Western Australia.
PE-4	-	Flame structure in the Buck Formation, Macdonald Sheet area, Western Australia.
PE-5	-	Unconformable contact of the Crown Point Formation with the Langra Formation of the Finke Group near Rumbalara Siding.
PE-6	-	Reference locality of the Crown Point Formation at Crown Point on the Finke River.
PE-7	-	Impact markings on a quartzite boulder from the Crown Point Formation near Rumbalara Siding.

MESOZOIC

K-1 - Rumbalara Shale (Klr), De Souza Sandstone (Md) and Crown Point Formation (Pc) at Colsons Pinnacle.

K-2 - Light coloured Rumbalara Shale overlying dark beds of the De Souza Sandstone at Mount Rumbalara.

K-3 - Rumbalara Shale with dissected duricrust capping. Near Mount Wilyumpa.

K-4 - Rumbalara Shale with prominent beds of fine kaolinitic sandstone and resistant duricrust capping north-east of Andado Homestead, Simpson Desert.

CAINOZOIC

QUATERNARY

Q1	-	Seif dunes in the western Simpson Desert.
Q2	-	Active dune field, ten miles west-north-west of Finke township. Finke River in the background.
Q3	-	Dune field ten miles west-north-west of Finke township.
Q4	-	'Ribbon' dune on ferricrete platform 25 miles east of Finke township. Western edge of the Simpson Desert.
Q5	-	Longitudinal dune in the Simpson Desert, showing active sand on the crestal area.
Q6	-	Salt crust of Lake MacDonald. Blocks are travertine from lake margin.
Q7	-	Active dune on the western side of the Simpson Desert.

STRUCTURE

DIAPIRISM AND DECOLLEMENT

DS-1	-	Mass of sheared and brecciated gypsum with weathered earthy crust and rafted mass of dark dolomite of the Bitter Springs Formation at Johnstone Hill.
DS-2	-	Sheared gypsum in core of anticline, south-east Mount Rennie Sheet area.
DS-3	-	Sinkhole in diapiric mass of gypsum in the Bitter Springs Formation, south of the George Gill Range.
DS-4	-	Brecciated gypsum derived from the Bitter Springs Formation, anticlinal core, south-east Mount Rennie Sheet area.
DS-5	-	Johnstone Hill Diapir.
DS-6	-	Overlay to photograph above (DS-5).
DS-7	-	Gypsum from Mt. Gillen Member of the Bitter Springs Formation in the Ringwood Dome.
DS-8	-	Goyder Pass Diapir in the MacDonnell Range.
DS-9	-	Occurrences of gypsum, evaporites and diapiric structures associated with the Bitter Springs Formation and Chandler Limestone.
DS-10	-	Sections through thrust nappes in the north-eastern part of the Amadeus Basin.
DS-11	-	Interpretation of thrust nappes in the north-eastern part of the Amadeus Basin.

PETROLEUM

TABLES

FIGURES

PETROLEUM (Cont.)

FIGURES (Cont.)

NON-METALLIC DEPOSITS

N1 - Occurrences of non-metallic minerals in the Amadeus Basin.

N2 - The occurrence of important non-metallic minerals in rock units of the Amadeus Basin.

N3 - Banded phosphorite - thin bands of phosphate (apatite) and chert in the Areyonga Formation, Alice Springs Sheet area.

N4 - Peletal phosphorite (dark) with a sandy matrix (light) in the Stairway Sandstone.

N5 - Pelletal phosphorite with some nodules showing concentric banding. Stairway Sandstone.

N6 - Phosphorite nodules weathering out from a limestone matrix. Stairway Sandstone at Johnny Creek.

HYDROLOGY

PLATES

SUMMARY

The Amadeus Basin, a large intracratonic depression covering approximately 60,000 square miles, lies across the Northern Territory south of latitude 23°30'. The Basin is elongated east-west for about 450 miles and is about a maximum of 160 miles from north to south. The western part of the Amadeus Basin extends into Western Australia. The Basin includes Proterozoic, Cambrian, Ordovician, possibly Silurian, and Devonian sediments, together with minor Permian and Tertiary freshwater lacustrine and fluviatile deposits. The maximum thickness of preserved sediments is about 30,000 feet.

The sediments in the Amadeus Basin can be related to major tectonic events. Proterozoic sedimentation was terminated by the Petermann Ranges Orogeny, the Cambrian-Ordovician marine sedimentation by the Rodingan Movement and the Devonian-Carboniferous continental sediments are mainly synorogenic sediments formed during the Alice Springs Orogeny.

The Amadeus Basin sediments were not highly metamorphosed during either the Alice Springs or Petermann Ranges Orogeny. The Heavitree Quartzite and Bitter Springs Formation were subjected to low grade regional metamorphism in the zones of recumbent folding and nappe complexes; the overlying sediments were not affected because stress was not transmitted from the underlying incompetent Bitter Springs Formation and hence the overlying succession was not involved in the recumbent folding.

The basement includes a large variety of sedimentary, metamorphic and igneous rocks. It comprises the Arunta Complex along the northern margin of the Basin, the Musgrave-Mann Complex along the southern margin and other undifferentiated Precambrian rocks around other parts of the Basin margin. The Arunta Complex of igneous and metamorphic rocks was folded and metamorphosed by the Arunta Orogeny before deposition of the Amadeus Basin succession. In the south-western part of the Basin the basal Proterozoic sandstone of the Amadeus Basin succession is underlain with a regional unconformity by thick sequences of sediments and acid and basic volcanic rocks which in places are metamorphosed and appear to be intermediate in age between the crystalline basement complex and the Amadeus Basin succession. The details of the early Precambrian history of this region are not known.

In later Proterozoic times the basal sediments of the Amadeus Basin succession were laid down unconformably on the crystalline basement rocks or

in the south west part of the Basin they were deposited locally conformably or unconformably on Precambrian sediments and volcanics. At this stage the region was part of a very wide, stable, epicontinental shelf and a basal blanket sand, comprising the Heavitree and Dean Quartzites of fairly uniform thickness (about 2000 feet), was deposited. Probably as a result of a period of mild epeirogeny the shelf then became an area of restricted deposition with only limited access to the sea and evaporite deposition prevailed. The evaporites were succeeded by penesaline sediments and finally marine stromatolitic carbonate rocks and shale. These rocks are no more than 3000 feet thick and comprise the Bitter Springs Formation and the equivalent Pinyinna Beds. The only known volcanics in the Amadeus Basin succession occur in the upper part of the Bitter Springs Formation in the north-east part of the Basin.

The area was then affected by an important tectonic event, the Kulgera Tectonism, and several distinct tectonic elements developed at this stage. They represent the first phase of the development of an intracratonic trough which roughly paralleled the present trend of the Amadeus Basin. Uplifted areas to the south of the Basin were the main provenance for Proterozoic sediments which were poured into a subsiding trough to the north, the Erldunda Orogeosyncline, in which about 15,000 feet of clastics accumulated. The Erldunda Orogeosyncline was separated from a northern shelf area, the MacDonnell Shelf, by the east-west trending Parana Arch which, as well as marking a pre-existing hinge-line area, was subsequently a zone where there was uplift and erosion of a large thickness of shelf type Proterozoic sediments. The average thickness of the shales and oolitic carbonate rocks of the shelf is about 2000 feet. Glaciation was prevalent during the Proterozoic sedimentation and mainly affected the sediments deposited on the shelf-ward side of the Basin. Two periods of glaciation are known; the earliest was more widespread and formed part of the Areyonga Formation on the northern stable shelf area. The equivalent Inindia Beds in the southern trough have a thin glacial horizon near the top and correlation of these beds with the glacials in the Areyonga Formation suggests that Proterozoic sedimentation began initially in the Erldunda Oregeosyncline. An angular unconformity in places at the base of the Areyonga Formation suggests mild tectonism and erosion of the underlying Bitter Springs Formation on the MacDonnell Shelf during the early phase of sedimentation in the Erldunda Orogeosyncline.

The younger period of Proterozoic glaciation was limited to the north-eastern part of the shelf during deposition of the Pertatataka Formation. In this area a markedly thickened lobe of sediments formed, partly as a result of the contribution of a large amount of glacial sediment. The equivalent Winnall Beds of the trough have no identifiable glacial horizons.

The Petermann Ranges Orogeny, in the late Proterozoic or early Cambrian, uplifted a large area in the south-western part of the Basin and caused recumbent folding. The Pinyinna Beds and Dean Quartzite were complexly infolded with the basement rocks whereas the younger Proterozoic sediments slid northwards over the incompetent beds of the Bitter Springs Formation and were tightly folded along the margin of the Petermann Ranges Nappe. The intensity of folding decreased northwards and its effects were almost negligible north of the Parana Arch (Fig. 2 p C15). The main effects of the Petermann Ranges Orogeny appear to be localised along what was originally the axis of maximum sedimentation in the Erldunda Orogeosyncline.

The uplifted mass formed by the Petermann Ranges Orogeny was the main provenance for Cambrian sediments of the Cambrian Pertaoorrta Group. Thick conglomerate and arkose (Mount Currie Conglomerate and arkose at Ayers Rock) were deposited in south-eastern areas adjacent to the provenance. Further north deltaic sands of the Cleland Sandstone were deposited and these interfinger to the north-east with sands, shales and some marine sediments. These predominantly clastic sediments are separated from predominantly carbonate rocks in the north-east part of the Basin, which form the thickest part (7000 feet) of the Pertaoorrta Group, by a north-south trending zone near the centre of the Basin where there was probably structural growth during sedimentation. The sequence in the carbonate facies in the north-east part of the Basin closely parallels the earliest Proterozoic sedimentation of the Amadeus Basin succession. The basal Arumbera Sandstone of the Pertaoorrta Group was followed, in many places, by evaporite deposits of the Chandler Limestone and then by pensaline and finally normal marine stromatolitic carbonate rocks. The basal Arumbera Sandstone and the youngest unit of the Pertaoorrta Group, the Goyder Formation, show only minor facies changes throughout the Basin.

The sandstone, shale and minor carbonate rocks of the Cambrian to Ordovician Larapinta Group were deposited conformably on the Pertaoorrta Group during several marine regressions and transgressions in a widespread epeiric sea. There was no major change in the limits of sedimentation after deposition of the Pertaoorrta Group. Sedimentation was initially restricted to the northern half of the Basin but the Ordovician sea gradually spread south-wards and the younger formations of the Group transgressed the Pertaoorrta Group and at the southern and western margins of the Basin were deposited unconformably on Proterozoic rocks. The Amadeus Basin constituted a small, probably marginal, portion of a very much larger deposition Basin during the Ordovician, which originally extended many miles further north. The maximum thickness of the Larapinta Group is about 8000 feet at the northern edge of the Basin. Deposition of the Larapinta Group was brought to a close by the deposition of a regressive body of deltaic or estuarine sand which may have been the last marine sedimentation in the Amadeus Basin.

A period of gentle epeirogeny, known as the Rodingan Movement, then upwarped the Amadeus Basin, commencing approximately in the lower Silurian and 5-10,000 feet of sediments were eroded from the north-east part of the Basin reducing the area to a peneplain. Large continental desert areas resulted and the Mereenie Sandstone was deposited probably mostly in Devonian times. The formation was derived by fluviatile and aeolian action and deposited in part in a shallow sea transgressing from the west. Shallow marine environments probably graded into lacustrine and aeolian environments. As a result of the constantly moving strandline there was probably no distinct form to the Basin.

The second major orogenic event, the Alice Springs Orogeny, commenced in the Amadeus Basin in the late Devonian. The orogeny caused a large block of Precambrian rocks, and the superincumbent sedimentary load along the northern margin of the Basin, to be uplifted and the base of the sedimentary sequence to be complexly infolded with the crystalline basement to produce such structures as the Blatherskite Nappe and the Arltunga and Ormiston Gorge Nappe Complexes. A decollement at the base of the Bitter Springs Formation facilitated this complex folding in contrast to the over-lying sediments which were mostly deformed into broad folds. In places the overlying sediments yielded by thrusting with the incompetant beds in the Bitter Springs Formation acting as the lubricating medium.

Large areas of sediments uplifted over the Arltunga Nappe Complex probably moved southwards by gravity sliding on decollement surfaces in the Bitter Springs Formation and at the base of the Cambrian sequence. In this way large complex thrust nappes were formed and most of the sediments in the north-eastern part of the Basin are preserved in allochthonous blocks. The thrusts nappes were in most places subsequently folded.

The Palaeozoic and Precambrian rocks of the orogen formed were deeply eroded and a thick wedge of molasse was deposited on the south flanks of the mountain chains to form the Pertnjara Group. Initial deposition, following conformably on the Mereenie Sandstone, consisted of lacustrine siltstones of the basal part of the Pertnjara Group; as the orogeny progressed coarser sediments were deposited. The maximum thickness of the Group is about 12000 feet adjacent to the northern margin of the Basin. Uplift and erosion of the provenance was synchronous with deposition so that younger formations of the Pertnjara Group successively overlap older formations with the youngest formation, the Brewer Conglomerate, overlying rocks as old as Proterozoic.

The molasse deposits of the Pertnjara Group become thinner and finer grained to the south. Penecontemporaneous deposition of the Finke Group occurred to the south-east in a basin which was probably separated from the Amadeus Basin by a basement swell; parts of the swell were probably emergent during deposition.

The major folding of the Amadeus Basin succession took place during the Alice Springs Orogeny and deformation was in part synchronous with deposition of the Pertnjara Group. Crestal thinning of the Palaeozoic sediments over anticlines show that several of the structures were forming during the Lower Palaeozoic sedimentation and in places were subsequently obscured by the synorogenic Pertnjara Group. Some of the structures were caused either by doming of salt in the Proterozoic Bitter Springs Formation, by thrusting in the basement rocks, or a combination of both these mechanisms. Others may have been formed during the early stages of the Alice Springs Orogeny. Folding of the sediments was facilitated by a decollement surface at the base of the Bitter Springs Formation so that the cores of many of the folds are occupied by tightly folded incompetant beds of this formation; seismic surveys indicate that the basement surface is relatively flat.

The Amadeus Basin was stabilized after the deposition of the Pertnjara Group and the deformation of the succession during the Alice Springs Orogeny. A long period of erosion ensued and the weathered detritus was transported outside the Basin and incorporated in the fluvioglacial and paludal Permian Buck and Crown Point Formations, and deltaic ?Jurassic sands and the shallow marine Cretaceous deposits in the Simpson and Gibson Deserts.

Middle Tertiary fluvial and lacustrine sediments were deposited in ancestral river valleys and pre-and post date the formation of silcrete and ferricrete in central Australia. These sediments are Miocene or younger. The laterite over most of the area is probably no younger than Miocene. The Tertiary deposits indicate a wetter climate in the region. Small faults and tilting of the deposits suggest subsequent minor crustal movements.

The deposits in the Tertiary valleys were eroded, the valleys were breached by headwater erosion of streams and the present drainage was initiated. The dissection was caused by crustal down warping in the Lake Eyre Basin. An arid phase prevailed at this stage with initiation of internal drainage and dune formation. Resumption of drainage incision suggests an amelioration of the climate with the development of alluvial fans and flood plains.

The Amadeus Basin is being prospected for hydrocarbons and two areas with wet gas accumulations have so far been discovered by exploratory drilling. They are at the Mereenie and Palm Valley anticlines and in both cases the producing rocks are Ordovician, chiefly the upper part of the Lower Ordovician Pacoota Sandstone. Small oil production was obtained from the Mereenie Anticline but insufficient permeability exists in the reservoir rocks. The Ordovician and Cambrian sediments offer the best prospects for petroleum accumulation and the northern province of the Amadeus Basin, the Missionary Synclinorium, is probably the most prospective area. Several large structures, with closure in Ordovician and Cambrian, have been mapped under the cover of Devonian sediments. One of the main problems is to outline areas where there is significant permeability in the Ordovician reservoir sands.

The transition zone, where there is interfingering of sandstone and carbonate rocks in the Pertaoorrta Group, is probably worth further investigation.

Reservoir rocks may be developed on the central north-south trending zone in the Basin where there was structural growth during deposition and roughly corresponds to the transition zone in the Cambrian sediments. The existence of a topographically high area during sedimentation suggests an area of reworked clean sands suitable for hydrocarbon traps.

Water supply is important in the development of the pastoral industry in the area. Aquifers which usually yield large supplies of good quality water are available in the Quaternary and Tertiary deposits, the Permian Crown Point Formation, the ?Jurassic De Souza Sandstone, parts of the Finke Group, the Mereenie Sandstone and the Pacoota Sandstone and Goyder Formation of the Pertaoorrta Group.

Non-metallic deposits include asbestos, barytes, beryl, building stone, clays, brown coal, dolomite, feldspar, fluorspar, gemstones, gypsum, kyanite, limestone, mica, ochre, phosphate, potash, salt, sand, gravel, and talc; only materials used in the building industry are at present worked on a commercial scale.

Metalliferous deposits in the Amadeus Basin sediments and fringing basement rocks include copper, lead, silver, tin, radioactive minerals, gold and ferruginous deposits; none are currently economic.

INTRODUCTION

General

Regional mapping of the Amadeus Basin by the Bureau of Mineral Resources was completed in 1964. The Basin was mapped in stages: Joklik and others in 1949-1951, Prichard, Quinlan and others 1956, Wells, Forman, Ranford and others from 1960 to 1964 inclusive. The results of these surveys have been published: Joklik 1955 (Bulletin 26), Prichard and Quinlan, 1962 (Report 61), Wells, Forman & Ranford 1964 and 1965 (Reports 65, 85), Ranford, Cook & Wells, 1966 (Report 86), Forman, 1965 (Report 87), Wells, Stewart & Skwarko 1966 (Report 88), Forman, Milligan & McCarthy 1967 (Report 103) and Wells, Ranford, Stewart, Cook & Shaw, 1967 (Report 113).

The area mapped lies in the southern part of the Northern Territory and in Western Australia between latitudes 23°S and 26°S and longitudes 127°30'E and 136°30'E (See fig. I1). The area is 575 miles long and 205 miles wide and occupies 118,000 square miles. Of this area about 60,000 square miles contains outcrop of the Amadeus Basin sediments and the remainder is underlain by basement rocks or sediments of the Great Artesian Basin (in the south-east) and the Canning Basin (in the west).

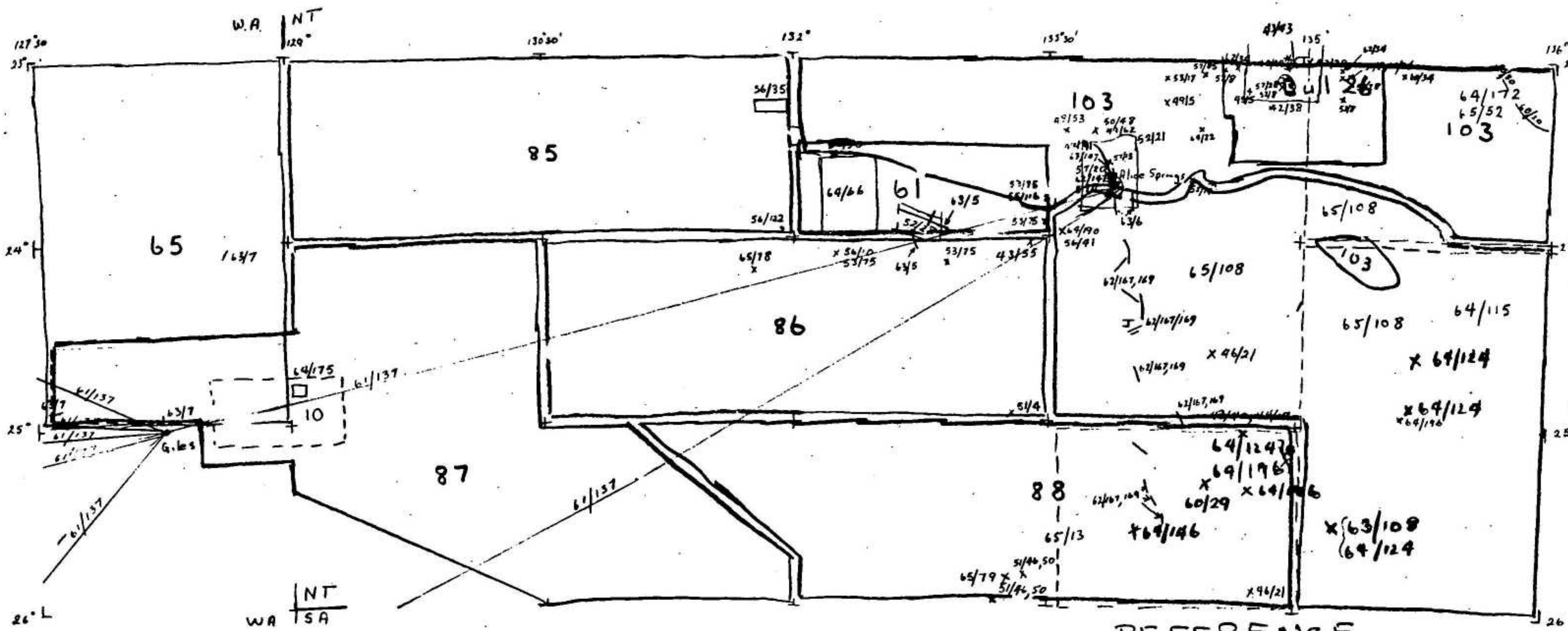
Geological tectonic, gravity, aeromagnetic and radiometric maps at 1:500,000 scale covering this area are included with this Bulletin (Plates 1-4, 9). The Bulletin is designed to summarize the important conclusions arising from the data already published and to give brief descriptions of the rock units mapped.

Isopachous maps and rock distribution maps for the units within the Proterozoic sediments, Larapinta Group, Pertaoorrta Group, Mereenie Sandstone and Pertnjara Group are included. The descriptions and correlations of the rock units are designed to show the relationship of sedimentation to the tectonic activity on the margins of the Basin. Structure and the petroleum prospects within the Basin are dealt with on a regional basis. Figure I2 shows the location of B.M.R. geological and geophysical surveys. Previous investigations have been dealt with in more detail in the Reports and only an outline of the early exploration of the region and a bibliography is given here.


LOCALITY MAP OF THE AMADEUS BASIN.
WEST IRIAN
NORTHERN NEW GUINEA BASIN
PAPUAN BASIN
MOREHEAD BASIN
CAPE VOGEL BASIN
ARAFURA SEA
TIMOR SEA
CORAL SEA
MESOZOIC SEDIMENTS
BONAPARTE GULF BASIN
KIMBERLEY BLOCK
DALY RIVER BASIN
ORD BASIN
GEORGINA
CARPENTARIA BASIN
LAURA BASIN
Cape York Peninsula
OCEAN
FITZROY BASIN
CANNING BASIN
KIDSON BASIN
WISO BASIN
NGALIA BASIN
GREAT ARTESIAN BASIN
DRUMMOND BASIN
BOWEN BASIN
YARROL BASIN
MARYBOROUGH BASIN
ESK RIFT
IPSWICH-CLARENCE BASIN
BUNDOCK, CLARKE RIVER AND STAR BASINS
TERTIARY/? MESOZOIC SEDIMENTS
UPPER PALAEOZOIC SEDIMENTS
STYX BASIN
1 ONSLOW BASIN
2 MERLINLEIGH BASIN
3 GASCOYNE BASIN
4 BIDGEMIA BASIN
5 BYRO BASIN
CARNARVON BASIN
AMADEUS BASIN
EROMANGA BASIN
ADAVALE BASIN
SURAT BASIN
OFFICER BASIN
EUCLA BASIN
PERTH BASIN
LAKE FROME EMBAYMENT
DEVONIAN SEDIMENTS
COONAMBLE BASIN
OXLEY BASIN
LORNE BASIN
PIRIE-TORRENS BASIN
MURRAY BASIN
SYDNEY BASIN
ST VINCENT BASIN
ADELAIDE
Great Australian Bight
OTWAY BASIN
GIPPSLAND BASIN
BASS BASIN
TASMANIA BASIN
INDIAN
SOUTH PACIFIC OCEAN
100 0 100 200 300 400 500
MILES
REFERENCE
Main Basins
Subdivisions of Basins
Basins under Main Basins
Other Basins and Provinces
Boundaries indicated by geophysical anomalies
Mainly non-prospective for petroleum
B.M.R. P.E.B. July, 1965.

LOCATION OF AREAS COVERED BY B.M.R. BULLETINS, REPORTS AND RECORDS — AMADEUS BASIN.

I2.



REFERENCE

Bulletins — Bull 26

Reports — 85

Records — 63/5

—— Traverse

× Point Locality

□ Area

General Reference Records

1964/34

1963/152

1962/24

1959/40

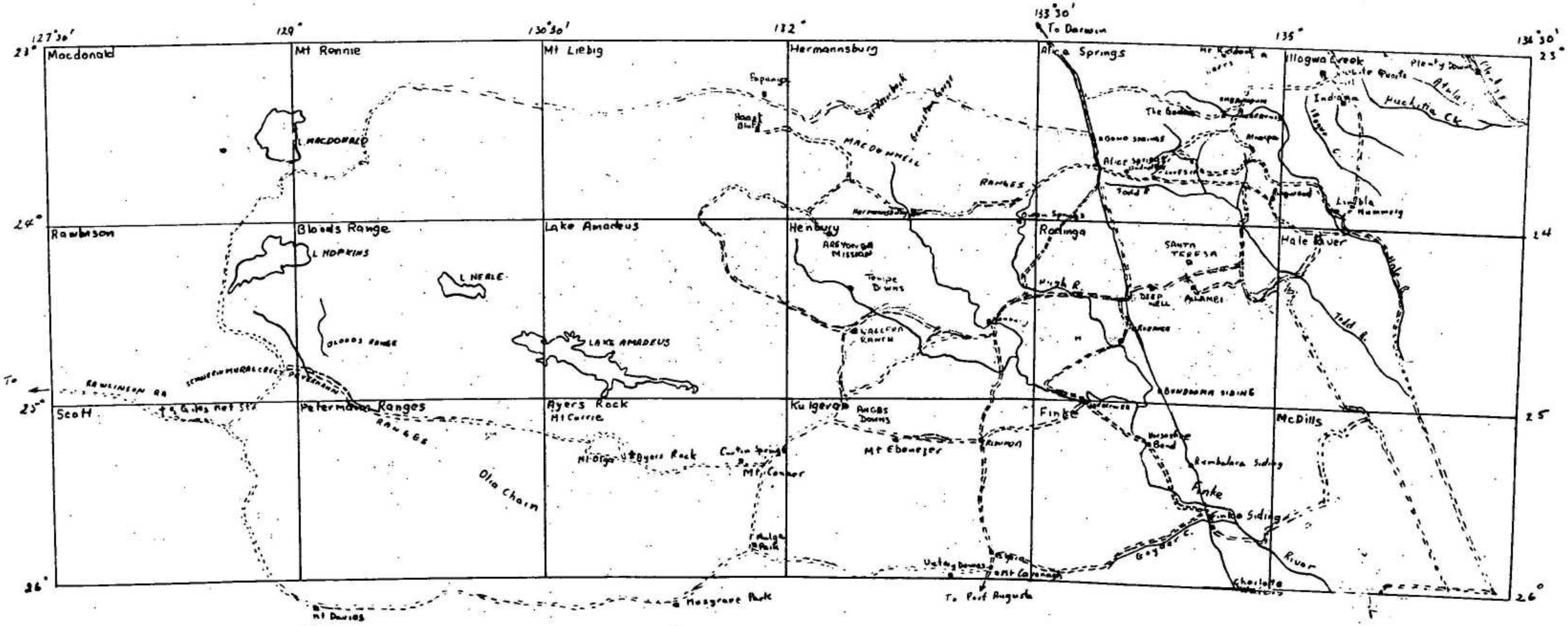
59/77

62/6

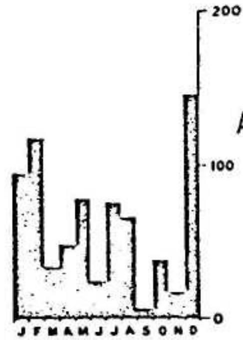
65/126

65/128

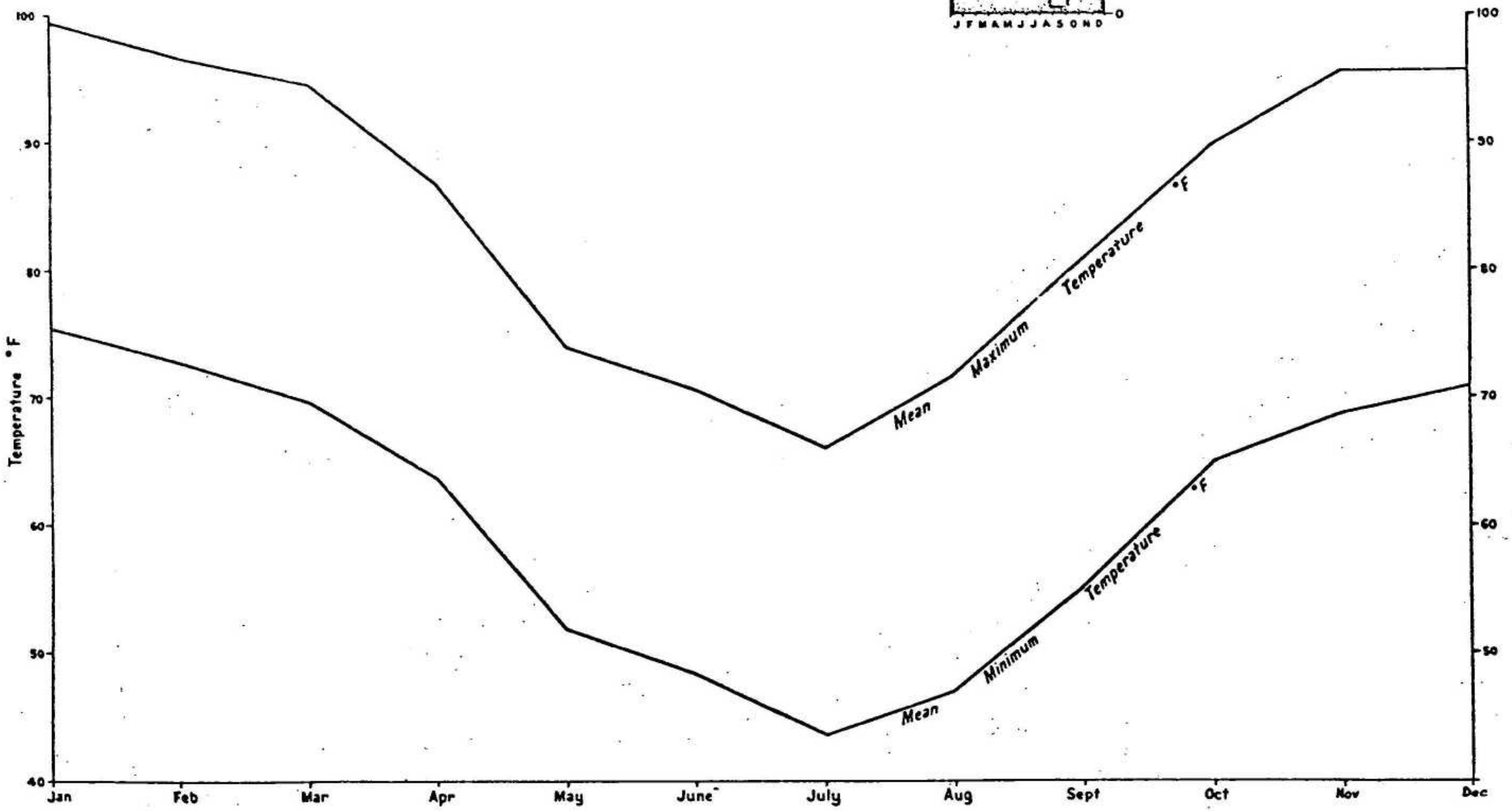
MAIN ACCESS ROUTES - AMADEUS BASIN.



METEOROLOGICAL DATA
GILES WEATHER STATION
(Average 1957 - 1962 inc.)



Average Rainfall in Points
(1957 - 1962 inc.)



Bureau of Mineral Resources, Geology and Geophysics. April 1964.

Figure I3 shows the main access routes to the area and the location of a number of cattle stations and tourist resorts most of which are served by aerodromes.

Climate

Central Australia is within the Arid Zone, as defined by Meigs (1953), as the rainfall is not adequate for the regular production of crops. The diurnal and seasonal variations in temperature are large and the median annual rainfall is between 5 and 10 inches (Australian Water Resources Council, 1963). This is less than the potential free-water evaporation, which is between 94 and 104 inches (Slatyer, 1962).

The Commonwealth Bureau of Meteorology (unpublished data) considers that high pressure weather systems are dominant over the area at all times of the year, and that dry weather is experienced on more than 92 percent of days (in the year). With the exception of localized thunderstorms, rainfall over central Australia is not an orographic phenomenon, but is the direct result of anomalies in the large-scale atmospheric circulation. A synoptic situation which commonly produces rain is that of an intense trough, between high pressure centres, moving from west to east. The north-westerly air flow preceding the trough introduces a deep mass of moist air into the area. Condensation and precipitation of this moisture results if a simultaneous depression to the north-west or to the south-east causes sufficient uplift.

Slatyer (1962) has shown that the average monthly rainfall is greater in the summer than in the winter months and the monthly averages are lowest in the south-eastern part of the area, where the surface elevation is lower.

Not all falls of rain will be sufficient to promote vegetative growth or produce run off. Slatyer (1962) expects that there would be 0.6 and 2 occurrences of 'initial effective rainfall' per annum at Charlotte Waters and at Alice Springs respectively. Quinlan and Woolley (1966) have estimated the probability to be 50 percent, for a return period of less than 40 days, for floods in the Todd River, and that for a period of less than one year to be 91 percent. On this basis it could be expected that run off would not follow falls of rain during one year in 10.

Droughts, or long periods of rainfall deficiency, can be expected as fairly regular events. Foley (1957), using records of rainfall since 1880, has designated periods of drought and assessed the severity of each.

Early Exploration of the Region

In 1860 the area now known as the Northern Territory was legally under New South Wales administration. Attempts at settlement in the north had been unsuccessful and the nature of the southern part of the Territory which lay in the centre of Australia was unknown. John McDouall Stuart (1865) was the first explorer to try and cross Australia from south to north, and became the first white man to enter the Amadeus Basin. In 1860, he travelled due north from Chambers Creek, near Port Augusta in South Australia, to the Finke River which he then followed to the Hugh River. He crossed the James Range and the Waterhouse Range and the MacDonnell Ranges. Stuart crossed the Chewings Range between Paisley Bluff and Brinkley Bluff at Stuart Pass and then proceeded northwards to Attack Creek north of Tennant Creek. He returned south by the same route. In his second attempt in 1861 he followed the same route and penetrated farther north to Newcastle Waters, but was again forced to return. In his third and successful attempt he left Adelaide (in October 1861) and reached the Indian Ocean at Van Diemans Gulf in July 1862. On his return to Adelaide, the South Australian Government applied for annexation of the whole of the Territory. Their request was granted and confirmed on July 6th, 1863.

In 1872 the overland telegraph line from Adelaide to Darwin was completed, the contract taking about two years. Probably the earliest pastoral leases granted were in 1872 for "Undoolya" (nos. 1 and 2) and "Owen Springs" (nos. 3, 4 and 5).

During 1872-1874 Ernest Giles (1889) set out to explore the country west of the telegraph line. In 1872 he travelled from Chambers Pillar up the Finke River and then south of the MacDonnell Range to Gosses Bluff and then west-north-west to the Ehrenberg Range. From the Ehrenberg Range he travelled southwards to Lake Amadeus and then returned to Chambers Pillar. In 1873 he started from Ross' Waterhole on the Alberga River and travelled westerly, near the present South Australia-Northern Territory border to the Musgrave, Mann and Tomkinson Ranges and farther west into Western Australia.

On his return trip he travelled northwards and explored the Rawlinson Range, Schwerin Mural Crescent, Petermann Ranges and Mount Olga. Also in 1873 Gosse (1874) left from the telegraph line at latitude 22°28'S and travelled west-north-west and then south-west to Mount Liebig. He then travelled southwards to the eastern arm of Lake Amadeus and to Ayers Rock which he named. He then continued to near the Warburton Ranges in Western Australia and returned via the Mann and Musgrave Ranges and the Alberga River.

In 1876, Giles (1889) started from Perth, Western Australia and travelled via Geraldton and the Ashburton Range to the Rawlinson and Petermann Ranges and then south-eastwards to the telegraph line.

Tate (1880), recorded the occurrence of large plates of mica in the MacDonnell Ranges.

The first geologist to visit the Amadeus Basin was Chewings (1866) who in 1886 investigated the source of the Finke River. He revisited the Amadeus Basin on a number of subsequent occasions between 1891 and 1935 and published a number of papers (Chewings, 1891, 1894, 1914, 1928, 1931, 1935).

Gold was discovered at Paddys Hole near Arltunga in 1887 and mica bearing pegmatites were being worked in the Harts Range area in November 1888. Before this, garnets from the Maude and Florence Creeks and the Hale River had been collected in large quantities and sold in some cases at high prices as rubies (Rennie, 1889).

Probably in 1888, East (1889) made geological observations along the telegraph line and between Alice Springs and the Harts Ranges. East drew the first section across the northern margin of the Amadeus Basin and recognized, but did not name, the Arunta Complex, Heavitree Quartzite and Bitter Springs Formation. Later in the same year Brown (1889) visited the gold diggings near Paddys Hole Creek and farther north-east, south of the Hale River. He revisited the area in 1889 or 1890 (Brown, 1890) and in his report recognized that the sedimentary rocks, which he suggested were of Cambrian age, overlay the metamorphic and plutonic rocks unconformably.

In 1889, Tietkins (1891) led an expedition westwards from Bond Springs Station and explored the country near the northern margin of the Amadeus Basin. He traversed around Lake Macdonald in Western Australia and then travelled south-east to Bloods Range and returned to the telegraph line via Mount Olga and Mount Conner.

Fossils were first found in the Amadeus Basin by Brown and Thornton in September 1890 probably near Tempe Downs (Brown, 1890b; Etheridge, 1892). Etheridge reported on additional fossils in 1893.

In 1892 the Horn Expedition (Tate and Watt, 1896, 1897; Winnecke, 1897) left from the Charlotte Waters Telegraph Station and made geological observations in the vicinity of the Finke River on the Finke, Charlotte Waters and Henbury Sheet areas. They collected many fossils from the Larapinta Group (Tate, 1896) and Tate later reported on the glacial sediments at Yellow Cliff (Tate, 1897).

In 1897 Carnegie (1898) traversed through parts of the MacDonald, Mount Rennie and Rawlinson Sheet areas on an exploring trip between Halls Creek and Coolgardie in Western Australia. He travelled to the east of Lake MacDonald and then west of the Rawlinson Ranges. Brown had investigated progress on the Arltunga Goldfield and the Harts Range mica-field (Brown, 1897). In 1897 gold was discovered and worked in the Heavitree Quartzite at White Range; and in 1902, gold was discovered in the Heavitree Quartzite south of Winnecke's Depot. The deposits were investigated by Brown (1902, 1903).

In 1901, two South Australian Government prospecting expeditions investigated the Musgrave, Mann and Rawlinson Ranges (Wells, 1904) and a further expedition investigated the Musgrave, Mann and Tomkinson Ranges in 1903 (Wells & George, 1904). In 1902, Maurice (Murray, 1904) crossed from south to north through the area near the Western Australian border. H. Basedow led a prospecting and geological expedition to the south-west in 1903 and recorded geological observations on the Musgrave Ranges, Mount Olga, Mount Conner and Ayers Rock.

Brown (1905) investigated the boundary of the Great Artesian Basin near Goyder Creek and the Finke River. In 1905 and 1906, F.R. George (George & Murray, 1907) led a government prospecting expedition into the south-west corner of the Northern Territory and then via Deering Creek to Alice Springs.

On the 1st January, 1911, the control of the Northern Territory by South Australia was terminated and the Territory was formally transferred to the Commonwealth Government of Australia.

STRATIGRAPHY

The Amadeus Basin (fig. I1) contains Upper Proterozoic, Cambrian, Ordovician, possible Silurian, Devonian and possible Carboniferous sediments resting upon Precambrian basement rocks. Superficial Permian, Mesozoic, Tertiary and Quaternary sediments overlie the Amadeus Basin sediments unconformably. The stratigraphy is summarized in Table S1 and the evolution of nomenclature in the northern part of the Amadeus Basin is shown in Table S2. Reference and type sections and areas of formations in the Amadeus Basin are shown in Fig. S3.

PRECAMBRIAN

Basement complex

The oldest rocks known in the area are the low and moderate grade metamorphics of the Arunta Complex (Mawson and Madigan, 1930) which crop out along the northern margin of the Amadeus Basin (BC-1 and BC-2). The age of the Arunta Complex is not known but an age of about 1800 million years has been obtained by the Rb/Sr method from a granite intrusive on the Huckitta Sheet area (Wilson et al 1960). Younger ages of about 400 million years have been obtained in the Harts Range area but Forman, Milligan & McCarthy (1967) correlate these with the age of the Alice Springs Orogeny. The most detailed study of the Arunta Complex was made by Joklik (1955). Others are by Prichard & Quinlan (1962), Wells, Forman & Ranford (1964 and 1965), Forman, Milligan & McCarthy (1967).

The Arunta Complex is overlain by little altered to low grade metamorphics and volcanics in the north-western margin of the Amadeus Basin. These units have not been named.

Low, moderate and high grade metamorphics crop out to the south of the Amadeus Basin in the Musgrave Ranges - Mann Range area in South Australia. These are overlain unconformably by a volcanic sequence in the Warburton Range Sofoulis (1962) and Horwitz and Soufoulis (1963) - Tolly Camp area Johnson (1963), in Western Australia. A similar succession occurs in the Rawlinson Range, Bloods Range, Petermann Ranges area in the south-western margin of the Amadeus Basin. These were named the Mount Harris Basalt, Bloods Range Beds (Forman, 1965) and Dixon Range Beds (BC-3) (Wells et al

TABLE S1

STRATIGRAPHY OF THE AMADEUS BASIN

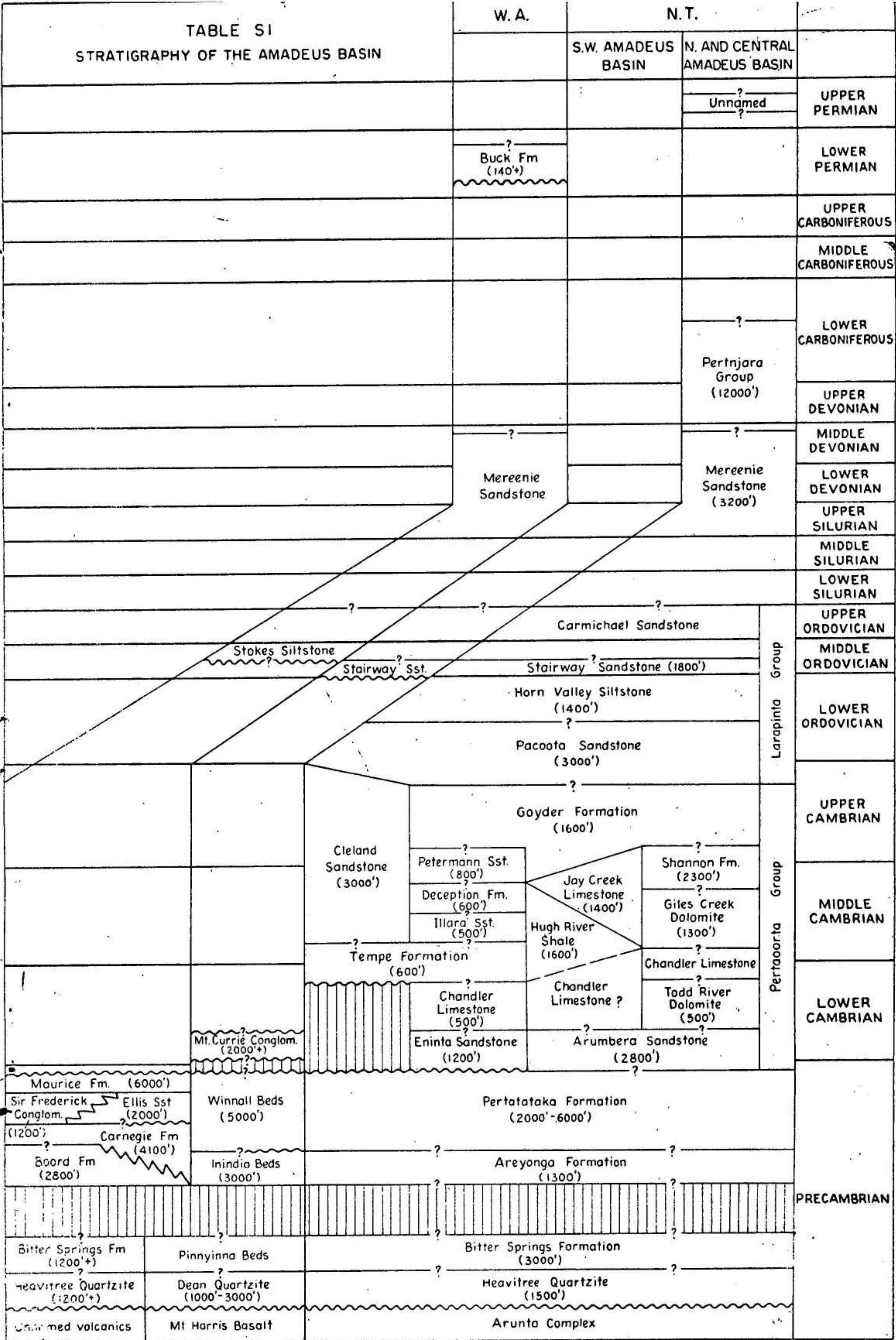


TABLE S2

EVOLUTION OF STRATIGRAPHIC NOMENCLATURE, NORTHERN PART OF AMADEUS BASIN

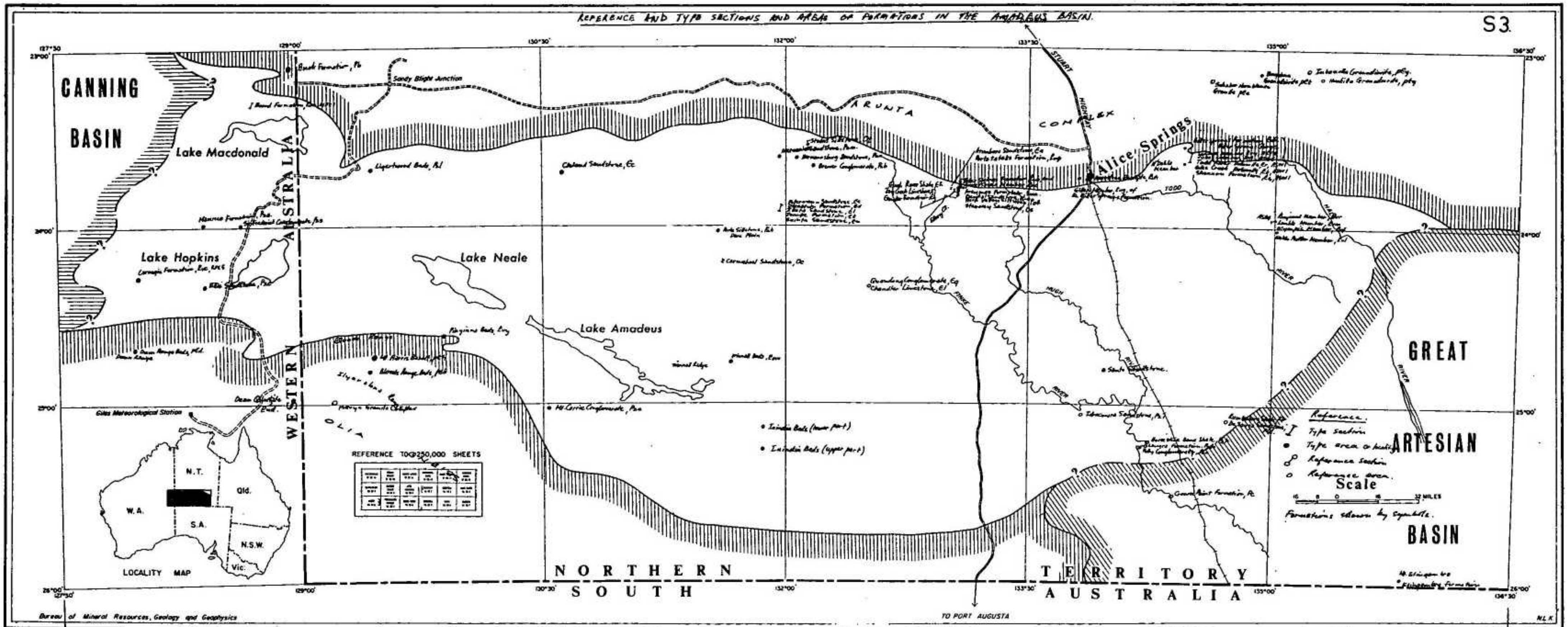
Pre 1932			Madigan, 1932		Chewings, 1935		Prichard & Quinlan, 1962	
Walker Creek Series (1)		Pertnjara Series (3)	Pertnjara Series		Pertnjara Series		Pertnjara Formation	
			Larapintine Series	Mareenie Sandstone	Larapinta Series	Marena Red Sandstone	Mereenie Sandstone	
				Horn Valley Beds		Mareena Valley Shales and Mudstone		Stokes Formation
Mareeno Bluff Series (1)						Stairway Quartzite and Sandstone		Stairway Sandstone
						Stairway Valley Beds		Horn Valley Formation
		Pacoota Quartzite		"No. 4 quartzite"		No. 4 Quartzite		Pacoota Sandstone
	Pataoorrta Series (2)	Pertaoorrta Series (3)	Pertaoorrta Series		Pertaoorrta Series		Pertaoorrta Group	Western MacDonnell Ranges
								Goyder Formation
								Jay Creek Limestone
								Hugh River Shale
				"No. 3 quartzite"		No. 3 Quartzite	Arumbera Greywacke	
Helen Springs Series (1)	Pataknurra Series (2)	Pertaknurra Series (3)	Pertatataka Series		Pertatataka Series		Pertatataka Formation	
				No. 2 quartzite		No. 2 Quartzite	Areyonga Formation	
			Pertaknurra Series		Pertaknurra Series		Bitter Springs Limestone	
				Heavitree quartzite		No. 1 Quartzite	Heavitree Quartzite	
Arunta Complex			Arunta Complex		Arunta Complex		Arunta Complex	

(1) Chewings (1894)

(2) Mawson & Madigan (1930)

(3) Chewings (1931)

Wells, Forman & Ranford, (1965(b))		Ranford, Cook & Wells, 1965		Wells, Ranford, Stewart, Cook & Shaw, 1966		Revision of Nomenclature in this Bulletin
Pertnjara Formation		Pertnjara Formation		Pertnjara Formation.		Pertnjara Group
Mereenie Sandstone		Mereenie Sandstone		Mereenie Sandstone		
		Larapinta Group		Larapinta Group		
Stokes Formation		Stokes Formation		Stokes Formation		Carmichael Sandstone Stokes Siltstone
Stairway Sandstone		Stairway Sandstone		Stairway Sandstone		
Horn Valley Siltstone		Horn Valley Siltstone		Horn Valley Siltstone		
Pacoota Sandstone		Pacoota Sandstone		Pacoota Sandstone	N'Dahla Member	
Pertaoorrta Formation		Pertaoorrta Group		Pertaoorrta Group		
Western MacDonnell Ranges	Gardiner Range	Western MacDonnell Ranges	Central Amadeus Basin	N.E. Amadeus Basin		
Goyder Member	Goyder Member	Goyder Formation	Goyder Formation	Goyder Formation		
Jay Creek Limestone Member	Petermann Sandstone Member	Jay Creek Limestone	Petermann Sandstone	Shannon Formation		
	Deception Member		Deception Formation	Giles Creek Dolomite		
	Illara Sandstone Member		Illara Sandstone			
			Tempe Formation			
Hugh River Shale Member	Tempe Member	Hugh River Shale	Chandler Limestone	Chandler Limestone Todd River Dolomite		
Arumbera Greywacke Member	Eninta Sandstone Member	Arumbera Greywacke	Eninta Sandstone Quandong Conglomerate	Arumbera Sandstone		
Pertatataka Formation		Pertatataka Formation		Pertatataka Formation Cyclops Member	Julie Member Waldo Pedlar Member Olympic Member Limbla Member Ringwood Member	
Areyonga Formation		Areyonga Formation		Areyonga Formation		
Bitter Springs Limestone		Bitter Springs Limestone		Bitter Springs Formation	Loves Creek Member Gillen Member	
Heavitree Quartzite		Heavitree Quartzite		Heavitree Quartzite		
Arunta Complex		Arunta Complex		Arunta Complex		



REFERENCE AND TYPE SECTIONS AND AREAS OF FORMATIONS IN THE AMADEUS BASIN.

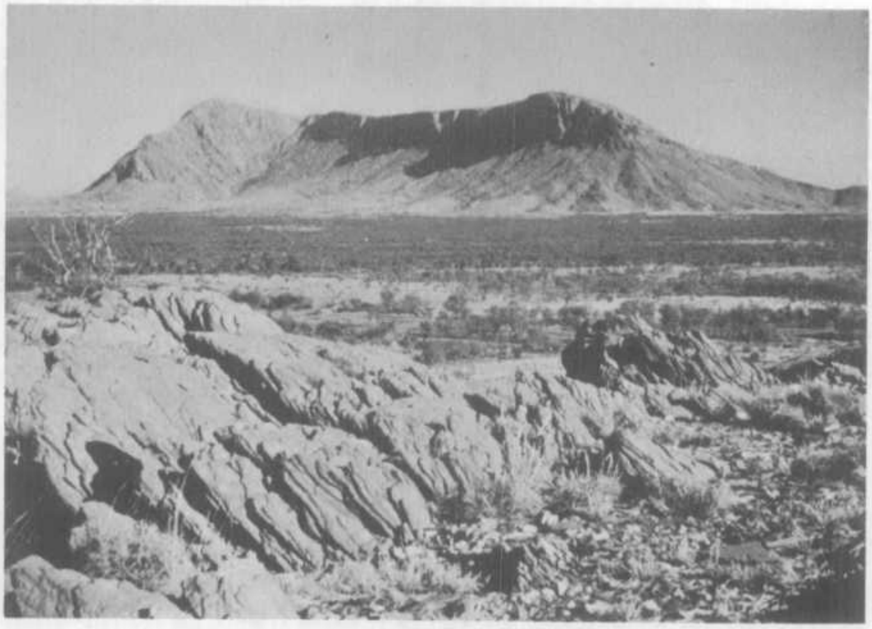


Fig. BC-1 Arunta Complex metamorphics in foreground near Blanche Tower and Precambrian Quartzite in the background.
G/9126

Fig. BC-2 Precambrian crystalline rocks in foreground and basalt unconformably beneath Heavitree Quartzite at Mount Strickland in the Kintore Range.
G/9127

Fig. BC-3 Dixon Range Beds in the Dixon Range Western Australia. Dean Quartzite in the Robert Range on the horizon.
G/9157

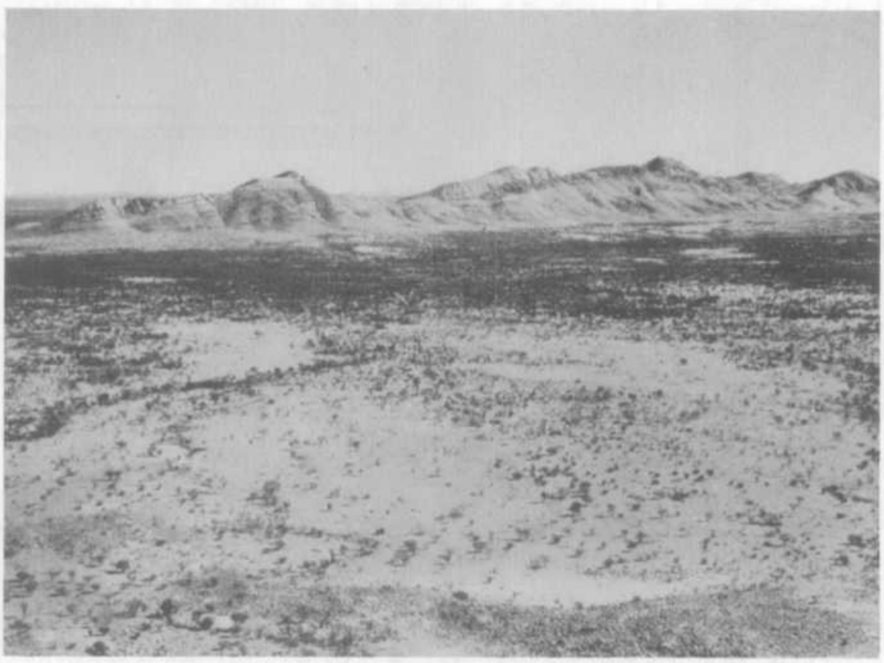


Fig. BC-4 Precambrian Quartzite at Mount Udor, looking west from Mount Putardi.
G/4369

1964). The Bloods Range Beds and Mount Harris Basalt are either little altered or metamorphosed to porphyroblastic schist, gneiss and granite.

The largest body of metasomatic granite in this area the "Pottoyu Granite Complex" has a total rock age by the Rb/Sr method of about 1200 million years and mineral ages of about 600 million years. The 600 million years age is clearly related to the Petermann Ranges Orogeny (Forman 1965) and at that time the rock probably acquired its granitic texture. The low and moderate grade gneiss (named Olia Gneiss, Forman 1965) and granite which formed during the Petermann Ranges Orogeny have not been differentiated from the older gneisses of the Musgrave-Mann area. The older gneisses have been converted to phyllonite or cataclasite in the southern part of the Ayers Rock Sheet area (McCarthy pers comm). The 1000 million years age by the Rb/Sr method, on muscovite from pegmatite near Kulgera (Wilson et al. 1960), suggests that these rocks in the south-eastern margin of the Amadeus Basin were not metamorphosed during the Petermann Ranges Orogeny.

PROTEROZOIC

Nomenclature

The nomenclature of the Precambrian rocks of Australia is under review. In this Bulletin the term Proterozoic is used for the rocks lying below Cambrian sediments and in most places immediately above the crystalline basement rocks of the Precambrian Arunta and Musgrave-Mann Complexes. The general terms Proterozoic and Precambrian are used because there is doubt as to the precise age of the rocks involved. All the rocks occurring below the Heavitree Quartzite are referred to as Precambrian. The thick sequence of sediments volcanics and metasediments along the south-western margin of the Basin, intermediate in age between the basement complex and the Heavitree Quartzite, are included in this division.

Preliminary age dating on a few samples of the Amadeus Basin sediments suggest that the Pertatataka Formation, Areyonga Formation and possibly the Bitter Springs Formation are Adelaidean (lying below the base of the Cambrian and no more than about 1400 million years old) and that the Arunta Complex is probably Archaean. The age of the intervening rocks is uncertain. Many of the ages obtained in the crystalline basement rocks are those of later metamorphism and a comprehensive study on age determination of the Precambrian rocks is required before reliable correlations and sub-divisions are possible.

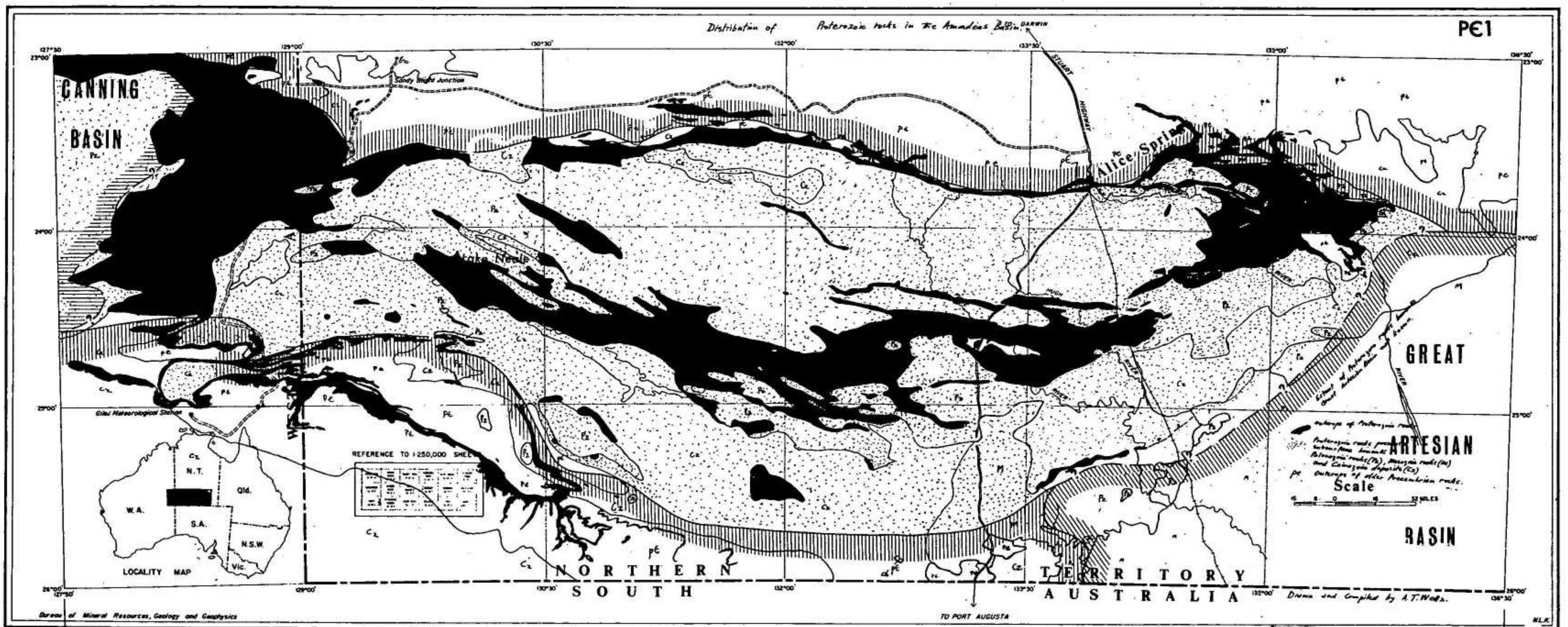
Distribution and thickness

Sediments considered to be Proterozoic in age crop out, or occur beneath thin superficial deposits, over about one quarter of the area of the Amadeus Basin (Fig. PCI). They crop out over large areas at the eastern and western extremities of the Basin, in narrow strips along its northern and south-western margins and in a wide median belt trending east-west through the centre of the Basin. A large area of Proterozoic sediments is probably concealed beneath superficial Cainozoic deposits in the southern part of the Basin. The central part of the Basin, which has exposures of Palaeozoic rocks, is undoubtedly underlain by Proterozoic sediments which are exposed in the cores of some of the eroded anticlines. The rocks assigned to the Proterozoic have been divided into thirteen formations and some of these formations have been further sub-divided into members. The relationship of these units is shown in PC 2.

The aggregate thickness of the Proterozoic rocks is greatest in the southern and western parts of the Basin where they comprise a total of about 20,000 feet of sediments. In the central part of the Basin the total thickness is generally less than 5000 feet, a figure estimated from incomplete exposures in the cores of eroded anticlines. In the north-eastern part of the basin the aggregate thickness is locally about 10,000 feet.

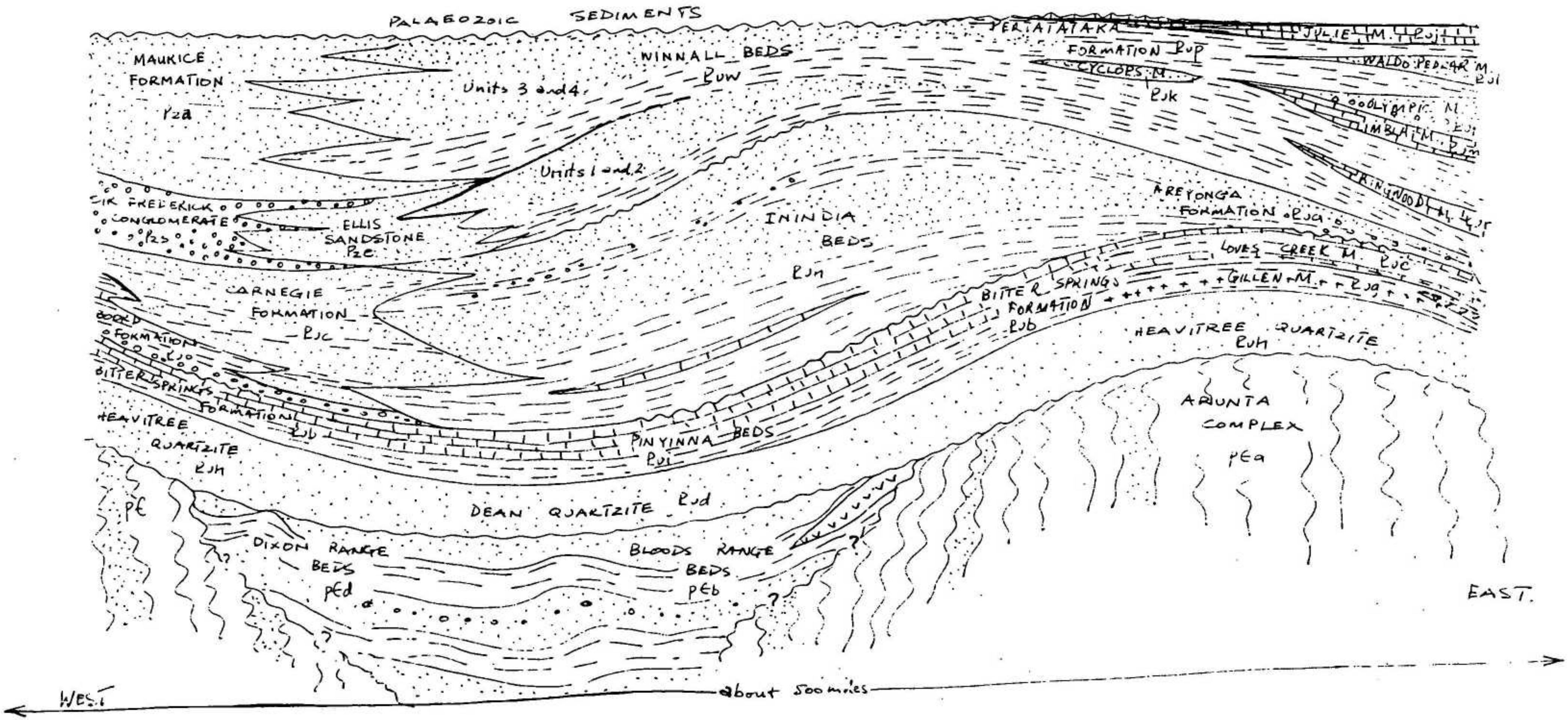
Relationships with older and younger rocks and influence of tectonism

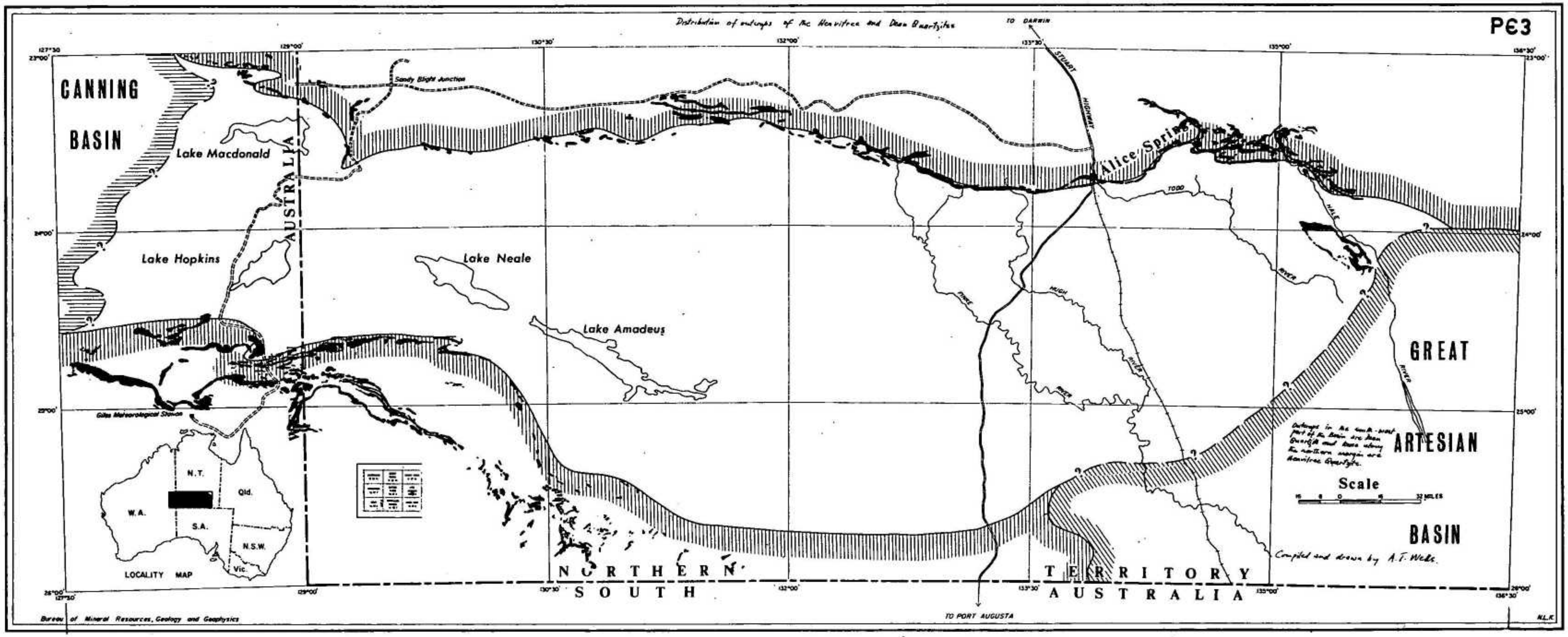
Along the northern and south-western margins of the Basin the Proterozoic formations have been infolded with crystalline basement rocks and complex nappe structures, recumbent folds and large thrusts have been formed. In exposures along the northern margin of the basin the Proterozoic sediments are conformably overlain by Palaeozoic rocks and they rest with an angular unconformity on crystalline rocks of the Arunta Complex and undifferentiated Precambrian rocks. The tectonic events affecting the sediments in this region and consequent formation of nappes and infolding with basement rocks took place in Upper Palaeozoic times.


PЄ1
Distribution of Proterozoic rocks in the Amadeus Basin.
DARWIN
CANNING
BASIN
Sandy Blight Junction
STUART
HIGHWAY
Alice Springs
Lake Neale
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
GREAT
ARTESIAN
BASIN
Scale
16 8 0 16 32 MILES
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Drawn and Compiled by A.T. Wells.
Bureau of Mineral Resources, Geology and Geophysics
pЄ Outcrops of older Precambrian rocks.
Scale

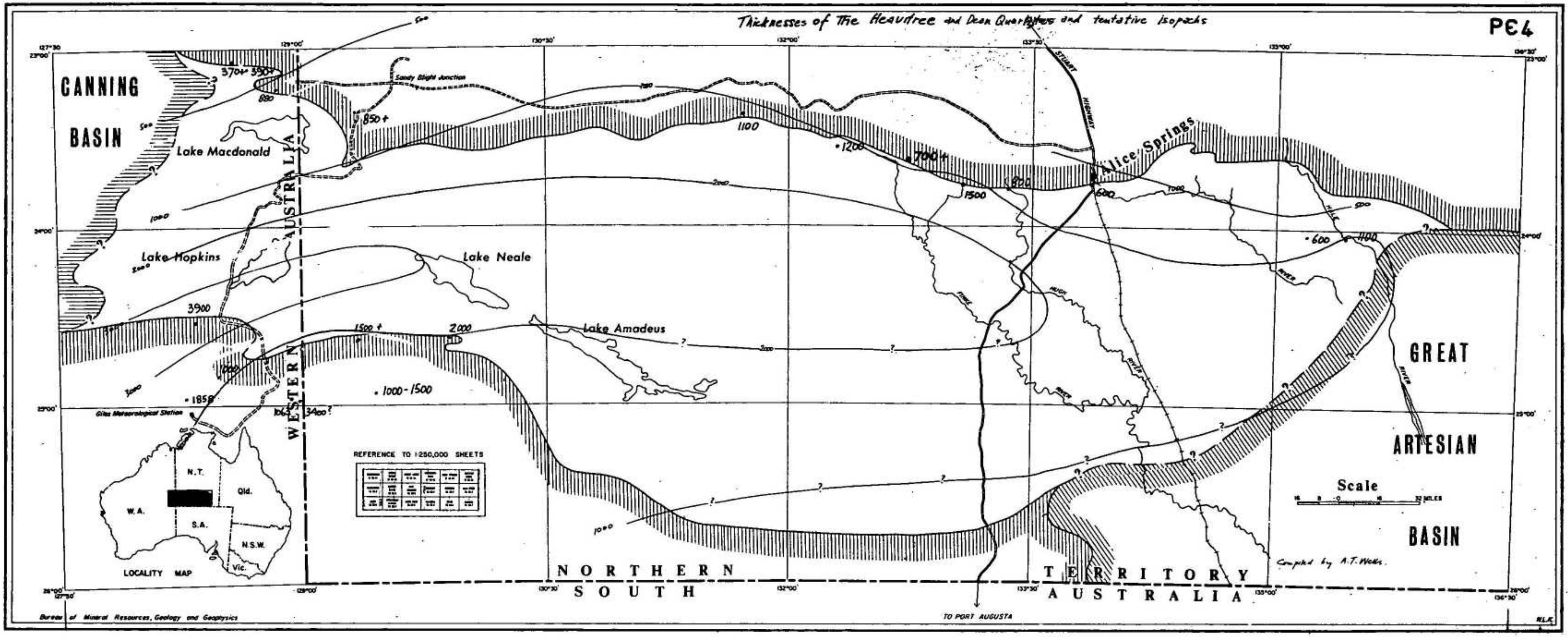
RELATIONSHIPS OF PROTEROZOIC UNITS IN THE AMADEUS BASIN

PE 2.





Distribution of outcrops of the Heavitree and Dean Quartzites
PЄ3
TO DARWIN
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
STUART
HIGHWAY
TODD
HALE
RIVER
FINKE
HUGH
RIVER
GREAT
ARTESIAN
BASIN
Giles Meteorological Station
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
Compiled and drawn by A.T. Wells.
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'



Thicknesses of The Heavitree and Dean Quartzites and tentative isopachs
PE4
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
STUART HIGHWAY
Giles Meteorological Station
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT
ARTESIAN
BASIN
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
Scale
Compiled by A.T. Wells.
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
3700+
3500+
880
850+
1100
1200
700+
800
1500
600
1100
3900
1500+
2000
1000
1000-1500
1858
1063
3400?

In the south-western part of the Basin the Upper Proterozoic rocks rest with a regional unconformity on the Bloods Range Beds, Mount Harris Basalt and other igneous rocks which are possibly younger than the crystalline basement rocks and may be Lower Proterozoic or even younger. Both the Proterozoic sediments and the units unconformably beneath were recumbently folded in later Proterozoic or early Cambrian time. Consequently most of the sediments in the Petermann Range Nappe, and generally along the southern margin of the Basin, were isoclinally folded, deeply eroded and overlain by Cambrian and Ordovician sediments. The magnitude of the angular unconformity between the Proterozoic and Lower Palaeozoic sediments decreases gradually northwards and in the northern parts of the Amadeus Basin sedimentation was continuous from Proterozoic to Cambrian.

Heavitree Quartzite and Dean Quartzite

The Heavitree Quartzite was named and defined by Joklik (1955) and Heavitree Gap, south of Alice Springs, is inferred as the type locality. The formation forms ridges and escarpments (PC-17) along the northern margin of the Amadeus Basin from the Hale River in the east to the Dover Range in Western Australia, a distance of about 950 miles. The correlate of the Heavitree Quartzite, the Dean Quartzite (Wells, Forman & Ranford, 1964, Forman 1966 in press) is known only from the south-western part of the Basin where it also forms ridges and escarpments that crop out between Mulga Park Homestead and the western end of the Rawlinson Range, a distance of 250 miles. The correlation of the two formations is based on their stratigraphic position at the base of similar successions. The distribution of outcrops and thickness of both formations is shown in PC-3/4.

The Heavitree Quartzite unconformably overlies crystalline rocks of the Arunta Complex (PC-18) and undifferentiated Precambrian rocks (PC-16). In the Kintore Range, in the west, it unconformably overlies slightly metamorphosed, flow banded amygdaloidal and vesicular, porphyritic basalt (BC-2). This basalt may be equivalent to the Mount Harris Basalt. The Heavitree Quartzite is overlain conformably throughout the basin by the Bitter Springs Formation.

The formation is predominantly white, slabby, silicified orthoquartzite with a very high maturity index, together with minor conglomeratic sandstone, shale and conglomerate all of which weather pink and grey. The highly siliceous nature of most of the quartzite ridges is due to surface weathering and excavations into the outcrop reveal a moderately friable sandstone. The phenomenon is probably a combination of concentration of silica in the surface layers of the sandstone and leaching of silica from deeper parts of the formation. It does not necessarily imply that the whole of the formation at depth is friable and porous. The quartz grains in the sandstone are moderately well rounded and average 1 mm across although in many places it is bimodal. The grains are commonly strained and show undulose extinction. The matrix is siliceous and has small amounts of muscovite, sericite and iron oxides. The sandstone may be in part ripple marked and cross-bedded with sun cracks and synaeresis cracks. Possible invertebrate tracks have been noted at Blanche Tower, at Temple Bar Gap and near Bitter Springs. In the Dover Range the sandstone is commonly foetid when struck with a hammer. In many places, noteably at Mount Rennie, it contains moulds which formerly housed pyrite crystals up to ½ inch across.

Conglomerate, arkose, greywacke sandstone and siltstone in variable proportions constitute the basal portion of the formation depending on the composition and topography of the underlying basement rocks. Minor siltstone is present interbedded with the sandstone but thicker sequences are generally found locally near the base of the formation and more commonly near its contact with the overlying Bitter Springs Formation. The basal siltstone is well exposed in Heavitree Gap, south of Alice Springs, where it is 30 feet thick and overlies weathered gneiss of the Precambrian Arunta Complex. In the area between Mount Liebig and Haasts Bluff the contact with the Arunta Complex is well exposed and where the Heavitree Quartzite overlies pinnacles of the Arunta Complex a local conglomerate is present, whereas 100-120 feet of siltstone is present in the eroded valleys.

Prichard and Quinlan (1962) describe three members in the Heavitree Quartzite at Ellery Creek. They are from the base -

700 feet - quartz sandstone, medium to coarse grained, cemented to quartzite.

200 feet - siltstone, coarse grained, with 40% medium to coarse quartz grains.

500 feet - quartz greywacke, medium grained, silicified to quartzite with pale yellow-brown argillaceous quartz siltstone up to 100 feet thick.

Condon (in Prichard and Quinlan, 1962) considers that the middle siltstone member is the same as the siltstone at the base of the formation at Heavitree Gap.

The metamorphism of the formation varies considerably and in the western exposures on the Macdonald Sheet area, as in many other places, the silicification is superficial resulting in a case-hardened effect. The metamorphism is generally more noticeable where thrusting and folding have produced a silicified quartzite. In places it may be shattered, brecciated, show strong schistosity and in other places is recrystallised to sericitic quartzite, sericite metaquartzite and schistose quartzite. Most of the original sedimentary structures, such as cross-bedding, have been obliterated by the metamorphism. The formation is generally free of quartz veins. In areas where the formation is infolded with the Arunta Complex, the relationship between the Heavitree Quartzite and adjacent schists appears to be conformable on the overturned limb. However, it may be deduced that the conformable schists were derived from the older unconformable high grade Precambrian rocks by retrograde metamorphism during the infolding, and the schistosity so formed would be parallel to the bedding in the Heavitree Quartzite.

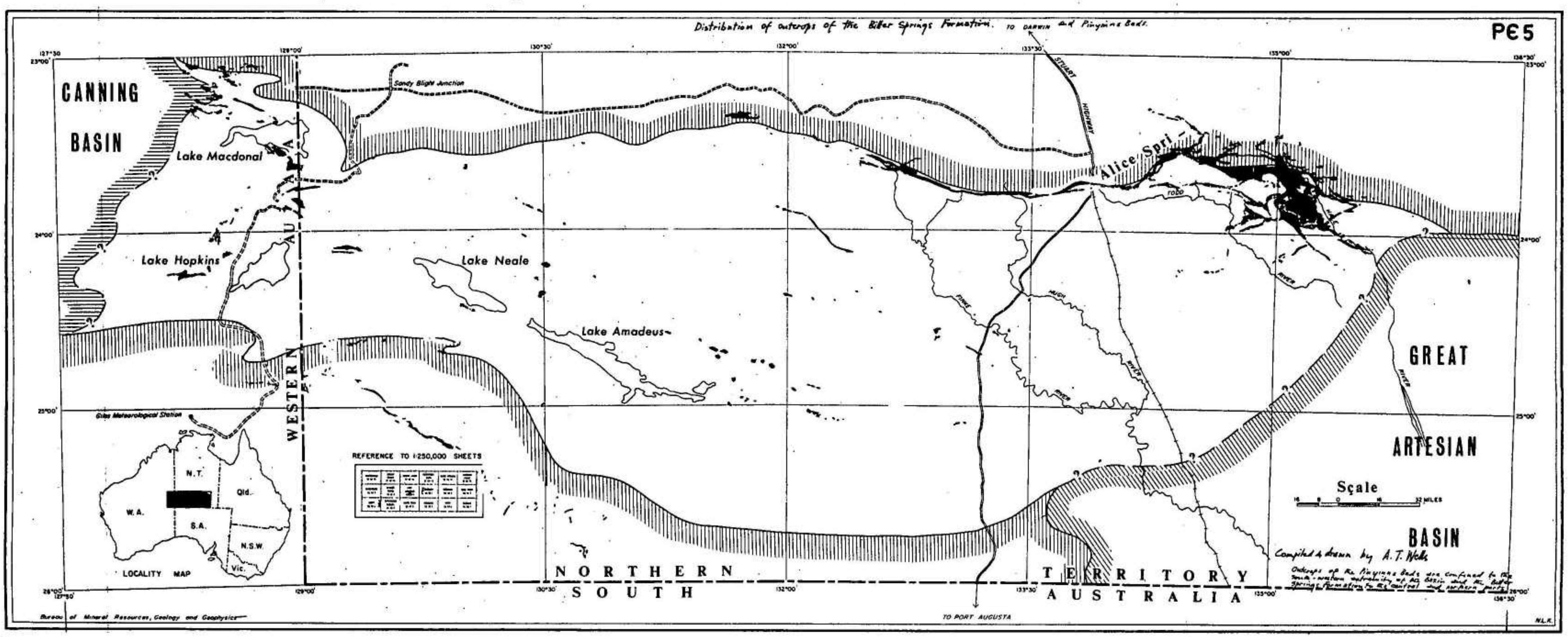
Some of the quartzite originally mapped as Heavitree Quartzite (Prichard and Quinlan, 1962) near Ormiston Gorge, and generally referred to as the Chewings Range Quartzite, has been shown to be part of the Arunta Complex and the Heavitree Quartzite overlies the metaquartzite of the Chewings Range unconformably. Forman, Milligan and McCarthy (1967) suggest that some of the quartzites here may be pre-Heavitree Quartzite and post Arunta Complex. The White Range Quartzite of Joklik (1955) has been shown to be Heavitree Quartzite.

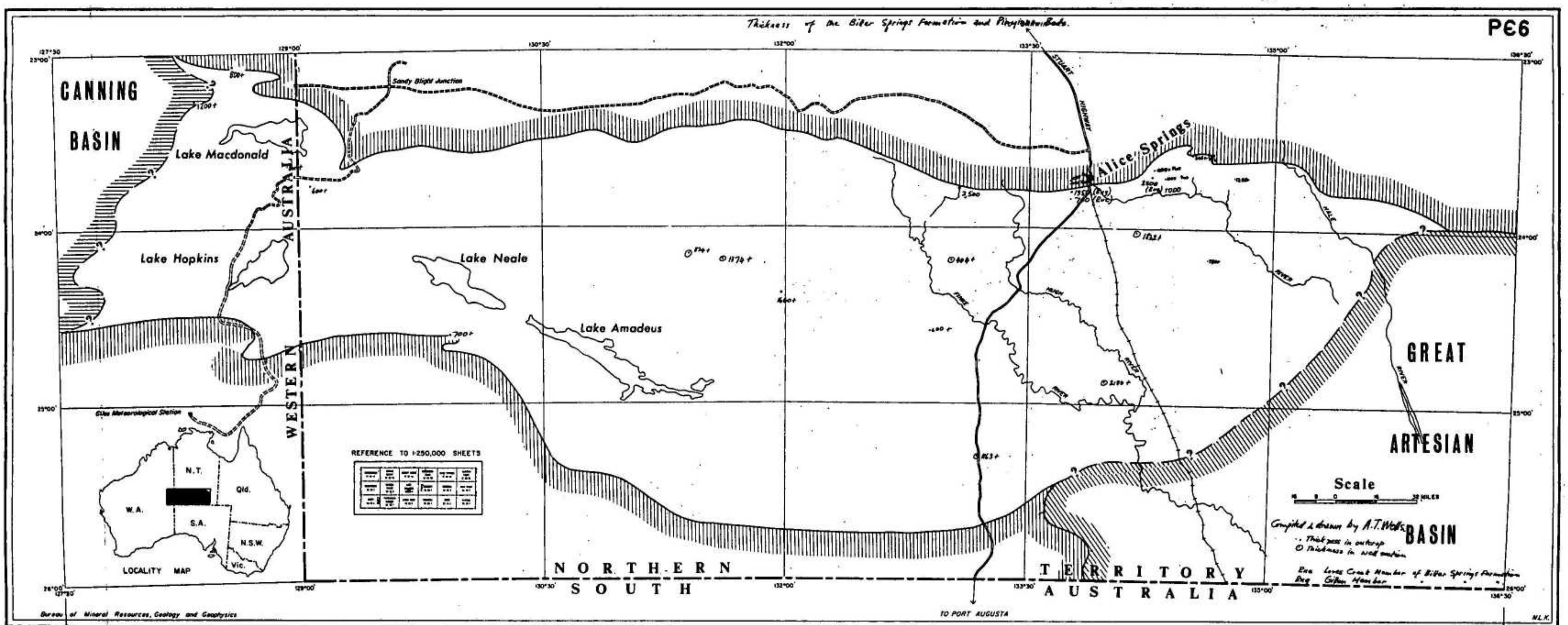
The thickness of the Heavitree Quartzite is known only at a few localities mainly because in most outcrops the beds are repeated in complex isoclinal folds making measurements impracticable. The known thicknesses and isopachs are shown in PC-3/4. There are no exposures of the Heavitree Quartzite in the central part of the basin. The isopachs suggest that the Heavitree

Quartzite was deposited in a shallow downwarp with an axial trend parallel to that of the Amadeus Basin but the lack of measurements from the centre of the Basin makes this conclusion very tentative. The thickest measured sections occur in the western part of the Basin in the Rawlinson Range-Dean Range area.

The extent of the formation suggests widespread deposition in a shallow marine, epicontinental sea under relatively stable conditions. The correlation of the formation with units of similar lithology and stratigraphic position in areas outside the Basin to the north, west and south suggests widespread deposition possibly on interconnected shelf areas. The coarse grained lower part of the formation suggests a littoral environment in contrast to the overlying beds which may have accumulated in a neritic zone.

The Dean Quartzite (Wells, Forman & Ranford, 1964, Forman, 1966 in press), forms many prominent ranges, hills and escarpments on the south-western margin of the Amadeus Basin. It consists of a thick sequence of fine to coarse quartzitic sandstone and minor conglomerate and in places sericitic quartz schist, siltstone, schistose sericitic quartzite and sericitic quartzite which overlies porphyroblastic schist, granite, Bloods Range Beds, Mount Harris Basalt and the Dixon Range Beds. The Dean Quartzite is apparently conformable on the Dixon Range Beds and Bloods Range Beds on the western side of the Basin but is unconformable on these older sediments further east. In places the basal parts of the Dean Quartzite contain small subangular fragments of basalt and vein quartz and hence an unconformity is deduced with the Mount Harris Basalt. The unconformity surface in the eastern area is uneven and is overlain by basal beds of conglomerate, greywacke, sandy siltstone and conglomeratic sandstone of varying thickness and in most places of local extent. Metamorphism of these basal beds has produced sericitic quartz-schist. In contrast to the Heavitree Quartzite, siltstone is apparently absent in the Dean Quartzite. In places the contact with older beds is a metamorphic gradational contact from granite or gneiss to quartzite and in places both the underlying rocks and Dean Quartzite have been partly converted to gneiss and granite. The metamorphism of the quartzite varies from slight to very strong depending on its position in the infolded parts of the recumbent fold. The rock types range from foliated and lineated quartzite and sericitic quartzite to friable sandstone.


Distribution of outcrops of the Bitter Springs Formation. and Pinyinna Beds.
PE5
TO DARWIN
STUART HIGHWAY
Sandy Blight Junction
CANNING
BASIN
Lake Macdonal
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Spri
GREAT
ARTESIAN
BASIN
Giles Meteorological Station
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
16 8 0 16 32 MILES
Compiled & drawn by A.T. Wells
Outcrops of the Pinyinna Beds are confined to the south-western extremity of the basin and the Bitter Springs Formation to the central and eastern parts.
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.


PЄ6
Thickness of the Bitter Springs Formation and Pinyinna Beds.
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Giles Meteorological Station
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
TODD
FINKE
HUGH
HALE
RIVER
GREAT
ARTESIAN
BASIN
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
Compiled & drawn by A.T. Wells
Thickness in outcrop
Thickness in well section
Loves Creek Member of Bitter Springs Formation
Gillen Member
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.

About 3900 feet of section was measured in the Dean Quartzite in the Robert Range in the Rawlinson Sheet area. Here it shows very little metamorphic effect and is a fine to coarse, pebbly, cross-bedded, moderately to poorly sorted sandstone with ripple marks. Lenses of conglomerate are common in the base of the formation.

The gneiss and granite which formed during the regional deformation of the Dean Quartzite have been dated (P.J. Leggo, B.M.R., 1965) as 600 million years old and this evidence together with its stratigraphic position suggest that the age of the formation is Proterozoic.

Bitter Springs Formation and Pinyinna Beds

The thick formation of mixed calcareous and arenaceous rocks that conformably overlies the Heavitree Quartzite was named the Bitter Springs 'Limestone' by Joklik (1955). The name was subsequently revised to Bitter Springs Formation by Wells et al. (1967, in press). The type locality is at Bitter Springs, east of Alice Springs, but because the formation is complexly folded here, the reference section has been selected at Ellery Creek and is figured in Wells et al. (op. cit.). Wells et al. (op. cit.) also recognised two members in the Bitter Springs Formation, the younger Loves Creek Member and the basal Gillen Member. These two members have been mapped in parts of the north-east Amadeus Basin.

The formation is best exposed along the northern margin and in the north-east part of the Basin, and discontinuous poor outcrops occur throughout the remainder of the area. The distribution of the formation and estimates of the thickness of the formation are shown in PG-5/6.

The rocks comprising the formation are laminated and flaggy, fine and some medium grained, tough, interbedded crystalline dolomitic limestone, crystalline dolomite, dolutite, dolarenite, calcarenite, shale, siltstone, gypsiferous siltstone and sandstone. The carbonate rocks are locally haematitic, micaceous, sandy or pelletic, cryptocrystalline to microcrystalline and contain banded pre-diagenetic chert laminae. Crystalline dolomite makes up the greater percentage of outcrops outside the northern and south-eastern parts of the Basin. Secondary silicification of the calcareous rocks is widespread and has produced laminae, lenses and beds of chert, silicified dolomite and limestone. Oolites are common in the dolarenite and calcarenite and the oolitic texture is retained where the rock is replaced by chert. Large masses of sheared and brecciated gypsum are associated with outcrops of the formation in several places, principally in outcrops between Johnstone Hill in the north-west to a point about 50 miles north of Mount Connor. Gypsum is also associated with the formation in outcrops on the south side of the Gardiner Thrust, on the north side of the Gardiner Range, and in the Ringwood Dome, about 65 miles east of Alice Springs. The gypsum is sheared and laminated and contains fragments of dolomite breccia and is mostly overlain by isoclinally folded, brecciated dolomite and limestone. In most of the occurrences the gypsum is probably involved in diapiric intrusions. Salt and gypsum was intersected in the formation in the Ooraminna No. 1, Mount Charlotte No. 1 and Erldunda No. 1 wells. A small thickness of thin-bedded, silty, fine grained, silicified, dark purple-brown sandstone with pseudomorphs after halite occurs at the top of the formation in the westernmost exposure in the Erldunda Range; salt casts in mottled green and red-brown siltstone are common in the Gillen Member in the north-eastern part of the Basin.

Discrete lenses of sandstone are present near the top of the Bitter Springs Formation (probably the Loves Creek Member) in the Parana Hill Anticline. The sandstone is white or pale brown, well sorted, medium grained and friable with very little interstitial material. In the section measured through the formation here the sandstone is 56 feet thick and its base is 200 feet below the exposed top of the formation. Thick beds of sandstone are present in the Gillen Member in the north-east part of the Amadeus Basin but sandstone is rare in outcrops outside this area, especially in the Loves Creek Member.

Prichard and Quinlan (1962) measured 2500 feet through the formation at Ellery Creek and this is the only complete measured section. The graphic log is figured in Wells et al. (1967, in press). Most of the formation at this locality is tough, dark grey, well bedded and laminated dolomite and cherty limestone. 100 feet of poorly exposed dark grey siltstone occurs at the base. The interval 1270-1890 feet above the base consists of dull red, argillaceous, non-dolomitic limestone which has no stromatolites. Colonial algae are found in the upper part of the formation in a darker dolomitic limestone and algal biostromes (PG-19, PG-30) and Collenia bioherms are common near the middle of the formation. The red argillaceous limestone and the carbonate rocks with stromatolites are part of the Loves Creek Member defined in the north-east part of the basin.

In many exposures the Bitter Springs Formation has steep dips and overturning and is intensely folded, brecciated and faulted because of the incompetent nature of the beds. Their incompetency is due mainly to the presence of thick evaporites in the sequence. This property of the formation has played an important role in determining the structural expression of the overlying sediments during deformation. A decollement has formed at the base of the formation and in many places large wedges of sediments have been thrust over younger rocks with the formation acting as a lubricating medium.

The formation is overlain conformably by the Proterozoic Carnegie Formation, or disconformably by the Boord Formation in the western part of the Basin. In the northern part of the Basin it is overlain either disconformably or with an angular unconformity by the Areyonga Formation and is locally overlain by the Pertatataka Formation. In the southern part of the Basin the formation is either disconformably or unconformably overlain by the Proterozoic Inindia Beds, and in places unconformably overlain by the Ordovician Stairway Sandstone, Cambrian Pertaoorrta Group, the Upper Palaeozoic Langra Formation and by the Proterozoic Winnall Beds. In the central part of the Basin the base of the formation is never exposed and upper contacts are rare. In some of the breached anticlines in this area it is disconformably overlain by the Areyonga Formation and overlain with an angular unconformity by the lower Middle Cambrian Tempe Formation of the Pertaoorrta Group.

McCarthy (A.M.D.L., 1965a) described metamorphic effects in the Bitter Springs Formation. In the Arltunga and Ormiston Nappe Complexes it is metamorphosed to phyllite and slate, and brecciation, crushing and development of fracture cleavage is noticeable near the nappe complexes. Samples of the formation from the Ooraminna No. 1 well were examined and found to be recrystallised which may be caused by the incompetent folding of the formation. The carbonate rocks have been plastically deformed by differential shearing after diagenesis.

A Rb/Sr determination on a single specimen of shale from the Bitter Springs Formation in the Mount Charlotte No. 1 well, indicated an apparent maximum age of 1170 m.y. (Bofinger, pers. comm.).

Wells et al. (1967 in press) divided the Bitter Springs Formation into two members, the Gillen Member overlain by the Loves Creek Member. This division into two members follows partly the work carried out by Banks (1964) which entailed a detailed study of the Bitter Springs Formation principally in the north-east part of the Basin.

The type section of the older member of the Bitter Springs Formation, the Gillen Member, is just south of Mount Gillen, west of Alice Springs. In some areas, particularly east of Ross River, the member is overlain with an angular unconformity by the Areyonga Formation. The member consists mainly of dolomite with lesser amounts of sandstone, siltstone and shale. Most of the dolomite occurs in the middle and upper parts of the unit and is dark grey, bluish grey or grey-brown, fine grained, laminated, very closely jointed and fractured, tough and weathers grey-green. Veins of quartz, calcite and earthy magnesite occur in places. Schmerber (1966a & b) considers that the dolomite in the lower part of the formation can be considered as primary or pre-diagenetic because of its relationship with sulphates, silica and salt deposits. Siltstone occurs mostly near the base. It is commonly white or green, also red or brown, slightly micaceous, laminated to thin bedded, tough and has interbeds of green micaceous shale. Friable, poorly bedded, medium to coarse grained, slightly kaolinitic sandstone is found in places near the base of the member but is not common. A prominent bed of sandstone and granule conglomerate, 200 feet thick, occurs in the member near Limbla Homestead and in places contains halite pseudomorphs. Halite pseudomorphs are also common in the siltstone of the member, and large 'hopper'* shaped forms up to 3" across were noted. Brecciated and plastically deformed gypsum is associated with the member in the Ringwood Dome and most of the occurrences of gypsum in the Amadeus Basin are associated with the Bitter Springs Formation. Halite which was penetrated in several well sections was probably derived from this member.

The upper member of the Bitter Springs Formation, the Loves Creek Member, lies conformably on the Gillen Member and is overlain disconformably or with an angular unconformity by the Areyonga Formation. 18 miles south-west

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* Read, 1960, pp. 216 (Rutley's Elements of Mineralogy)

of Alice Springs the member is locally overlain by the Pertatataka Formation. Ellery Creek is the type locality but the reference section given in Wells et al. (1967, in press) is compiled from several localities. The member consists mostly of siltstone with interbeds of chert, dolomite and rare limestone. The siltstone is commonly calcareous, red-brown, poorly bedded, friable to tough and is characterised by the presence of white bleached spots. Haematite concretions are present and chert is plentiful. The dolomite is tough, laminated, fine grained and has some interbeds of edge-wise conglomerate and chert bodies. Limestone is rare and occurs as thin beds commonly with algae, interbedded with the red siltstone. It is dark grey, white, tough and cavernous with elongate chert nodules. The dolomite is grey-brown, fine grained and has abundant Collenia like algae.

Probably most of the outcrops of the Bitter Springs Formation, outside the northern margin and the north-eastern part of the Basin, could be included in the Loves Creek Member because the dolomite is usually rich in stromatolities and commonly has beds of red-brown spotted siltstone.

Basic volcanics are associated with the Loves Creek Member and they may occur at the base, at the top or interbedded with the member. The volcanics are found only in outcrops east of Alice Springs and were intersected in the Ooraminna No. 1 Well. the rock is a fine grained, amygdaloidal, oligoclase and albite spilite and is mostly deeply weathered. The volcanics are interbedded with and overlain by ferruginous and cherty fine grained rocks up to five feet thick. These are believed to be sediments interbedded with the volcanics.

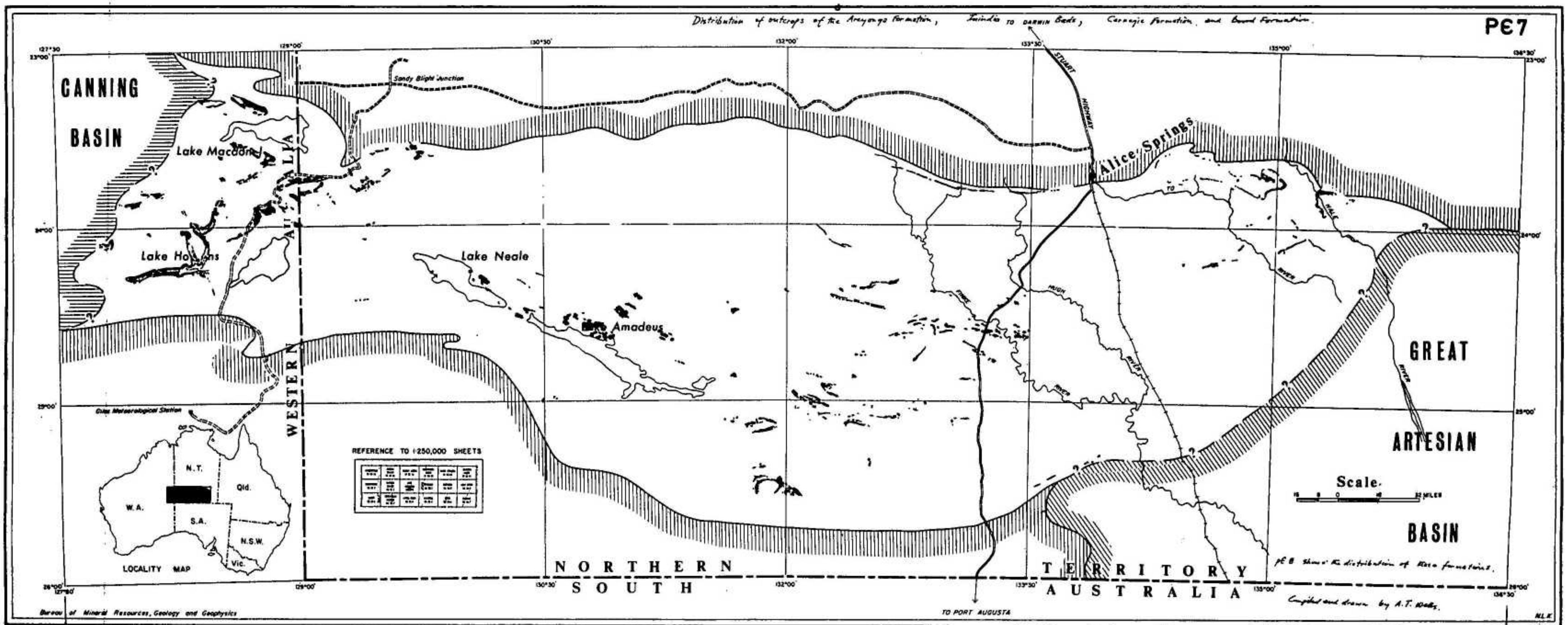
The sequence of crystalline dolomite, limestone with a few poorly preserved stromatolites, and siltstone associated with gypsum, which conformably overlies the Dean Quartzite in the south-west part of the Amadeus Basin, is defined as the Pinyinna Beds (Forman, 1966 in press). They are the infolded and generally altered portion of the Bitter Springs Formation within or immediately adjacent to the regional recumbent fold in the Petermann Ranges. The Pinyinna Beds are unconformably overlain by the Mount Currie Conglomerate. A basal siltstone of the Pinyinna Beds, up to 700 feet thick, generally overlies the Dean Quartzite and it is more widely distributed than the carbonate rocks within the cores of many isoclinal and recumbent folds.

The Pinyinna Beds are commonly brecciated, contorted and silicified. In recumbent folds they are sheared and recrystallised to medium grained, lineated schist, slate and phyllite, or only slightly recrystallised; in places they contain calcite veins. In places the basal siltstone is metamorphosed to a sericite schist. Boulders of dolerite within some areas of outcrop of the carbonate rocks suggest that they may be intruded by dolerite.

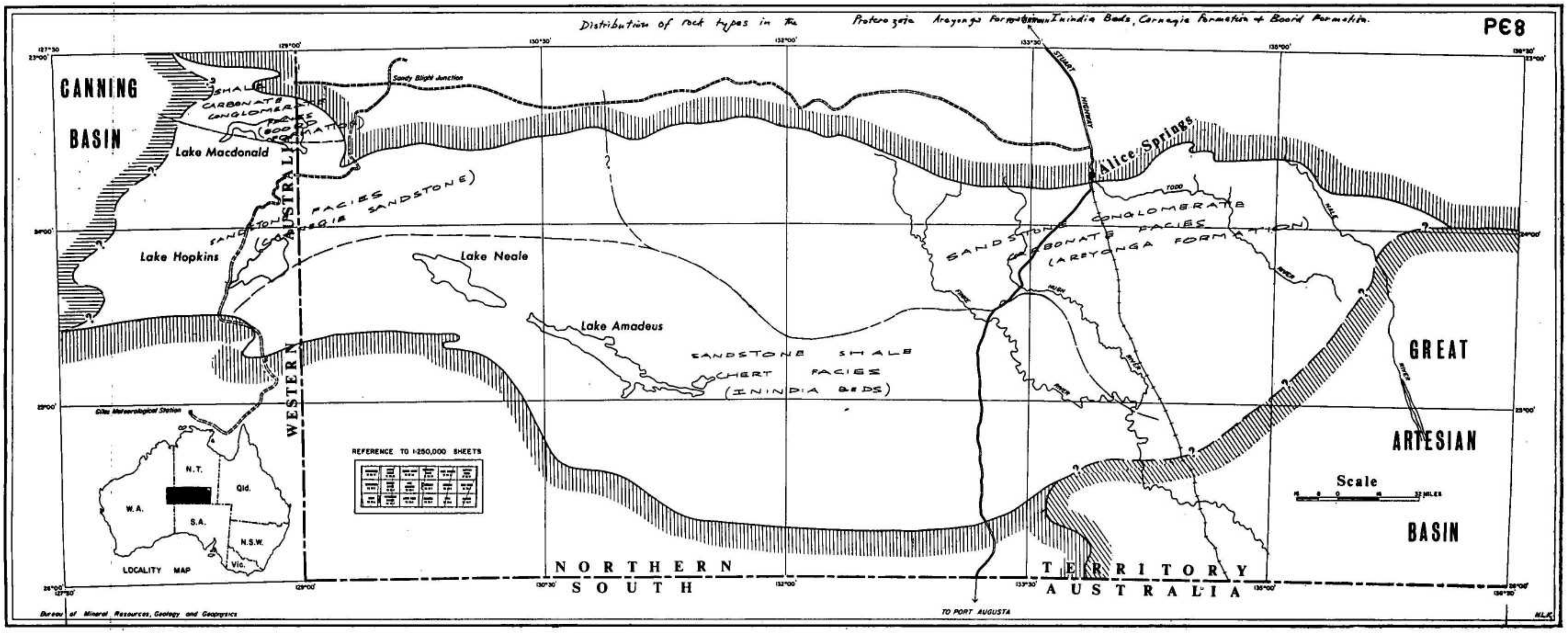
Palaeogeography and history of the Heavitree Quartzite, Bitter Springs Formation and their equivalents

The Bitter Springs Formation and the Heavitree Quartzite and their equivalents were deposited over the whole of the Amadeus Basin and undoubtedly over large areas outside its present margin. The sparse data available suggests that the formations were probably deposited in far removed areas further west in the Gibson Desert of Western Australia but there are no indications that they are preserved or were deposited in areas of sedimentary rocks immediately to the north, for example in the Ngalia and Georgina Basins. Preliminary mapping in the Ngalia Basin suggests that the oldest sediments are younger Proterozoic glacial beds. Supporting evidence for their wide-spread deposition is the presence of phenoclasts derived from both formations in many of the younger formations and shows that subsequently large areas of these sediments were exposed and eroded.

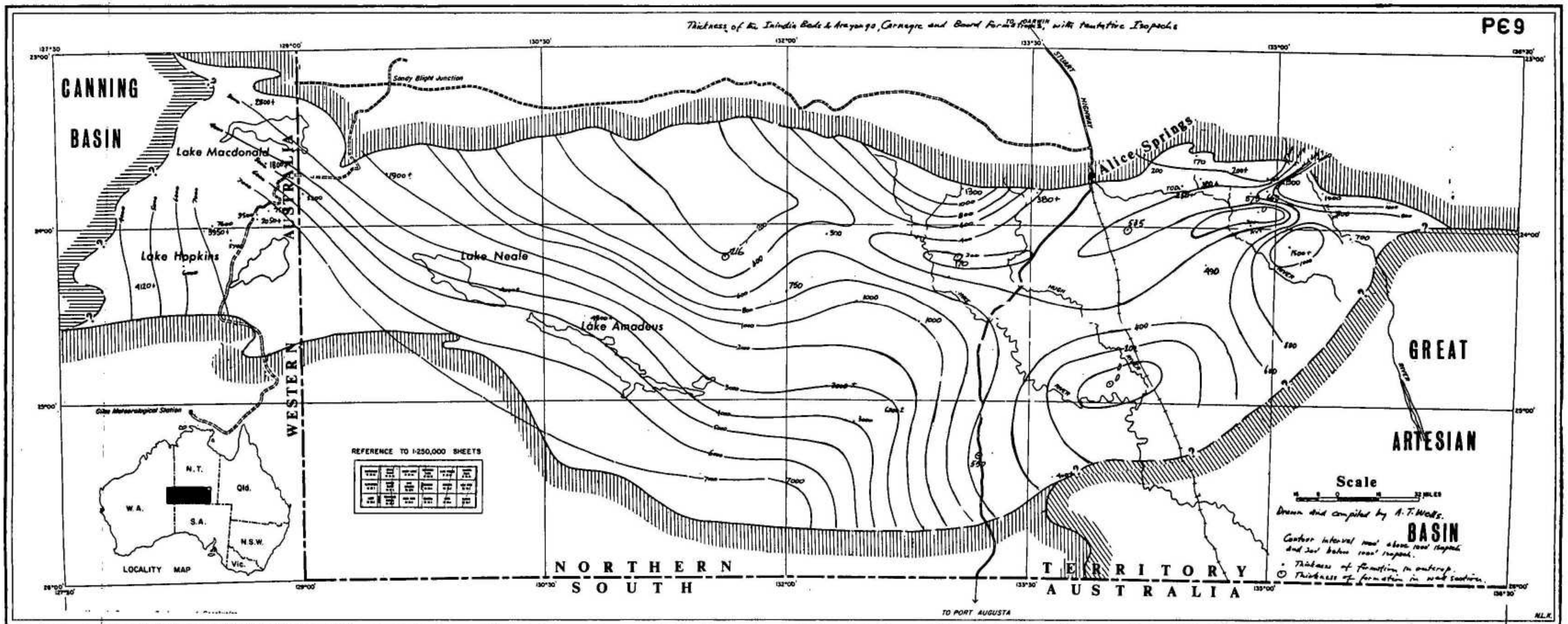
The Bloods Range Beds and Mount Harris Basalt in the south, and the Arunta Complex in the north, were uplifted and eroded before the deposition of the basal part of the Proterozoic succession. Both the Heavitree Quartzite and the Bitter Springs Formation and their equivalents were deposited in a relatively stable, epicontinental, shallow marine environment. The Heavitree Quartzite was deposited on an irregular basement floor in a shallow sea to form a blanket-sand deposit. As sedimentation proceeded parts of the shelf became partly or totally landlocked with the formation of barred basins and lagoons. In this environment the sedimentation was predominantly lutites and carbonate rocks, interspersed with evaporites. The evaporites accumulated in local barred basin environments which existed during the early history of deposition of the Bitter Springs Formation. The gypsum, which occurs on a line trending south-east from Johnstone Hill, may roughly outline one or possibly several interconnected basins of restricted circulation. The succession in the Bitter Springs Formation is characterised

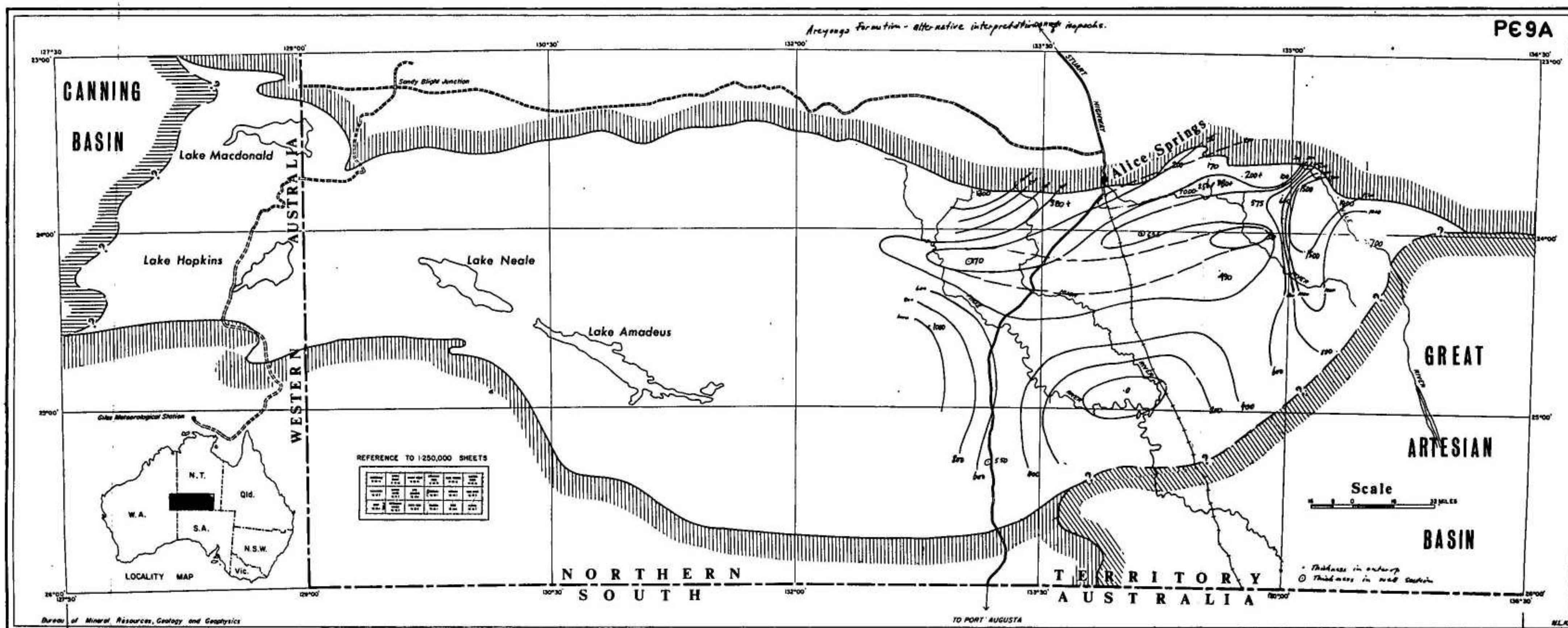


Distribution of outcrops of the Areyonga Formation, Inindia Beds, Carnegie Formation and Boord Formation.
PЄ7
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
STUART HIGHWAY
TO DARWIN
TO PORT AUGUSTA
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT
ARTESIAN
BASIN
REFERENCE TO 1:250,000 SHEETS
N.T.
W.A.
Qld.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
PЄ 8 shows the distribution of these formations.
Compiled and drawn by A.T. Wells.
Bureau of Mineral Resources, Geology and Geophysics



Distribution of rock types in the Proterozoic Areyonga Formation, Inindia Beds, Carnegie Formation + Boord Formation.
PЄ8
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Giles Meteorological Station
Alice Springs
STUART
HIGHWAY
TODD
HALE
RIVER
FINKE
HUGH
SHALE
CARBONATE
CONGLOMERATE
FACIES
(BOORD FORMATION)
SANDSTONE FACIES
(CARNEGIE SANDSTONE)
SANDSTONE CONGLOMERATE
CARBONATE FACIES
(AREYONGA FORMATION)
SANDSTONE SHALE
CHERT FACIES
(ININDIA BEDS)
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT
ARTESIAN
BASIN
Scale
MILES
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


PЄ9
Thickness of the Inindia Beds & Arayonga, Carnegie and Bouvd Formations, with tentative Isopachs
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
STUART
HIGHWAY
TO DARWIN
TO PORT AUGUSTA
GREAT
ARTESIAN
BASIN
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
Drawn and compiled by A.T. Wells.
Thickness of formation in outcrop.
Thickness of formation in well section.


Areyonga Formation - alternative interpretation isopachs.
PЄ9A
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Giles Meteorological Station
Alice Springs
STUART
HIGHWAY
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
GREAT
ARTESIAN
BASIN
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
N.T.
W.A.
Qld.
S.A.
N.S.W.
Vic.
Scale
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'

by a marked cyclical repetition of units representing stages in the restriction of a seaway and the concentration of soluble salts. The presence of glauconite, phosphate, pyrite and bituminous matter indicate anaerobic conditions in shallow water ranging from a saline to a marine environment. Shale, siltstone and numerous fine streaks of sandstone indicate interruptions of the evaporitic environment and introduction of detrital material. The environment was initially highly saline with halite, and rhythmic interbeds of anhydritic dolomite and anhydrite, followed by penesaline conditions with deposition of fine, laminated dolomite and anhydrite and finally by marine conditions with algal dolomite and fine detrital material.

The distribution of outcrops of the formation in the Basin in areas outside the eroded marginal exposures may be partly controlled by the presence of comparatively thick sections of evaporites. Anticlinal structures and the thrusts were possibly localised over these areas and breaching of the anticlinal cores exposed the Bitter Springs Formation. In other places the evaporites penetrated the overlying sediments by diapiric intrusion and were later exposed by erosion.

The Petermann Ranges Orogeny followed late in the Proterozoic after the basal Proterozoic succession had been covered by several thousand feet of sediments. The orogeny was accompanied by metamorphism of the Mount Harris Basalt, Bloods Range Beds, Dixon Range Beds, Dean Quartzite and Pinyinna Beds.

The Heavitree Quartzite and Bitter Springs Formation experienced somewhat similar metamorphic effects at the northern margin of the basin during the Alice Springs Orogeny which occurred mainly in the Devonian. The formations were covered at this time by several thousand feet of mainly Palaeozoic sediments and some later Proterozoic rocks before the orogeny took place.

Areyonga Formation, Inindia Beds, Carnegie and Boord Formations

These four formations are discussed together because they have a similar stratigraphic position and environment of deposition, and were probably for the most part contemporaneous. The distribution of outcrops, the areas covered by each formation and the dominant rock types, and thicknesses and isopachs are shown in Fig. PC-7-9.

The siltstone and quartz greywacke that disconformably overlies the Bitter Springs Formation at Ellery Creek and is conformably overlain by the Pertatataka Formation was named the <u>Areyonga Formation</u> by Prichard and Quinlan (1962). In the central part of the Amadeus Basin the formation is overlain with an angular unconformity by units of the Pertaoorrta Group.

Outcrops of the Areyonga formation are confined to the central and north-eastern parts and along the northern margin of the Amadeus Basin. It is known as far east as the Parana Hill Anticline, and west to the Hale River, a distance of 225 miles, and southwards to near the Chandler Range, about 70 miles south-west of Alice Springs. Outside this area it has been intersected in the East Johnny Creek No. 1 Well unconformably below sediments of the Pertaoorrta Group.

The formation contains boulder clay, pebble, cobble and boulder conglomerate, arkose, poorly sorted siltstone, lithic or feldspathic sandstone and dolomite, commonly with abundant chert masses. The sediments have very low maturity indices. The largest boulders are about 6 feet across. Arkose is prominent at the base of the formation in the north-eastern part of the Basin and in places a thin bed of phosphate rock (PC-20) occurs at the contact with the underlying Bitter Springs Formation beneath the arkose.

The lithology and thickness of the formation varies considerably and it is characterised by the lens-like nature of the constituent lithologies. The thickest section is probably in exposures just north of Limbla Homestead. Depositional textures are rare but the sandstone beds are in places cross-bedded. The percentage of sandstone increases in outcrops in the central part of the Amadeus Basin and is associated with an increase in thickness of the formation. A sequence of siltstone with chert interbeds is commonly exposed towards the base of the formation in this area.

At Ellery Creek the formation consists of two members (Prichard and Quinlan, 1962), the lower member is 750 feet thick and consists of quartz greywacke. The erratics are of many rock types and are mostly rounded; many are faceted and striated. In the Hermannsburg Sheet area this member crops out between 8 Mile Gap and 9 miles east of the Finke River and near Areyonga. The younger member consists of 550 feet of current-bedded, medium grained, quartz greywacke. This member is much more widespread and occurs from Jay Creek to one mile west of the Finke River and at Areyonga. These members probably also occur outside the areas mentioned but their recognition is difficult because of the paucity of outcrops.

Fossil remains are limited to algal stromatolites, which occur in the dolomite of the formation, 'pipe rock' in a sandstone near Areyonga Native Settlement, and a possible fossil in a sandstone west of Alice Springs which is figured by Wells et al. (1967, in press).

Prichard and Quinlan (1962) consider that the whole of the Areyonga formation in the Hermannsburg area is the product of a marine glacial environment. In other areas, however, there appears to be rapid variations in the conditions of sedimentation and an interplay of several environments. In the sequence penetrated in Ooraminna No. 1 Well (Schmerber, 1966a) for example, the lower arenaceous and calcitic sediments probably accumulated in a paralic environment with intercalations of marine oolitic dolomite. The pyritic siltstone with organic matter in the middle part indicates euxinic conditions and the carbonate rocks in the upper part were deposited in shallow marine conditions.

In the southern part of the Amadeus Basin the Inindia Beds (Wells, Stewart & Skwarko, 1967, in press) a sequence of siltstone, sandstone, arkosic sandstone, claystone, shale, chert, chert breccia, fine angular conglomerate and thin interbeds of dolomite and limestone, disconformably or unconformably overly the Bitter Springs Formation and are unconformably overlain by the Winnall Beds, the Pertaoorrta Group, Larapinta Group (principally the Stairway Sandstone) and the Finke Group. In the western part of the basin outcrops doubtfully referred to the Inindia Beds are unconformably overlain by the Mount Currie Conglomerate.

The Beds crop out as far west as the Souths Range and east as far as the Black Hill Range, a distance of 290 miles. The reference areas for the Inindia Beds are amended in this Bulletin, because more complete exposures have been located and described since the Beds were first named and the reference area nominated (Ranford, Cook & Wells, 1966, in press). The reference area for the upper part of the Beds is now the exposures on the northern slopes of Mount Connor, and the exposures 12 miles north-east of Curtin Springs Homestead is the reference area for the lower part of the Inindia Beds.

Sandstone and siltstone are the most common rock types in the Inindia Beds and there are at least eight sandstone intervals usually less than 100 feet thick. In the central southern part of the Basin a semi-detailed sequence 7000 feet thick has been described by Wells, Stewart & Skwarko (1966 in press). A tillitic siltstone in the sequence has been described from several localities. The erratics in this siltstone are quartzite, black oolitic chert, jasper, siltstone, banded chert, silicified dolomite and rare igneous fragments. Beds of dolomite up to 50 feet thick containing stromatolites occur in the Inindia Beds in the western exposures.

Wells et al (1967) consider that the greater part of the Inindia Beds are probably marine mainly because of the considerable thickness of the units and their extent. Towards the end of deposition glacial conditions prevailed and the overlying thickly cross-bedded, coarse arenites may indicate deposition under terrestial conditions. Halite pseudomorphs have been reported in the siltstones near Dead Bullock Plain and thin sandstone interbeds with scattered glauconite grains occur a few miles north-west of Palmer Valley Homestead. However, these occurrences appear to be exceptional. Chert is abundant near the base of the Inindia Beds and is commonly oolitic suggesting that it was formed by replacement of oolitic carbonate rocks. The fine to coarse sandstone of the Inindia Beds penetrated in the Erldunda No. 1 Well (Schmerber, 1967) has rare glauconite, phosphate pellets, tourmaline and zircon and a calcareous shale contains abundant ? organic material. These sediments are considered to be a marine shelf deposit. The sandstone is predominant in the well section and has minor interbeds of dark siltstone and thin bedded dolomite.

The sequence of siltstone, calcilutite, calcarenite, dolomitic limestone, sandstone and boulder beds which disconformably overlies the Bitter Springs Formation in the western part of the Amadeus Basin was defined and named the Boord Formation by Wells, Forman and Ranford (1964) and the type section is at Boord Ridges. It is probably conformably overlain by the Ellis Sandstone and interfingers with the Carnegie Formation. The greatest thickness measured is about 2800 feet.

The base of the formation is marked by a persistent horizon consisting of mounds of debris with angular chert, ferruginous material and limestone, weathered from a basal breccia, which formed during a preceding period of weathering of the underlying Bitter Springs Formation. This horizon is overlain by pebbly sandstone and calcareous sandstone and in turn by about 250 feet of tillitic, pebble and boulder conglomerate, with fragments up to 8 feet across, of algal limestone, sandy limestone, dolomite, fine conglomerate, chert, quartz sandstone, quartzite, jasper, vein quartz, schist and quartz feldspar porphyry in a matrix of sandstone. Many of the phenoclasts are faceted and a few are striated.

The upper half of the formation is a calcilutite and calcarenite with stromatolites and is oolitic in part. The calcareous rocks are interbedded with siltstone and shale which probably make up the major part of the upper half of the formation.

The boulder beds at the base of the formation have many of the characteristics of glacial sediments. The overlying siltstone and stromatolitic carbonate rocks were deposited in a stable, shallow marine, shelf environment. The main mass of detritus that was derived from southern sources was deposited to the south to form the Carnegie Formation and only fine detritus reached the northern shelf area where the Boord Formation was deposited. As far as is known the glacial boulder beds, at least in this western part of the basin, were restricted to the northern edge of the basin and were probably deposited on a stable foreland area in a shallow marine environment.

The laminated, micaceous siltstone and fine and medium grained, kaolinitic sandstone, which disconformably overlies the Bitter Springs Formation and is conformably overlain by the Ellis Sandstone and the Sir Frederick Conglomerate, was named the <u>Carnegie Formation</u> by Wells, Forman and Ranford (1964). South of the Ligertwood Cliffs, the Carnegie Formation underlies the Cambrian Cleland Sandstone but no contacts were seen. The Carnegie Formation is found only in the western part of the Amadeus Basin and the most easterly outcrops are those in the Mount Rennie Sheet area, about 6 miles south-west of Mount Rennie. In this area the formation contains beds of conglomerate with phenoclasts of dolomite probably from the Bitter Springs Formation.

The Carnegie Formation consist of sandstone, quartz sandstone and siltstone and minor shale. The formation interfingers with the Boord Formation and has a maximum measured thickness of over 4000 feet. Clay pellets, ripple marks and cross-bedding are common throughout the section. The arenites contain up to 20% fragments of quartzite, chert and fine sericitic quartzite. In places the sediment has a calcareous cement and rarely contains up to 50% granular calcite. Current bedding indicates sediment movement from the west or south-west. The formation was probably deposited in a shallow marine environment in a rapidly subsiding part of the basin which was receiving abundant detritus from a southern provenance.

Alternatively the formation could be a marine deltaic deposit on an unstable shelf, or deposited towards the centre of an intracratonic basin with rapid rate of sedimentation and burial.

Correlation and age

The Boord and Carnegie Formations are correlated with the Areyonga Formation and Inindia Beds. The presence of a postulated glacial horizon at the base of the Boord Formation in the upper part of the Inindia Beds and the abundant evidence of glaciation in the Areyonga Formation supports this correlation. The upper part of the Boord Formation could conceivably be equivalent to part of the Pertatataka Formation and the overlying Ellis Sandstone could be equivalent to part of the Winnall Beds, a sandy facies of the Pertatataka Formation. It has been suggested therefore that the Winnall Beds could be correlated with part of the Carnegie Formation but the first interpretation given above is preferred and will be discussed further in the section dealing with correlation of Proterozoic formations.

Palaeogeography and history of deposition of the Areyonga Formation and its equivalents

The formations included in this discussion are the Areyonga Formation, Inindia Beds, Boord Formation and Carnegie Formation, as it is believed that they are for the most part laterally equivalent (Fig. PC-7-9).

The greatest thickness of sediments, which includes the Inindia Beds and Carnegie Formation, is preserved in a roughly west-north-west trending trough in the south-western and southern parts of the basin. An east-west trending eroded arch near the centre of the Basin, which is included in a zone within which the formations are thin or absent, separated the area of maximum sedimentation from a northern shelf area where the sediments (Areyonga and Boord Formations) are of intermediate thickness. The zone was probably the hinge line area along the northern edge of the subsiding trough.

The Areyonga Formation was deposited in a paralic environment on a shelf. The rapid changes in lithology indicate alternations of highly oxygenated conditions in shallow marine waters with periods of more stagnant water. Periodic influxes of glacially derived sediments in most places interrupted the shelf conditions and at times continental deposition may have taken place. This fact as well as the presence of the irregular topography of the depositional surface accounts for the remarkable variations in thickness of the formation and the abrupt changes of lithology. The boulders in the Areyonga Formation show that the glaciated land masses to the north were composed of the Heavitree Quartzite, Bitter Springs Formation as well as the Arunta Complex.

In the western part of the basin by contrast the glacial environment ceased after the deposition of the basal few feet of the Boord Formation and deposition continued in a shallow marine environment on a stable foreland.

The influence of the glacial environment is more pronounced on the northern shelfward side of the basin and the sediments deposited in southern subsiding trough show only minor evidence of glaciation. The clastic 'red-beds' of the Carnegie Formation are laterally equivalent to the Boord Formation but the only boulder beds in the Carnegie Formation occur locally in the north-west Amadeus Basin. The formation was deposited in a paralic environment.

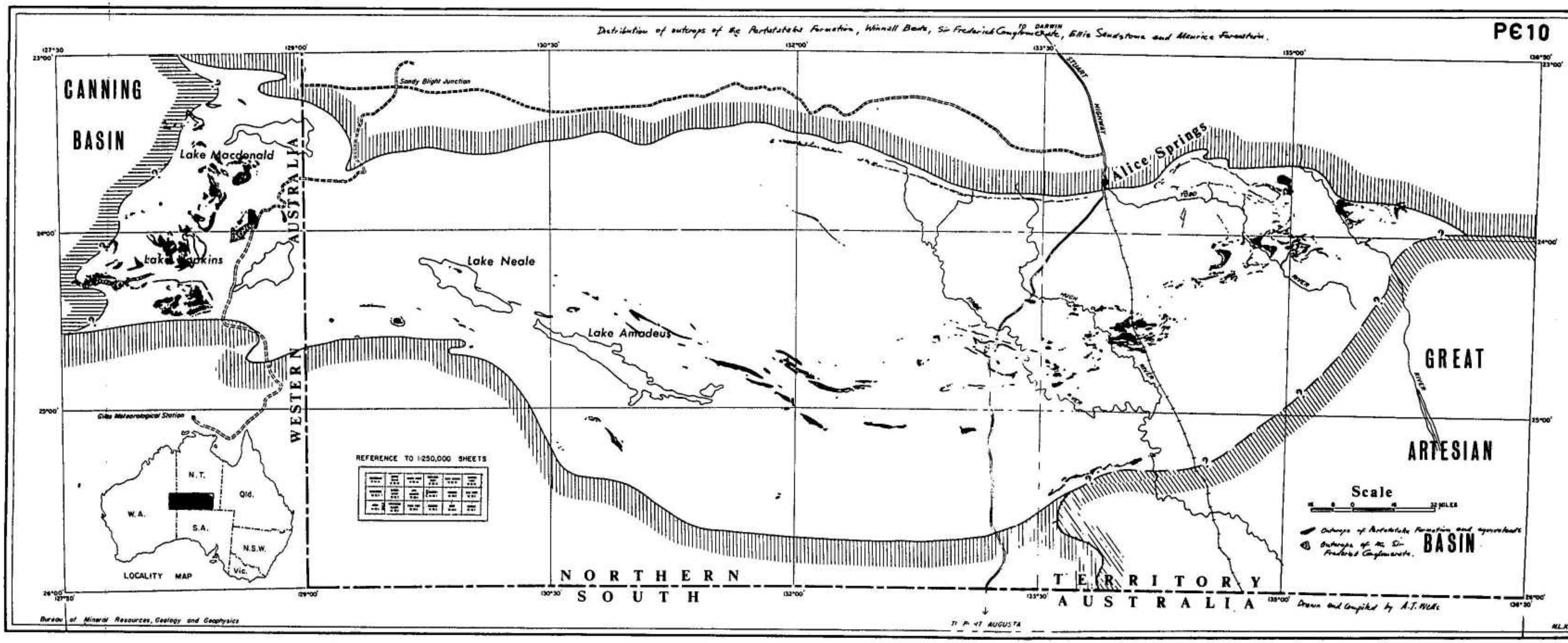
The Inindia Beds make up a thick pile of sediments deposited in the southern subsiding trough. They have a thin boulder clay horizon just beneath the topmost sandstone unit which suggests that, if this earlier period of Proterozoic glaciation was synchronous throughout the Basin, deposition of sediments following the Bitter Springs Formation was initiated in this subsiding trough.

The presence of red clays and silts and chert in the basal part of the Inindia Beds would, at first sight, suggest deposition in deep water of a pre-existing trough. But the fact that many of the chert beds are oolitic and fragmental suggests a shallow water high energy environment and an origin by silicification of thin beds of oolitic and fragmental limestone. The red colouration of the silts and clays was probably produced by weathering of iron bearing minerals in the regolith and the sediments may have been partly deposited in a terrestrial environment.

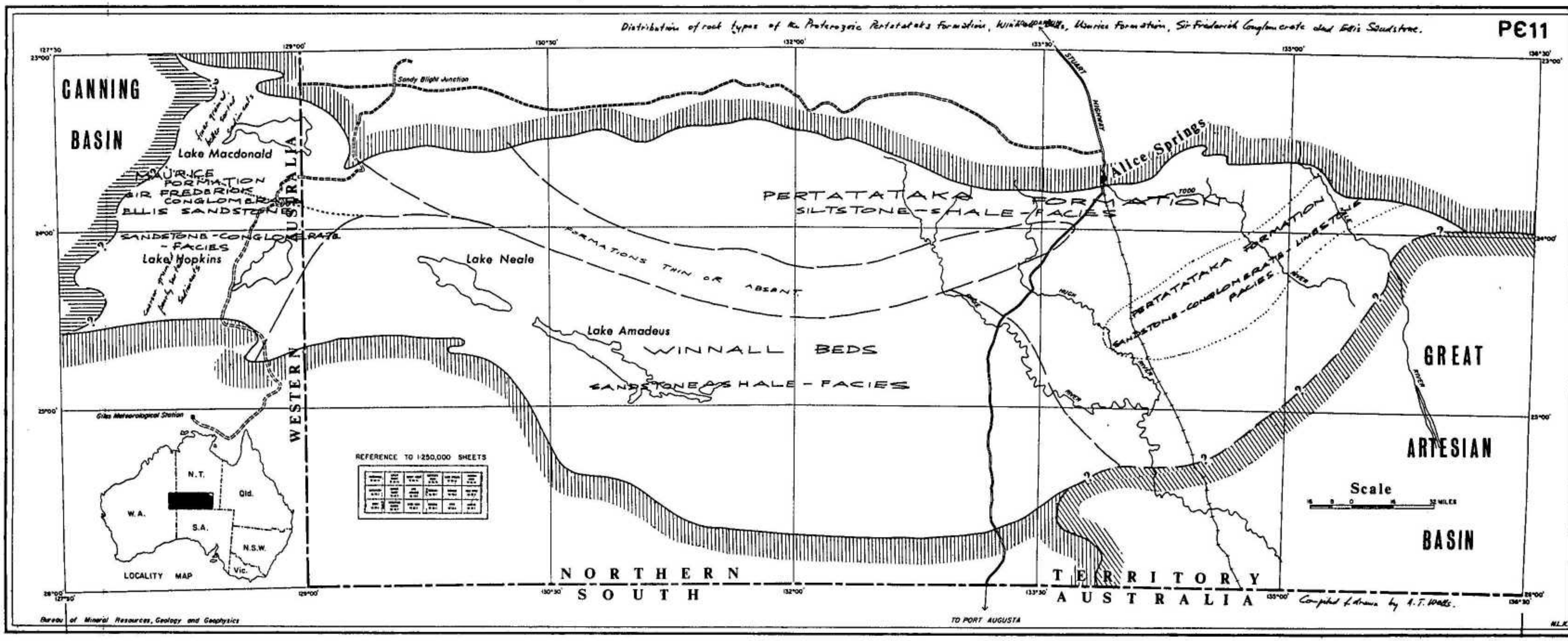
The 'red beds' of the Inindia Beds are probably primary in origin and may have been in part deposited in sluggish streams or in temporary lakes on broad nearly flat alluvial plains or transported in a fluviatile environment and deposited in a marine delta. Hydration and oxidation of the ferruginous material would be accomplished in the flood plain deposits. The red silts in the lower part of the sequence contrast with the thick sandstone sequences in the upper part of the Inindia Beds and possibly indicate renewed uplift of the provenance area, an increase in the rate of sedimentation and rapid filling of the trough with coarse detritus. Deposition of the youngest arenites of the Inindia Beds may have been under continental conditions. In the south-eastern part of the basin, the mineralogy of the sandstone of the Inindia Beds suggests deposition on a marine shelf or platform.

In the western part of the Basin the subsiding trough was possibly closer to the source area and a thick wedge of sandstone of the Carnegie Formation was deposited. The uniform nature of this deposit suggests that sedimentation kept pace with subsidence. The glacial environment did not reach areas where this formation was deposited. A minor phase of epeirogeny occurred after the deposition of the Inindia Beds, and in places a large part of the sequence was eroded before the overlying Winnall Beds were deposited.

The central east-west trending eroded arch (Figs. PC-12 & 15) which separates the shelf sediments from those of the subsiding trough reflects both an original hinge line area and a tectonic feature with structural growth both occurring during the Petermann Ranges Orogeny and possibly continued growth during Palaeozoic sedimentation. The arching of this zone was probably accentuated by decollement folding accompanied by the movement of salt from the Bitter Springs Formation into the anticlinal cores. Piercement of the salt has so far not been proved. The arch trends into the north-west part of the basin where outcrops of Proterozoic sediments, identifiable with the formations under discussion, are for the most part absent. There is very poor control on the shape of the isopachs and hence the precise position of the arch in this north-western area is not certain.



Distribution of outcrops of the Pertatataka Formation, Winnall Beds, Sir Frederick Conglomerate, Ellis Sandstone and Maurice Formation.
PЄ10
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Lake Neale
Lake Amadeus
Alice Springs
TO DARWIN
STUART
HIGHWAY
GREAT
ARTESIAN
BASIN
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
32 MILES
TO PORT AUGUSTA
Drawn and Compiled by A.T. Wells
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'


Distribution of rock types of the Proterozoic Pertatataka Formation, Winnall Beds, Maurice Formation, Sir Frederick Conglomerate and Ellis Sandstone.
PЄ11
CANNING
BASIN
Lake Macdonald
MAURICE FORMATION
SIR FREDERICK CONGLOMERATE
ELLIS SANDSTONE
SANDSTONE-CONGLOMERATE - FACIES
Lake Hopkins
Sandy Blight Junction
STUART HIGHWAY
Alice Springs
PERTATATAKA FORMATION
SILTSTONE-SHALE-FACIES
FORMATIONS THIN OR ABSENT
Lake Neale
Lake Amadeus
WINNALL BEDS
SANDSTONE-SHALE-FACIES
PERTATATAKA FORMATION
SANDSTONE-CONGLOMERATE-LIMESTONE FACIES
TODD
GREAT
ARTESIAN
BASIN
Scale
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Compiled & drawn by A.T. Wells.
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
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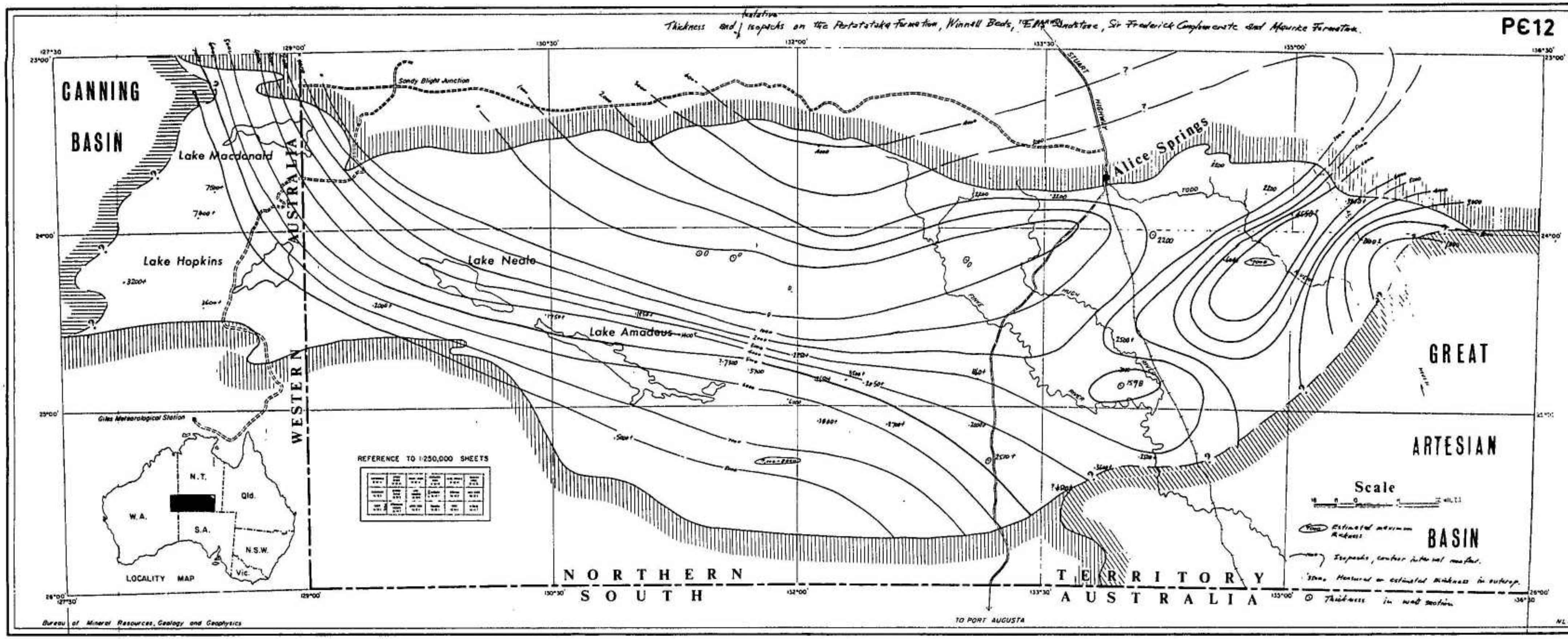
23°00'
24°00'
25°00'
26°00'


PЄ12
Thickness and tentative isopachs on the Pertatataka Formation, Winnall Beds, "Eller" Sandstone, Sir Frederick Conglomerate and Maurice Formation.
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
Giles Meteorological Station
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
Estimated maximum thickness
Isopachs, contour interval
Measured or estimated thickness in outcrop
Thickness in well section
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics

The thin development of sediments of the Areyonga Formation on the arch may be caused by the existence of a topographically high area during deposition, structural growth during sedimentation, and erosion of part of the formation or in places complete removal from the crests of anticlines in the zone after folding. The existence of a topographically high ridge along the hinge line zone during sedimentation is suggested because there are rapid variations in thickness encountered in the formation outside areas that have been effected by the Petermann Ranges Orogeny. The existence in some places of an angular unconformity at the base of the Areyonga Formation and the locally irregular unconformity surface supports this view. The isopachs on the Areyonga Formation (P€-7-9) show that the swell trends into the north-eastern part of the Basin where the effects of the Petermann Ranges Orogeny were negligible and hence erosion of the formation from high areas produced by the Orogeny may be only part of the reason for the presence of a zone of thin sediments. The possibility of structural growth during sedimentation on the hinge line zone cannot be proved because of the unconformity at the top of the formation and there is little likelihood of tracing marker beds within the formation.

Pertatataka Formation, Winnall Beds, Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation

These five formations are grouped together because they are for the most part laterally equivalent. The distribution of outcrops of the formations, the areas covered by each formation and the dominant rock types, thicknesses and isopachs on the formations are shown in Fig. P€-10-12.

The sequence of siltstone with minor limestone and quartz sandstone, lying conformably between the Areyonga Formation below and the Arumbera Sandstone above at Ellery Creek, was named the Pertatataka Formation by Prichard and Quinlan (1962). Thin beds with pellets of green siltstone in the basal part of the Arumbera Sandstone at Ellery Creek may indicate a disconformable relationship with the Pertatataka Formation. In areas to the south of the MacDonnell Ranges there is an angular unconformity with the Arumbera Sandstone and the Eninta Sandstone of the Pertataoorrta Group and in places there is a disconformity or unconformity with the Chandler Limestone. In the north-eastern part of the Basin the formation locally overlies the Bitter Springs Formation and in places it is overlain with an angular unconformity by the Pertnjara Group.

Siltstone is the dominant lithology and it is generally poorly exposed and forms the floor of wide alluviated valleys. Lobate rill marks occur in the siltstone in the Gardiner Range near the top of the sequence and slumping occurs in some outcrops. The limestone near the top of the formation is commonly oolitic and stromatolitic and much of the interbedded sandstone at Ellery Creek is glauconitic.

In the type section at Ellery Creek the Pertatataka Formation is about 2,200 feet thick. It thickens westwards towards Stokes Pass where it is about 4,500 feet thick. It maintains a fairly uniform thickness east of Ellery Creek to the area south of Ringwood and here dilates rapidly and attains a maximum thickness of about 7,000 feet. The increase in thickness is accompanied by an influx of coarser detrital material, pelletal carbonate rocks and boulder beds with glacial affinities.

In the Gardiner Range the sandstone is fine grained, well sorted, micaceous, chloritic and pyritic, and accessory minerals include abundant muscovite, green biotite and some apatite.

Schmerber (1966a, e) has described the Pertatataka Formation in the Ooraminna No. 1 and Mount Charlotte No. 1 Wells. The dominant lithology is grey-green and rare red-brown, finely laminated shale and siltstone which contains muscovite, rare green biotite; a cement of chlorite, ? illite, limonite, haematite, with pyrite and ? organic matter; minute dolomite crystals occur throughout. Sandstone occurs in fine laminae with very fine to fine grained, angular, well sorted quartz, some potash feldspar, very rare albite, igneous and sericitised rock fragments and rare muscovite. Authigenic glauconite in various forms is associated with phosphatic grains and opaque minerals; tourmaline, zircon and apatite are accessories. The cement is chlorite with kaolinite, sericite, intergranular quartz and rare dolomite. The glauconite and phosphate in the fine sandstone suggest a neritic environment on a stable shelf.

Between Alice Springs and Ringwood Homestead two members within the Pertatataka Formation have been mapped and defined by Wellw, (1967 in press). They are separated from the base and top of the formation and from each other by varying thicknesses of siltstone. The upper predominantly carbonate rock

(Figs. PG-24) with sandstone lenses is the Julie Member and the lower Cyclops Member consists of flaggy, very fine, laminated and rhythmically, thin bedded sandstone.

The Julie Member was penetrated in the Ooraminna No. 1 Well (Schmerber, 1966a) and the lower part is made up of poorly sorted, fine to coarse sub-angular to rounded sandstone. The upper part of the sandstone is similar to the Arumbera Sandstone and is ferruginous with a large amount of biotite, strongly altered chlorite and a cement of hematite, silica and euhedral dolomite. Dark green siltstone with chlorite, cryptocrystalline calcite and dolomitized sandy limestone occur as interbeds. The lower part of the sandstone has 30 - 70% quartz, microcline and muscovite and a cement of cryptocrystalline calcite with microcrystalline dolomite crystals. The upper beds of the member are recrystallized, microcrystalline, dolomitized limestone with thin oolitic bands, abundant detrital, rounded to angular quartz (0.1 - 2m.m.) rare orthoclase microcline, 5 - 40% lithic fragments, muscovite and strongly altered biotite. Pyrite and rounded tourmaline are accessories together with minor hematite.

The Julie Member has been mapped as far west as Jay Creek Homestead and southwards onto the Rodinga Sheet area. It has been recognised but not mapped in the eastern MacDonnell Ranges and in the Gardiner Range. Along the northern part of the Gardiner Range the siltstone is poorly exposed but two separate ridges high in the formation can be traced for some distance. The upper ridge of predominantly carbonate rock is identified with the Julie Member and the stratigraphically lower ridge, which is made up of fine and medium grained, laminated, tough, silicified platy sandstone, is tentatively identified with the Cyclops Member of the formation.

In the outcrops between Haasts Bluff and the Idirriki Range the formation is coarser grained and consists of fine, thin-bedded, micaceous sandstone in isolated strike ridges with intervening beds of laminated, micaceous siltstone.

The thick sequence in the Pertatataka Formation in the north-eastern part of the Basin, south of Ringwood Homestead, has been divided into six members and has been described by Wells, et al (1967, in press).

The uppermost Julie Member continues eastwards from its type area into the region of dilated formation thickness with little lithological change (Fig. PC-2). The main lithological change in the formation has taken place in the sequence below the Julie Member. The Cyclops Member, the only other member in the Pertatataka Formation at its type locality to the west, cannot be recognised in the north-eastern part of the Basin and its equivalent horizon cannot be determined. Until these facts are available it is not possible to state whether deposition of the Pertatataka Formation commenced in the north-eastern area before the major part of the Formation was laid down in the remaining larger part of the Basin or whether commencement and termination of sedimentation was more or less synchronous throughout the Basin during Pertatataka times. The Members of the Pertatataka Formation in the north-eastern part of the Basin and their thicknesses, either estimated or from measured sections, are from top to bottom -

<u>Julie Member</u> 1800 feet - forms ridges consisting of dark grey, oolitic dolomite and dark grey limestone which contain poorly preserved stromatolites. Sandstone occurs in thick lenticular bodies usually towards the base of the member (PC-22). Siltstone occurs as minor interbeds.

<u>Waldo Pedlar Member</u> 200 ± feet - crops out in rounded low hills and consists of thin bedded, silicified, tough, fine grained, flaggy, dark green-grey sandstone with ripple and current flow markings.

<u>Olympic Member</u> 630 feet - the physiographic expression depends on lithology which is extremely variable. Sandstone, siltstone, conglomerate, shale, boulder clay, dolomite and lenticular sandstone bodies are characteristic. The sandstone beds commonly show weathered out clay pellets (PC-32). Thin beds of pink and grey dolomite occur at the top of the member and are fine grained, laminated, with manganese stains and pseudomorphs after pyrite. The Member consists of an aggregate of the various constituent lithologies in lens like bodies. The conglomerate has phenoclasts of dolomite, sandstone, quartz and a variety of igneous and metamorphic rocks (PC-29) commonly derived from underlying formations. The clasts are commonly striated and soled and may occur in a matrix varying from poorly sorted siltstone to edgewise conglomerate with thin dolomite plates (PC-28) and very coarse, angular, milky quartz granules.

Limbla Member 470 feet - probably in places disconformable with the Olympic Member, as fragments of the Limbla Member occur in the Olympic Member. The upper part of the Member is a cross-laminated and slumped sandstone (PC-31) and intra-formational conglomerate.

Ringwood Member 540 feet - is characterised by tough, cherty, algal dolomite (PC-26) overlain by cross-laminated fragmental dolomite, limestone and calcarenite. Minor interbedded siltstone occurs, particularly near the base.

The members are separated from each other and from overlying and underlying formations by beds of siltstone of varying thickness with the exception of the Olympic and Limbla Members which are probably separated by a disconformity. The boulder beds in the Olympic Member suggest a second period of glaciation in the Proterozoic. The presumed glacials in the Olympic Member persist from near Ringwood Homestead to the south-west as far as the Mount Burrell area. Even in the area where these members occur in the Pertatataka Formation the dominant lithology is still siltstone. (See Fig. PC-2).

The thick sequence of siltstone, sandstone, and pebbly sandstone, which occurs in the southern part of the Amadeus Basin and lies unconformably above the Inindia Beds and unconformably below the Pertaoorrta Group, was named the Winnall Beds by Ranford, Cook and Wells (1966, in press). In places the Beds may be unconformable on the Bitter Springs Formation. In western exposures they are unconformably overlain by either the Mt. Currie Conglomerate or the Cleland Sandstone, further east by the Stairway Sandstone and Carmichael Sandstone of the Larapinta Group, and at the south-eastern margin of the Basin by the Polly Conglomerate and Langra Formation of the Finke Group. The maximum exposed thickness is about 7,000 feet.

A four fold division of the Winnall Beds is possible with basal and middle siltstone units overlain and separated by beds of sandstone. The resistant sandstone beds form many prominent topographic features in the southern part of the Basin (Souths Range, Long Range, Mount Unapproachable, Mount Cowle, Winnall Ridge, Mount Connor, Kernot Range, Liddle Hills, Basedow Range, Erldunda Range, Mount Kingston and the Black Hill Range.).

The sandstone units, particularly the lower one, show a variety of ripple marks, cross-bedding, slumping, convolute laminations, mud cracks, current lineation, groove casts, synaeresis cracks and mud pellet markings. The sands were probably deposited close to strand line conditions and in places the large cross-beds could indicate terrestrial conditions. "Sand sticks" in the formation, 30 miles south-west of Reedy Waterhole, are comparable with Syringomorpha (Nathorst).

The four units in the Winnall Beds, with thicknesses from exposures in the Liddle Hills area, are from top to bottom -

Unit 4 - 600 feet - sandstone, dark brown, poorly sorted, medium-bedded, moderately well exposed, silicified in some places, friable in others, with weathered out clay pellets, chert fragments in places, small cross-beds, ripples and slumps.

Unit 3 - 1100 feet - siltstone and silty sandstone, poorly exposed, variegated, thin bedded.

Unit 2 - 1800 feet - lower part is massive, cross-bedded, fine grained, silicified sandstone, and upper part composed of thin to medium bedded, coarse grained, silicified sandstone, with some interbeds of conglomerate with some chert fragments. 15 - 20 feet of conglomerate is present at the base of the unit at Mt. Conner. The resistant sandstone forms prominent ranges.

Unit 1 - 500 feet - siltstone, thin bedded, dark, and some fine grained, slightly calcareous silty sandstone.

The largest percentage of outcrops of the Winnall Beds are made up of Unit 2.

In some places the lower siltstone unit is absent and Unit 2 rests unconformably on the Inindia Beds. The erosional surface at the top of the formation occurs at different levels in the Winnall Beds. In the Henbury Sheet area Unit 4 of the Winnall Beds is the more consistant of the sandstone units and crops out over a wide area. The distribution of this sandstone and its proximity to outcrops of the Inindia Beds suggest that deposition of Unit 2 sandstone may have been restricted to the south of this area.

The four lithological divisions described in the outcrop of the

Winnall Beds have been recognised in the sequence penetrated in the Erldunda No. 1 well (Schmerber, 1967).

Unit 4 - 820 feet sandstone, grey to brown, angular to subangular, well to medium sorted, submature to mature, orthoquartzite, rare detrital feldspar, 1 - 10% partly sericitised muscovite and partly chloritised biotite, minor glauconite and phosphate pellets, and tourmaline, zircon, apatite, pyrite and leucoxene as accessories. Minor interlaminated siltstone is chloritic, sericitic and pyritic.

Unit 3 - 960 feet - siltstone and shale, greyish-green, fissile, finely laminated, very chloritic, sericitic or illitic and pyritic, and the lower beds contain 10% minute dolomite rhombs. Light to medium grey, calcareous, sandstone occurs in thin beds in 10' sections mainly angular, some subrounded, well sorted, very fine grained, orthoquartzite with some phosphatic and glauconite pellets, and locally rounded, coarse grained quartz and rare chert grains.

Unit 2 - 65 feet - conglomerate, polymict, white and grey, angular and some subangular to subrounded, poorly sorted pebbles (up to 30 m.m.) of chert, granoblastic quartz, metaquartzite, some mica-schist, rare granite, cryptocrystalline to microgranular and some finely laminated dolomite with some algal structures. The cement is mainly fine carbonate minerals. The overlying sandstone has angular to rounded, well sorted, medium grained quartz (80%), rare microcline, sericitised orthoclase, rare sodic plagioclase, 5% chert and metaquartzite. There are some fine muscovite flakes, and the cement is secondary silica and 10% calcareous matter.

Unit 1 - 670 feet - siltstone, dark grey and brown, micaceous, calcareous chloritic and haematitic, very pyritic and slightly phosphatic. Thin lenses and laminae of cryptocrystalline dolomite, as interbeds in siltstone, in places silty, micaceous and pyritic, grading to clayey dolomite. Secondary anhydrite and gypsum occur in fissures and small patches.

In the south-eastern part of the Basin at the Souths Range, the basal pebble conglomerate beds at the unconformity with the Inindia Beds are well exposed. The pebbles consist of chert, feldspathic sandstone, coarse quartz sandstone, and silicified siltstone in a medium to coarse grained sandstone matrix. The conglomerate is overlain by a cross-laminated sandstone with cross bedding sets up to 10 feet thick.

The beds exposed in the Black Hill Range and Mount Kingston have been mapped as the Winnall Beds but it is evident that considerable variation in lithology occurs along strike from west to east. The outcrop is mainly sandstone in the west but siltstone is the dominant lithology at the eastern end of the range. The siltstone has glauconite and shows lobate rill marks, flow casts and silt and clay pellets. It is similar in lithology here to the Pertatataka Formation.

The deposition of the Winnall Beds began with siltstone deposited in slightly stagnant water with a surrounding peneplained land mass. The abrupt change to conglomerate suggests a tectonic uplift of a southern provenance and the erosion of the Bitter Springs formation as well as metamorphic and igneous rocks.

The siltstone and sandstone, which contain glauconite and phosphate, suggest conditions approached those of a stable shelf but the environment over most of the area was shallow marine in a rapidly subsiding trough. The detrital content is mainly submature to mature reworked material.

Wells, Forman & Ranford (1964) introduced the name Ellis Sandstone for the sequence of kaolinitic sandstone and pebbly sandstone with subordinate calcareous sandstone and siltstone which is exposed in the western part of the Amadeus Basin. The Ellis Sandstone lies above the Carnegie or Boord Formations, interfingers with the Sir Frederick Conglomerate, and is conformably overlain by the Maurice Formation. The contact between the Ellis Sandstone and Boord Formation is not exposed but in most places appears to be conformable. The maximum measured thickness is about 2,000 feet. Outcrops are confined to the area between the Rawlinson Range and Lake Macdonald in Western Australia.

The predominant lithology is medium, cross-bedded, kaolinitic quartz sandstone with up to 15% of metaquartzite and chert grains. Cross-beds indicate sediment transport from the west and south-west. Current lineation, ripple marks, current crescents, slump structures, scour and fill structures and laminae with heavy minerals are common. Interbedded calcareous sandstone and micaceous siltstone are rare. Scattered pebbles are common in the southernmost outcrops. North of the Sir Frederick Range and at the western end of a large range north of the Carnegie Range the pebbly sandstone grades into the Sir Frederick Conglomerate.

The Sir Frederick Conglomerate (Wells, Forman & Ranford 1964) is the sequence of pebble, cobble and boulder conglomerate with kaolinitic sandstone matrix, and thin interbeds and lenses of sandstone and pebbly sandstone that is conformably overlain by the Maurice Formation, lenses laterally into the Ellis Sandstone and possible unconformably overlies the Carnegie Formation.

Outcrops are confined to the area between the Rawlinson Range and Lake Macdonald in Western Australia. The combined thickness of the Ellis Sandstone and Sir Frederick Conglomerate at the north end of the Sir Frederick Range is approximately 7,000 feet.

Boulders in the conglomerate measure up to 42 inches in length and are composed of silicified sandstone and metaquartzite with smaller quantities of vein quartz and quartz-mica schist. The coarsest conglomerate is exposed in the Gillespie Hills. All the rock types present as phenoclasts in the Sir Frederick Conglomerate are represented in the Upper Proterozoic and Pre-cambrian metamorphic rocks to the south and most are derived from the Dean Quartzite.

The sequence of sandstone, quartz greywacke, fine micaceous sandstone, and micaceous siltstone, which conformably overlies the Ellis Sandstone and the Sir Frederick Conglomerate, was defined as the Maurice Formation by Wells, Forman & Ranford (1964). The top of the formation is eroded and is unconformably overlain by the Permian Buck Formation or by undifferentiated Permian sediments. The formation is estimated to be at least 6,000 feet thick in the Maurice Hills. The rock types grade from predominantly even-grained quartz sandstone and siltstone in the northern most outcrops to predominantly cross-bedded quartz greywacke with minor greywacke and micaceous siltstone in the south.

The basal beds in the northern exposures are fine to medium-grained, medium to thin bedded, cross-bedded, finely micaceous sandstone with clay pellets. The ridges at Maurice Hills that comprise the middle of the formation are quartz sandstone with interbedded micaceous siltstone. The sandstone is medium-grained, thick bedded, cross-bedded, ripple marked, and has interbeds rich in clay pellets, and some laminae rich in heavy minerals. The youngest beds are fine, micaceous sandstone, with interbeds of chocolate siltstone and minor shale. Clay pellets are common in the sandstone. Much of the upper part of the formation is poorly exposed and probably consists for the most part of calcareous, friable sandstone.

In the southern exposures the sediments of the Maurice Formation are much coarser grained and poorly sorted. They consist of cross-bedded, poorly bedded and sorted quartz greywacke and interbedded chocolate-brown, laminated, micaceous siltstone. Some heavy mineral concentrations and pebbles occur in the quartz greywacke. The cross-beds indicate sediment movement from the south-east and south. The quartz greywacke has 20% sub-angular quartz, quartz-sericite schist, quartzite, and chert fragments and rare large mica flakes in a matrix of fine sericite, limonite and kaolin. Some specimens contain up to 20% kaolinite as tabular cleaved plates.

The lithology of the Ellis Sandstone and the Maurice Formation suggest derivation of sediments from source areas in the south and south-east with comparatively rapid deposition of coarser sediment in the near shore areas to the south, and better sorted sandstone deposited further north.

Correlation of the Proterozoic sequences in the western and southern parts of the Amadeus Basin

The relationship of the Proterozoic units in the Amadeus Basin is shown diagrammatically in Fig. PC-2.

The basal part of the Proterozoic sequence (exposed in the MacDonnell Ranges), comprising the Heavitree Quartzite and the Bitter Springs Formation, continues uninterrupted and with little lithological change into the western part of the Basin. The metamorphosed equivalents of these two formations in the Rawlinson and Petermann Ranges, in the south-west part of the Basin, are the Dean Quartzite and Pinyinna Beds. In the western part of the Basin the Bitter Springs Formation is disconformably overlain by the Boord Formation which contains basal boulder beds of glacial origin. The Boord Formation and the laterally equivalent Carnegie Formation are correlated with the Inindia Beds and the Areyonga Formation. They occur in similar stratigraphic positions and, with the exception of the Carnegie Formation, glacial beds are common to all of the units.

The stratigraphic position of the Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation, lying conformably on sediments correlated with the Areyonga Formation, indicates that they themselves can be correlated with the Winnall Beds. The following brief resumé of the geological history of this area provides supporting evidence for this relationship. A period of folding and considerable erosion of the Proterozoic rocks preceded the deposition of Cambrian and Ordovician sediments in the western and southern part of the basin. The Proterozoic rocks were eroded to different stratigraphic levels and most are now overlain unconformably by either sediments of the Larapinta Group or the Pertaoorrta Group or both. Between the Sir Frederick Range and the Maurice Hills the Ordovician rocks are flat lying and occur close to outcrops of the Bitter Springs and Carnegie Formations and these and the neighbouring Proterozoic Formations are folded with dips up to about 80°. The Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation show essentially conformable relationships with each other and with underlying formations and have a similar style of folding to the Winnall Beds. These facts suggest that all these units were folded at the same time during the Petermann Ranges Orogeny. If they were considered to be Cambrian and equivalent to the Cleland Sandstone or to the late Proterozoic or early Cambrian Mount Currie Conglomerate then an angular unconformity would be expected at the base of the sequence, and the intensity of folding would not be as great.

A comparison between lithology, topographic expression, photo-pattern and style of folding indicates fairly close correlation of the Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation with different parts of the Winnall Beds. The Ellis Sandstone can be correlated with the Unit 2 sandstone of the Winnall Beds, and the Maurice Formation with Unit 4 sandstone. The formations in the western part of the basin are generally coarser grained, poorer sorted and the siltstone occurs as thin interbeds rather than distinct units as in the Winnall Beds. This difference in lithology suggests that the sediments equivalent to the Winnall Beds in the western part of the basin were deposited under high energy conditions adjacent to source areas, which included both the clean quartzite ridges of Dean Quartzite and older Precambrian rocks. In this environment predominantly arenite was deposited and probably a large part of the lutite fraction was washed basinwards to become part of the Pertatataka Formation and Winnall Beds. Generally unstable slopes were common so that subaqueous sliding took place as shown by the occurrence of slumped cross laminated beds and intra-formational contortions.

It appears most likely from the evidence in the foregoing discussion that the whole sequence in the western part of the Amadeus Basin above the Carnegie Formation and below the Ordovician rocks is equivalent to the whole of the Winnall Beds in the southern part of the Basin.

Palaeogeography and history of deposition of the Pertatataka Formation and its equivalents

The formations included in this discussion are the Pertatataka Formation, Winnall Beds, Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation. These formations were deposited in one essentially uninterrupted cycle of sedimentation and are probably more or less contemporaneous. The combined isopachs drawn on these formations, and the distribution of the formations is shown in PG-10-12.

Sedimentation took place in a southern rapidly subsiding area and on a northern shelf area with an east-west trending hinge line, now represented by an eroded arch, separating the two main sedimentary provinces. The thickest deposits which includes the Winnall Beds and the equivalent Ellis Sandstone, Maurice Formation and Sir Frederick Conglomerate were laid down in the southern trough and the thinner northern shelf deposits include the sediments of the Pertatataka Formation. A subsidiary sub-basin developed in the north-eastern part of the basin where a comparatively large thickness of the Pertatataka Formation accumulated to form a south-west trending lobe. This sub-basin includes the only known younger Proterozoic glacial deposits.

The presence of a comparatively thick arenaceous facies (Winnall Beds) in the southern part of the Basin grading northwards into thin lutites and carbonate rocks (Pertatataka Formation) suggest derivation of the bulk of the sediments from a southern provenance during this period of deposition. Spasmodic uplifts of these southern source areas is suggested by the alternation of thick sandstone and shale in the Winnall Beds.

In the western part of the basin the distribution and variation in composition of the Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation also suggest provenance areas in the south and south-west. The predominance of rounded quartzite boulders in the Sir Frederick Conglomerate and the complex interfingering of the beds with the Ellis Sandstone suggest that deposition was relatively close to the provenance area and that deposition was in a combination of continental and transitional environments. The conglomerates are probably mainly fluvial and the interfingering sands mainly littoral deposits. The Sir Frederick Conglomerate probably has a counterpart in the thin conglomerates at the base of lower sandstone unit of the Winnall Beds in the southern part of the Basin.

The succeeding Maurice Formation is very poorly sorted and coarse grained in southern exposures but more mature sediments occur in the northern exposures showing that a southern provenance area was still extant. It was probably deposited in a combination of fluvial and shallow marine conditions.

The Pertatataka Formation was deposited on a northern shallow shelf in a neritic environment where only fine detritus accumulated. The presence of pyrite and the reduction of iron oxide to various minerals indicate reducing conditions. Towards the end of deposition of the Pertatataka Formation, when the shelf was practically filled by sediment and the supply of terrigenous sediments was reduced, dominant limestone deposition took place under shallow marine conditions. The provenance area was probably a northern, essentially flat, landmass. The low relief of the provenance can be explained by the peneplanation that took place during the preceeding Areyonga glacial phase.

The hinge line that marked the separation of the trough from the shelf sedimentation is now represented by a zone where the Pertatataka Formation is absent or very thin. Erosion in this zone followed the arching of the sediments by folding during the Petermann Ranges Orogeny. The Pertatataka Formation was completely removed from anticlinal culminations and in places the underlying Areyonga Formation was also removed and the Bitter Springs Formation exposed and eroded before deposition of the Cambrian Pertaoorrta Group. No other parallel linear zones with thinning of the formation are indicated which suggests that there were no significant basement highs at the time.

The variety and composition of lithologies present in the Pertatataka Formation in the north-eastern part of the Basin indicate an environment of deposition differing from that interpreted for most of the northern shelf deposits. Glacial conditions were restricted to this comparatively small area of the Basin at this time. Deposition of normal shelf siltstone was interrupted during prolonged intervals by invasions of coarser detrital material and by boulder beds and boulder clays with glacial affinities indicating high energy environments. The cross-laminated and slumped, fine sandstones could represent fluvioglacial meltwater deposits; they have similar sedimentary structures to point bar deposits described from modern rivers (Davies, 1966). In periods of quiescence, when there was a reduction in the volume of detritus, oolitic and fragmental sandy shelf carbonate rocks were deposited.

The derived boulders in the conglomeratic parts of the formation show that older members of the Pertatataka Formation, the Bitter Springs Formation, Heavitree Quartzite, and a terrain of igneous and metamorphic rocks (probably mostly Arunta Complex) were exposed in a neighbouring uplift near the north-eastern part of the Basin and were vigorously eroded by glaciers. Arkose and fresh feldspar suggest the proximity of source areas composed of crystalline rocks. The presence of clasts derived from the underlying Limbla Member and the common occurrence of edgewise dolomite breccias indicate penecontemporaneous erosion of the Pertatataka Formation.

The question of whether sedimentation began first in the north-eastern part of the Basin or in the southern subsiding area cannot be resolved as there are no marker beds to correlate through the succession.

COMPARISONS OF PROTEROZOIC PALAEOGEOGRAPHY AND THE DEVELOPMENT AND CONFIGURATION OF THE PROTEROZOIC BASIN

The two major divisions of Proterozoic rocks deposited after the Bitter Springs Formation appear to have experienced a similar geological history. A comparison of the distribution, lithology, isopach and lithofacies maps show broad similarities and it is apparent from the distribution of the units (PC-7-9 and PC-10-12) that the outcrops are closely associated and were deposited over much the same areas.

For convenience the older Areyonga Formation and its equivalents (Boord Formation, Carnegie Formation and Inindia Beds) will be referred to as Group 1 sediments and the Pertatataka Formation and its equivalents (Winnall

Beds, Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation) as group 2 sediments.

Prior to the deposition of groups 1 and 2, the first stage of the Proterozoic cycle of sedimentation commenced with the deposition of the Heavitree Quartzite on a stable continental platform as a shallow marine blanket sand. The Bitter Springs Formation that followed conformably consists of basal saline deposits followed by penesaline and "normal" marine sediments. The presence of thick evaporites at or near the base of the formation marks the development of an intracratonic basin and the deposition of an arid restricted basin association during which time there was limited access to the open sea. Shallow marine conditions prevailed when the youngest sediments of the formation were laid down. The limits of this intracratonic basin are not known.

A major tectonic event then took place, subsequent to the deposition of the Bitter Springs Formation, which resulted in a radical change of the palaeogeography and was the initial stage of the development of the Amadeus Basin. This tectonism, which resulted in the second stage of the Proterozoic cycle of sedimentation, was responsible for the development of a southern mobile belt including a southern borderland or geantictinal welt, a subsiding geosynclinal trough, and a northern shelf and stable foreland area.

The thickness of the sediments in the two groups, as illustrated in the isopach maps, and the composition of the sediments suggest that uplifts to the south of the present margin of the Amadeus Basin were the main source of sediments. As sedimentation proceeded a rapidly subsiding trough developed to the north of the provenance area and predominantly coarse grained sediments accumulated. At the same time an east-west trending hinge line developed at the northern edge of the trough and separated it from a stable shelf area. Finer grained sediments were deposited north of the hinge line on the shelf. Correlation of glacial beds suggests that a considerable thickness of sediments had accumulated in the trough prior to shelf sedimentation. The thickest sediments of groups 1 and 2 were formed in the southern geosynclinal trough and from this area wedge out markedly onto the stable foreland area.

It is proposed that the area of the thick wedge of sediments in the geosynclinal trough be called the Erldunda Orogeosyncline. It is apparent that the site of thickest Proterozoic sedimentation was a zone of maximum orogenic activity during the Petermann Ranges Orogeny and the term orogeosyncline denotes a geosyncline that developed into an orogen. The process causing the uplift of the southern Proterozoic provenance area and the complementary down-warping to the north to form a trough of sediments is called the Kulgera Tectonism. The name MacDonnell Shelf is proposed for the area of thin stable shelf deposits to the north and the name Parana Arch for the zone separating the Erldunda Orogeosyncline and the MacDonnell Shelf. The Parana Arch probably outlines the hinge line at the northern edge of the trough in the Proterozoic Basin where there was later arching of the sediments during the Petermann Ranges Orogeny followed by erosion of a large part of the sequence. These structural elements are shown in PC-15.

The Proterozoic episode of sedimentation was terminated by the Petermann Ranges Orogeny with mountain building and accompanying recumbent folding localized mainly along the axial zone of the Erldunda Orogeosyncline. The maximum amount of folding and faulting occurred on the southern borderland side of the Proterozoic Basin.

The variation in rock types in groups 1 and 2 and their change across the Proterozoic Basin are very similar. Thus the transition of the relatively thin siltstone - shale facies of group 2 (Pertatataka Formation) in the north to sand - shale facies of the Winnall Beds in the south corresponds to a similar change from siltstone - sandstone - conglomerate facies of group 1 (Areyonga Formation) to sandstone - shale facies in the south (Inindia Beds).

The presence of a comparatively moderate thickness of predominantly arenaceous sediments in the southern trough and the fact that the period of subsidence spanned only part of the Proterozoic period suggests that the trough can be classified as a parageosyncline, and includes an area of subsidence within the Craton itself.

The sediments at the cratonic borders on the shelf include marine, stromatolitic fragmental limestone and green and black glauconitic shales. The limestones of the shelf deposits commonly contain spherical quartz grains and gradation from quartz sand to carbonate deposition is common. These features are typical of the Julie Member of the Pertatataka Formation. Glauconite is common in the shales of the Pertatataka Formation, a feature found commonly in sediments of stable shelf areas.

In the western part of the Basin the north-south gradation of lithologies is also apparent. The shelf siltstones and carbonate rocks of the Boord Formation grade southwards into coarser red-beds and sands of the Carnegie Formation in group 1. In group 2 the coarse-conglomerates of the Sir Frederick Conglomerate and the coarser, poorly sorted sediments of the Maurice Formation are prevalent in the southern part of the Basin. Occurrences of the Ellis Sandstone, the fine grained equivalent of the Sir Frederick Conglomerate, and the more mature sediments of the Maurice Formation are found mainly in the northern part of the Basin.

The Parana Arch has an east-west trend through the centre of the basin. It changed position slightly from group 1 to group 2 sedimentation (PG-15). The arch appears to widen to the north-west and the apparent absence of group 1 and 2 sediments here may indicate the existence of a shallow platform during sedimentation. Shallow platform areas with thin sediments in the south-eastern part of the basin are common to both groups as well as thickened lobes of sediments which in each group reflects a major development of glacial sediments in north-eastern sub-basins.

The sequences in both of these major divisions show the influence of glacial environments but to different degrees. The earlier period of Proterozoic glaciation, during group 1 times, was widespread and influenced to a small degree the type of sediments deposited in the southern trough of the Basin whilst at the same time adding to most of the shelf sediments which in places show predominantly glacial affinities.

The younger glaciation was restricted to one part of the shelf area during group 2 times. Hence even though the sediments of both groups were deposited on the shelfward side of the basin, and may have had a similar palaeogeography, the differing scales of glaciation on the neighbouring provenance areas produced different lithological associations.

Summary of regional tectonics and sedimentation

Prior to the Petermann Ranges Orogeny up to 15,000 feet of Inindia Beds and Winnall Beds were deposited in a rapidly subsiding trough at the southern margin of the Amadeus Basin. The Orogeny shows that during the late Proterozoic tectonic history of this region there was major uplift along the axis of the Proterozoic trough and recumbent folding involving the sediments beneath the Pinyinna Beds.

This folding caused uplift and mountain building along the southern margin of the Basin and thick wedges of the Mount Currie Conglomerate and arkose at Ayers Rock of probable Cambrian age were deposited against the northern front of the fold mountains. The tightly folded Winnall Beds and Inindia Beds are overlain with an angular unconformity by the succeeding Palaeozoic sediments.

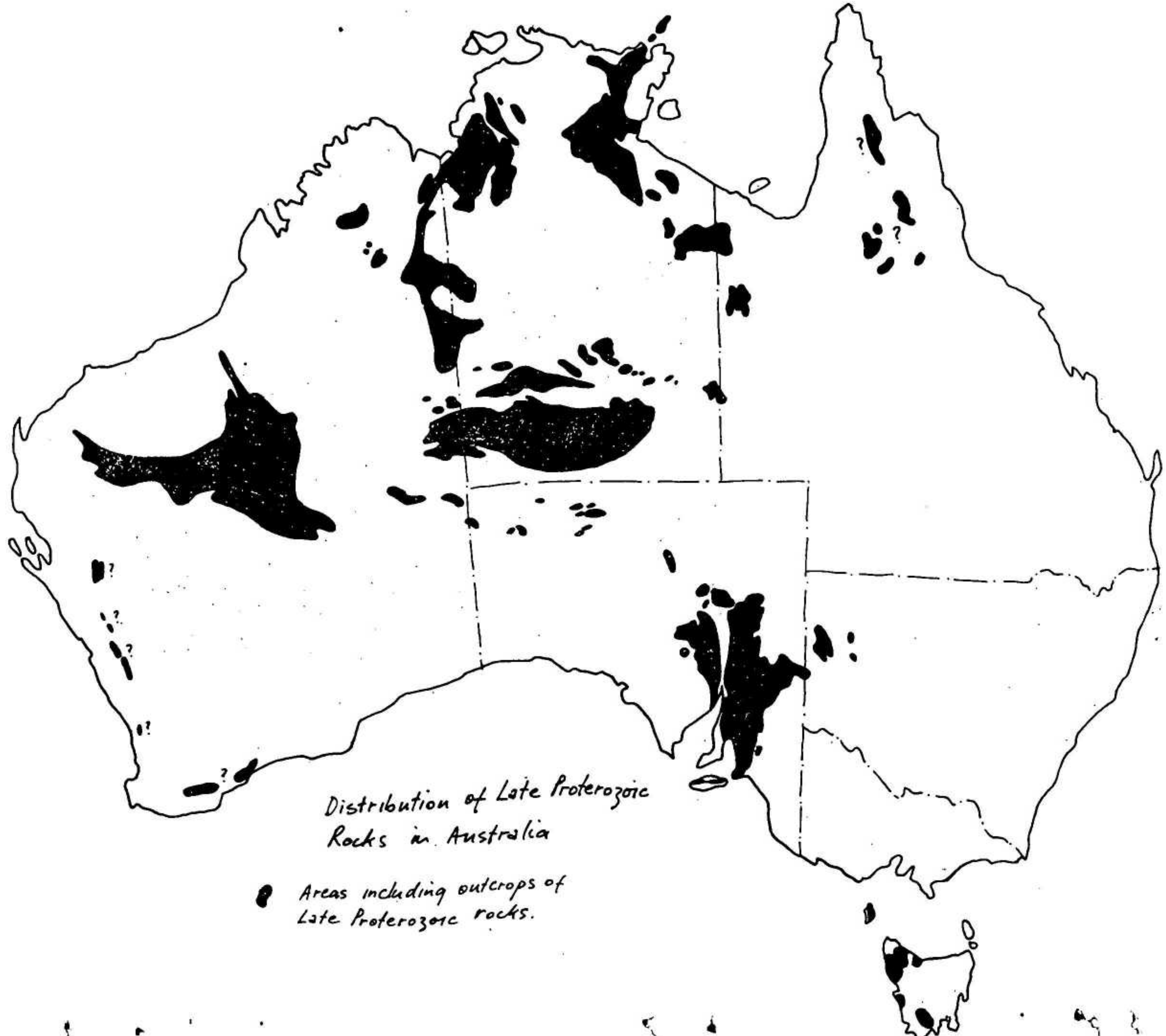
The Petermann Ranges Orogeny is reflected in two unconformities in the sedimentary section. The first beneath the Winnall Beds and the second beneath the Pertaoorrta Group. Both these unconformities are more marked at the southern edge of the Basin than further north, which suggests that folding was initiated in the south and subsequently extended northwards and ended with the strong folding in the Lake Neale - Lake Amadeus areas.

In the western part of the Basin there is no angular unconformity within the succession from Heavitree Quartzite to Maurice Formation. For this reason it is proposed that this sequence is all Proterozoic in age. If Cambrian sedimentation occurred in this area an angular discordance should be evident. The Mount Currie Conglomerate and arkose at Ayers Rocks are locally distributed next to the mountain chains formed after the Petermann Ranges Orogeny. Correlation of the Proterozoic Sir Frederick Conglomerate, Ellis Sandstone, and Maurice Formation with these two units implies a much wider area of deposition mainly in the western part of the Amadeus Basin and in areas far removed from the provenance. This possibility is highly unlikely. The conglomerates and sandstone in this western late Proterozoic sequence are probably near shore unstable shelf deposits and piedmont conglomerates equivalent to the Winnall Beds. A similar conglomerate occurs in the Winnall Beds at Mount Connor. The equivalents of the Mount Currie Conglomerate and arkose at Ayers Rock have presumably been eroded from the most westerly areas and were probably part of the source for later sediments of the Pertaoorrta Group and probably the Larapinta Group as well.

Tentative Correlations with Proterozoic Sequences in Australia

The distribution of late Proterozoic rocks in Australia is shown in Fig. PG-13, and the probable original distribution of rocks of this age is shown in Fig. PG-13A. It seems likely that the large areas of exposed igneous and

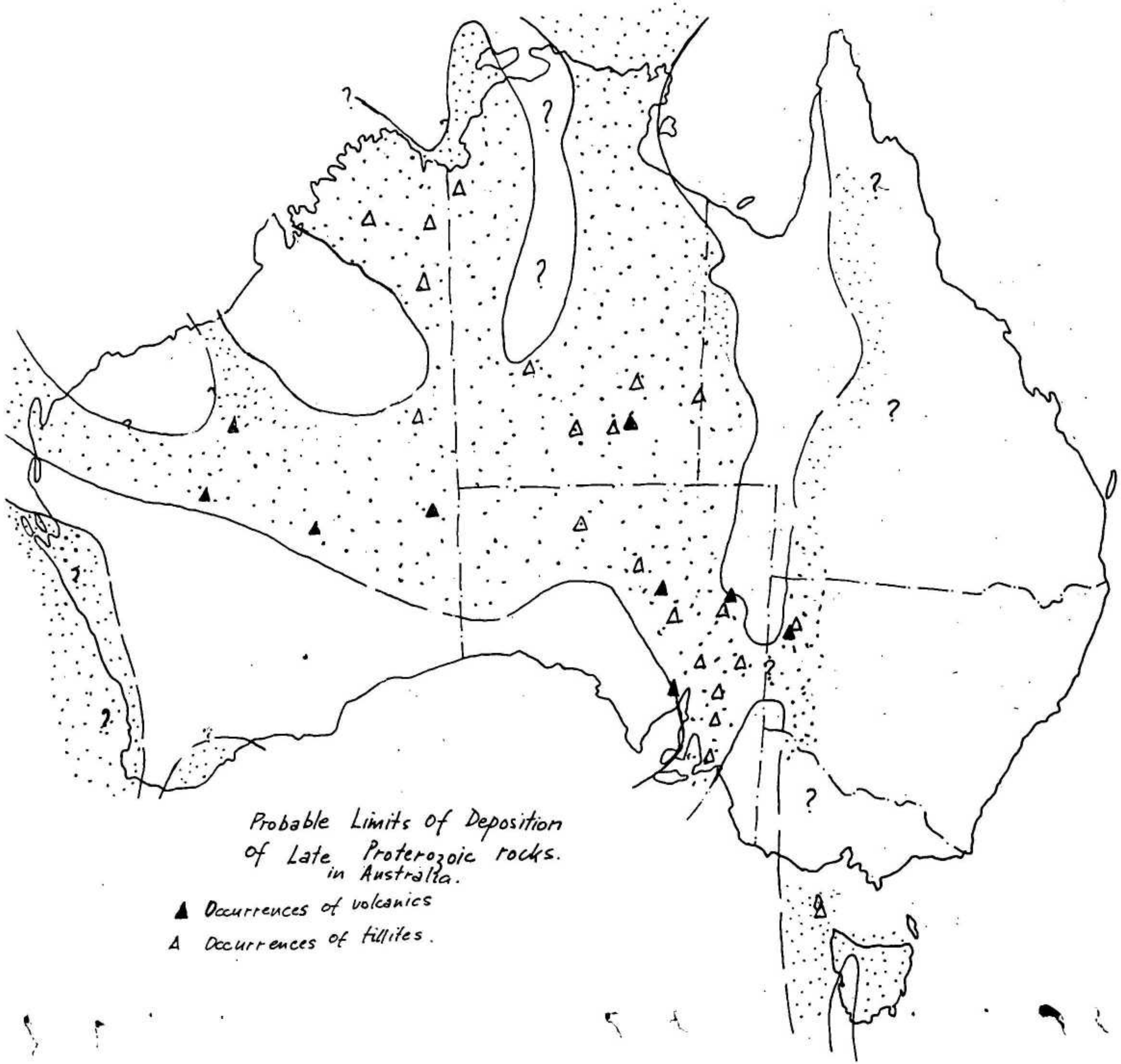
PE 13.



Distribution of Late Proterozoic Rocks in Australia

Areas including outcrops of Late Proterozoic rocks.

PE 13A.

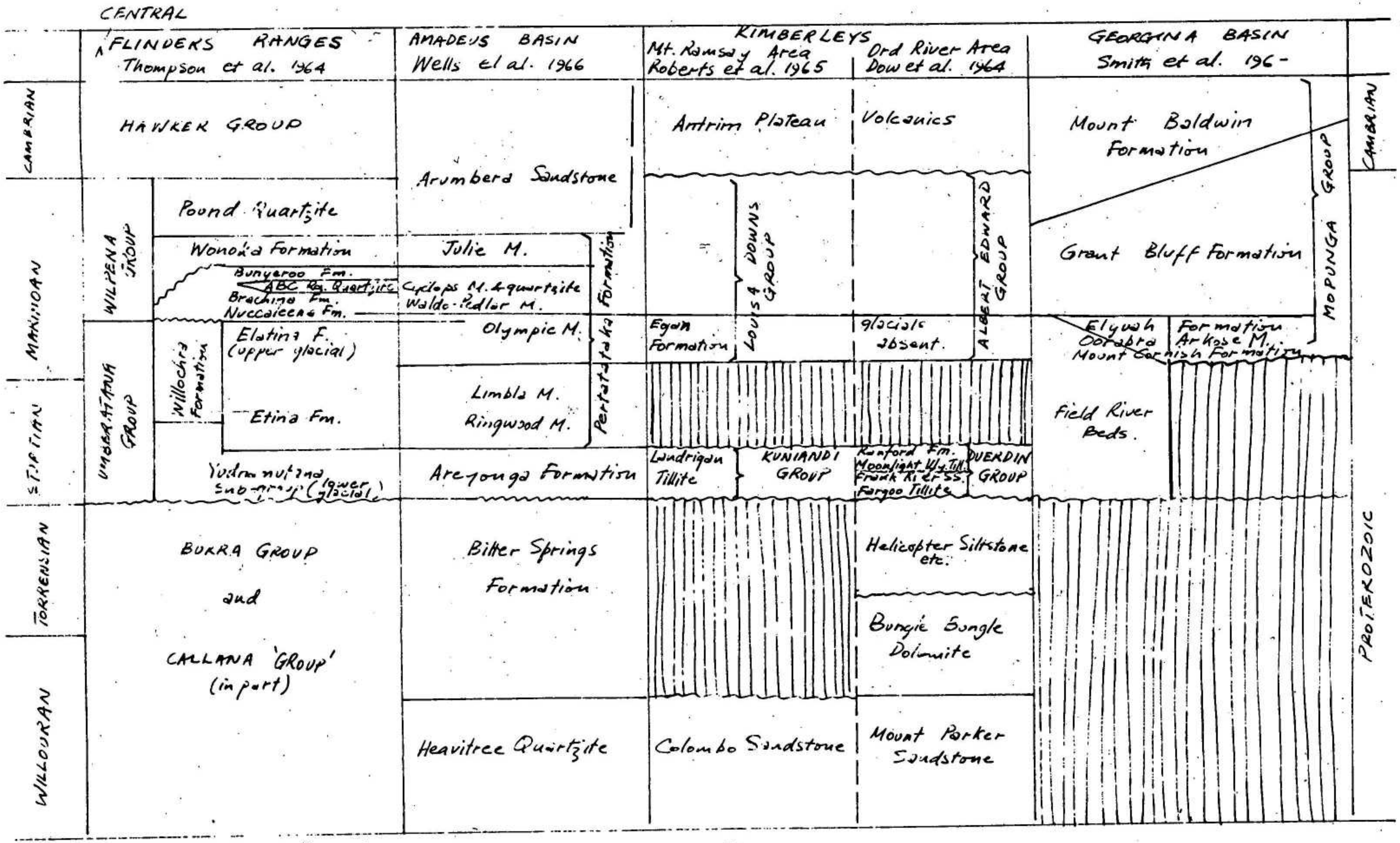


Probable Limits of Deposition of Late Proterozoic rocks in Australia.

▲ Occurrences of volcanics

△ Occurrences of tillites.

TENTATIVE CORRELATIONS OF PROTEROZOIC SUCCESSIONS IN AUSTRALIA. PE-14



Hiatus

Not all formations are shown.

PE15

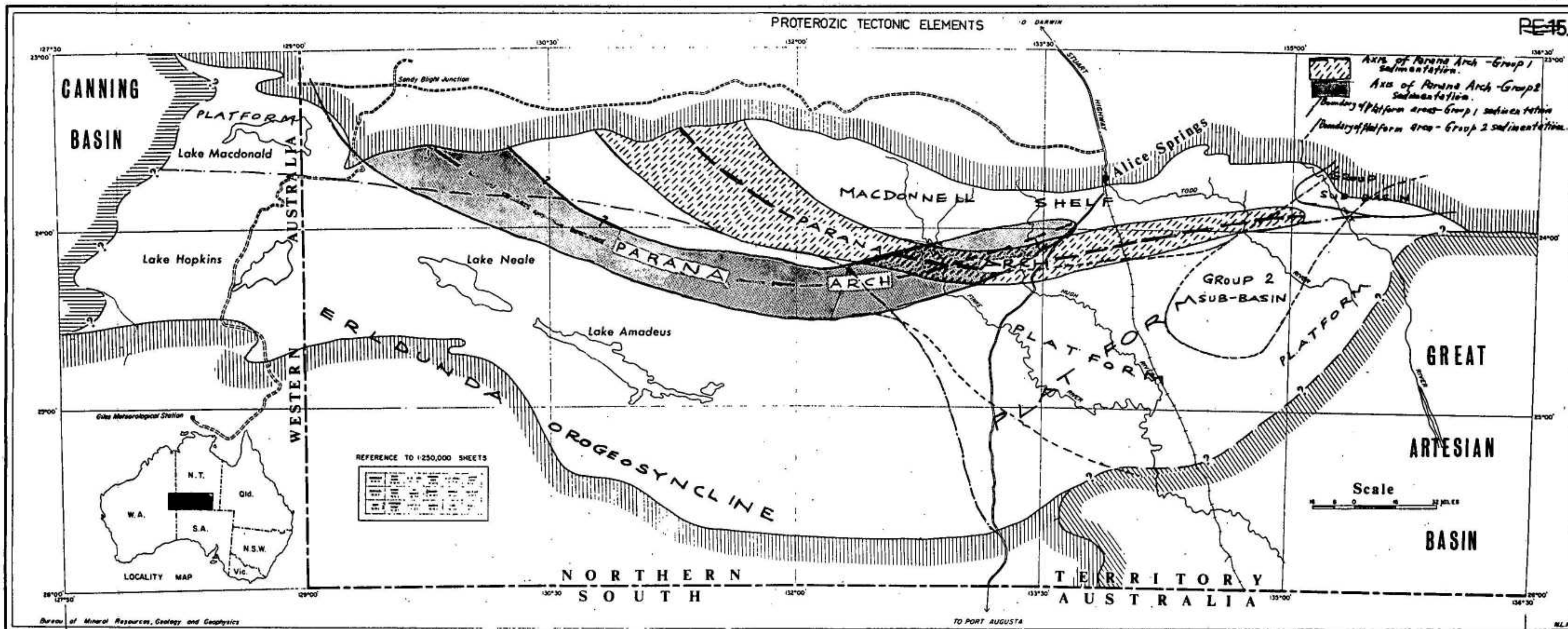

PROTEROZOIC TECTONIC ELEMENTS
PE15.
Axis of Parana Arch - Group 1 sedimentation.
Axis of Parana Arch - Group 2 sedimentation.
Boundary of Platform areas - Group 1 sedimentation
Boundary of Platform area - Group 2 sedimentation.
CANNING BASIN
PLATFORM
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Alice Springs
MACDONNELL SHELF
PARANA ARCH
Lake Neale
Lake Amadeus
ERYDUNDA OROGEOSYNCLINE
GROUP 2 SUB-BASIN
PLATFORM
GREAT ARTESIAN BASIN
Scale
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics

Fig. pЄ-16 Unconformable contact of the Heavitree Quartzite and Precambrian mica schists at Mount Rennie, northern margin of the Amadeus Basin.
G/4326

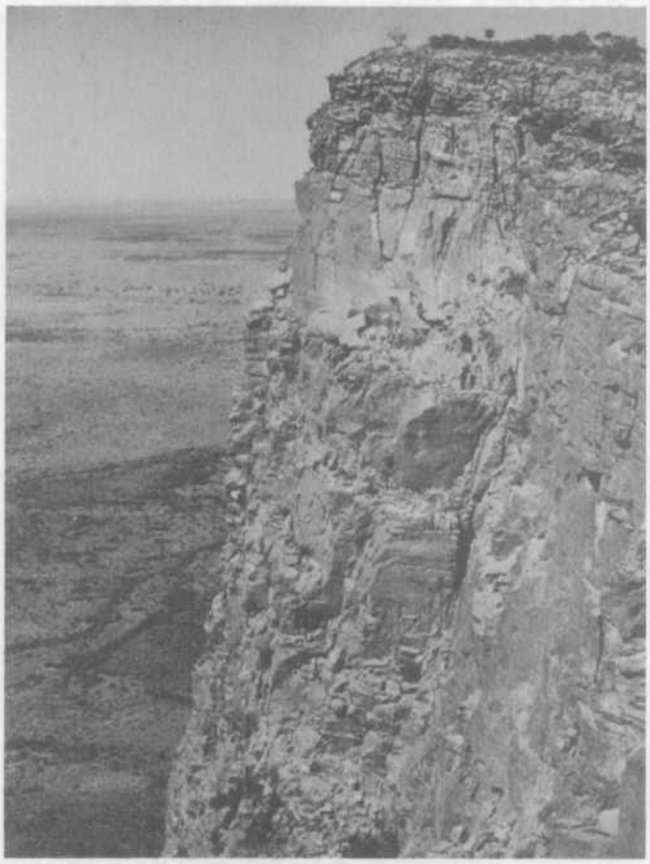


Fig. pЄ-17 Flaggy silicified Heavitree Quartzite in eastern scarp of Mount Leisler.
G/9135

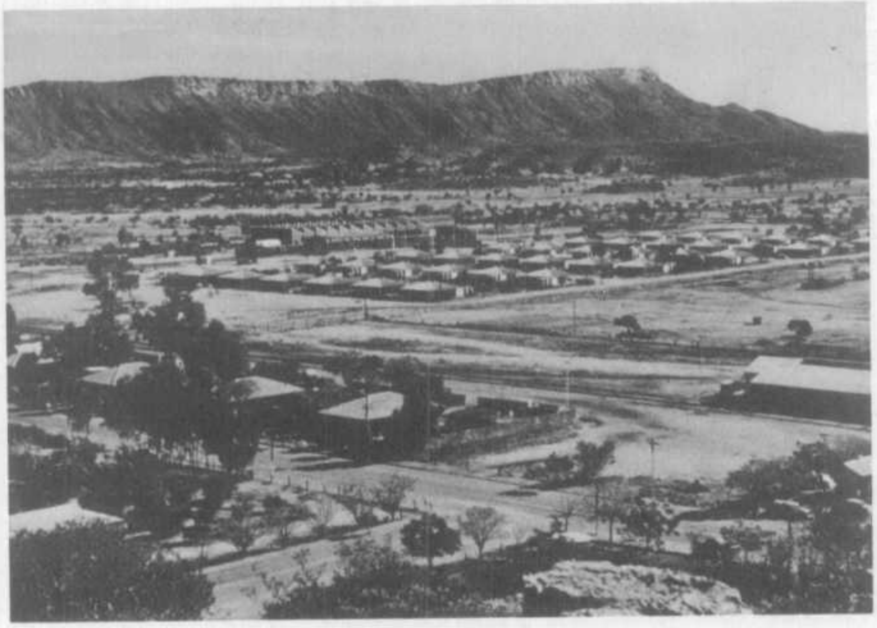


Fig. pG-18 Heavitree Quartzite at Mount Gillen dipping southwards and unconformably overlying Arunta Complex exposed on lower slopes and low hills. Alice Springs in the foreground.
G/9122

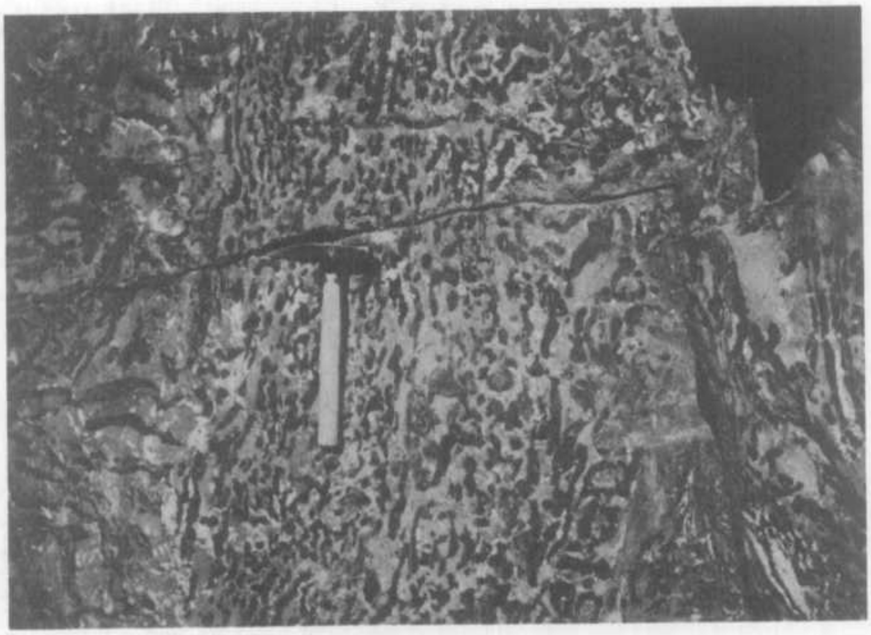


Fig. pG-19 Irregular stromatolites in the Bitter Springs Formation at Ellery Creek.
G/9576

Fig. p€-20 Polygonal joints in thin phosphate bed at the base of the Areyonga Formation, 2 miles north of Pulya-Pulya Dam.
G/9118

Fig. p€-21 Interbedded shale, siltstone and prominent beds of fine sandstone in the Pertatataka Formation near Areyonga.
G/9136

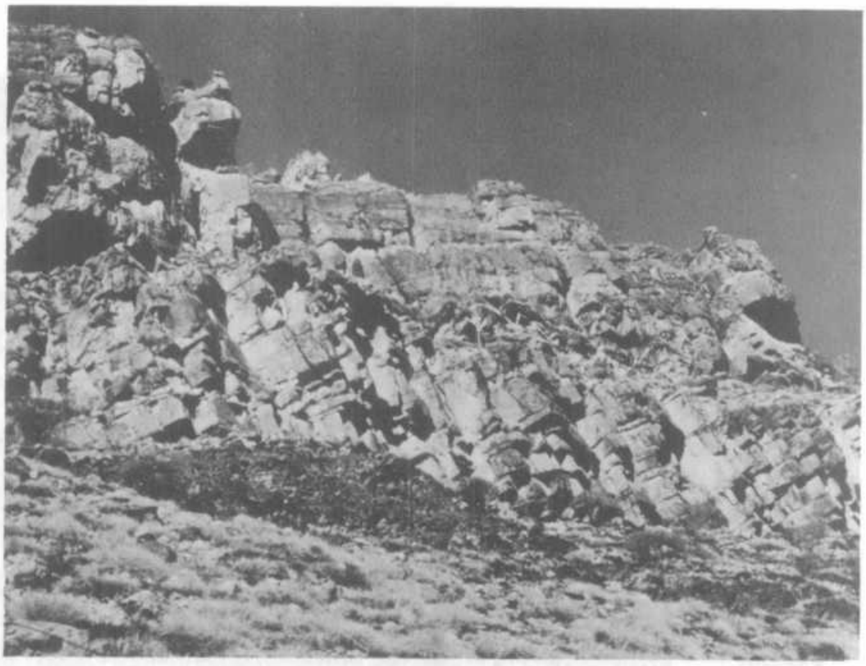


Fig. pЄ-22 Julie Member of the Pertatataka Formation, east of Loves Creek homestead. Upper massive oolitic dolomite forming scarp, overlying vertically jointed sandstone, and darker coloured thin bedded limestone and shale on lower slopes.
G/7518

Fig. pЄ-23 Bed of dolomite pebble and boulder conglomerate in the Carnegie Formation, north-western Amadeus Basin.
G/4334

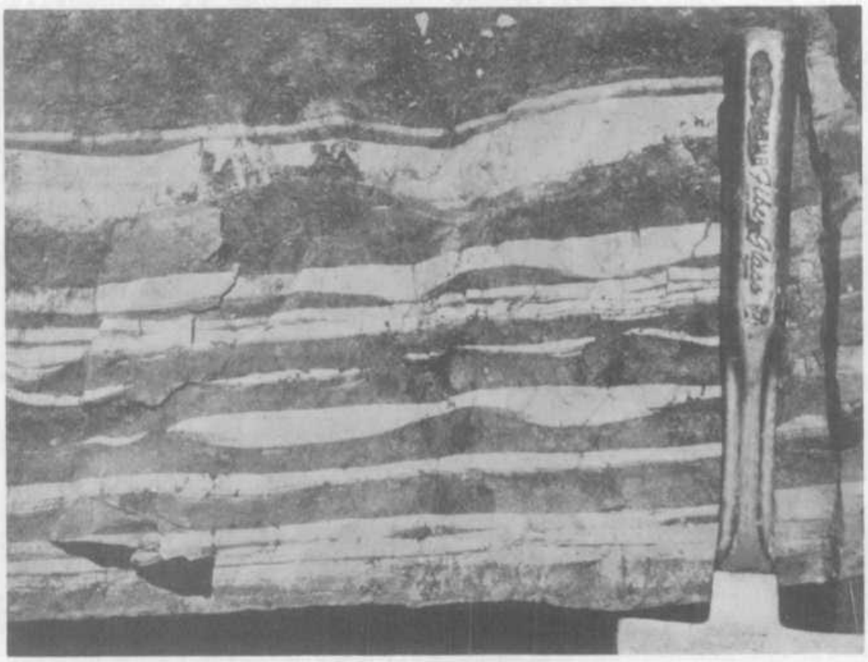


Fig. pЄ-24 Lensoid beds in dolomite of the Julie Member of the Pertatataka Formation, 4 miles south-east of Box Hole Bore.
G/9154

Fig. pЄ-25 Fragmental limestone of the Julie Member of the Pertatataka Formation, exposed in the Gardiner Range.
G/9144

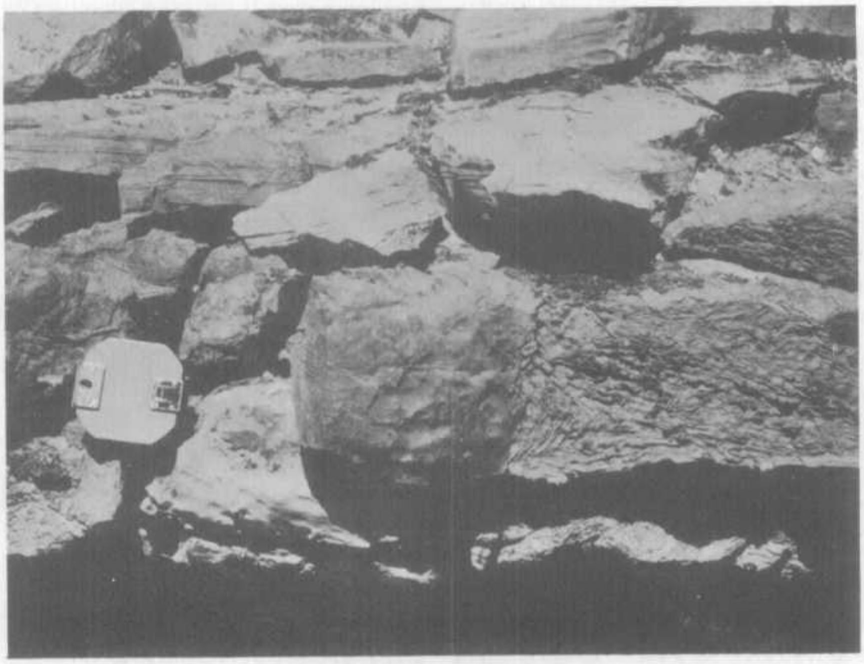


Fig. p€-26 Ringwood Member of the Pertatataka Formation near Limbla Homestead. Circular stromatolite colony of limestone showing flanking derived fragmental limestone.
G/9155

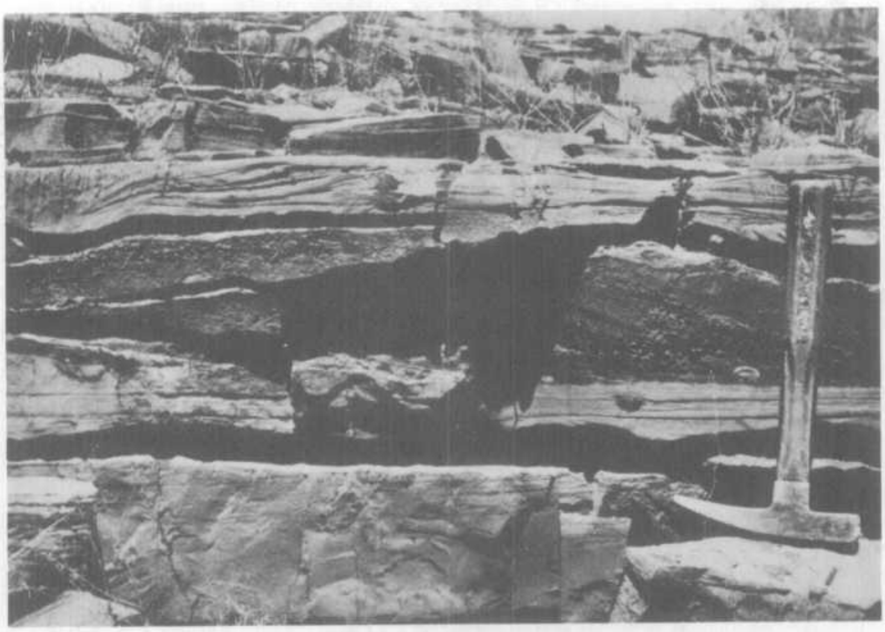


Fig. p€-27 Ringwood Member of the Pertatataka Formation. Interbedded cross laminated fine sandy limestone and fragmental cross bedded limestone probably derived from the breakup of stromatolite colonies.
G/9116

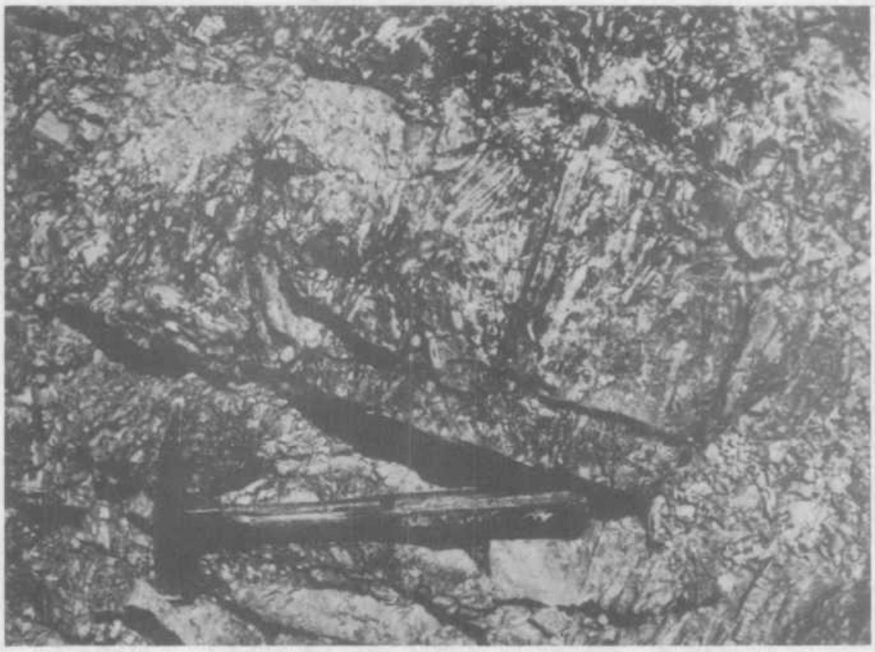


Fig. p€-28 Edgewise conglomerate of dolomite plates in matrix of coarse angular sand, Olympic Member of the Pertatataka Formation.

GA/19

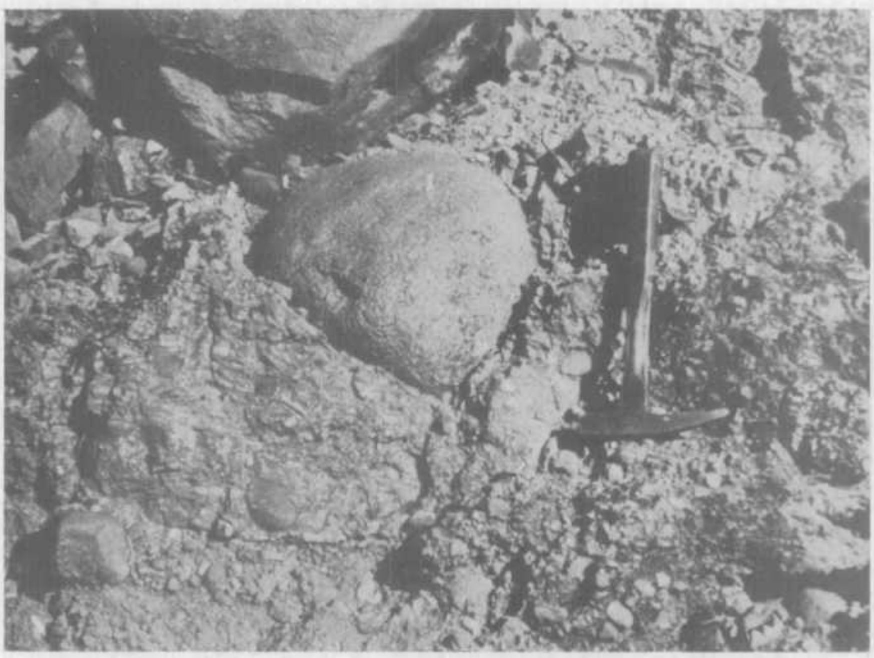
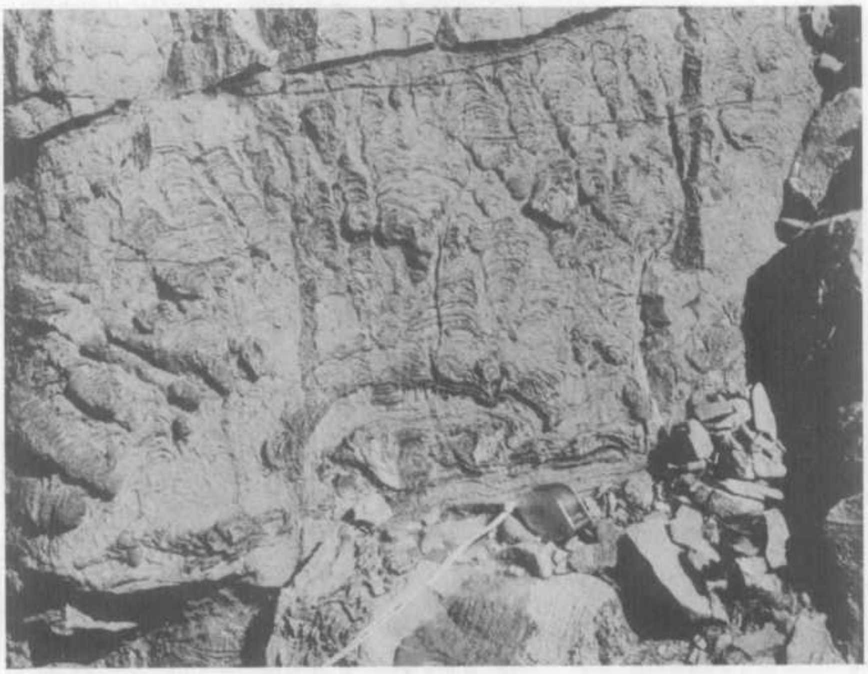


Fig. p€-29 Rounded boulder of granite in conglomerate of the Olympic Member, Pertatataka Formation.

GA/20



pЄ 30. Stromatolite colony in the Bitter Springs Formation, Katapata Gap, Gardiner Range.
M/94-20

pЄ 31. Slump structure in the upper sandstone of the Limbla Member, Pertatataka Formation.
M/405-28.

pC 32. Olympic Member - Pertatataka Formation. Sandstone with cavities left after weathering of clay pellets. GA/21

metamorphic rocks of the Musgrave and Arunta Complexes to the north and south of the Amadeus Basin were also covered by seaways at times during the Proterozoic, as indicated in Fig. PC-13-A.

The Proterozoic succession in the Amadeus Basin can be tentatively correlated with sequences in the Kimberley area in the north-western part of Australia, the Adelaide Geosyncline and the Georgina Basin by means of glacial horizons, preliminary radioactive age dating, the correlation of stromatolitic algae and by a comparison of stratigraphic sequences. Of these criteria the glacial beds probably offer the best means of correlation at the present time as no systematic age dating has been carried out. A few tentative correlations are presented here using these criteria.

The oldest glacial horizon in the Amadeus Proterozoic sequence, (the Areyonga Formation and its equivalents, the Boord Formation and Inindia Beds), can be correlated with the Fargoo Tillite and Moonlight Valley Tillite in the East Kimberley Region. (Dow and Gemuts, 1967, in press). The younger glacial horizon, the Olympic Member of the Pertatataka Formation can be correlated with the Egan Glacials of the Mount Ramsay area (Roberts et al., 1967 in press). In the Adelaide Geosyncline the Areyonga Formation can be correlated with the Yudnamutana Sub-Group (Sturtian; Coats, 1964) and the Olympic Member with the Elatina Formation and Nuccalena Formation (Marinoan) of the central Flinders Ranges (Coates, 1964, and Dalgarno and Johnson, 1964) and the Mount Cornish Formation in the Georgina Basin (Smith, 1967 in press). These correlations are shown in PC-14.

When the lithologies of some of the formations in these widely separated areas are compared in detail there are some striking similarities. The siltstone of the Pertatataka Formation bears lithological similarities to the Timperley Shale of the Albert Edward Group in the Ord River Region and the McAlley Shale of the Louisa Downs Group in the Mount Ramsay Sheet area. The McAlley Shale is about 5,000 feet thick and consists of black, grey and green shale showing rare flow and groove casts. By contrast with the shelf environment postulated for the Pertatataka Formation, according to Roberts et al (1967 in press), the McAlley Shale was deposited in a bathyal environment during epeirogenic subsidence of extensive parts of the area. The Timperley Shale consists of grey and green shale and is 4,150 feet thick (Dow et al., 1967, in press). It constitutes over half the thickness of the Albert Edward

Group and the McAlley Shale comprises the major part of the Louisa Downs Group. The Colomba Sandstone and Mount Parker Sandstone can be correlated with the Heavitree Quartzite. The Mount Parker Sandstone underlies the Bungle Bungle Dolomite which is similar lithologically to the Bitter Springs Formation and both formations contain carbonate rocks rich in stromatolites. The Callana Beds (Thompson and Coats, 1964) constitute the mobile formation in the diapiric structures in the Adelaide Geosyncline and contain volcanics. These two facts have suggested a correlation with the Bitter Springs Formation but the Skillogalee Dolomite of the Burra Group bears more lithological similarity to the Bitter Springs Formation and the underlying Yednalue Quartzite could therefore be correlated with the Heavitree Quartzite.

CAMBRIAN

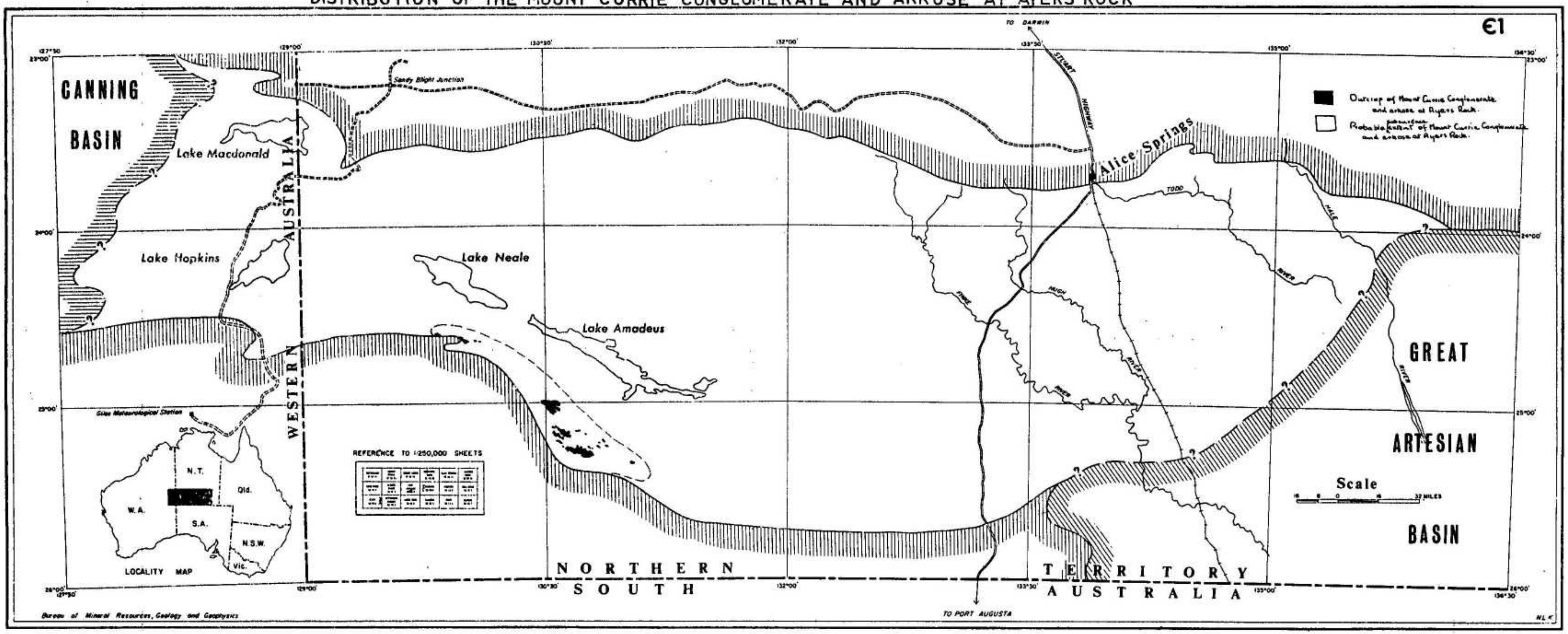
Mount Currie Conglomerate and the arkose at Ayers Rock

Forman (1967, in press) defined the Mount Currie Conglomerate and described the arkose from Ayers Rock. He suggested that both units may have been deposited at the same time and that they were wedge-like bodies of non-marine sediment deposited in front of the mountain chain formed by recumbent folding (Petermann Ranges Orogeny). The distribution of outcrop and probable subsurface extent of the units are shown in Figure (Є1).

The Mount Currie Conglomerate consists of a sequence of pebble, cobble and boulder conglomerate which rests unconformably on Upper Proterozoic sediments at Mount Currie (the type area) in the north-western corner of the Ayers Rock 1:250,000 Sheet area. The formation crops out between the Pinyinna Range in the Bloods Range Sheet area and Mount Olga Є-9 in the Ayers Rock Sheet area. Forman (1966, in press) has estimated that there is about 2000 feet of the unit exposed at Mount Olga and has suggested that it may have a maximum thickness of 20,000 feet in this area.

Forman (1966, in press) has described the scattered outcrops of Mount Currie Conglomerate and has suggested that the phenoclasts near the base of the formation consist mainly of sandstone; in the middle part of the unit they are fine-grained acid and basic rocks, and towards the top of the formation they are mostly granite and gneiss. The rounded inselbergs at

DISTRIBUTION OF THE MOUNT CURRIE CONGLOMERATE AND ARKOSE AT AYERS ROCK



Mount Currie and Mount Olga are thought to consist of the middle and upper parts of the formation which are more resistant to erosion.

The basal unit contains silicified sandstone phenoclasts, up to 2 feet in diameter, in a sandy matrix. The phenoclasts were probably derived from the Dean Quartzite and the Winnall Beds. The middle part of the unit is well exposed at Mount Currie and comprises conglomerate with phenoclasts of brown feldspar porphyry, greenish grey basalt, green epidotized amygdaloidal basalt, gray quartz sandstone and rare vein quartz. The boulders are well rounded and ellipsoidal, and up to about 14 inches in length. They are set in a matrix of quartz, feldspar and epidote. At Mount Olga, which is considered to be higher in the section, the conglomerate contains phenoclasts of granite, gneiss and fine-grained acid and basic igneous rocks, in an epidote-rich matrix. W. Oldershaw (pers. comm. in Forman, 1966, in press) has described a sample of the Mount Currie Conglomerate from Mount Olga: 'the phenoclasts are set in a granular matrix of angular fragments, 0.2 - 2 mm. across, of quartz-albite intergrowths, devitrified glass, fresh microcline, orthoclase perthite, plagioclase, quartz and augite. The interstices are filled with fine-grained epidote'. He suggests that the epidote cement could be due to regional metamorphism which only affected the fine-grained cement of the rock or that it could be of hydrothermal or volcanic origin and he points out that the feldspars show very little alteration.

The Mount Currie Conglomerate overlies the Pinyinna Beds with a visible unconformity at Pinyinna Range in the Bloods Range Sheet area and it is assumed to lie unconformably on the Winnall Beds in the Ayers Rock Sheet area because of the presence of phenoclasts apparently derived from the Winnall Beds and also because of the discordance between the strike of the Mount Currie Conglomerate and that of the underlying Winnall Beds. Since deposition the formation has been folded and deeply eroded. Forman (1966, in press) has suggested that the Mount Currie Conglomerate may be a lateral equivalent of the thin conglomerate at the base of the Cleland Sandstone. However, the present author is of the opinion that the Cleland Sandstone is considerably younger than the Mount Currie Conglomerate although both units probably had a similar provenance.

The <u>arkose at Ayers Rock</u> (Є-10) is pale grey, dark grey, pink-grey and green-grey and coarse-grained with some medium-grained laminae. The sediments are cross-laminated and contains fragments of feldspar up to 1 inch long and are poorly sorted, with subangular grains and scattered clay pellets. Forman (1966, in press) has estimated that about 8,000 feet of arkose is exposed in the vicinity of Ayers Rock and the total thickness of the arkose unit may be over 20,000 feet, assuming that there is continuity between scattered outcrops. The unit has no exposed contacts with older or younger formations and is correlated with the Mount Currie Conglomerate. Both the Mount Currie Conglomerate and the arkose at Ayers Rock show signs of epidotization.

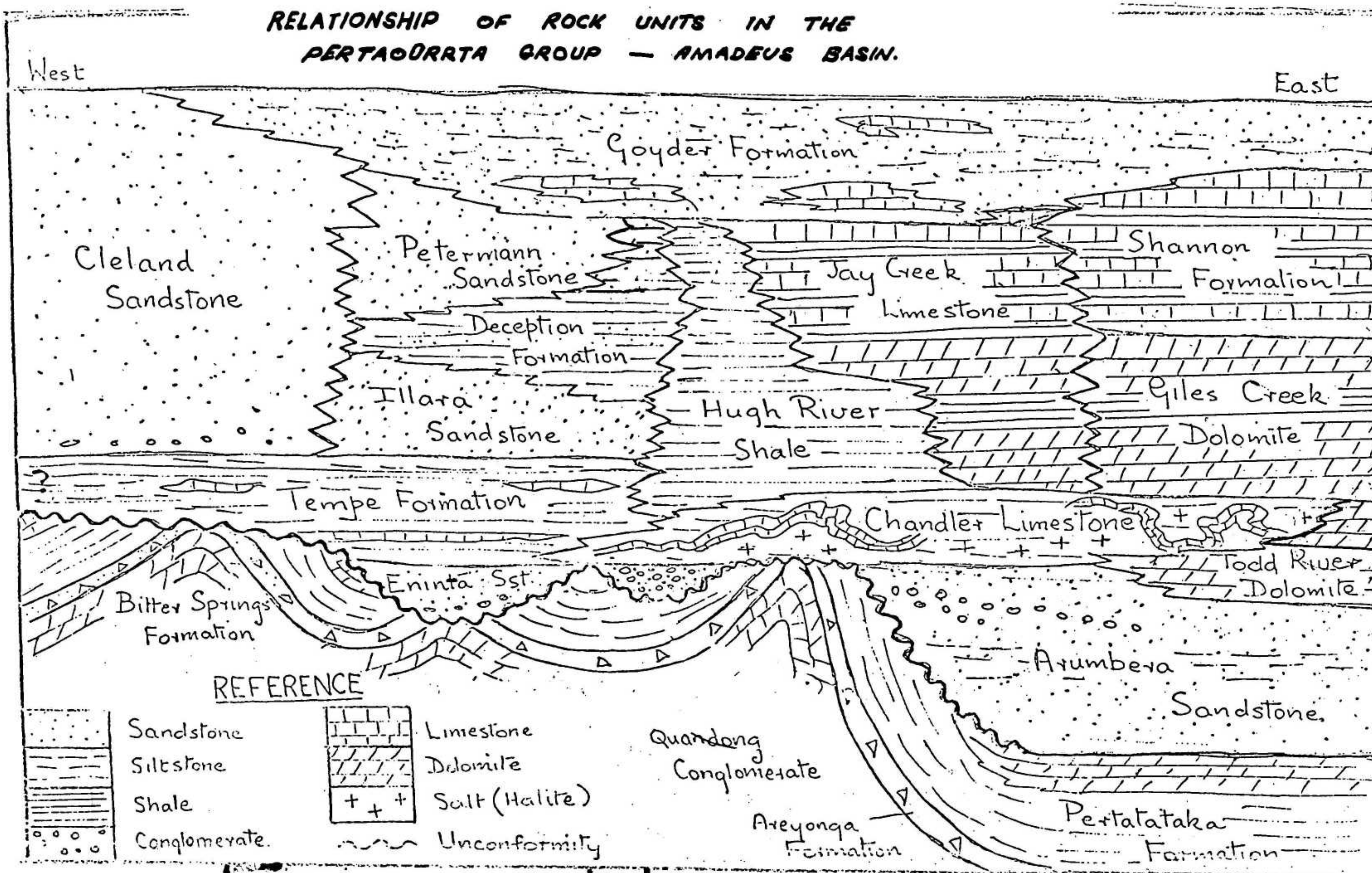
Correlation and age of the Mount Currie Conglomerate and arkose at Ayers Rock

Fossils have not been found in these sediments and therefore their age must be deduced either from their stratigraphic position or by lithological correlation with units of known age.

Quinlan (1962) suggested that the arkose of Ayers Rock and the boulder conglomerate at Mount Olga are lithologically similar to the Pertnjara Formation and tentatively correlated these units with that formation.

Forman (1966, in press) considered the Mount Currie Conglomerate and the laterally equivalent arkose at Ayers Rock to be synorogenic sediments associated with the Petermann Ranges Orogeny and suggested a possible correlation with the thin conglomerate at the base of the Cleland Sandstone. He tentatively placed the unit in the Cambrian.

The Mount Currie Conglomerate unconformably overlies the Winnall Beds of presumed Upper Proterozoic age and both the Mount Currie Conglomerate and the arkose at Ayers Rock appear to have been largely derived from Precambrian igneous rocks exposed along the southern margin of the Amadeus Basin. Flat-lying or gently folded Ordovician sediments are preserved near the southern margin of the Amadeus Basin and these sediments rest unconformably on metamorphosed and intensely folded Precambrian rocks (Forman, 1966, in press). Therefore, the Petermann Ranges Orogeny and the associated synorogenic sediments must lie within the limits of Precambrian to Ordovician. However, in the central part of the Amadeus Basin, Ranford, Cook and Wells (1966, in press) have established a major hiatus between lower Middle Cambrian and


RELATIONSHIP OF ROCK UNITS IN THE PERTAOORRTA GROUP — AMADEUS BASIN.
West
East
Goyder Formation
Cleland Sandstone
Petermann Sandstone
Deception Formation
Illara Sandstone
Hugh River Shale
Jay Creek Limestone
Shannon Formation
Giles Creek Dolomite
Tempe Formation
Chandler Limestone
Todd River Dolomite
Eninta Sst.
Bitter Springs Formation
Arumbera Sandstone
Quandong Conglomerate
Areyonga Formation
Pertatataka Formation
REFERENCE
Sandstone
Siltstone
Shale
Conglomerate.
Limestone
Dolomite
Salt (Halite)
Unconformity

Upper Proterozoic sediments. This major unconformity is thought to represent the effects of the Petermann Ranges Orogeny. If this is so, the time of Petermann Ranges Orogeny can be limited to Upper Proterozoic to lower Middle Cambrian. It is difficult to imagine a major tectonic event such as the Petermann Ranges Orogeny, not being reflected in the conformable sequence of sediments which were deposited in the north-eastern part of the Amadeus Basin during the late Upper Proterozoic or Lower Cambrian and almost certainly any major movements would have interrupted the carbonate shale deposition which started in the Lower Cambrian and continued without major change until the Upper Cambrian.

It seems probable that the Petermann Ranges Orogeny correlates with the appearance of the Arumbera Sandstone in the north-eastern part of the Amadeus Basin in the late Upper Proterozoic or early Lower Cambrian and that the Mount Currie Conglomerate and the arkose at Ayers Rock accummulated during this period.

Pertaoorrta Group

The sediments of the Pertaoorrta Group were first named 'Pataoorrta Series' by Mawson & Madigan (1930) and the name was amended to 'Pertaoorrta Series' by Madigan (1932a). Prichard & Quinlan (1962) defined the Pertaoorrta Group in the Hermannsburg Sheet area and Wells, Forman & Ranford (1965) re-defined the interval and named it the Pertaoorrta Formation. Ranford, Cook & Wells (1966, in press) used the name Pertaoorrta Group for the interval defined as Pertaoorrta Formation by Wells et al. (op. cit.) and raised the status of the Members to formation. Ranford et al. (1966, in press) also defined two new Formations which they included within the Pertaoorrta Group. Since that time Wells, Ranford, Stewart, Cook & Shaw (1967, in press) and Ranford (1967a, in press) have defined new formations which have been included in the Pertaoorrta Group. A summary of the evolution of the stratigraphic nomenclature in the northern part of the Amadeus Basin is shown in Table S.2. Table C-23 shows the formations of the Pertaoorrta Group at seven localities in the Amadeus Basin which have been selected to include all the defined formations and indicate the changes which take place in an east-west direction along the length of the Basin. The relationships between these formations are shown in Fig. C2.

The Pertaoorrta Group sediments include sandstone, siltstone, shale, carbonates, evaporites and minor conglomerate (C-14); they range in age from lowermost Cambrian (or possibly late Upper Proterozoic) to middle Upper Cambrian. The known distribution of outcrop and the subsurface extent of the Pertaoorrta Group sediments are shown in Fig. C3.

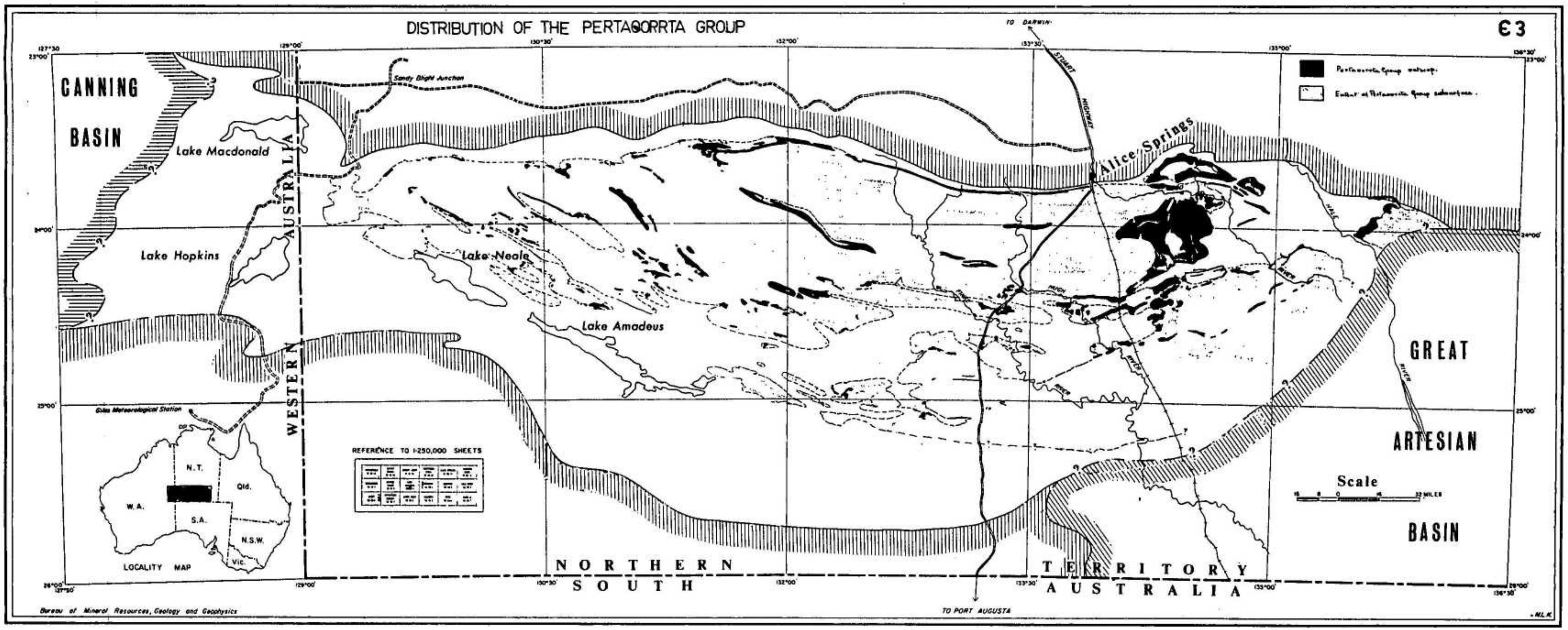
An isopachous map (Fig. C4), a clastic ratio map (Fig. C5) and maps showing percent sand (Fig. C6A), shale (Fig. C6B) and carbonate (Fig. C6C) are based upon information from about 25 surface sections and data from Alice No. 1 and Mount Charlotte No. 1 exploratory wells. The surface information was gathered from sections published by the Bureau of Mineral Resources and from the field notes of geologists of the Bureau of Mineral Resources. The isopachous map (Fig. C4) indicates two main centres of sedimentation. The occurrence of the thickest sequence near the present northern margin of the basin is characteristic of the pre-Permian Palaeozoic sediments in the Amadeus Basin.

The clastic ratio map (Fig. C5) indicates a predominance of carbonates and evaporites in the north-eastern part of the basin. The maps showing distribution of the lithologies as a percentage of the total section reinforce the pattern seen in the clastic ratio map and indicate the coarse clastics predominate in the west (C-14) and the finer clastics (siltstone and shale) are concentrated in the south-east part of the basin. Fig. C7 (a-f) shows the distribution of the formations of the Pertaoorrta Group and where information is sufficient, isopachs on individual units or groups of units.

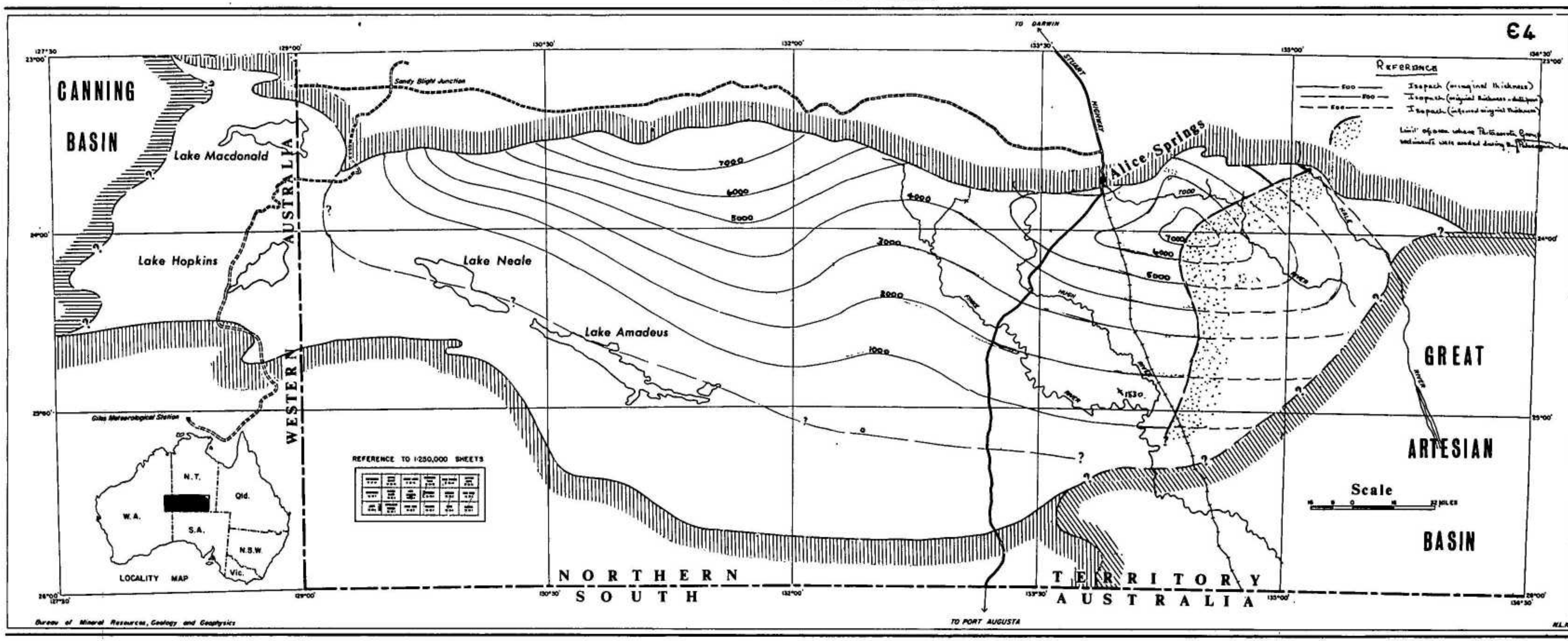
The individual Formations of the Pertaoorrta Group are discussed below. The fossil content of each Formation is briefly mentioned but will be discussed at length in a separate publication by J.G. Tomlinson (B.M.R. in prep).

Quandong Conglomerate

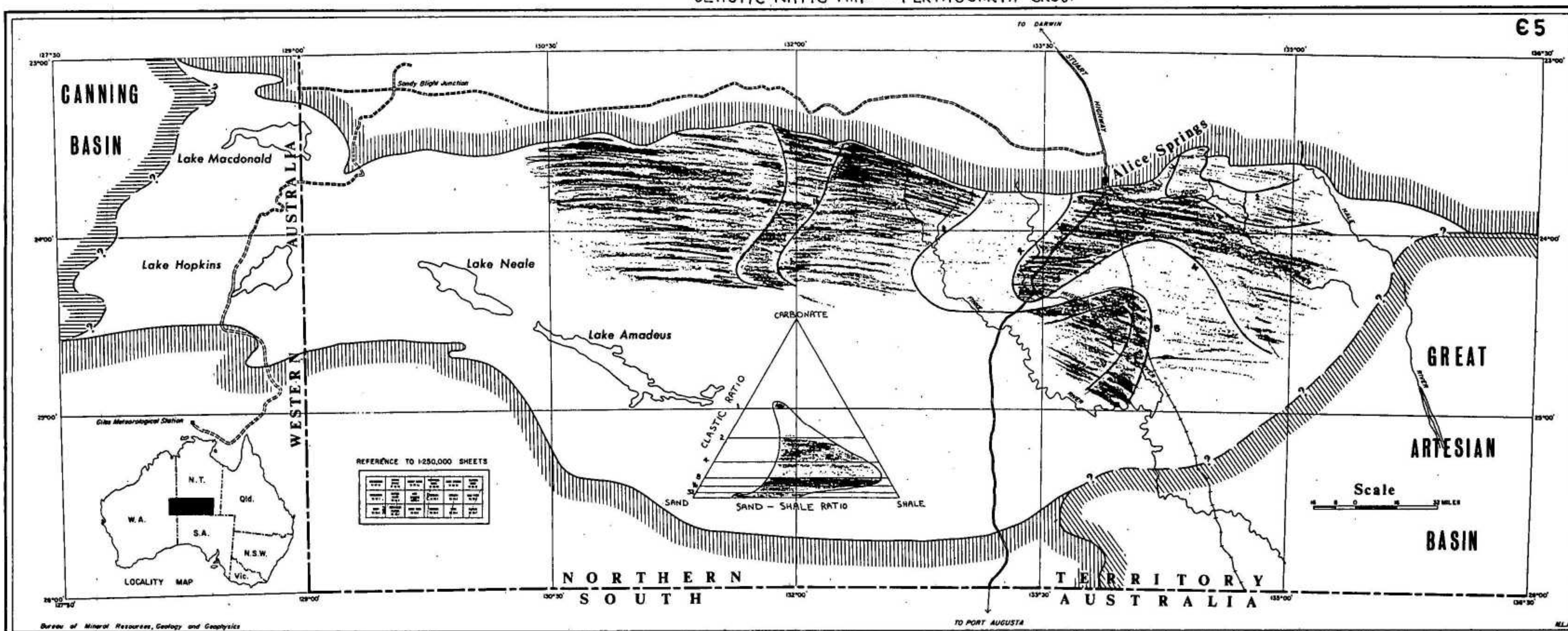
The Quandong Conglomerate was defined by Ranford, Cook and Wells (1966, in press). It consists of conglomerate, and conglomeratic sandstone which crops out as a prominent strike ridge in the type area 6 miles north-east of Tempe Downs Homestead and as a low ridge in the core of James Range 'B' anticline (both localities in the Henbury Sheet area). It also occurs in the small eroded anticline between the Petermann Creek and Parana Hill


DISTRIBUTION OF THE PERTAOORRTA GROUP
Є3
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART
HIGHWAY
TO PORT AUGUSTA
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
GREAT
ARTESIAN
BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
N.T.
W.A.
Qld.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Bureau of Mineral Resources, Geology and Geophysics

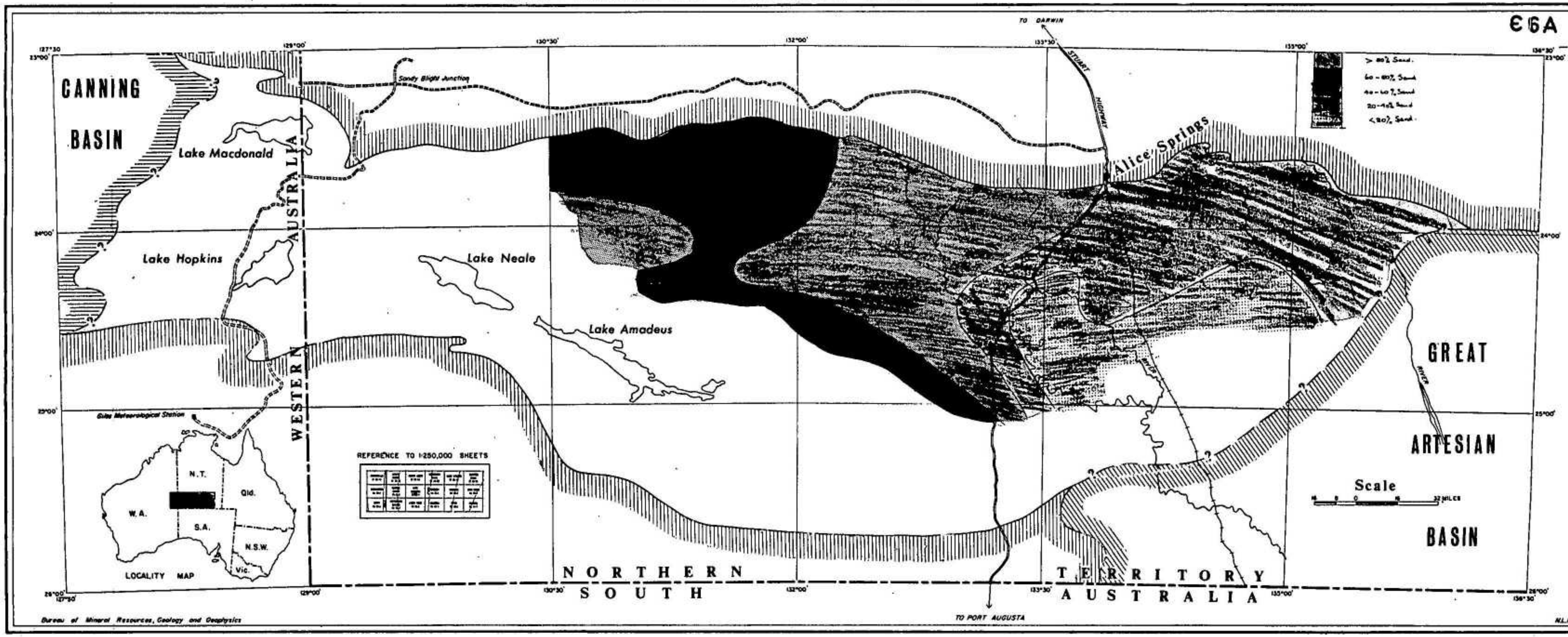
Isopachous Map - Pertaoorrta Group

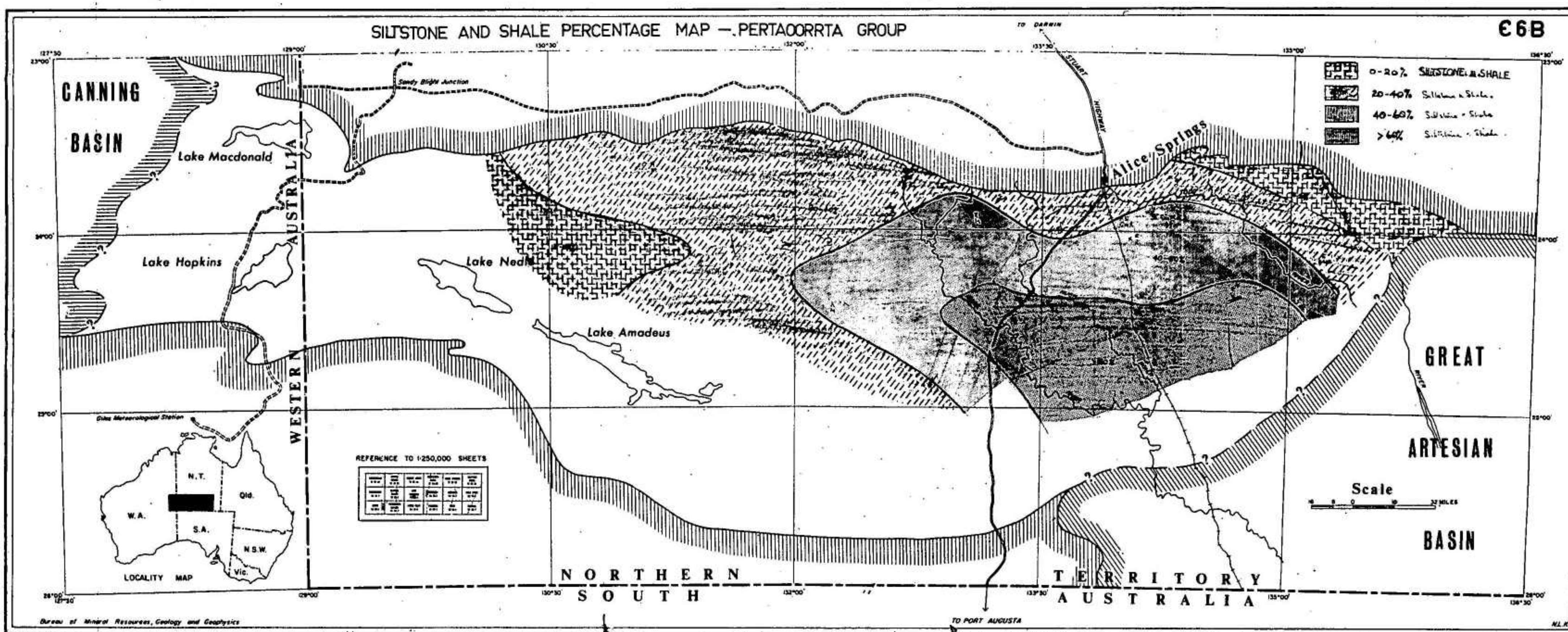


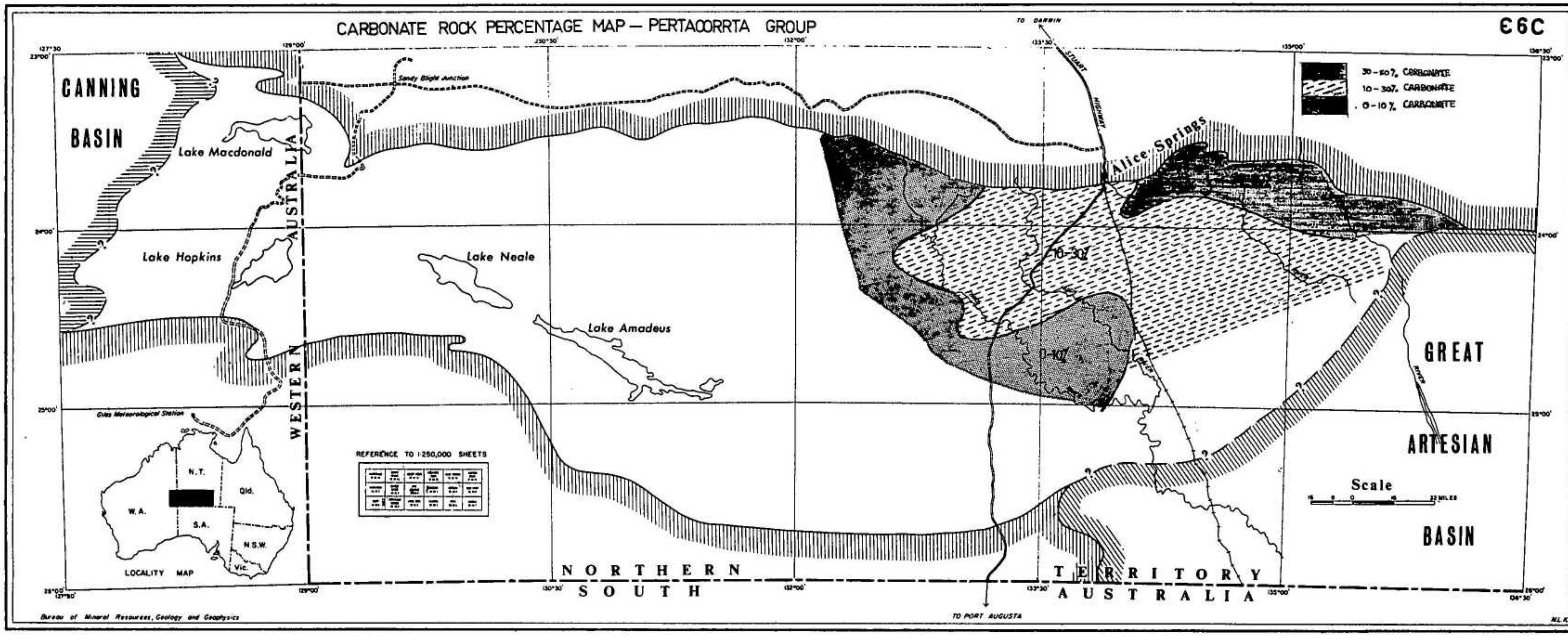
CLASTIC RATIO MAP – PERTAOORRTA GROUP

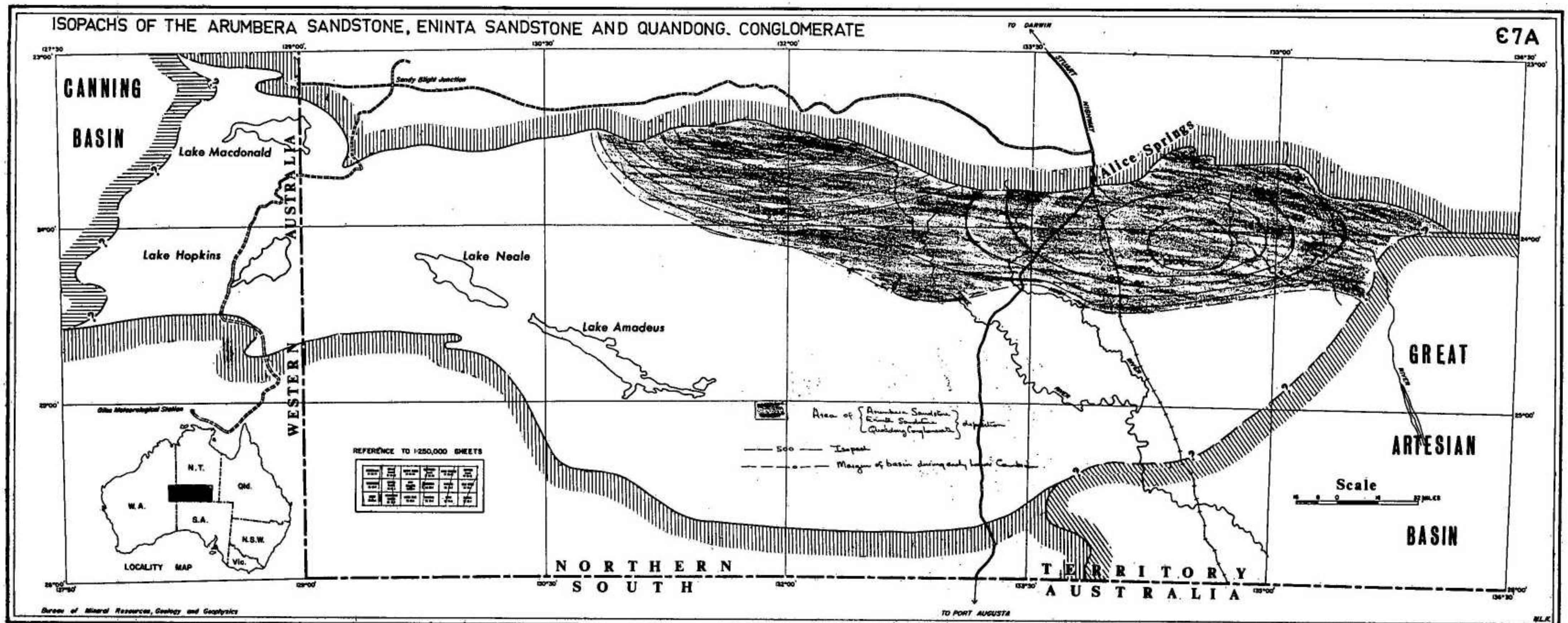


SAND PERCENTAGE MAP - PERTAOORRTA GROUP



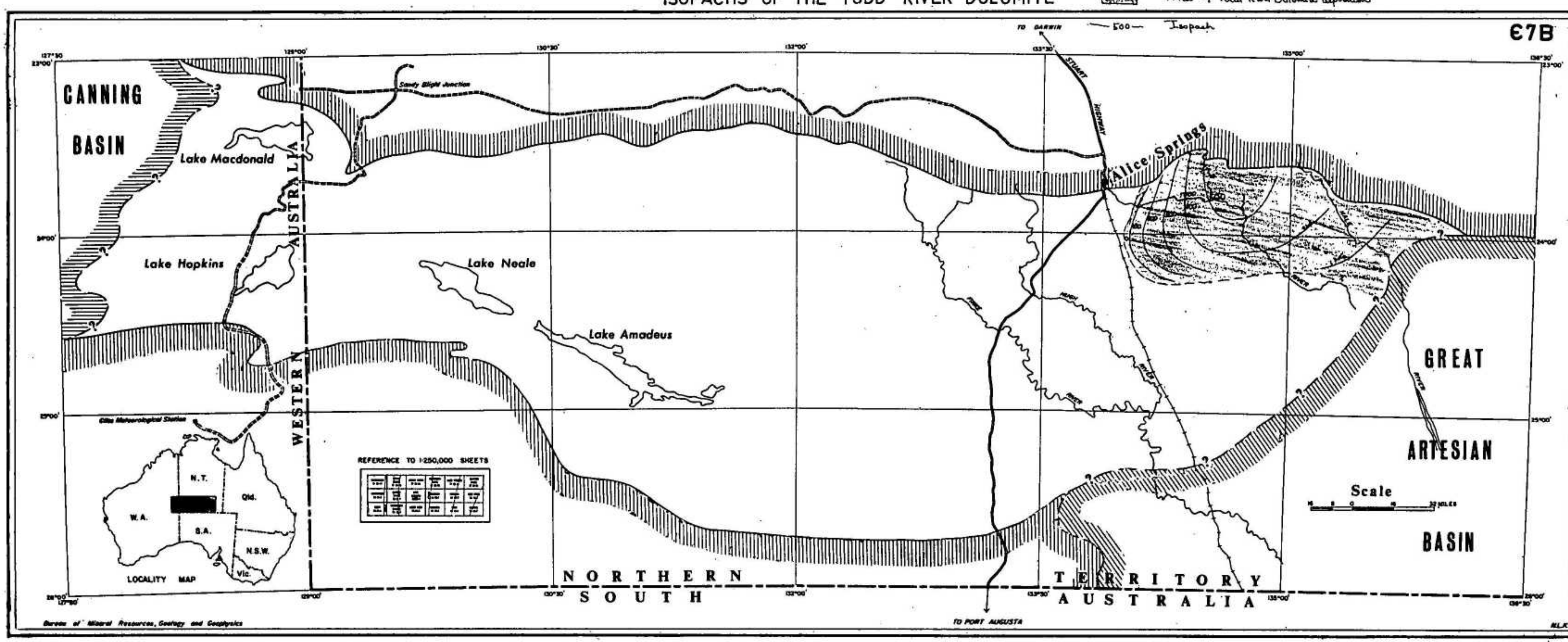

SILTSTONE AND SHALE PERCENTAGE MAP —.PERTAOORRTA GROUP
€6B
0-20% SILTSTONE & SHALE
20-40% Siltstone & Shale
40-60% Siltstone & Shale
>60% Siltstone & Shale
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART
HIGHWAY
Alice Springs
GREAT
ARTESIAN
BASIN
Scale
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


CARBONATE ROCK PERCENTAGE MAP — PERTAOORRTA GROUP
€6C
30-50% CARBONATE
10-30% CARBONATE
0-10% CARBONATE
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
TO DARWIN
STUART HIGHWAY
10-30%
0-10%
GREAT
ARTESIAN
BASIN
Scale
Giles Meteorological Station
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
REFERENCE TO 1:250,000 SHEETS
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics



ISOPACHS OF THE ARUMBERA SANDSTONE, ENINTA SANDSTONE AND QUANDONG. CONGLOMERATE

ISOPACHS OF THE TODD RIVER DOLOMITE



Anticlines although it has not been mapped here. It unconformably overlies the Bitter Springs Formation and is overlain by the Chandler Limestone. The Quandong Conglomerate is a basal conglomerate of lenticular shape which changes in thickness and lithology over very short distances. The estimated maximum thickness is 500 feet in the area 6 miles north-east of Tempe Downs. The distribution of this unit is not known but it is considered to be laterally equivalent to the Eninta Sandstone and the Arumbera Sandstone and Fig. C7a combines the distribution and isopachs on these units. The Quandong Conglomerate unconformably overlies Upper Proterozoic sediments and is conformably overlain by the Chandler Limestone. Fossils have not been found in the formation but it is considered to be Lower Cambrian; it lies conformably beneath the lower Middle Cambrian Tempe Formation.

Eninta Sandstone

The Eninta Sandstone was defined by Wells, Forman & Ranford (1965) as a Member of the 'Pertaoorrta Formation' and was upgraded to a Formation by Ranford, Cook & Wells (1966, in press). The unit comprises sandstone with minor siltstone and conglomerate and is exposed only in the Gardiner Range where it forms a prominent dark red-brown strike ridge. The limits of distribution of this formation are not known but is considered to be laterally equivalent to the Arumbera Sandstone and the Quandong Conglomerate and Fig. C7a shows the distribution and isopachs drawn from the combined information available on all three units. The Eninta Sandstone has a maximum measured thickness of 1200 feet in the Gardiner Range. The Formation lies unconformably on Upper Proterozoic Pertatataka Formation and Areyonga Formation and is conformably overlain by the Lower Cambrian Chandler Limestone or the Tempe Formation (Table C-23, Fig. C2). Fossils have not been found in the Eninta Sandstone but its stratigraphic position indicates that it is probably Lower Cambrian.

Chandler Limestone

The Chandler Limestone was defined by Ranford, Cook & Wells (1963, in press). It comprises limestone, dolomite and interlaminated chert in outcrop but may include evaporites and shale in the subsurface. The unit is exposed in low ridges and hills; the outcrops are generally discontinuous and the sediments strongly contorted and in places brecciated. The Chandler

Limestone is widespread in the central and eastern parts of the Amadeus Basin (Fig. C7c) and evaporites encountered in both Alice No. 1 and Mount Charlotte No. 1 exploratory wells are considered to belong to this unit.

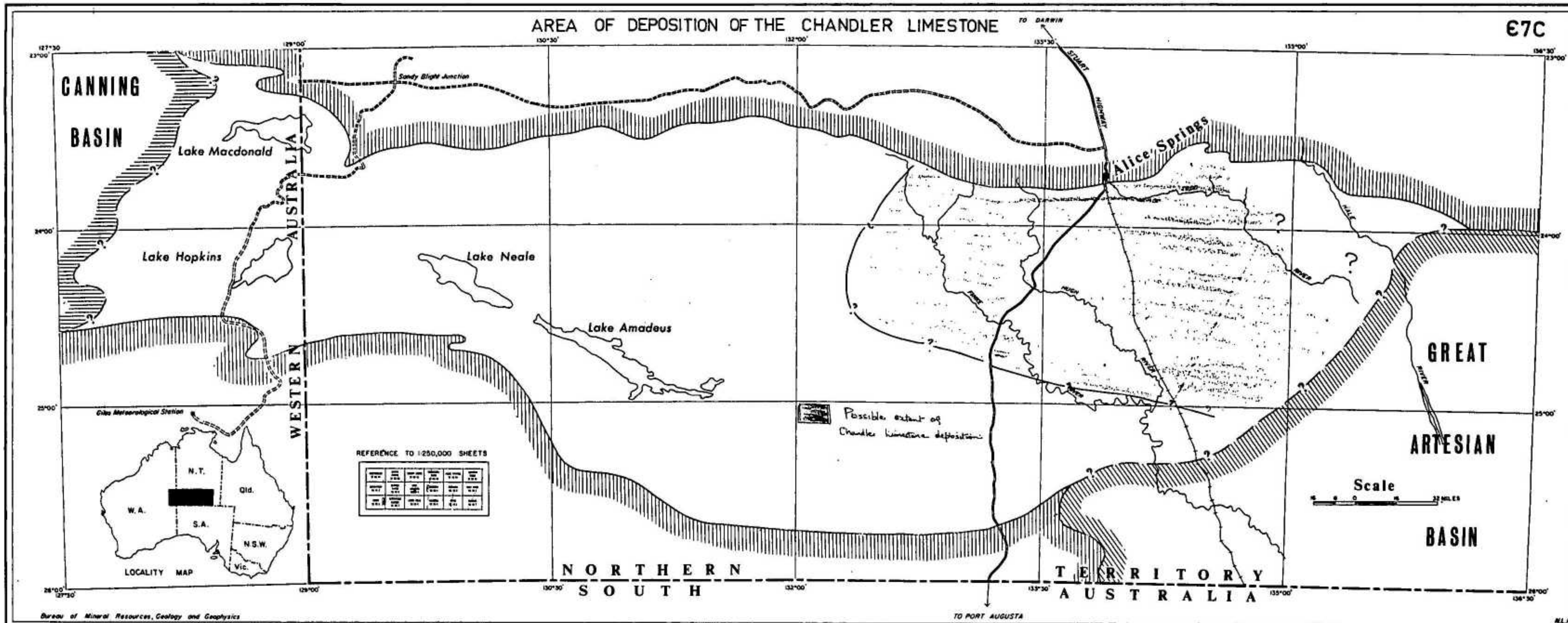
The Chandler Limestone is strongly folded at the surface and this together with the very poor exposure prohibits the accurate assessment of the thickness of the unit, but it probably ranges from 10 to 460' in outcrops, (Ranford, Cook & Wells, 1966, in press; Wells, Ranford, Stewart, Cook & Shaw, 1967, in press). The Chandler Limestone lies above the fossiliferous Lower Cambrian Todd River Dolomite in the north-eastern part of the Amadeus Basin (Table C-23; Fig. C2) but overlies the Arumbera Sandstone, Quandong Conglomerate and possibly the Eninta Sandstone in outcrops further south and west. The Chandler Limestone is overlain by the Giles Creek Dolomite, the Jay Creek Limestone and the Tempe Formation; it may be overlain by the High River Shale in the western MacDonnell Ranges. The limestone in the basal part of the Tempe Formation in the Gardiner Range could be considered a tongue of the Chandler Limestone which here overlies the Eninta Sandstone.

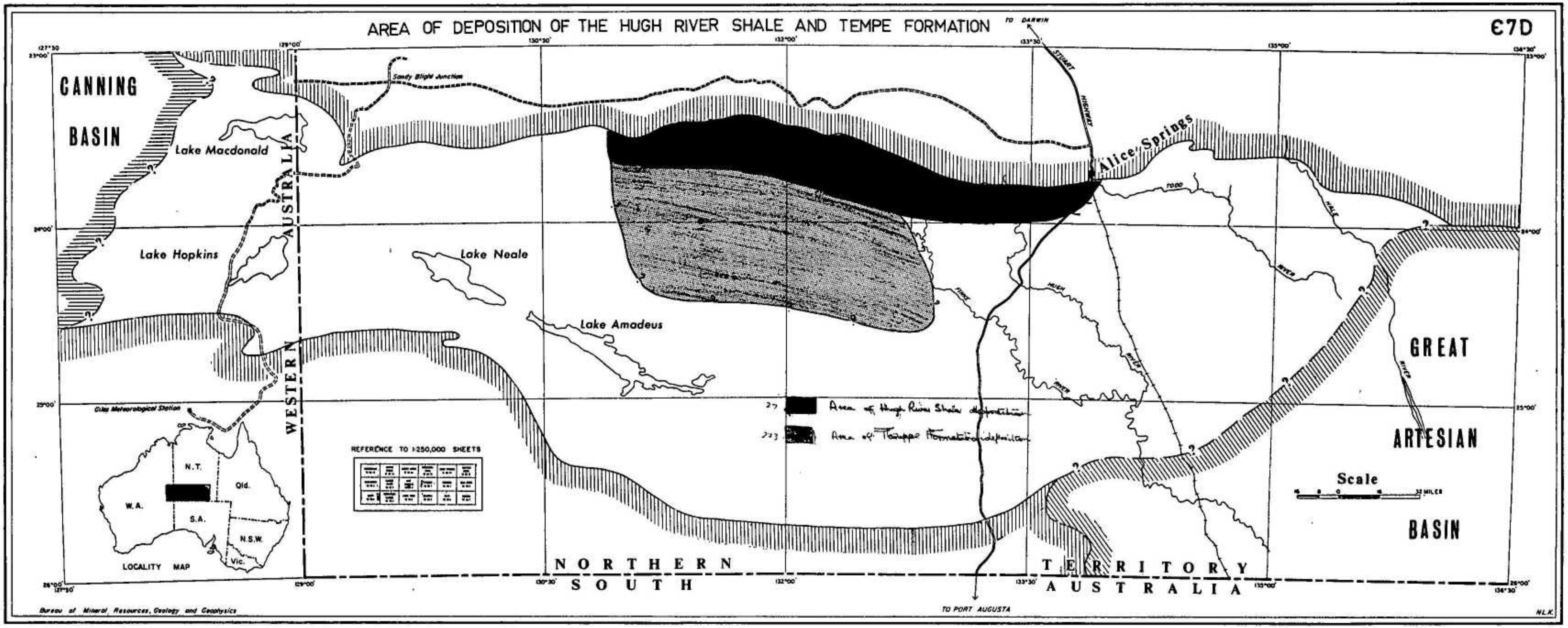
The formation lies in places between fossiliferous Lower Cambrian Todd River Dolomite and lower Middle Cambrian Giles Creek Dolomite. No fossils have been found within the formation but is tentatively regarded as Lower Cambrian.

<u>Tempe Formation</u>

The Tempe Formation was defined by Wells, Forman and Ranford (1965) as the Tempe Member of the 'Pertaoorrta Formation' and was upgraded to a Formation by Ranford, Cook and Wells (1967, in press). The Tempe Formation comprises siltstone, dolomite and glauconitic sandstone; it has been mapped in the Gardiner Range, Walker Creek, Petermann Creek and Parana Hill Anticlines and in a small unnamed anticline 12 miles south of Reedy Rockhole in the Lake Amadeus Sheet area. The unit has not been recognised east of longitude 132°30'E. or south of latitude 24°30'S. The probable area of deposition is shown in Fig. C7d.

The Tempe Formation lies conformably beneath the Illara Sandstone in the central part of the Amadeus Basin but probably underlies the Cleland Sandstone further west (Table C-23; Fig. C2). The Formation rests conformably on the Eninta Sandstone in the Gardiner Range and is apparently conformable on


AREA OF DEPOSITION OF THE CHANDLER LIMESTONE
Є7C
TO DARWIN
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Lake Neale
Lake Amadeus
Alice Springs
STUART
HIGHWAY
GREAT
ARTESIAN
BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Giles Meteorological Station
Possible extent of
Chandler limestone deposition
REFERENCE TO 1:250,000 SHEETS
Scale
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


AREA OF DEPOSITION OF THE HUGH RIVER SHALE AND TEMPE FORMATION
€7D
TO DARWIN
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
STUART HIGHWAY
Alice Springs
Lake Neale
Lake Amadeus
Area of Hugh River Shale deposition
Area of Tempe Formation deposition
WESTERN AUSTRALIA
Giles Meteorological Station
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
REFERENCE TO 1:250,000 SHEETS
GREAT
ARTESIAN
BASIN
Scale
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.

the Chandler Limestone, 6 miles north-east of Tempe Downs Homestead. However, it is unconformable with the Bitter Springs and Areyonga Formations in the western culmination of Petermann Creek Anticline and in Parana Hill Anticline. Brachiopods, trilobites, hyolithids and gastropods have been collected from the upper part of the Tempe Formation which is considered to be lower Middle Cambrian (J.G. Tomlinson pers. comm.). The Tempe Formation contains the oldest fossils found in the western half of the Amadeus Basin and records the first marine transgression in this area since the Upper Proterozoic.

Illara Sandstone

The Illara Sandstone was defined as a Member of the 'Pertaoorrta Formation' by Wells, Forman & Ranford (1965) and was upgraded to a Formation by Ranford, Cook & Wells, (1966, in press). It is restricted to the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill Anticlines, where it forms prominent strike ridges. The area of deposition of the Illara Sandstone has been grouped with the two overlying units in Fig. C7e. The unit is thickest in the Gardiner Range where it is approximately 650 feet.

The Illara Sandstone lies conformably between the Tempe Formation and the overlying Deception Formation. It was suggested by Wells, Forman & Ranford (1965, p.20) that the Illara Sandstone may be equivalent to part of the Arumbera Sandstone. However, in the same publication (p. 22) they state that the unit is considered to be laterally equivalent to part of the Hugh River Shale. The latter correlation is now preferred. The Illara Sandstone is also considered to be a time equivalent of parts of the Cleland Sandstone, Jay Creek Limestone and Giles Creek Dolomite (Table C-23 Fig. C2). No fossils have been found in this formation but it is considered to be of Middle Cambrian age because of its stratigraphic position.

Deception Formation

The Deception Formation was defined as a Member of the Pertaoorrta Formation by Wells, Forman & Ranford (1965) and was upgraded to a Formation by Ranford, Cook & Wells (1966, in press). It crops out in the Gardiner Range, Walker Creek, Petermann Creek, and Parana Hill Anticlines. The formation consists mainly of red siltstone and shale and is easily eroded. It is usually concealed beneath alluvium in strike valleys but in some areas the more resistant beds form low strike ridges. The area of deposition is included with the Petermann Sandstone and the Illara Sandstone in Fig. C7c. It has a maximum known thickness of about 600 feet in the Gardiner Range.

The Deception Formation lies conformably between the Petermann Sandstone and the underlying Illara Sandstone in most areas. However, in the eastern end of the Gardiner Range the Deception Formation lies conformably between the Goyder Formation and the Illara Sandstone. It is considered to be laterally equivalent to parts of the Cleland Sandstone, Hugh River Shale, Jay Creek Limestone and possibly the Giles Creek Dolomite (Table C-23; Fig. C2). No fossils have been found but the stratigraphic position indicates a Middle Cambrian age.

Petermann Sandstone

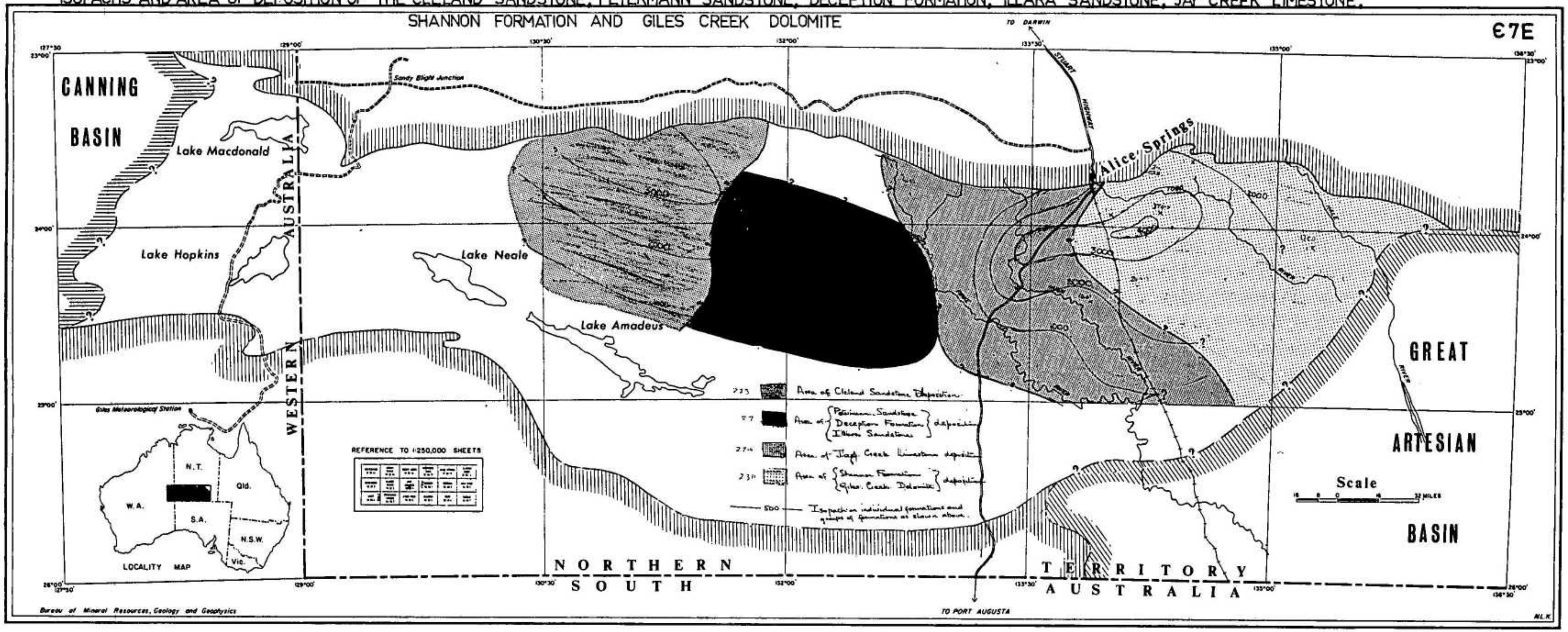
The Petermann Sandstone was defined as a Member of the Pertaoorrta Formation by Wells, Forman & Ranford (1965) and was upgraded to a Formation by Ranford, Cook & Wells (1966, in press). The unit consists of sandstone with minor siltstone and sandy limestone and forms a prominent red-brown strike ridge in the Gardiner Range, Walker Creek, Petermann Creek and Parana Hill Anticlines (C-11). The Petermann Sandstone is not exposed east of Areyonga Native Settlement. In Fig. (C7e), the distribution of the Petermann Sandstone, Deception Formation and Illara Sandstone are combined to show the area of deposition, but this is an approximation as the two older units extend further east (and possibly south) than the younger Petermann Sandstone. The Petermann Sandstone has a maximum thickness of about 640 feet. It lies conformably between the Deception Formation and the Goyder Formation and is laterally part of the Cleland Sandstone, Goyder Formation, Jay Creek Limestone and Shannon Formation (Table C-23; Fig. C2).

A gastropod of possible Upper Cambrian age (J.G. Tomlinson, pers. comm.) has been collected from this Formation south of Areyonga Mission. No other fossils have been found in the Sandstone and it is considered to be late Middle to early Upper Cambrian in age.

Cleland Sandstone

The Cleland Sandstone was defined by Wells, Forman and Ranford (1965) and was included in the Pertaoorrta Group by Ranford (1967a, in press). The unit consists of sandstone and pebbly sandstone and crops out as prominent

ISOPACHS AND AREA OF DEPOSITION OF THE CLELAND SANDSTONE, PETERMANN SANDSTONE, DECEPTION FORMATION, ILLARA SANDSTONE, JAY CREEK LIMESTONE, SHANNON FORMATION AND GILES CREEK DOLOMITE



strike ridges and low rounded hills. A variety of sedimentary structures occur in the formation (C-13). The Cleland Sandstone is restricted to the western part of the basin and thickens towards the northern margin (Fig. C7e). The Formation is a uniform sequence with no obvious marker horizons; in some areas it can be divided into two units on air-photo patterns. It has a maximum known thickness of about 3490 feet in the Glen Edith Hills.

The Cleland Sandstone lies conformably beneath and interfingers with the Goyder Formation in the Idirriki Range but is conformably overlain by the Pacoota Sandstone in outcrops further west (Table C-23; Fig. C2).

Todd River Dolomite

The Todd River Dolomite was defined by Wells, Ranford, Stewart, Cook & Shaw (1967, in press). The unit comprises pink, brown and grey dolomite; it is moderately resistant and crops out in low scarps, rounded hills or in discontinuous ridges. The Dolomite is exposed in the north-eastern part of the Amadeus Basin in the Ross River, Fergusson and Gaylad Synclines, in Ooraminna Anticline and Phillipson Pound. The most easterly exposure is situated about 4 miles south-east of Aralka Bore (Hale River Sheet area) and the most westerly occurs in the Ooraminna Anticline. Isopachs and the presumed area of deposition of Todd River Dolomite are shown in Fig. C7b. The unit has a maximum known thickness of about 510 feet at Ross River Gorge.

The Todd River Dolomite conformably overlies the Arumbera Sandstone and is overlain by either the Chandler Limestone or the Giles Creek Dolomite (Table C-23; Fig. C2). The contact between the Todd River Dolomite and the overlying units may be conformable or in places disconformable according to Wells, Ranford, Stewart, Cook & Shaw (1967, in press). Parts of both the Hugh River Shale and the Chandler Limestone have been considered as possible time-rock equivalents (Wells, Ranford, Stewart, Cook & Shaw, op. cit.) and field evidence suggests interfingering of the Todd River Dolomite and Arumbera Sandstone as shown in Fig. C2.

J.G. Tomlinson (pers. Comm. in Wells, Ranford, Stewart, Cook & Shaw, op. cit.) has suggested that the Todd River Dolomite can be divided into two parts on faunal grounds. Tomlinson indicates that the older part contains archaeocyathans and the brachiopod Micromitra etheridgie (Tate) and the younger part archaeocyathans, brachiopods, hyolithids and trilobite fragments.

Both faunas are considered to be Lower Cambrian.

Giles Creek Dolomite

The Giles Creek Dolomite was defined by Wells, Ranford, Stewart, Cook & Shaw (op. cit.). The unit comprises dolomite with interbeds of limestone, siltstone and shale. It crops out as sharp strike ridges in the north-eastern part of the Amadeus Basin as far west as the railway line and as far south as latitude 24°30'. The easternmost exposure occurs at a point 15 miles east-south-east of No. 6 Phillipson Bore on the Hale River Sheet area (Fig. C7e). The thickest known section of Giles Creek Dolomite was measured on the north flank of the Ooraminna Anticline, where the unit is about 1320 feet thick.

The Giles Creek Dolomite is conformably overlain by the Shannon Formation and is underlain by either the Chandler Limestone or the Todd River Dolomite (Table C-23). The Formation is laterally equivalent to parts of the Jay Creek Limestone, Hugh River Shale and Tempe Formation and may also be partly equivalent to the Illara Sandstone and Cleland Sandstone.

Fossils have been collected in the Giles Creek Dolomite and J.G. Tomlinson (pers. comm. in Wells, Ranford, Stewart, Cook & Shaw, 1967, in press) has stated that 'the fossils consist of hyolithids (including _Biconulites_), brachiopods, gastropods, and trilobites, indicating an early Middle Cambrian age. The alga _Girvanella_ is also present.

Shannon Formation

The Shannon Formation was defined by Wells, Ranford, Stewart, Cook & Shaw (1967, in press). The Formation comprises siltstone, limestone and dolomite and crops out in the north-eastern part of the Amadeus Basin as a series of strike ridges and valleys (C-16, C-19). Stromatolite colonies are common in the formation (C-17, C-18). The area of deposition of the Shannon Formation is shown in Fig. C7e. The thickest measured section occurs on the north flank of the Ooraminna Anticline where the unit is about 2340 feet thick.

The Shannon Formation is conformably overlain by the Goyder Formation near the northern margin of the basin but is overlain by the Pacoota Sandstone, Stairway Sandstone, Mereenie Sandstone and the Pertnjara Formation in poor exposures in the north-eastern part of the basin. The Shannon Formation may also interfinger with the Goyder Formation in the north eastern part of the basin and it is possible that the Shannon Formation has a similar relationship to the Goyder Formation to that shown between the Cleland Sandstone and Goyder Formation on the western side of the basin (Fig. C2). If this is so the Pacoota Sandstone-Shannon Formation contact may be conformable. However, the Stairway Sandstone, Mereenie Sandstone and Pertnjara Formation must all rest disconformably or possibly unconformably on the Shannon Formation. The Shannon Formation overlies the Giles Creek Dolomite throughout the north-eastern part of the Amadeus Basin.

Fossils have been collected from the Shannon Formation and J.G. Tomlinson (pers. comm. in Wells, Ranford, Stewart, Cook & Shaw, 1967, in press) states that 'the fossils are of early Upper Cambrian age (late Mindyallan; zone of Glyptagnostus stolidotus) and are indistinguishable from those of the overlying (carbonate part) of the Goyder Formation. Fossils of the same age have been found in the upper part of the Jay Creek Limestone in the western MacDonnell Ranges and in the Waterhouse Range.'

Arumbera Sandstone

The Arumbera Sandstone was originally defined as the 'Arumbera Greywacke' by Prichard & Quinlan (1962). It was redefined as the 'Arumbera Greywacke Member of the Pertaoorrta Formation' by Wells, Forman & Ranford (1965b) and was amended to Arumbera Sandstone by Wells, Ranford, Stewart, Cook & Shaw (1967, in press).

The Arumbera Sandstone comprises red-brown and white sandstone, with minor siltstone, shale, conglomerate and dolomite. Flow casts in the sandstone are shown in C-20. The unit is typically ferruginous and feldspathic and forms prominent red-brown strike ridges along the northern margin of the basin (C-24). The Formation is considered to be laterally equivalent to the Eninta Sandstone and Quandong Conglomerate; Fig. C7a shows the combined area of deposition and isopachs. The isopachs indicate maxima near the western extremity of the MacDonnell Range, where the unit is about 4000 feet thick, and in the Phillipson Pound area where the thickest section is about 2700 feet.

The Arumbera Sandstone lies conformably between the underlying Pertatataka Formation and the overlying Todd River Dolomite in the north-eastern part of the Amadeus Basin but further west it is overlain by the Hugh River Shale or the Chandler Limestone. The contact with the underlying Pertatataka Formation is probably unconformable near the western and the southern limits of deposition (Fig. C2). Impressions in sandstone beds in the basal part of the Arumbera Sandstone in the area about 4 miles east of Deep Well homestead have been assigned to the Upper Proterozoic Rangea arborea by Glaessner (in Taylor 1959b). However, arthropod tracks and Scolithus occur higher in the Arumbera Sandstone in the Eastern MacDonnell and Fergusson Ranges (C-21) and in Phillipson Pound and these are considered to be of Cambrian age (J.G. Tomlinson - pers. comm.).

Hugh River Shale

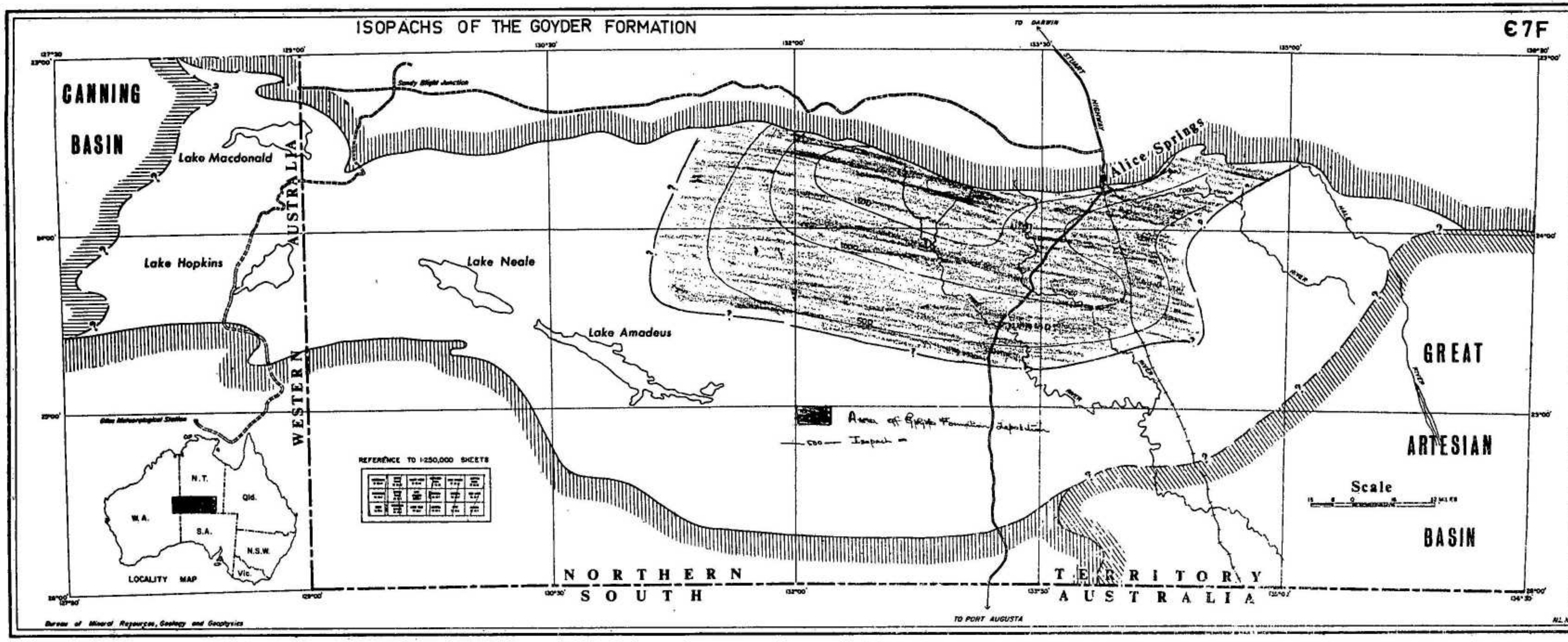
The Hugh River Shale was defined by Prichard & Quinlan (1962). It was amended to 'Hugh River Shale Member of the Pertaoorrta Formation' by Wells, Forman & Ranford (1965) and it was reinstated as a formation by Ranford, Cook & Wells (1966, in press).

The Hugh River Shale comprises shale and siltstone with minor thin carbonate and sandstone beds. The unit is easily eroded and poorly exposed. The limits of deposition are shown in Figure C7d.

The Hugh River Shale has an estimated maximum thickness of 1600 feet. According to Prichard & Quinlan (1962) and Wells, Ranford, Stewart, Cook & Shaw (1967, in press) it conformably overlies the Arumbera Sandstone and is conformably overlain by the Jay Creek Limestone. However, P.J. Cook (pers. comm.) has recognised the Chandler Limestone in the Ellery Creek area of the western MacDonnell Ranges in the basal part of the Hugh River Shale and this information has been used in constructing Figs. C2 and C7c and Table C-23. The Hugh River Shale is considered to be laterally equivalent to parts of all the Pertaoorrta Group units except the Goyder Formation, the Eninta Sandstone, the Quandong Conglomerate and the Arumbera Sandstone. Fossils have not been found in the Hugh River Shale and it is considered to be Lower Cambrian to lower Middle Cambrian because of its stratigraphic position.

Jay Creek Limestone

The Jay Creek Limestone was defined by Prichard & Quinlan (1962). It comprises algal and oolitic limestone and dolomite, siltstone and shale


ISOPACHS OF THE GOYDER FORMATION
€7F
TO DARWIN
STUART HIGHWAY
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Giles Meteorological Station
Alice Springs
1500
1000
500
WESTERN AUSTRALIA
GREAT ARTESIAN BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics

with a few thin calcareous sandstone interbeds. The unit forms low rises with ridges of the more resistant carbonate horizons. The area of deposition of the unit is shown in Fig. C7e.

The Jay Creek Limestone is conformably overlain by the Goyder Formation and is underlain by the Hugh River Shale and the Chandler Limestone. It is laterally equivalent to the Shannon Formation and the Giles Creek Dolomite. The Jay Creek Limestone is also considered to be partly equivalent to the Goyder Formation the Hugh River Shale, the Illara Sandstone, the Deception Formation, the Petermann Sandstone and the Cleland Sandstone (Fig. C2). Fossils have been collected in a number of localities from the Jay Creek Limestone and according to J.G. Tomlinson (pers. comm.) the age is lower Middle Cambrian near the base and lower Upper Cambrian (Mindyallan) at the top.

Goyder Formation

The Goyder Formation was defined by Prichard & Quinlan (1962). The name was amended to 'Goyder Member of the Pertaoorrta Formation' by Wells, Forman & Ranford (1965) and was amended again to Goyder Formation by Ranford, Cook & Wells (1966, in press).

The Goyder Formation consists of sandstone, siltstone, dolomite and limestone. Bedding planes commonly show halite pseudomorphs. It is generally poorly exposed in a dissected pediment (Fig. C-22) below the ridge of overlying Pacoota Sandstone. It is widespread but poorly exposed throughout the Amadeus Basin (Fig. C7f).

Prichard & Quinlan (1962) measured a thickness of about 1800 feet for the Goyder Formation in the Stokes Pass area of the western MacDonnell Ranges and this is the thickest known section.

The Goyder Formation lies conformably beneath the Pacoota Sandstone and in various places lies conformably on the Cleland Sandstone, Petermann Sandstone, Jay Creek Limestone, High River Shale and Shannon Formation (Table C-23, Fig. C2). The Formation is laterally equivalent to part of the Cleland Sandstone, the Jay Creek Limestone and the Shannon Formation.

Fossils found in the Goyder Formation include algal stromatolites, trilobites, gastropods and hyolithids. According to J.G. Tomlinson (pers.

comm. in Wells, Ranford, Stewart, Cook & Shaw, 1967, in press) the fossils in the Goyder Formation are early Upper Cambrian (Mindyallan) in the lower carbonate part of the formation and middle Upper Cambrian (late Franconian) in the upper arenitic part.

Palaeogeography and Geological History

The Amadeus Basin is the preserved remnant of an intracratonic basin whose sediments range in age from Upper Proterozoic to Upper Palaeozoic. The outline of the Amadeus Basin in Lower Palaeozoic times was controlled by the Petermann Ranges Orogeny in late Upper Proterozoic or early Lower Cambrian times. This Orogeny was centred near the south-western margin of the basin. It resulted in folding of Upper Proterozoic sediments in the western part of the basin and in a general regression of the seas. Coarse continental synorogenic sediments (Mount Currie Conglomerate and the arkose at Ayers Rock) were laid down in a depression formed in front of the newly developed mountain ranges (Fig. C1) and a land ridge probably separated this basin from the main basin to the north where transitional deltaic sediments (Arumbera Sandstone) were deposited without a major break on the Upper Proterozoic marine sediments (Pertatataka Formation). The general shape of the basin during this early lower Cambrian period can be seen from the distribution of the Arumbera Sandstone and its lateral equivalents the Eninta Sandstone and Quandong Conglomerate (Fig. C7a). The zero isopach is considered to mark approximately the margin of the basin. The discordant relationship between the isopachs and the northern margin of the basin is almost certainly due to uplift and erosion of the northern part of the basin following the Alice Springs Orogeny in Upper Devonian or Carboniferous times. Similarly the close spacing of the isopachs near the central part of the Basin (south-east of Alice Springs) can be explained by crustal shortening due to folding and thrust faulting during the Alice Springs Orogeny. The two sub-basins, indicated by the isopachs, may have been of fundamental importance throughout the Palaeozoic history of the Amadeus Basin. Even in early Lower Cambrian times there is evidence to suggest a more marine influence in the Arumbera Sandstone laid down in the eastern sub-basin and the connection to the sea was almost certainly on the eastern side of the basin.

Sedimentation occurred in an elongate east-west trending basin of the shallow water shelf or embayment type, open to the sea on the eastern side

CAMBRIAN

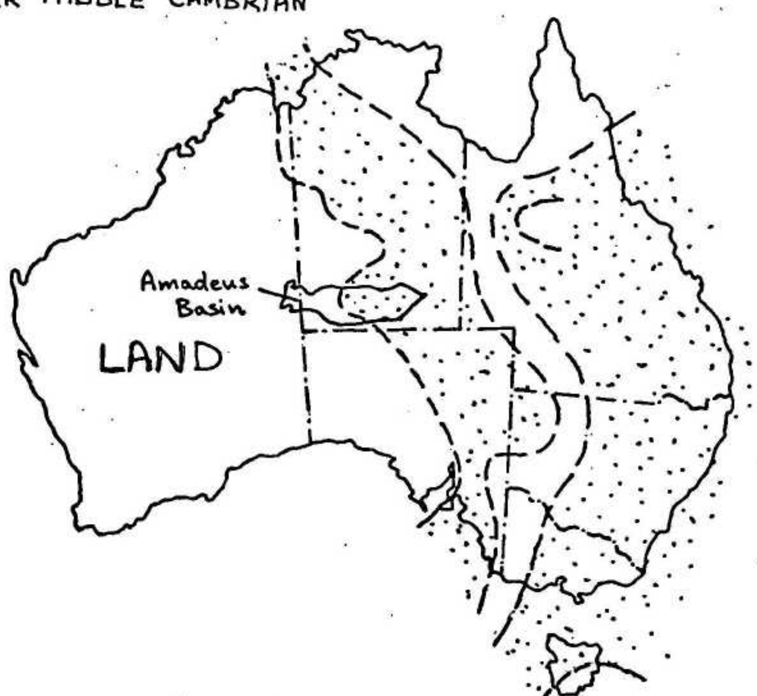
PALAEOGEOGRAPHIC MAPS OF AUSTRALIA

Adapted from Öpik (1957)

Sea

LOWER CAMBRIAN

LOWER MIDDLE CAMBRIAN



UPPER CAMBRIAN

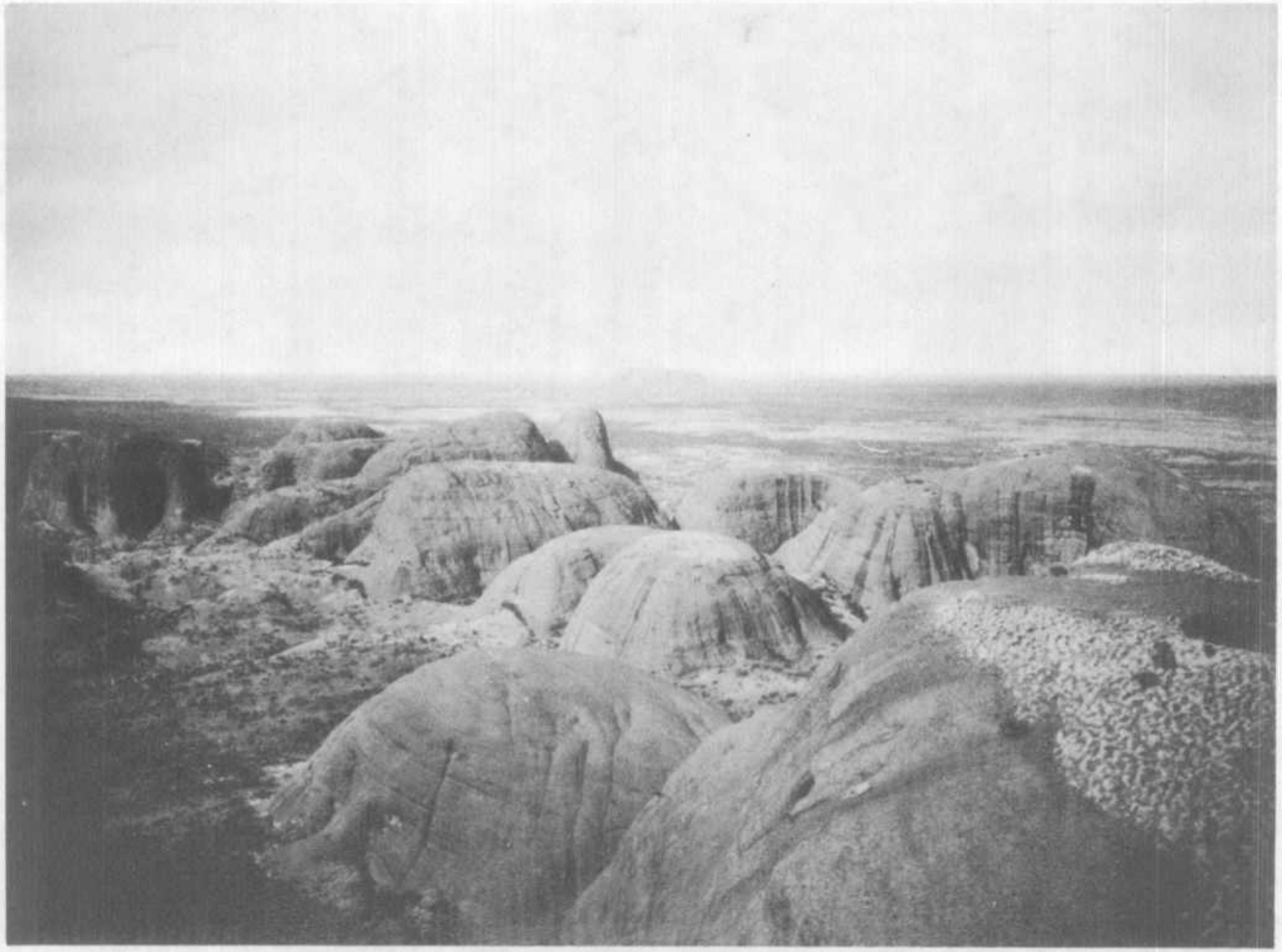
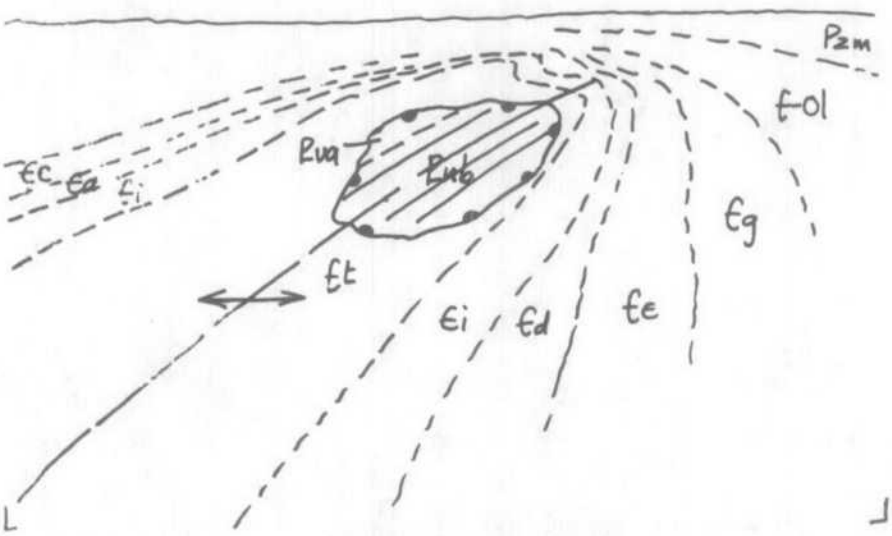


Fig. 69 Gently dipping beds of Mount Currie Conglomerate at Mount Olga.
(Australian News and Information Bureau Photo).
GA/18

Fig. 6-10 Near vertical beds of arkose at Ayers Rock. (Australian News and Information Bureau Photo).
L23147

Fig. G-11 Parana Hill Anticline showing prominent ridges of the Bitter Springs Formation exposed in the eroded core unconformably overlain by the Cambrian Pertaoorrta Group. G/8619



View west across the Parana Hill Anticline showing Bitter Springs Formation (Ꝑub) and Areyonga Formation Ꝑua in the eroded core unconformably overlain by the Pertaoorrta Group. Ꞓt Tempe Formation, Ꞓi Illara Sandstone, Ꞓd Deception Formation, Ꞓe Petermann Sandstone, Ꞓg Goyder Formation, Ꞓ-Ol Larapinta Group, Pzm Mereenie Sandstone. Unconformity

Fig. G-12 Overlay of the photograph above (G-11)

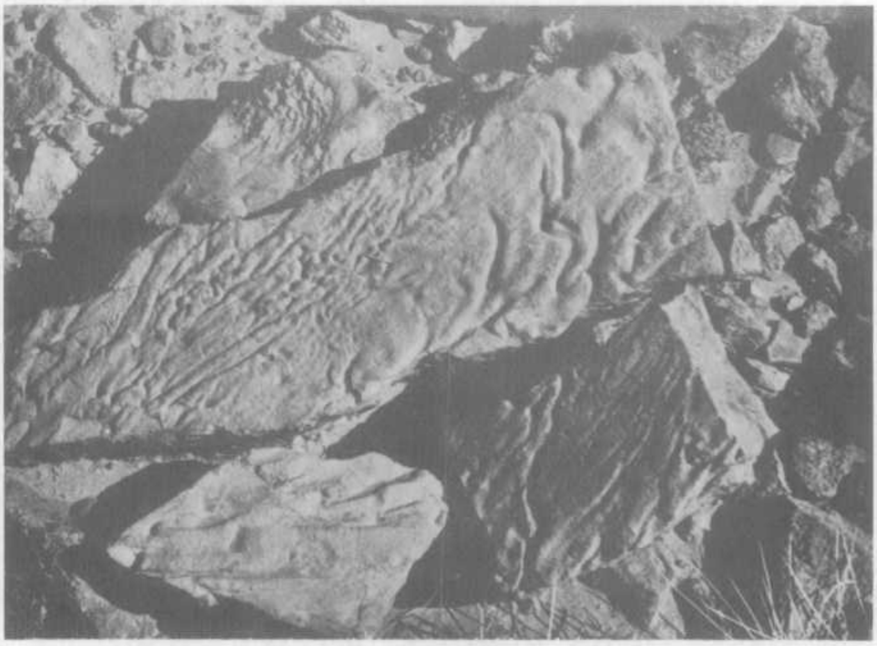


Fig. G-13 Current crescents and flow casts in the Cleland Sandstone.
G/9139

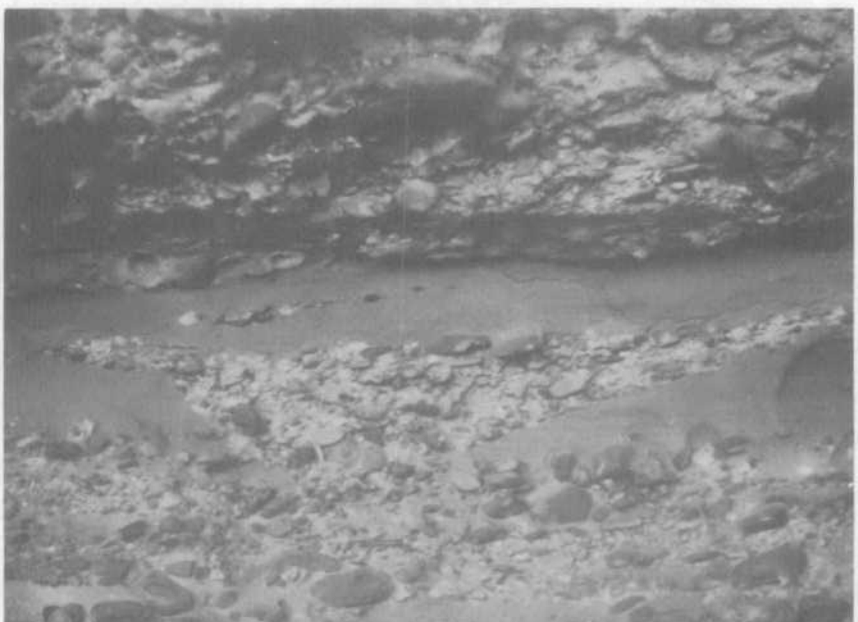


Fig. G-14 Conglomerate beds and lenses in the Pertaoorrta Group, north of Angas Downs homestead.
G/9132

Fig. G-15 Interbedded shale and limestone of the Giles Creek Dolomite on the north flank of the Ooraminna Anticline. Dark ridge at top right is Chandler Limestone.
G/6287

Fig. G-16 Shannon Formation in the Ross River Syncline.
G/7499

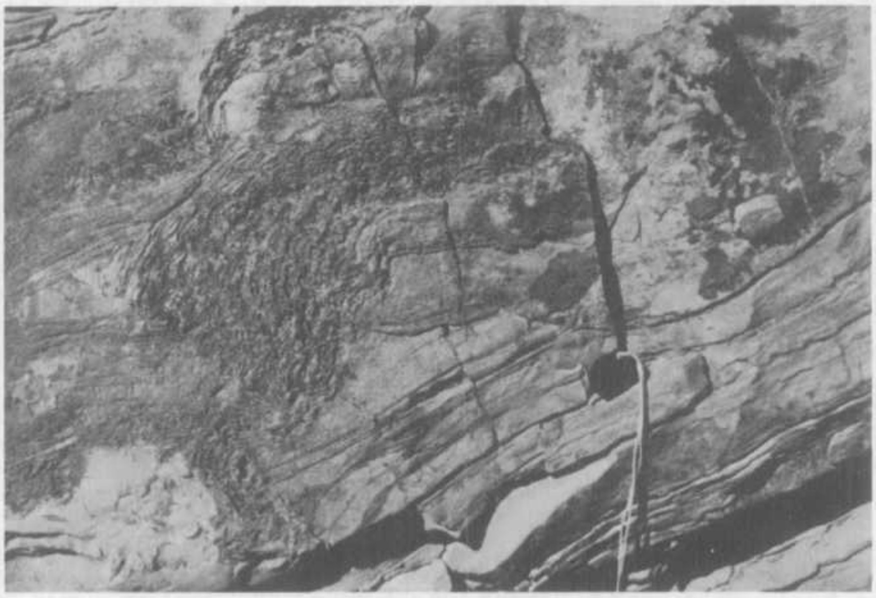


Fig. 6-17 Stromatolite colony in the Shannon Formation, south flank of the Fergusson Syncline.
M/400-6

Fig. 6-18 Stromatolite colony in the Shannon Formation, south flank of the Fergusson Syncline.
M400-5

Fig. 6-19 Shannon Formation of the Pertaoorrta Group on the south flank of the Ross River Syncline. G/9156

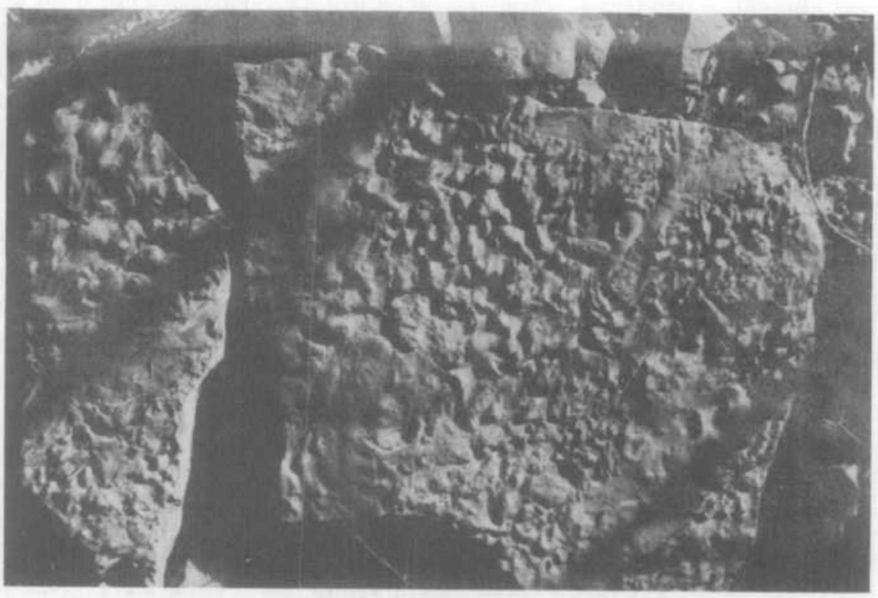


Fig. 6-20 Flow casts in the upper part of the Arumbera Sandstone, Alice Springs Sheet area. M401-35

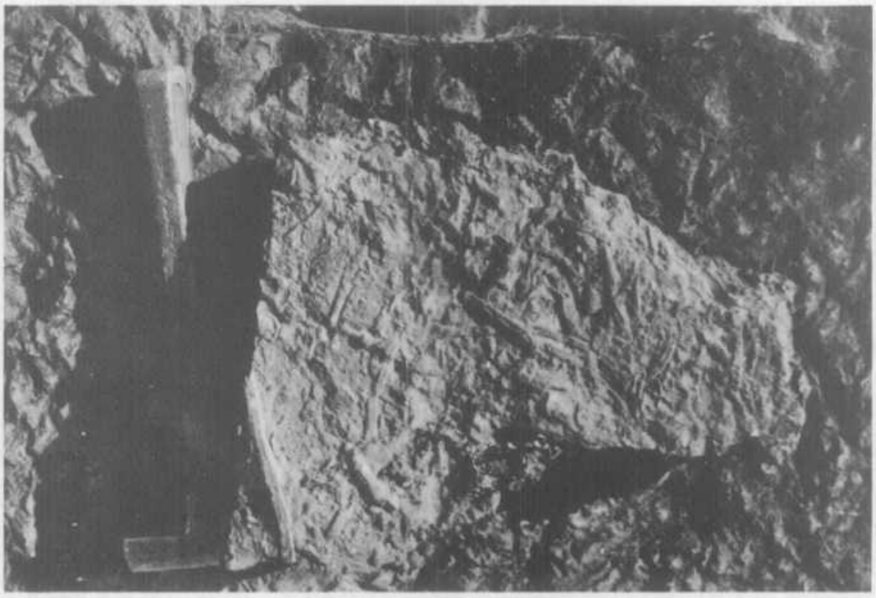


Fig. G-21 Invertebrate tracks in the Arumbera Sandstone, near the middle of the formation.
M401-37.

Fig. G-22 Pseudomorphs after halite in the Goyder Formation, near the contact with the Petermann Sandstone, western Petermann Creek Anticline.
G/9131

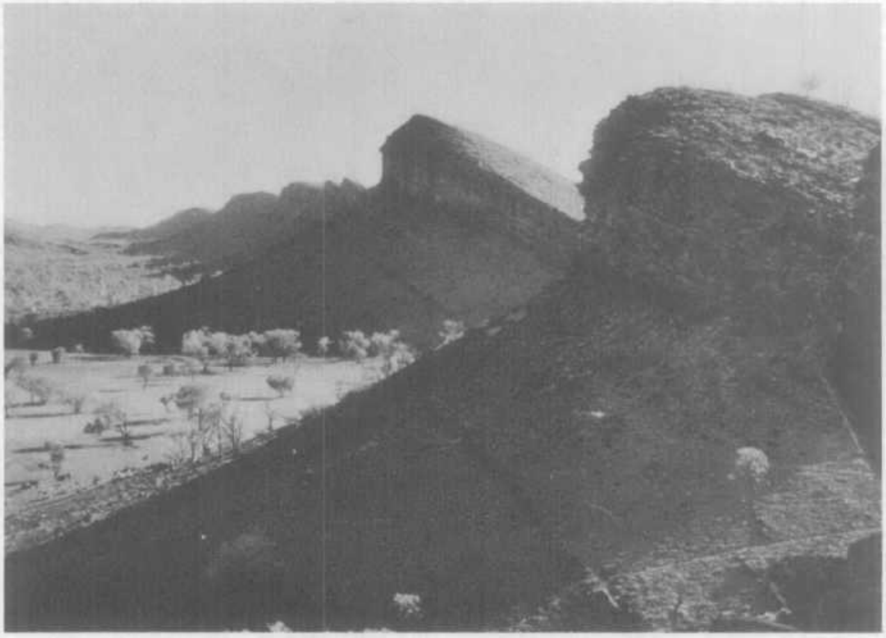
TABLE Є-23

FORMATIONS OF PERTAOORRTA GROUP

Unconformable contacts indicated by wavy line

	Cleland Hills Area	Ochre Hill Area	Areyonga Area	Tempe Downs Area	Western MacDonnell Range	Phillipson Pound Area	Ross River Area
Ordovician	← Pacoota Sandstone →						
Upper Cambrian	Cleland Sandstone	Goyder Formation Cleland Sandstone	Goyder Formation Petermann Sandstone Deception Formation	Goyder Formation Petermann Sandstone Deception Formation	Goyder Formation Jay Creek Limestone	Goyder Formation Shannon Formation	Goyder Formation Shannon Formation
Middle Cambrian		Tempe Formation	Illara Sandstone	Illara Sandstone Tempe Formation	Hugh River Shale	Giles Creek Dolomite Chandler Limestone	Giles Creek Dolomite
Lower Cambrian			Tempe Formation Eninta Sandstone	Chandler Limestone Quandong Conglomerate	* Arumbera Sandstone	Todd River Dolomite Arumbera Sandstone	Todd River Dolomite Arumbera Sandstone
Upper Proterozoic	← Pertatataka Formation →						

* Chandler Limestone is considered to be present although it has not been mapped in the western MacDonnell Ranges.



G24. Upper beds of Arumbera Sandstone on south side of the Ross River Syncline.
M/400-24

and receiving detritus mainly from the west and south. This pattern of sedimentation continued without major change throughout the Cambrian. The clastic ratio map of the Pertaoorrta Group sediments (Fig. C5) indicates very clearly the predominance of the clastic sediments in the west, and the approximate north-south strike of the facies trend. The facies maps, showing distribution of sand, shale-siltstone and carbonate (Figs. Cba, b & c), reinforce the interpretation of the clastic ratio map and further indicate the relationship between the facies and the sub-basins mentioned previously. Broadly speaking the western sub-basin was a centre of coarse clastic sedimentation whereas the eastern sub-basin was a centre of carbonate sedimentation. The facies distribution is clearly related to a westerly source and scattered observations of current bedding in the Cambrian sandstones suggest a predominance of currents from the west.

During the Lower Cambrian the influx of coarse detrital material to the eastern sub-basin became negligible and carbonate and shale deposition was predominant until the Upper Cambrian. The Lower Cambrian Todd River Dolomite is very glauconitic and contains archaeocyathans and phosphatic brachiopods. A large area of the Pertaoorrta Group was uplifted along the north-western margin of the basin during the Alice Springs orogeny and subsequently eroded so that only the truncated edges of the formations are exposed along this margin. This explains the thick development of the Group along the northern margin of the present basin (Fig. C7b). Fossils of Lower Cambrian age have not been found in the western half of the Amadeus Basin and it is not possible to say whether the clastic sedimentation continued in this area during the period in which the Todd River Dolomite was deposited in the east. The probable extent of the Lower Cambrian seas is shown in Fig. C8 (adapted from Öpik, 1957).

The Lower Cambrian marine sediments in the east and the continental or transitional sediments in the central part of the basin were followed by unfossiliferous evaporitic sediments (Chandler Limestone) in the Lower Cambrian or very early in the Middle Cambrian. The possible distribution of this unit is shown in Fig. C7c.

The lower Middle Cambrian was a time of transgression in the Amadeus Basin and elsewhere in Australia - Fig. C8 and the first fossiliferous marine sediments (Tempe Formation) were deposited in the western sub-basin during this period. However, the sediments of the eastern sub-basin (Giles Creek Dolomite and Jay Creek Limestone) are very different from those (Tempe Formation) in the western sub-basin. After the widespread transgression in the Lower Middle Cambrian, a mixture of continental and transitional red-beds were deposited in the west, but shallow water marine conditions prevailed in the eastern sub-basin. The pattern of sedimentation during this period is clearly shown in Fig. C7e.

In the Upper Cambrian there is evidence of a change in the pattern of distribution of the detrital material with a gradual migration of the coarse clastics to the east and a corresponding migration of the marine environment to the west. The Upper Cambrian Goyder Formation is a mixture of marine sandstone, shale and limestone and represents the most widespread marine transgression since the lower Middle Cambrian. This unit interfingers with a continental and transitional red-bed sequence (Cleland Sandstone) in the west and with a marine carbonate and shale facies (Shannon Formation) in the east. The probable distribution of land and sea during the Upper Cambrian is shown in Fig. C8.

In summary, the Lower Palaeozoic part of the Amadeus basin was deposited as a consequence of the Petermann Range Orogeny in late Upper Proterozoic or early Lower Cambrian times. It is considered an intracratonic basin of the embayment type and the transport direction and the palaeoslope were probably parallel to the axis of the basin. The sediments were deposited during two broad cycles of regression and transgression and range from predominantly continental or transitional deltaic sandstone in the west to marine carbonate and shale in the east.

CAMBRIAN - ORDOVICIAN

THE LARAPINTA GROUP

Previous Investigations

The name "Larapintine Series" was first used by Tate (1896) in the report on the Horn Expedition of 1892, but the "Series" was not defined. Madigan (1932) also used the term "Larapintine Series" and placed the base of the Series at the base of the "No. 4 Quartzite" (the Pacoota Sandstone). Chewings (1935) subsequently modified the name to "Larapinta Series". Prichard and Quinlan (1962) further modified the name and defined it as the Larapinta Group; they also formally defined the four formations making up the group. However, the names of two of the formations were amended to Horn Valley Siltstone and Stairway Sandstone by Wells, Forman and Ranford (1965).

As a result of the possible economic potential for oil, gas and phosphate, the Larapinta Group has been subjected to more investigation than most other parts of the Amadeus Basin section. Work dealing specifically with formations of the Larapinta Group includes that of Haites (1963b, unpubl., 1932) who was concerned with the physical relationship of the various formations; Cook (1963, 1966a, unpubl., 1968), Barrie (1964 unpubl.,) and Prichard and Cook (1965) who discussed the Stairway Sandstone in some detail; and Williams, Hopkins and McNaughton (1965) who dealt with the Pacoota Sandstone at length. In addition the Larapinta Group is also discussed in all the regional reports by the Bureau of Mineral Resources, Frome Broken Hill Pty. Ltd., and Magellan Petroleum (Australia) Ltd. (see bibliography).

When Prichard and Quinlan (1962) defined the Larapinta Group, they included a silty red-brown sandstone within the Stokes Siltstone. This sandstone, which was poorly developed in the type area, occurred at the top of the Formation. Subsequent workers in the Amadeus Basin (Wells et. al., 1965, 1966; Ranford et. al., 1966) mapped areas where this red-brown sandstone was much better developed and they were unaware that the red-brown sandstone they were mapping was the sandstone Prichard and Quinlan (1962) had included in the Stokes Formation. Instead, Wells et. al. (1965) considered it to be a lower unit of the Mereenie Sandstone and it was informally referred to as Pzm(1) whilst the upper unit of the Mereenie Sandstone (which was in fact the Mereenie Sandstone as originally defined by Prichard and Quinlan (1962)) was informally referred to as Pzm(2).

This confusion was discovered during the course of a regional compilation of all the available data.

In order to clarify the stratigraphy it is proposed to redefine the Stokes Formation as the Stokes Siltstone and name the red-brown sandstone the Carmichael Sandstone. (The use of the formation names by various authors is shown in Fig. L32).

The Larapinta Group as defined by Prichard and Quinlan (1962) included the Stokes Formation; as the redefined Stokes and the Carmichael Sandstone are present in the type section, it is logical that these two formations should be included in the Larapinta Group.

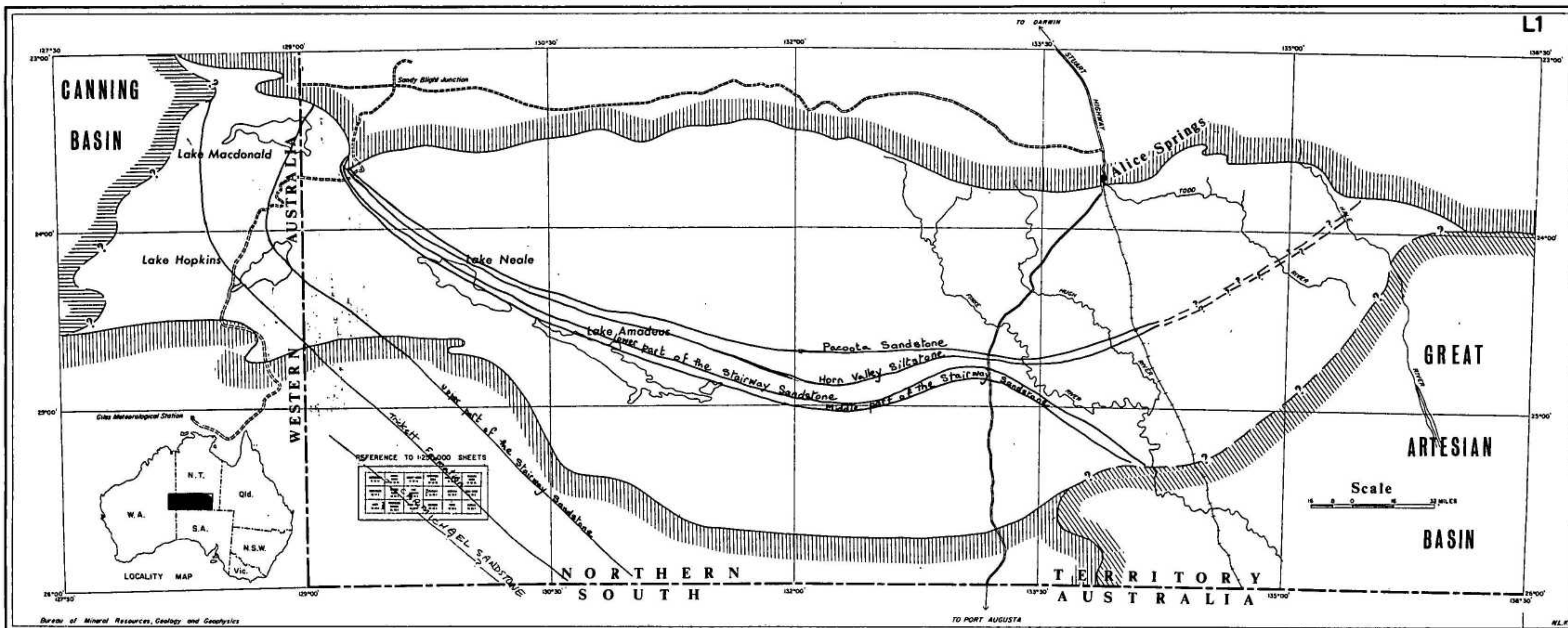
The Larapinta Group is therefore redefined to include five formations (in ascending order); the Pacoota Sandstone, the Horn Valley Siltstone, the Stairway Sandstone, the Stokes Siltstone and the Carmichael Sandstone. The group, which ranges in age from Upper Cambrian to Upper Ordovician conformably overlies the Pertaoorrta Group and is unconformably overlain by the Mereenie Sandstone.

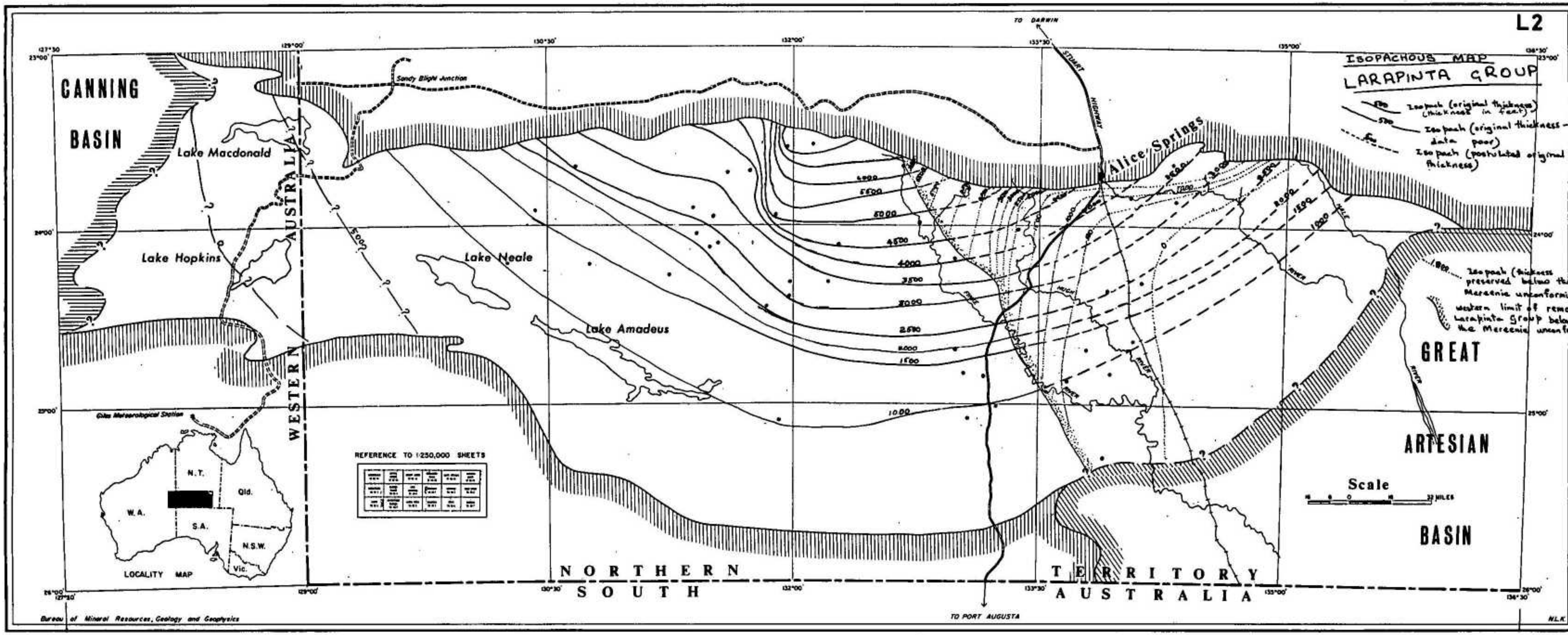
General

The formations of the Larapinta Group occur sporadically throughout much of the basin but are particularly well developed in the northern half where all five are present (Figs. L45-L50). To the south the Pacoota Sandstone, the Horn Valley Siltstone, and the lower part of the Stairway Sandstone are absent; the limit of deposition of the formations of the Larapinta Group are shown in Fig. L1. The geology of the pre-Larapinta Group surface is shown in Fig. L3 and it is evident that in most areas the formations were deposited either conformably or disconformably on formations of the Cambrian Pertaoorrta Group. On the southern and western margins of the basin, the upper formations of the Larapinta Group were deposited unconformably on Upper Proterozoic units. The Group has its maximum thickness of 7,700 feet in the eastern end of the Idirriki Range (Fig. L2). Near the southern margin of the basin the total thickness of the group is about 1,000 feet. Towards the western margin it is only a few hundred feet thick. As can be seen in Fig. L2 a considerable thickness (in some areas the entire thickness) of Larapinta Group sediments was removed during the pre-Mereenie Sandstone uplift and the subsequent period of erosion. The name Rodingan Movement is proposed for this epeirogeny.

The ratio of the thickness of the predominantly arenitic formations (the Pacoota Sandstone, the Stairway Sandstone and the Carmichael Sandstone) to the predominantly lutaceous formations (Horn Valley Siltstone plus Trickett Formation) is about 1.5:1 in most areas. Haites (1963b) has also commented on this feature of the Larapinta Group.

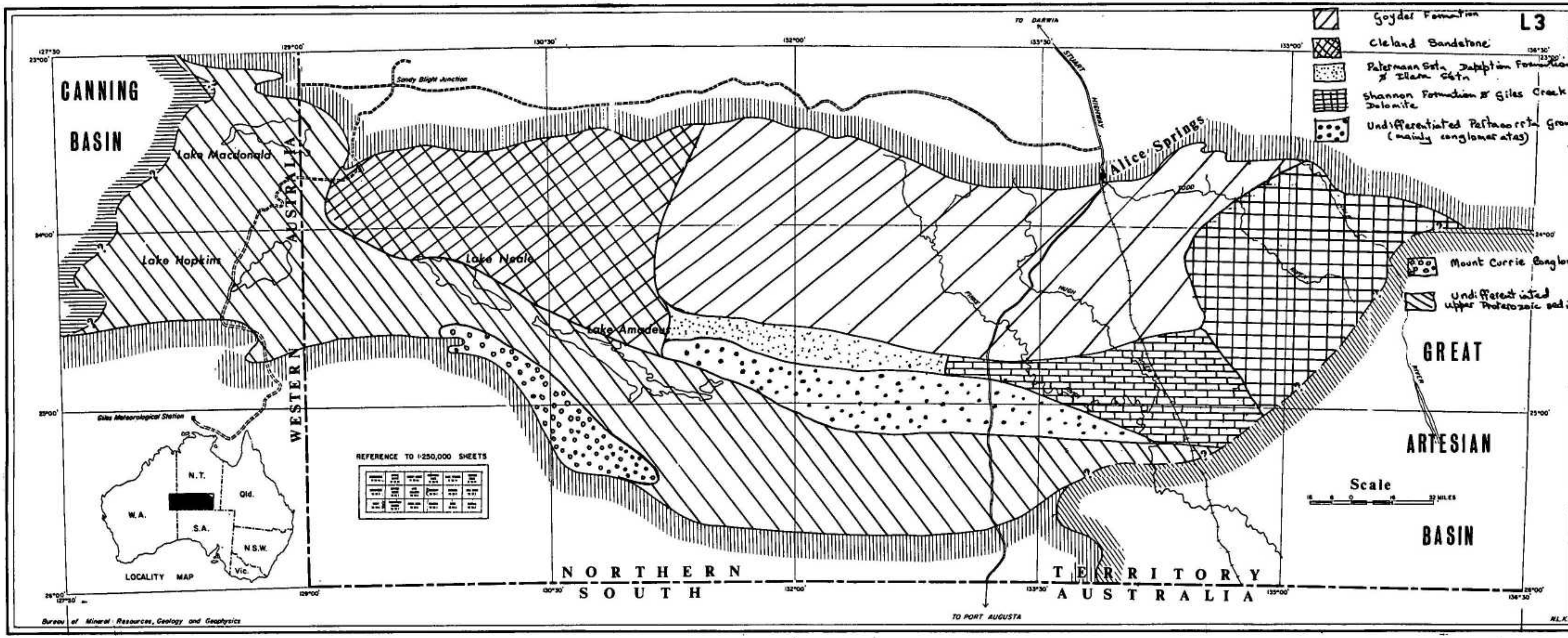
The southern limit of units of the Larapinta Group





L2
ISOPACHOUS MAP
LARAPINTA GROUP
Isopach (original thickness) (thickness in feet)
Isopach (original thickness - data poor)
Isopach (postulated original thickness)
Isopach (thickness preserved below the Mereenie unconformity)
western limit of removal Larapinta group below the Mereenie unconformity
CANNING BASIN
GREAT ARTESIAN BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
TO PORT AUGUSTA
STUART HIGHWAY
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
Scale
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
Bureau of Mineral Resources, Geology and Geophysics

Palaeogeologic map of the pre-Larapinta Group surface



Provisional correlations between the Larapinta Group section and Cambro-Ordovician sections in northern Australia are given in Fig. L22. The "time lines" have been suggested by J.G. Tomlinson (pers. comm.) from palaeontological data. It is apparent that in some parts of the section there are also marked lithological similarities between time units; for instance the upper part of the Pacoota Sandstone is very similar to the Pander Greensand (Traves, 1955), of the Bonaparte Gulf Basin. Similarly the Horn Valley Siltstone is not unlike the Emanual Formation (Veevers and Wells, 1961) of the Fitzroy Basin.

All palaeontological information from the Larapinta Group, together with the palaeontological information from other parts of Australia used in the compilation of the palaeogeographic maps, have been supplied by Miss J.G. Tomlinson. The published and unpublished information of the Bureau of Mineral Resources has been used in this account of the Larapinta Group.

The nomenclature used for arenites and carbonates is that suggested by Folk (1961).

Pacoota Sandstone

The Pacoota Sandstone, the oldest formation of the Larapinta Group, occurs only in the northern half of the basin (Fig. L4) and the area of deposition was probably the most restricted of all the formations of the Group. It underlies an area of approximately 10,000 square miles and also has large areas of outcrop, particularly in the Macdonnell Ranges, the Idirikki Range, the James Ranges and the Johnny Creek area, where it commonly forms prominent strike ridges (Fig. L96) or high escarpments.

In most areas the Pacoota Sandstone overlies the Goyder Formation with a conformable and gradational contact but to the west it overlies the Cleland Sandstone either conformably or disconformably. The Pacoota Sandstone is conformably overlain by the Horn Valley Siltstone in most parts of the basin but is unconformably overlain by the Mereenie Sandstone in the north-west corner of the basin.

The formation has a maximum preserved thickness of about 3,000 feet in the Finke Gorge area of the western Macdonnell Ranges (Fig. L5); it is possible that the area of greatest depositional thickness of the Pacoota

Sandstone was in the north-east corner of the Amadeus Basin. It is suggested (Fig. L5) that in this north-east corner the Pacoota Sandstone was approximately 4,000 feet thick before the post-Rodingan Movement erosion.

The Pacoota Sandstone has an age of late Upper Cambrian (Trempealeauan) to Lower Ordovician (Arenigian) (J.G. Tomlinson, pers. comm.). Fossils are present in the formation and whilst considerable thicknesses of sandstones are apparently completely barren, some bands are richly fossiliferous (particularly in the Ross River area) and yield trilobites, brachiopods, lamellibranchs, gastropods, ribeirioids, nautiloids, and numerous trace fossils (Figs. L35). Scolithus the vertical worm tube, forms "pipe-rock" which is a prominent feature of the Pacoota Sandstone (Figs. L34).

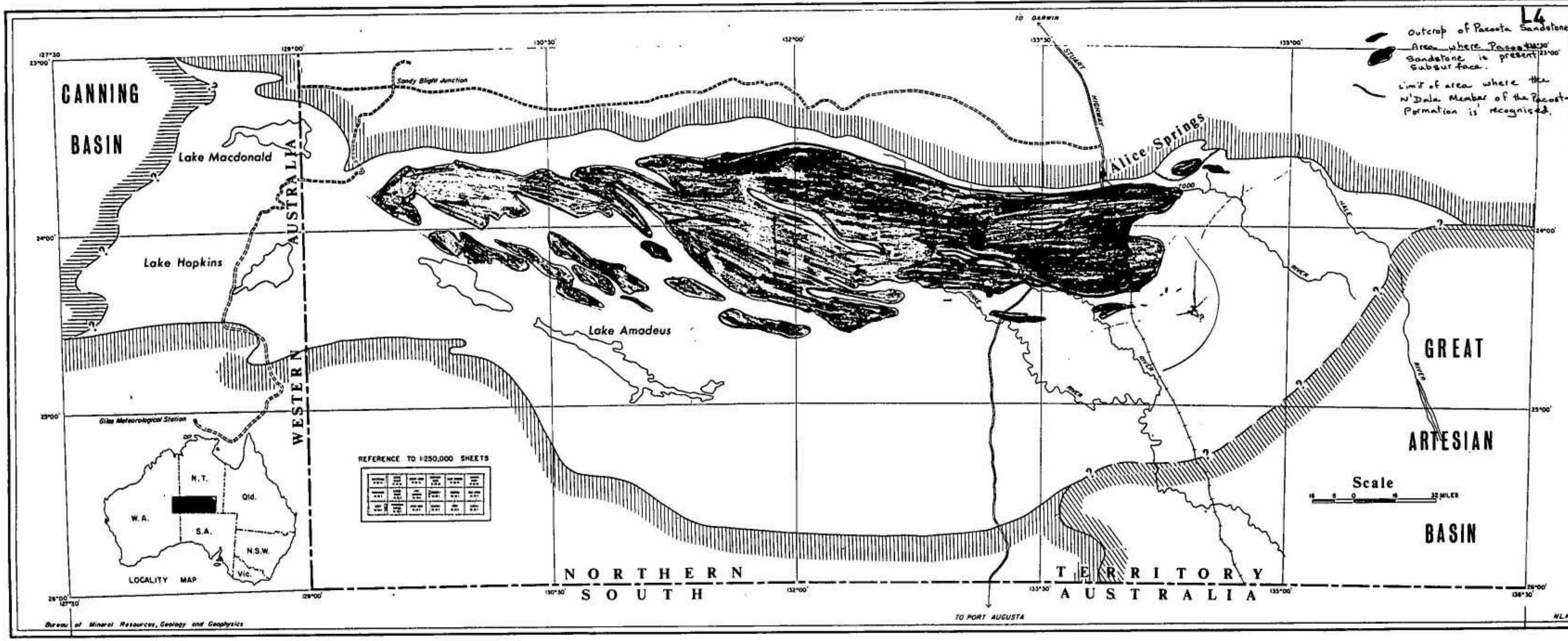
Tomlinson (pers. comm.) is able to distinguish eight faunal assemblages from which three time units can be recognized. These time units are informally designated Pacoota I, Pacoota II and Pacoota III and correspond respectively to uppermost Cambrian, (Trempealeauan), Tremadocian, and Arenigian. The only rock unit sub-division of the Pacoota Sandstone so far attempted has been the N'Dahla Member on the northern flank of Ross River Syncline, in the north-east corner of the Amadeus Basin; here the member is 50 feet thick. The N'Dahla Member is Lower Ordovician in age. Elsewhere, the Pacoota Sandstone is mapped as a single rock unit.

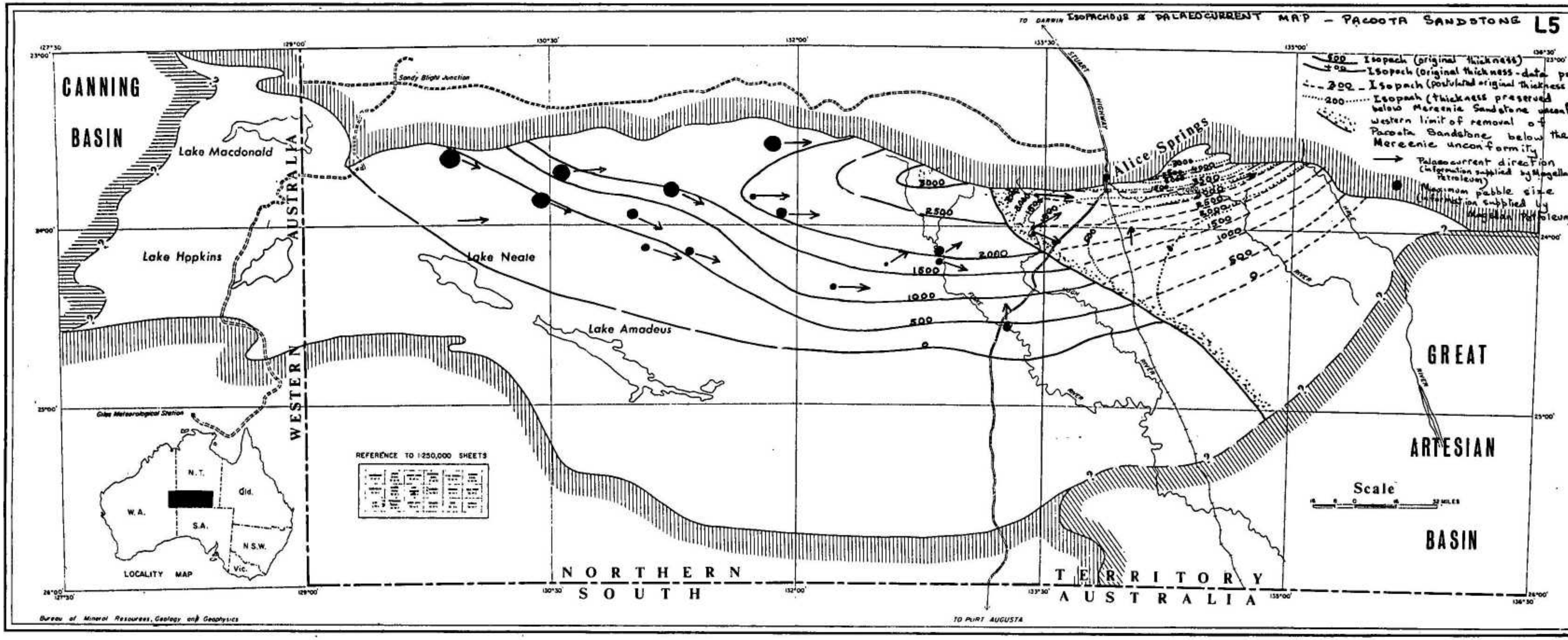
Lithology

The formation consists predominantly of quartzose sandstones with interbeds of siltstone which are generally thin but which may be thick towards the top. As is shown in Fig. L6, the ratio of sand to shale decreases to the south.

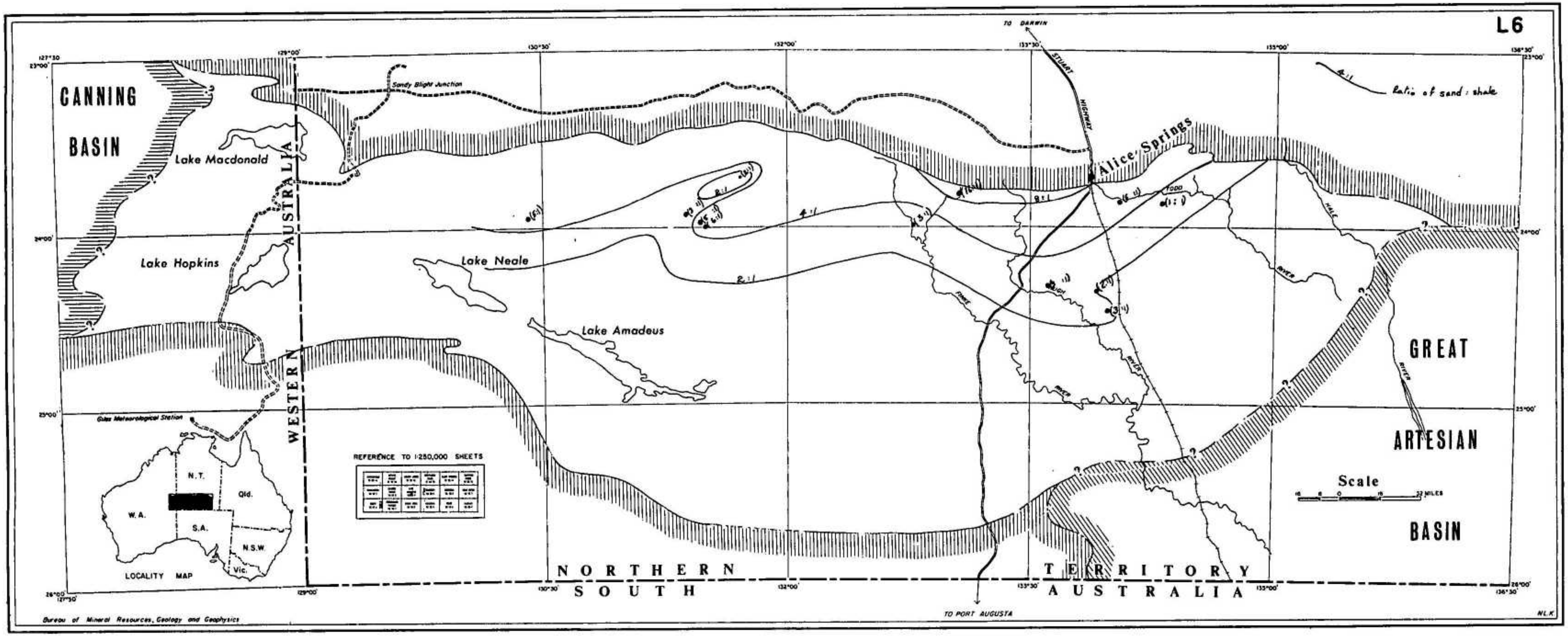
The sandstones are fine to coarse grained and in places very coarse grained. Pebbly sandstones are also fairly common with pebbles up to 4 inches in diameter. The pebbles which tend to increase in size to the west, (Fig. L5) are generally composed of vein quartz or silicified sandstone. Both the pebbles and the sand-size grains are well rounded and moderately well sorted. Many of the sandstones are crumbly and saccharoidal in outcrop. The sandstones are generally grey, white or brown, thin to thickly bedded, ripple marked, and cross-bedded, (with cross-beds generally indicating palaeo-currents flowing from the west or north-west - see Fig. L5). Such features as mud-pellets

DISTRIBUTION OF THE PACOOTA SANDSTONE




ISOPACHOUS & PALAEOCURRENT MAP - PACOOTA SANDSTONE
L5
TO DARWIN
500 Isopach (original thickness)
400 Isopach (original thickness - data poor)
300 Isopach (postulated original thickness)
200 Isopach (thickness preserved below Mereenie Sandstone unconformity)
western limit of removal of Pacoota Sandstone below the Mereenie unconformity
Palaeocurrent direction (information supplied by Magellan Petroleum)
Maximum pebble size (information supplied by Magellan Petroleum)
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
STUART HIGHWAY
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
3000
2500
2000
1500
1000
500
0

Lithofacies map - Pacoota Sandstone
sand:shale ratio



marking and fossil tracks and trails (particularly Scolithus, and Cruziana) are also very common. In general, the sandstones are well exposed and form prominent scarps or strike ridges. In places the sandstones contain abundant glauconite; in the Gardiner and Idirriki Ranges there is a particularly prominent glauconite band about 20 feet thick, in the upper part of the formation. This same band is known to occur throughout an area of hundreds of square miles. There are also other glauconitic bands in some areas. The glauconite may form up to 50% of the rock and is present as either granular or intergranular glauconite.

Sandstones are commonly ferruginized and at places in the western half of the basin there is a thin pisolitic ironstone at the base of the unit. South of the George Gill Range, in the central part of the Amadeus Basin, near the top of the Pacoota Sandstone, there is also a sandstone about 4 feet thick which contains abundant ferruginous vugs, which commonly weather out to give the rock a very characteristic honeycomb appearance (Fig. L36).

The interbedded siltstones, and claystones are variegated white, grey, brown, red, thin bedded, micaceous and possibly kaolinitic in places and invariably very poorly exposed. The contacts between the lutites and the arenites of the Pacoota Sandstone are commonly gradational.

Thin phosphorite bands with nodules up to 3 inches in diameter also occur in the Pacoota Sandstone but are not common. Rare limestones are present near the base of the Pacoota Sandstone in the Ross River Gorge area. The limestones are ferruginized and glauconitic and have a maximum thickness of 10 feet.

The N'Dahla Member of the Pacoota Sandstone has a distinctive appearance. It consists of dark red-brown and purple-brown medium to coarse grained poorly sorted sandstone, clayey sandstone, and pebbly sandstone. Some of the sandstones are glauconitic. There are a few conglomeratic beds, with poorly rounded pebbles and cobbles of siltstone and limestone in a coarse glauconitic sandstone matrix. Some thin limestone bands also occur within the member.

Petrography

Quartzose sandstones are the dominant rock type in the Pacoota

Sandstone. In thin section they are generally well sorted and well rounded although there are a few well rounded - poorly sorted combinations. The modal grain size ranges from very fine grained to coarse grained sand. Most of the arenites may be classified as super-mature orthoquartzites with generally 30-60% non-undulatory quartz, 30-60% undulatory quartz, and 10-30% composite quartz. Chert is rarely present. In a few specimens the percentage of grains of metaquartzite is sufficiently high for the rock to be termed a sub-greywacke or the percentage of feldspar (mainly microcline) sufficiently high for the rock to be a sub-arkose. The accessory minerals are tourmaline and zircon.

Cement may be rarely clayey, calcareous, glauconitic or phosphatic, but is most commonly siliceous, with well developed quartz overgrowths. This silicification has adversely affected the reservoir characteristics of the formation. It is considered to be a post-depositional feature possibly due to deep burial or the effects of the Alice Springs Orogeny.

The clays of the Pacoota Sandstone are probably predominantly kaolinitic and illitic with minor chlorite and montmorillonite.

The petrography of the N'Dahla Member is slightly different from that of the undifferentiated Pacoota Sandstone in that there are a number of re-worked sand grains in some specimens (rarely up to 10%) and up to 20% of meta-quartzite grains - some of the metaquartzite grains are better rounded than the non-undulatory quartz, which suggests the material has passed through an earlier cycle of erosion.

The Environment of Deposition

It is apparent that the Pacoota Sandstone is a shallow water marine formation. This is indicated by the fauna, the abundant cross-beds and ripple marks and by the presence of glauconite. Williams et. al., (1965) suggest that the presence of intergranular sulphates and carbonates indicates relatively high salinity conditions with restricted circulation of marine water. It is however impossible to be certain that the sulphate and carbonates were not introduced during diagenesis. The abundance of cross-beds and the coarseness of the grain size suggests fairly vigorous conditions during Pacoota Sandstone times. The presence of glauconite, phosphorites and a rich infaunal development suggests periods of slow deposition. However, the straightness of infaunal burrows may also be taken as evidence of fairly fast deposition, i.e. the burrowing organism was only able to keep pace with sedimentation by "straight chewing" and did not have time for diverging in the search for food. Therefore it is probable that conditions were variable with first rapid then very slow sedimentation. It is possible that during the period of slow sedimentation arenites acquired their super maturity.

It is difficult to imagine how a thick and extensive body of orthoquartzite such as the Pacoota Sandstone can be deposited. A possible mechanism is the coalescing of longshore bars so that with repeated minor transgression and regression a thick body of sand was gradually built up.

Some of the pebble bands within the formation may be beach sediments, deposited either on land-adjacent beaches or on barrier-island beaches.

A further possibility is that a body of coarse sand results from the impinging of fairly high energy waves upon the shallow-water shelf. Winnowing of fines will take place where the waves impinge so that a body of coarse sand will develop. This body of sand would transgress or regress as the sea-level of the shelf rose or fell.

Another possibility is that some of the sandstones may result from the reworking of a large desert area, with repeated transgressions, and regressions. Abundant kaolinite is also used as a criteria for a non-marine environment (Weaver, 1958a). Desert influences are perhaps supported by a report by Williams et. al. (1965); many of the coarser grains may have been subjected to wind action as they are frosted. However, frosting may also be produced by chemical weathering and cannot therefore be taken as certain proof of aeolian activity.

Horn Valley Siltstone

The present-day distribution of the Horn Valley Siltstone (Fig. L7), and probably also the original area of deposition is very similar to that of the Pacoota Sandstone. The formation underlies a considerable area but very rarely crops out and almost invariable forms a deep alluvium-covered strike valley. It is best exposed in the western Macdonnell Ranges, the Ochre Hill area, Mount Olifent and on the flanks of some of the anticlines west of Tempe Downs homestead.

The Horn Valley Siltstone overlies the Pacoota Sandstone conformably, except in a small area along the southern limit of the formation (e.g. the Seymour Range area), where the Horn Valley Siltstone rests disconformably on the Cambrian Goyder Formation or the Jay Creek Limestone. In general, the Horn Valley Siltstone is conformably overlain by the Stairway Sandstone, except to the east, where the formation is unconformably overlain by the Mereenie Sandstone.

The Horn Valley Siltstone has a maximum thickness of 1,400 feet in the Western Macdonnell Ranges (see Fig. L8). This thickness includes about 600 feet of siltstones and shales of doubtful affinities, which are not considered to be "normal" Horn Valley Siltstone lithology. The maximum thickness of "unquestionable" Horn Valley Siltstone is about 800 feet.

"The Horn Valley Siltstone contains a rich, extremely well preserved fauna of trilobites, brachiopods, peleycypods, nautiloids, ostracods, conodonts, graptolites and gastropods (Fig. L37A) of Lower Ordovician (Arenigian) age (J.G. Tomlinson, pers. comm.).

Lithology

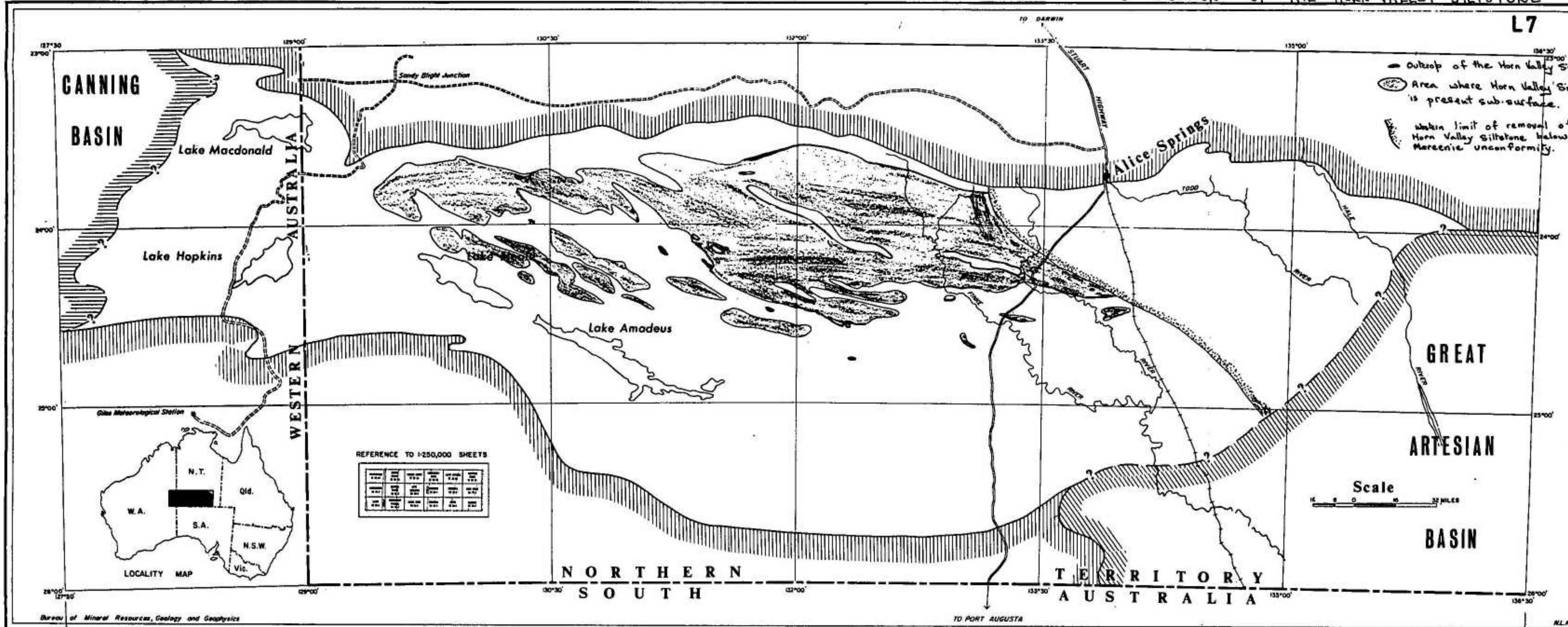
The Horn Valley Siltstone consists of siltstone, calcareous siltstone, claystone, limestone and minor sandstone and sandy siltstone. As can be seen in Fig. L9 the ratio of non-calcareous to calcareous sediments ranges from 2:1 to greater than 32:1 with the highest percentage of calcareous sediments occurring towards the southern margin.

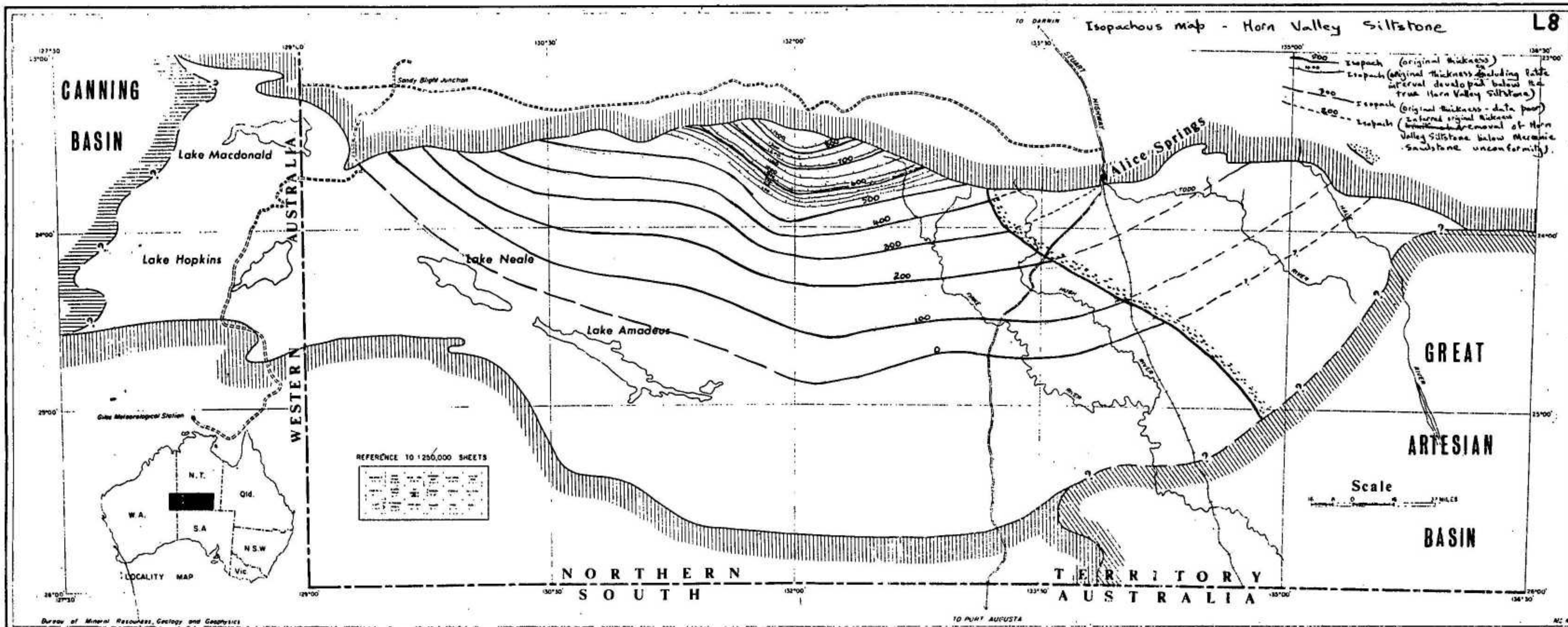
The siltstone and claystone are predominantly grey-green and pale brown in outcrop but black in the sub-surface. They are laminate to thinly bedded, calcareous in part, soft and readily weathered, pyritic, and possibly gypseous (the selenite may be due to the weathering of the pyrite).

The limestones are yellow-brown, grey-brown or dark grey in outcrop but are commonly light grey in the sub-surface. They are thin-bedded, brittle, moderately resistant to weathering, rarely sandy and largely composed of fossil fragments. They are recrystallized in places and may be veined by calcite.

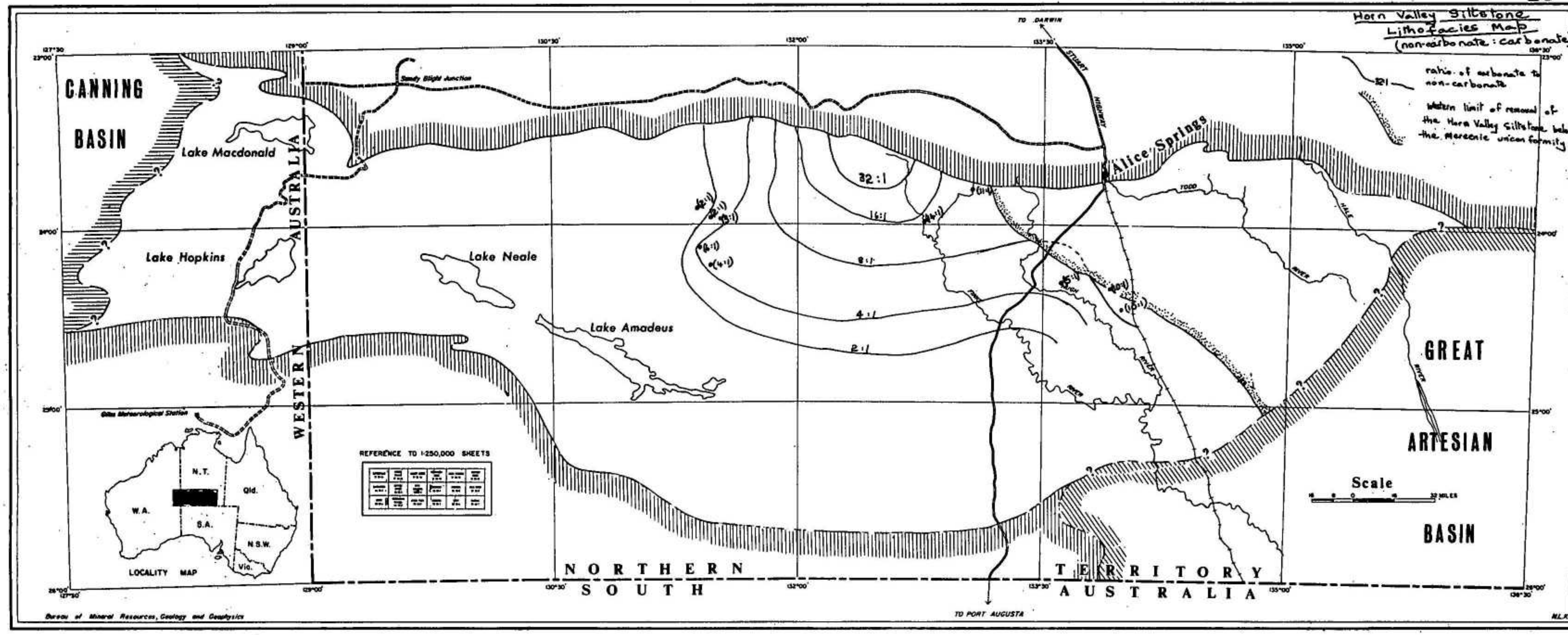
The few sandstones which occur within the formation are brown or

DISTRIBUTION OF THE HORN VALLEY SILTSTONE





Isopachous map - Horn Valley Siltstone
L8
Isopach (original thickness)
Isopach (original thickness excluding latite interval developed below the true Horn Valley Siltstone)
Isopach (original thickness - data poor)
Isopach (Inferred original thickness removal of Horn Valley Siltstone below Mereenie Sandstone unconformity).
CANNING
BASIN
Lake Macdonald
Lake Hopkins
WESTERN AUSTRALIA
Sandy Blight Junction
Lake Neale
Lake Amadeus
Alice Springs
TO DARWIN
STUART HIGHWAY
TODD
700
600
500
400
300
200
100
0
GREAT
ARTESIAN
BASIN
Scale
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


Horn Valley Siltstone
Lithofacies Map
(non-carbonate : carbonate)
32:1
ratio of carbonate to non-carbonate
Western limit of removal of the Horn Valley Siltstone below the Mereenie unconformity
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
32 : 1
16 : 1
8 : 1
4 : 1
2 : 1
GREAT
ARTESIAN
BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO DARWIN
TO PORT AUGUSTA
Sandy Blight Junction
Giles Meteorological Station
STUART HIGHWAY
TODD
HALE
RIVER
REFERENCE TO 1:250,000 SHEETS
Scale
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics

grey-brown in colour, thin-bedded, silty, friable and easily weathered. Glauconite occurs very rarely in the sandstone and limestone. A few pelletal phosphorites of the Stairway Sandstone type are present towards the top of the formation. Also present near the top of the formation is a distinctive oolitic ironstone band which, although generally only a few inches thick, occurs over thousands of square miles. The oolites are limonitic in outcrop but are pyritic when fresh.

Petrography

The limestones are composed largely of fossil fragments, with a sparry calcite cement and may be classified as biosparites or biosparrudites.

The quartz of the sandy limestone, sandy siltstone and sandstone, is mainly of the non-undulatory (common) type with minor undulatory and rare composite grains. The sand-size grains are moderately well to well sorted and poorly rounded. Glauconite occurs only rarely but may be either granular or intergranular and in some cases may replace calcite. Pyrite ooliths occur occasionally in a few of the limestones. The claystone is probably composed mainly of illite and kaolinite with minor chlorite.

The Environment of Deposition

A marine environment is suggested by the fossils and also by the clay-mineral assemblage (Weaver, 1958). The abundance of fossils such as graptolites, suggests that the upper waters were well aereated and able to support a prolific fauna; the lack of infauna and the extremely good preservation of the numerous fossils suggest euxinic conditions on the sea bottom. The presence of pyrite also suggests strongly reducing bottom conditions as does the fetid smell, the black colour and the abundance of organic carbon in the sediments.

During most of Horn Valley Siltstone times, conditions of sedimentation were probably very tranquil, due to the sediments being deposited either in fairly deep waters below wave base or in enclosed basins or lagoons with restricted circulation. However, biosparites are considered by Folk (1961) to be evidence of fairly strong winnowing action during or immediately following the deposition of the calcareous sediments. This is perhaps supported by the form of the lithofacies map (Fig. L9) in which the highest percentage of calcareous sediments occurs towards the margin of deposition - the area where wave action and winnowing are most likely to have occurred. Therefore it follows that as conditions appear to have been more vigorous on the margin of deposition, anaerobic conditions resulted from stagnation in deep bottom waters below wave base.

Stairway Sandstone

The Stairway Sandstone is one of the most widespread units of the Larapinta Group. It is estimated to underlie an area of at least 20,000 square miles although its outcrop area is only 600 square miles or less (Fig. L10).

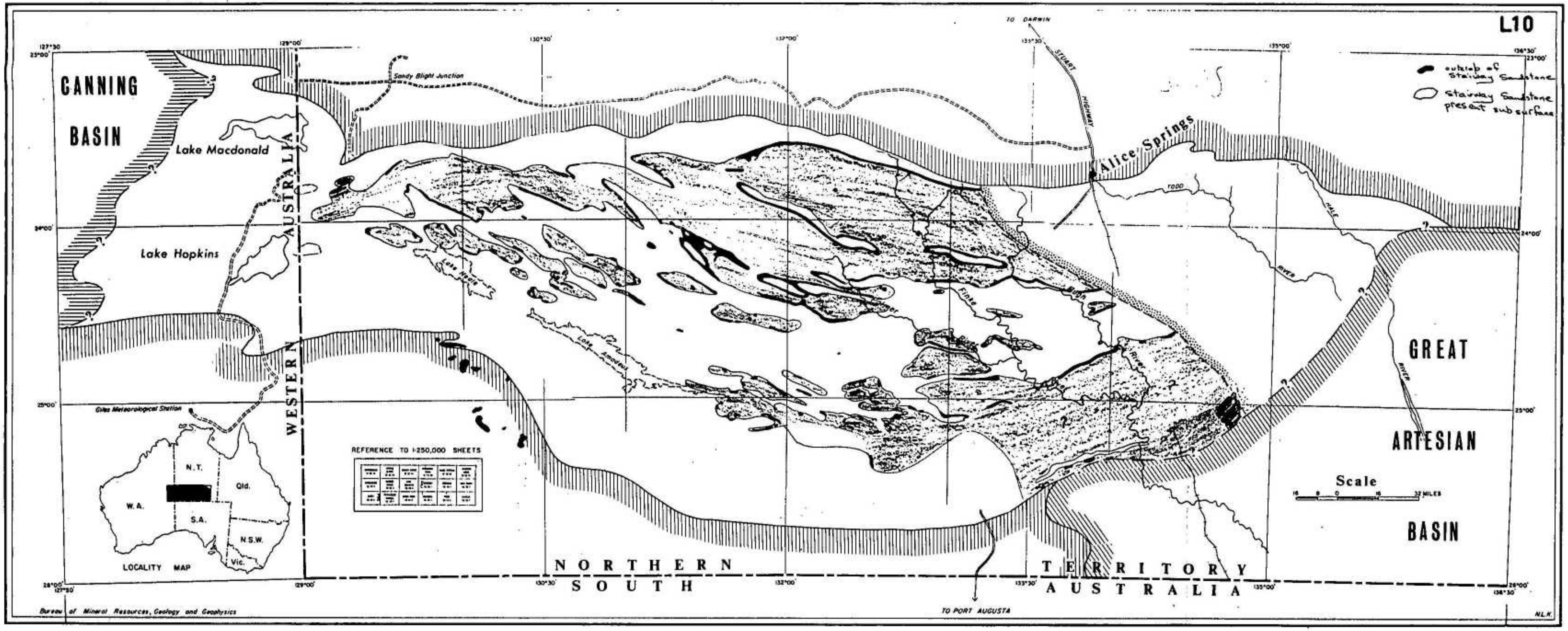
In the northern half of the Amadeus Basin the formation overlies the Horn Valley Siltstone conformably; to the south it disconformably overlies the Cambrian Pertaoorrta Group and unconformably overlies Upper Proterozoic sedimentary rocks. Further south and west (e.g. Petermann Range area), the formation rests unconformably on igneous and metamorphic rocks. In most areas the Stairway Sandstone is conformably overlain by the Stokes Siltstone but in the eastern part of the basin it is overlain unconformably by the Mereenie Sandstone.

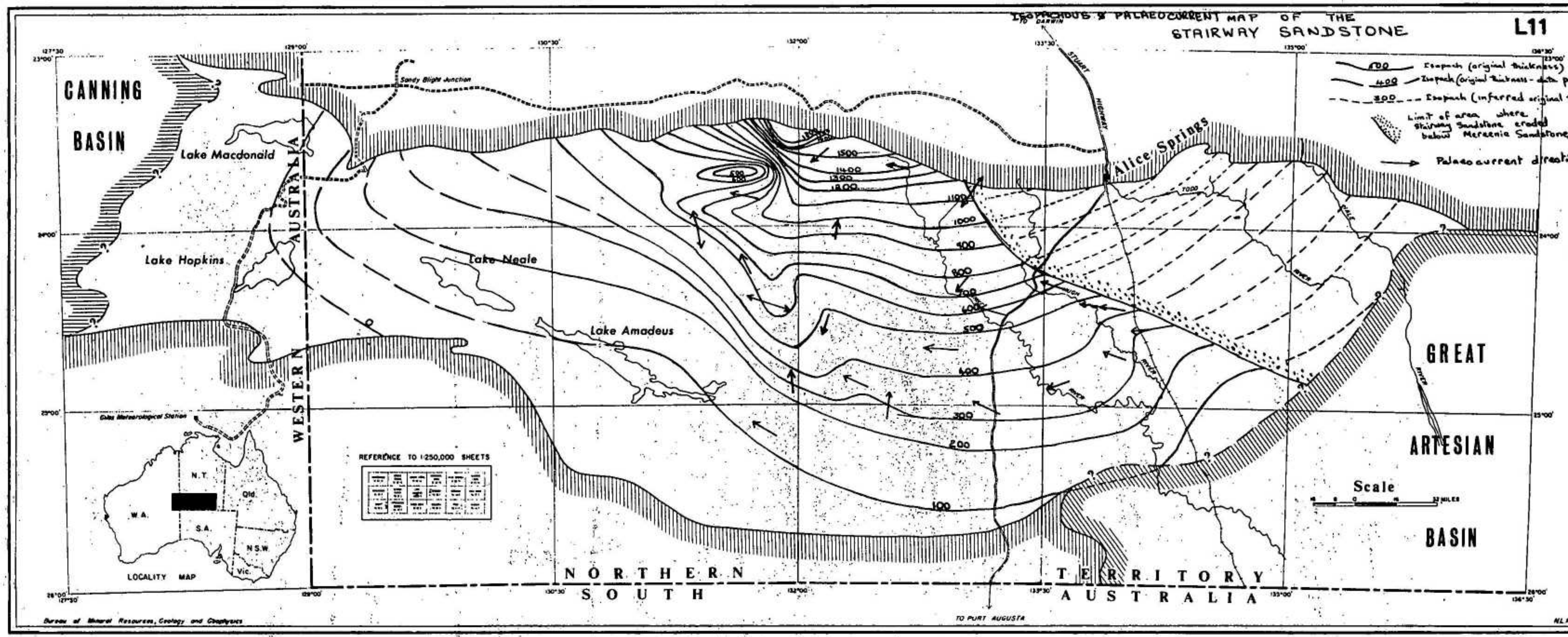
The formation ranges in thickness from 1840 feet in the Idirriki Range to 100 feet or less on the southern margin of the basin, (Fig. L11).

The Stairway Sandstone is of middle Ordovician age with an estimated range of Upper Llanvirnian-Llandeilian (J.G. Tomlinson, pers. comm.). The formation is richly fossiliferous and the fauna includes trilobites, brachiopods, pelecypods, gastropods, nautiloids, sponge spicules, numerous trace fossils and microfossils.

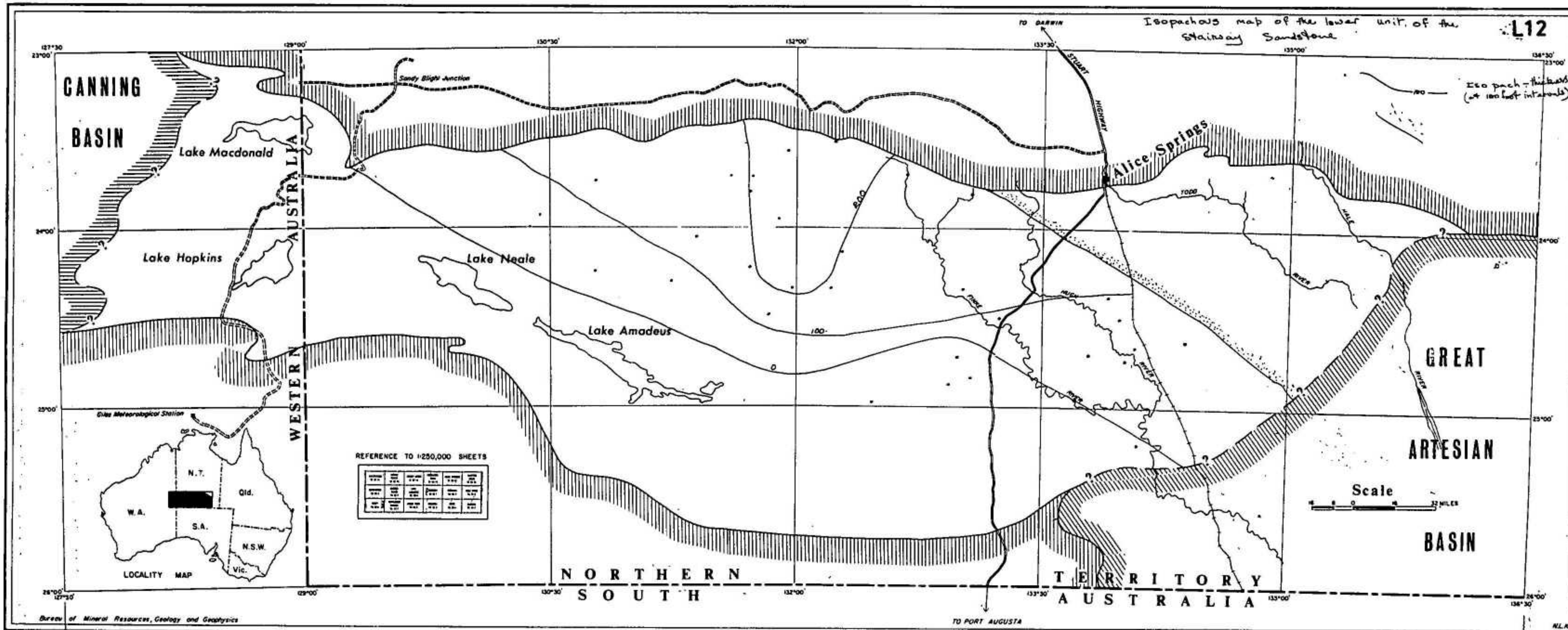
Lithology

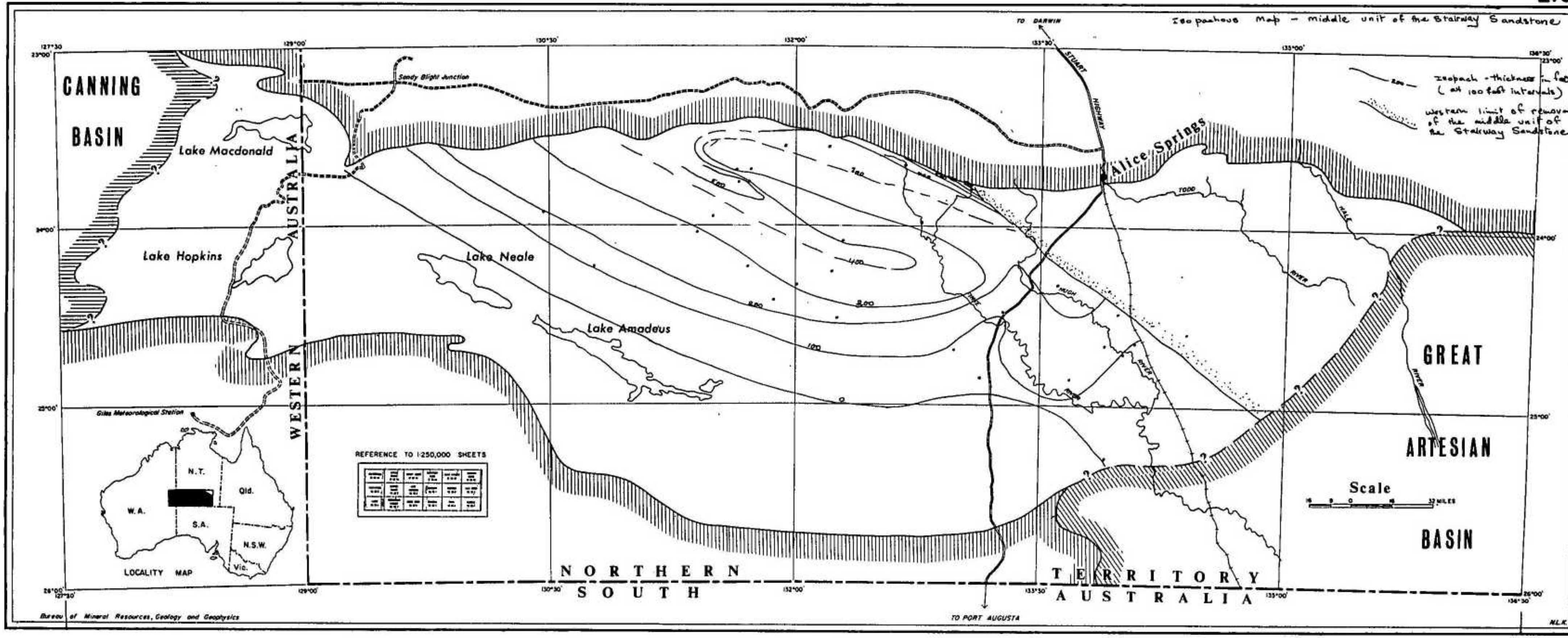
The Stairway Sandstone has an arenite lutite ratio which ranges from about 1:1 to about 4:1, with the area of greatest lutite percentage situated in the middle of the basin (Fig. L15). However the lithofacies map illustrates the present picture after erosion rather than the original deposition. Cook (1966a, unpubl., and 1968) divides the Stairway Sandstone into lower, middle and upper units, purely on lithological criteria. However the boundary between the middle and upper rock units possibly corresponds approximately to the


L10
outcrop of Stairway Sandstone
Stairway Sandstone present subsurface
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
TO DARWIN
STUART HIGHWAY
Alice Springs
TODD
HALE
RIVER
Finke
GREAT
ARTESIAN
BASIN
Giles Meteorological Station
WESTERN AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
Scale
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.



ISOPACHOUS & PALAEOCURRENT MAP OF THE STAIRWAY SANDSTONE
L11
Isopach (original thickness)
Isopach (inferred original thickness)
Limit of area where Stairway Sandstone eroded below Mereenie Sandstone
Palaeocurrent direction
CANNING BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
TO DARWIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
W.A.
N.T.
Qld.
S.A.
N.S.W.
Vic.
Scale
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
NLK


L12
Isopachous map of the lower unit of the Stairway Sandstone
Isopach - thickness in feet (at 100 feet intervals)
100
CANNING
BASIN
GREAT
ARTESIAN
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART
HIGHWAY
TO PORT AUGUSTA
TODD
HALE
RIVER
FINKE
HUGH
200
100
0
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics
W.L.K.


Isopachous Map - middle unit of the Stairway Sandstone
Isopach - thickness in feet (at 100 foot intervals)
western limit of removal of the middle unit of the Stairway Sandstone
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Giles Meteorological Station
Alice Springs
TO DARWIN
STUART
HIGHWAY
TODD
HALE
RIVER
WESTERN AUSTRALIA
GREAT
ARTESIAN
BASIN
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
400
300
200
100
0

early Larapintan-late Larapintan time boundary (J.G. Tomlinson, pers. comm.). As can be seen in Fig. L1 all three units are present in the northern half of the basin but in the south only the upper unit is present.

The lower unit of the Stairway Sandstone shows little lateral variation in either lithology or thickness; its maximum thickness is 200 feet on the northern margin of the basin (Fig. L12). It is a white or grey, fine to very coarse grained sandstone with well rounded and sorted quartz grains. It is pebbly in places and in particular there is a single pebble band, approximately 1 foot in thickness, which forms a marker band over an area of at least 10,000 square miles in the Rodinga, Henbury and Lake Amadeus Sheet areas. The sandstones are thin to massively bedded, ripple marked and cross-bedded; bedding plane markings, various tracks and trails (Fig. L40) and pipe rock, which is in places difficult to distinguish from some of the pipe rock of the Pacoota Sandstone, are all common. In places sandstones near the base of the unit contain up to 20% of ooliths which are pyritic in the subsurface but limonitic in outcrop. The regional form and lithology of the body of sand forming the lower unit of the Stairway Sandstone is a typical example of what is commonly referred to as a blanket sand or sheet sand.

By contrast the middle unit of the Stairway Sandstone has a varied lithology. It has a maximum thickness of about 700 feet near the northern margin of the basin (Fig. L13). The dominant lithology is lutaceous with siltstones, mudstones and claystones which are black in the sub-surface but grey or green in outcrop. The lutites are commonly sandy, micaceous, laminate, easily weathered and very poorly exposed. Interbedded with the lutites are grey or white, very fine-grained thin-bedded sandstones and grey, brown or black pelletal and nodular phosphorites.

The middle unit shows a marked lateral variation and the lutite-arenite-phosphorite sequence is replaced by a lutite-carbonate sequence to the south-east (the Seymour Range area). The carbonates in this area are thin-bedded dark grey limestones and dolomites which contain a distinctive fauna of very small, pyritized gastropods. Further east, the middle unit of the Stairway Sandstone is composed mainly of lutites and arenites, which are red in colour. Phosphorites occur in both the carbonate and the red-bed facies but are rare. There is a striking similarity between the phosphatic shale - carbonate-red-bed facies variation in the middle unit of the Stairway

Sandstone and the facies distribution shown by Sheldon (1964) for the Phosphoria Formation of western Wyoming.

The upper unit of the Stairway Sandstone ranges in thickness from less than 100 feet on the southern margin of the basin to 1,000 feet on the northern margin (Fig. L14). Lithologically, it is similar to the lower unit, being predominantly an arenite sequence, but there are interbeds of lutite and some thin phosphorite bands. The arenites are predominantly white or grey very fine-grained silicified sandstones which are cross-bedded and commonly contain abundant trace fossils such as Diplocraterion and Cruziana. (Fig. L42).

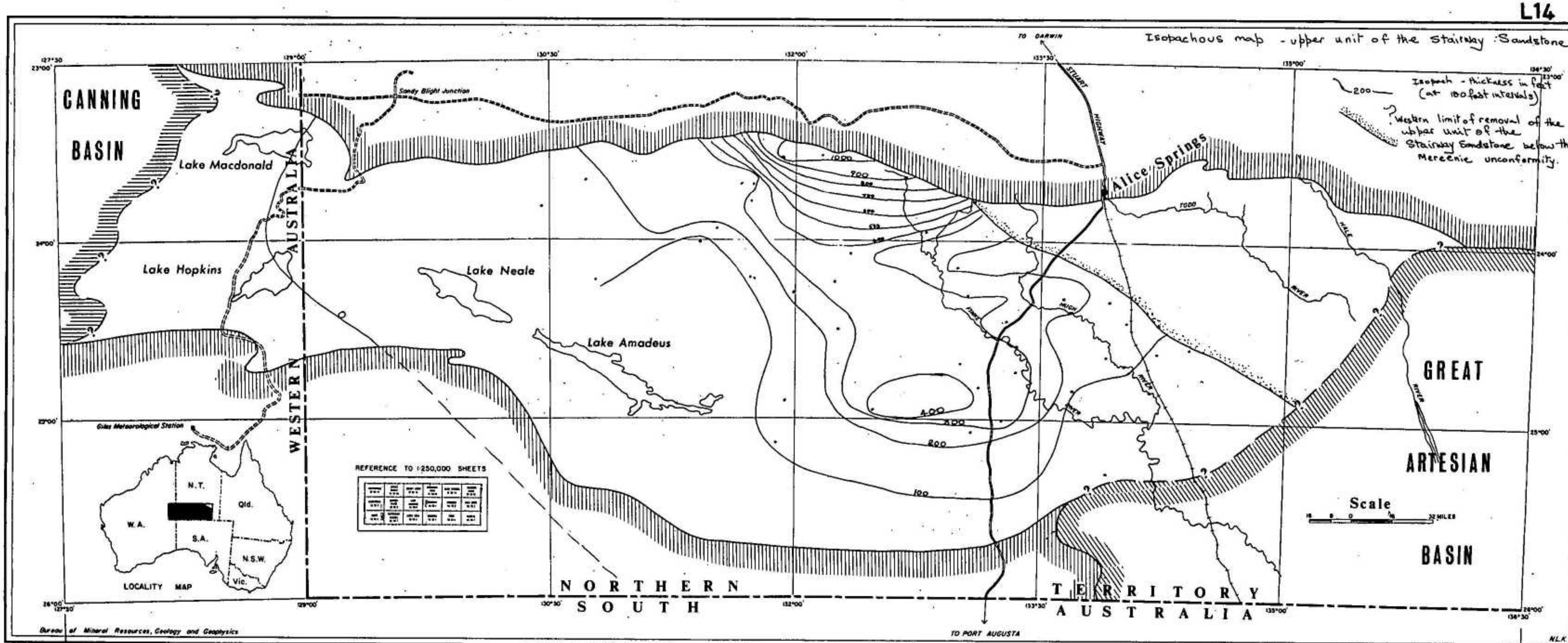
Petrography

There are four basic rock types in the Stairway Sandstone: - arenites, lutites, carbonates and phosphorites.

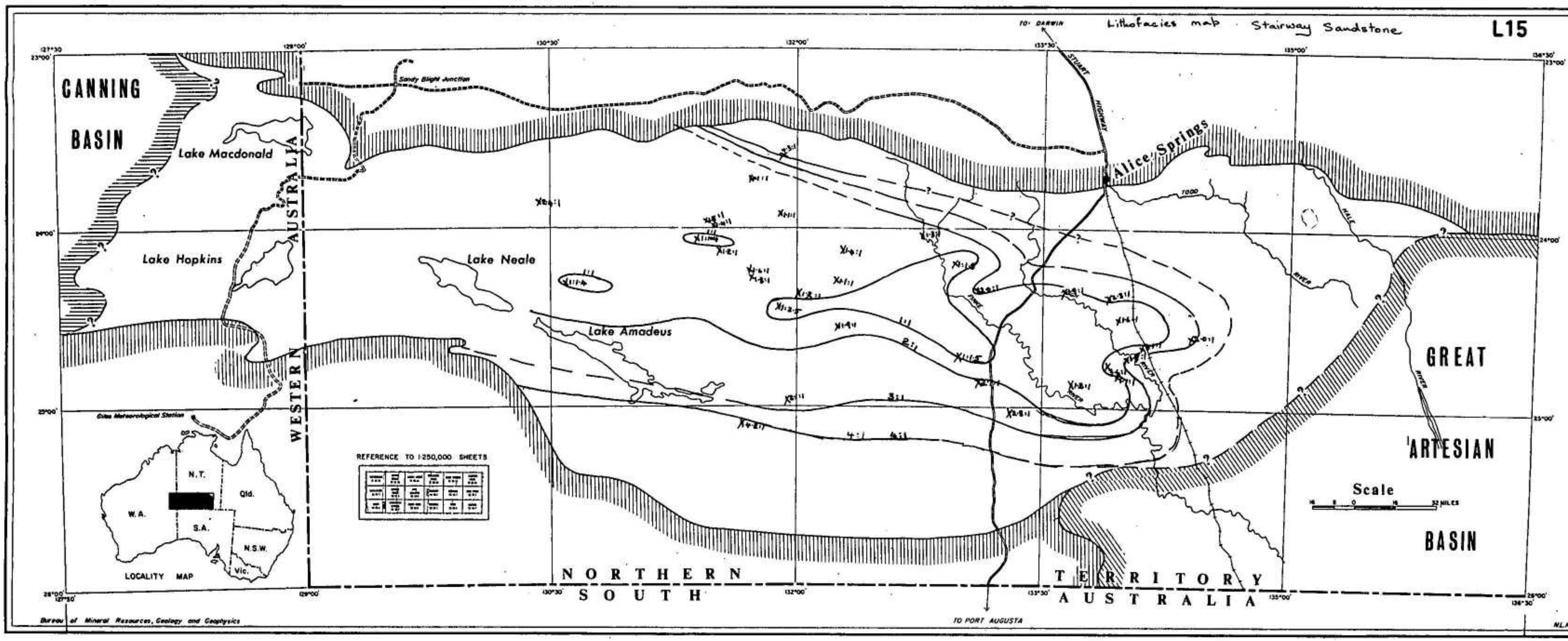
The majority of the arenites can be classified as super-mature orthoquartzites, which contain greater than 95% (in many cases up to 99%) quartz grains. The quartz is generally non-undulatory with only a small percentage of undulose quartz and an even smaller number of grains of composite quartz. The cement of the orthoquartzites is generally siliceous though a few have calcareous cement. Rarely, the cement may be phosphatic or glauconitic. The orthoquartzites of the lower unit of the Stairway Sandstone are generally coarse grained, and are well rounded and sorted. Bimodality is fairly common and the two modes are each well sorted. The orthoquartzites of the upper unit are generally of fine grained sand size; some of the sands are sub-angular and moderately sorted. The number of grains of chert and feldspar, whilst still very low, is higher in the upper unit than in the lower unit. The arenites of the middle unit are mainly very fine grained sub-mature to immature orthoquartzites.

The heavy mineral assemblage of the orthoquartzites is a typical super-mature tourmaline-zircon (both well rounded) assemblage. A few of the Stairway Sandstone arenites fall into the sub-arkose group in which the feldspar (mainly microcline) content is from 5% to 25%.

The lutites include both siltstones and claystones. The siltstones may be considered as orthoquartzite-type siltstones as their mineralogy (with the exception of having a higher percentage of feldspar) is much the same as

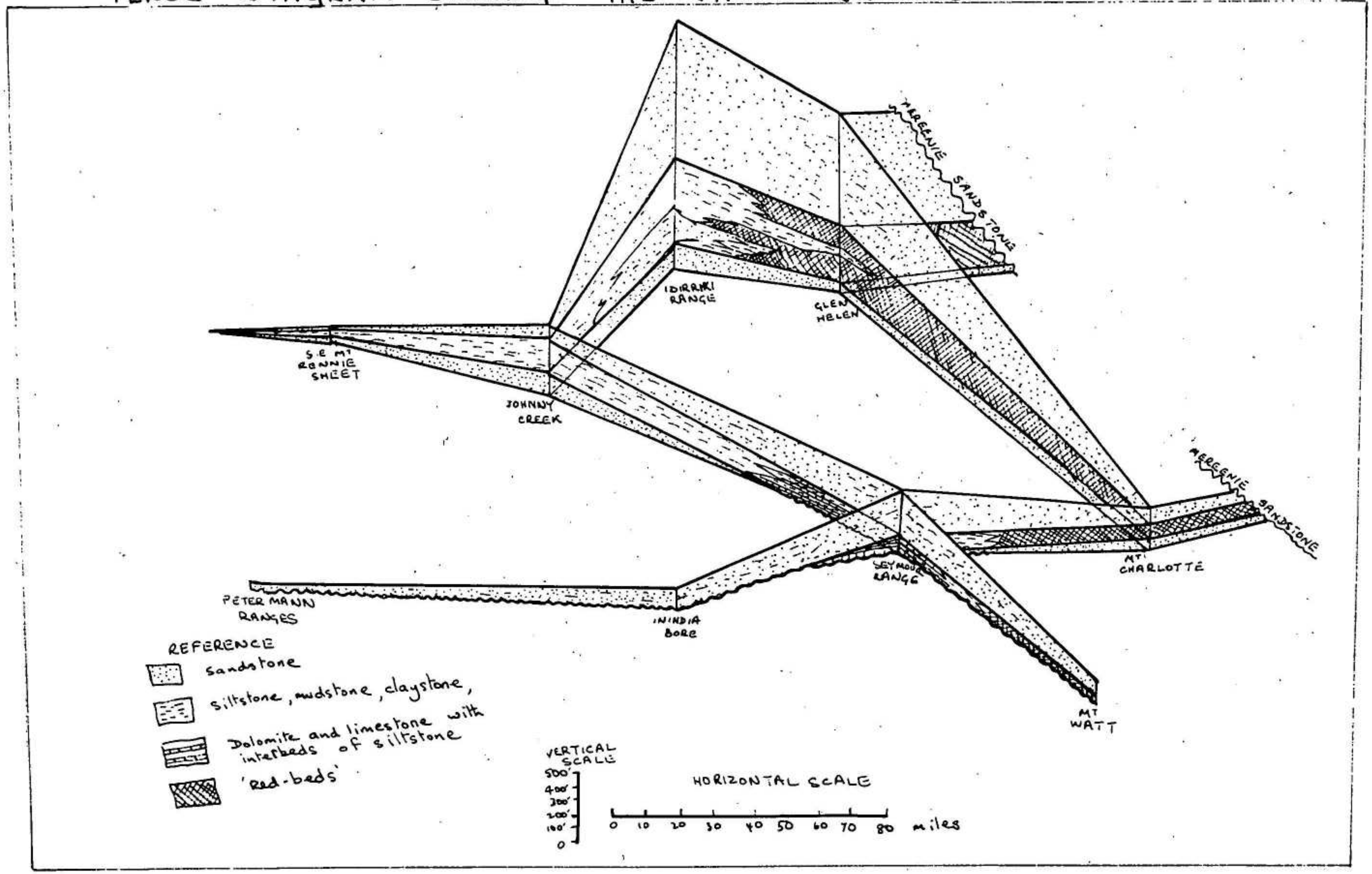


Isopachous map - upper unit of the Stairway Sandstone
Isopach - thickness in feet (at 100 feet intervals)
200
? Western limit of removal of the upper unit of the Stairway Sandstone below the Mereenie unconformity.
CANNING
BASIN
GREAT
ARTESIAN
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
TO PORT AUGUSTA
STUART
HIGHWAY
TODD
HALE
RIVER
HUGH
FINKE
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
SOUTH
AUSTRALIA
1000
900
400
300
200
100
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics
NLK



Lithofacies map Stairway Sandstone
L15
TO DARWIN
STUART HIGHWAY
Alice Springs
CANNING BASIN
Sandy Blight Junction
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Giles Meteorological Station
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
TODD
HALE RIVER
FINKE RIVER
1:1
2:1
3:1
4:1
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
NLK

FENCE DIAGRAM SHOWING THE FACIES VARIATIONS WITHIN THE STAIRWAY SANDSTONE



that of the quartz arenites. The grains are however much less well rounded and sorted. The mudstones and claystones are rarely sandy or silty, rarely pyritic and very rarely calcareous (calcitic, dolomitic or sideritic). The clay minerals are predominantly illitic with minor kaolinite and chlorite.

The carbonates are either calcium or magnesium rich (siderite is only known to occur in the claystones) and may contain high percentages of terrigenous quartz in places. The limestones are mainly micrites and biomicrites. The dolomites are generally aphanocrystalline to coarsely crystalline dolomites. In places the dolomite crystals have an extremely well developed rhombic form. The dolomite appears to have replaced the calcite in places.

The phosphorites are varied in form and Cook (1966a, unpubl., and 1968) and described ten distinctive modes of occurrence. The commonest is either as structureless pellets which show no internal structure whatsoever or as sandy pellets in which a high percentage (up to 60%) of detrital quartz grains occurs within the phosphatic pellets. Other modes of occurrence are pellets showing concentric banding; composite pellets which are composed of other smaller pellets; structured pellets which have an irregular (commonly convoluted) internal form; encasing pellets which form a thin skin around detrital (generally quartz) grains; as a cement; as phosphatized fossils; and as secondary phosphate such as corkite (a lead arseno-phosphate).

The Environment of Deposition

The coarseness of the sand grains of the lower unit of the Stairway Sandstone, together with the high degree of rounding and sorting, suggest that these orthoquartzites were deposited either in a vigorous environment or alternatively one in which the rate of sedimentation was so slow that the efficiency of the rounding and sorting mechanism matched the rate of deposition. The first idea is favoured. The bimodality suggests that mixing of sediments from different environments has occurred. The orthoquartzites of the upper unit of the Stairway Sandstone were probably deposited in much the same environment as the lower unit, except that it was much less vigorous. A barrier island or a beach are environments which would produce these types of sandstones, with the body of "blanket sand" being laid down by the coalescing of these elongate sand bodies.

The middle unit of the Stairway Sandstone was probably laid down under conditions of very slow deposition. This is suggested by the presence of phosphorites and by the abundance of chewing by infauna (suggested by Middlemiss, (1962) as an indication of the rate of deposition). In addition the presence of pyrite, organic matter and phosphorites suggests pH conditions within the range 7.0 to 7.8 (Krumbein and Garrells, 1952), and Eh conditions of about -0.2 to 0.4, i.e. strongly reducing, but possibly becoming more oxidizing to the south-east. These conditions are consistent with a poorly aerated lagoonal environment.

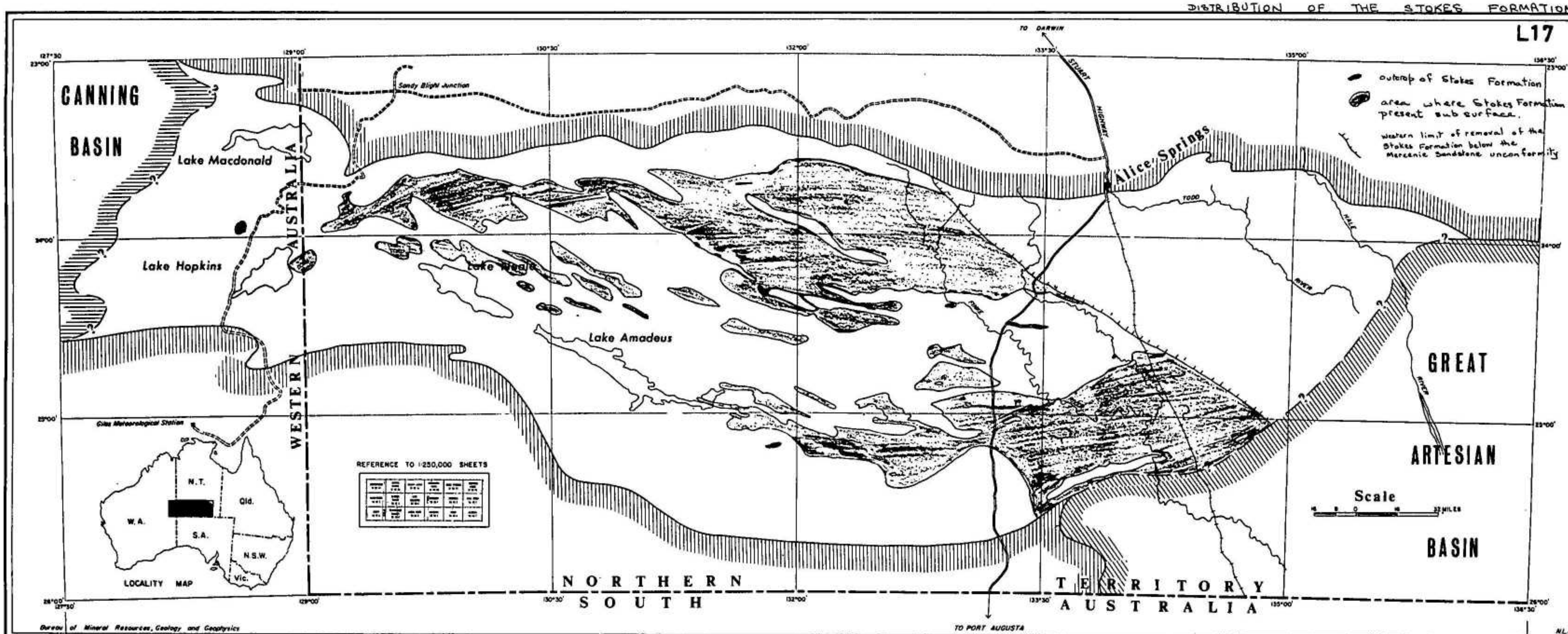
Detailed work on the Stairway Sandstone, using the graphic log approach of Bouma (1962) for the study of depositional environments, suggests either the lagoon-barrier island environment of the Laguna Madre type (Rusnak, 1960), or the inter-tidal flat environment of the Wash type as described by Egans (1965). Both these modern day environments have restricted areal distribution whereas the original area of deposition of the Stairway Sandstone was probably at least 40,000 square miles. Irwin (1965) and Shaw (1964) have suggested a model for epeiric sea sedimentation with a wide, low-energy, open-sea environment, a narrow high energy environment where the open-sea waves impinge on the epeiric sea floor (suggested as a possible depositional environment of the orthoquartzites of the lower and upper units of the Stairway Sandstone) and a wide landward zone of low energy, where there are few currents or large waves with a reducing environment (possibly the depositional environment of the middle unit of the Stairway Sandstone).

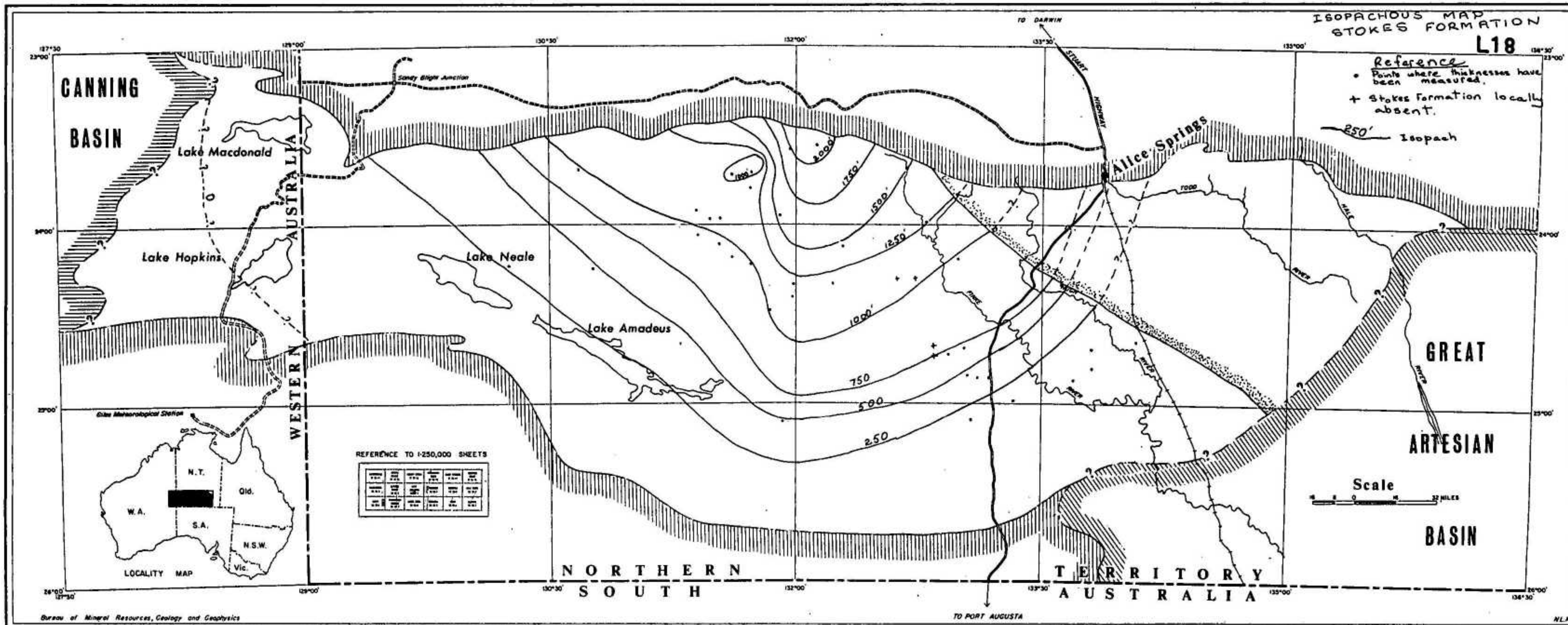
Stokes Siltstone

The name Stokes Siltstone is given to the sequence of grey and green siltstone and claystones with minor thin bedded limestone and a few sandstone interbeds which lies conformably between the Stairway Sandstone below and the Carmichael Sandstone above. The base of the Stokes Siltstone has been selected at the top of the last major sandstone of the Stairway Sandstone. The top of the formation is taken as being at the base of the first prominent sandstone of the Carmichael Sandstone. The type section, where the formation is about 2,000 feet thick, is at Stokes Pass.

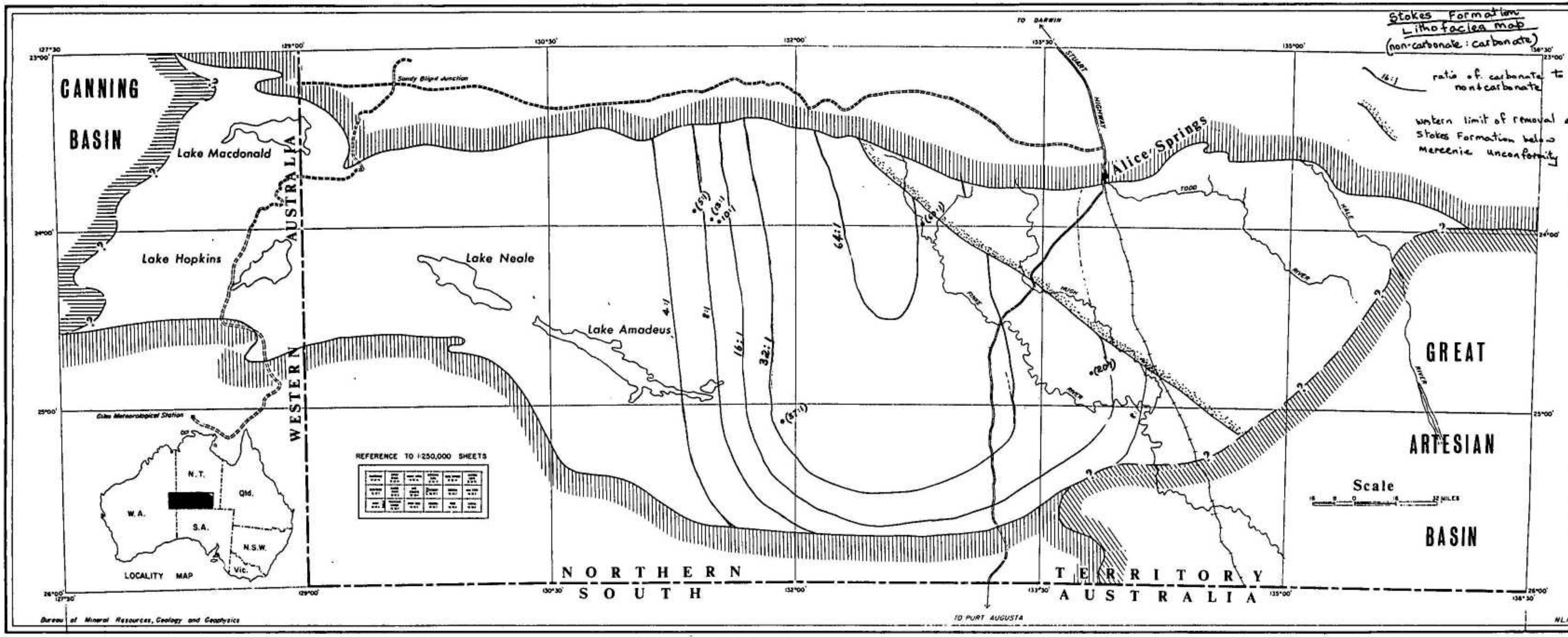
The Stokes Siltstone underlies a considerable portion of the Amadeus Basin (Fig. L17) and is one of the most extensive formations of the Larapinta

DISTRIBUTION OF THE STOKES FORMATION





ISOPACHOUS MAP
STOKES FORMATION
L18
Reference
Points where thicknesses have been measured.
+ Stokes Formation locally absent.
250' Isopach
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
TO DARWIN
STUART HIGHWAY
WESTERN AUSTRALIA
GREAT
ARTESIAN
BASIN
NORTHERN TERRITORY
SOUTH AUSTRALIA
2000'
1900'
1750'
1500'
1250'
1000'
750
500
250
REFERENCE TO 1:250,000 SHEETS
Scale
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
Giles Meteorological Station
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'


Stokes Formation
Lithofacies map
(non-carbonate : carbonate)
16:1
ratio of carbonate to non+carbonate
western limit of removal of Stokes Formation below Mereenie unconformity
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
TO DARWIN
STUART HIGHWAY
TODD
HALE
RIVER
FINKE
RIVER
4:1
8:1
16:1
32:1
64:1
GREAT
ARTESIAN
BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
Scale
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
TO PORT AUGUSTA
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics

Group. It is rarely exposed, and generally forms wide alluvium-covered valleys. The only areas where it is well exposed are in the western MacDonnell Ranges, at the extreme eastern end of Johnny Creek Anticline and on the flanks of the anticlines west of Tempe Downs Homestead.

The Stokes Siltstone overlies the Stairway Sandstone with a conformably and gradational contact, except in the extreme western margin of the Amadeus Basin where it unconformably overlies the Bitter Springs Formation and other Upper Proterozoic units. It is overlain by the Carmichael Sandstone in the western half of the basin, and the contact is both conformable and gradational. To the east it is unconformably overlain by the Mereenie Sandstone.

The formation has a maximum thickness of about 2,000 feet at Stokes Pass but is less than 200 feet thick near the southern margin of the basin (Fig. L18).

Fossils are fairly common, particularly in the limestone, but most of them are in a fragmentary form. They include brachiopods, trilobites, gastropods, pelecypods, echinoderms, nautiloids, conodonts, and some trace fossils. Perhaps the most characteristic fossil of the formation is the brachiopod Orthis leviensis (Fig. L43). The fossils are of Upper Ordovician (Caradocian) age (J.G. Tomlinson, pers. comm.).

Lithology

The Stokes Siltstone is composed primarily of lutites (siltstones and claystones) with minor limestones and a few sandstones.

The lutites are generally green, grey-green or pale brown in outcrop. In places they are micaceous, sandy, or calcareous; they are generally laminate or thin bedded, and easily weathered. One of the notable features of the lutites of the Stokes Siltstone is the abundance of salt clasts (pseudomorphs after halite - see Fig. L44).

The limestones, which are most common in the lower half of the formation, are pink, grey or grey-green in colour, thin bedded, moderately resistant to weathering, and generally composed of a large number of fossil fragments; they can probably be classed as coquinites. As is shown in Fig. L19, the ratio of non-calcareous to calcareous sediments ranges from 4:1 to

64:1, with the highest percentage of limestones tending to occur towards the margin of deposition.

The sandstones generally occur in the upper half of the formation and particularly close to the contact with the Carmichael Sandstone. They are brown, grey-brown, or grey in colour, fine grained, silty, commonly calcareous, thin bedded and poorly exposed.

Petrography

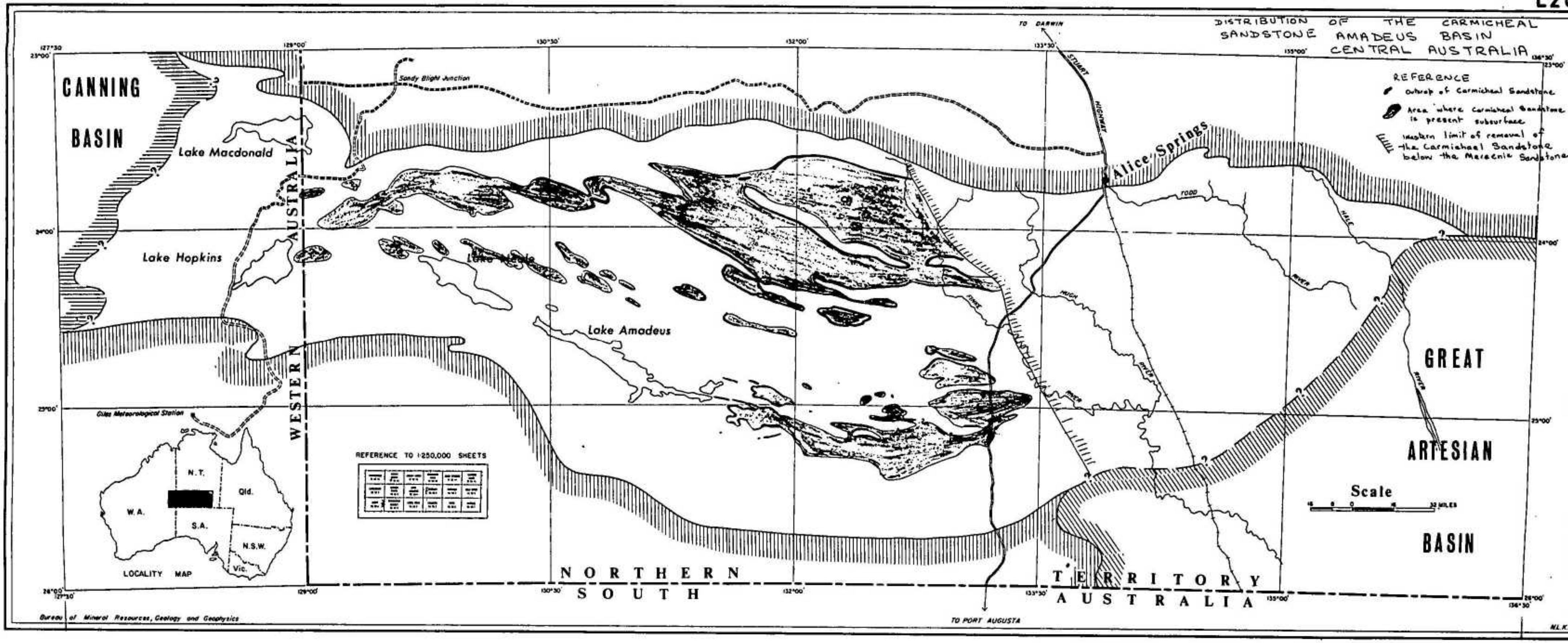
The commonest type of limestone is probably a biomicrite or a biomicrudite, in which the fossil fragments are embedded in a microcrystalline calcite cement. In some cases the cement may be sparry or else there are patches of sparry calcite within a predominantly microcrystalline calcite cement, possibly due to disturbance of the matrix by boring organisms. In some limestones the fossils are predominantly of one phyllum; echinoid-biomicrites are common.

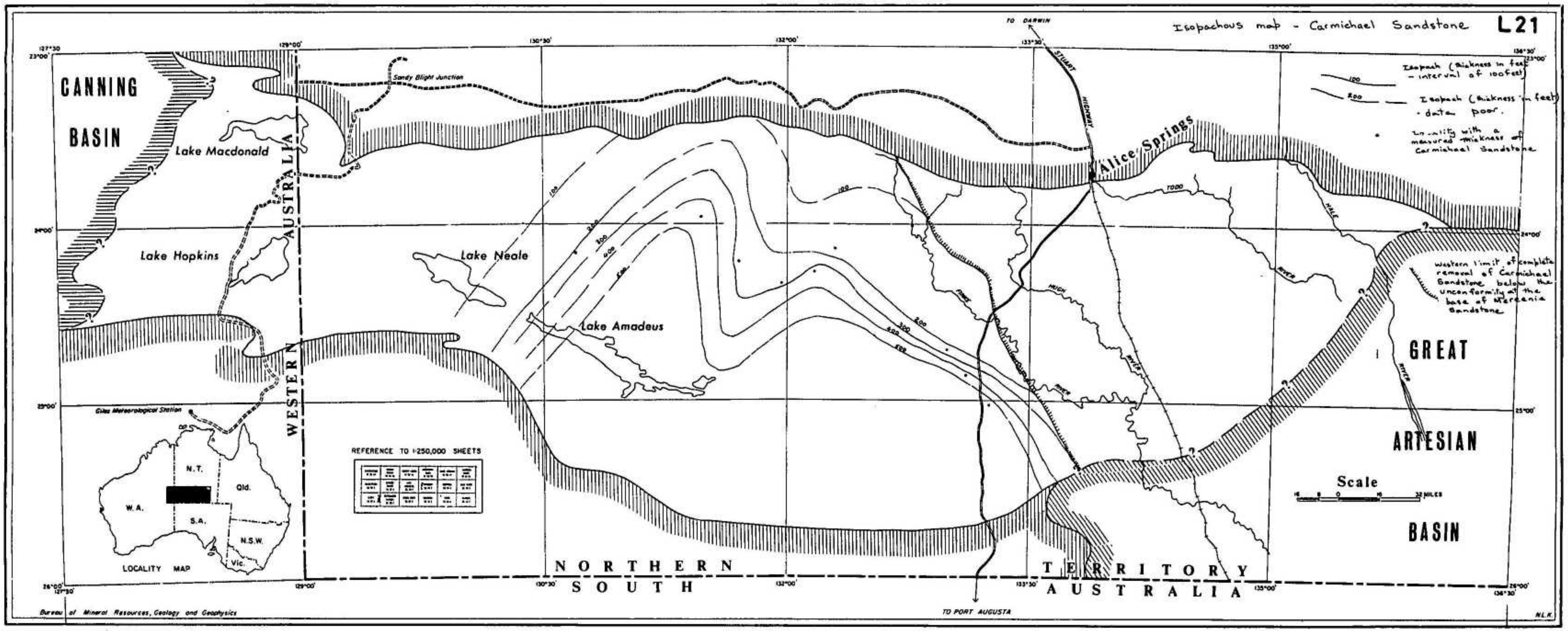
The terrigenous material in the limestones, lutites and arenites is almost entirely fine to very fine grained quartz grains which are moderately rounded and sorted. The quartz is almost entirely non-undulatory with only very minor undulatory quartz and virtually negligible composite quartz. The predominant clay mineral of the lutites is probably illite with minor chlorite.

Environment of Deposition

The predominantly lutaceous character of the sediments suggests that conditions were generally tranquil. The abundance of illite is not environmentally significant (Weaver, 1958).

The pseudomorphs after halite suggest abnormally high salinities, possibly resulting from restriction of circulation by a topographic barrier, followed by evaporation. There is however no evidence of such a topographic barrier in the Amadeus Basin during Stokes Siltstone times. In addition, it is difficult to imagine a lagoon with an areal extent of 60,000 square miles. A second possibility is that the high salinity resulted from the restriction of circulation in an epeiric sea with oceanic currents (and also tides) unable to enter the epeiric sea because it was too broad and too shallow. As a result of these conditions higher salinities developed in the shallow undisturbed sea. Due to their higher density the more saline waters would have


DISTRIBUTION OF THE CARMICHEAL
SANDSTONE AMADEUS BASIN
CENTRAL AUSTRALIA
REFERENCE
Outcrop of Carmichael Sandstone
Area where Carmicheal Sandstone is present subsurface
Western limit of removal of the Carmichael Sandstone below the Mereenie Sandstone
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART HIGHWAY
TO PORT AUGUSTA
GREAT
ARTESIAN
BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
W.A.
N.T.
Qld.
S.A.
N.S.W.
Vic.
Scale
Bureau of Mineral Resources, Geology and Geophysics



Isopachous map - Carmichael Sandstone
L21
Isopach (thickness in feet - interval of 100 feet)
Isopach (thickness in feet) - data poor.
Locality with a measured thickness of Carmichael Sandstone
Western limit of complete removal of Carmichael Sandstone below the unconformity at the base of Mereenia Sandstone
CANNING BASIN
GREAT ARTESIAN BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
TO PORT AUGUSTA
STUART HIGHWAY
TODD
HALE RIVER
HUGH RIVER
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.

sunk giving super-salinity in the bottom waters, so that large halite crystals were able to form at the sediment-water interface or perhaps just below the interface.

Carmichael Sandstone

The name Carmichael Sandstone is given to the sequence of brown and red-brown cross-bedded sandstone, and silty sandstone with interbedded red-brown siltstone and claystone, which conformably overlies the Stokes Siltstone and is unconformably overlain by the Mereenie Sandstone. The base of the Carmichael Sandstone is at the base of the first major sandstone. The top of the formation is at the change from silty poorly sorted sandstone and siltstone to the clean well-sorted sandstones of the Mereenie Sandstone. The type section, where the formation is about 300 feet thick, is situated 1 mile south of Langs Well on the north side of the George Gill Range (section LAC1, Ranford, et. al., 1966). The name is derived from Carmichael Crag, a very prominent crag at the western end of the George Gill Range, about 8 miles west of the type section. The lower slopes of Carmichael Crag are composed of Carmichael Sandstone.

The Carmichael Sandstone is the least known formation of the Larapinta Group though it crops out sporadically over a large area of the Amadeus Basin (Fig. L21). Its western limits are uncertain but it is thought to have an extent somewhat similar to that of the Trickett Formation. To the south it may be the most extensive of the units of the Larapinta Group (see Fig. L1). To the east, the formation was removed by the post-Rodingan Movement erosion.

The Carmichael Sandstone is poorly exposed in most places. It commonly underlies the steep scree-covered slopes below the Mereenie Sandstone scarp and is only exposed in the creek beds cutting through the scree.

Within the Amadeus Basin, the Carmichael Sandstone overlies the Stokes Siltstone with a conformable and gradational contact. It is everywhere overlain by the Mereenie Sandstone, with a very low angle regional unconformity.

Isopachous data on the Carmichael Sandstone is incomplete at the present time. Fig. L21 suggests that the formations thicken to the south, the thickness ranging from less than 100 feet in the western MacDonnell Ranges to about 500 feet near the southern margin of the basin. It is not known whether this pattern, which is contrary to that shown by all other formations of the Larapinta Group, is a function of the depositional thickness or is merely the thickness which remained after the post-Rodingan Movement erosion. The fact that the Carmichael Formation becomes coarser and more pebbly to the south suggests the former.

Fossils are rare; trace fossils and Cruziana suggest that the formation is Ordovician (late Caradocian or Ashgillian).

Lithology

The Carmichael Sandstone is composed mainly of red-brown, yellow, purple-brown and pale brown sandstone and silty sandstone. They are moderately to poorly sorted and rounded, becoming more poorly sorted and pebbly in the south. The sandstones are thin to thickly bedded, cross-bedded and ripple marked in places. Mud crack and halite pseudomorphs occur in the formation (in both the silty sandstones and the siltstones).

Interbeds of siltstone and claystone are common throughout the formation - they are red-brown or green in outcrop, micaceous in part, thinly bedded or laminate and poorly exposed.

Petrography

The arenites are generally immature or sub-mature orthoquartzites ranging from very fine to medium grained. Non-undulatory quartz predominates over undulatory quartz and there is only minor composite quartz and very minor metaquartzite and chert grains. Feldspar is present but rarely forms more than 2 - 3% of the total. ?Limonitic cement is common in many of the arenites; ?kaolinitic cements are also fairly common.

The lutites are siltstones and claystones with kaolinite the predominant clay mineral.

The Environment of Deposition

The presence of Cruziana indicate a shallow-water marine environment. The abundant ripple-marks and cross-beds suggest that the water was very shallow and the presence of the halite pseudomorphs implies that in addition the environment was probably highly saline. The immature nature of some of the arenites suggests the environment was insufficiently vigorous for the sorting and rounding of the sediments to keep pace with the rate of deposition such as is commonly the case in a low energy estuarine or deltaic environment. The presence of kaolinite also indicates the influence of continental conditions (Weaver, 1958).

Therefore the sediments of the Carmichael Sandstone show both shallow water marine and continental characteristics. The most likely deposition environment where such a mixing will occur is in an estuarine or deltaic environment in a very shallow sea with periods of high salinity. The marine deltaic environment is supported by thickening of the formation toward the source area, and by the abundance of limonitic cement.

GEOLOGICAL HISTORY OF THE LARAPINTA GROUP

Palaeoclimate

The abundance of super-mature orthoquartzites and the almost complete absence of feldspar in the arenites of the Larapinta Group suggest severe tropical weathering. Alternatively, less severe weathering of a predominantly sedimentary source area could also produce super-mature orthoquartzites. The palaeolatitude data of Irving (1964) suggests that during the Ordovician, the Amadeus Basin may have been nearer to about 15°N, so that a gradual drift north may have occurred during Larapinta Group times. This suggests that during this time the climate may have gradually become more arid. The clay mineralogy of the Larapinta Group would also support this conclusion as kaolinite (which is common in the lower half of the Larapinta Group) is abundant in the soils of humid areas (Jackson, 1959) whilst illite (which is common in the upper half of the Larapinta Group) is abundant in the soils of arid desert areas. Phosphorites are also most commonly found within the present day trade-wind belt, an area where the climate is generally arid. In addition, the presence of pseudomorphs after halite is also evidence of a fairly arid climate during Stokes Siltstone and Carmichael Sandstone times. Therefore, the Larapinta Group times opened with a humid tropical climate, gradually the climate became less humid until in the upper part of Larapinta Group times the climate was probably semi-desert or desert.

Provenance

It is apparent from the well rounded but poorly sorted sand grains in arenites, reworked sand grains (with abraded overgrowths) and chert grains, that the provenance of the Larapinta Group was at least in part sedimentary. In particular the N'Dahla Member of the Pacoota Sandstone and the upper part of the Stairway Sandstone show evidence of reworking of sedimentary rocks.

Blatt (1963, 1964) and Blatt and Christie (1963) have shown that an abundance of non-undulatory quartz in arenites is an indication of a predominantly sedimentary provenance. Therefore in Pacoota Sandstone times the provenance was probably mixed sedimentary-igneous with sedimentary rocks in the majority. By upper Stairway, Stokes and Carmichael times, there was a high proportion of non-undulatory quartz suggesting that the source area was almost entirely composed of sedimentary rocks. This is supported by the heavy mineral assemblage of the Stairway Sandstone - predominantly very well rounded grains of tourmaline and zircon but with a few euhedral grains (the euhedral form of the grains is not due to authigenic overgrowths on detrital grains). The implications of this are that the rounded grains are recycled detrital grains derived from sedimentary rocks (probably predominantly arenites) whilst the few euhedral grains are derived from a plutonic source area, which from the small number of euhedral grains, obviously constitutes a very minor provenance.

Therefore it seems that in the early part of Larapinta Group times the provenance was mixed sedimentary-igneous and gradually the contribution from the igneous source area became less until by the upper part of Larapinta Group times the provenance was almost entirely sedimentary. The most likely reason for this gradual change of provenance is that although the igneous source area was distant large tropical rivers were able to transport the detritus into the basin. As the climate became more arid the rivers became smaller and slower and detritus from distant sources was no longer able to reach the area and probably most of the sediments were derived from nearby sandstones (such as those of the Winnall Beds). Towards the close of Larapinta Group sedimentation (Carmichael Sandstone times) the climate may have once again become wetter, so that a larger river may have flowed into the area, bringing in detritus from a more distance source.

Palaeogeography

Larapinta Group times opened with currents flowing mainly from the east as is shown in Fig. L5. Williams et. al. (1965) suggest that there is divergence around some of the anticlines, such as the Waterhouse Range Anticline. They conclude from this that the anticlines were growing, and formed topographic highs during Pacoota Sandstone times. There is also a marked decrease in the maximum size of pebbles in the Pacoota Sandstone from west to east, suggesting the main source area lay to the west.

There is no palaeocurrent information available for the Horn Valley Siltstone but it is apparent that between the close of Pacoota Sandstone sedimentation and the commencement of Stairway Sandstone sedimentation there was a major change in the palaeogeography. During Stairway Sandstone times the predominant current direction was from south-east to north-west. This together with the distribution of lithologies suggests that the main source area lay to the south east. There is no palaeocurrent data available for the Stokes Siltstone or the Carmichael Sandstone, although the Carmichael Sandstone becomes coarser to the south, suggesting that the main source area lay to the south.

Little is known of the topography of the land area on the margin of the basin, but it is thought that at the opening of Larapinta Group times there was notable elevation, particularly in the areas of Upper Proterozoic sediments (see Fig. L3). It can be seen in Fig. L1 how closely the boundary of the southern margin of the Pacoota Sandstone, the Horn Valley and the lower and middle parts of the Stairway Sandstone follow the Cambrian - Upper Proterozoic palaeogeologic boundary. It is considered that the reason for this is that the Upper Proterozoic sediments formed a topographic high throughout much of the Lower Palaeozoic. The development of the Mount Charlotte Embayment (Cook, 1966a), probably followed the erosion of the area of the Jay Creek Limestone - a readily eroded carbonate-lutite facies of the Pertaoorrta Group (the area of the Mount Charlotte embayment corresponds precisely with the area of pre-Larapinta Group outcrop of the Jay Creek Limestone shown in Fig. L3). By the opening of Upper Stairway Sandstone times the hinterland had been peneplained and there was little or no relief (see Fig. L23).

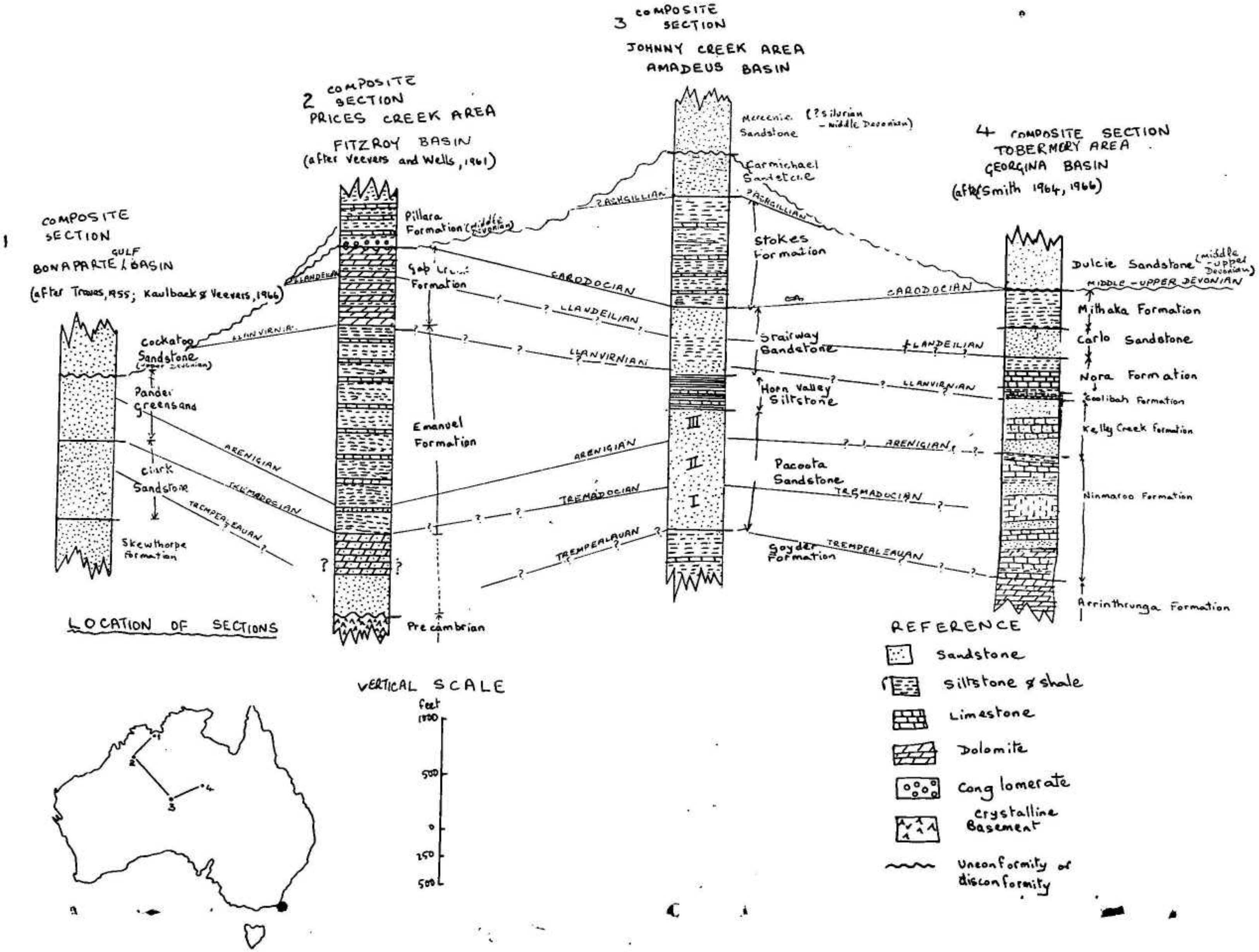
The actual form of the Amadeus Basin throughout Larapinta Group times is shown in a series of diagrams (Fig. L24 to L.31) and it is apparent from these that the Amadeus Basin constituted a small, probably marginal portion of a very much larger depositional basin. During the late Cambrian (Pacoota I times) the Amadeus Basin was part of a broad shallow embayment which opened to the east (Fig. L24). In the Tremadocian and early Arenigian (Pacoota II and III times) the embayment expanded with major embayment developments to the west (Fig. L.25). By Horn Valley Siltstone times (Arenigian) strong connections had been established to the west with probably a deep trough connecting for instance the Amadeus Basin with the Fitzroy Basin (Fig. L.26). Well developed connections still existed with the open sea to the east. In lower Stairway Sandstone times (Arenigian-Llanvirnian), a minor embayment formed in the south-east part of the basin due to the erosion of Pertaoorrta Group carbonates and the connection to the east became slightly restricted by the development of a small peninsula (Fig. L.27). This peninsula continued to develop until it formed a major feature by middle Stairway Sandstone times and severely restricted any link with the open sea to the east. The main link with the open sea now lay to the west (Fig. L.28).

A change in the palaeogeography of the area occurred at the opening of upper Stairway Sandstone times (Llandeilian) with a major expansion of the Ordovician sea. The sea now transgressed over the peneplained hinterland and broad open connections were once more established with the open sea both to the east and the west (Fig. L.29).

The transgressing of the Ordovician sea continued into Stokes Siltstone times (Carodocian) so that the Amadeus Basin lay well within the broad shallow embayment, the nearest margin lying some distance to the south (Fig. L.30). The palaeogeography during the deposition of the Carmichael Sandstone is uncertain due to the lack of diagnostic fossils and also because a considerable area of Carmichael Sandstone was removed in the east during the post-Rodingan Movement erosion. It is considered that the Carmichael Sandstone may be the time equivalent of the Tandalgoo Red-beds and the Carribuddy Formation in the Sahara No. 1 Well in Western Australia. This suggests that following Stokes Siltstone sedimentation the connection to the open sea closed once more in the west and now lay to the east (Fig. L.31).

In the Amadeus Basin area the Carmichael Sandstone seas were probably initially as extensive as those of Stokes Siltstone times although in other areas (particularly in the west and possibly the north) some regression occurred.

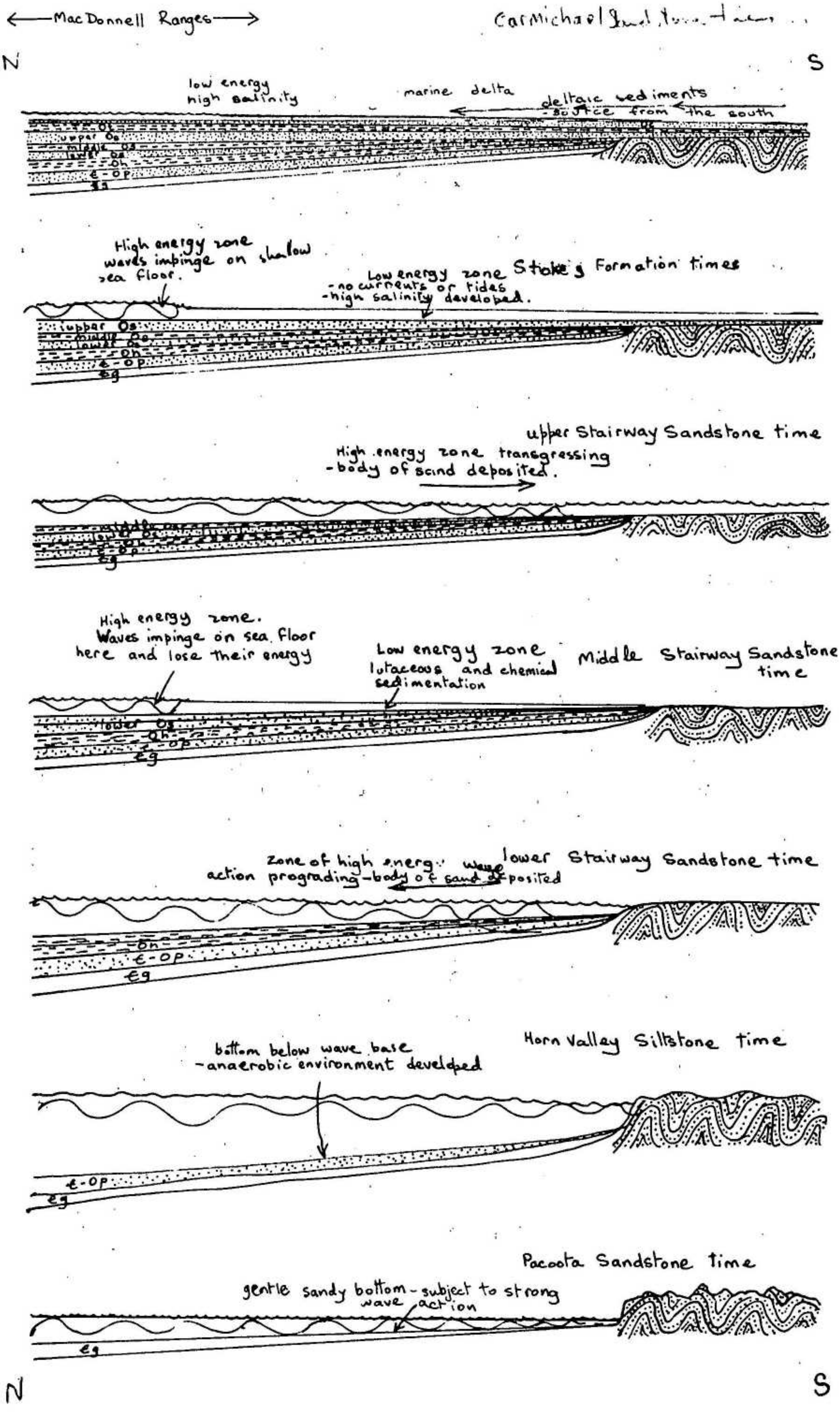
POSSIBLE TIME CORRELATIONS BETWEEN THE LARAPINTA GROUP AND THE CAMBRO-ORDOVICIAN OF OTHER CENTRAL & WESTERN PARTS OF AUSTRALIA



L23

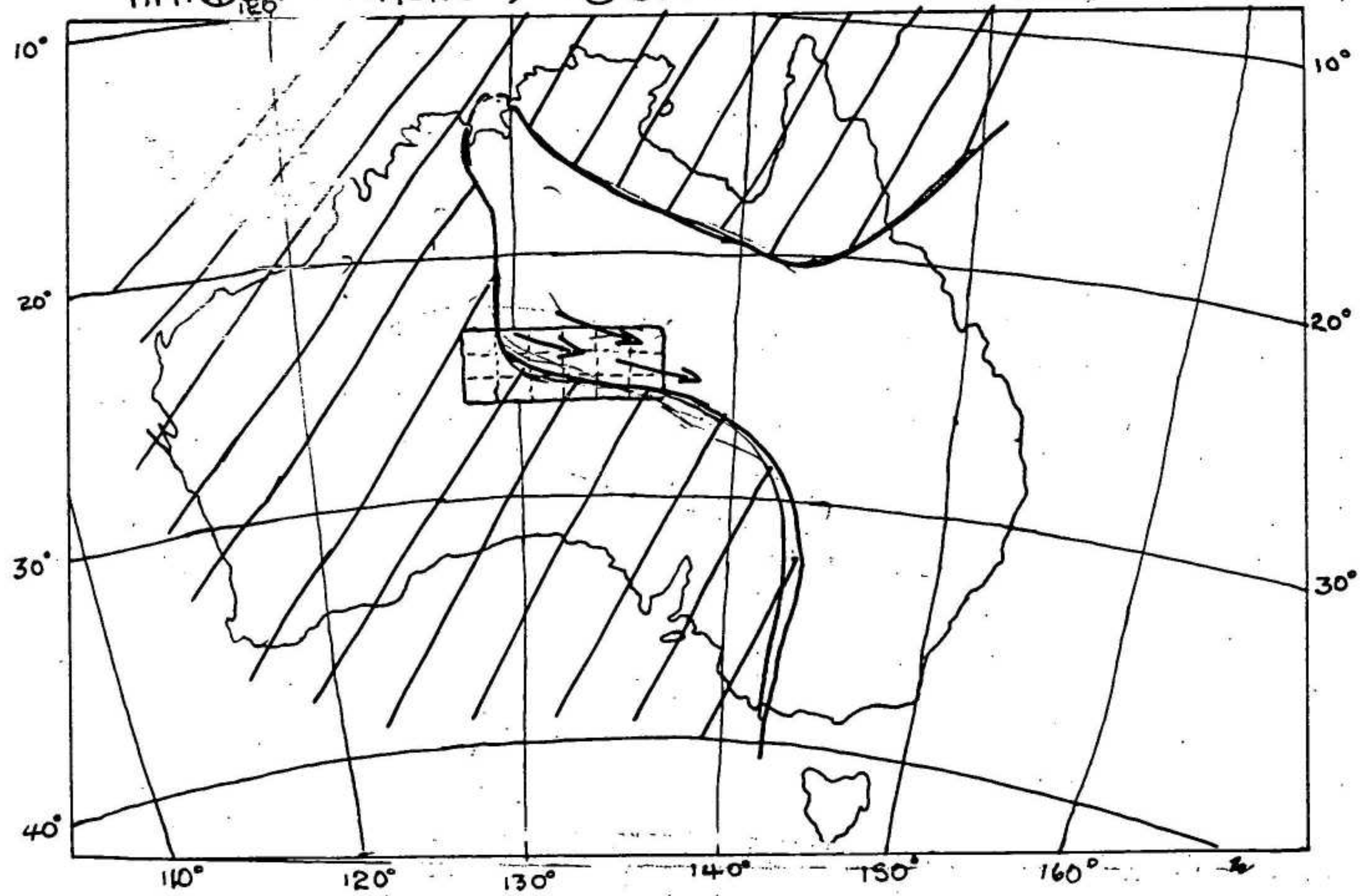
THE DEVELOPMENT OF LARAPINTA GROUP SEDIMENTATION

(diagrammatic sections across the Amadeus Basin)



L 24.

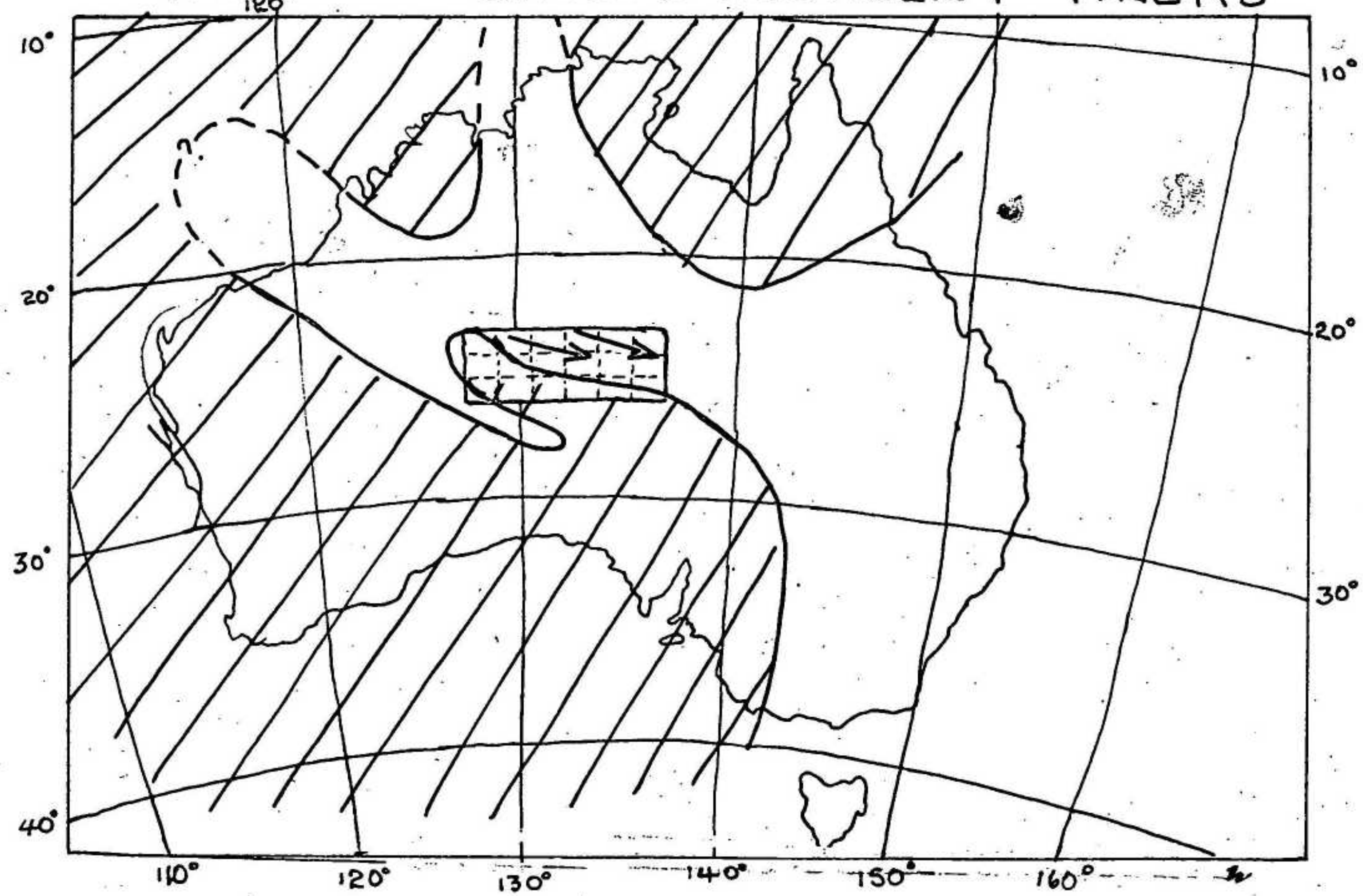
PALAEOGEOGRAPHIC MAP (Pacoota Sandstone I times - Trempealeauvan)
AMADEUS BASIN & ADJACENT AREAS



L25.

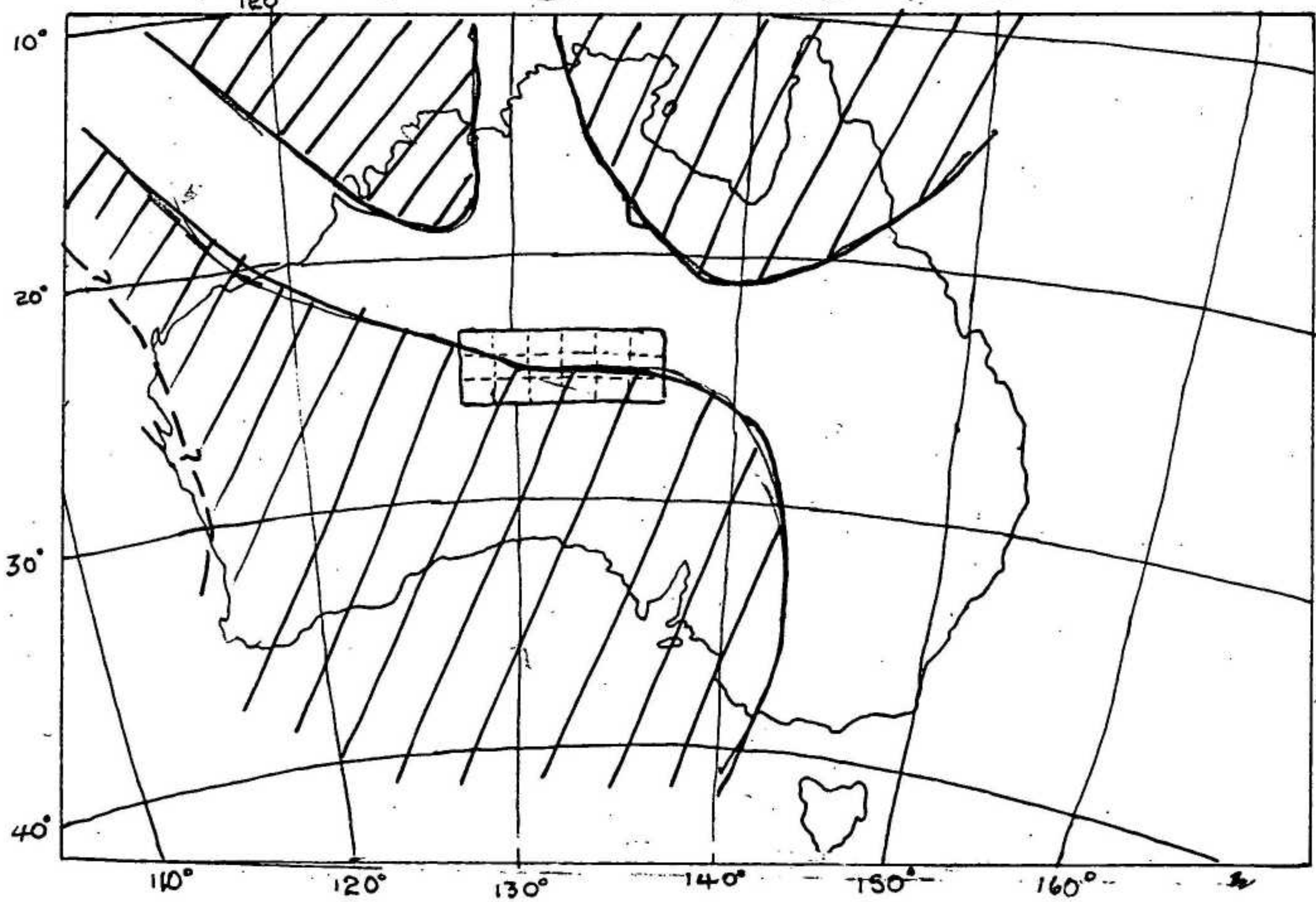
Pacoota Sandstone II & III times : Tremadocian - Arenigian)

PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



Horn Valley Siltstone Times & (Arenigian)

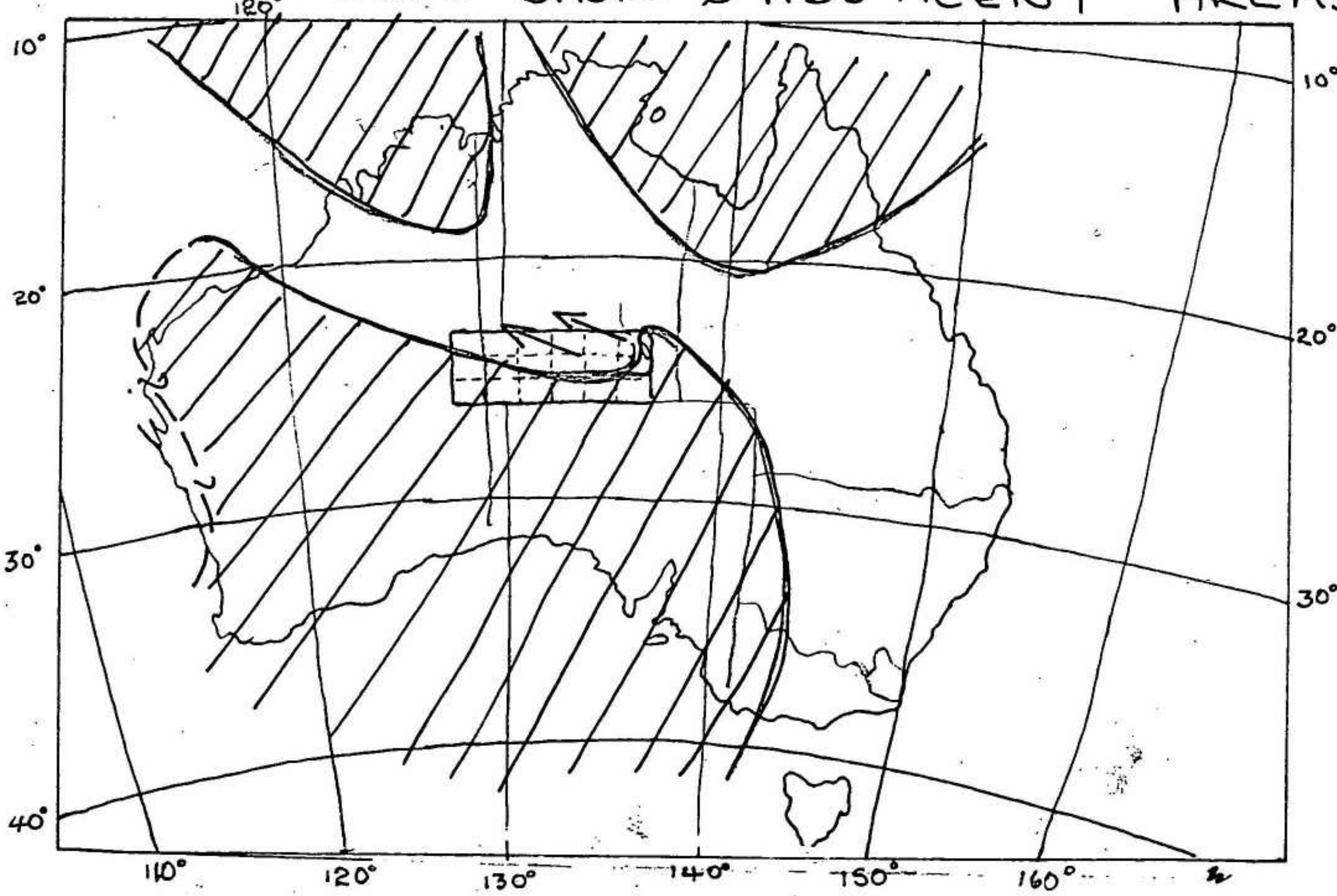
PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



L 27.

Lower Stairway Sandstone times (Arenigian - Llanvirnian)

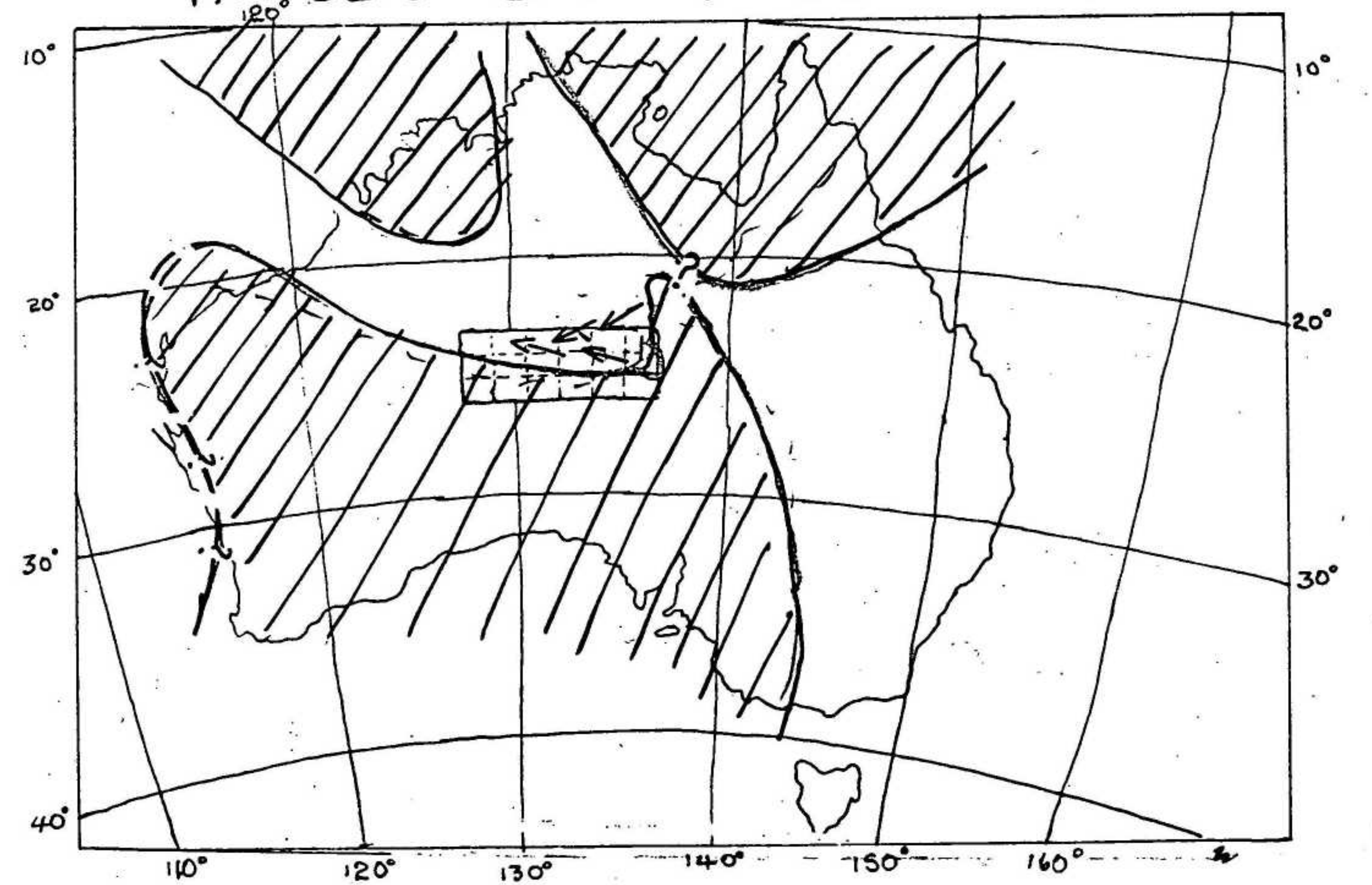
PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



L 28.

Middle Stairway times (Arenigian - Llanvirnian)

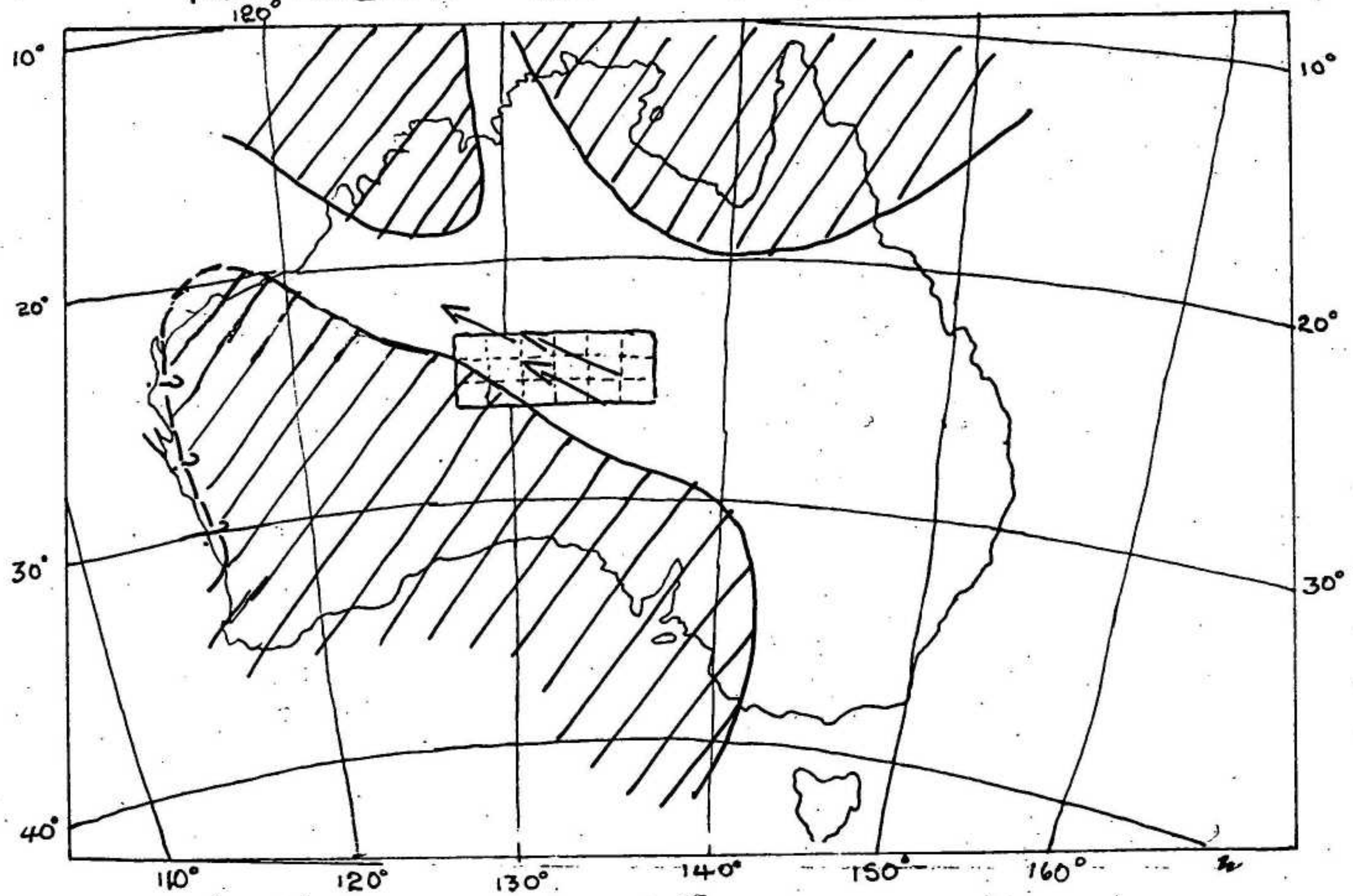
PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



L 29.

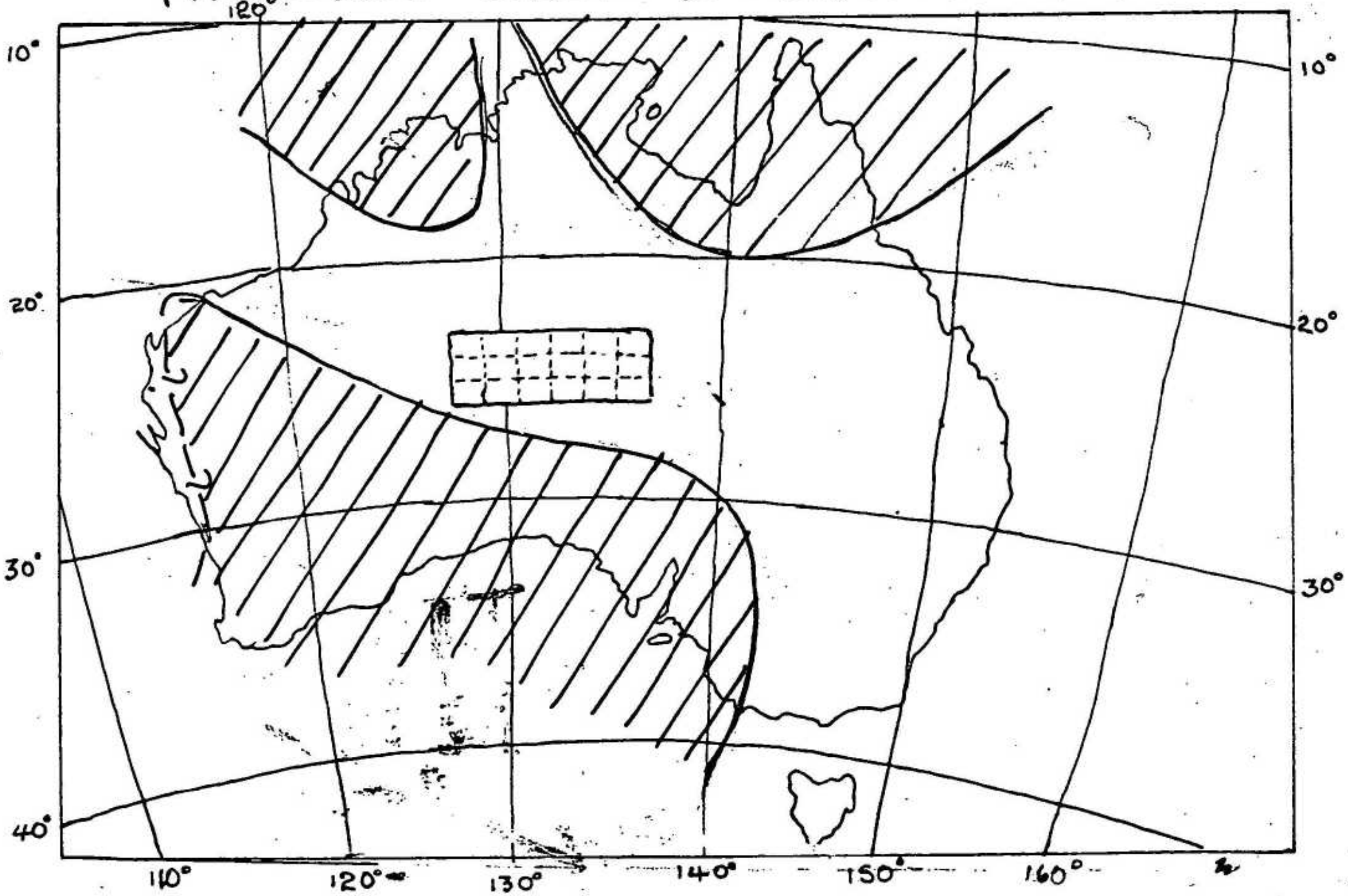
Upper Stairway Sandstone times (Llandeilian)

PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



Stokes Siltstone times (Carodocian) L 30.

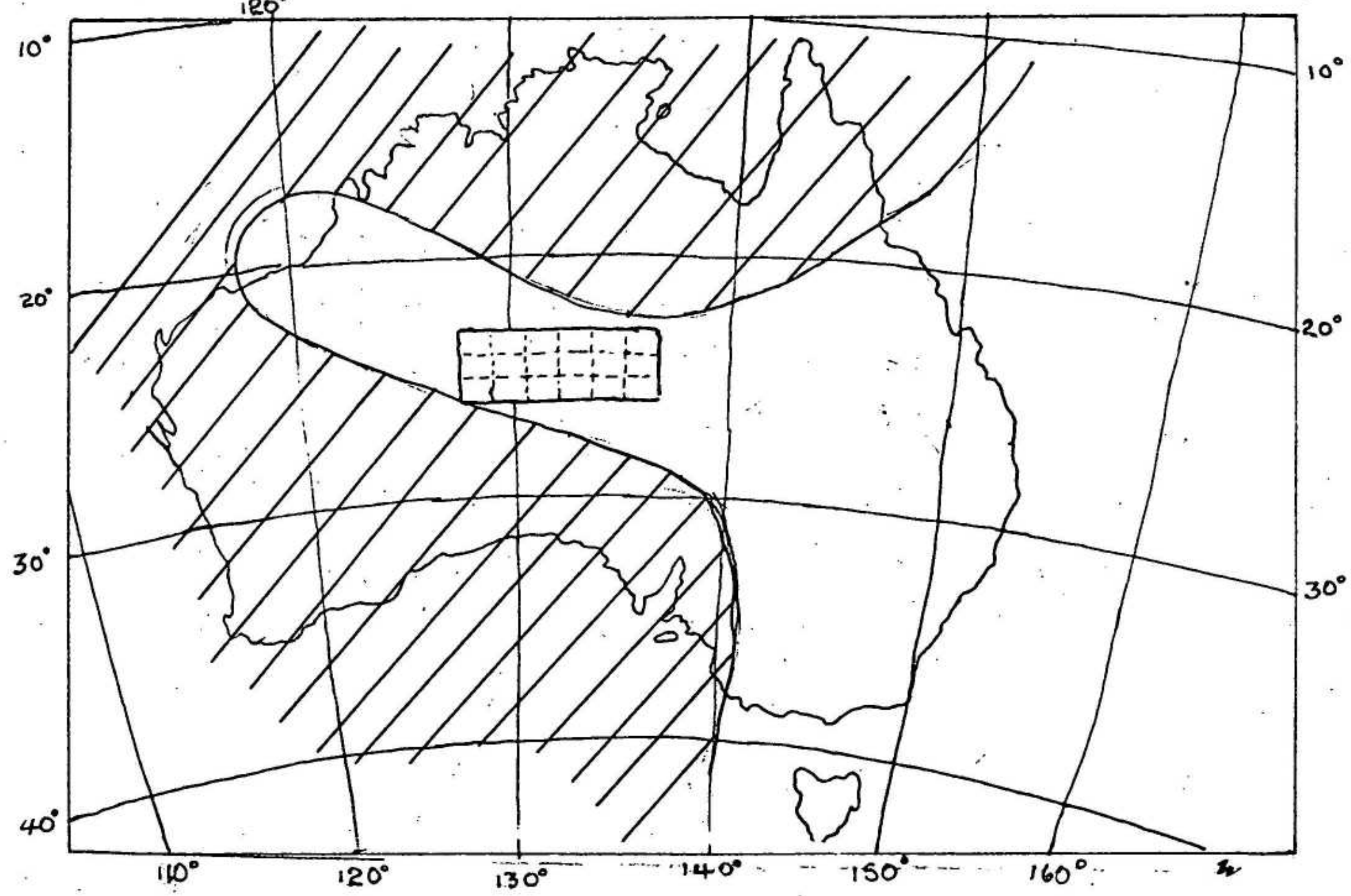
PALAEOGEOGRAPHIC MAP
AMADEUS BASIN & ADJACENT AREAS



CARMICHAEL SANDSTONE TIMES (?Ashgillian)

PALAEOGEOGRAPHIC MAP L31.

AMADEUS BASIN & ADJACENT AREAS



L 32.

LITHOLOGY	PRE-EXISTING NOMENCLATURE				NEW NOMENCLATURE	
	Prichard & Quinlan (1962)		Wells, Forman & Ranford (1965,b)			
well sorted sandstone	Mereenie sandstone (Pzm)		upper unit Mereenie sandstone (Pzm (2))		Mereenie Sandstone (Pzm)	
silty sandstone	Stokes Formation (Ot)	Larapinta Group	lower unit Mereenie Sandstone (Pzm (1))		Carmichael Sandstone (Oc)	Larapinta Group
siltstone claystone & limestone			Stokes Formation (Ot)	Larapinta Group	Stokes Siltstone (Ot)	
well sorted sandstone	Stairway Greywacke		? Stairway Sandstone		Stairway Sandstone	
	Horn Valley Siltstone		Horn Valley Siltstone		Horn Valley Siltst	
	Pacoota Sandstone		Pacoota Sandstone		Pacoota Sandstone	

Previous concepts of the Larapinta Group and the new nomenclature

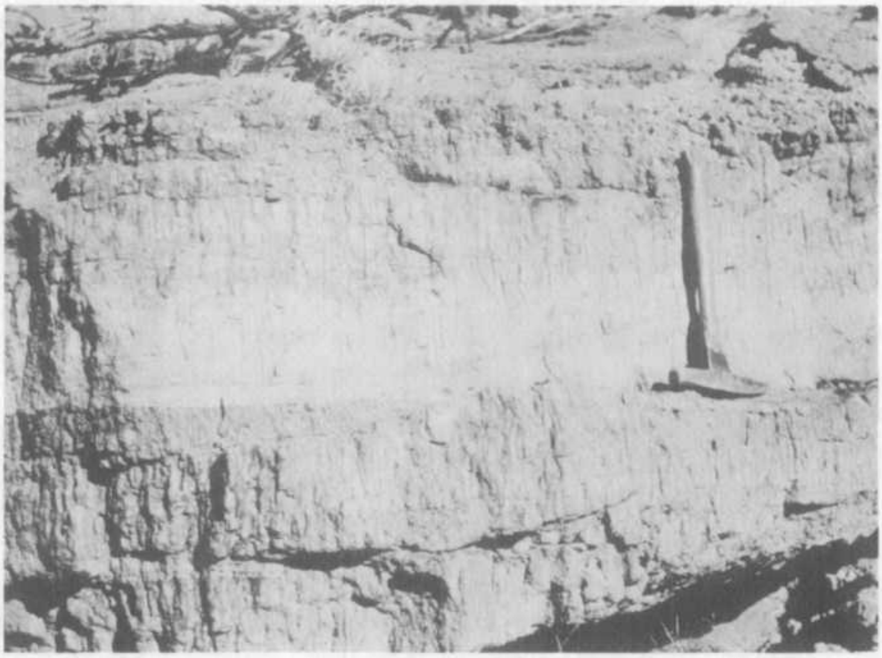


Fig. L.33 Close-up of typical "pipe-rock" in the Pacoota Sandstone.
G/4325

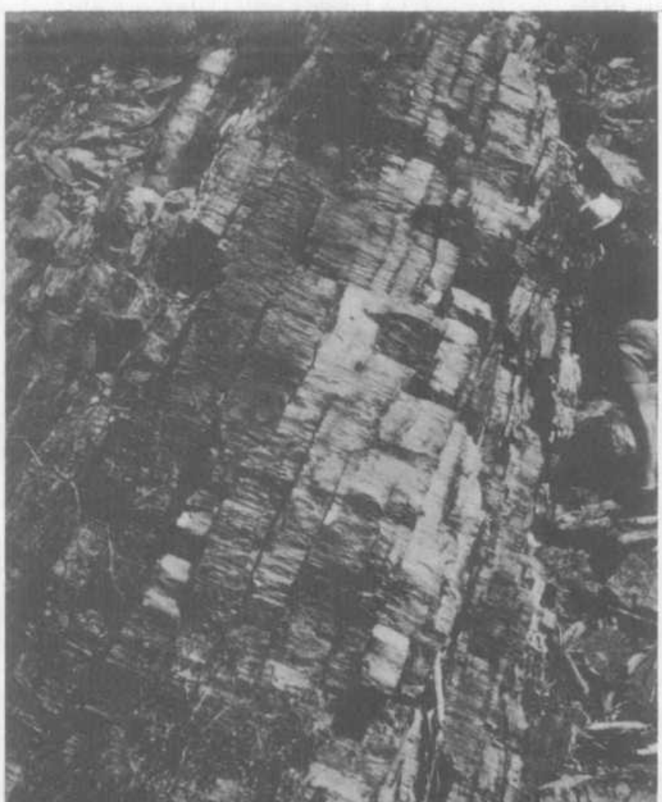


Fig. L.34 Pipe rock in the Pacoota Sandstone at Ellery Creek.

G/9143

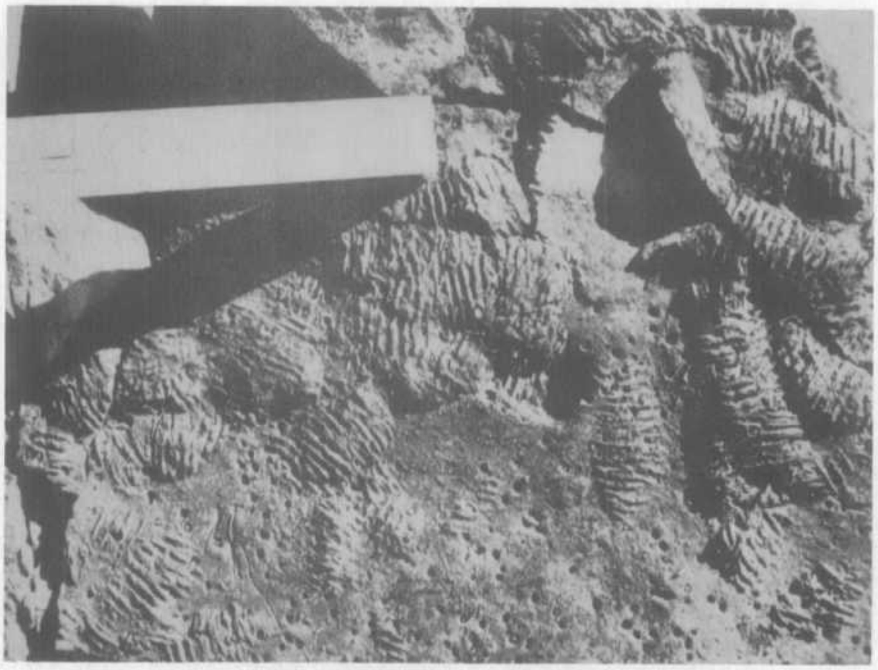


Fig. L.35 Pacoota Sandstone at Ellery Creek. Cruziana on a bedding plane. Transverse sections through Scolithus also visible. (Photography by K.A.W. Crook).
GA/22

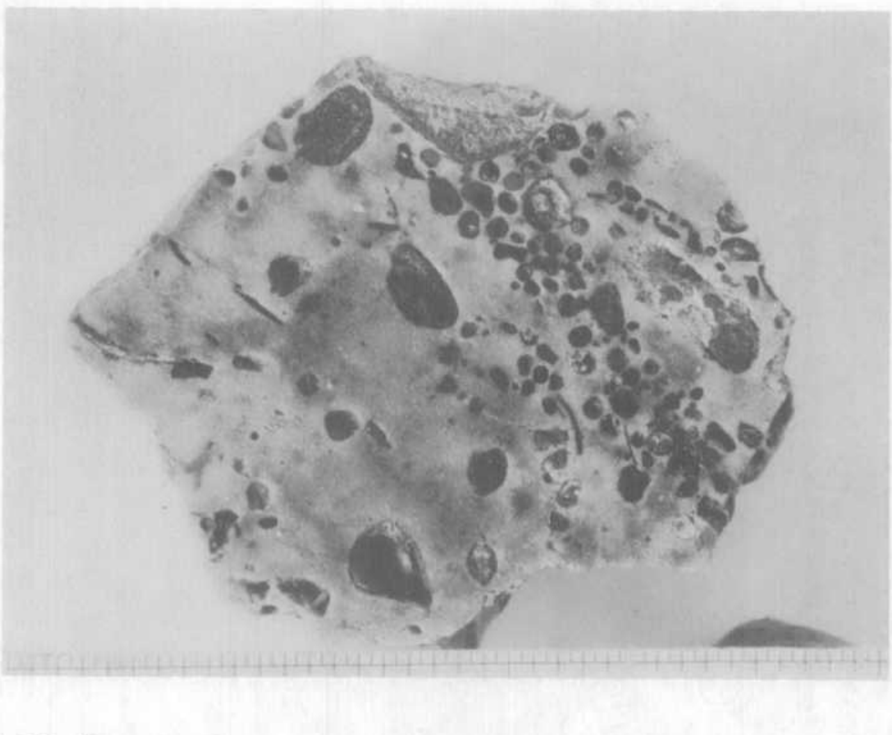


Fig. L.36 Pacoota Sandstone, south of the George Gill Range. Sandstone (orthoquartzite) containing vugs filled with limonite. (Photography by C. Zawartko).
G/9070

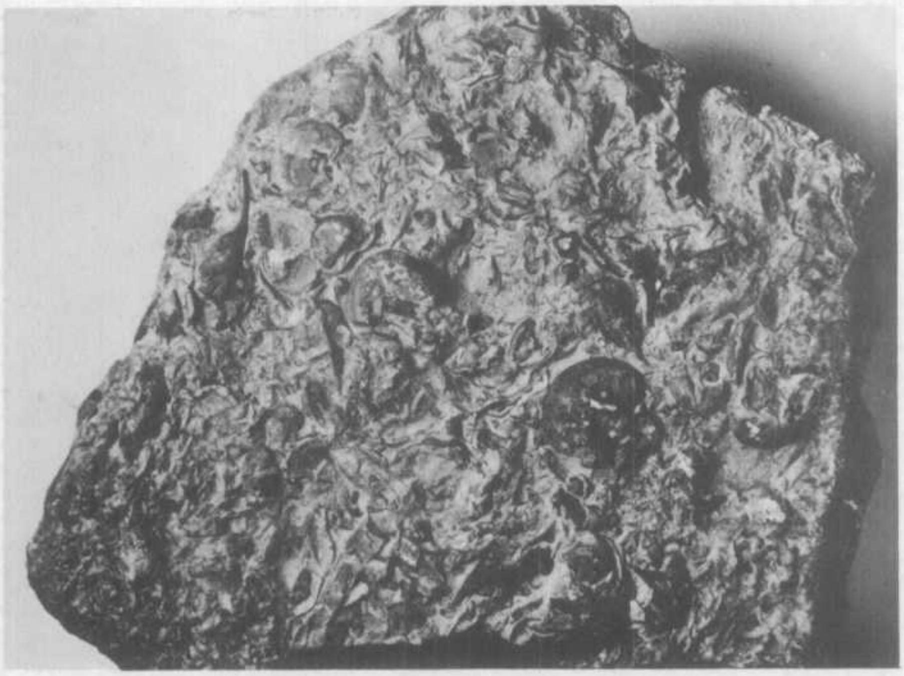


Fig. L.37A Richly fossiliferous limestone of the Horn Valley Siltstone; Carolinites and asaphid trilobites (J.G. Tomlinson, pers. comm.) are present. Photograph by C. Zawartko.
G/9216

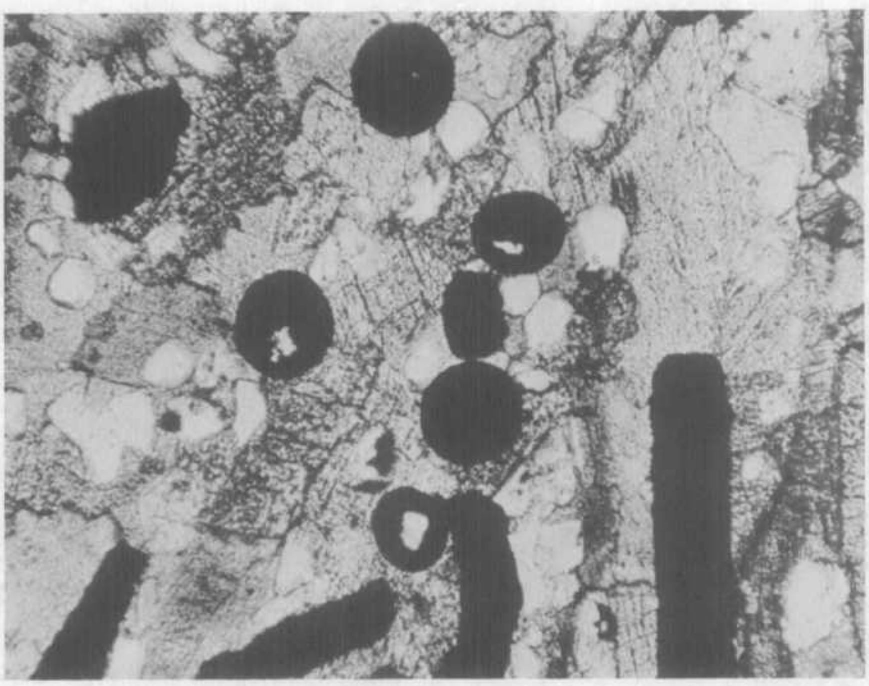


Fig. L.37B Sandy limestone with ooliths of pyrite in Horn Valley Siltstone, diamond drill Hole API, depth 700 feet.
M422/14

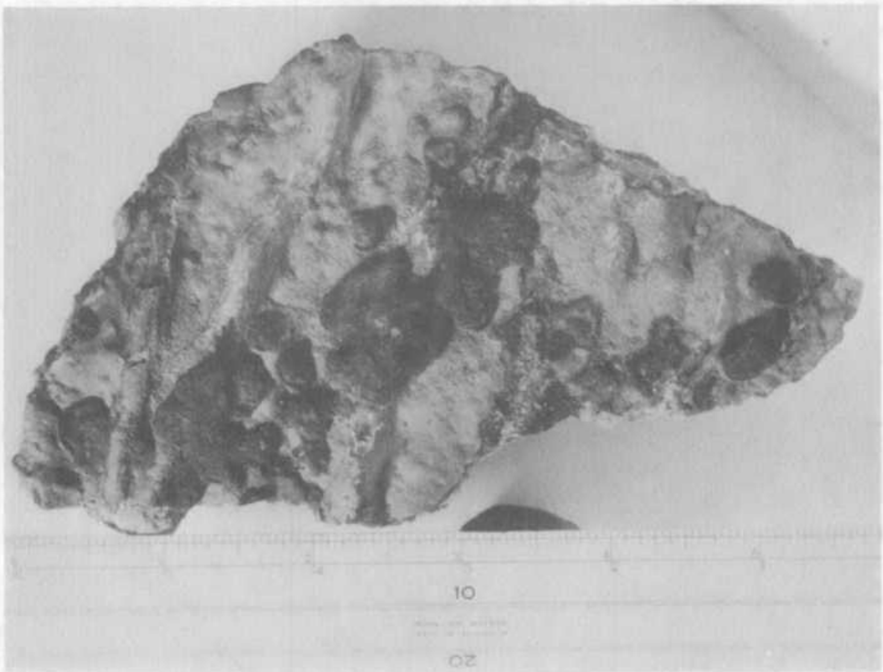


Fig. L.38 Manganese nodules on the unconformity surface at the base of the Stairway Sandstone. Mount Sunday Range. (Photography by C. Zawartko).
G/9071

Fig. L.39 Stairway Sandstone. Phosphorite nodules in a basal conglomerate. Mount Sunday Range. (Photograph by C. Zawartko).
G/9076

Fig. L.40A Typical "ropey" texture in the lower unit of the Pacoota Sandstone, due to the weathering out of abundant fossil tracks and trails.
G/4333

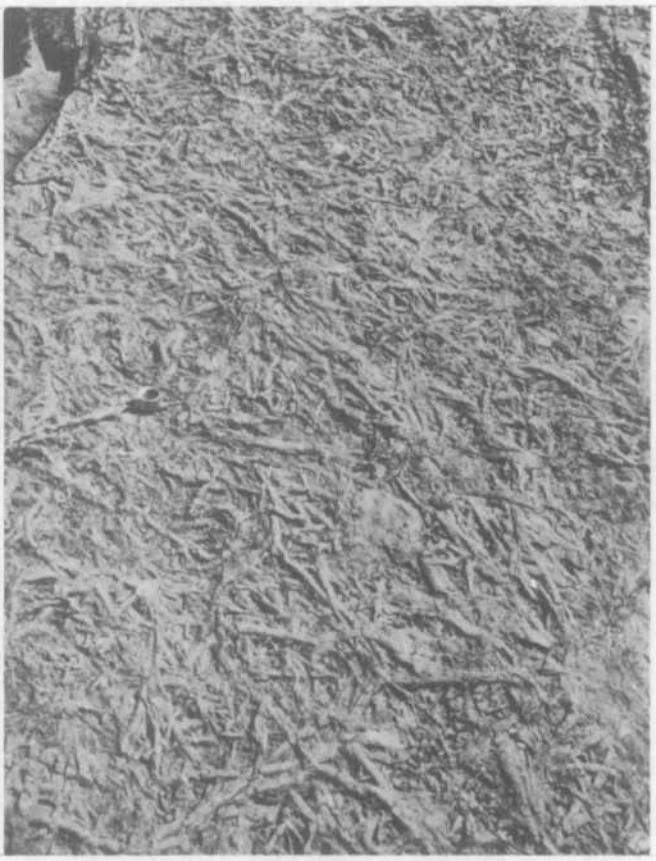


Fig. L.40B Mosaic of invertebrate tracks, Stairway Sandstone, Basedow Range, west of Mount Ebenezer homestead.
G/9146

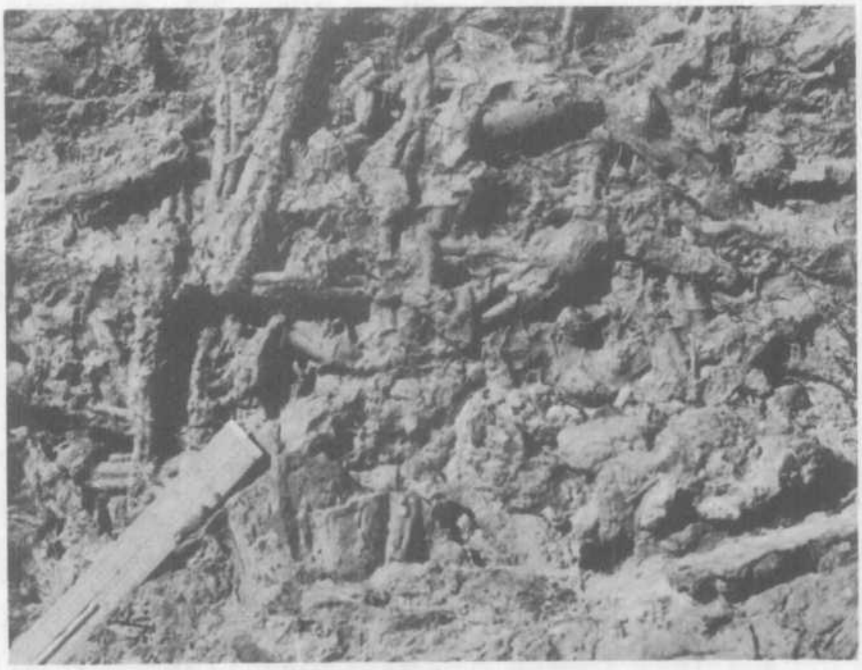


Fig. L.41 "Ropey" textured sandstone in the lower unit of the Stairway Sandstone.
M420/36

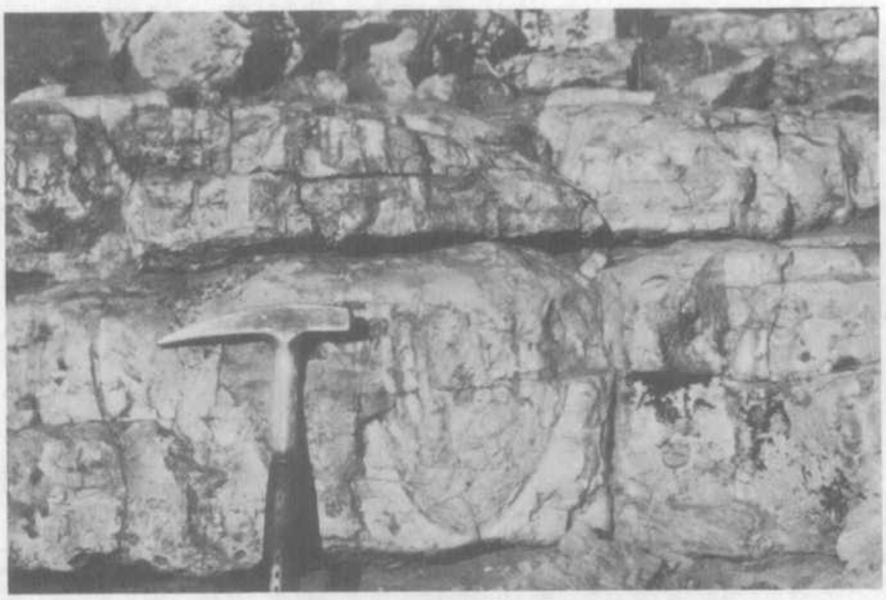


Fig. L.42 Diplocraterion in the Stairway Sandstone.
G/6298

Fig. L43 Orthis leviensis in limestone of the Stokes Siltstone. (Photograph by C. Zawartko).
G/9214

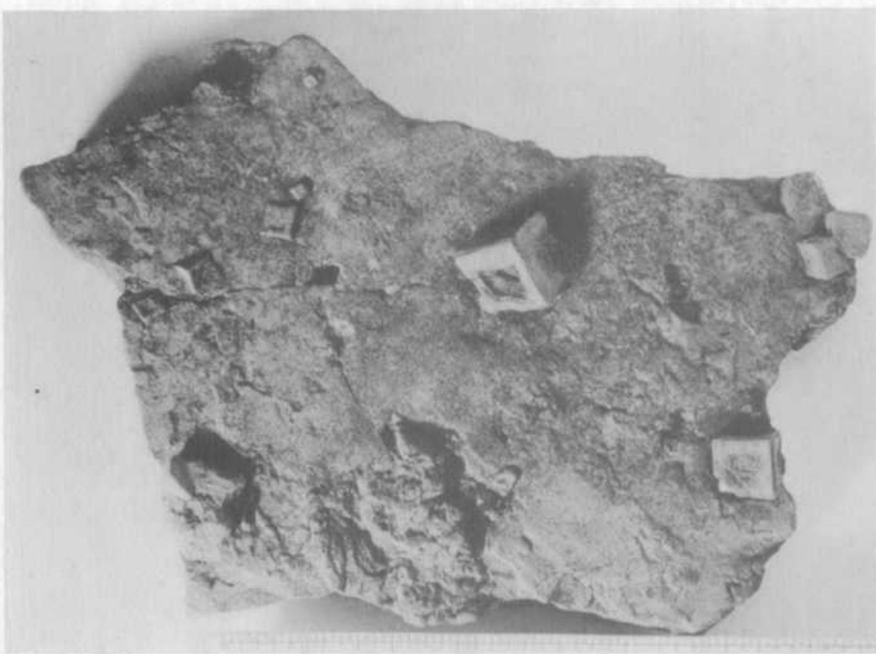


Fig. L.44 Halite pseudomorphs in the Stokes Siltstone. (Photography by C. Zawartko).
G/9077

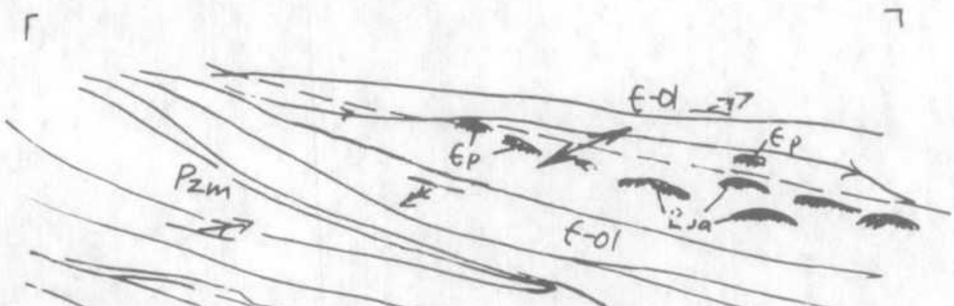
Fig. L.45 Western end of the Walker Creek Anticline (near Boomerang Valley) with a core of Larapinta Group, a prominent rim of steeply dipping Mereenie Sandstone and a wide alluvium-covered valley (overlying Parke Siltstone) in the foreground. (Photography by C. Zawartko). G/8637

Fig. L.46 Western MacDonnell Ranges looking east towards the Finke Gorge. Formations visible from left to right are Pacoota Sandstone, Horn Valley Siltstone (Valley), Stairway Sandstone, Stokes Siltstone (Valley), Carmichael Sandstone, Mereenie Sandstone, Harmannsburg Sandstone, Brewer Conglomerate. (Photograph by C. Zawartko). G/8578
5

Fig. L.47 Formations of the Larapinta Group in the western nose of James Range 'A' anticline.
G/9579

Fig. L.48 Formations of the Larapinta Group in the western MacDonnell Range. Scarp of the Mereenie Sandstone in Mereenie Bluff at top right.
G/9577

Fig. L.49 Palaeozoic sediments exposed in the Walker Creek Anticline, viewed north-westwards from its south flank of fold.
G/8642



Walker Creek Anticline looking north-west.

Pua Areyonga Formation, Єp Pertaoorrta Group, Є-Ol, Larapinta Group, Pzm Mereenie Sandstone.

Fig. L.50 Overlay for the photograph above.

By the close of Carmichael Sandstone times the seas may have regressed considerably in many areas.

THE DEPOSITIONAL HISTORY OF THE LARAPINTA GROUP (see Fig. L.23)

With the close of Pertaoorrta Group sedimentation, no major change took place in the limits of deposition; there was however a major change in the type of deposition. Thick orthoquartzites were deposited where there had previously been carbonate deposition.

The Pacoota Sandstone sediments were probably deposited in a broad shallow sea with sub-marine sand flats and some low longshore bars and possibly submarine dunes. All these bodies of sand were situated above wave base so that considerable reworking of the sands occurred and gradually a continuous sand body was built up.

This pattern of sedimentation was brought to a close by a relative rise in sea-level so that the sea-bottom was now well below wave base. Anaerobic conditions developed in the deep bottom waters so that the predominant form of sedimentation was black carbonaceous lutites.

Predominantly sandy sedimentation returned to the Amadeus Basin during lower Stairway Sandstone times. This change was associated with a regression and a shallowing of the sea so that the sea-bottom was above wave-base and subject to considerable hydrodynamic energy. There may have also been a corresponding increase of sand-sized detritus into the basin. As the shallowing of the seas proceeded throughout lower Stairway times a high energy zone gradually migrated across a very shallow broad shelf producing a regressive body of sand.

By middle Stairway times the low energy zone of a very shallow epeiric sea covered the area (see Shaw, 1964, and Irwin, 1965). This zone was situated shoreward of the point where the waves first impinge on the shelf. Therefore all the hydrodynamic energy of the waves was lost in this zone of impingement and the shoreward part of the epeiric sea was not subjected to strong current or tidal action. Consequently this low energy Middle Stairway epeiric sea was one of predominantly lutaceous and chemical (phosphorites and carbonates) sedimentation.

At the opening of upper Stairway Sandstone times a relative rise in sea level again occurred and the sea transgressed over the now peneplained hinterland to the south. This transgression continued into Stokes Siltstone times, particularly on the western margin of the basin. As a result of the transgression and the attendant deepening of the sea, a large transgressive body of sand was deposited over the area as the high energy zone migrated across. There may also have been an accompanying increase in the detrital sand.

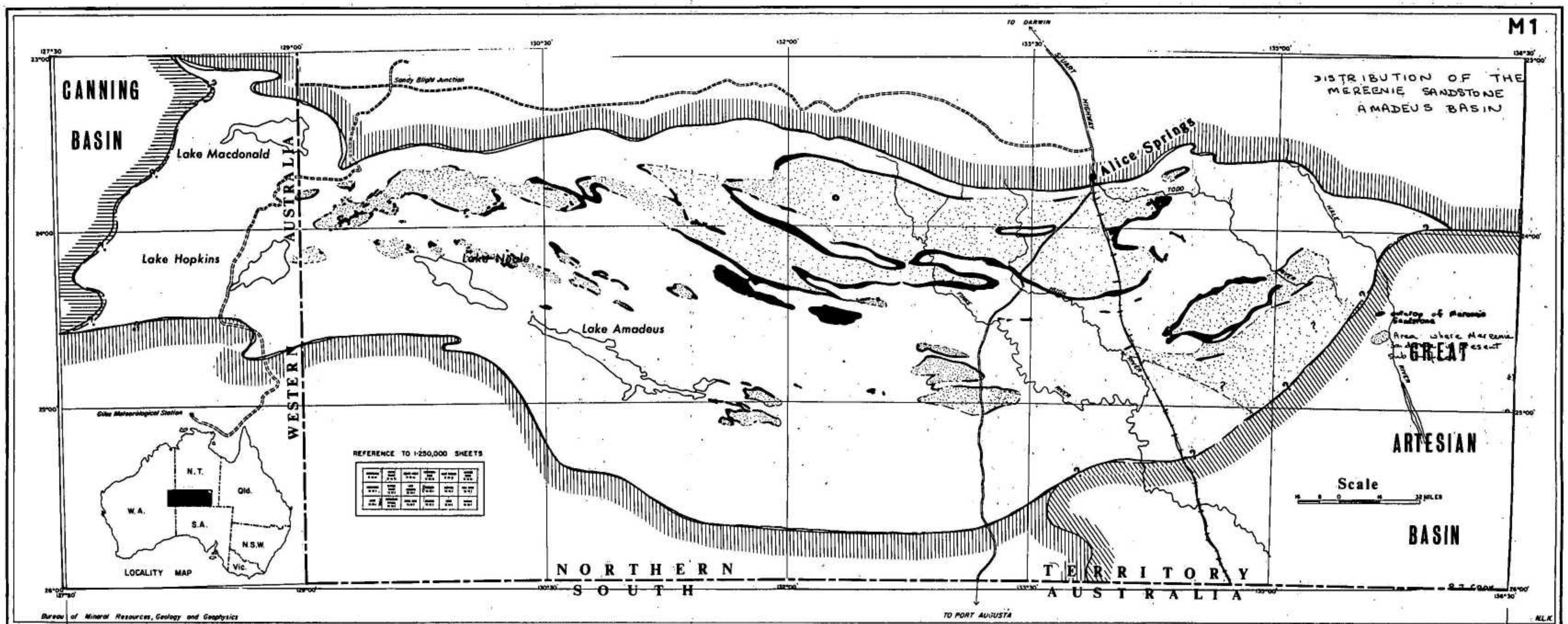
Following the deposition of the transgressive sand body, by Stokes Siltstone times, the sea was both very broad and shallow. Shaw (1964) has demonstrated that in such an epeiric sea there is no tidal action or currents so that there is no influx of "fresh" sea-water. This results in a considerable increase in salinity occurring because of water losses by evaporation. In the seas of Stokes siltstone times, the salinity increased sufficiently for halite precipitation. The sea was shallow at the close of Stokes Siltstone times when the deltaic or estuarine body of sand started to spread across the area. Alternatively the climate became wetter and there was a greater inflow of rivers carrying terrigenous material into the area. The presence of halite pseudomorphs high in the Carmichael Sandstone would not support this however. Whether the regressive body of deltaic or estuarine sand brought marine sedimentation to a close in the Amadeus Basin or whether there was a further transgression is not known as a considerable thickness of sediments was probably removed in the post-Rodingan (?Silurian) Movement erosion. It is suspected that the Rodingan Movement brought Larapinta Group sedimentation to a close or else the movement started a short time after sedimentation ceased.

SILURIAN? - DEVONIAN

The Mereenie Sandstone

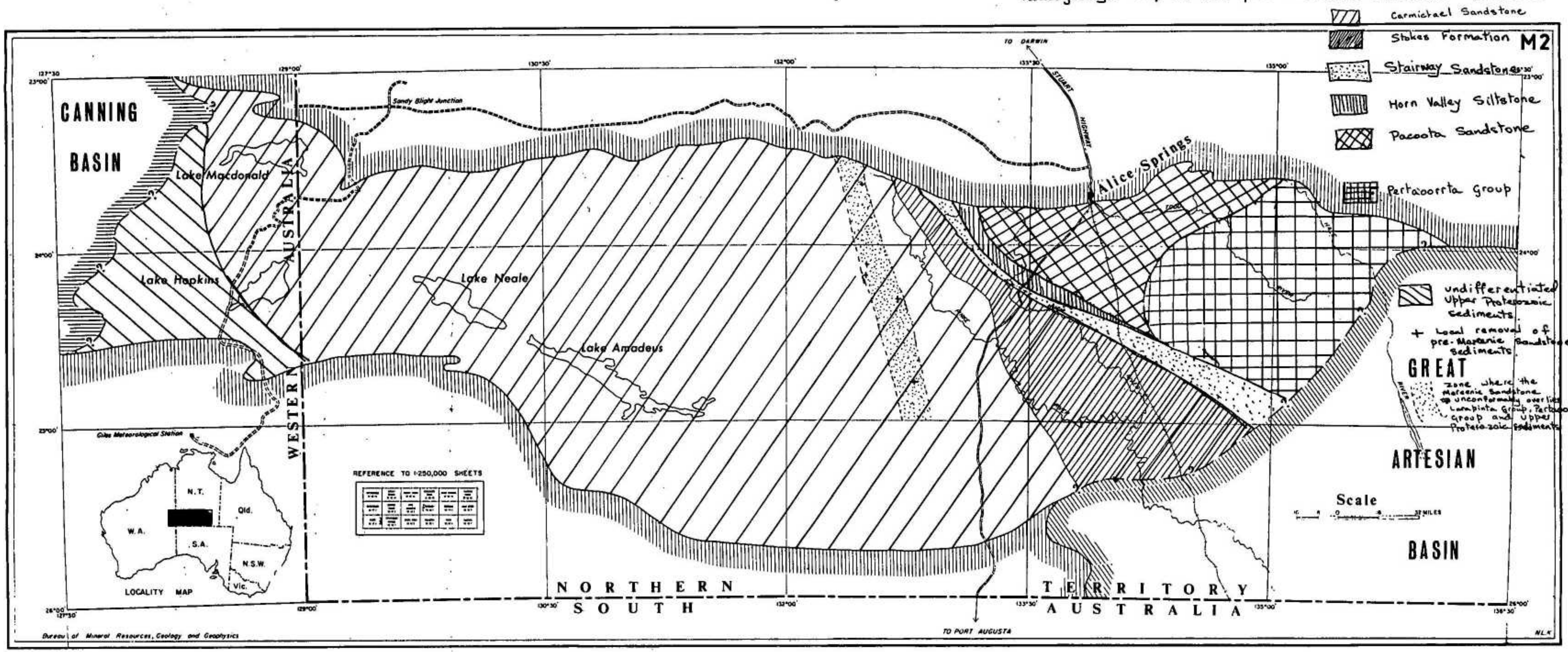
General

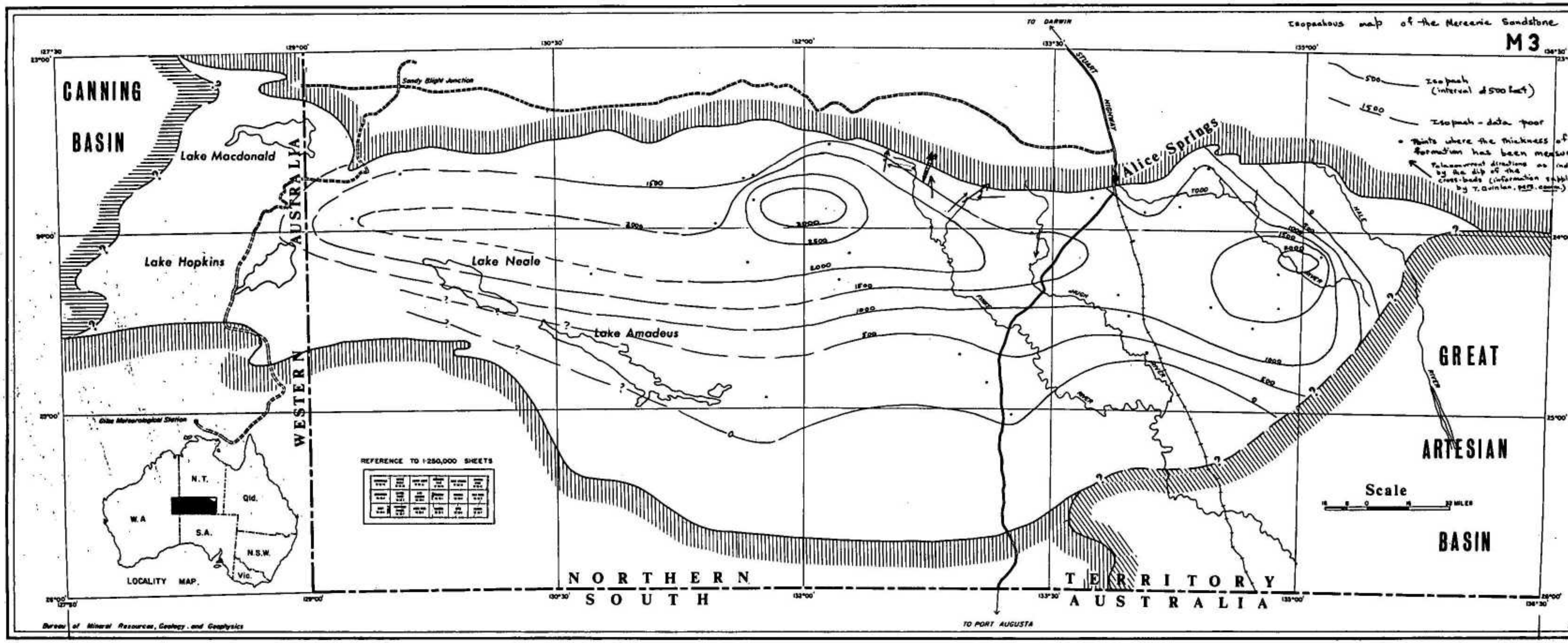
The term "Mareena Bluff Formation" was first used by Chewing (1894) for the sandstones of the George Gill Range (Fig. M7) and other areas. Madigan



M1
DISTRIBUTION OF THE
MEREENIE SANDSTONE
AMADEUS BASIN
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART HIGHWAY
TODD
TO PORT AUGUSTA
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT
ARTESIAN
BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
N.T.
W.A.
S.A.
Qld.
N.S.W.
Vic.
LOCALITY MAP
Bureau of Mineral Resources, Geology and Geophysics

Palaeogeologic map of the pre-Mereenie Sandstone surface




Isopachous map of the Mereenie Sandstone
M3
Isopach (interval of 500 feet)
Isopach - data poor
Points where the thickness of the formation has been measured
Palaeocurrent directions as indicated by the dip of the cross-beds (information supplied by T. Quinlan, pers. comm.)
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
TO DARWIN
STUART HIGHWAY
TO PORT AUGUSTA
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
W.A
N.T.
Qld.
S.A.
N.S.W.
Vic.
Scale
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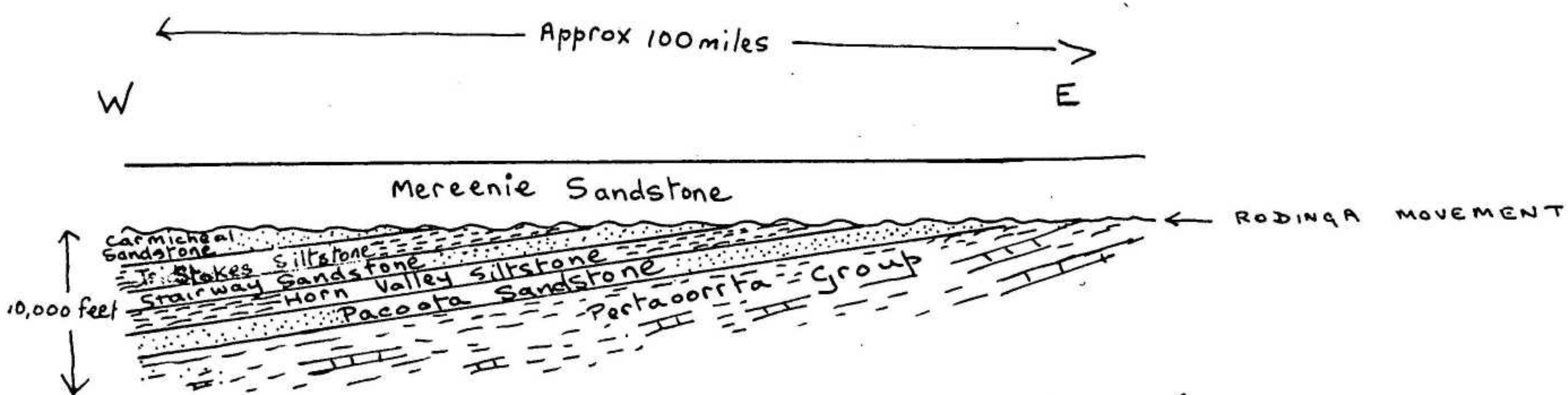
M4.



Diagrammatic section showing the sucessive truncation of units of the Larapinta group and Pertaoorrta group below the Mereenie Sandstone

(1932a) defined the formation as the Mareenie Sandstone but Prichard and Quinlan (1962) subsequently amended the spelling to Mereenie Sandstone.

The Mereenie Sandstone crops out sporadically throughout much of the Amadeus Basin. It has a total outcrop area of approximately 1,000 square miles and in addition underlies an area of approximately 10,000 square miles.

The Mereenie Sandstone overlies the Carmichael Sandstone with no apparent unconformity in the western half of the basin; however in the east the contact is regionally unconformable on formations of the Larapinta Group and Pertaoorrta Group (see Fig. M.4). On the extreme margin of the basin, it may rest unconformably on Upper Proterozoic sediments but contacts are not exposed. It is overlain by the Pertnjara Group.

The Mereenie Sandstone has a maximum preserved thickness of about 3,000 feet in the Gardiner Range (see Fig. M.3). There may however have been pre-Hermannsburg Sandstone erosion in the north-east part of the basin, with a considerable thickness of Mereenie Sandstone stripped off, and it is possible that the maximum thickness may have originally been deposited in the Steele's Gap area where there is about 2,000 feet of Mereenie Sandstone. There is considerable thinning of the formation to the south (see Fig. M.3), the southern limit of sedimentation occurring at about 25°10'S.

The Mereenie Sandstone is very poorly fossiliferous; it contains vertical or near vertical <u>Scolithus</u>-like pipes in places and a few trace fossils, none of which are diagnositc. The maximum age of the formation is probably Silurian. The minimum age is late Middle or early Upper Devonian (Bothriolepis and spores occur in the overlying Parke Siltstone).

Lithology

The Mereenie Sandstone is a white or pale brown (weathering to dark brown in places) fine grained, thin to thickly bedded, very strongly cross-bedded sandstone (Fig. M8). Rarely there is slumping of the cross-laminae and mud-crack markings and in the Tempe Downs area Ranford et. al. (1966) record a sand pipe which is probably a sand volcano. The cross-bedding in the Mereenie Sandstone is a most notable feature; the cross-bed sets are up to 10 feet thick and single beds may be traced for 100 feet or more. In a few places in the north-east corner of the basin, there is a thin basal conglomerate. In this same area there are also a few thin conglomeratic lenses within the formation.

Petrography

The arenites of the Mereenie Sandstone are generally fine grained mature or super-mature orthoquartzites. They are generally well rounded and well sorted.

Observation of the quartz types of the orthoquartzites indicate that non-undulating quartz forms approximately 40 - 50% of the total quartz, undulatory quartz also about 40 - 50%, composite quartz 5 - 20% and rarely, there is 1 - 2% chert and 1 - 2% metaquartzite. Very rarely the orthoquartzites contain up to 1% feldspar (mainly microcline). The only detrital heavy minerals observed were well rounded grains of tourmaline and zircon.

Lutites are uncommon in the Mereenie Sandstone but where present the predominant clay mineral is probably kaolinite.

Environment of Deposition

The presence of indeterminate trace fossils and vertical worm tubes suggests that part of the Mereenie Sandstone was probably laid down under shallow marine conditions. In other respects the formation has all the appearance of a "desert sandstone" such as the Coconino Sandstone of the western United States. In particular the abundant massive cross-bedding and the frosting and pitting of grains suggests aeolian deposition. A major problem arises with the thickness of the formation; it is difficult to visualize a predominantly aeolian sandstone attaining a thickness of up to 3,000 feet.

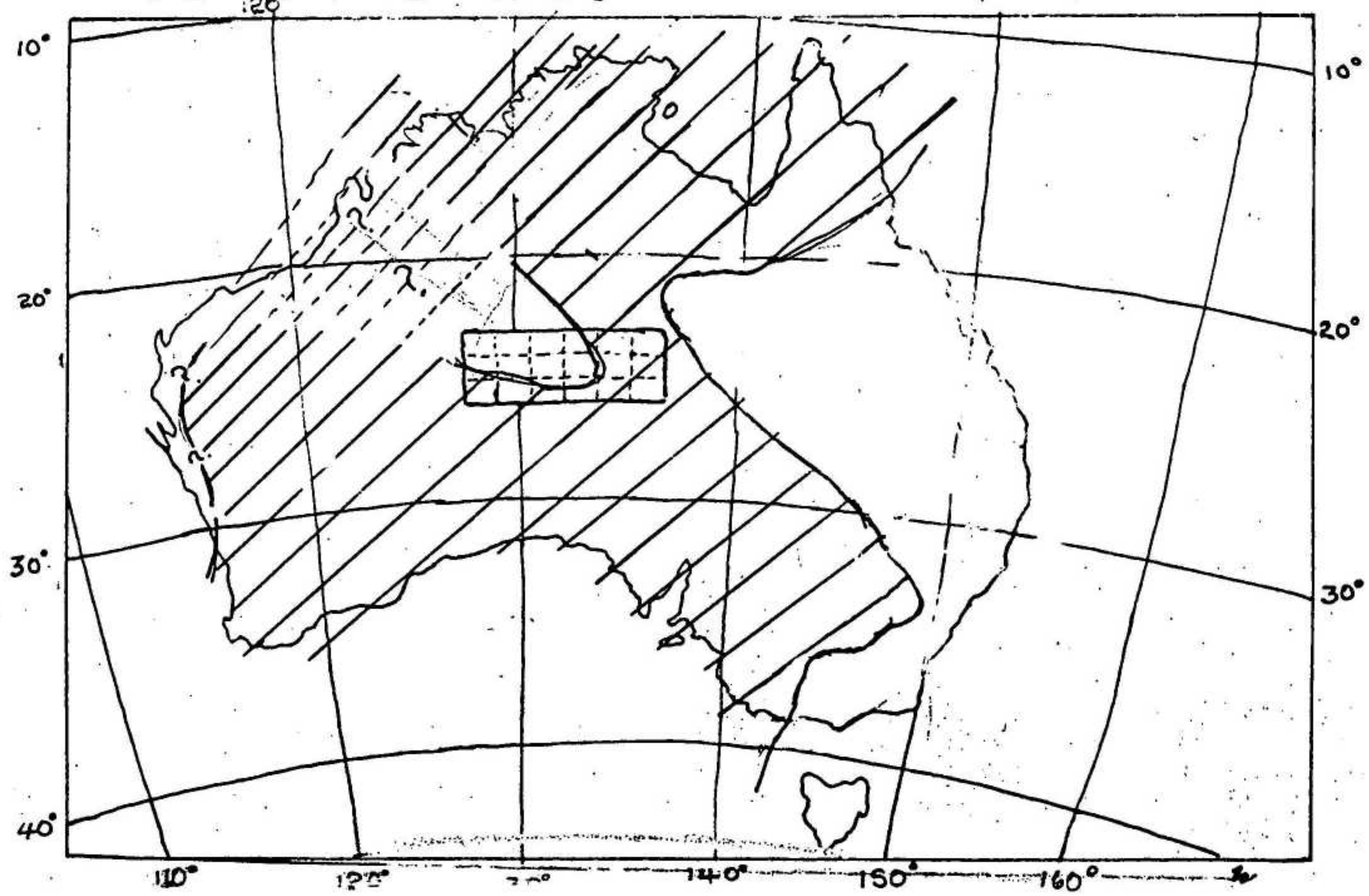
The depositional environment was in all probability a complex interplay of several environments - aeolian, deltaic, lacustrine and very shallow water marine (probably with abundant aeolian sand being blown into the aqueous environment). Until more detailed studies of the formation are carried out, it is impossible to be more specific.

Provenance

The presence of detrital grains of chert, and a few rare grains

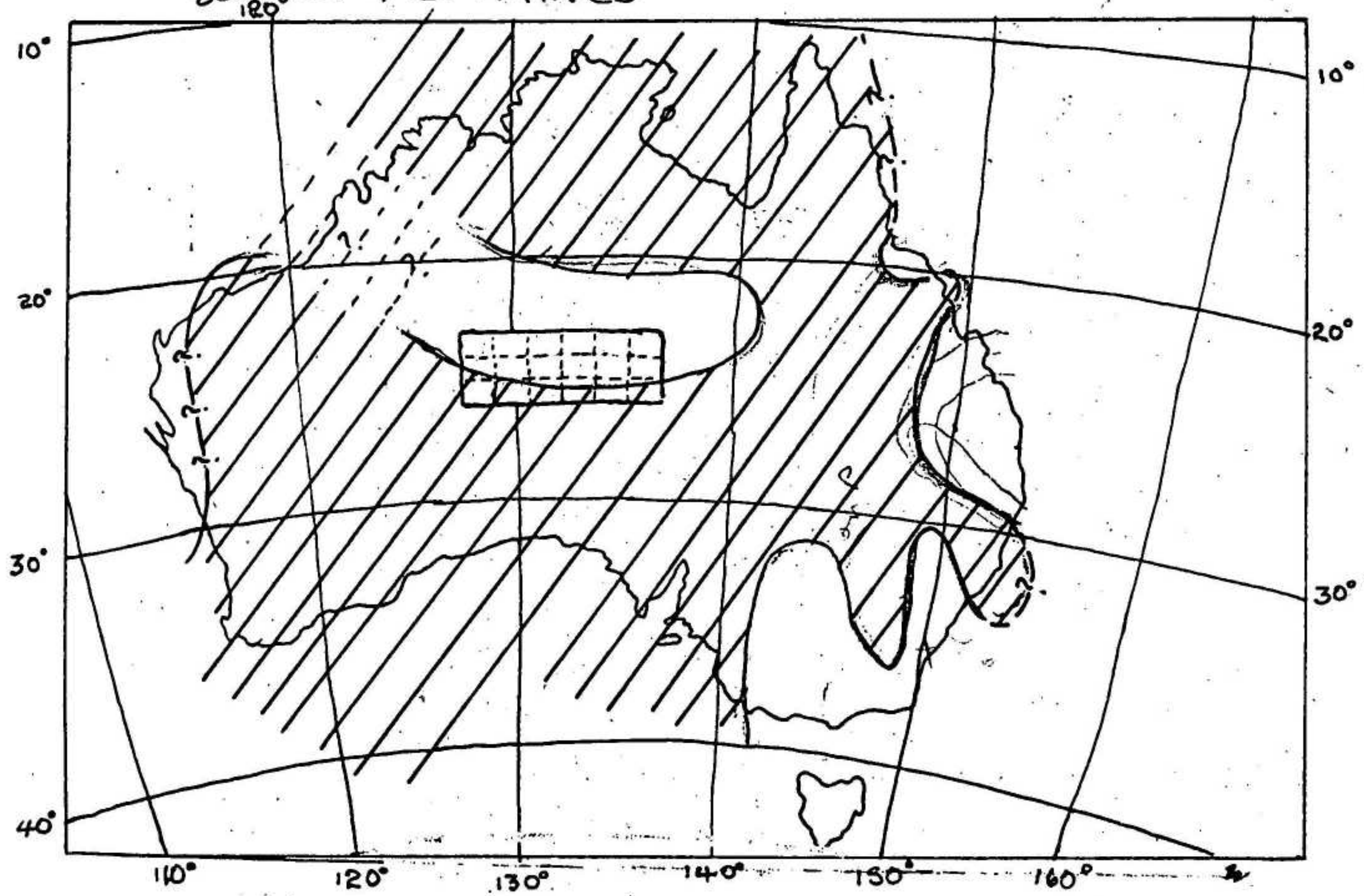
M5.

PALAEOGEOGRAPHIC MAP in early Mereenie Sandstone times



M6.

PALAEOGEOGRAPHIC MAP in late Mereenie sandstone times



showing reworked overgrowths indicates that the provenance was sedimentary in part. Some of the arenites are well rounded yet poorly sorted, also suggesting reworking of a sedimentary source area. In addition the work of Blatt (1963, 1964) and Blatt and Christie (1963) has shown that a high percentage of non-undulatory quartz is indicative of reworking of sedimentary rocks. Therefore it appears that the provenance was predominantly sedimentary and probably mainly arenitic; the chert grains may indicate a minor limestone or dolomite provenance. Rarely, in some areas (e.g. towards the western margin of the basin) a relatively high percentage of metaquartzite grains suggests that a significant contribution to the supply of sediments was obtained from a metamorphic provenance for a short time in a limited area.

Palaeoclimate

As mentioned earlier, there is abundant evidence of aeolian activity. It is therefore probable that throughout most of Mereenie Sandstone times a desert climate prevailed. The palaeolatitude data of Irving (1964) suggests that during Mereenie Sandstone times the Amadeus Basin was situated at a palaeolatitude of about 20°S which would correspond to the present day trade-wind belt.

Palaeogeography

The lack of time control in the Mereenie Sandstone makes palaeogeographic reconstruction conjectural. Lithologically and probably chronologically, it is equivalent to the lower part of the Dulcie Sandstone of the Georgina Basin (J.G. Tomlinson, pers. comm.). It may also be in part the time equivalent of the Pillara Formation of the Fitzroy Trough but is probably older than the Cockatoo Sandstone of the Bonaparte Gulf Basin.

In early Mereenie Sandstone times there was probably a major ridge in the north-east part of the Amadeus Basin (stretching far beyond the present limits of the basin) resulting from the Rodingan Movement (?Silurian), which initially may have separated off the Georgina Basin from the Amadeus Basin (Fig. M.5). Pebbles and cobbles also became considerably more common to the east, suggesting that the main source area for the Mereenie sandstone lay to the east. It is certain that initially the source area consisted of Cambro-Ordovician sediments of the Amadeus Basin (see palaeogeologic map, Fig. M.2).

As the Mereenie Sandstone (and its equivalents) may be in part continental an area of land may have constituted a "connection" rather than a "barrier". Figs. M.5 and M.6 are interpretations of the palaeogeography during Mereenie Sandstone times. It is suggested that the connection between the open sea and the Amadeus Basin in Mereenie Sandstone times lay to the west. As Mereenie sedimentation proceeded, the sea transgressed to the east until the Georgina and Amadeus Basins were linked (Fig. M.6).

The Depositional History of the Mereenie Sandstone

Some time after the close of Carmichael Sandstone times, a gentle uplift (or upwarping) occurred in the Amadeus Basin. This epeirogeny was followed by erosion which may have continued for some considerable time, perhaps for much of the Silurian and possibly even into the lower Devonian. Age dating of pegmatites from the Hart's Range (Hurley <u>et. al.</u>, 1961) suggests that this movement probably started about 410 m.y. ± 10 m.y. i.e. lower Silurian, but as 5 - 10,000 feet of sediments were eroded from the north-east corner of the basin prior to the deposition of the Mereenie Sandstone there was probably a major time break between the epeirogenic movement in the Silurian and the onset of Mereenie Sandstone sedimentation. The lack of massive conglomerates (of for instance the Pertnjara Group type) suggests there was no violent movement. The area was probably finally reduced to a peneplain. As a result large continental desert areas were established around (and probably within) the Siluro-Devonian Amadeus Basin. It was from these desert areas that the Mereenie Sandstone sediments were derived by both fluviatile and aeolian action and deposited in part in a very shallow sea which may have been gradually transgressing across the area from the west.

Throughout deposition it is probable the form of the Amadeus Basin was somewhat nebulous, with a constantly moving strand line and with shallow marine environments grading into and interfingering with lacustrine and aeolian environments.

This rather patchy pattern of sedimentation was brought to a close with the onset of Pertnjara Formation sedimentation, and perhaps by the violent orogenic movement reflected in an age of 367 m.y. ± 10 m.y. obtained from pegmatites of the Hart's Range by Hurley <u>et al.</u> (1961).

Fig. M.7 Looking south-east over the George Gill Range. Carmichael Cragg in the foreground, with the lower slopes of the scarp composed of Carmichael Sandstone and the upper part and the plateau composed of Mereenie Sandstone. The deep incision of Kings Canyon is visible in the middle of the photograph. (Photograph by C. Zawartko).
G/8616

Fig. M.8 Well developed cross-bedding in the Mereenie Sandstone.
G/9123

Forman et. al. (1967) have suggested that the pre-Mereenie and the post Mereenie Movement should all be considered as part of the Alice Springs Orogeny. In the present author's opinion the gap of approximately 50 m.y. between the two movements, the completely different type of tectonic movement and the very stable conditions which prevailed in the interval of 50 million years, make the inclusion of the pre-Mereenie movement in the Alice Springs Orogeny most undesirable. The name Rodingan Movement has been proposed for this ?Silurian epeirogeny.

DEVONIAN - CARBONIFEROUS?

THE PERTNJARA AND FINKE GROUPS

Introduction

Continental deposits of siltstone, sandstone and conglomerate of the Pertnjara Group, which have a maximum thickness of about 12,000 feet, are the youngest known Palaeozoic sediments of the Amadeus Basin succession. The Group has Upper Devonian fossils near its base and the uppermost beds may be Carboniferous. The Group has its maximum development on the southern flanks of the MacDonnell Ranges and thins rapidly to the south and intertongues with sediments of the Finke Group in the south eastern part of the Basin. Exposures of the Finke Group are about 1500 feet thick. By inference the Finke Group is probably also Devonian to Carboniferous in age. The solid geology and distribution of the Pertnjara and Finke Groups is shown in figure DC-1. Approximate isopachs on the preserved thickness of the Pertnjara Group are shown in figure DC-9 and a diagrammatic reconstruction of the thickness of the Pertnjara Group at the end of deposition is shown in figure DC-9A.

PERTNJARA GROUP

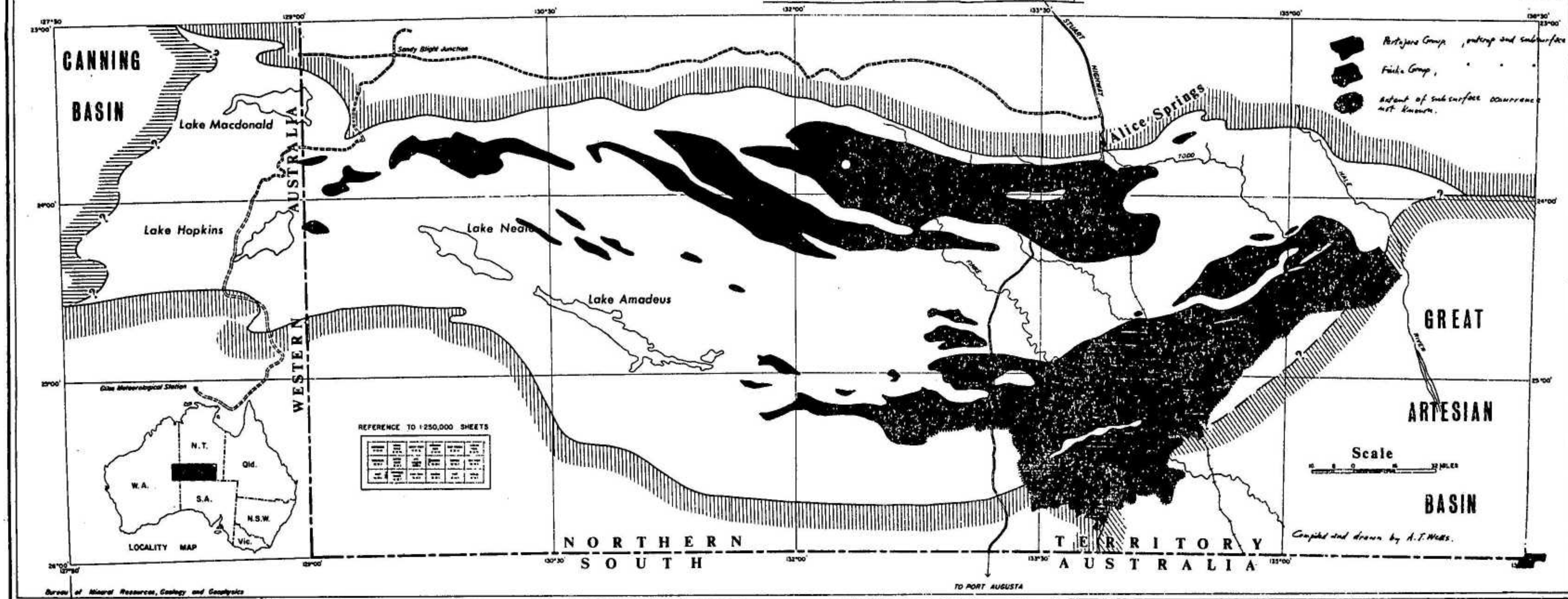
The Pertnjara "Formation" of Prichard and Quinlan (1962) was described as a sequence of sandstone, quartz greywacke and conglomerate that overlies the Mereenie Sandstone with a regional unconformity in the type area on the southern flanks of the western MacDonnell Ranges (Figs. DC-12, DC-13). It has since been demonstrated that a thick wedge of basal siltstone is an important component of the sequence in the central part of the Amadeus Basin. In previous reports the three major rock bodies - siltstone, sandstone and conglomerate - were mapped as informal units in the Pertnjara "Formation" but because of their wide extent and continuity they are here defined as formations and the Pertnjara elevated to group status. They are the Parke Siltstone at the base, followed apparently conformably by the Hermannsburg Sandstone and the Brewer Conglomerate at the top (Fig. DC-14, DC-15). The distribution of these formations is shown in fig. DC-2. The Hermannsburg Sandstone is the most widespread formation whereas the underlying Parke Siltstone is confined to a central belt of outcrops trending south of the western MacDonnell Ranges. Outcrops of the Brewer Conglomerate are confined to the southern flanks of the MacDonnell Ranges and in isolated erosional remnants at the northern margin of the Basin near the eastern and western extremities.

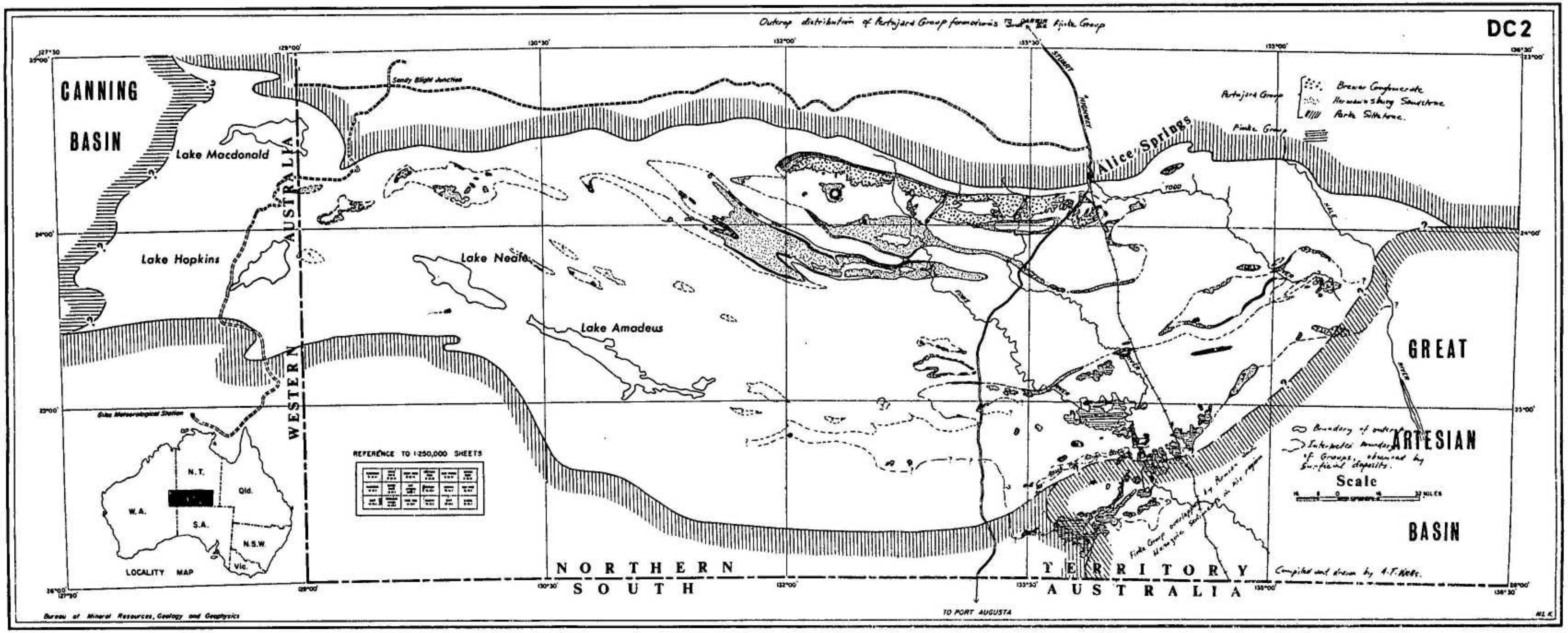
The pre-Pertnjara depositional surface was consisted of the Mereenie Sandstone over a large part of the Basin but to the south the Pertnjara Group overlapped the depositional edge of the Mereenie Sandstone to rest on formations of the Larapinta Group. Uplift and erosion, contemporaneous with sedimentation along the northern margin of the Basin, exposed all older rocks including the Archaean basement, and younger sediments of the Pertnjara Group successively overlapped older rocks. Therefore in most places the Parke Siltstone follows apparently conformable on the Mereenie Sandstone, whereas the Hermannsburg Sandstone lies in part unconformably on the Mereenie Sandstone, and the Brewer Conglomerate transgresses the Hermannsburg Sandstone and unconformably overlies rocks as old as Proterozoic. This shows that in the northern part of the Basin the edge of deposition moved from near Ellery Creek to at least as far as the Hale River in the east. This concept is shown in Fig. DC-3.

The maximum thickness of the Pertnjara Group is estimated at about 12,000 feet on the southern flanks of the western MacDonnell Ranges, but about 22,000 feet was measured by Prichard and Quinlan, (1962) from Ellery Creek in the MacDonnell Ranges southwards towards the axis of the Missionary Syncline. This large apparent thickness can be accounted for in part by foresetting which is particularly evident in the upper conglomerate.

A summary of the succession in the western MacDonnell Ranges, south

DC1


Distribution of the Pertnjara Group and "Finke" Group
Pertnjara Group, outcrop and subsurface
Finke Group,
extent of subsurface occurrence not known.
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
STUART HIGHWAY
TODD
FINKE
HALE
GREAT
ARTESIAN
BASIN
Scale
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Compiled and drawn by A.T. Wells.
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


DC2
Outcrop distribution of Pertnjara Group formations and Finke Group
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Lake Neale
Lake Amadeus
Alice Springs
Pertnjara Group
Brewer Conglomerate
Hermannsburg Sandstone
Parke Siltstone.
Finke Group
GREAT
ARTESIAN
BASIN
Boundary of outcrop
Interpolated boundary of Groups, obscured by surficial deposits.
Scale
Giles Meteorological Station
WESTERN AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
Compiled and drawn by A.T. Wells.
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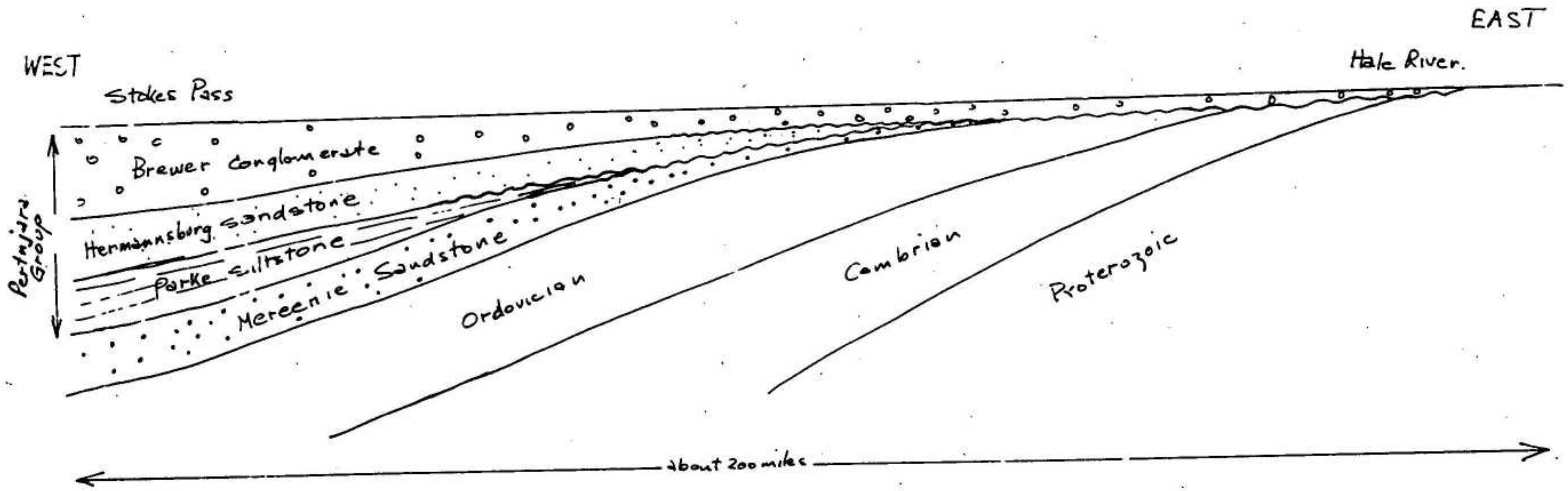
SIMPLIFIED DIAGRAM SHOWING RELATIONSHIP OF THE PERTNJARA GROUP WITH OLDER ROCKS.

DC-3.



of Ellery Creek, modified from Prichard and Quinlan (1962), is as follows -

100 feet - quartz sandstone, fine to medium grained, feldspathic, scattered pebbles and pebble lenses, grading into sandstone pebble conglomerate (derived from the Mereenie Sandstone).

250 feet - Conglomerate - cobbles and boulders from the Larapinta Group.

1000 feet - quartz greywacke, interbedded pebble conglomerate in upper part.

Several thousand feet thick.

- conglomerate, pebbles, cobbles and boulders in sandy matrix, in part calcareous. Fragments of Pertaoorrta Group in base, upper Proterozoic towards top, and mostly Arunta Complex at top. Calcareous greywacke interbeds in upper part.
- greywacke, friable, massive, calcareous, scattered pebbles and pebble bands, grades into coarse conglomerate along strike.
- conglomerate with derived pebbles from base to top in reverse of normal stratigraphic order as in lower conglomerate unit.

The basal 1000 feet of predominantly sandstone is included in the Hermannsburg Sandstone and the overlying thick sequence of conglomerate is the Brewer Conglomerate. The basal Parke Siltstone is not present in this section.

The distribution and composition of the sediments indicate four major phases of deposition each associated with successive uplifts of the source areas. In the initial phase of deposition when the Parke Siltstone was laid down, the source areas were relatively low but the orogenic phases gradually increased in intensity with corresponding uplift of source areas so that the basal siltstone was succeeded by sandstones and then by conglomerate. The composition of the conglomerates of the youngest part of the Pertnjara Group indicate two major phases of uplift of the source area. The distribution and thickness of the rock types indicate a provenance lying mainly to the north of the present margin of outcrop.

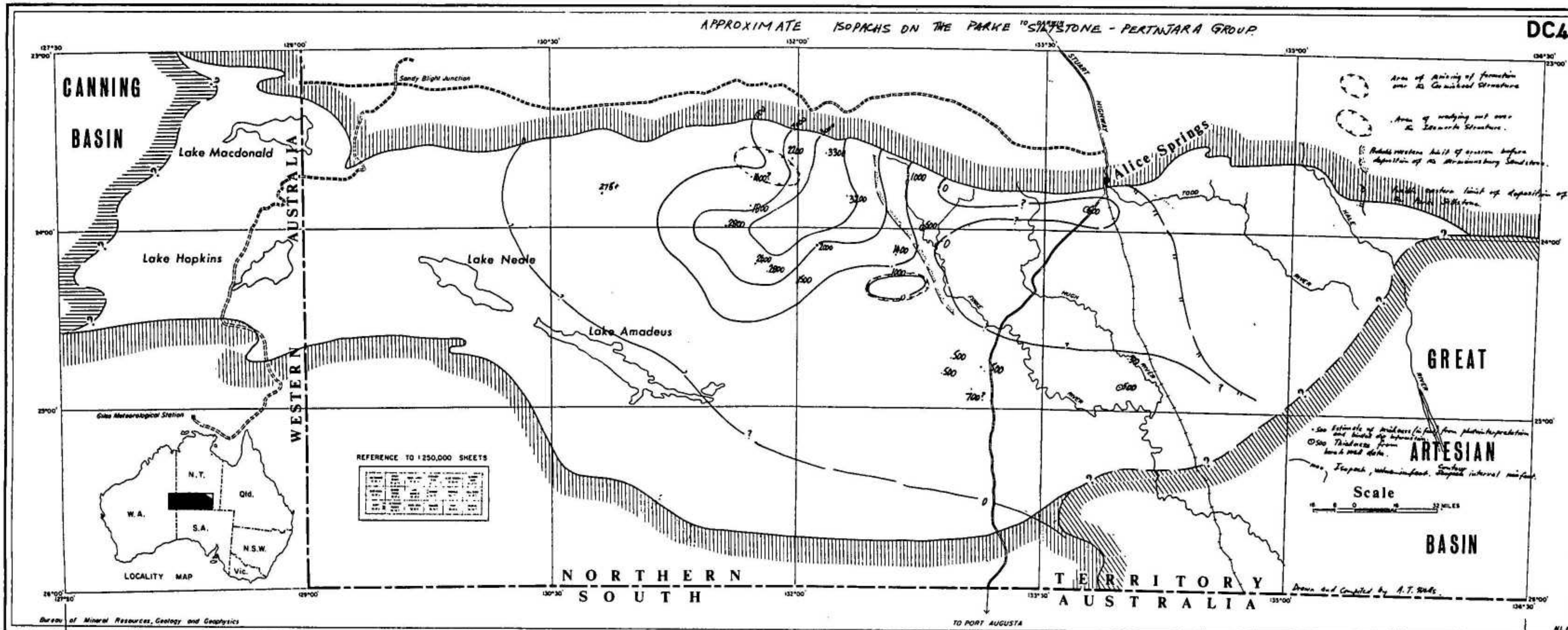
Parke Siltstone

The Parke Siltstone is defined as the basal formation of the Pertnjara Group and in the type area consists of siltstone with minor sandstone interbeds. The formation is named from Parke Creek, the headwaters of which drain Dare Plain in the north-east part of the Lake Amadeus Sheet area. The Parke Siltstone underlies Dare Plain and the type area is on the south-west flank of the Mereenie Anticline.

The major outcrops of the formation occur in the western part of the MacDonnell Ranges (Figs. DC-14, DC-15) and in the large ranges to the south in the central part of the Basin. In the northern half of the Basin the formation is not known east of the Finke River but has been tentatively identified in the subsurface in water bores in the Brewer Plain. Outcrops occur as far west at the Cleland Hills and the formation has been identified as far south as the Mount Charlotte Range. The sandstones of the underlying and overlying formations form prominent escarpments whereas the Parke Siltstone weathers recessively.

The Parke Siltstone was deposited apparently conformably on the Mereenie Sandstone and in most places is apparently conformably overlain by the Hermannsburg Sandstone. It is locally overlain by remnants of Tertiary sediments. The distribution and thickness of the formation in the northern part of the basin adjacent to the MacDonnell Ranges was probably modified, subsequent to deposition, by local erosion that preceded the deposition of the overlying Hermannsburg Sandstone. Consequently the Parke Siltstone wedges out to the east of Glen Helen Gorge and in the area between Glen Helen Gorge and Stokes Pass the upper contact is most likely an unconformity. It seems unlikely that the Parke Siltstone interfingers laterally with the Hermannsburg Sandstone because there are sharp contacts between the formations. The same unconformity is visible to the south in the area between the Gardiner Range and the eastern part of the James Range where the Hermannsburg Sandstone overlaps the Parke Siltstone and gradually transgresses the underlying Mereenie Sandstone. In water bores in areas to the west of this transgressive boundary, a gradational contact is apparent between the Parke Siltstone and Hermannsburg Sandstone.

In the southern part of the Basin the Parke Siltstone overlapped the depositional edge of the Mereenie Sandstone and locally unconformably overlies



APPROXIMATE ISOPACHS ON THE PARKE SILTSTONE - PERTNJARA GROUP
DC4
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
Sandy Blight Junction
Giles Meteorological Station
STUART HIGHWAY
TO DARWIN
TO PORT AUGUSTA
GREAT
ARTESIAN
BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
W.A.
N.T.
Qld.
S.A.
N.S.W.
Vic.
Scale
MILES
Drawn and Compiled by A.T. Wells.
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the Stairway Sandstone of the Larapinta Group. On structural ground it may be inferred that the formation is also unconformable on the younger formations of the Larapinta Group but these contacts are not exposed.

Isopachs drawn on the Parke Siltstone are shown in figure DC-4. The area of thickest deposition is encompassed by the Mereenie Anticline, Gosses Bluff, and Stokes Pass. At Stokes Pass the formation attains a maximum thickness of about 3000 feet. A smaller basin of preservation probably connected to the larger basin occurs south of Alice Springs which is interpreted from sequences penetrated in water bores. The thickness of the formation here is about 600 feet. The formation is absent over the Illamurta Structure (Cook, 1966b), and is considerably thinner on the Carmichael Structure. Both structures were probably 'growing' during sedimentation.

The top few feet of a prominent bed of sandstone 300-400 feet thick, lying 300 feet above the base of the formation on Dare Plain, contain fragments of the dermal armour of the antiarchan placoderm Bothriolepis (Tomlinson, in press). Spores have been recorded by Hodgson (in press) from a water bore sample at about the same horizon. At Gosses Bluff, 50 miles north-east of Dare Plain, a fragment of arthrodiran armour has been found in a sandstone that is probably continuous with the sandstone bed in the base of the Parke Siltstone at Dare Plain. The fossils from Dare Plain are dated as Upper Devonian, probably no older than late Frasnian.

The formation is poorly exposed. In the type area it consists of siltstone which varies from chocolate brown to yellow-brown, purple, brown, green, grey and orange-brown. Typically the weathered, leached rock is white. Much of it is micaceous and calcareous and it is laminated to massive. Some beds are sandy and in places a few thin limestone beds are known. Pseudomorphs after halite were seen in some of the siltstones. The 300 feet of fossiliferous, silty, poorly sorted sandstone near the base of the formation at Dare Plain increases in thickness towards the north and north-east as shown in figure DC-5. and comprises about half the total thickness of the formation at the western end of the MacDonnell Ranges (Figs. DC-14 and DC-15) and Gosses Bluff. The upper siltstone unit of the formation has wedged out at Stokes Pass and the dominant sandstone is conglomeratic. At Glen Helen only about 1000 feet of sandstone remains and the formation is absent at Ellery Creek where the younger

Hermannsburg Sandstone unconformably overlies the Mereenie Sandstone.

In the central part of the Amadeus Basin the prominent sandstone member is missing and the formation is primarily red-brown and purple-brown, micaceous (muscovite and some biotite), laminated to thin bedded siltstone, with minor interbeds of calcareous siltstone, grey limestone and silty sandstone. In the south-western part of the Basin the Parke Siltstone is only about 200 feet thick and consists of green and red, laminated, micaceous siltstone and shale with pseudomorphs after halite.

The lithology, distribution and fossil content of the Parke Siltstone indicate a lacustrine environment of deposition. The salt casts suggest playa lake deposits. Playa deposits such as these probably accumulated in a shallow central basin of a desent plain with periodic influxes of sediment and seasonal evaporation. The fine grained sediments suggest that no neighbouring major uplifts had taken place and that sediments were derived by desert weathering of relatively low source areas.

The increasing thickness of the sandstone member in the Parke Siltstone and its increase in grain size towards the north and east indicate major source areas in these directions. Probably a large part of the Mereenie Sandstone was exposed and eroded in the eastern half of the Basin during deposition of the Parke Siltstone. The presence of muscovite and biotite suggest inclusion of detritus eroded from metamorphic and igneous terrains.

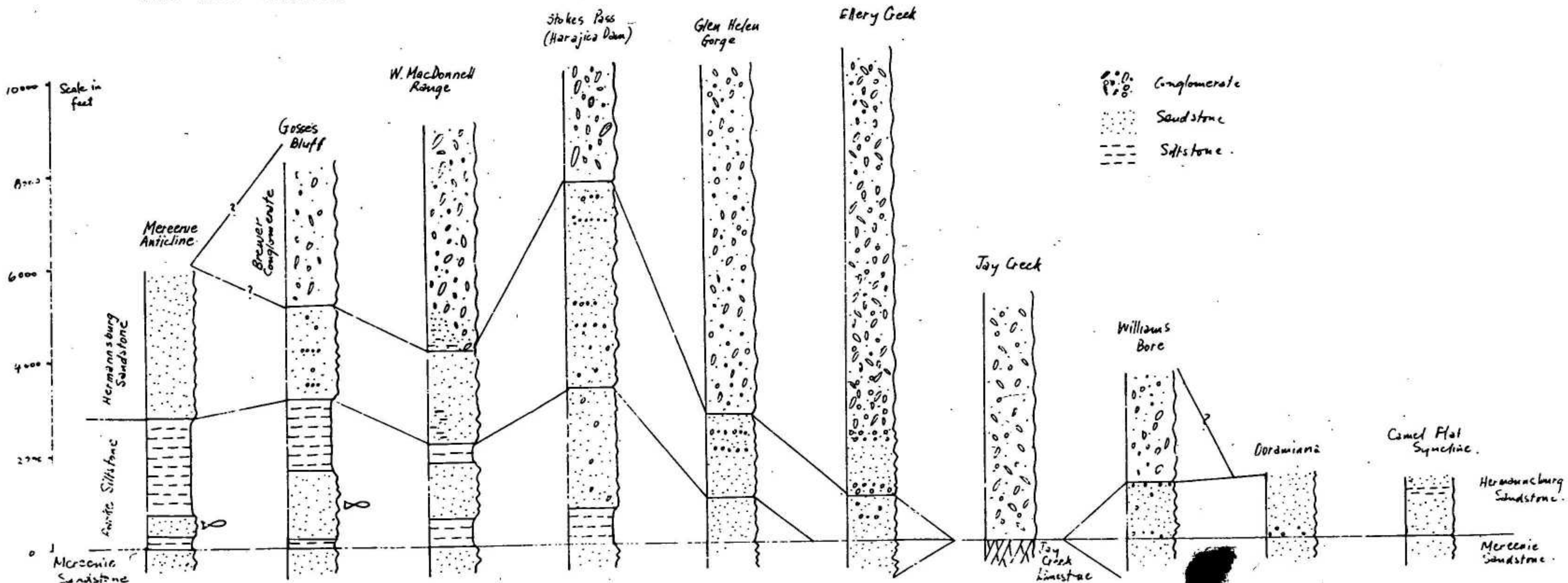
Hermannsburg Sandstone

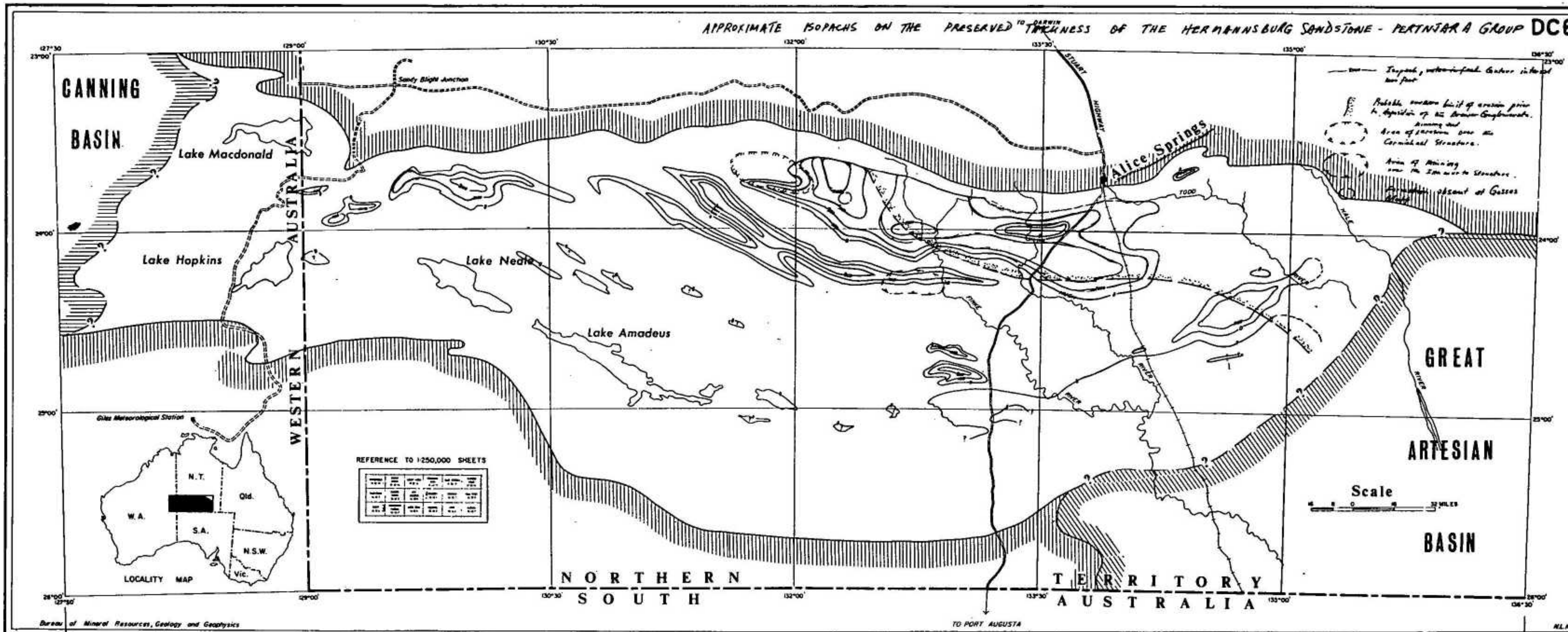
The Hermannsburg Sandstone is defined as a formation of red-brown sandstone and minor conglomerate and conglomeratic sandstone. In the type area, on the south flanks of the western MacDonnell Ranges near Stokes Pass, it lies between the Parke Siltstone below and the Brewer Conglomerate above (Figs. DC-14 and DC-15). The formation is widely distributed in the Amadeus Basin and is invariably well exposed (Figs. DC-16). The largest and more complete outcrops occur in the central and northern areas. Discontinuous outcrops occur as far south as the Mount Charlotte Range, westwards to near the Western Australia/Northern Territory border and east to the eastern end of the Rodinga Ranges. The formation is named from Mount Hermannsburg in the Krichauff Range about four miles south-west of Hermannsburg Mission.

SECTIONS OF THE PERTNJARA GROUP — MEREENIE ANTICLINE TO CAMEL FLAT SYNCLINE.

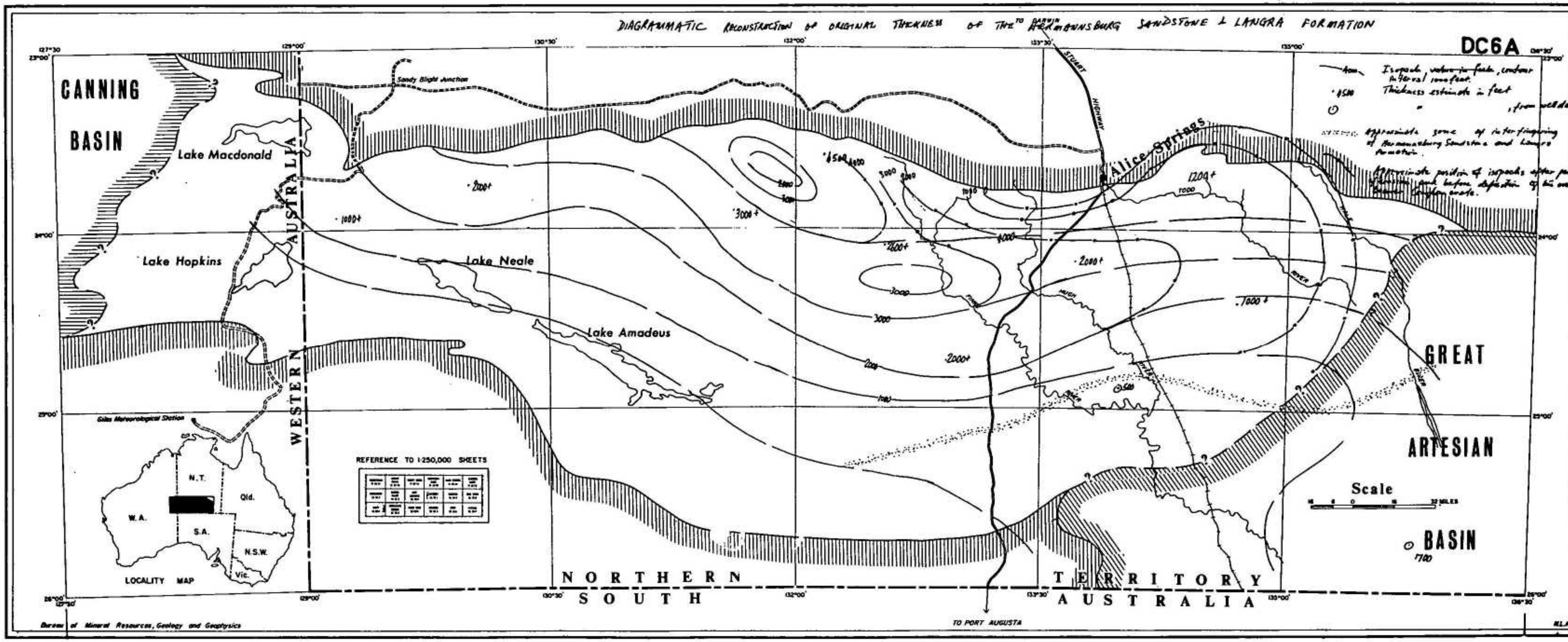
DC · 5.

THICKNESSES ARE APPROXIMATE AND COMPLETE SECTIONS OF THE BREWER CONGLOMERATE ARE NOT SHOWN.





APPROXIMATE ISOPACHS ON THE PRESERVED THICKNESS OF THE HERMANNSBURG SANDSTONE - PERTNJARA GROUP
DC6
TO DARWIN
STUART HIGHWAY
Alice Springs
CANNING BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
Lake Neale
Lake Amadeus
Giles Meteorological Station
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
TODD
FINKE
HALE
RIVER
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
MILES
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics
N.L.K.



DIAGRAMMATIC RECONSTRUCTION OF ORIGINAL THICKNESS OF THE HERMANNSBURG SANDSTONE & LANGRA FORMATION
DC6A
Isopach, contour interval 1000 feet.
Thickness estimate in feet
, from well data
Approximate zone of interfingering of Hermannsburg Sandstone and Langra Formation.
CANNING BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
GREAT ARTESIAN BASIN
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
Scale
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
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The contact with the Parke Siltstone is apparently conformable in the western part of the outcrop area but a regional unconformity separates the two to the east where the Hermannsburg Sandstone overlaps the Parke Siltstone and transgresses the underlying Mereenie Sandstone. The contact with the overlying Brewer Conglomerate is also apparently conformable in the west; in outcrops east of Glen Helen Gorge there is an unconformity at the top of the formation where it was eroded before the deposition of the overlying conglomerate.

The formation outcrops as the present erosion surface over a large part of the area. It is locally overlain by laterally discontinuous outcrops of Tertiary sediments and at the eastern end of the basin the formation passes beneath sediments of the Great Artesian Basin succession. Here it is probably unconformably overlain by sediments identified with the Permian Crown Point Formation. Outcrops in this area are mostly covered by sand and the contacts are poorly exposed.

Isopachs drawn on the preserved thickness of the formation are shown in figure DC-6 and a diagrammatic reconstruction of the original thickness of the formation is shown in DC-6A. Maximum sedimentation occurred adjacent to the MacDonnell Ranges and the greatest measured thickness is about 4,500 feet in the area south of Stokes Pass. In the central part of the Amadeus Basin the thickness preserved in the synclinal areas is probably no more than 2-3000 feet. The thickness decreases rapidly from the type area to the east and the formation is absent on the northern margin of the Basin eastwards from a point about two miles east of Ellery Creek. The formation thins locally over the Carmichael structure which was probably growing during sedimentation. It is also possible that the sandstone was locally eroded here before deposition of the Brewer Conglomerate. To the south and west of the area of thickest sedimentation it thins gradually at a more even rate and eventually wedges out. To the south-east the Hermannsburg Sandstone intertongues with sediments of the Finke Group.

The Hermannsburg Sandstone is a red-brown, and grey-brown, medium to thick bedded, cross-bedded, kaolinitic silty sandstone. In places it contains a few thin interbeds of siltstone, and is conglomeratic in part, particularly in the basal beds at the northern edge of the Basin (Fig. DC-18). No diagnostic fossils have been found apart from poorly preserved plant fragments. Leslie (1960) reported a plant fossil (aff. Sigillaria) about 1500 feet above the base of the formation in the Tempe Downs area. This fossil is considered to be Carboniferous in age, but an Upper Devonian or Permian age cannot be dismissed (Taylor, 1959b).

The distribution of the formation, the red-colouration and the presence of plant fragments indicate a continental environment of deposition for the Hermannsburg Sandstone. The thickest deposits were formed adjacent to large mountains on the northern margin of the basin where the sediments were poured into the basin and accumulated in large alluvial fans, but the major part of the formation was most likely deposited in a fluvial environment on broad alluvial plains. Glauconite has been reported in sediments equated with the formation in the Erldunda No. 1 Well (Schmerber, 1967) suggesting intermingling with marine waters in the southern part of the basin.

The increased coarseness and greater thickness of the sandstone along the northern margin of the basin suggests a northern provenance for the sediments. The clasts in the basal conglomeratic parts of the formation were derived from older Palaeozoic and Precambrian rocks that were being eroded in uplifted blocks to the north.

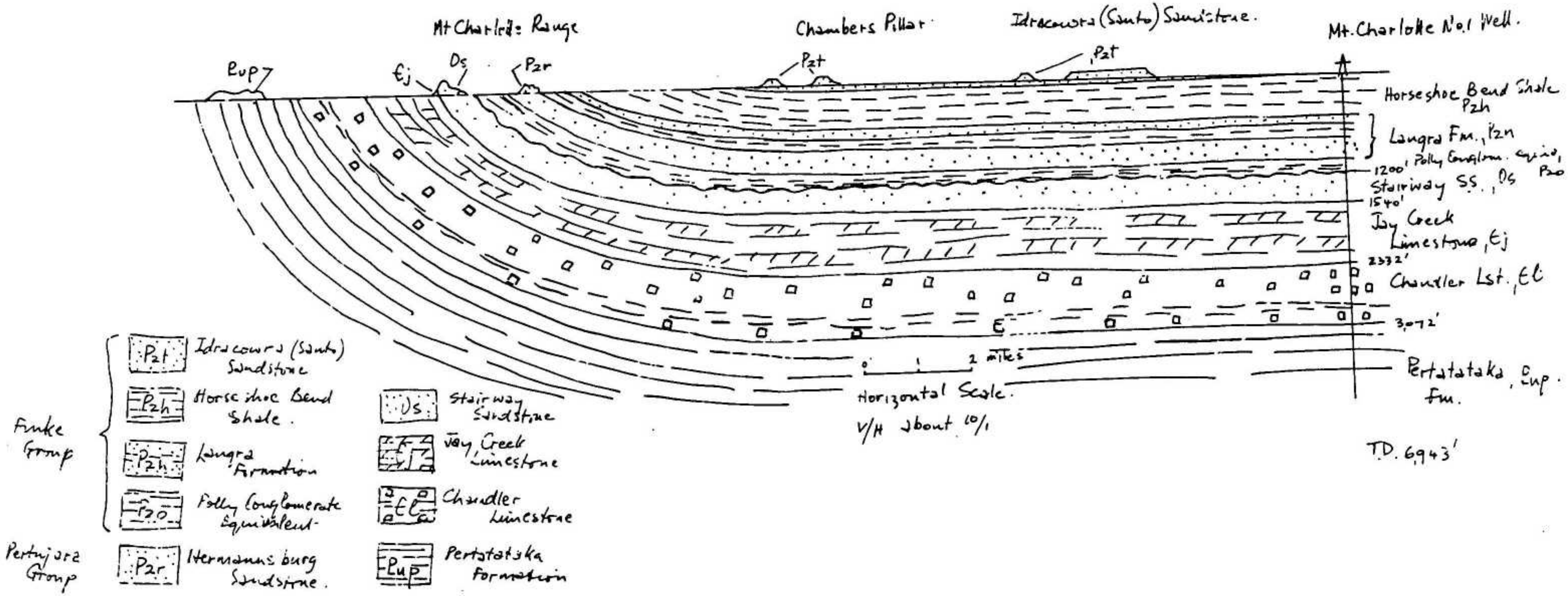
Brewer Conglomerate

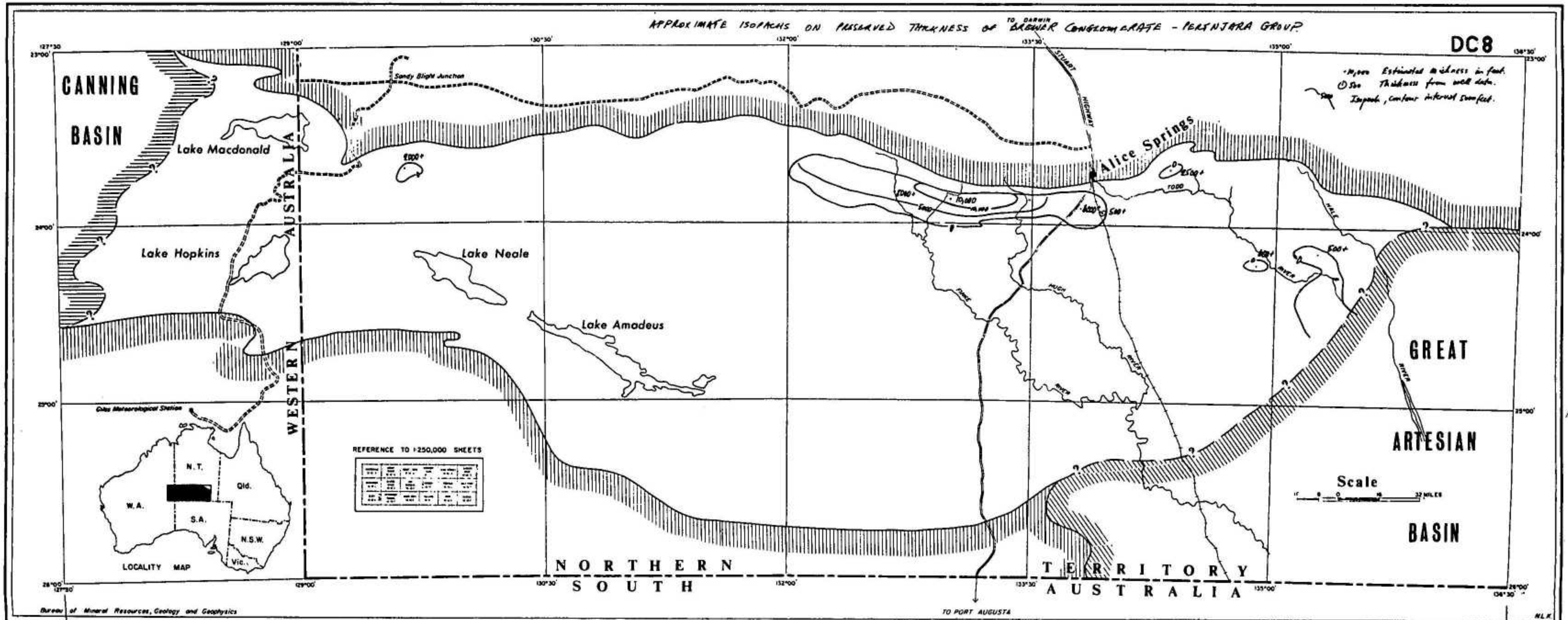
The Brewer Conglomerate, the youngest formation of the Pertnjara Group, consists of pebble, cobble and boulder conglomerate with minor interbedded sandstone and conglomeratic sandstone that overlies the Hermannsburg Sandstone. The type area is on the southern flanks of the western MacDonnell Ranges south of Stokes Pass (Figs. DC-14 and DC-15). The formation is exposed principally in the northern parts of the Basin in the Missionary and Brewer synclines south of the MacDonnell Ranges. Isolated remnants of the Brewer Conglomerate occur in the core of the Ross River Syncline, in the north-west part of the Hale River Sheet area, in exposures about 10 miles south-east of Ligertwood Cliffs on the Mount Rennie Sheet area, and near Larrier Bore on the Rodinga Sheet area. For the most part the outcrops are covered by an unconsolidated mass of the weathered-out phenoclasts in rounded hills (Fig. DC-19); very little of the unweathered outcrop is visible.

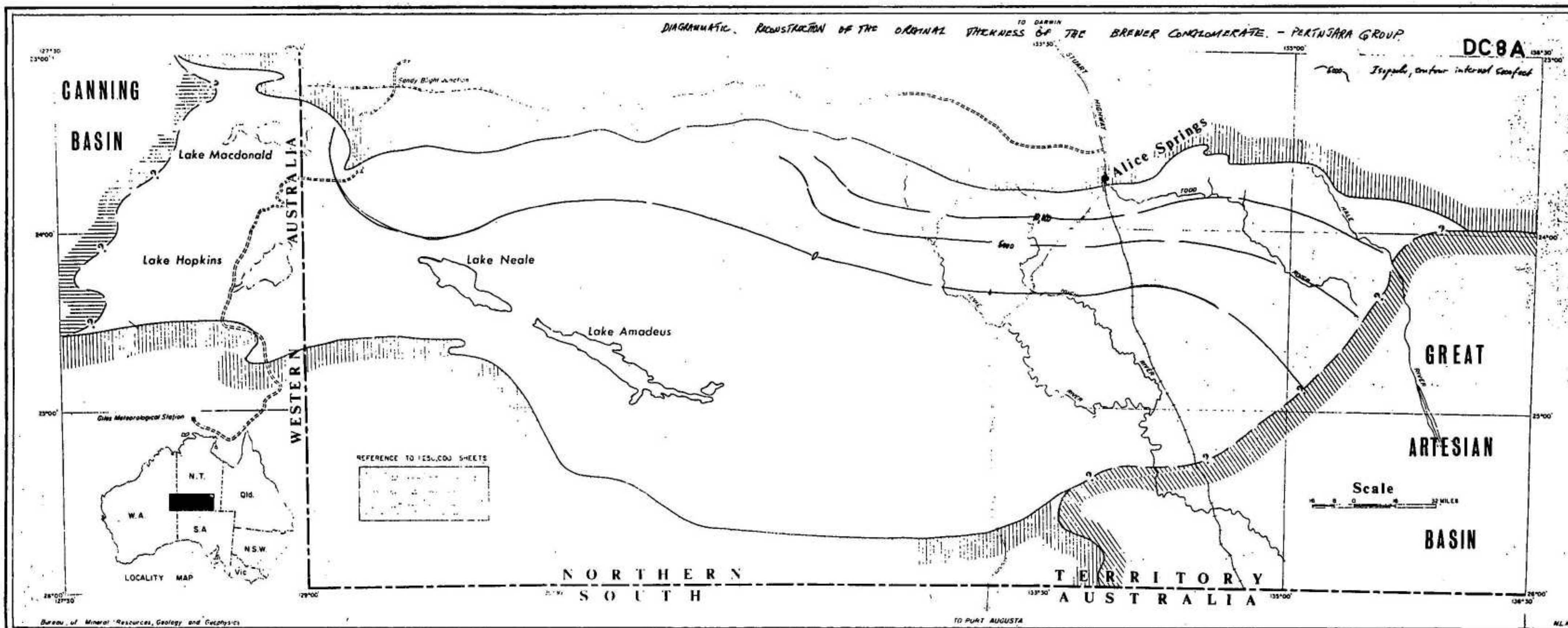
Contacts with the underlying Hermannsburg Sandstone are poorly exposed but are apparently conformable in western outcrops. In the area east of Ellery

DC 7.

POSSIBLE CORRELATION OF OUTCROPS IN THE MOUNT CHARLOTTE RANGE WITH FORMATIONS PENETRATED IN THE MOUNT CHARLOTTE No. 1 WELL.




APPROXIMATE ISOPACHS ON PRESERVED THICKNESS OF BREWER CONGLOMERATE - PERTNJARA GROUP
DC8
·10,000 Estimated thickness in feet.
500 Thickness from well data.
Isopach, contour interval 500 feet.
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Sandy Blight Junction
Alice Springs
STUART
HIGHWAY
TO DARWIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT
ARTESIAN
BASIN
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
W.A.
N.T.
Qld.
S.A.
N.S.W.
Vic.
Scale
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics


DIAGRAMMATIC RECONSTRUCTION OF THE ORIGINAL THICKNESS OF THE BREWER CONGLOMERATE. - PERTNJARA GROUP
DC8A
6000 Isopach, contour interval 500 feet
CANNING
BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
TO DARWIN
STUART
HIGHWAY
TODD
HALE
GREAT
ARTESIAN
BASIN
Scale
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A
N.S.W.
Vic
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
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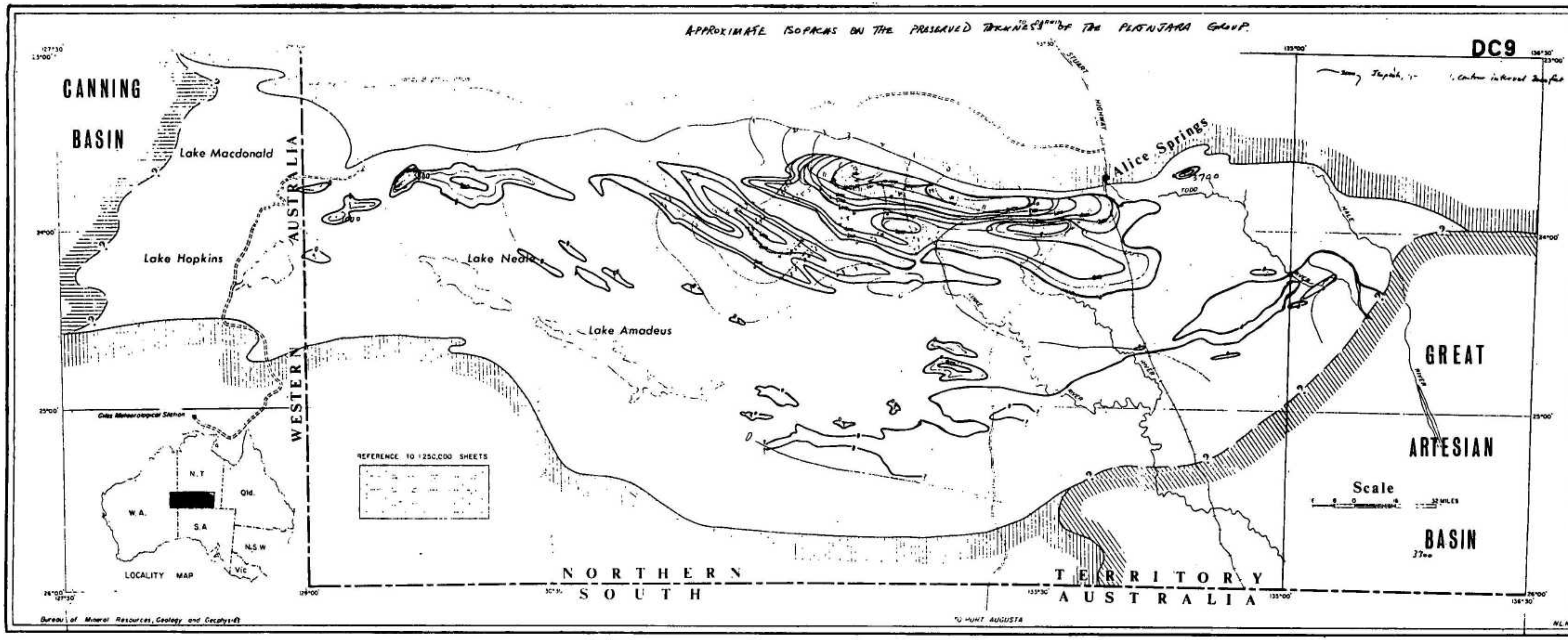
1


APPROXIMATE ISOPACHS ON THE PRESERVED THICKNESS OF THE PERTNJARA GROUP.
DC9
CANNING
BASIN
Lake Macdonald
Lake Hopkins
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
TODD
GREAT
ARTESIAN
BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
N.T
Qld.
W.A.
S.A
N.S.W
Vic
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
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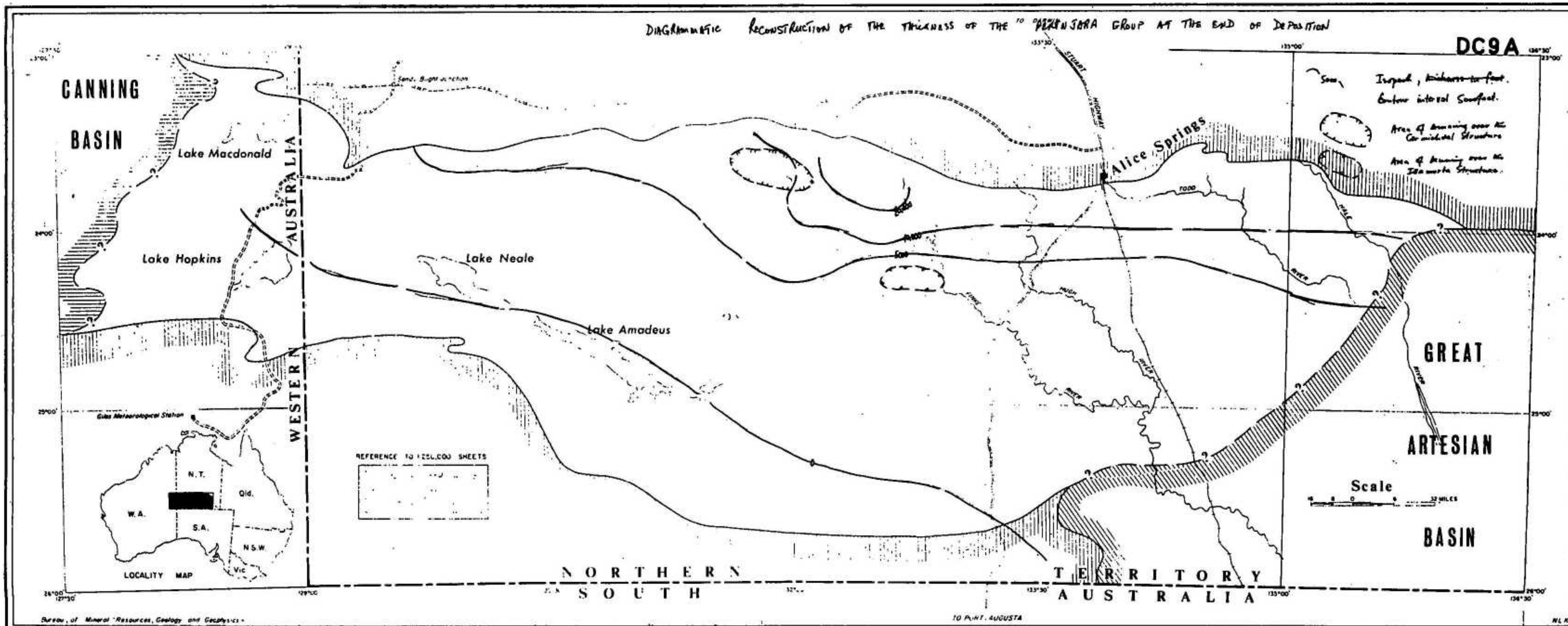
DIAGRAMMATIC RECONSTRUCTION OF THE THICKNESS OF THE PERTNJARA GROUP AT THE END OF DEPOSITION
DC9A
CANNING BASIN
Lake Macdonald
Lake Hopkins
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
TODD
GREAT ARTESIAN BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
Giles Meteorological Station
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic
LOCALITY MAP
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
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Creek, along the northern margin of the Basin, the Brewer Conglomerate transgresses the Hermannsburg Sandstone and unconformably overlies the Mereenie Sandstone and Palaeozoic rocks as old as the Cambrian Jay Creek Limestone. In the eastern part of the Basin, in the Hale River area, the formation occupies a similar stratigraphic position and rests unconformably on rocks as old as the Proterozoic Pertatataka Formation. It is apparent that a vigorous period of erosion of the uplifted blocks in these areas, including erosion of the Hermannsburg Sandstone in the eastern half of the Basin, preceded deposition of Brewer Conglomerate. The top of the formation is mostly an erosion surface but it is locally overlain by remnants of Tertiary lacustrine deposits. At the eastern edge of the Basin the distribution of the formation suggests that it continues beneath the sediments of the Great Artesian Basin and may be unconformably overlain by the Permian Crown Point Formation.

The thickness of the Brewer Conglomerate can only be estimated because outcrops are mostly covered by lag gravels and most of the observed dips were probably measured on cross-beds. The formation is about 4000 feet thick under Brewer Plain (Wells et al. 1967, in press). The maximum thickness of the formation probably does not exceed 10,000 feet and occurs on the northern flanks of the Missionary Syncline. Seismic surveys by Magellan Petroleum Corp. (Krieg and Campbell, 1965) suggest that about 10,000 feet of the Pertnjara Group occurs on the axis of the Missionary Syncline south of Glen Helen Gorge, and indicates that the Brewer Conglomerate has a maximum thickness of about 8000 feet in this area. Isopachs on the formation are shown in DC-8, and a diagrammatic reconstruction of the original thickness is shown in DC-8A.

No fossils have been found in the formation apart from those present in the derived phenoclasts. The formation may be as young as Carboniferous.

The Brewer Conglomerate consists of a polymictic pebble, boulder and cobble conglomerate with phenoclasts of most of the older formations, including the Precambrian Arunta Complex. Where the matrix is preserved it is generally calcareous sandstone. The conglomerate has some thick lenses of pebbly sandstone and on the south side of the Missionary Plain the formation changes to a predominantly calcareous pebbly and cobbly sandstone.

The Brewer Conglomerate is a continental synorogenic deposit probably formed mostly in a fluvial environment. The sediments accumulated in coalescing alluvial fans sloping southwards from high mountain ranges to the north. These piedmont deposits lie next to the Basin margin where an orogenic episode contemporaneous with deposition produced mountains flanking the subsiding basin. The deposits are poorly sorted and decrease in grain size southwards. The freshness of the phenoclasts, including unweathered feldspars in igneous fragments, suggest erosion in an arid climate. Bedding is poorly developed. The degree of rounding of the fragments in some places suggest reworking of parts of the formation in the fluvial environment. The variety of rock fragments indicate rapid and deep erosion of the source area along the northern margin of the Basin.

FINKE GROUP

The form 'Finke River Sandstone or series' of Chewings (1914) was used for the sediments exposed between Horseshoe Bend and Finke. The name was revised to Finke Group by Wells et al. (1966) and used in a more restricted sense for the sediments which occur unconformably below Permian rocks of the Crown Point Formation and Mesozoic sediments, and unconformably overlie Pre-cambrian rocks in the Finke Sheet area. The Group consists of four conformable formations, the Polly Conglomerate at the base, followed by the Langra Formation, the Horsehose Bend Shale and the Idracowra Sandstone. The Santo Sandstone, a formation mapped in the area south of the Mount Charlotte Range, lies conformably above the Horseshoe Bend Shale of the Finke Group and is undoubtedly contiguous with the Idracowra Sandstone of the Finke Group mapped further south. However it has not been formally included in the Finke Group and at present is regarded as a separate formation.

Outcrops of the Finke Group are confined to the south-eastern part of the Amadeus Basin and form part of the western edge of the Great Artesian Basin succession. The solid geology of the Finke Group is shown in figure DC-1 and the outcrop distribution in figure DC-2. The sediments are for the most part flat lying and occur in mesas, buttes and poorly exposed mounds usually with a thick duricrust capping. The largest part of the Group is obscured by Quaternary wind blown sand. Sediments of the Finke Group undoubtedly underlie large areas of the Hale River and McDills Sheet areas where they are covered by Permian and Mesozoic rocks. Sediments identified as the Finke Group have been intersected in the Mount Charlotte No. 1 Well where they overlie the Ordovician Stairway Sandstone of the Larapinta Group, and in the McDills No. 1 Well between the Mereenie Sandstone below and Permian rocks above. The sediments of the Finke Group transgressed the southern limit of deposition of the Larapinta Group and, in part, the Mereenie Sandstone. The basal unconformity of the Group shows that the depositional surface included large areas of Precambrian crystalline basement of the Musgrave Complex, and Proterozoic sediments.

The Finke Group is about 1500 feet thick in outcrop. Subsurface it is about 3000 feet thick in the McDills No. 1 Well and an incomplete section of 1150 feet is present in the Mount Charlotte No. 1 Well. The Finke Group is laterally equivalent to at least a large part of the Pertnjara Group and therefore is probably mostly Devonian in age.

Polly Conglomerate

The oldest formation of the Finke Group, the Polly Conglomerate (Wells et al. 1966), is exposed near the Black Hill Range where it unconformably overlies the Proterozoic Winnall Beds, and in the Umbeara area where it unconformably overlies Precambrian crystalline rocks. In the Mount Charlotte No. 1 Well the equivalent horizon below the Langra Formation is a red shale about 150 feet thick which lies on the Stairway Sandstone. In the McDills No. 1 Well the interval correlated with the Polly Conglomerate is 1290 feet thick (5800 - 7090 feet). In outcrop it is about 200 feet thick in the Black Hill Range and about 80 feet was measured at Horseshoe Bend on the Finke River. The formation is a polymictic conglomerate with pebbles, cobbles and boulders of granite, metamorphic and sedimentary rocks. Near Umbeara, where it overlies a granitic mass, the phenoclasts are mainly granite and vein quartz; near the Black Hill Range there is a high percentage of angular siltstone and sandstone fragments derived from the underlying Winnall Beds. Near this ridge of Proterozoic rocks the Phenoclasts are up to 8 inches across and consist of pink granite, porphyritic rocks, pegmatite, sandstone and siltstone from the Winnall Beds, some quartz and a few boulders of pink dolomite, probably from the Bitter Springs Formation. In the McDills No. 1 Well the sequence identified with the Polly Conglomerate has pebbles (2-3 inches across) of quartzite, chert, granite, marble and shale in a matrix of fine to coarse grained subangular sandstone. It contains some interbeds of fine to medium grained sandstone and shale. The composition and distribution of the formation indicates vigorous erosion of uplifted areas of Precambrian crystalline and sedimentary rocks, and deposition in a fluvial environment.

Langra Formation

The overlying Langra Formation also contains beds of conglomerate but consists predominantly of sandstone. The three units in the sequence established by Wells et al. (1966) at Horseshoe Bend are from top to bottom -

50 feet sandstone, white, fine grained

50 feet - siltstone, red-brown, micaceous

400 feet - sandstone yellow, white, poorly sorted, cross-bedded and interbedded conglomerate and red siltstone

The phenoclasts in the conglomerate in the basal unit are granite, banded chert, porphyry, metamorphic rocks and large fragments of Ordovician Stairway Sandstone. The surface distribution of the formation is larger than that of other formations of the Finke Group and the upper sandstone unit forms the greater percentage of the outcrops. The formation is about 500 feet thick in marginal exposures but in McDills No. 1 Well it is about 1730 feet thick and 530 feet thick in Mount Charlotte No. 1 Well. The sediments in the Mount Charlotte No. 1 Well can be divided into the three units found in outcrop; the upper sandstone is 110 feet thick, the middle shale 130 feet and the lower sandstone 290 feet thick. No conglomeratic units were encountered in this sequence. The sediments penetrated in McDills No. 1 Well were fine to coarse grained, cross-bedded, subangular to well rounded, porous sandstone, calcareous in its upper part and conglomeratic (with phenoclasts up to 3 inches across) in the lower part. It has interbeds of grey to green shale and the sandstone is in part pyritic. The conglomerate of the Langra Formation in the McDills No. 1 Well section contains red and green shale and quartz pebbles, quartzite, marble and some granite and large red and green shale inclusions.

Outcrops of the Langra Formation are confined to the Finke Sheet area but it probably occurs subsurface to the west on the Kulgera Sheet areas and northwards to the Hale River and Rodinga Sheet areas.

The sediments of the formation show slump structures, cut and fill and penecontemporaneous brecciation of the finer grained sediments within the unit. The sediments and structures indicate rapid erosion of source areas and rapid deposition in a predominantly fluvial environment.

Horseshoe Bend Shale

The red-brown and green, biotite shale and siltstone conformably overlying the Langra Formation has been named the Horseshoe Bend Shale (Wells et al. 1966). It is overlain disconformably by the Idracowra Sandstone and apparently conformably by the Santo Sandstone and unconformably by the Crown Point Formation and De Souza Sandstone. It is widely distributed over the central portion of the Kulgera and Finke Sheet areas. The formation is gypsiferous, contains pseudomorphs after halite, ripple marks, mud cracks and inclusions of gypsum and calcite. It is about 300 feet thick at Horseshoe Bend, 280 feet in McDills No. 1 Well and 460 feet in Mount Charlotte No. 1 Well. In the McDills No. 1 Well it is in part interbedded with fine, calcareous sandstone.

The finer grained sediments of the formation suggest less active erosion of the source areas with deposition probably in a fluviatile or estuarine environment. The large proportion of biotite and muscovite indicates that the source areas were probably mainly Precambrian crystalline rocks.

Idracowra Sandstone

The youngest formation of the Finke Group, the Idracowra Sandstone (Wells et al. 1966) is found only in the area between Horseshoe Bend on the Finke River and Idracowra Homestead. It disconformably overlies the Horseshoe Bend Shale and the top of the formation is an erosion surface. It is a medium to fine grained kaolinitic quartz sandstone, thin bedded or in places massive, with some clay pellets and rare quartz and quartzite pebbles. It is generally well sorted, but in places contains interbeds of poorly sorted, angular, yellow sandstone. It is seldom more than 200 feet thick in outcrop. The top of the formation is usually strongly silicified and covered by grey billy. The environment of deposition was probably mostly fluvial.

Santo Sandstone

The Santo Sandstone (Wells et al. 1967) is a white cross-bedded and pebbly sandstone which unconformably overlies the Horseshoe Bend Shale. It has an exposed maximum thickness of 200 feet and is found only in the area between the Mount Charlotte Range and Idracowra Homestead where it crops out in flat lying beds in isolated buttes and mesas (Fig. DC-20). The top of the formation is eroded. It is a white, poorly sorted sandstone with minor silty, kaolinitic sandstone and conglomeratic sandstone with pebbles and cobbles of vein quartz, metamorphic quartzite, chert and silicified sandstone up to 6 inches across. The pebbles and cobbles are generally well rounded unlike the detrital quartz in the matrix which is poorly rounded in most specimens. It is generally friable, thin to thick bedded and cross-bedded and contains heavy mineral concentrations in a few beds. Silt is either intergranular or else forms large lenses and pellets.

Outcrops of the Santo Sandstone are contiguous with those of the Idracowra Sandstone.

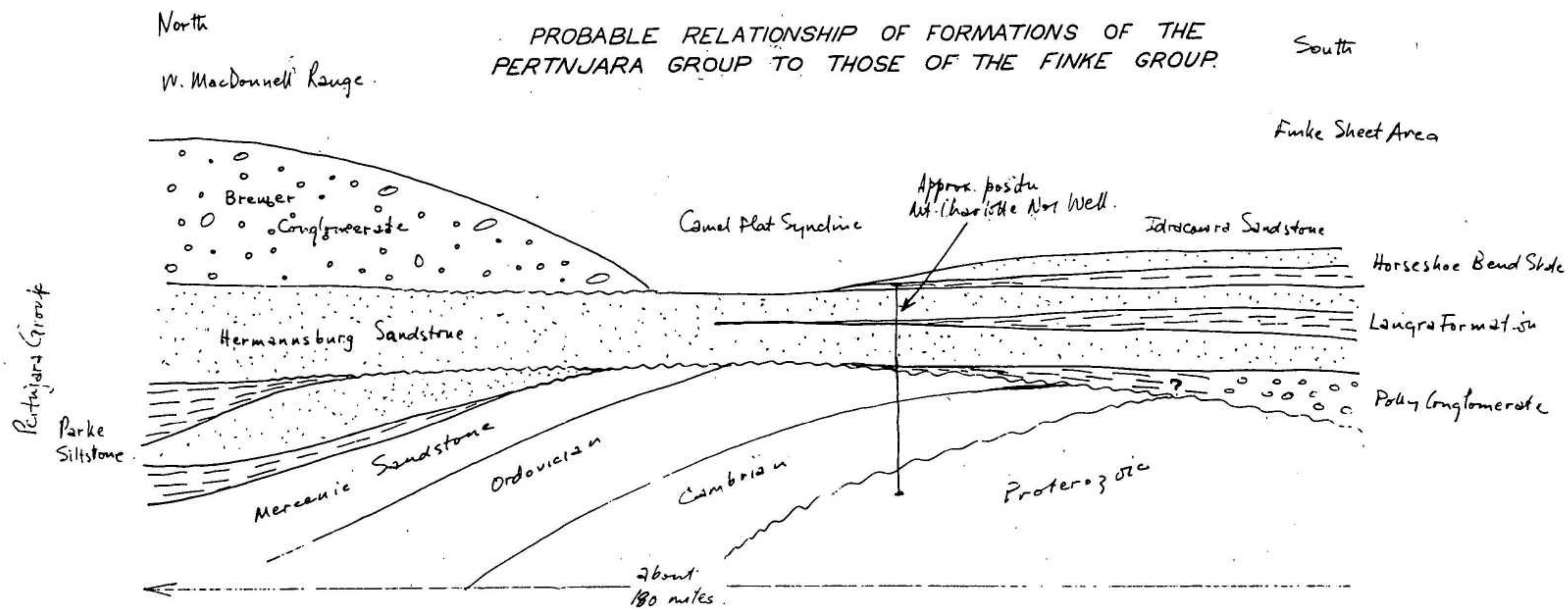
Correlation and Age of the Pertnjara and Finke Groups

Evidence for the interfingering of the Pertnjara and Finke Groups has been deduced mainly from outcrops in the area south and west of the Mount Charlotte Range and from a correlation of the formations of the Pertnjara Group with the sequence penetrated in the Mount Charlotte No. 1 Well (Fig. DC-7). In outcrop the Stairway Sandstone is overlain by a basal red-brown siltstone of the Pertnjara Group on the south side of the Mount Charlotte Range and is thought to be continuous with the red brown siltstone penetrated above the Stairway Sandstone in the Mount Charlotte No. 1 Well. Hence the sandstone of the Pertnjara Group in outcrop is probably continuous with the basal sandstone unit of the Langra Formation in the well section. The upper sandstone unit of the Langra Formation is not exposed south of the mount Charlotte Range but is probably contiguous with the upper part of the sandstone sequence exposed at Mount Duff south of the Finke River, the upper white sandstone of the Hermannsburg Sandstone exposed in the Camel Flat Syncline, Deep Well, Mount Ooraminna and perhaps even to the white sandstone beneath the contact with the Brewer Conglomerate south-east of Williams Bore.

On the north flank of the Camel Flat syncline the upper white sandstone of the Hermannsburg Sandstone is separated from the lower red-brown sandstone of the formation by a thin red-brown siltstone. This siltstone is

DC 10

PROBABLE RELATIONSHIP OF FORMATIONS OF THE PERTNJARA GROUP TO THOSE OF THE FINKE GROUP.



DC·11.

SKETCH CROSS-SECTIONS SHOWING HISTORY OF SEDIMENTATION OF THE PERTNJARA AND FINKE GROUPS.

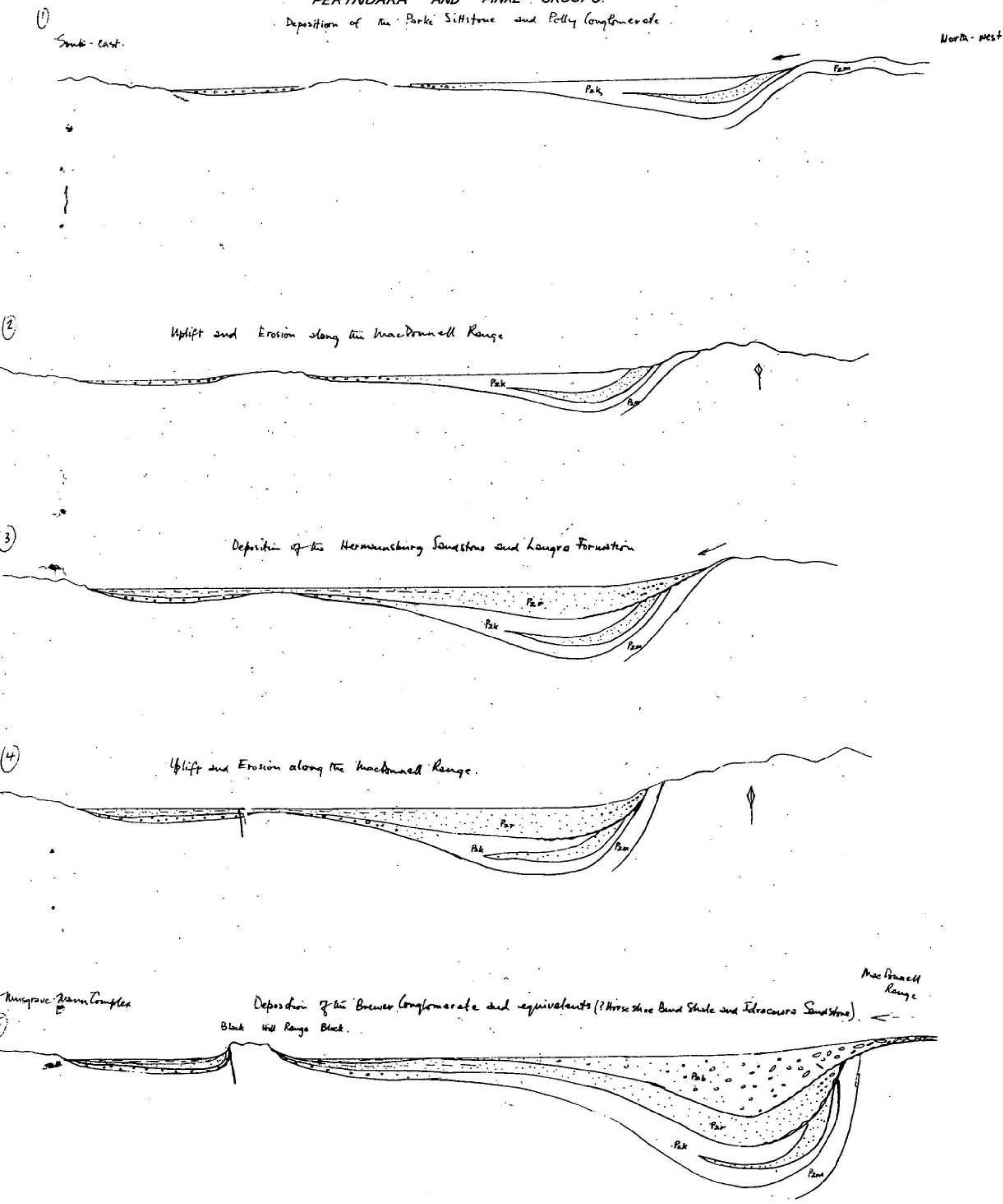
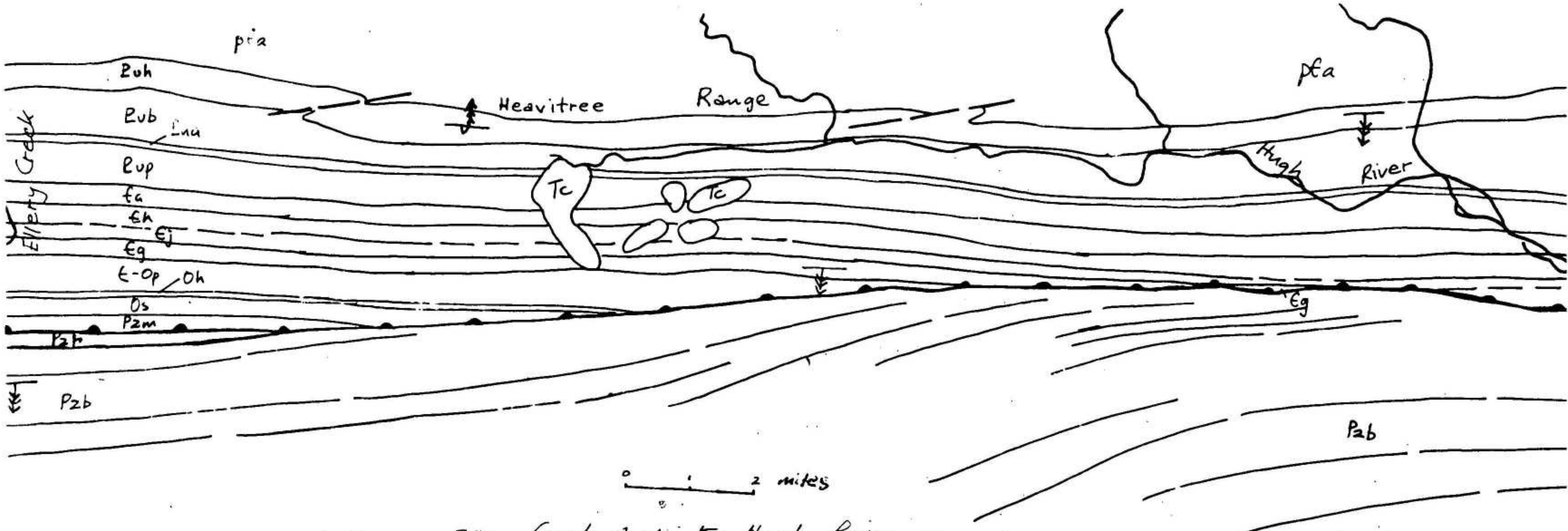


Fig. DC.12 Unconformity at the base of the Pertnjara Group between Ellery Creek and the Hugh River.

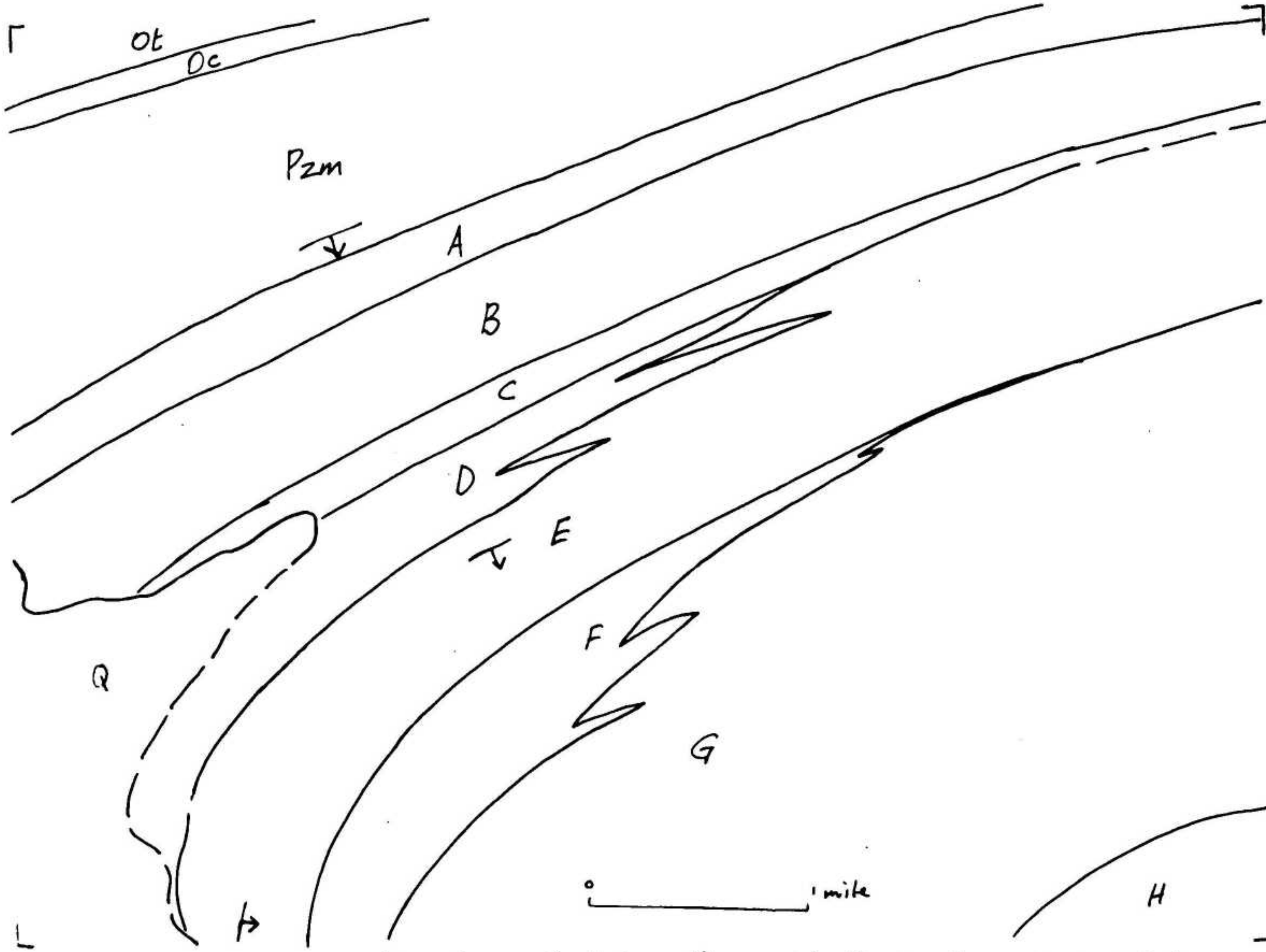


MacDonnell Ranges between Ellery Creek and the Hugh River. Solid geology showing unconformity at the base of the Pertnjara Group.

pЄa Arunta Complex, Puh Heavitree Quartzite, Pub Bitter Springs Formation, Pua Areyonga Formation, Pup Pertatataka Formation, Єa Arumbera Sandstone, Єh Hugh River Shale, Єj Jay Creek Limestone, Єg Goyder Formation, Є-Op Pacoota Sandstone, Oh Horn Valley Siltstone, Os Stairway Sandstone, Pzm Mereenie Sandstone, Pzp Pertnjara Group, Pzh Hermannsburg Sandstone, Pzb Brewer Conglomerate. —●—● Unconformity

Fig. DC-13 Overlay to photograph on previous page

Fig. DC-14 Units of the Pertnjara Group, western end of the MacDonnell Range.



Relationship of units of the Pertnjara Group at the western end of the Macdonnell Range

A, B and C = Parke Siltstone, (B is prob. ≡ fossil fish bearing Sandstone at the Mereenie Anticline)
D, E = Hermannsburg Sandstone, F, G and H = Brewer Conglomerate Pzm, Mereenie Sandstone; Oc, Carmichael Sandstone; Ot, Stokes Siltstone

Fig. DC-15 Overlay to photograph on previous page

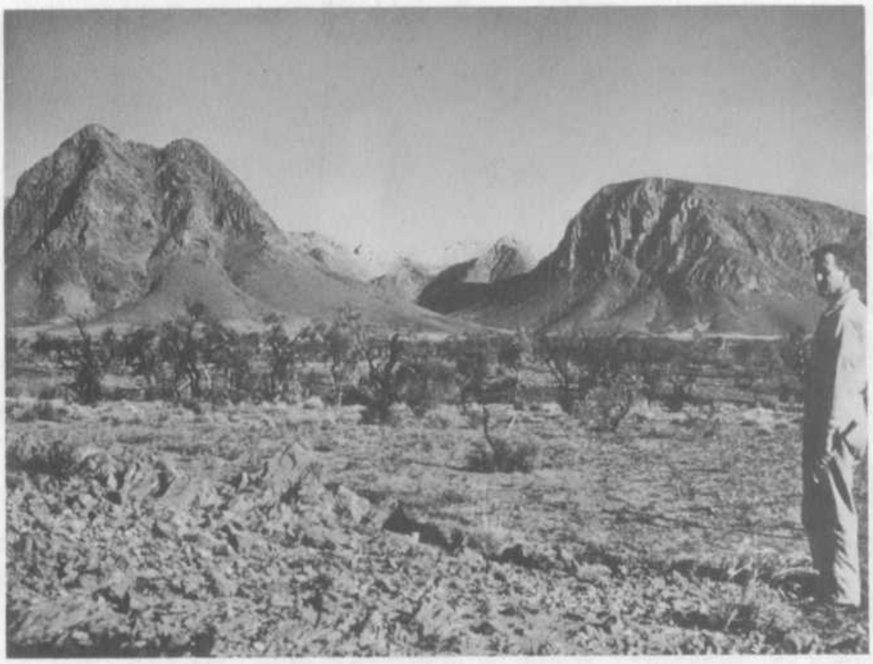


Fig. DC-16 Prominent hills of steeply dipping Hermannsburg Sandstone, Pertnjara Group, exposed at Gosses Bluff.
G/9153

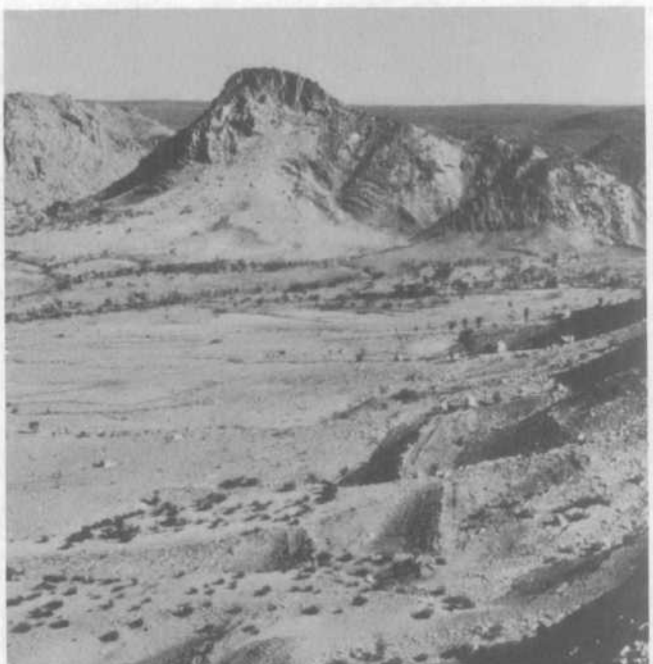


Fig. DC-17 Prominent hills of Mereenie Sandstone and Hermannsburg Sandstone on the western flank of Gosses Bluff. Thin-bedded Stokes Siltstone exposed on the lower slopes of the inside wall.
G/9109

Fig. DC-18 Basal conglomeratic beds of the Hermannsburg Sandstone, Pertnjara Group near the contact with the Mereenie Sandstone at Ellery Creek.
G/9152

Fig. DC-19 Brewer Conglomerate of the Pertnjara Group exposed on the south flanks of the western MacDonnell Range.
G/8579

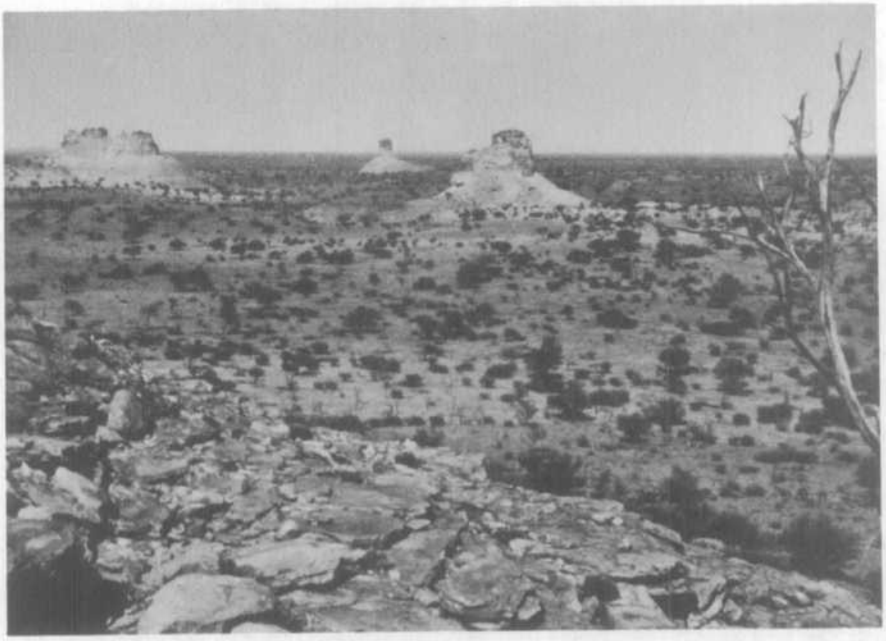


Fig. DC-20 Buttes of Santo Sandstone exposed near Chambers Pillar, south of the Mount Charlotte Range.
G/9128

most likely continuous with the middle red siltstone unit of the Langra Formation.

This relationship of the various units shows that interfingering of the Finke and Pertnjara Groups takes place in the area between the Mount Charlotte Range and the Finke River to the south (fig DC-10) and furthermore that the youngest formations of the Finke Group, the Horseshoe Bend Shale and Idracowra (Santo) Sandstone were most likely deposited at the same time as the Brewer Conglomerate.

The only definitive fossils found are fish plates and spores in the basal part of the Parke Siltstone indicating that the base of the Pertnjara Group is Upper Devonian. Sediments of the upper part of the Group cannot be dated with any accuracy. In the western part of the Basin outcrops of folded Pertnjara Group sediments occur close to outcrops of flatlying sediments interpreted as Permian in age. In the eastern part of the Basin, a few miles west of Allitra Tableland, the Brewer Conglomerate and Hermannsburg Sandstone are mapped as being overlain by sediments identified with the Permian Crown Point Formation. It seems reasonable to suppose then that parts of the Pertnjara Group may range up into the Carboniferous.

Indirect evidence for the age of the Group comes from radioactive age dating of the Precambrian Arunta Complex. The Pertnjara Group is mainly a synorogenic deposit so that any evidence for the age of the Alice Springs Orogeny which affected large parts of the Arunta Complex will also indicate the age of at least part of the Pertnjara Group. An age of 367 m.y. (Walpole and Smith, 1961) correspond to the formation of the Harts Range Pegmatite and to the age of the Alice Springs Orogeny which has affected the area. The fossil age and the apparent mineral age suggest the orogeny took place mostly in the Devonian.

Devonian fish are known from three distinct faunas in Australia (J.G. Tomlinson, pers. comm.). In Western Australia the fauna is marine and early Frasnian in age; in western N.S.W. it is non-marine and Famennian in age; the third fauna occurs in N.S.W., Victoria and the southern part of the Northern Territory. It is non-marine and late Frasnian or early Famennian in age. The western N.S.W. fauna may also be present in the Toko and Toomba Range areas in the Northern Territory. The fossils found in the Parke

Siltstone are comparable with the fauna found in units in other parts of Central Australia (Dulcie Sandstone and Cravens Peak Beds in the southern part of the Georgina Basin) and with south-eastern Australia. In the Ngalia Basin 7000 feet of sandstone and minor conglomerate unconformably overlie Lower Palaeozoic rocks. They are probably synorogenic continental deposits and resemble the Pertnjara Group. Farther north isolated outcrops of similar sandstone in the Wiso Basin may also be Devonian. The distribution of Devonian rocks in Australia is shown in Fig. DC-0 and the correlation of the Devonian rocks in central and Western Australia is shown in DC-01.

Geological History of the Pertnjara and Finke Groups

During the Alice Springs Orogeny in the Devonian a large block of Precambrian basement rocks and its superincumbent sedimentary load were uplifted and the base of the sedimentary sequence was complexly infolded with the crystalline basement. The Palaeozoic and Precambrian rocks of the orogen were deeply eroded and a thick wedge of molasse was deposited on the southern flank of the mountain chains to form the Pertnjara Group.

The thickest and coarsest sediments accumulated adjacent to the source area, and the youngest formation (the Brewer Conglomerate) is confined to a relatively narrow strip on the southern flank of the MacDonnell Ranges. Two cycles of derived phenoclasts in this formation, in reverse stratigraphic order, suggest successive major uplifts during sedimentation. The underlying Parke Siltstone and Hermannsburg Sandstone are more widespread but thin towards the south-east part of the Basin where the finer grained and better sorted parts of the formation were deposited.

The bulk of the sediments of the Pertnjara Group were confined to the northern part of the Basin by a topographically higher region probably caused by a basement swell along the south eastern margin of the Basin, separating two subsiding areas with the Pertnjara Group deposited in the northern basin and the Finke Group to the south. The sequence of events representing the history of sedimentation of the Pertnjara and Finke Groups is shown diagramatic in Figure DC-11. The initial sedimentation of fine grained sediments of the Pertnjara Group was probably in large inter-connected lakes. The large thickness of siltstone with minor sandstone interbeds indicates stable conditions of deposition in shallow water with the

DISTRIBUTION OF DEVONIAN ROCKS IN AUSTRALIA.

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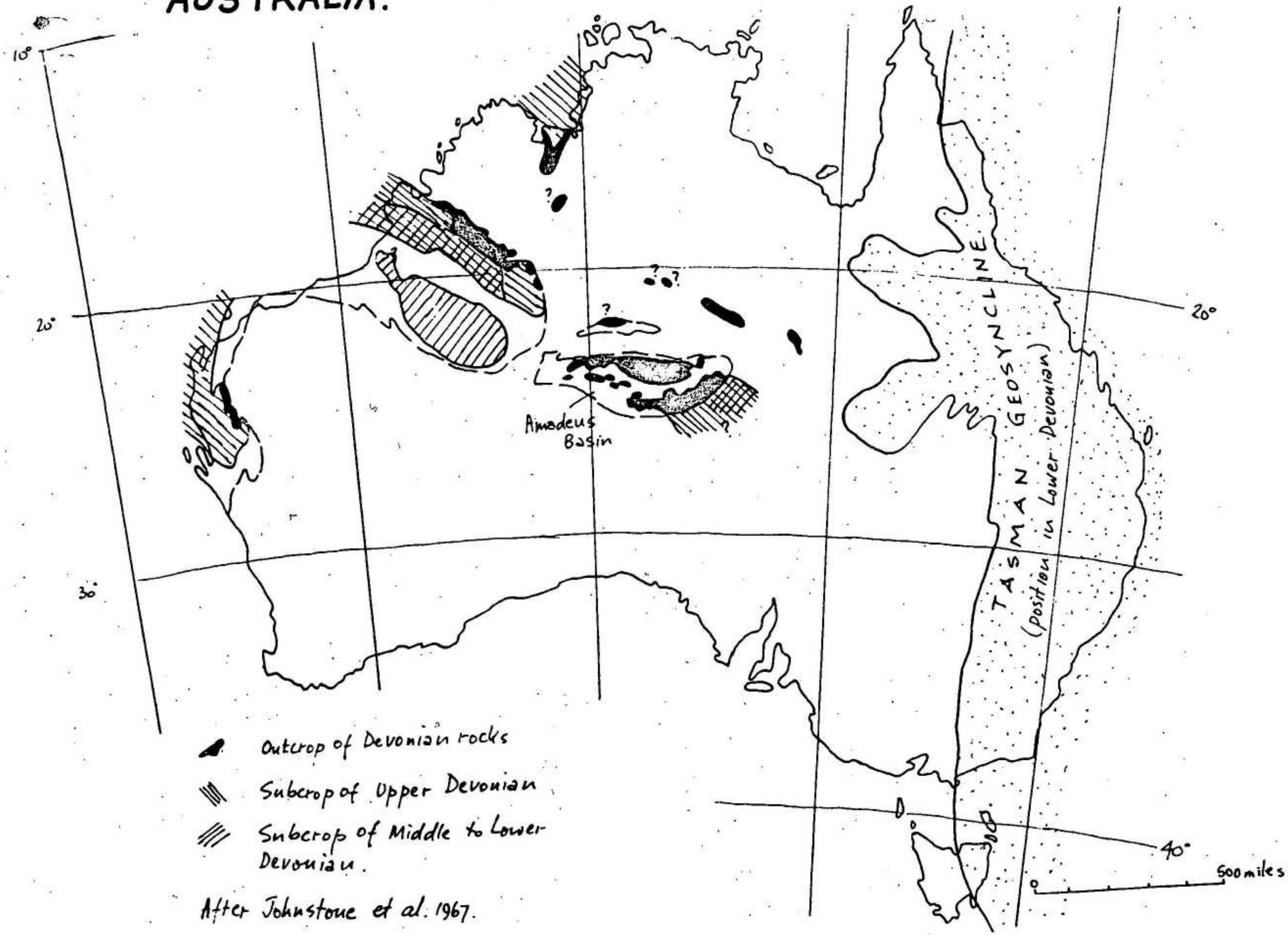

After Johnstone et al. 1967.

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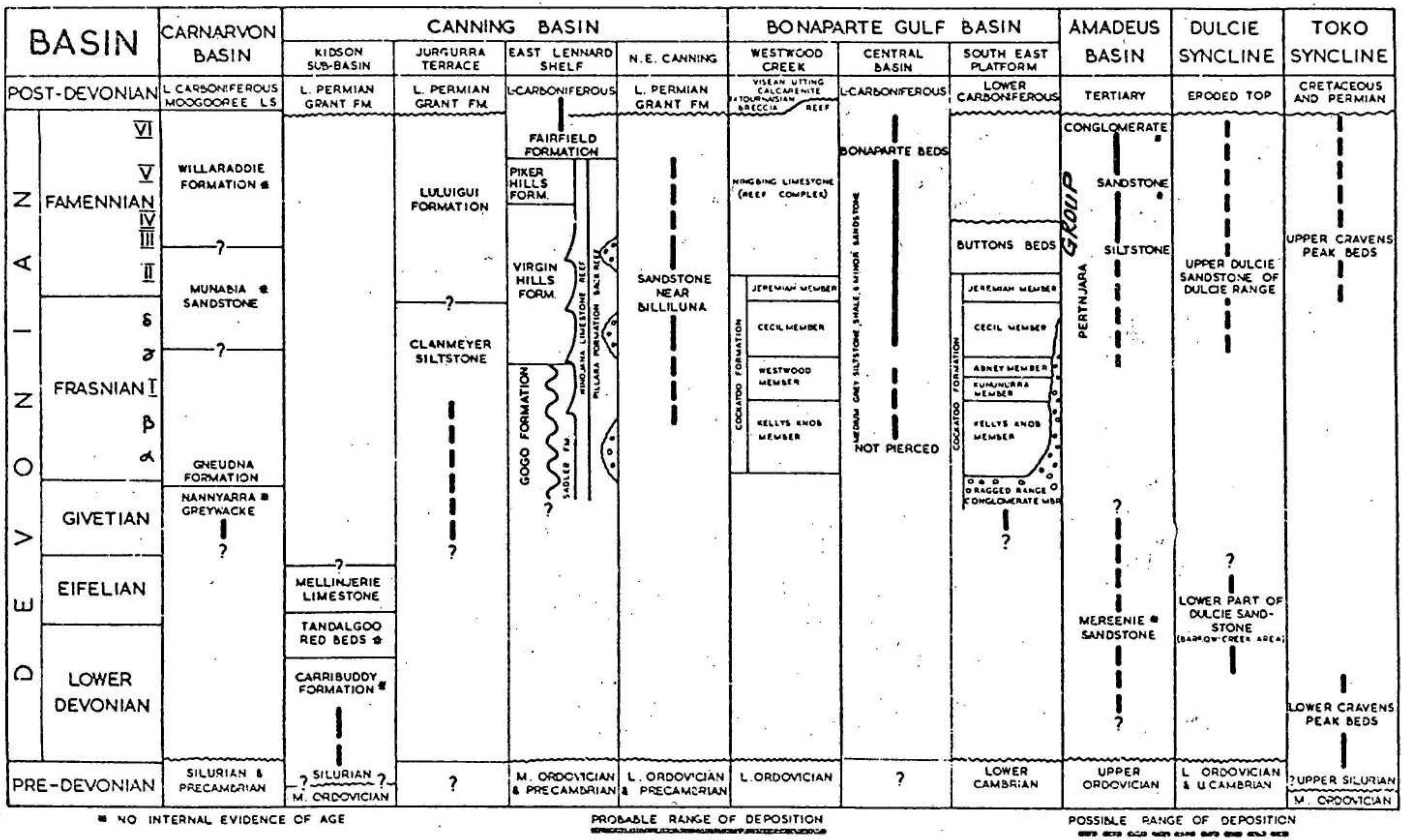


From Johnstone et al. (1967).

coarsest and largest volume of material deposited closer to the source areas in the north. The presence of salt casts in the siltstone indicates that the water was brackish and subject to periodic evaporation. The provenance for sediments in the Parke Siltstone included large areas of Mereenie Sandstone exposed in the eastern part of the Basin. Prior to the deposition of the overlying Hermannsburg Sandstone a large part of the Mereenie Sandstone was removed in these areas.

The succeeding sandstone and minor conglomerate of the Hermannsburg Sandstone were deposited mainly in a fluvial environment with coarser material in alluvial fans next to the uplifted orogen. The better sorted, finer grained and thinner sediments were deposited on a wide shelf or platform in the south-eastern region. At this stage the Mereenie Sandstone had probably been removed from a large part of the provenance so that erosion of Palaeozoic and Precambrian rocks supplied a large part of the detritus. The older Parke Siltstone was locally removed adjacent to the gradually rising orogen and the Hermannsburg Sandstone overlapped the Parke Siltstone and was deposited on the Mereenie Sandstone in the eastern half of the Basin. The main paroxysm of the Alice Springs Orogeny then caused major uplifts, and vigorous erosion of this provenance of Precambrian and Palaeozoic rocks produced thick molasse deposits to form the Brewer Conglomerate. Erosion of the Hermannsburg Sandstone took place next to the mountain front and the formation was overlapped by the transgressive conglomerate which was deposited on the upturned edges of Palaeozoic and Precambrian rocks exposed in the eroded mountain cores. Elsewhere in the subsiding Basin there was apparently conformable deposition on the Hermannsburg Sandstone.

The coarse detritus of the Brewer Conglomerate was probably deposited as piedmonts, and then reworked and distributed by large rivers. The conglomerates grade into finer conglomerates and conglomeratic sandstone to the south but are not preserved south of Missionary Plain. It is likely that the finer grained constituents were transported a considerable distance further southeast.

Fine grained sediments derived from the provenance at the northern edge of the Basin intermingled with coarser sediments derived from uplifted areas of Precambrian rocks in the Musgrave Block in the south-eastern areas of the Basin to form the Finke Group. Coarse conglomeratic sediments of the

Finke Group are known to occur as far east as the McDills No. 1 Well in the Simpson Desert suggesting major uplifts of the provenance area.

While the Parke Siltstone of the Pertnjara Group was being deposited in the north, a freshwater conglomerate (Polly Conglomerate) was filling hollows in the slowly sinking area of the basement swell and marginal basement outcrops and formed local piedmont deposits. The basement swell then became ineffectual as a barrier, and the finer equivalents of the Hermannsburg Sandstone overlapped it to the south-east to interfinger with the Langra Formation. The finer grained equivalents of the Brewer Conglomerate were probably also transported to this area and contributed to the formation of the Horseshoe Bend Shale and Idracowra (Santo) Sandstone. The Idracowra (Santo) Sandstone, the youngest formation of the Finke Group, is not known south of about latitude 25°15' and was probably confined to the area north of the Black Hill Range. Vertical dips in the Finke Group next to this ridge indicate uplifts of Proterozoic rocks in this range probably during the later stages of sedimentation.

The depositional environment of the Finke Group was mainly continental and probably involved a combination of local piedmont and alluvial flood plain environments. The coarse basal conglomerates were probably formed as piedomonts adjacent to outcrops of Precambrian rocks and well information suggests they grade northwards into red fluviatile siltstone. Coarser sediments apparently persisted a good deal farther south-east where they have been identified in the McDills No. 1 Well. Deposition of the finer grained sediments of the Group may have been by sluggish streams or in temporary lakes on broad alluvial plains under unstable shelf conditions. Periodic evaporation would account for the mud cracks and halite pseudomorphs in the siltstones and the primary red colouration was preserved in the oxidising environments. The red beds were probably formed on the piedmont and upper reaches of the alluvial plain. Red soil on interfluvial areas provided the colouring matter and erosion of the rising source areas would provide red clay from the soil and unweathered feldspar from the rapidly incising valleys. The Precambrian source areas were exposed for a considerable time and deep weathering (including lateritization?) of the crystalline and sedimentary rocks would provide a readily available source of iron oxides. Palaeomagnetic studies by Irving (1964) show that, during the Devonian, Australia was in equatorial regions and if a warm humid climate is postulated then red soils could develop

LB1. Ligertwood Beds at Ligertwood Cliffs. Lower dark calcareous conglomerate and mesa of upper sandstone beds in background.
M/139-9

on the source areas.

The large scale heterogeneity in the Langra Formation, cut and fill structures, brecciation of the finer beds, and irregular textural variations are consistent with the structures commonly found in alluvial flood plain deposits.

LIGERTWOOD BEDS

The Ligertwood Beds were defined by Wells, Forman & Ranford (1965). In the westernmost exposures they consist of an upper unit of fine to coarse conglomerate, poorly sorted, angular, medium to thin-bedded conglomeratic kaolinitic sandstone and coarse sandstone. The phenoclasts are probably mostly derived from those in the Sir Frederick Conglomerate. The lower unit consists of bedded, fine to coarse fragments of angular to subrounded dolomite and limestone probably derived from the unconformably underlying Bitter Springs Formation. The contact between the units appears to be conformable. The beds dip locally at more than 10° but are mostly flat-lying. The thickness has not been measured but may be several hundred feet in places.

Further west on the Mount Rennie Sheet Area two units are again distinguishable (LB-1). The lower unit is interbedded sandstone, calcareous sandstone and calcareous pebble and cobble conglomerate. The conglomerate contains angular to subangular tightly packed fragments of chert and dolomite derived from the Bitter Springs Formation. 40 feet of this unit is exposed and is disconformably overlain by 30 feet of silicified sandstone, conglomeratic sandstone and pebble conglomerate of the upper unit. The conglomerate has pebbles of siltstone silicified sandstone, chert, and fine and medium sandstone. The lower unit was eroded and cut by steep sided channels before the upper unit was deposited.

North of the type area at Ligertwood Cliffs the lower unit is absent and the upper unit unconformably overlies the Carnegie Formation. The distribution of the Ligertwood Beds follows major faults. Because the main period of folding in the area affects the Pertnjara Group, the Ligertwood Beds are considered to be younger. They are probably Upper Palaeozoic.

PERMIAN

Crown Point Formation, Buck Formation and Undifferentiated Permian Rocks

Sediments of Permian age occur on the fringes of the Amadeus Basin at its eastern and western extremities. The Permian sediments on the western margin have been described by wells et. al. (1964) and have been named the Buck Formation. The reference area is in the Buck Hills in the Macdonald Sheet area, Western Australia. Many of the outcrops of Permian rocks in this area were not specifically identified and are mapped as undifferentiated Permian.

Scattered remnants which probably formed a sheet continuous with the Buck Formation occur as far east as Warman rocks on the Mount Rennie Sheet area (Wells et. al., 1965). The Buck Formation is about 150 feet thick and consists of poorly sorted coarse sandstone, conglomerate with tillitic texture and siltstone (Figs. PE-1 and PE-2). The erratics are granite, schist, vein quartz, acid porphyry and black and white banded chert, and many are striated and faceted. In many places the erratics have deformed the underlying sediments and beds of coarse sandstone have deformed underlying incompetant siltstone beds (Fig. PE-4). The formation unconformably overlaps folded Proterozoic and Precambrian rocks of the Amadeus Basin succession and the surface of the unconformity has considerable relief. At one locality a possible glacial pavement occurs where the formation is in contact with the Heavitree Quartzite in the Dover Range. The faint striae on the pavement trend north-south. Wells et. al. (1964) state that the unit includes the terrestial and fluvio-glacial sediments which were products of a continental glaciation. The top of the unit has been eroded or is obscured by Quaternary sand.

These Permian rocks are considered as marginal deposits of the Canning Basin which lies to the north-west and to the Officer Basin in the south-west. The closest outcrops dated by fossils were found to the west in a core from a B.M.R. seismic shot hole, 28 miles west of Mount Everard in the Gibson Desert (Wells, 1963). The sample contained Lower Permian spores and pollen grains equivalent to the Nuskoisporites Assemblage defined by Balme (1964) (P.R. Evans, pers. comm.). To the north, rocks dated as Permian by fossils are found in the north-eastern part of the Canning Basin (Casey and Wells, 1964) and occur as far south as the Waterlander Breakaway. Lower Permian spores were found in

Fig. PE-1 Conglomerate of the Buck Formation, Buck Hills. Phenoclasts of quartz-feldspar porphyry.
G/9151

Fig. PE-2 Permain boulder beds of the Buck Formation, north of Lake Macdonald, W.A.
G/9149

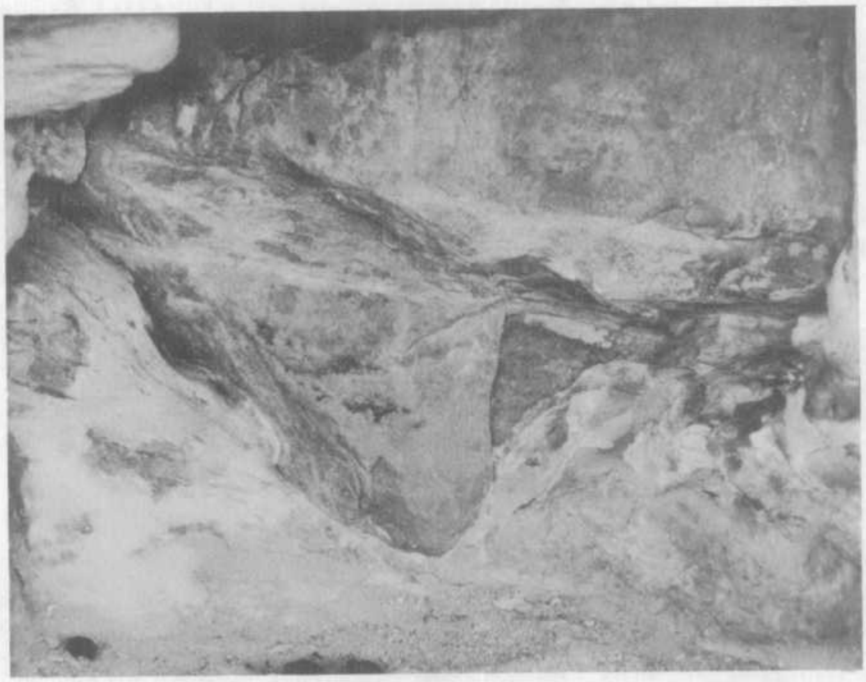


Fig. PE-3 Erratic in the Buck Formation showing deformation of the underlying sediments. Macdonald Sheet area, W.A.
M415/26, 27, 28.

Fig. PE-4 Flame structure in the Buck Formation, Macdonald Sheet area, W.A.
M415/29, 30

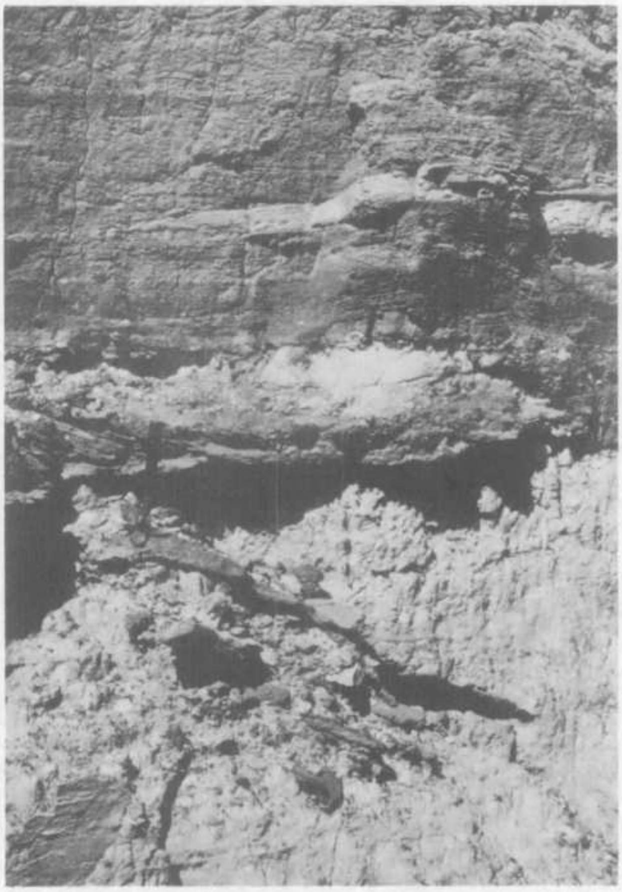


Fig. PE-5 Unconformable contact of the Crown Point Formation with the Langra Formation of the Finke Group near Rumbalara Siding. G/9117

Fig. PE-6 Reference locality of the Crown Point Formation at Crown Point on the Finke River. G/9133

Fig. PE-7 Impact marking on a quartzite boulder from the Crown Point Formation near Rumbalara Siding.
M403/22

Fig. PE-8 Large slump structures in the Crown Point Formation near Mount Humphries.
G/7520

the Point Moody No. 1 Well in the Stansmore Range (P.R. Evans 1966). The Buck Formation is similar lithologically to the Paterson Formation and Braeside Tillite (Traves, Casey & Wells, 1956), the Grant Formation (Guppy et al., 1958) and the Crown Point Formation, (Wells, Stewart, & Skwarko, 1966, in press).

In the south-eastern part of the Amadeus Basin the Crown Point Formation unconformably overlies sediments of the Finke Group (Fig. PE-5) and is unconformably overlain and overlapped by the Mesozoic De Souza Sandstone. Water bore information in the area north of Kulgera suggests that the formation may be unconformably overlain by the Cretaceous Rumbalara Shale. The Crown Point Formation is mainly Permian in age but an upper Carboniferous spore assemblage has been reported from the lower part of the formation in McDills No. 1 Well (Evans in Amerada Petrol. Corp., 1965).

The Crown Point Formation consists of siltstone, sandstone, tillite and conglomerate. The reference locality is Crown Point in the Finke Sheet area (Fig. PE-6). Many outcrops consist of mounds of rounded boulders with phenoclasts of quartzite and quartz up to 5 feet across. Smaller fragments of granite and schist occur in these lag gravel deposits. Many of the quartzite boulders show impact markings (Fig. PE-7) and a few of the smaller fragments are striated. Very large slump structures (Figs. PE-8, PE-9) and convolate laminations (Fig. PE-10) are common in the sediments and the larger structures have probably been formed in the unconsolidated sediment by ice wedging.

In outcrop the Crown Point Formation is about 200 feet thick. In Malcolms Bore the formation may be up to 1200 feet thick (Rochow, 1965) and in the McDills No. 1 Well is about 1440 feet thick. The well section includes fine to medium and locally coarse sandstone which is in part very pyritic and conglomeratic, and calcareous towards the base. The upper part of the sequence, from 2330-2630 feet in the well, contains lignite stringers. Nodules of mudstone were also noted in the sandstone in the well section, a common feature of the Crown Point Formation in outcrop. Grey shale and siltstone is interbedded with the sandstone throughout. The conglomeratic shale in the basal part of the formation is arenaceous and has phenoclasts of chert and some metamorphic rock fragments.

Permian spores have been recovered from several water bores in the Finke Sheet area, (Evans, 1964) from Malcolms Bore (Balme in Sprigg, 1963) and from the McDills No. 1 Well (Evans, P.R., in Amerada Petrol. Corp., 1965). The well preserved Lower Permian microfloras from the Finke Sheet area are of probable Sakmarian age, (Spore unit P1b), and Evans (op. cit.) considers that they were deposited towards the end of the Upper Palaeozoic glacial phase. The samples from Malcolms Bore contain a microflora of Lower Permian (Spore unit P1C) age. Balme (pers. comm.) comments that the assemblage is similar to that found in the upper part of the Grant Formation in the Canning Basin, and could be as old as late Sakmarian. Rochow (1964) reported that the fossiliferous samples in Malcolms Bore were in an interval overlying typical Crown Point Formation lithology. Lower Permian spores found in the McDills No. 1 Well are older than the assemblage reported from Malcolms Bore and some of the microfloras (from 2381 feet, spore unit P1b) are closely comparable with those previously described from shallow bore samples from the Crown Point Formation. Sporesof unit P1a were recored from 2908-3128 and Upper Carboniferous spores (spore unit C1/2) were found in samples from 3687 feet, about 130 feet above what is interpreted as the base of the Crown Point Formation in the McDills No. 1 Well. These are the earliest fossils described from the formation and show that deposition of the Crown Point Formation began in the McDills area in the Late Carboniferous. The sediments here consist of calcareous, fine and some coarse sandstone and differ from the sediments in the overlying part of the formation in that they are not conglomeratic and they contain no pyrite, lignite or mudstone nodules.

The Crown Point Formation is the product of erosion mainly by continental glaciation. The distribution of rock types on the western edge of the Great Artesian Basin shows that the coarsest deposits have formed in marginal areas, with estuarine or lagoonal deposits laid down at the same time in areas further east. This is demonstrated by the presence of lignite in the upper parts of the sequence in the McDills No. 1 Well west. The piles of rounded boulders in outcrop suggest original terrestrial deposits reworked to form fluvio-glacial sediments which probably rimmed the area of Permian paralic deposits. No fossil evidence has been found so far of definite marine deposition.

Upper Permian spores were found in a sample obtained from a water bore (F53/13-224) on the western side of the Hermannsburg Sheet area. The bore passed through about 120 feet of sediments and bottomed in Precambrian granite of the Arunta Complex. The sample was from 96 - 116 feet and consisted

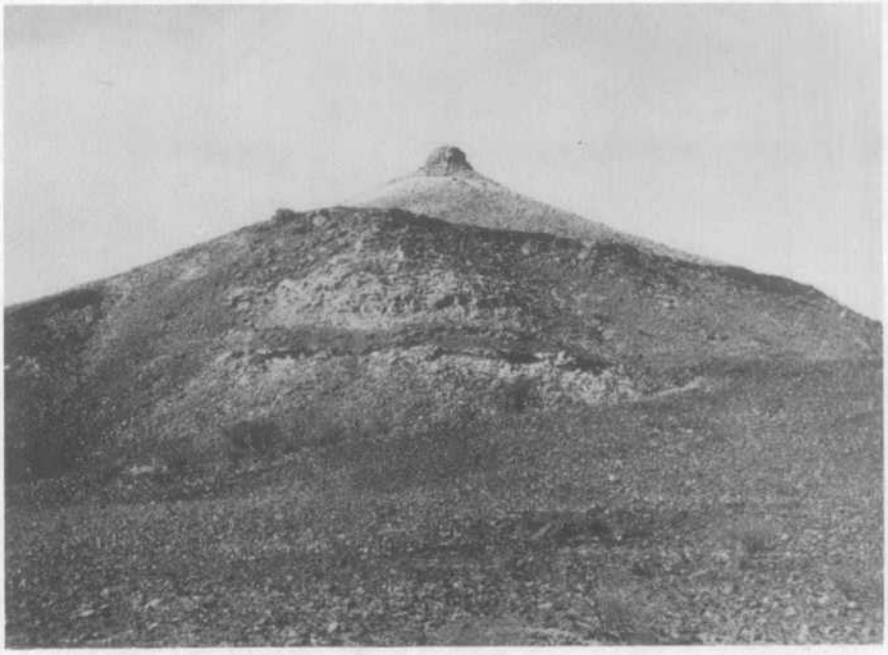


Fig. K-1 Rumbalara Shale (Klr), De souza Sandstone (Md) and Crown Point Formation (Pc) at Colsons Pinnacle. Prominent benches are ferruginized beds at the top and base of the De Souza Sandstone. M403/28

Fig. K-2 Light coloured Rumbalara Shale overlying dark beds of the De Souza Sandstone at Mount Rumbalara. G/9147 of unconsolidated sand with a brown-grey clay matrix. The age from the microflora is similar to that of the Liveringa Formation in the Fitzroy Basin. Evans (pers. comm.) says that the microflora from this bore would appear to be evidence of the existence of the limited pocket of late Permian deposits on Proterozoic basement. No late Permian deposits have been previously recorded from the Northern Territory outside the Bonaparte Gulf Basin.

MESOZOIC

Mesozoic deposits are found only at the south-eastern edge of the Amadeus Basin where they form part of the western fringe of the Great Artesian Basin succession. The sediments overlap and lie unconformably on sediments of the Amadeus Basin succession. Two formations have been mapped; the ?Jurassic De Souza Sandstone and the Lower Cretaceous Rumbalara Shale.

?JURASSIC

De Souza Sandstone

The most widespread rock type of the De Souza Sandstone (Sullivan & Öpik, 1951) is a friable, white, reddish or brown weathered, medium to coarse grained, steeply cross-bedded and micaceous sandstone. It is generally dark brown in outcrop because it is covered by a crust rich in limonite. The contacts with underlying and overlying formations is usually marked by iron rich beds (Fig. K-1). In many places the De Souza Sandstone is conglomeratic with pebbles of quartz and a few of quartzite. The phenoclasts are in part reworked from the older Crown Point Formation and many may also be derived from the Brewer Conglomerate of the Pertnjara Group. The formation is in part rich in kaolin and contains lenses and layers of siltstone and shale as well as conglomerate.

In the Finke Sheet area the De Souza lies unconformably on sediments of the Finke Group or unconformably on the Crown Point Formation and is unconformably overlain by the Rumbalara Shale. In several places there is evidence of erosion of the top of the De Souza Sandstone and cut and fill structures and angular discordances were observed at the contact with the Rumbalara Shale, but elsewhere the contact appears to be conformable.

In water bores the thickness of the formation varies between 50 and 300 feet, but the maximum thickness in outcrop is only about 100 feet.

The De Souza Sandstone contains only undiagnostic plant remains and its provisional Jurassic age is inferred from its similarity to sediments in the northern part of South Australia that lie between Permian glacigene deposits and Lower Cretaceous lutites. They occur at Mount Anna and Mount Dutton in the Peak and Denison Ranges. (Wopfner & Heath, 1963, Wopfner, 1964; Heath, 1965).

The similar sandstone from Mount Anna in the Peak and Denison Ranges is overlain by bleached silty shales of presumed Cretaceous age and rests unconformably on Upper Proterozoic rocks. The top few feet of sandstone is completely impregnated by limonite, a feature which is also characteristic of the De Souza Sandstone. Well preserved plant fossils in the sandstone have been dated as Upper Triassic to Lower Cretaceous.

At the north end of the Peak and Denison Ranges, Permian deposits in the Mount Dutton inlier are unconformably overlain by the Jurassic - Cretaceous Algebuckina Sandstone. The Permian rests with an angular unconformity on Proterozoic rocks at this locality. The similar geological setting in South Australia to that in the Amadeus Basin suggests that the Permian and Mesozoic formations are more or less contiguous.

The question of whether the De Souza Sandstone is present in the McDills No. 1 Well is so far unresolved. Amerada Petrol. Corp., (1965), consider that about 830 feet of clean, quartz sandstone lying above the Crown Point Formation is equivalent to the De Souza Sandstone. It is a fine to very coarse sandstone with clear quartz grains, subangular, unconsolidated, pyritic towards the base and very porous. The overlying 80 feet of fine to very fine, subangular sandstone with white clay matrix and interbeds of dark grey mudstone and siltstone is placed in a transition zone between the De Souza Sandstone and the Rumbalara Shale. This zone is probably best regarded as part of the De Souza Sandstone and has been mapped as such in outcrops in the Finke Sheet area.

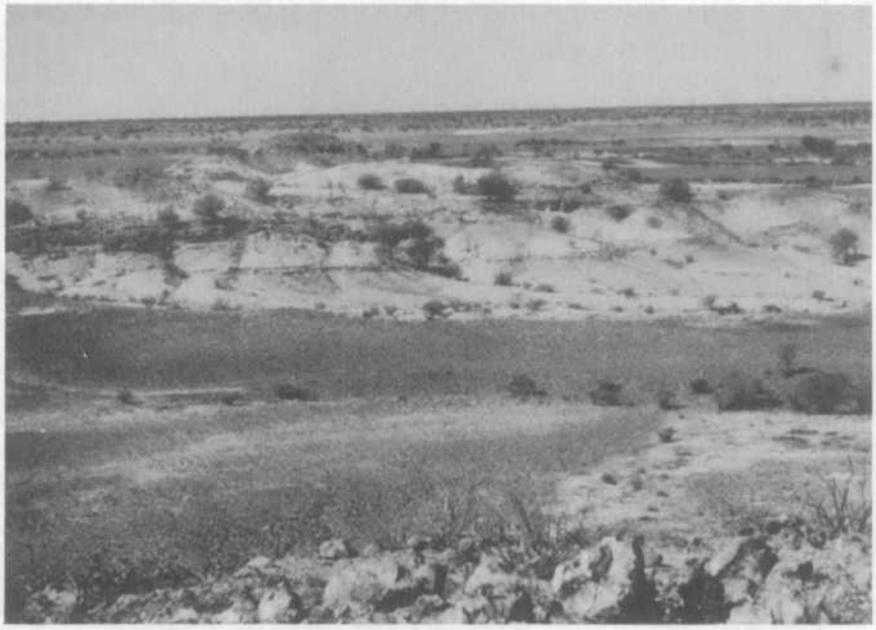


Fig. K-3 Rumbalara Shale with prominent beds of fine kaolinitic sandstone and resistant duricrust capping. North-east of Andado homestead, Simpson Desert.
G/7503

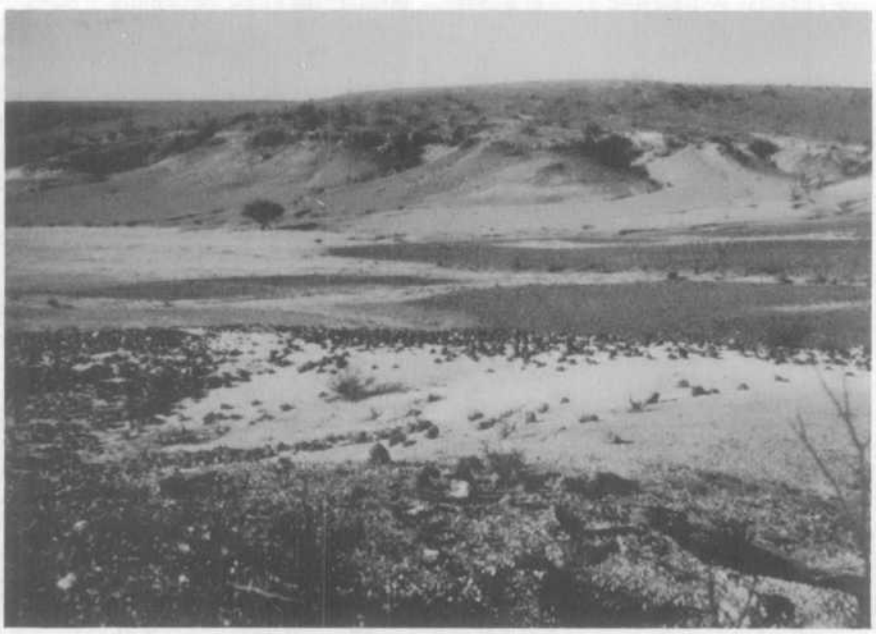


Fig. K-4 Rumbalara Shale with dissected duricrust capping. Near Mount Wilyumpa.
G/7504

The geologists of the Resident Staff, Alice Springs, believe that the succession assigned to the De Souza Sandstone in McDills No. 1 Well is part of the Permian Crown Point Formation. The abundant water supply from this interval in the McDills Well, tends to support the identification of sediments as De Souza Sandstone; in water bores the formation is invariably an excellent aquifer.

The De Souza Sandstone was probably deposited in a deltaic environment. Much of the sediment, particularly the conglomeratic parts, was probably reworked from the underlying Crown Point Formation and possibly also from the Pertnjara Group. The clean sands with abundant steep cross-beds and fragmentary plants indicate fast moving currents and deposition in wide deltas and possibly lagoons. There is no evidence of marine deposition.

CRETACEOUS

Rumbalara Shale

The Rumbalara Shale (Sullivan and Öpik, 1951) crops out at the south-eastern edge of the Amadeus Basin where it unconformably overlies the De Souza Sandstone (Fig. K-1). It forms part of the Mesozoic sequence of the western part of the Great Artesian Basin and contains Lower Cretaceous (Aptian) fossils. The Rumbalara Shale is part of a widespread Lower Cretaceous marine transgression that covered a major part of the Australian continent. The formation is lithologically similar to and the same age as the Bejah Beds in Western Australia (Veevers and Wells, 1961) and to the Lower Wilgunyah Formation of the Great Artesian Basin. The formation was dated by Öpik (in Sullivan & Öpik, 1951) and Skwarko (1962) as Aptian in age. Terpstra and Evans (1963) reached the same conclusion by a study of microfossils from Birthday Bore, 10 miles north of Andado Homestead.

The top of the Rumbalara Shale is mostly an erosion surface (Fig. K-2) but in places it is unconformably overlain by the sands and fine conglomerates of the Tertiary Etingambra Formation. Evidence from water bores in the area between Erldunda and Kulgera Homesteads suggests that the Rumbalara Shale unconformably overlies either the Crown Point Formation or formations of the Finke Group.

Rochow (1963) gives the thickness of the formation as 900 feet in the area south of Charlotte Waters Bore, but its thickness decreases gradually westwards towards what must have been an old shore line in the Lower Cretaceous. At least 300 feet of the formation is present in Malcolms Bore, about 300 feet in Pebbles Bore, 450 feet in Birthday Bore, and about 1300 feet in McDills No. 1 Well.

In outcrop the formation is a predominantly soft, white porcellanite, claystone and siltstone with sandstone interbeds. Yellow ochre is common at the base of the formation especially at and near the Rumbalara Ochre Mine. The white friable leached sediment is typical of outcrops, but is mostly blue-grey below the weathering profile. In most surface exposures the formation is covered by a thick siliceous grey-billy capping. The sediments are commonly opalised with white and translucent chalcedony, and ferruginized and stained by iron oxide. The composition of the formation is remarkably persistent over large areas.

The section in McDills No. 1 Well consists of dark grey mudstone, interlaminated with some darker grey siltstone. The sequence is locally glauconitic, and has limonite inclusions, scattered Inoceramus prisms, and interbedded stringers of tan, cryptocrystalline limestone in the lower part.

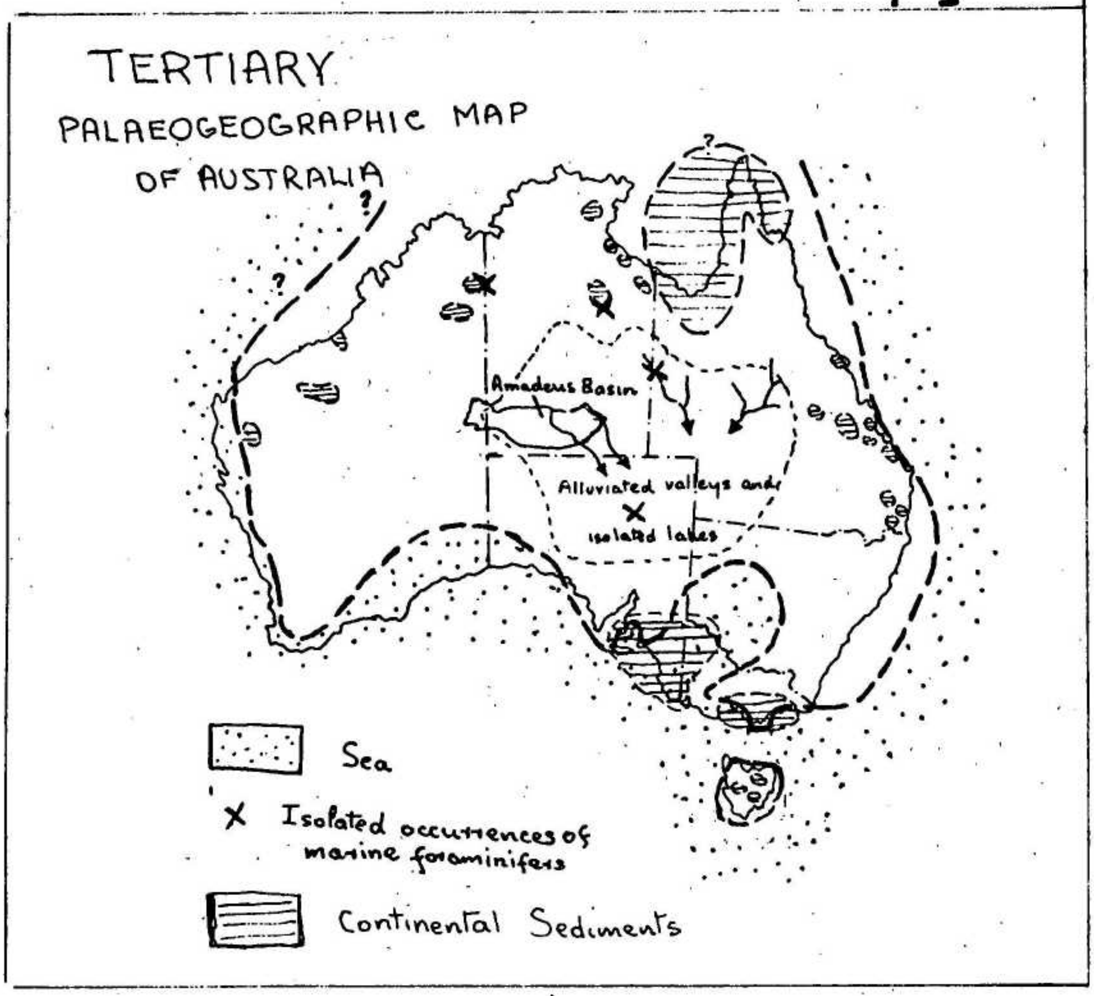
CAINOZOIC

TERTIARY

Sediments of probably Tertiary age have been mapped at numerous localities throughout the Amadeus Basin and in the surrounding area. The sediments are subhorizontal and lie unconformably on Precambrian igneous and metamorphic rocks and Upper Proterozoic, Palaeozoic and Mesozoic sediments (Fig. T2).

The Tertiary sediments include piedmont gravels, fluviatile sandstone and conglomerate, lacustrine limestone, shale and sandstone and chemically formed products of weathering such as silcrete (siliceous billy or grey billy), ferricrete (laterite or ironstone gravel) and kunkar (or caliche). There is no

T1


TERTIARY
PALAEOGEOGRAPHIC MAP
OF AUSTRALIA
Amadeus Basin
Alluviated valleys and
isolated lakes
Sea
Isolated occurrences of marine foraminifers
Continental Sediments

TERTIARY FOSSIL LOCALITIES — AMADEUS BASIN

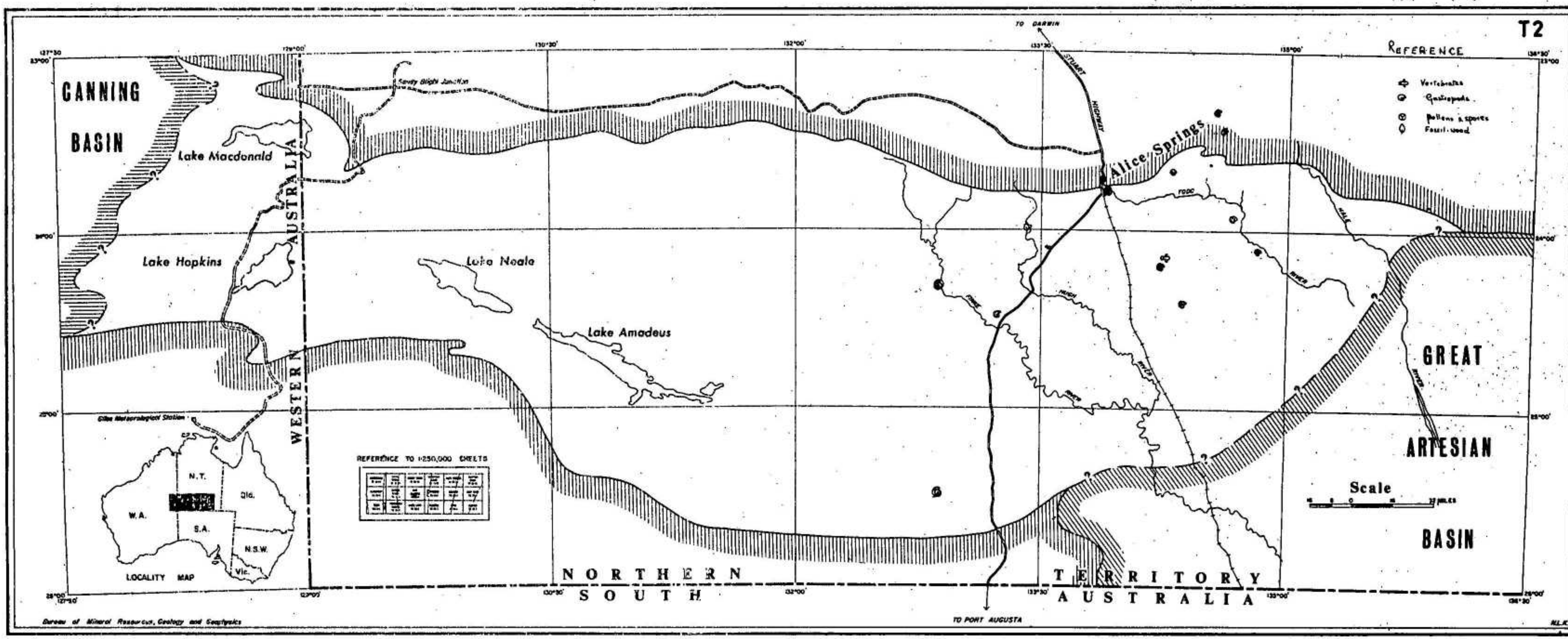


Fig. T2A Tertiary sediments in mesa in the Mereenie Anticline
G/4337

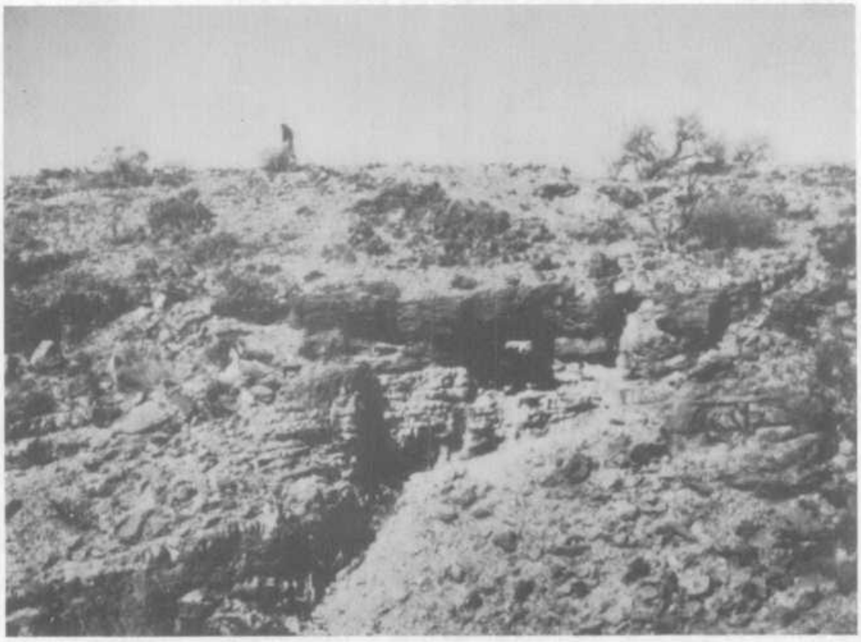


Fig. T3 Unconformable contact between the Etingambra Formation and the Rumbalara Shale at Mount Etingambra.
G/7461

Fig. T4 Duricrusted rubble covered plain on Rumbalara Shale with incipient drainage pattern north of Andado Homestead.
G/7507

evidence of a marine incursion into this part of Australia during the Tertiary (Fig T1).

Three formal stratigraphic units, the Etingambra Formation (Wells, Ranford, Stewart, Cook and Shaw 1967, in press), the Arltunga Beds (Smith, 1964), and the Waite Formation (Woodburne, 1967) have been defined in the Amadeus Basin and environs, but other informal units have been named on the basis of lithology, age relative to the time of formation of silcrete, and the presence of fossils.

The simplest division of the Tertiary sediments in central Australia is on the basis of age relative to the time of formation of silcrete and ferricrete and the sediments have been divided in this manner for the discussion that follows.

Pre-silcrete Tertiary Sediments

Etingambra Formation (Wells, Ranford, Stewart, Cook and Shaw, 1967, in press). This formation, which is up to 40 feet thick, consists of sandstone, siltstone and conglomerate. It is exposed above the Rumbalara Shale in mesas up to 100 feet high in the central part of the southern half of the Hale River Sheet area, and at scattered localities in the McDills Sheet area. The formation disconformably and unconformably overlies the Lower Cretaceous Rumbalara Shale (Fig. T3) and is capped with about 5 feet of silcrete.

The Etingambra Formation is tentatively correlated on lithological grounds with an unnamed fossiliferous sandstone unit which crops out in the northern part of South Australia.

Unnamed Units

These sediments comprise sandstone, claystone, siltstone and conglomerate and include some sequences known only from scattered water bore information. They are subhorizontal and crop out in mesas with a silcrete capping.

In the past, some of these sediments have been mapped as possible Mesozoic (Prichard and Quinlan, 1962; Quinlan, 1962; Wells, Forman and

Ranford, 1965; Ranford, Cook & Wells, 1966 in press) based on unpublished reports by Crespin (1948, 1949, 1950, 1951). The specimens identified by Crespin have been lost but Lloyd (1968 in prep.) has examined one of the samples from which Crespin described radioloria and has stated that the radiolaria-like objects are of inorganic origin and that there is no evidence for a Mesozoic age.

Recently, Evans (in Wells, Ranford, Stewart, Cook and Shaw, 1967 in press) has described a Tertiary microflora from a water bore in the Alice Springs Farm area and Lloyd (1968 in prep.) has suggested that the pre-silcrete Tertiary sediments may be Eocene to Miocene. Wells, Ranford, Stewart, Cook & Shaw (1967, in press) correlate the fossiliferous subsurface sediments in the Alice Springs Farm area with other unfossiliferous pre-silcrete sediments in the north-eastern part of the Amadeus Basin.

If there are Mesozoic sediments in the Alice Springs area, they will probably be continental sediments similar in lithology to the fossiliferous Tertiary section.

Subhorizontal, coarse-grained sandstone which was mapped by Forman (1967, in press) in the south-western part of the Amadeus Basin and the older Tertiary sediments described by Forman, Milligan & McCarthy (1967, in press) from the north-east margin of the Amadeus Basin may also belong to this division of pre-silcrete Tertiary sediments.

Ferricrete (Laterite)

Laterite profiles with pisolitic ironstone have not been recorded from within the Amadeus Basin but are present over the Arunta Complex on the north-east margin of the basin (Forman, Milligan & McCarthy 1967, in press). However, ferruginized sediments were reported from the central part of the Amadeus Basin (Ranford, Cook & Wells, 1966, in press) and from the north-eastern part of the Amadeus Basin (Wells, Ranford, Stewart, Cook and Shaw, 1967, in press.).

Most of the ferruginization appears to have taken place before the deposition of the post-silcrete sediments and Wells, Ranford, Stewart, Cook & Shaw (1967 in press) suggest that the process may have been contemporaneous with the formation of the silcrete. However, minor occurrences of ferruginized post-silcrete sediments have been recorded from the central and the north-eastern parts of the Amadeus Basin.

Silcrete ('Billy')

Silcrete or 'billy' cappings are common on the mesas of sediments ranging in age from Precambrian to Tertiary in the eastern half of the Amadeus Basin. The silcrete is best developed on the clastic formations with a high percentage of clay matrix (Fig. T4). Most of the silcrete occurs as sub-horizontal or low-dipping sheets, but it also forms vertical dyke-like bodies in the Pertnjara Formation and Mereenie Sandstone in some areas (Wells, Ranford, Stewart, Cook & Shaw, 1967, in press).

The silcrete is presumed to have been precipitated during a prolonged period of weathering in the Tertiary. The vertically dipping dyke-like silcrete bodies were probably formed as a result of silica precipitation from solutions moving along joint planes.

Post-silcrete Tertiary Sediments

Post-silcrete Tertiary sediments from the Amadeus Basin and environs have been described by Madigan (1932a & 1932b), Joklik (1955), Prichard and Quinlan (1962), Wells, Forman and Ranford (1965), Ranford, Cook & Wells (1966, in press), Forman (1966, in press), Wells, Stewart & Skwarko (1966, in press), Lloyd (1968, in prep.) and Woodburne (1967). The sediments have been divided, in most areas, into two units; a conglomerate and a sequence of finer clastics with interbeds of limestone.

The conglomerate ranges from a lithified sediment with sand and carbonate matrix to an unconsolidated deposit of angular to well rounded phenoclasts without significant matrix. Much of the conglomerate is locally derived and occurs as piedmont gravels adjacent to the prominent ranges. However, some of it is fluviatile in origin and is preserved in low rises along the margins of the river courses. The deposits of conglomerate are up to 50 feet higher than the surrounding plain in the central part of the Amadeus Basin (Ranford, Cook & Wells, 1966, in press). The disposition of these river conglomerates indicates there has been very little shift in the position of the major drainage channels in post-Tertiary time. Madigan (1932a) recorded abundant fossil wood in conglomerate in the Waterhouse Range and suggested the sediments were Tertiary or Quaternary. Prichard & Quinlan (1962) considered these sediments might be Tertiary but Condon (footnote, in Prichard & Quinlan, 1962) considered them to be Pleistocene. Similar sediments were described from the central part of the Amadeus Basin by Ranford, Cook & Wells (1966, in press) who suggested that the conglomerate occur in places as a rim around the fossiliferous Tertiary lacustrine sediments and that they were probably penecontemporaneous with these sediments.

The interbedded sandstone, siltstone, claystone and limestone sequence of post-silcrete sediments is the best exposed, the most fossiliferous and the most studied division of the Tertiary section. These sediments crop out in mesas, which are, in most areas, capped by resistant chalcedonic limestone.

Madigan (1932b) used the name Arltungan Beds to include all the Tertiary sediments to the east of Alice Springs and Smith (1964) revised the name to Arltunga Beds and extended the unit to include possible Tertiary sediments in the Huckitta Sheet area. Forman, Milligan & McCarthy, (1967, in press) and Lloyd (1968, in prep.) have attacked the usage of the Arltunga Beds outside the type area (in the vicinity of the Arltunga airstrip) on the grounds that the sediments include various lithologies and are not physically continuous. Lloyd (1968, in prep.) has mentioned all the known fossil localities (Fig. T2) and discussed their environmental significance and age. The fossils include kangaroos, crocodile, turtle and bird bones, ostracods, pelecypods, gastropods and oogonia of the alga Chara. The molluscs have been described by McMichael (1968, in prep.).

The post-silcrete sediments are predominantly lacustrine and fluviatile but some of the limestone may have formed as a secondary deposit of the caliche or kunkar type. The sediments were probably deposited in a series of lakes which were distributed along the major river courses. Lloyd (1968, in prep.) has suggested that the fossiliferous post-silcrete Tertiary sediments are Miocene and the unfossiliferous post-silcrete Tertiary sediments may be Miocene or younger.

Similar Middle Tertiary sediments at Alcoota, about 80 miles north-east of Alice Springs have been named the Waite Formation (Woodburne, 1967).

The formation rests on Precambrian basement and on the laterite profile developed on these rocks with an angular unconformity. The early sediments with gastropods and animal remains were lacustrine siltstone and minor limestone and are disconformably overlain by fluviatile sandstone and conglomerate. The fossil vertebrates are late Miocene or early Pliocene and the laterite here is considerably older. A chalcedonic limestone caprock on the sediments was probably formed by silicification of calcium carbonate formed in the soil profile.

It is unlikely that the widespread deposits formed a lithogenetic unit and seem to occur as old fillings of present day river valleys.

QUATERNARY

Superficial Quaternary deposits cover approximately three quarters of the Amadeus Basin. These deposits are made up principally of wind blown sand, supplemented by alluvium collected in valley deposits, outwash plains and alluvial fans, and evaporite deposits in the large salt lakes. A C.S.I.R.O. publication on lands of the Alice Springs area (Perry et al., 1962) details, among other things, land systems, geomorphology, geology and soils and includes descriptions of the surface deposits which mask outcrops in the Amadeus Basin.

Quinlan (1962) divides the Quaternary deposits into five categories which correspond approximately to those mapped in the Amadeus Basin. They are:

1. Terrace travel - derived during the Pleistocene period of erosion. They cover bevelled surfaces of older rocks, and occur in strike valleys with material derived from the valley wall.

2. Evaporite and clay - concentrated in basins of internal drainage in which clay as well as salts have accumulated mainly from evaporation of ground water.

3. Travertine, kunkar, calcrete and alluvium - concentrated on edges of salt lakes from evaporation of ground water. Travertine has also formed in low lying areas in alluvium and sand by deposition from ground water.

4. Aeolian sand - ancient and active seif type dunes and redistributed sand.

The sand is now mostly fixed by vegetation. The greatest concentrations of dunes are in the east and west in the Simpson Desert and Gibson Desert respectively.

5. Recent sediments - superficial soil, creek alluvium and alluvial fans. The soils of the area are strongly weathered and leached. They include red clayey sands with minor areas of yellow earth. There are also extensive areas of shallow skeletal soils and some alluvial soils. Calcareous earths are associated with basic rocks or alluvium. Black soils are not common.

Ubiquitous sand, in the form of dunes and sand plains, is the most widespread and covers the largest area of any of the Quaternary deposits. On the eastern fringes of the Gibson Desert in the western part of the Amadeus Basin the dune trend is about east-west; the direction varies considerably around the larger ranges most probably caused by the influence of the high strike ridges on the prevailing wind regime. In these areas complex systems of braided dunes are common and the simple linear seif dunes are in the minority.

Around Lake Amadeus and in the central region of the Amadeus Basin, dunes are less common and are comparatively poorly defined. They trend in a south-westerly direction.

On the eastern margin of the Basin in the Simpson Desert, well defined long seif dunes are common and they trend south-south-east. The eastern dune faces are steeper than the western. The parallel, red dunes average about 50 feet high, are almost 500 yards apart and have flat sandy swales. Only relatively minor areas of bare sand occur on the unstable crests. An unusual area of unstable dunes occurs on the eastern side of the Finke River about ten miles west-north-west of Finke township. They are devoid of vegetation and have an irregular pattern but crescent shaped crests are common. (Figs. Q2, Q3). A good deal of the sand is derived from the underlying, friable, easily abraded De Souza Sandstone, and in part from the wide flat bed of the Finke River. Unusual dune forms are also found on the lateritised rock platforms about 25 miles east of Finke. The dunes are wide and made up of unstable sand with a braided pattern but heaped into a well defined ribbon (Fig. Q4). The dunes are widely separated and the intervening rock platforms are practically bare of sand. The most common form of dune in the Simpson Desert are the long, near symmetrical, unbraided and generally unbranched

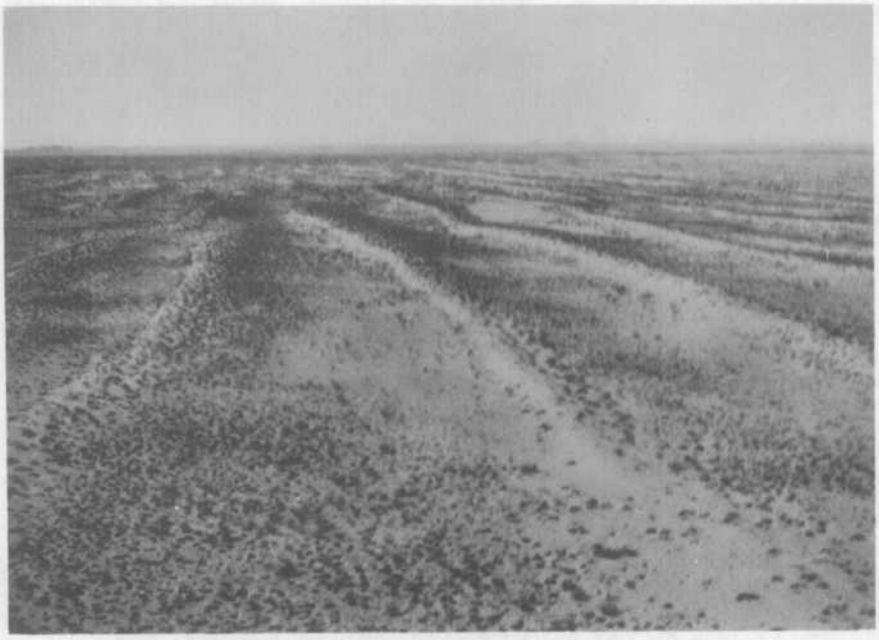


Fig. Q1 Seif dunes in the western Simpson Desert.
G/9108

Fig. Q2 Active dune field, ten miles west-north-west of Finke township. Finke River in the background.
G/9130

Fig. Q3 Dune field ten miles west-north-west of Finke Township. Finke River and outcrops of the De Souza Sandstone in the background.
G/9150

Fig. Q4 "Ribbon" dune on ferricrete platform 25 miles east of Finke township. Western edge of the Simpson Desert.
G/9120

Fig. Q5 Longitudinal dune in the Simpson Desert, showing active sand of the crestal area.
G/7512

Fig. Q6 Salt crust of Lake Macdonald. Blocks are travertine from lake margin.
G/9115

Q7. Active dune on the western side of the Simpson Desert

G/6299

seif dunes (Figs. Q5, Q7).

Evaporite deposits occur in most of the large salt lakes which include Lakes MacDonald (Fig. Q6), Hopkins, Anec, Orantjugupr, Amadeus and Neale, and a chain of salt pans that trend easterly from the eastern end of Lake Amadeus for about 140 miles. Surface samples from some of these lakes showed that the evaporites are mainly composed of halite with minor amounts of calcium and magnesium chloride and sulphate. The thin surface crust is mainly halite whereas the underlying layers are mainly gypsum (commonly in large crystals) together with brine saturated dark sand and silt.

A summary of the recent history of the area, taken from the C.S.I.R.O. Land Research Series No. 6, (Perry et al., 1962) is as follows. The deep weathering profile developed in the Tertiary and was later dissected. Mesas 300 feet high in the south-east, capped by deep weathering products, attest to the degree of dissection which was initiated by crustal warping in the Lake Eyre Basin. In the area to the west and north-west the Tertiary plain was altered mainly at higher levels with etching out by erosion and extensive deposition in the lowlands. An arid phase probably prevailed at this stage with initiation of internal drainage and dune formation. The resumption of drainage incision in some parts suggests an amelioration of the climate with development of alluvial fans and flood plain. The Finke River is the only stream that has maintained its drainage beyond the area, the other rivers dispersing their water within the area.

STRUCTURE

The Amadeus Basin is a remnant of a much larger basin in which sedimentation ranged from shelf type deposits to continental. The main features of the Basin are shown on the tectonic map at 1:1,000,000 scale (Plate 9) and maps showing depth to basement contours (from aeromagnetic surveys) (Plate 2) and Bouguer anomaly contours (Plate 3).

The Craton

The craton or Precambrian basement rocks are named the Arunta Complex (Mawson and Madigan, 1930) on the northern margin of the Amadeus Basin and the Musgrove-Mann complex (Glaessner) and Parkin, 1955) on the southern margin. Wilson (1953) considered that the major trends in the Musgrove 'Block' were in a northerly direction and that these were subjected to later east-west warpings. Forman, Milligan and McCarthy (1967) have shown that the prominent lineation in the Arunta Complex is northerly and that this has been refolded about east-west axes. Forman and Milligan defined the Arunta Orogeny as the orogeny which folded and metamorphosed the Arunta Complex before the Heavitree Quartzite was deposited. The moderate grade metamorphic rocks are overlain, probably unconformably, by a little altered or low-grade metamorphic volcanic and sedimentary succession at the western end of the basin. These volcanic and sedimentary rocks are treated in this Bulletin as part of the basement.

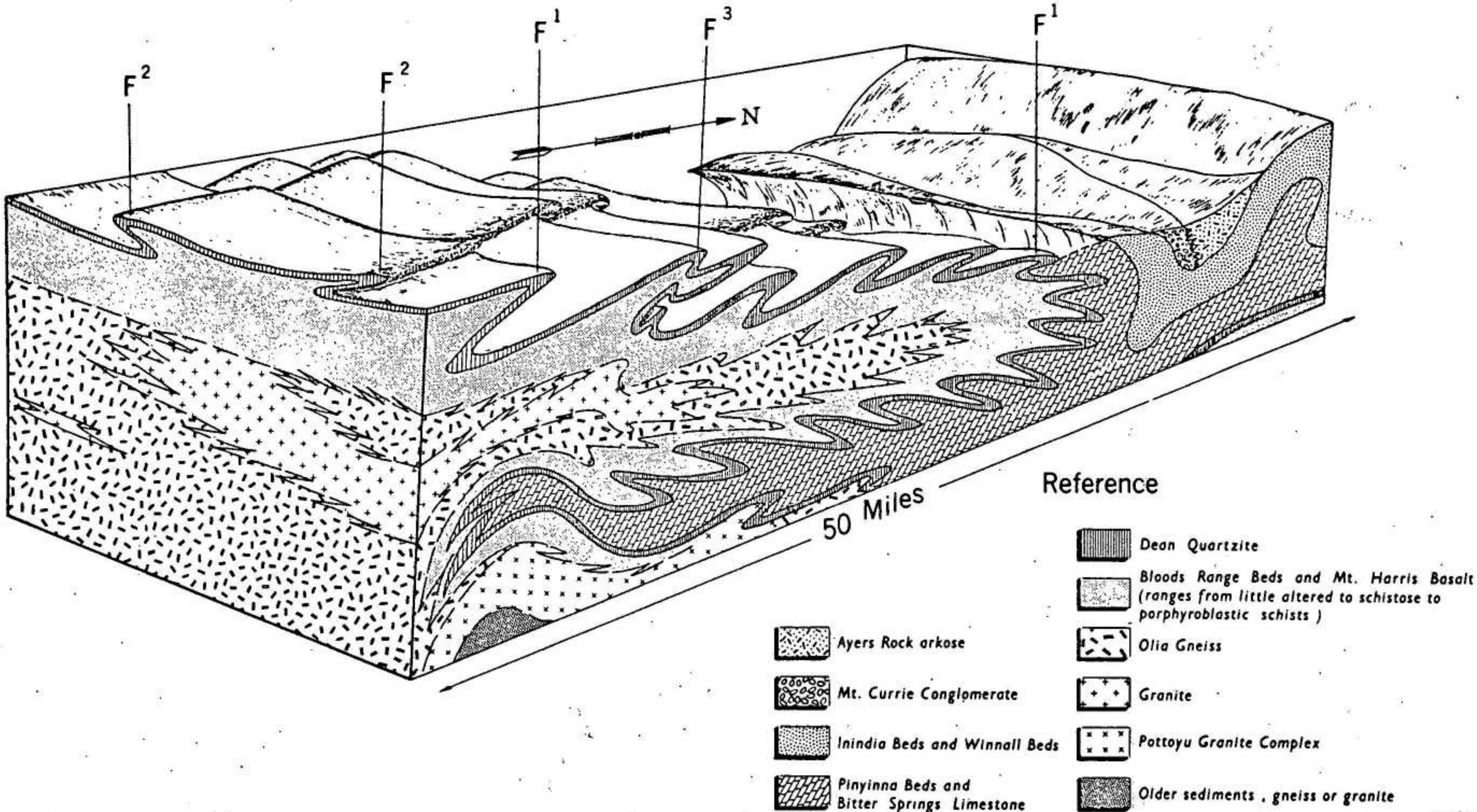
The Amadeus Basin

Proterozoic Isolated Basin (Autogeosyncline)

Sedimentation began in the Amadeus Basin in a Proterozoic marine basin. The basal formations and the Heavitree Quartzite and Deam Quartzite unconformable overlie the basement complex. The uniform lithology and the great lateral extent of the two formations (at least 450 miles in an east-west direction and over 150 miles from north to south) suggest that deposition was remote from uplifted source areas. The Bitter Springs Formation and Pinyinna Beds with a similar distribution, include fine clastics, abundant carbonate rocks and evaporites.

ST-1.

RECONSTRUCTION OF THE REGIONAL STRUCTURE
SOUTH-WESTERN MARGIN, AMADEUS BASIN.



G 52/3
M.E.N.

Proterozoic-Cambrian

The abrupt change in sediment type from the carbonate of the Bitter Springs Formation and Pinyinna Beds to the sand and conglomerate of the Areyonga Formation, the siltstone and shale of the Pertatataka Formation, Inindia Beds and Boord Formation and the red beds of the Carnegie Formation indicate a change in environmental conditions. Sediment was derived from nearby positive uplifted areas, particularly to the south and south-west of the Amadeus Basin and to a lesser extent to the north and north-east of the Amadeus Basin.

The uplift in the south-western area of the Amadeus Basin was violent and was named the Petermann Ranges Orogeny (Forman, 1966). In the early stages, the orogenic disturbance was either less intense or farther removed from the Amadeus Basin *. During this stage the Upper Proterozoic formations: Inindia Beds; Winnall Beds; Carnegie Formation; Boord Formation; Areyonga Formation, and Pertatataka Formation were deposited. In the south-west the Carnegie Formation and Winnall Beds show an increase in sand and thickness compared to the formations in the centre of the Amadeus Basin. In the north-east the Pertatataka Formation is thicker and contains more sand than it does in the centre of the basin. There is evidence throughout the Basin for a disconformity or gentle unconformity between the Bitter Springs Formation and the succeeding unit.

The Petermann Ranges Orogeny reached a climax late in the Upper Proterozoic or early in the Cambrian. A large recumbent fold over 200 miles long and 30 miles across the strike (see fig. ST-1) formed in the rocks below the Bitter Springs Formation (or Pinyinna Beds) along the south-western margin of the Basin. The Upper Proterozoic rocks above the Bitter Springs Formation were not incorporated within the recumbent fold but were thrust forward in a northerly direction over a plane of decollement in the lubricant Bitter Springs Formation and folded into a series of anticlines and synclines. The intensity of the folding dies out to the north and north-east. The

* Wells (see earlier Section on Proterozoic rocks) considers that the only uplift was unrelated to the Petermann Ranges Orogeny and has been named the Kulgera Tectonism. This tectonism occurred in the early Proterozoic and the Petermann Ranges Orogeny occurred in the late Proterozoic and folded all the sediments deposited after the earlier tectonism.

basement complex the Dean Quartzite and the Pinyinna Beds (equivalent of the Bitter Springs Formation) were deformed and metamorphosed within the recumbent fold. Forman (1966) believes that a new suite of metamorphic rocks was formed during the recumbent folding. The Bloods Range Beds and the Mount Harris Basalt were converted to schist, porphyroblastic schist, schistose gneiss, gneiss, gneissic granite and granite. Mineral ages of 600 million years (Leggo, B.M.R. pers. com.) have been obtained from biotite and potash feldspar from gneissic granite and granite from within the largest body of metasomatic granite, the Pottoyu Granite Complex. However, the total rock age is about 1200 million years (Leggo, B.M.R. pers. com.). The Dean Quartzite and Pinyinna Beds are also metamorphosed to quartzite and schist. The Dean Quartzite is locally intruded by granite and the Pinyinna Beds contain pegmatite veins. These metamorphic rocks have not been differentiated from the older metamorphic rocks of the Musgrove-Mann area but McCarthy (A.M.D.L. pers. comm.) has recognized phyllonite or cataclasite in the area south of Ayers Rock which he considers to have formed from pre-existing coarse-grained gneiss or granite. Dolerite dykes and sills were intruded into these rocks after their deformation.

Formation of the recumbent fold late in the Proterozoic or early in the Cambrian (created) a mountain chain along the southern-western margin of the Amadeus Basin and erosion of this chain contributed sediment to the Basin. The Mount Currie Conglomerate and Ayers Rock arkose were deposited on the northern flank of the mountain chain, unconformably over the folded Upper Proterozoic sediments in the Amadeus Basin, in a continental environment which may have been separated from the marine environment by a land ridge. The Ellis Sandstone, Sir Frederick Conglomerate and Maurice Formation may have been deposited under similar conditions *. The Arumbera Sandstone was deposited north-east of the land ridge in a paralic environment. The ?Lower Cambrian red brown sandstone is believed te represent the first influx of sediment following the Petermann Ranges Orogeny. The Quandong Conglomerate and the Eninta Sandstone were deposited adjacent to the land ridge, in a fluviatile and paralic environment marginal to the Arumbera Sandstone. The

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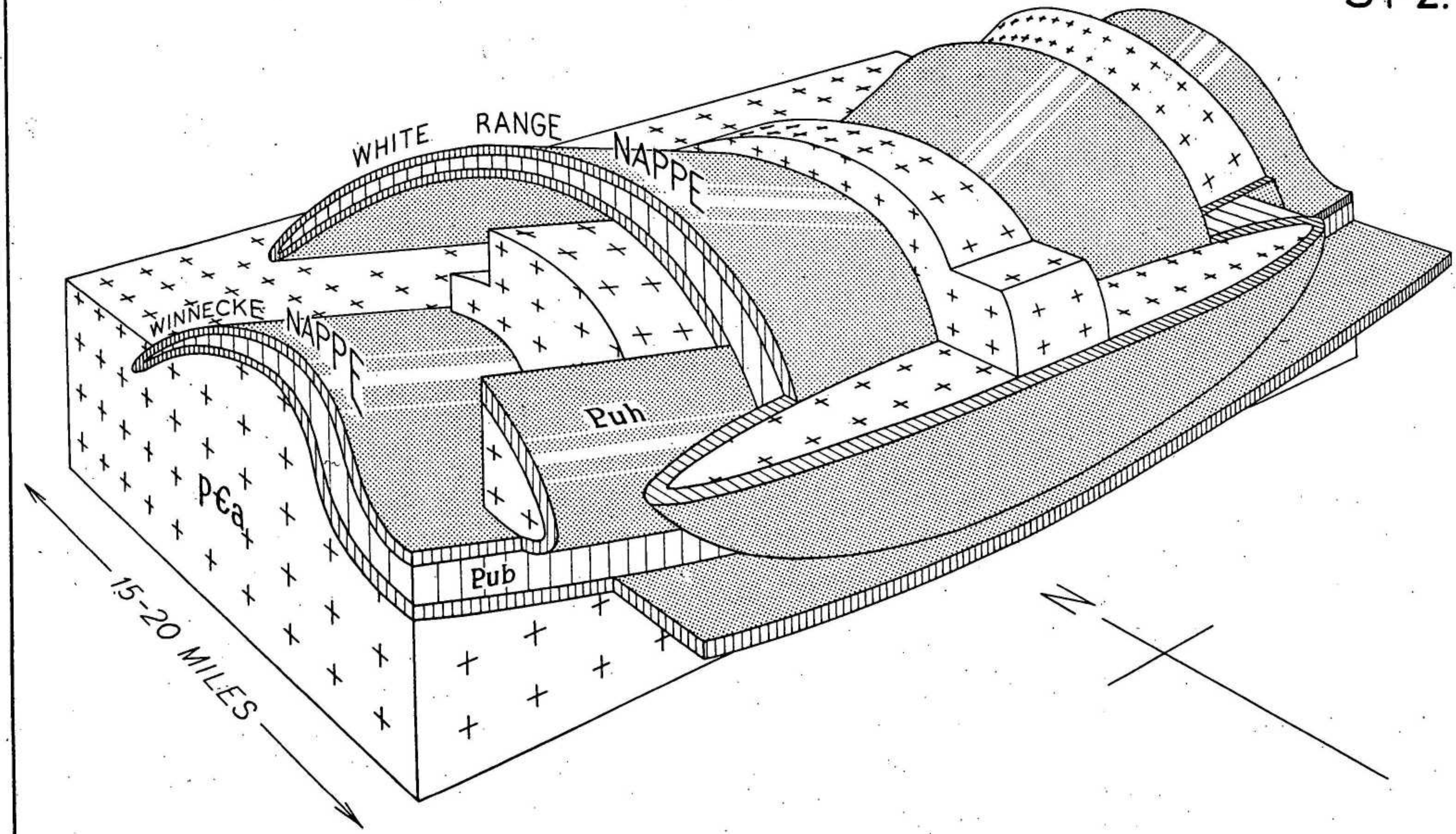
* Wells (this Bulletin) believes that these formation were deposited earlier in the Proterozoic cycle of sedimentation and are unrelated to the Petermann Ranges Orogeny.

ST-2.



ARLTUNGA NAPPE COMPLEX

Bureau of Mineral Resources, Geology and Geophysics.

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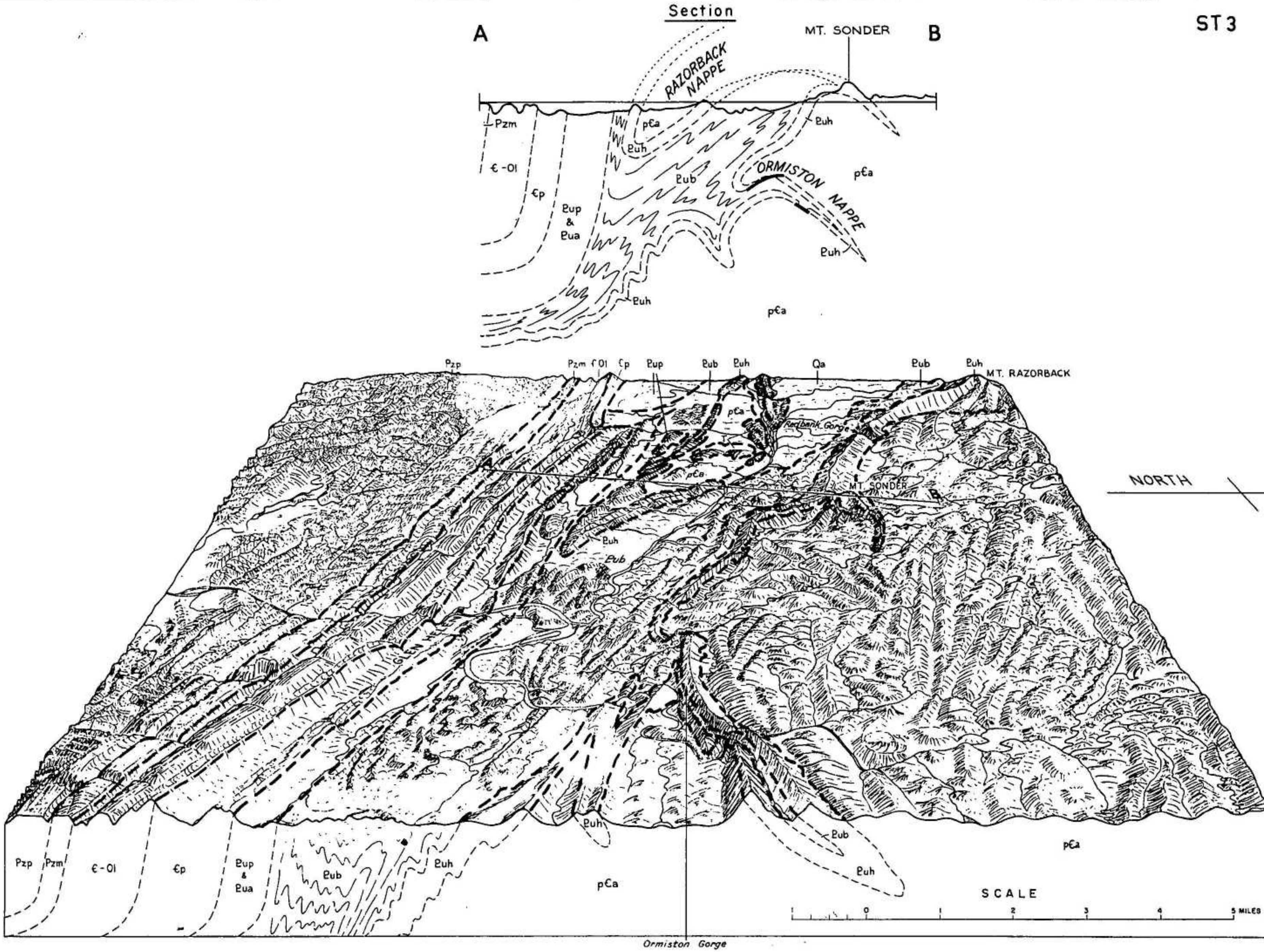
ST 3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Redbank Gorge
NORTH
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0 1 2 3 4 5 MILES
Ormiston Gorge

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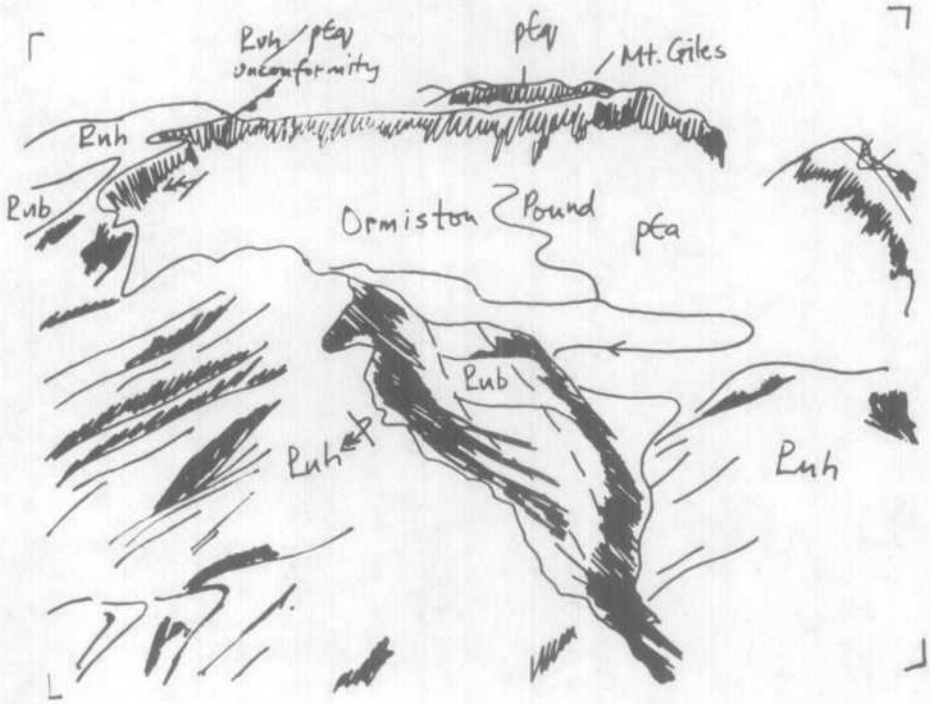
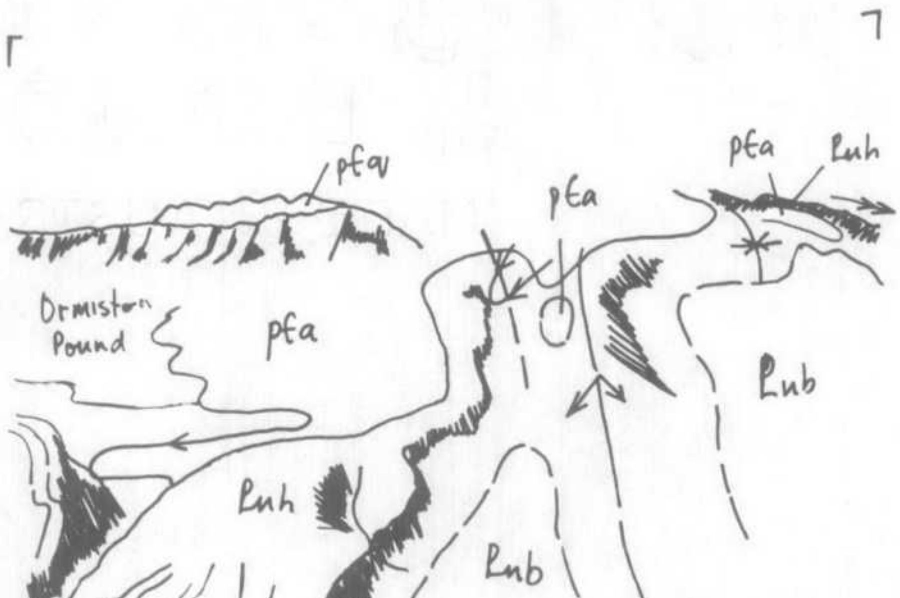
Fig. ST-4 Prominent ridges of Heavitree Quartzite and low lying areas underlain by the Arunta Complex, Ormiston Nappe Complex. G/8573



pЄa Arunta Complex, pЄq Precambrian quartzite,
Ƿuh Heavitree Quartzite, Ƿub Bitter Springs Formation.

Fig. ST-5 Overlay to photo above.

Fig. ST-6 Ridges of Heavitree Quartzite at the Ormiston Nappe Complex.
G/8575

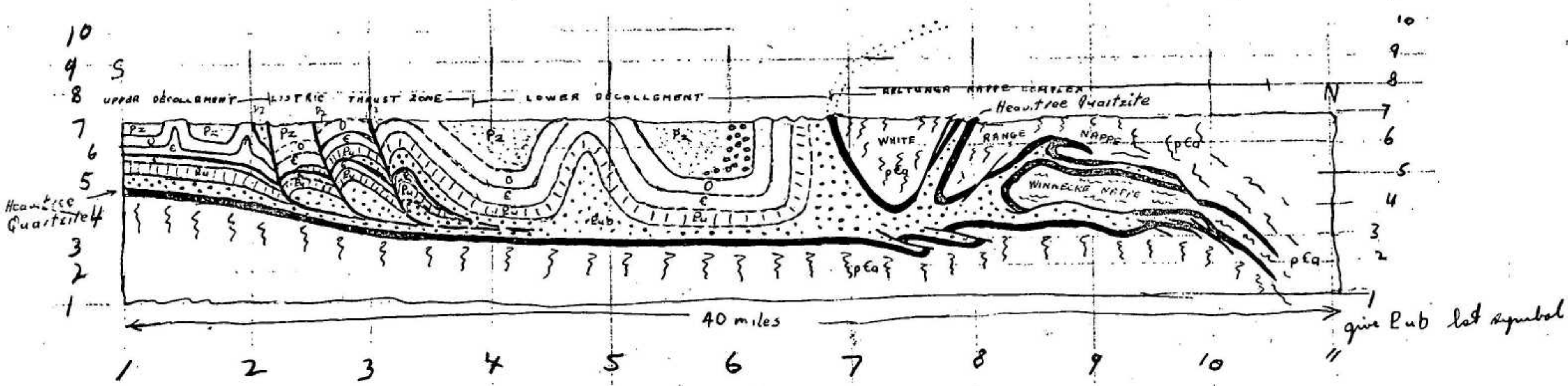


pЄa Arunta Complex, pЄq Precambrian quartzite,
Ꝑuh Heavitree Quartzite, Ꝑub Bitter Springs formation

Fig. ST-7 Overlay to photograph above.

ST-8.

COMPOSITE CROSS SECTION — N.E. AMADEUS BASIN.



overlying Tempe Formation is a silty marine facies marginal to the carbonates of the Petermann Group in the north-east. The upper formations of the Pertaoorrta Group are probably equivalent to the Cleland Sandstone.

Cambrian-Ordovician

Deposition of the sand, shale, siltstone and limestone of the Larapinta Group was accompanied by a southwards and westwards marine transgression and in the south and west the younger units of the Larapinta Group rest unconformably on Upper Proterozoic rocks and the Olia Gneiss.

Ordovician-?Carboniferous

Tectonic activity commenced adjacent to the present northern margin of the Amadeus Basin late in the Ordovician. The tectonic cycle has been named the Alice Springs Orogeny (Forman, 1966, Forman, Milligan and McCarthy 1967). In the early stages of the orogeny gentle uplift occurred associated with some tilting in the north-eastern part of the basin*. The Mereenie Sandstone of ?Silurian-Devonian age was deposited during this period. In the central part of the Basin the Mereenie Sandstone rests apparently conformably on the Larapinta Group (Ranford, Cook & Wells, 1966, in press), but in the north-east the Mereenie Sandstone rests with gentle unconformity on the older sediments. The orogeny reached a climax in the Devonian to ?Carboniferous with the formation of the Arltunga Nappe Complex (fig. ST-2) and the Ormiston Nappe Complex (fig. St3-7), and was accompanied by deposition of the Pertnjara Group and the Finke Group (Forman, Milligan and McCarthy, 1967; Wells et. al. 1967). The sediments overlying the Bitter Springs Formation were thrust southwards over a plane of decollement within the Bitter Springs Formation. Listric thrusting occurred from the lower decollement surface onto an upper decollement surface in the Chandler Limestone (see fig. ST8). The listric thrusting occurred in the area of the Mount Burrel Anticlinorium (Wells, Ranford, Cook, Stewart and Shaw, 1967) and westwards

* Cook (see earlier section on the Mereenie Sandstone) has named this uplift as the Rodingan (?Silurian) Movement. He considers that it is probably unrelated to the Alice Springs Orogeny which should be restricted to movement which occurred during Pertnjara Group times.

TECTONIC TABLE - AMADEUS BASIN

ST-9

	Age	Orogenic Event	Sedimentary Units			
PALAEOZOIC	Carboniferous					
			Pertnjara Group		Finke Group	
	Devonian	Alice Springs Orogeny				
	Silurian		Mereenie Sandstone			
	Ordovician		Larapinta Group			
	Cambrian	Peterman Ranges Orogeny	Mt.Currie Congl.and arkose at Ayers Rock	Maurice Formation* Ellis Sandstone	Cleland Sandstone	Pertaoorrta Group
	Upper Proterozoic			Sir Frederick Congl.	Winnall Beds	Pertatataka Formation
			Carnegie Fm.	Boord Fm.	Inindia Beds	Areyonga Formation.
			Pinyinna Beds			Bitter Springs Fm.
			Dean Quartzite			Heavitree Quartzite
			BASEMENT ROCKS			
PRE-CAMBRIAN		Arunta Orogeny				

* An alternative interpretation of the position of the Maurice Formation, Ellis Sandstone and Sir Frederick Conglomerate is shown in pG -2.

onto the Henbury Sheet area and north-easterly onto the Alice Springs sheet area (see plate 9). The sediments folded into a series of Jura-type anticlines and synclines over the decollement surfaces (see fig. ST8).

The Pertnjara Group was folded by the Alice Springs Orogeny but it is probably that it was never deposited in the area of the Mount Burrel Anticlinorium (L.C.R. pers. comm.)

The age of the climax of the Alice Springs Orogeny is Devonian. The Pertnjara Group contains fossils of middle or upper Devonian age (E.A. Hodgson, 1968, J.G. Tomlinson pers. comm.). Radioactive ages of 367 and 420 million years have been obtained on minerals from pegmatites and gneiss in the Harts Range area (Forman, Milligan and McCarthy, 1967).

Since the Alice Springs Orogeny the area has been relatively stable and the Permian, Mesozoic, Tertiary and Quaternary sediments are flat lying.

A summary of the tectonic events effecting the Amadeus Basin is shown in Table ST-9.

The positive Bouguer anomaly which lies parallel to and north of the Amadeus Basin is flanked to the north and south by large negative Bouguer anomalies.

The hypotheses which have been advanced to explain regional linear gravity anomalies are summarized in figure St11 (after Bean, 1953). Similar Bouguer anomalies in India, United States and Canada have been interpreted as crustal "warps" or folds by Glennie (1953), Woollard (1939), Longwell (1943), Bean (1953) and Wilson & Brisbin (1961). The Amadeus Basin anomaly was first treated as a crustal warp by Marshall & Narain (1954).

Figure ST12 demonstrates the close fit between a calculated Bouguer anomaly curve assuming crustal folding (using a line integral method; Hubbert, 1948) and the actual Bouguer anomaly. A two layer crustal model with the commonly accepted rock densities for these layers has been used. the section line from which the Bouguer anomaly profile has been taken is shown in figure ST10

A density of 2.5 has been chosen for the sediments of the Amadeus Basin, but it can be seen that the resultant density contrast between basin sediments and upper crustal rock produces an anomaly of about 50 mgals. (see figure ST12) distributed over the northern margin of the Amadeus Basin. The calculated anomaly due to the sediments is too small to explain the total of 170 milligals in the gravity gradient and it lies south of the actual gradient. It is cleas that the 170 mgal. gradient cannot be explained by density contrast between the sediments in the Amadeus Basin and their basement rocks.

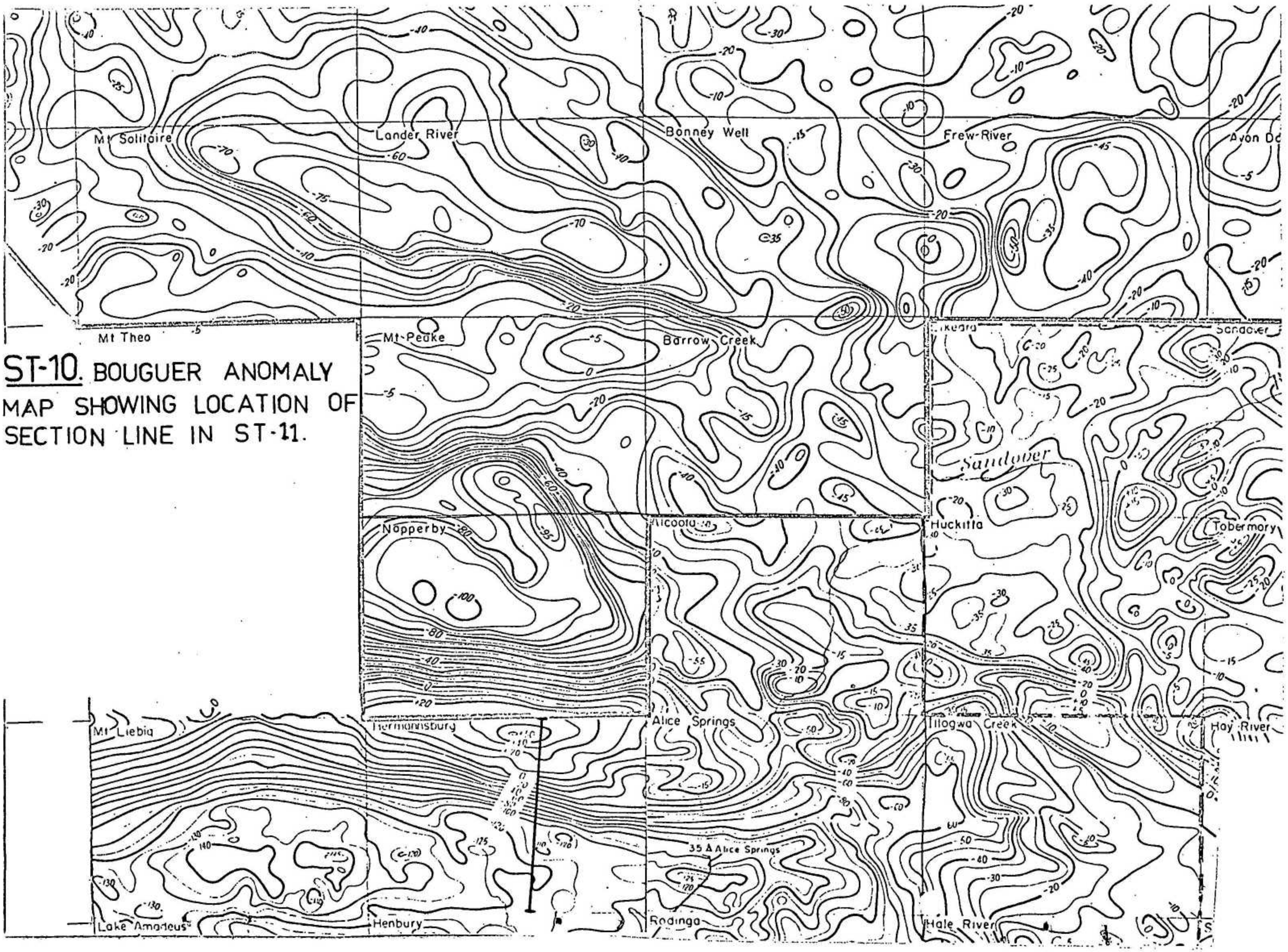
Correlation of suface structure with the suggested crustmantle structure

It is postulated that the Bouguer anomaly reflects folding of the crust and mantle. The area to the north of the Amadeus Basin was uplifted and the Amadeus Basin sediments were folded in the Devonian to ?Carboniferous. So far as it is known the area has not been affected by folding since. This suggests that the Bouguer anomaly is a fossil Bouguer anomaly remaining from the Devonian Carboniferous.

If this is true then the lower crustal structure may be related to the surface structure in one of two ways: either the lower crustal structure was reflected at the surface by a nearly identical fold (figure ST13a) which was then modified by gravity to the present geometry (figures ST13a-d); or the lower crustal structure may be related to the surface structure if it passes upwards into a conjugate fold "system" as in figure ST14.

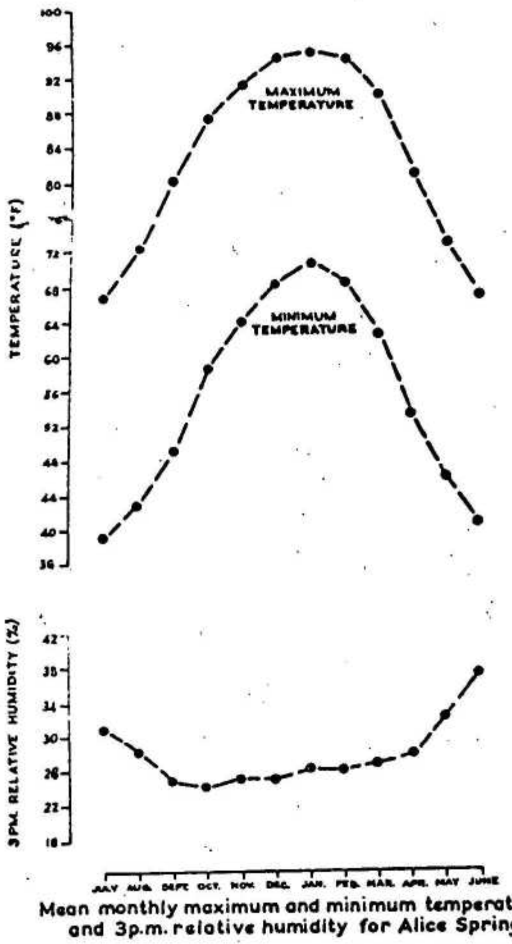
Bouguer Anomalies

The Bouguer anomaly values shown on plate 3 reflect the structure of the Amadeus Basin. The main gravity trough south of the Macdonnell Ranges in the Missionary Plain outlines the area of deepest sedimentation (Lonsdale and Flavelle, 1963). However, the major gravity gradient lies to the north of the northern margin of the Amadeus Basin. Also the southern part of the gravity trough in the Ayers Rock area is underlain by basement rocks. Langron (1962a) attempted to explain the gravity gradient to the north of the Macdonnell Ranges by overthrusting or overfolding of the Arunta Complex over the Amadeus Basin sediments. In addition Langron (1962a) and Marshall & Narain (1954) point out that there is good reason to expect crustal warping

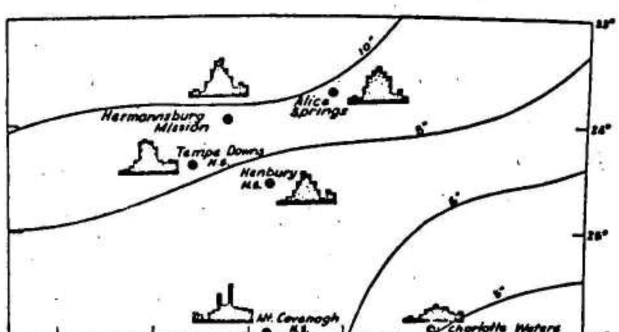


ST-10. BOUGUER ANOMALY MAP SHOWING LOCATION OF SECTION LINE IN ST-11.

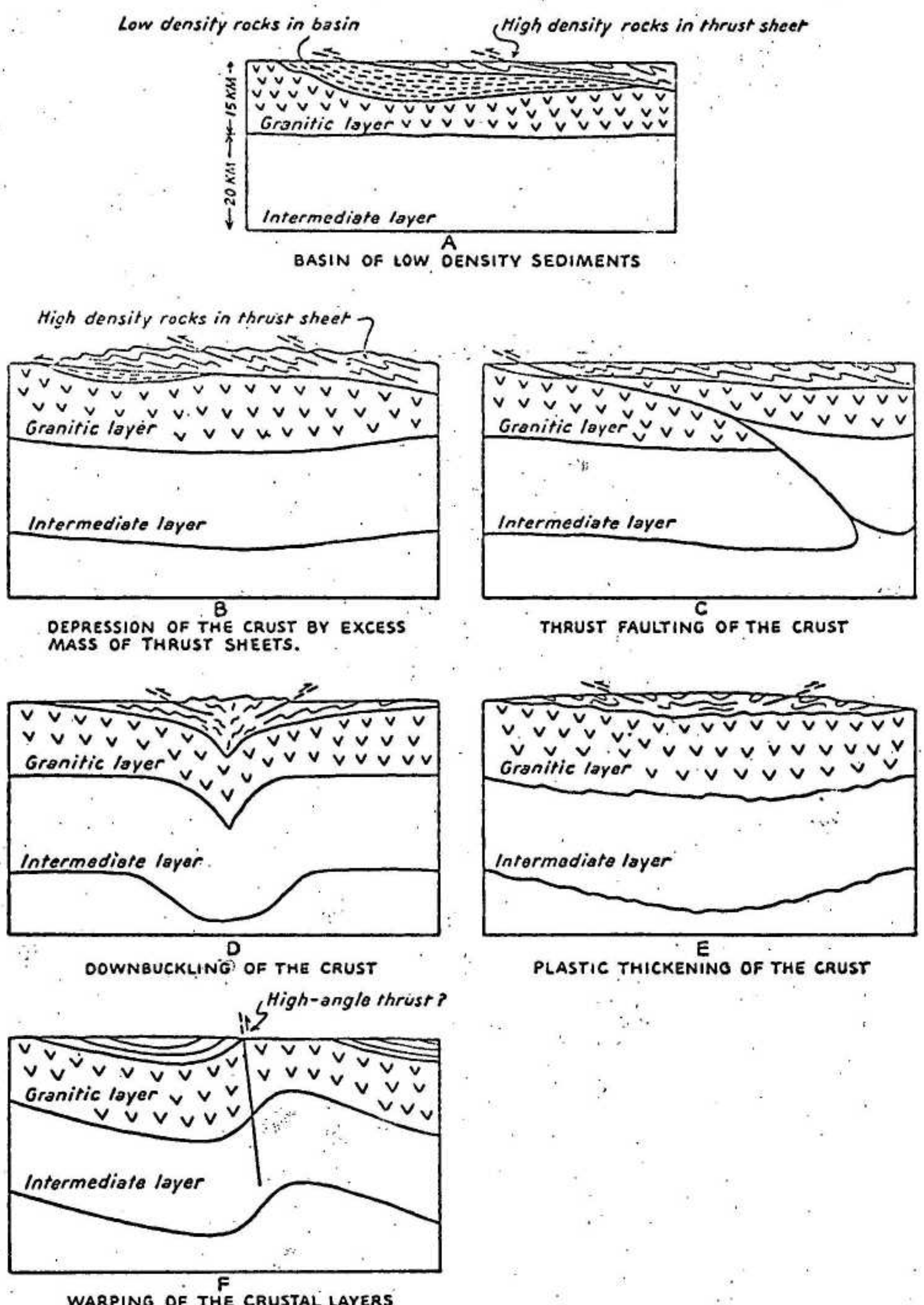
TEMPERATURE, RELATIVE HUMIDITY & RAINFALL (ADAPTED FROM CSIRO 1962)



Mean monthly maximum and minimum temperatures and 3p.m. relative humidity for Alice Springs



Isohyets and histograms of annual rainfall distribution (July to June) at recording stations.



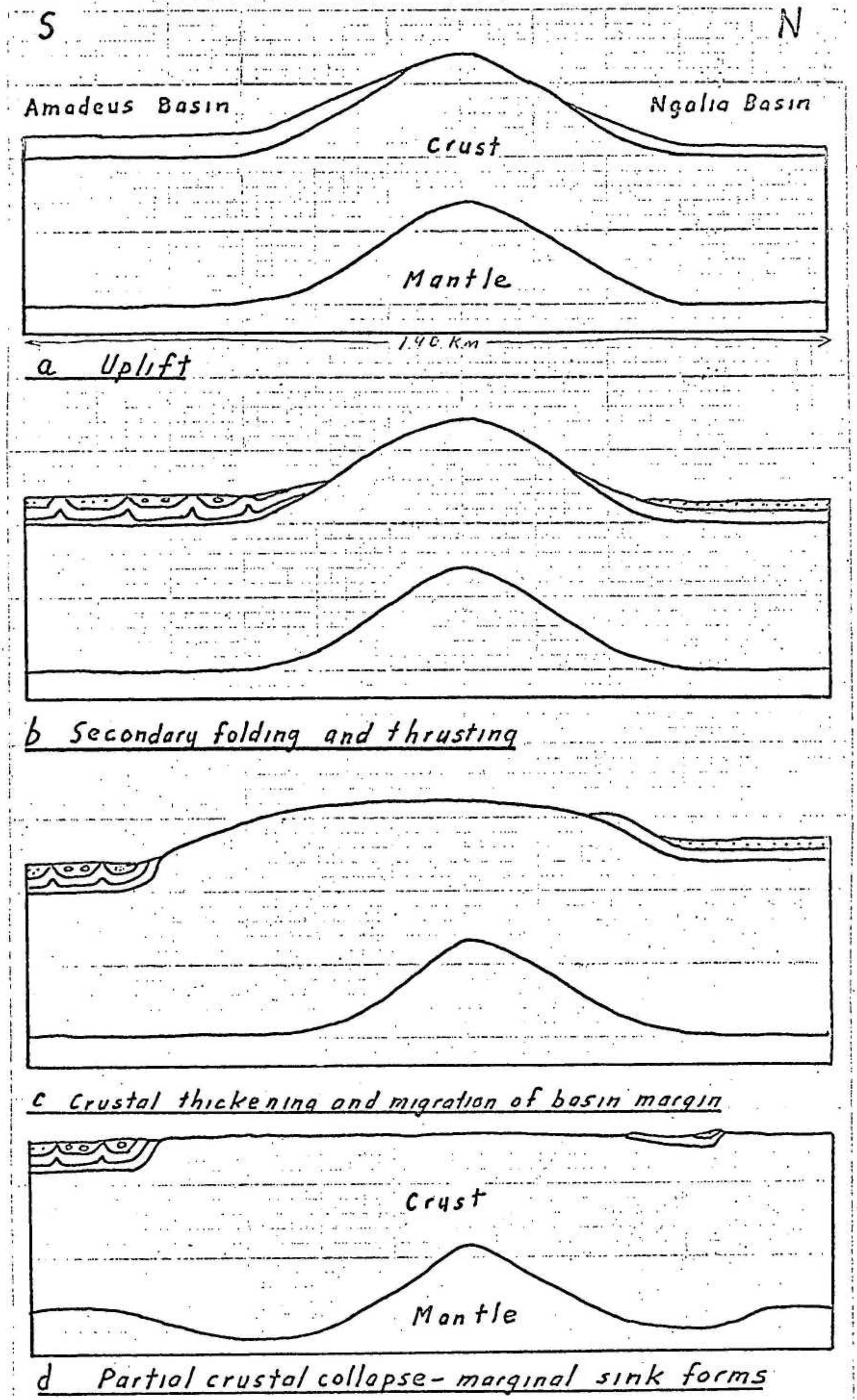
ST-11. STRUCTURAL CONFIGURATIONS OF THE CRUST WHICH WOULD PRODUCE NEGATIVE GRAVITY ANOMALY STRIPS

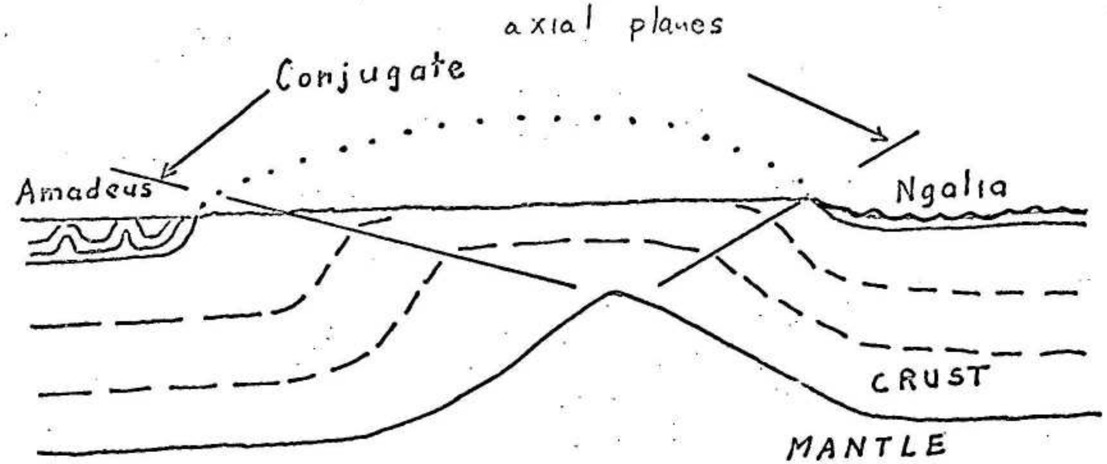
(after Bean, 1953)

ST-12.

Calculated anomaly curve resulting from crustal warps — Northern margin Amadeus Basin

STAGES IN THE FORMATION AND COLLAPSE OF A CRUSTAL WARP





ST-14. Formation of a lower crustal fold and an upper conjugate fold system. (diagrammatic) within the area. Langron concluded that the gradient was due to a combination of the density contrast between basement and sediments, the very great thickness of sediments overthrusting and crustal warping. Forman, Milligan and McCarthy (1967) show that the overfolding on the northern margin of the Amadeus Basin is restricted to the Arunta Complex, Heavitree Quartzite and Bitter Springs Formation and that therefore a great thickness of sediments would not be involved. Further they show that the gradient lies to the north of the root zone of the nappe structures and not over them. They conclude that crustal warping has caused the gravity gradient, the nappe structures and the north-eastern margin of the Amadeus Basin.

Heavitree Quartzite have been deformed into nappe complexes. The Bitter Springs Formation is preserved in the cores of the recumbent synclines but the overlying, more competent, units were "squeezed" out.

The Upper Proterozoic - Palaeozoic sediments within the Amadeus Basin are folded and thrust faulted. During the folding the sediments above the Bitter Springs Formation were detached from the rocks below to form a decollement. The underlying Heavitree Quartzite is comparatively flat-lying beneath the folded sediments.

The age of the folding is probably Devonian. The molasse-like Pertnjara Formation contains Devonian fossils and anomalour radiometric ages (367 - 420 m.y.) have been obtained from within the Arunta Complex.

As the sharp gravity gradients on the northern margin of the basin are most probably caused by crustal warping and the gravity trough near Ayers Rock contains metamorphic rocks it is probable that many of the major gravity trends associated with the Amadeus Basin reflect density contrast and deformation within the basement rocks. Bearing this in mind the interpretation of other gravity results within the area becomes difficult as they may reflect basement structure rather that the structure of any overlying sediments.

Detailed gravity work carried out for Magellan Petroleum Corporation has shown the presence of small gravity negatives superimposed on gravity positives over the cores of may of the anticlines tested and over Gosse's Bluff, a circular structure. The gravity negatives are probably indicative of salt.

Aeromagnetic and Radiometric Anomalies

Airborne magnetic surveys over the Amadeus Basin include those of Young and Shelley (1966) Geophysical Associates (1965) and Hartmann (1963). The results of these surveys are shown in Plate 2. The survey of Young and Shelley (op. cit.) covers the major part of the sedimentary Basin and a radiometric survey was made concurrently. The following summary is taken from their report.

The aeromagnetic surveys show that the deepest part of the Basin lies along the northern border and the maximum depth to magnetic basement is 38,000 feet below sea level in the area south of the western MacDonnell Ranges. The general shape of the basin interpreted from magnetic results agrees with the gravity data and numerous basement high and low features outlined by these surveys correspond fairly closely.

The strong Bouguer anomaly gradients to the north and south-west of the Basin were shown by the magnetic data to be produced by changes in basement rock types. Magnetic anomaly trends are generally ill defined in areas of basement outcrop.

The form of the basement in the Ooraminna and Gosses Bluff localities corresponds to the data obtained by seismic surveys. For purposes of comparison the main results of the B.M.R. seismic surveys (Turpie and Moss, 1963; Moss, 1964 and 1966) are as follows. The Palm Valley anticlinal structure continues with depth and includes at least 18,000 feet of sediments. 3 miles east of Hermannsburg Mission good reflections were obtained from depths in excess of 26,000 feet. Another survey showed that the Missionary Plain Synclinorium contained 26,000 feet of sediments at the Gardiner Range thrust and 33,000 feet of sediments 25 miles further north. Gosses Bluff was shown to be a structure in the sediments and not an expression of basement relief. The traverses from Deep Well across the Ooraminna Anticline showed that the sediments attain a thickness of about 20,000 feet to the north and south of the fold axis and thin to about 16,000 feet over the crest.

The seismic survey in the Missionary Plain area (Krieg and Campbell, 1965) shows that the maximum thickness of sediments above the Bitter Springs Formation to the north-west of Gosses Bluff is about 28,000 feet, so that the maximum basement depth is approximately 31,000 feet below sea level. This depth and the form of the seismic contours agree substantially with the magnetic basement contours.

The rate of shallowing of seimic contours on top of the Bitter Springs Formation to the south is considerably greater that the magnetic basement, which suggests a thickening of the Bitter Springs Formation across the axis of the Palm Valley Anticline.

In the south-eastern part of the basin the seismic traverses in the Kulgera Sheet area indicated a tectonically disturbed Proterozoic sequence with maximum depth of 8,000 feet to the deepest reflector interpreted to be near the top of the Bitter Springs Formation. The magnetic basement depth is about 12,000 feet. The differences between the irregular suface of this lower seismic horizon and the simple form of the underlying magnetic basement suggest that salt from the Bitter Springs Formation has formed diapiric structures on the south side of reverse faults.

The interpretation of magnetic data shown in Plate 2 is quantitative within the sedimentary basin but only qualitative in areas of basement outcrop to the north and south. The probable error of the depth to magnetic basement contours is ± 10%. In both the northern and southern areas of basement outcrop several zones have been defined with reference to the prominent magnetic characteristics and these are listed below.

Northern Basement

Zone	Magnetic character
A	Magnetic anomalies mainly less than 50 gammas.
B	Magnetic anomalies in the range 50-250 gammas.
C	Magnetic anomalies in the range 250-1000 gammas.

Southern Basement

Zone	Magnetic character
A	Magnetic anomalies mainly less than 25 gammas.
B	Magnetic anomalies in the range 25-125 gammas.
C	Magnetic anomalies in the range 125-500 gammas.

The northern basement outcrop shows magnetic trends indicating that the magnetic strike is east-west paralleling surface geological trends. The east-west trend is further reflected by the boundary between zones B and C and coincides roughly with the line of the maximum gravity gradient to the north of the Amadeus Basin. The increase in magnetic disturbance to the north of this boundary is interpreted as evidence for an increase in the basic nature and density of the basement rocks.

Zones of type A correspond to the Arltunga and Ormiston Nappe Complexes and suggests the presence of less dense acidic rocks. In some places type A zones correspond with major outcrops of granite but the correlation is not always as simple as this. Intense magnetic disturbance is confined to the Alice Springs sheet area where mineralization is known in the basement rocks.

The southern boundary of the Basin is not clearly defined because of the presence of minor magnetic anomalies within the Basin. Magnetic anomalies throughout the Ayers Rock Sheet area suggest the presence of near surface dykes or volcanic rocks but none are evident in outcrops. Magnetic anomalies in the southern part of the Basin in the Petermann Ranges, Ayers Rock and Kulgera sheet areas appear to have a north-south trend. East-west trends in the Bloods Range sheet area correspond to outcrops of the Mount Harris Basalt. In the area of basement outcrop the magnetic zones correlate with Bouguer anomaly results.

There are major basement susceptibility contrasts within the Basin oriented approximately north-south, in contrast to the trends in the exposed basement. They are probably plutonic bodies in the Arunta Complex. The basement features correspond with those indicated by the gravity anomalies. The deepest part of the magnetic basement is collinear with the axis of thickest sedimentary sections as indicated by the gravity data.

A summary of the various features shown on the magnetic basement contour map are as follows:

L1 - a basement depression with 29,000 feet of sediments but control is poor.

L2 & L3 - the most prominent magnetic depressions along the axis of the deepest part of the Basin and coincide with regions of maximum sedimentary thickness indicated by the Amadeus Gravity Depression. The maximum sedimentary thicknesses are 35,000 feet at L2 and 37,000 at L3. It is possible that the crystalline basement is shallower than the magnetic basement in the south-eastern part of the Mount Rennie Sheet area where 35,000 feet of sediments is indicated. The granite basement which crops out to the north shows little associated magnetic disturbance.
Depth estimates at L3, south of the western MacDonnell Range, are in the range 31,000 to 39,000 feet. The magnetic data do not reveal the minor basement uplift associated with Gosses Bluff as indicated by the seismic results. (Moss, 1964)

L4 - a maximum sedimentary thickness of 23,000 feet. The structure is confirmed by gravity and seismic data.

L5 - magnetic basement is 34,000 feet below sea level but is not supported by gravity data and is unreliable because of the few depth estimates.

L6 - a extension of the depression L3 and is associated with a gravity 'low'.

L7 - probably caused by a basement fault and has at most 23,000 feet of sediments.

L8 - corresponds to the western end of a gravity 'low' and crystalline basement is within 10,000 feet of sea level.

L9 - a basement 'low' with relief of about 6,000 feet superimposed on a north dipping basement surface. No corresponding feature is indicated by the gravity data.

H1 - an uplift in the magnetic basement surface with about 6,000 feet of relief.

H2, H6 & H7 - form a major ridge in the magnetic basement. H7 has about 10,000 feet of relief; H6 is a small associated high and H2 separates the depressions at L2 and L3. These basement highs correlate well with gravity features. The lineaments produced by contours between L6 and H6, H7 and between L6 and H6, H7 suggest major basement faulting.

H3 - a west trending ridge of 2,000 feet of relief.

H4, H5 - north-east trending ridges with 4,000 and 2,000 feet of relief respectively.

H8 - a minor east-west high with 2,000 feet of relief.

H9 - a prominent high in the magnetic basement with relief of 6,000 feet but has little agreement with the gravity data.

H10 - a 'high' in the magnetic basement with 4,000 feet of relief with good correlation with the Bouguer gravity contours.

H11 - a magnetic basement feature with 2,000-4,000 feet of relief trending north-west, which correlates with the eastern end of the Angas Downs Gravity-Ridge, and its continuation to the west corresponds approximately to the axis of this gravity feature. Hence the gravity ridge attributed to shallow Proterozoic rocks is probably also controlled by upwarping of Precambrian basement rocks.

H12 - a minor basement feature which may be correlated with the extension of the Angas Downs Gravity Ridge.

G1 - a discontinuity of the contours corresponding to a mapped fault. Estimated displacement is about 10,000 feet.

G2, & G3 - the gradients show deepening basement to the north and west and correlate with gravity and seismic work.

G4 - the gradient shows basement rising strongly to the south-west.

G5 - a steep rise to the north in the basement with the gradient probably caused by a fault. This structure agrees with the gravity results.

G6 - a Precambrian basement upwarp which probably delineates the south-east margin of the main area of thick sediments. It has no direct correlation with gravity data.

G7 - the gradient is interpreted as evidence of a fault, and continues eastwards for a considerable distance.

A contour presentation of the radiometric data (Plate 4) reveals a correlation between radioactive 'highs' and sediments of the Larapinta and Pertaoorrta Groups. Although a definite correlation has not yet been established between gamma radiation and phosphorites in the Amadeus Basin, a radioactive 'high' associated with the Johnny Creek Anticline suggests that this is one of the most promising areas for further search for phosphate deposits.

The western parts of the northern basement have a similar radioactive mineral content, but the Precambrian basement in the eastern part has higher radioactivity. Generally there is correlation between high radioactivity and moderate to low magnetic disturbance. The abrupt change in magnetic basement coincident with a steep gravity gradient is also shown by the radioactive contours. The south-western basement outcrop shows two well defined belts of radioactive anomalies which correspond to zones showing different magnetic susceptibility.

There are numerous anomalies over the sediments in the Amadeus Basin particularly on the Lake Amadeus and Henbury sheet areas and a high proportion are associated with outcrops of the Larapinta and Pertaoorrta Groups. Radioactive anomalies near the northern margin of the Basin occur over outcrops of the Brewer Conglomerate and the large proportion of igneous material in the conglomerate may account for the high radioactiviy.

In general few exposures of the phosphate bearing Larapinta Group appear to be abnormally radioactive when compared to radioactivity exhibited by shales of the Pertaoorrta Group. The anomaly associated with the Johnny Creek Anticline is the most significant. The relationship between radioactivity and phosphate minerals here is not known.

<u>Summary</u>

1. The agreement of the gravity and magnetic form of the basement suggests that in general the magnetic and crystalline basement are identical.

2. The absence of direct correlation of individual magnetic anomalies with Bouguer anomalies supports this conclusion because Bouguer anomalies are primarily dependant upon the density contrast between sediments and crystalline basement whereas magnetic anomalies are produced by intrabasement susceptability contrasts.

3. Different magnetic trends occur in the basement beneath the Amadeus Basin as compared to those over basement outcrops. The north trend beneath the basin may be due to susceptability contrasts between crystalline rocks, whereas the more common easterly trend in outcrop areas may reflect tectonic activity associated with the development of the Basin.

4. The rapid change in basement depth at the Basin boundary restricts the recognition of typical magnetic anomalies associated with basement rocks.

5. The easterly magnetic trends in the south-west part of the Basin correlate with outcrops of the Mount Harris Basalt.

6. Numerous magnetic anomalies in the south-west part of the Basin suggest the presence of volcanic rocks. Some of the anomalies are similar

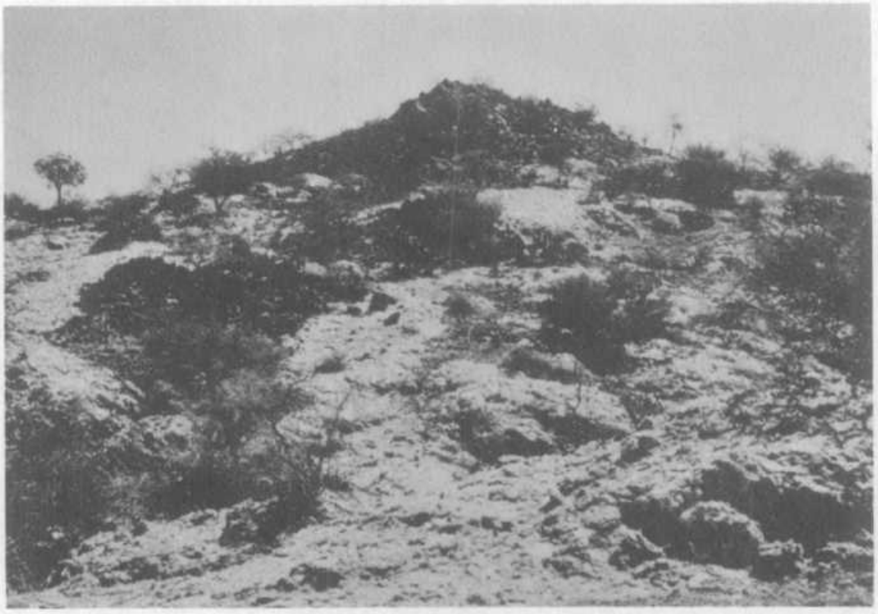


Fig. DS-1 Mass of sheared and brecciated gypsum with weathered earthy crust and rafted mass of dark dolomite of the Bitter Springs Formation at Johnstone Hill.
G/4328

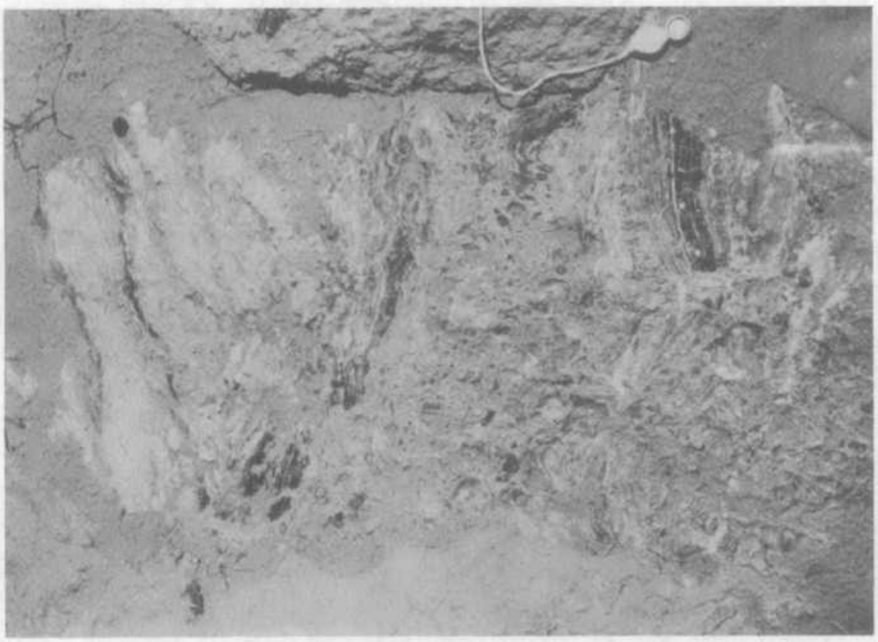


Fig. DS-2 Sheared gypsum in core of anticline south-east Mount Rennie.
G/4324

Fig. DS-3 Sinkhole in diapiric mass of gypsum in the Bitter Springs Formation south of the George Gill Range.
G/9134

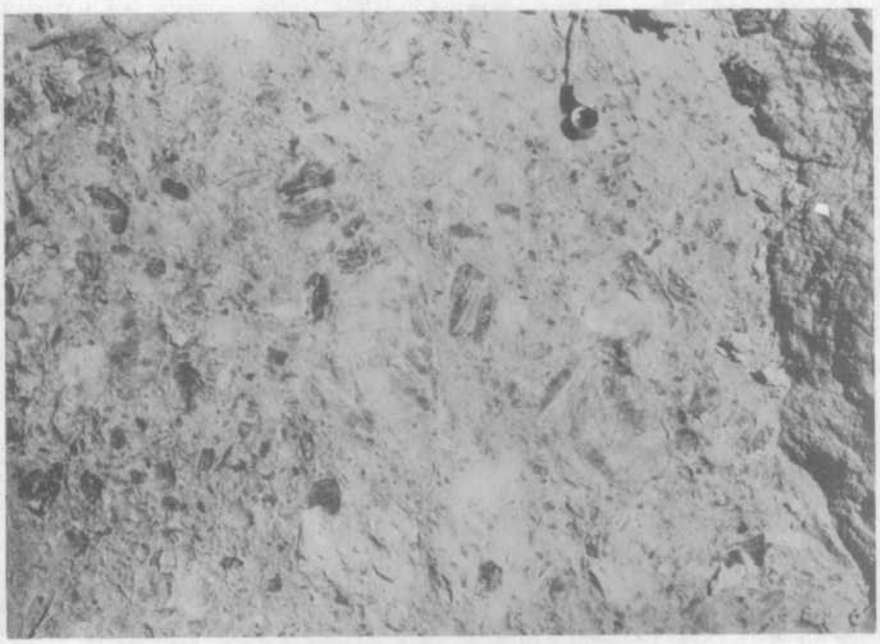


Fig. DS-4 Brecciated gypsum derived from the Bitter Springs Formation, anticlinal core, south-east Mount Rennie Sheet area.
G/4330

to those produced by dyke like bodies.

7. The radioactive anomalies over the Pottoyu Hills indicate granitic rocks. Decrease in radioactivity and increase in magnetic disturbance over basement rocks to the south suggest occurrences of more basic rocks and agrees with the gravity data. Similar correlation between gravity, magnetic and radioactive anomalies over the northern basement outcrop suggest that the basement becomes more basic in composition to the north.

Diapirism and Decollement

In the early stages of the regional mapping of the Amadeus Basin several anomalous structures were outlined which were at variance with the prevailing style of folding and faulting in the sediments. For several reasons these structures were attributed to diapirism. It was postulated that the diapirism was probably caused by movement of evaporites derived from within the Bitter Springs Formation because in several places large masses of brecciated and contorted gypsum were associated with exposures of the Bitter Springs Formation (figures DST and DS3) both in isolated outcrops and in outcrops associated with local doming of the overlying sediments. At this stage no petroleum exploration wells had been drilled and consequently no details of the stratigraphic succession in the Bitter Springs Formation were known, because outcrops of the formation were incomplete and too strongly folded.

Allied to the presence of gypsum intrusions was the fact that outcrops of the Bitter Springs Formation invariably have complex crumpled bedding as a result of folding of the incompetant sediments; the overlying competant rocks have rectilinear outcrops and generally broad symmetrical folds. Several of the breached anticlines in the Amadeus Basin have outcrops of Bitter Springs Formation in the cores which in some places include masses of dolomite breccia and sheared and brecciated gypsum (figures DS2). No outcrops of the underlying Heavitree Quartzite are found in the eroded anticlinal crest and in fact the Heavitree Quartzite and its equivalent, the Dean Quartzite, are found only in exposures along the margins of the Basin. This led to the idea that there was a decollement surface at the base of the Bitter Springs Formation which would account firstly for the dissimilar style of folding above and below the Bitter Springs Formation, and for the absence of the Heavitree Quartzite in the eroded axial zones of folds within the Amadeus Basin.

The formation of the decollement surface at the base of the Bitter Springs Formation was responsible for the style of folding impressed on the Amadeus Basin sediments after the two main orogenic events - the Petermann Ranges Orogeny in the late Proterozoic or early Cambrian in the south-west part of the Basin, and the Alice Springs Orogeny in the Devonian along the northern edge of the Basin. The recumbent folding along the south-western edge of the Basin involves Precambrian crystalline rocks, Dean Quartzite and Pinyinna Beds. The recumbent folds, nappe complexes and thrust sheets described along the northern margin of the Basin involve the Arunta Complex, Heavitree Quartzite and Bitter Springs Formation. In both cases the overlying sediments were folded but they were not involved in the recumbent folding and the nappe complexes. Along the south-eastern margin the overlying thick sequence of Proterozoic rocks were thrown into tight chevron folds in places accompanied by wide basin structures. Along the northern margin the overlying Proterozoic and Palaeozoic sediments were steeply upthrown and are now preserved in a long homocline. In the north-eastern part of the Basin the sediments yielded primarly by gravity sliding, and large thrust nappes were formed.

Gravity surveys in the Amadeus Basin have shown that many of the anticlines are associated with gravity minima. Seismic surveys showed no reflections at depths along the crests of the folds but there was evidence of flat basement beneath many of the anticlines as well as thrusts originating in the Bitter Springs Formation. It was concluded that evaporites and other incompetent beds of the Bitter Springs Formation had been squeezed in the cores of the anticlines during folding. It became evident from a study of the exposed thrust structures in the north-eastern part of the Basin that the Bitter Springs Formation was acting as a lubricant for the movement of overlying large blocks of sediments. In this way large thrust nappes were formed which in some cases moved laterally for tens of miles and the Bitter Springs Formation was emplaced in a position structually above much younger rocks. In places, thrusts originating in the Bitter Springs Formation, migrated up section and formed a higher thrust plane near the base of the Cambrian Giles Creek Dolomite where evaporites provided a second lubricant layer. This migrating type of thrust is known as a listric surface. Many of the thrusts mapped in the north-eastern part of the Basin have a considerable lateral displacement and in places one thrust sheet is superimposed over the top of another (figure DC10). The thrust sheets and thrust complexes were subsequently folded and in plan the thrust planes now have an arcuate outline. In places the folded thrust was complexly faulted and an imbricate structure formed. Several thrust sheets, listric surfaces and imbricate structures are described by Wells et al. (1967, in press).

Probably the most significant thrust nappe that throws light on the interpretation of the structure of the north-eastern part of the Amadeus Basin is the Ringwood-Olympic folded thrust described by Wells et al. (1967) (figure DS10). Two thrust planes have been interpreted in this structure with movement occurring along two decollement surfaces, one in the Bitter Springs formation and the other at the top of the lowermost Cambrian formation, the Arumbera Sandstone. Most of the thrust planes mapped in the north-eastern part of the Amadeus Basin occur in one of other of these horizons.

The interpretation of Wells et al. (1967) shows that considerable movement of the sediments has taken place along the thrust planes. The sediments now preserved in the thrust sheets in the Ringwood-Olympic folded thrust were originally deposited much further north probably over the now exposed Precambrian Arunta Complex. Forman et al. (1967) showed that during the Devonian Alice Springs Orogeny a major uplift occurred along the northern margin of the Amadeus Basin and two large fold nappes (the Arltunga Nappe Complex, figure ST2) were formed. The nappes have cores of Precambrian crystalline rocks and enveloped the basal Proterozoic sequence (Heavitree Quartzite-Bitter Springs Formation) of the Amadeus Basin. The younger overlying sedimentary pile was not involved in the nappe folds because of the decollement in the Bitter Springs Formation. It seems most likely that the sediments younger than the Bitter Springs Formation and in a position above the Arltunga Nappe Complex slid southwards into their present position possibly by a combination of gravity sliding and by being pushed in front of the growing nappe complex, to form the two major thrust nappes, one on top of the other.

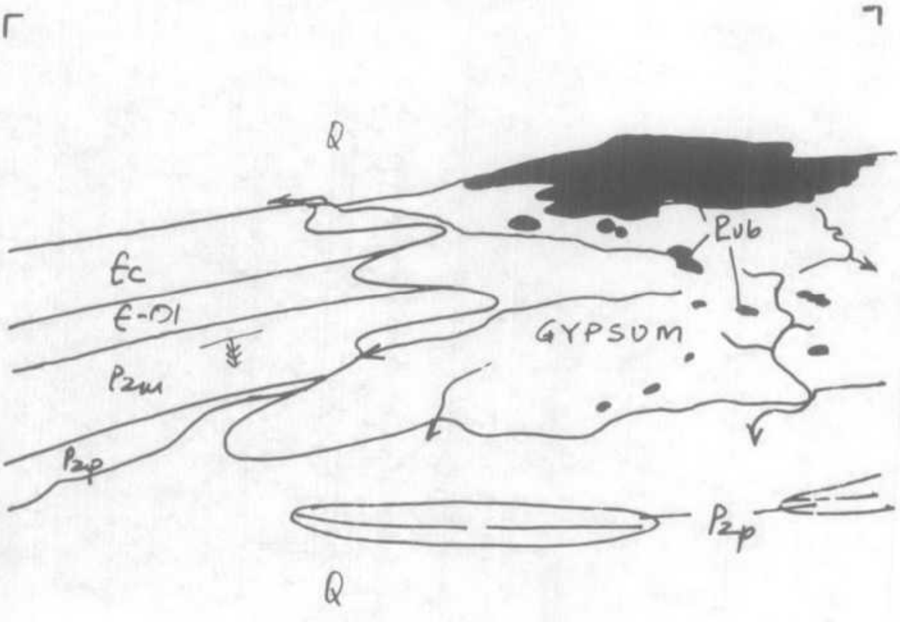
This mechanism produced structures such as the Ringwood-Olympic Folded Thrust. The sediment preserved in these thrust sheets are then, in fact, large allochthonous blocks.

It is possible to extend the interpretations given for the Ringwood-Olympic and Hi Jinx Folded Thrusts (Wells et al. 1967) to the remainder of the north-eastern part of the Amadeus Basin (A.J. Stewart, pers. comm.) and to connect the numerous thrust mapped to form two much larger lower angle thrust faults and to interpret these as the surfaces of two large scale thrust nappes, one on top of the other. The southern front of the upper larger thrust nappe extends from the Hi Jinx Folded Thrust westwards to the Allambi Imbricate Structure and the southern margin of the Phillipson Pound. The southern front of the lower smaller thrust nappe is mostly obscured and occurs several miles to the north of the front of the overlying nappe (figure DS11).

Erosion of the thrust nappes after folding left two large klippen of the larger nappe; one forms the eastern MacDonnell and Ferguson Ranges, and the other the Phillipson Pound. The rocks exposed between the two klippen of the upper nappe belong to the lower or earlier nappe which is smaller in extent. The trailing edge of both nappes lies in the large area of contorted Bitter Springs Formation north of the MacDonnell Range and south of the Arltunga Nappe Complex. The area of sediments about 5 miles outh-west of Ringwood Homestead form a tectonic window in the lower thrust nappe and hence are autochthonous. A similar window may also occur in the area east of Undoolya Gap.

This interpretation is still tentative and requires further field evidence to support the extension of the interpretation given for the Ringwood-Olympic Folded Thrust to the remainder of thrusted sediments in the north-eastern part of the Amadeus Basin. The interpretation of two thrust nappes involves considerable movement of the sediments from their original depositional site and in fact the southern front of the larger upper thrust nappe may have moved as much as 60 miles. This suggest that there should be considerable differences in the stratigraphic succession between the autochthonous and allochthonous blocks. There appears to be a disparity between the succession in the Pertatataka Formation exposed in the eastern end of the southern klippen of the upper thrust nappe and the succession exposed to the south of the front of the nappe and in the autochthonous block exposed in the tectonic window south of Ringwood. In other areas the evidence is

Fig. DS-5 Johnstone Hill Diapir. Large mass of gypsum in light toned rounded hills intruding Palaeozoic sediments now exposed in strike ridges. Dark hills of Bitter Springs Formation in right background.
G/4368

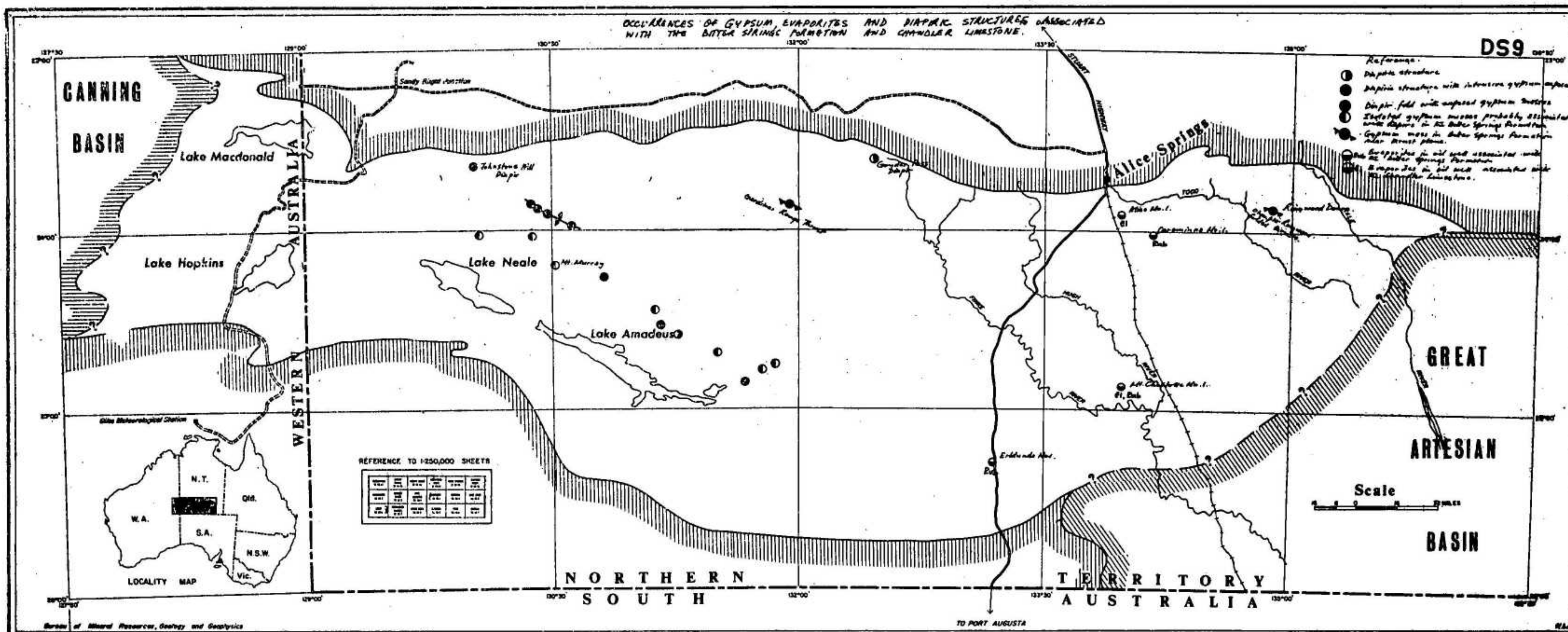


Johnstone Hill diapir.
Pub, Bitter-Springs Formation, €c Cleland Sandstone, €-O1, Larapinta Group, Pzm Mereenie Sandstone, Pzp, Pertnjara Group, Q Quaternary deposits

Fig. DS-6 Overlay to photograph above.

Fig. DS-7 Gypsum from the Gillen Member of the Bitter Springs Formation in the Ringwood Dome.
G/9121

Fig. DS-8 Goyder Pass Diapir in the MacDonnell Range. Prominent scarp in the centre of photograph is the Pacoota Sandstone.
G/9578


OCCURRENCES OF GYPSUM, EVAPORITES AND DIAPIRIC STRUCTURES ASSOCIATED WITH THE BITTER SPRINGS FORMATION AND CHANDLER LIMESTONE.
DS9
Reference.
Diapiric structure
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
STUART HIGHWAY
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
GREAT ARTESIAN BASIN
Scale
REFERENCE TO 1:250,000 SHEETS
LOCALITY MAP
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
TO PORT AUGUSTA
Bureau of Mineral Resources, Geology and Geophysics

SECTIONS THROUGH THRUST NAPPES IN THE NORTH EASTERN PART OF THE AMADEUS BASIN. DS 10

Figure DS 10A

V/H ≈ 1

Diagrammatic S/N cross-section through Phillipson and Todd River Nappes. Most of the movement of the nappes was toward the reader.

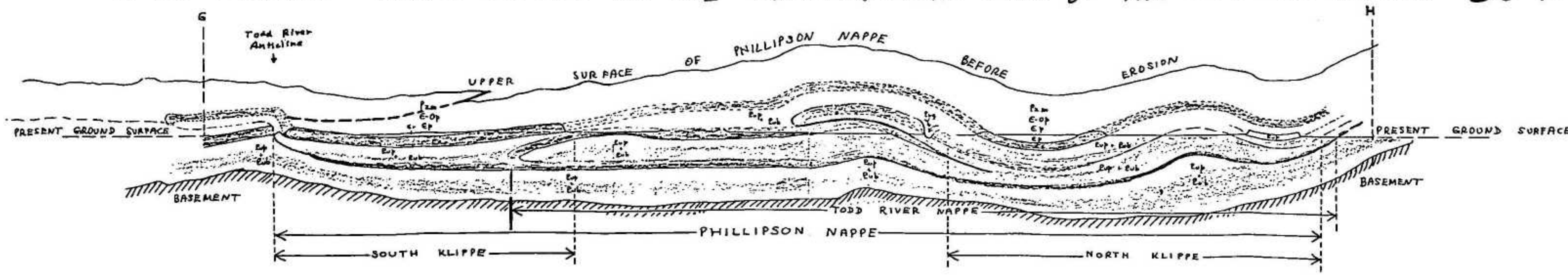


Figure DS 10B

north-south

Diagrammatic cross-section through Phillipson and Todd River Nappes, central part.

V/H ≈ 2

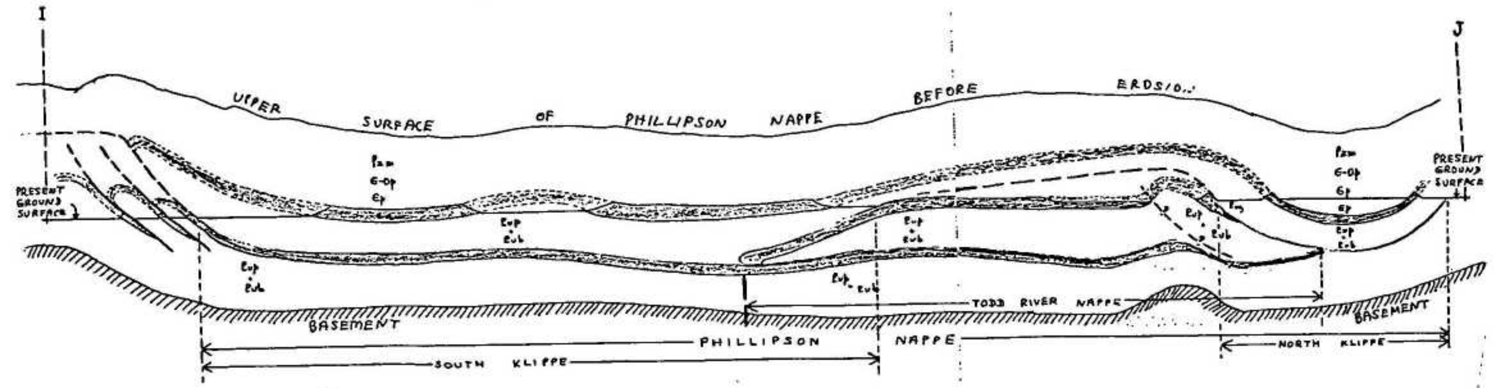
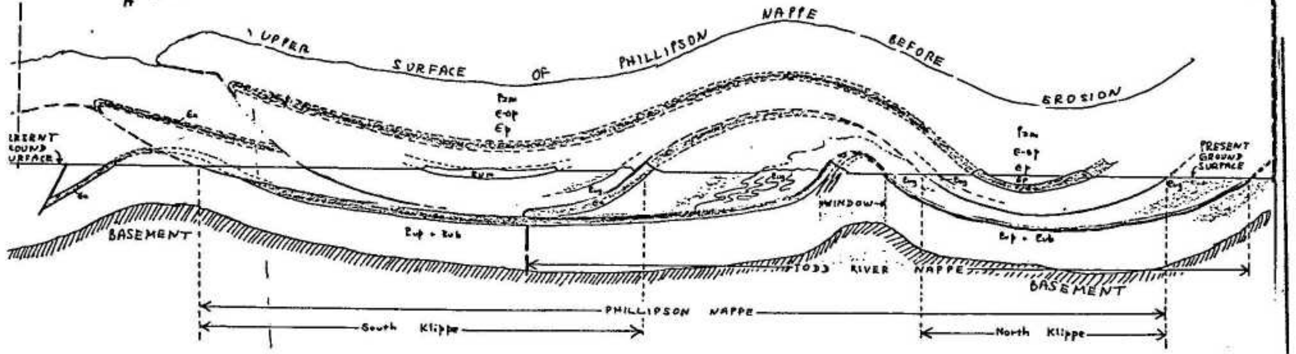


Figure DS10C

Diagrammatic north-south cross-section through Phillipson and Todd River Nappes, eastern part

V/H ≈ 2



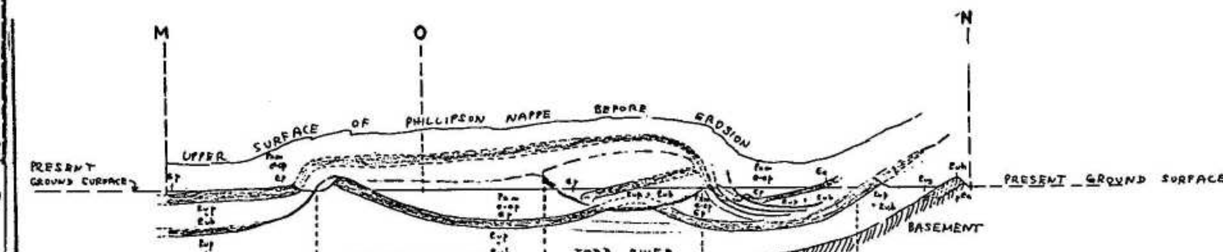


Figure DS10D

north-south

Diagrammatic cross-section through Phillipson and Todd River Nappes, western part.

V/H ≈ 1½

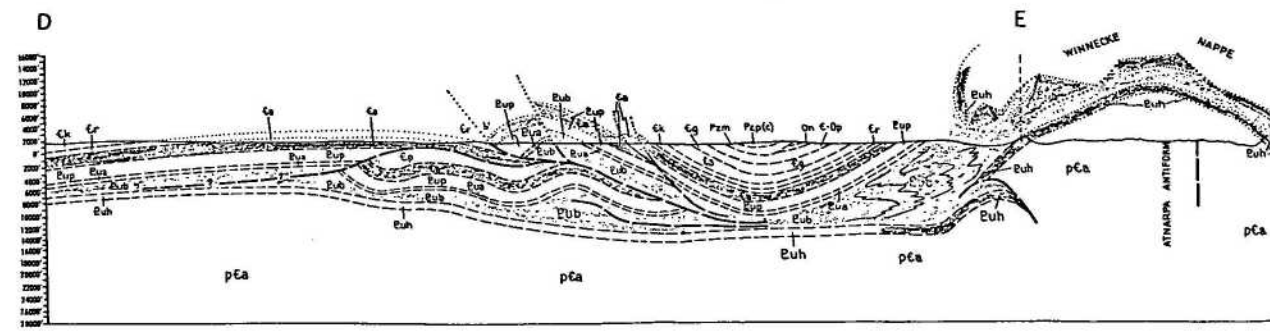


Figure DS 10E

V/H = 1

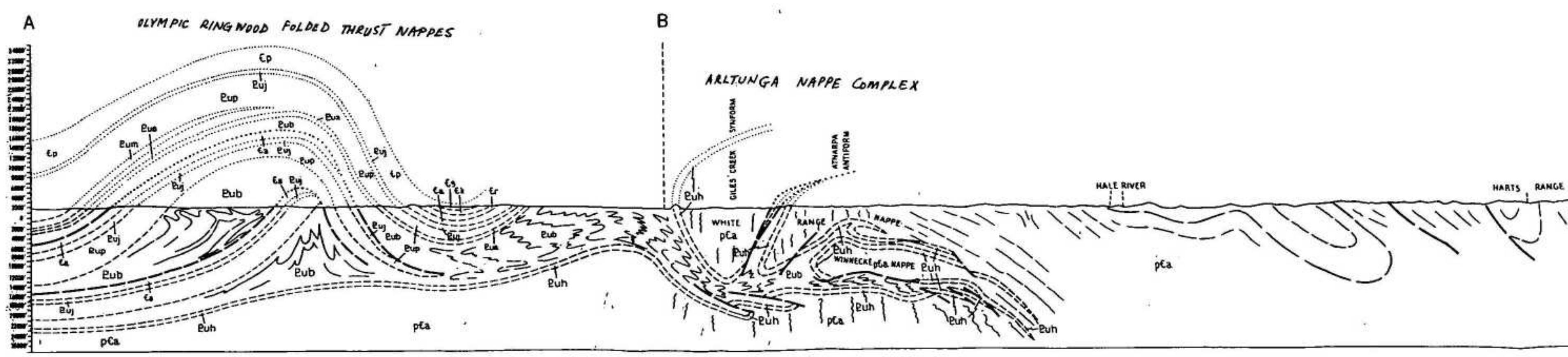


Figure DS 10F

V/H = 1

inconclusive. For example there is little apparent difference in the succession exposed in the Todd River Anticline and the Phillipson Pound. Further detailed section measuring in these area will be necessary to prove dissimilarities of the sections in adjacent autochthonous and allochthonous blocks.

The recent exploratory petroleum wells drilled in the Amadeus Basin have shown that large thicknesses of evaporites are present both in the Gillen Member of the Bitter Springs Formation and in the Lower Cambrian Chandler Limestone (Plates 7 and 8). The present known occurrences of gypsum and evaporites in the Bitter Springs Formation and the Chandler Limestone both in wells and in outcrop are shown in figure DS-9). Ooraminna No. 1 Well, drilled on the crest of the Ooraminna Anticline, penetrated over 130 feet of rock salt in the Bitter Springs Formation. Salt in this formation was also penetrated in Mount Charlotte No. 1 and Erlunda No. 1 Wells. In each of these wells a total of about 150 feet of salt was penetrated but in incomplete sections of the formation. About 300 feet of Lower Cambrian salt was penetrated in Alice No. 1 Well and about 650 feet in Mount Charlotte No. 1 Well, both in complete sequences.

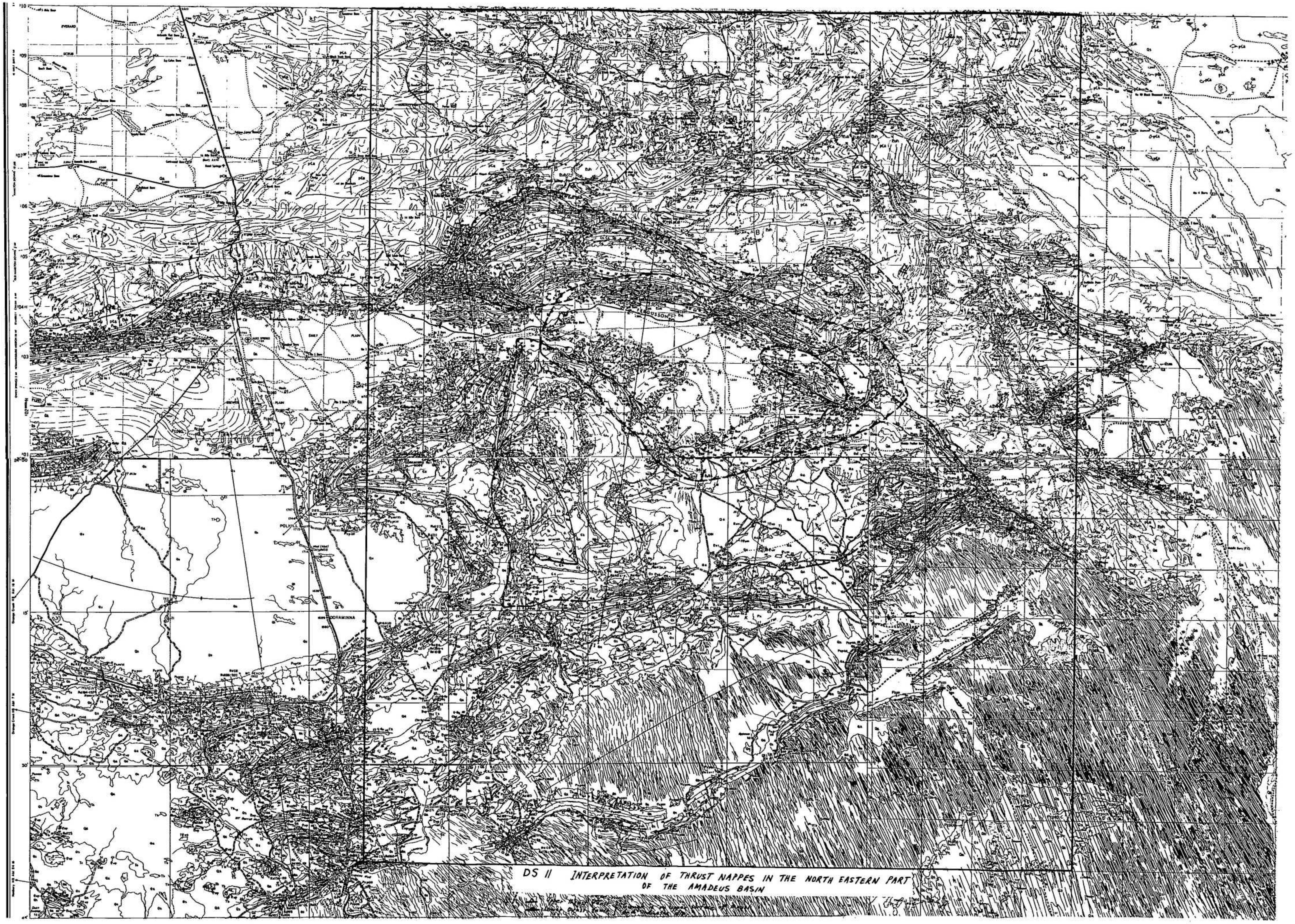
The known outcrops of gypsum extend south-eastwards from the occurrence in the Johnstone Hill Diapir (figures DS-5, DS-6) to a point about 12 miles north-north-west of Inindia Bore, a distance of 145 miles (figure DS-9). In this zone of outcrops most of the occurrences of gypsum are thought to be of diapiric origin with the possible exception of the outcrops in the core of the eroded anticline south of the Cleland Hills. Initiation of diapiric movement of salt probably occurred during the Petermann Ranges Orongeny in the late Proterozoic or early Cambrian. Most of the occurrences of gypsum are on the northern edge of the trough in which there was maximum sedimentation during the Proterozoic. This trough was separated from a northern shelf area by a hinge line which at times during the Proterozoic was a structural high and probably constituted a stable buttress against which the thick Proterozoic sediments of the trough were squeezed during the Petermann Ranges Orogeny. The details of these Proterozoic structural elements are described in the section discussing the development of the Proterozoic Basin and its palaeogeography. This buttress would cause high confining pressures in the sedimentary sequence and the more mobile evaporites would flow into the axial zones of the folds and local piercing of the overlying beds would take place at this time.

The folding during the Alice Springs Orogeny probably further accentuated the decollement and further diapirism took place as shown by the presence of gypsum intrusions in Palaeozoic rocks and the thinning of these sediments over the crest of these Palaeozoic structures.

Outcrops of gypsum outside the central south-east trending zone occur in the north flank of the Gardiner Range next to the Gardiner Thrust, and in a dome 7 miles south-west of Ringwood Homestead which occurs in the Olympic-Ringwood thrust zone. Both these occurrences are probably the result of flowage of evaporites and incompetant folding of the Bitter Springs Formation during thrusting. In both cases the formation is preserved in the upper thrust plate.

The outcrop of gypsum south-east of Ringwood is in a well defined dome shaped body, the Ringwood Dome (figure DS-7), which is surrounded by upturned beds of the formation. The dome has a cap of brecciated gypsum which suggests that piercement may have taken place. Small piercement structures, involving intrusion of the Bitter Springs Formation into younger formations where the sediments are involved in thrust structures, have been described in the north-east part of the Amadeus Basin (Wells, et al., 1967, in press). The regional structure in this area shows that large blocks of Palaeozoic and Proterozoic sediments were dissrupted by differential stresses in the underlying mass of incompetant Bitter Springs Formation. Intrusion of the formation occurred along major lines of weakness possible during the late stage folding of the earlier formed thrust nappes.

The Goyder Pass Diapir (McNaughton et al., 1967, in press) (figure DS-8) is most likely a trap door structure with a large block of sediments disrupted on its eastern side by a fault along which evaporites were intruded, and hinged on the opposite (western) side where considerable bending but no disruption of the beds took place. The variation in thickness of the sediments, and the arching of the formations over this structure show that



DS II INTERPRETATION OF THRUST NAPPES IN THE NORTH EASTERN PART OF THE AMADEUS BASIN movement was gradual and was taking place up until the deposition of the lower parts of the Pertnjara Group. The first movements cannot be defined accurately but were probably no younger than Cambrian. No evaporites are exposed at Goyder Pass but they undoubtedly occur at shallow depths beneath superficial deposits. Beds of dolomite apparently concordant with the overlying Areyonga and Pertatataka Formations occur in the core of the diapir and are probably part of the Loves Creek Member of the Bitter Springs Formation. The evaporites and incompetant beds of the Gillen Member occupy the zone where diapiric intrusion is postulated. This zone is an area without outcrop and occurs stratigraphically below the outcrops of the Loves Creek Member.

The Missionary Plains seismic survey (Krieg and Campbell, 1965) has shown that the zone of disrupted sediments at Goyder Pass trends south-westwards and can be connected to the eastern end of the Carmichael Structure. The Carmichael Structure is an east-west overturned anticlinal trend with the beds of the south flank steeply overturned to the north. Units in the Pertnjara Group thin considerably over the axis of the anticline where they are exposed at the eastern end of the Carmichael Structure which indicates structural growth during sedimentation. Measured sections in the Ordovician sediments exposed on the south flank of the anticline show also that they are considerably thinner than in outcrops to the north and south suggesting very early and continued growth of the structure.

The Illamurta Structure (Cook, 1966b), in the central part of the Amadeus Basin, is a complex anticlinal feature which grew during sedimentation. Aeromagnetic and gravity data suggests that the movement producing the structure resulted from folding and thrusting in the Archaen Basement and diapirism of the Bitter Springs Formation. The Illamurta Structure, together with three other similar structures, lies on a zone which trends about north-north-west across the Basin. The Goyder Pass Diapir, Gardiner Range "pinchout" and Seymour Range "pinch-out" all lie on this zone. The zone probably formed a topographic high over which thinning of stratigraphic units occurred and which effected the distribution of different sedimentary rock facies at times throughout the late Proterozoic and the Palaeozoic.

The zone formed an important boundary of sedimentation particularly in the Cambrian and strongly influenced the distribution of lithologies, forming the western limit of carbonate sedimentation. The Cambrian formations also show a marked thinning along this zone and a very noticeable bending of the isopachs along its length.

PETROLEUM

Geological Setting

In the deepest part of the Amadeus Basin about 30,000 feet of sediments are preserved. Of this thickness the most prospective rocks for petroleum exploration are essentially conformable marine Cambrian and Ordovician sediments which make up about 40% of the section. The remainder consists of approximately 20% Proterozoic rocks, and 40% continental sediments probably mostly Devonian in age.

The Basin has been shaped by two major orogenies. The first occurred in the late Proterozoic or early Cambrian (Petermann Ranges Orogeny) and decollement folding of the Proterozoic rocks took place mainly in the south-western part of the Basin. The weak shale, dolomite and salt beds in the Bitter Springs Formation served as a lubricant over which the higher stratigraphic units slid. The Precambrian rocks of this orogen were one of the main sources of Lower Palaeozoic rocks so that the Pertaoorrta Group sediments are arenaceous near this provenance and pass through a transition zone of mixed sands, silts and minor carbonate rocks to predominantly carbonate rocks in the north-eastern part of the Basin. The predominantly arenaceous Ordovician rocks were deposited in a shallow marine, stable shelf environment during several transgressive and regressive phases.

The second orogeny (Alice Springs Orogeny) occurred in the Devonian and was responsible for major decollement folding, thrusting and formation of potential structural traps for hydrocarbons in the Amadeus Basin sediments. Prior to the Alice Springs Orogeny, epeirogenic uplift (Rodingan Movement) occurred in the north-eastern part of the Basin and 5 - 10,000 feet of Cambrian and Ordovician sediments were removed before deposition of the overlying continental sediments. Crestal thinning of the Palaeozoic sediments over anticlines show that several of the structures were forming during the lower Palaeozoic sedimentation. They were caused either by doming of salt in the Proterozoic Bitter Springs Formation, or by thrusting in the basement rocks, or a combination of both these mechanisms.

Stabilization of the Basin occurred with the deposition of several thousand feet of partly synorogenic continental sediments in the Upper Palaeozoic. Several major unconformities occur within this sequence. Permian glacial beds and Mesozoic deltaic and marine sediments were deposited in marginal areas of the Great Artesian Basin at the south-eastern edge of the Amadeus Basin.

Source and Reservoir Rocks

The most promising source rocks in the Amadeus Basin occur in the marine Cambrian and Ordovician sediments. In general it is considered that the most likely source beds in these sequences would be siltstones, shales and carbonate rocks, and in the Ordovician Larapinta Group the Stokes Siltstone and Horn Valley Siltstone probably have good source rock potential. The Horn Valley Siltstone accumulated in a euxinic environment and the generation of hydrocarbons would be enhanced by these conditions. By contrast most of the Stokes Siltstone probably accumulated in an epeiric sea with restricted circulation and high salinities and its source potential may not be as good as the Horn Valley Siltstone. In addition its original organic content was probably considerably less than the Horn Valley Siltstone, judging from the preserved fauna which is restricted to minor limestone beds and shows evidence of considerable reworking.

Because of the original high organic content the Pacoota and Stairway Sandstones of the Larapinta Group are probably also potential source rocks as well as being potential reservoirs. The Carmichael Sandstone, at the top of the Larapinta Group, possesses good reservoir rock properties.

Potential source rocks in the Cambrian Pertaoorrta Group include siltstones and carbonate rocks in the Jay Creek Limestone, Hugh River Shale, Shannon Formation, Giles Creek Dolomite, Todd River Dolomite, Chandler Limestone and Tempe Formation. The Arumbera Sandstone is probably the best reservoir rock in the Pertaoorrta Group. Other potential reservoirs in the Group are the Petermann, Illara, Eninta and Cleland Sandstones.

The only Proterozoic Formation with potential as a source rock is the Bitter Springs Formation. Clean sandstone lenses with reservoir properties are developed in the Formation.

In the Great Artesian Basin the Crebaceous Rumbalara Shale probably includes minor source beds. Source beds of greater potential may be present if basin ward marine facies of the Permian glacial sediments or younger marine Permian formations can be found in the area.

Potential cap rocks are widely developed in the Amadeus Basin sediments. They are the Parke Siltstone of the Pertnjara Group, Stokes Siltstone, Horn Valley Siltstone, siltstone of the middle unit of the Stairway Sandstone, and lutites in the Jay Creek Limestone, Hugh River Shale, Shannon Formation, Deception Formation, and salt and shale beds in the Chandler Limestone and Bitter Springs Formation.

The reservoir potential of sands in the Ordovician sequence has been confirmed by drilling in the Amadeus Basin and the Stairway and Pacoota Sandstones have been proved to be gas and oil reservoirs. The properties of these and other sediments and their relative porosities and permeabilities will be discussed later under the results of drilling.

Reservoir Traps

Structural Traps

The structures in the potential source and reservoir beds in the Amadeus Basin sediments were impressed mainly during the Alice Springs Orogeny. In some cases structural relief on preexisting anticlines was further increased during this period of folding. Well defined, practically symmetrical, doubly plunging 'canoe' shaped folds predominate and trend generally in a north-west direction. The folds were formed by decollement slippage in the incompetant Bitter Springs Formation. The incompetant beds, including salt, flowed into the cores of the folds (figure P16) and the formation is now exposed in the breached axial zones of many of the anticlines, and salt has been penetrated in several wells. In places structural growth is evident during sedimentation as there is crestal stratigraphic convergence and local unconformities confined to certain structures. This phenomenon can be explained by salt flowage from the Bitter Springs Formation caused by sedimentary loading which would initiate salt anticlines and salt domes. Examples of these structures are Johnstone Hill and Goyder Pass Diapirs and probably the Carmichael Structure. The Illamurta Structure (Cook, 1966) is also a complex anticlinal feature which grew whilst sedimentation proceeded, but probably resulted not only by diapirism of the Bitter Springs Formation, but also by folding and thrusting in the Precambrian basement. The Illamurta Structure, Goyder Pass Diapir, Gardiner Range 'pinchout' and Seymour Range 'pinchout' lie along a north-north-west belt running across the Amadeus Basin that was probably active throughout the history of sedimentation and during part of this time constituted a topographic high. It is possible that these supratenuous folds, formed early in the history of deposition, and provided potential traps for hydrocarbons before the later orogeny. Folding during the Alice Springs Orogeny greatly increased structural relief on the anticlines and thereby created large traps.

Many of the structures that were forming during deposition of the Lower Palaeozoic sediments, or were formed during the early stages of the Alice Springs Orogeny, are obscured by the overlying continental deposits.

Large thrust structures that originated in the Bitter Springs Formation caused sheets of sediments to over-ride younger rocks and it is feasible that structural traps could occur (with reservoir rocks confined) either beneath or above the fault plane. The trap could be bounded on one side by the fault or formed by folding after the thrust faulting.

Porosity and permeability may also be produced by fracturing of brittle reservoir rocks and can occur in almost flat lying uniform textured sediments. Fracturing is present in the Ordovician sediments in the Palm Valley No. 1. Well and has probably played an important part in the production of hydrocarbons from the Horn Valley Siltstone.

Stratigraphic Traps

Several types of potential stratigraphic traps are present in the Amadeus Basin sediments. They include variations in the stratigraphy and lithology of the reservoir rocks by facies change, variable local porosity and permeability, traps formed by solution and secondary cementation and the upstructure termination of the reservoir rocks at unconformities.

Stratigraphic traps in the Amadeus Basin sediments could be expected to occur mainly as lenses and in areas of changing facies of clastic rocks, but similar changes in the chemically deposited rocks such as the development of biostromes, organic reefs and bioherms particularly in the Pertaoorrta Group may also be important. The lithofacies change in the Pertaoorrta Group, already described, suggests that the zone of interfingering of the major rock types may include stratigraphic traps in the form of lenticular bodies of permeable sands enclosed by impermeable shale. The structural trend on which the Illamurta and other structures are situated probably influenced Pertaoorrta Group sedimentation to the extent of confining the predominantly arenaceous rocks to the west and carbonate rocks to the east. As the structure was extant during sedimentation the sands in the zone may have at times been subject to reworking and removal of the finer grained fractions, and a trap would form by arching of the sand lenses over the structures.

In outcrop the Arumbera Sandstone of the Pertaoorrta Group contains distinct discrete lenses of white clean sandstone enclosed by siltstones and silty sands, and apparently possesses good reservoir properties. This lithological variation is more noticeable in the north-eastern part of the Basin, and is not known in areas of closed structure.

Algal bioherms are present in the Bitter Springs Formation and bioherms and coquinas are present in the Cambrian and Ordovician sediments, but their potential as reservoirs is uncertain. Porous carbonate rock facies may be developed in the large thicknesses of dolomite in the north-eastern facies of the Pertaoorrta Group by either local or widespread dolomitization of limestone.

Potential unconformity traps occur in the sediments at the base of

TABLE I - SUMMARY OF WELLS DRILLED IN THE AMADEUS BASIN

Name	Latitude, Longitude and 1:250,000 Sheet area	Total Depth (feet)	Remarks	Name	Latitude, Longitude and 1:250,000 Sheet area	Total Depth (feet)	Remarks
Ooraminna No. 1	24° 00' 06" S. 134° 09' 50" E. F/53 - 14 Alice Springs	6,097	Subsidised. Gas show in Areyonga Formation. Dray, abandoned.	Johnny Creek No. 1	24° 08' 46" S. 131° 28' 41" E. G/52 - 4 Lake Amadeus	877	Not subsidised Abandoned
Alice No. 1	23° 54' 47" S. 133° 58' 00" E. F/53 - 14 Alice Springs	7,518	Subsidised. Oil bleeding from core in Giles Creek Dolomite. Dry, capped water well.	East Johnny Creek No. 1	24° 11' 00" S. 131° 37' 55" E. G/52 - Lake Amadeus	6,344	Not subsidised Dry, abandoned
Mereenie No. 1	23° 59' 08" S. 131° 30' 10" E. F/52 - 16 Mt. Liebig	3,983	Not subsidised. Open flow 11 m.c.f.d. gas from Pacoota Sandstone & Stairway Sandstone. Plugged and temporarly abandoned gas well.	Gosses Bluff No. 1	23° 49' 15" S. 132° 18' 00" E. F/53 - 13 Hermannsburg	4,535	Subsidised Dry, abandoned
East Mereenie No. 1	24° 00' 31" S. 131° 33' 51" E. G/52 - 4 Lake Amadeus	4,710	Not subsidised. Gas flow 20 m.c.f.d. Completed as gas condensate well from Pacoota Sandstone	James Range A No. 1	24° 10' 42" S. 133° 00' 40" E. G/53 - 1 Henbury	3,000	Not subsidised Dry, abandoned
East Mereenie No. 2	24° 02' 47" S. 131° 38' 50" E. G/52 - 4 Lake Amadeus	5,175	Not subsidised but completion report released. Completed as gas condensate well. 4.5 m.c.f.d. from Pacoota Sandstone.	Highway Anticline No. 1	24° 20' 23" S. 133° 27' 06" E. G/53 - Henbury	3,770	Subsidised Dry, abandoned
West Mereenie No. 1	23° 56' 57" S. 131° 24' 44" E. F/52 - 16 Mt. Liebig	5,504	Not subsidised. Completed as gas condensate well. 10.1 m.c.f.d. from Pacoota Sandstone.	Erldunda No. 1	25° 18' 36" S. 133° 11' 48" E. G/53 - 5 Kulgera	5,463	Subsidised Dry, abandoned
West Mereenie No. 2	23° 58' 49" S. 131° 32' 22" E. F/52 - 16 Mt. Liebig	4,997	Not subsidised. Gas flow 10.6 m.c.f.d. Completed as gas well in Pacoota Sandstone	Ochre Hill No. 1	24° 07' 58" S. 131° 23' 49" E. G/52 - 4 Lake Amadeus	3,761	Not subsidised Abandoned
East Mereenie No. 3	24° 00' 45" S. 131° 33' 10" E. G/52 - 4 Lake Amadeus	5,215	Not subsidised Abandoned	McDills No. 1	25° 43' 50" S. 135° 47' 25" E. G/53 - 7 McDills	10,515	Subsidised Dry, abandoned
Mt. Charlotte No. 1	24° 53' 41" S. 133° 59' 11" E. G/53 - 2 Rodinga	6,943	Subsidised Abandoned. Water well.	Orange No. 1	24° 02' 34" S. 133° 46' 32" E. G/53 - 2 Rodinga	8,886	Subsidised Dry, abandoned.
Palm Valley No. 1	24° 00' 00" S. 132° 46' 20" E. F/53 - 13 Hermannsburg G/53 - 1 Henbury	6,658	Subsidised. Completed as gas well with 11.7 m.c.f.d. from Horn Valley Siltstone. Pacoota and Stairway Sandstones.	Waterhouse No. 1	24° 01' 00" S. 133° 32' 00" E. G/53 - 2 Rodinga	3,081	Not subsidised Dry, abandoned

the Cambrian in the central and southern parts of the Basin, and at the base of the Mereenie Sandstone in the eastern part of the Basin. In both cases the unconformity surface is in the form of overstep. The formation transgressively overlaps the edges of erosionally truncated series of formations. The Pertaoorrta Group transgresses the Pertatataka, Areyonga and Bitter Springs Formations in the central folded belt in the Basin, and the Mereenie Sandstone transgresses formations of the Larapinta Group and unconformably overlies the Pertaoorrta Group in the eastern part of the Basin. A similar overstep is present at the base of the Pertnjara Group and the youngest formation rests in places on rocks as old as the Pertatataka Formation.

Reservoirs may be present in sands truncated below the unconformity surface or in places buttress sands may be present where beds of sandstone intersect the underlying plane of unconformity. Buttress sands of this type could be developed at the unconformity surface at the base of the Pertaoorrta Group in the central part of the Basin. The basal Eninta Sandstone of the Pertaoorrta Group is not exposed in the cores of the eroded anticlines, but may be present subsurface as pinchouts against the unconformity surface. In these examples the stratigraphic element forms the edge of permeability of the reservoir rock, and subsequent deformation completes the trap. Hence if basal buttress sands are proved at the unconformity at the base of the Pertaoorrta Group against pinnacles of Proterozoic rocks then closure would form by subsequent folding during the Alice Springs Orogeny.

The presence of diapiric structures in the Amadeus Basin suggests the possibility of several types of traps such as the uplifting of sediments against the dome, block faulting of the sediments, overlapping of reservoir formation during successive phases of movement of the evaporites, and accumulation of hydrocarbons under salt dome cap rocks. Although salt diapirs are present in the Amadeus Basin succession none have been proved in a suitable structural position in potential source and reservoir rocks.

Results of Drilling

Up until mid 1966 a total of 18 exploratory wells had been completed in the Amadeus Basin and one well completed on the western fringe of the Great Artesian Basin.

A summary of drilling results in the Amadeus Basin is shown in Tables 1 - 2.

The location of oil wells and stratigraphic bores in the Amadeus Basin is shown in figure P5 and details of formations penetrated their electrical characteristics and correlations between wells are shown in Plates 5-8.

The information on the [illegible] results of this drilling is summarised in the following well completion reports.

Well	Reference to completion report
Ooraminna No. 1	Planalp and Pemberton, 1963
Alice No. 1	Pemberton, Chambers, Planalp and Webb, 1963
Mereenie No. 1	Pemberton, Planalp, Chambers and Webb, 1964
East Mereenie No. 1	Benbow, Lawson and Planalp, 1964 (a)
East Mereenie No. 2	Benbow, Lawson and Planalp, 1964 (b)
West Mereenie No. 1	Benbow, Lawson and Planalp, 1965
West Mereenie No. 2	Benbow, and Lawson, 1965
East Mereenie No. 3	Benbow, 1966
Mount Charlotte No. 1	McTaggart, Pemberton and Planalp, 1965
Palm Valley No. 1	Magellan Petroleum (N.T.) Pty Ltd., 1965
Johnny Creek No. 1	Benbow and Planalp, 1965
East Johnny Creek No. 1	McTaggart and Benbow, 1965a
Gosses Bluff No. 1	Pemberton and Planalp, 1965
James Range 'A' No. 1	McTaggart and Pemberton, 1965a
Highway Anticline No. 1	McTaggart and Pemberton, 1965b
Erldunda No. 1	Pemberton and McTaggart, 1965
Ochre Hill No. 1	McTaggart and Benbow, 1965b
McDills No. 1	Amerada Petroleum Corp. of Aust. Ltd., 1965
Waterhouse No. 1	Centralia Oil Pty Ltd., 1965

The exploratory drilling resulted in the discovery of two gas producing areas, the Mereenie and Palm Valley Anticlines. The Mereenie Anticline has a total of six wells and is probably a major field but the extent of the Palm Valley discovery is not known.

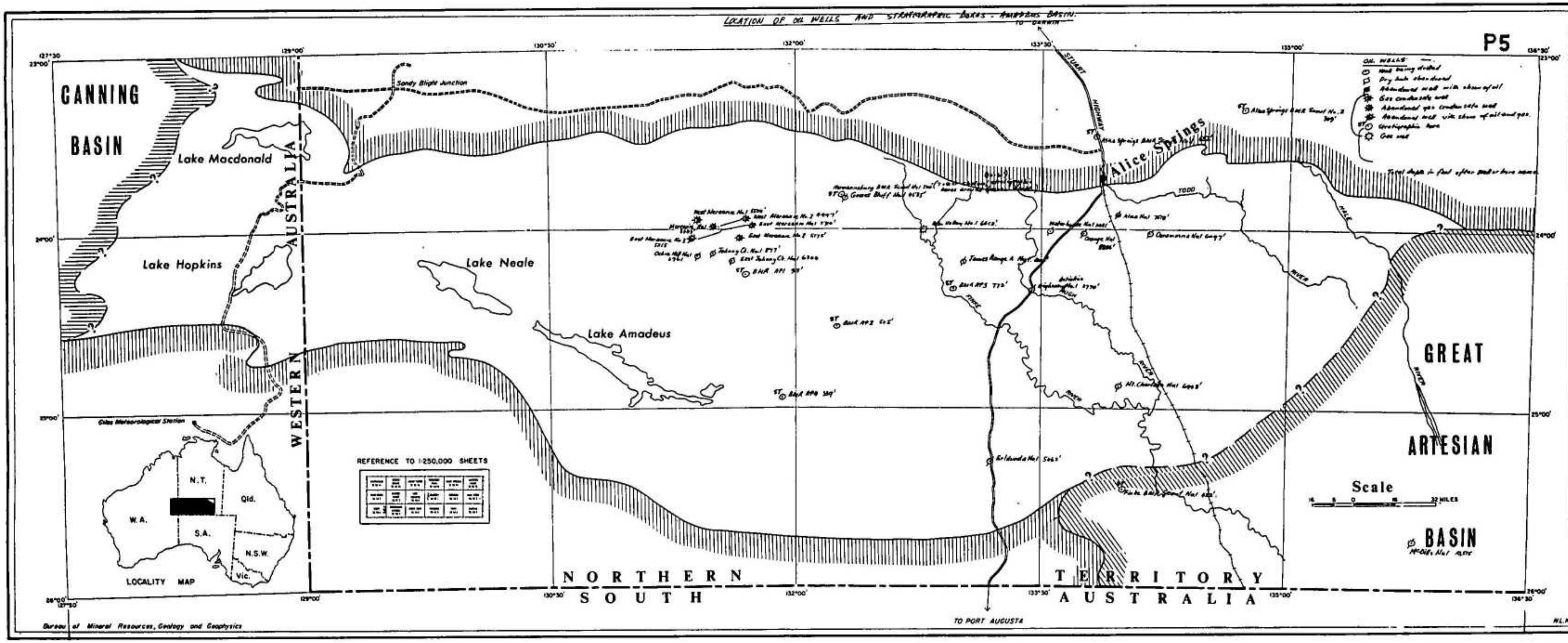

LOCATION OF OIL WELLS AND STRATIGRAPHIC BORES - AMADEUS BASIN
P5
TO DARWIN
STUART HIGHWAY
Alice Springs
CANNING BASIN
Lake Macdonald
Lake Hopkins
Sandy Blight Junction
WESTERN AUSTRALIA
Lake Neale
Lake Amadeus
GREAT ARTESIAN BASIN
Giles Meteorological Station
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
REFERENCE TO 1:250,000 SHEETS
Scale
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
TODD
Total depth in feet after well or bore name.
Bureau of Mineral Resources, Geology and Geophysics

TABLE II. FORMATION THICKNESSES IN WELLS - AMADEUS BASIN

(Data from Well Completion Reports unless otherwise stated, Thickness in feet)

	Well Name	Ooraminna No. 1	Alice No. 1	Mereenie No. 1	East Mereenie No. 1	East Mereenie No. 2	West Mereenie No. 1
	Datum (feet a.s.l.)	K.B. 1624	K.B. 1753	K.B. 2583	K.B. 2529	K.B. 2357	K.B. 2482
	Formation						
	Quaternary						
	Rumbalara Shale						
	De Souza Sandstone						
	Crown Point Formation						
Pertnjara Group	Brewer Conglomerate		539+(surf. - 550)				
	Hermannsburg Sandstone		615 (550 - 1165)				
	Parke Siltstone					583+ (surf. - 594)	
Finke Group	Idracowra Sandstone						
	Horseshoe Bend Shale						
	Langra Formation						
	Polly Conglomerate						
	Mereenie Sandstone		950 (1165 - 2115)	1205+(surf. - 1216)	1193+(sruf. - 1204)	1274 (594-1868)	1081+(surf. - 1092)
Larapinta Group	Carmichael Sandstone			315 (1216-1531)	296 (1204-1500)	210 (1868-2078)	348 (1092-1440)
	Stokes Siltstone			1039 (1531-2570)	1016 (1500-2516)	1028 (2078-3106)	1158 (1440-2598)
	Stairway Sandstone			830 (2570-3400)	812 (2516-3328)	777 (3106-3883)	852 (2598-3450)
	Horn Valley Siltstone			230 (3400-3630)	222 (3328-3550)	201 (3883-4084)	258 (3450-3708)
	Pacoota Sandstone		889 (2115-3004)	353+ (3630-3983)	1065 (3550-4615)	1021 (4084-5105)	1095 (3708-4803)
Pertaoorrta Group	Goyder Formation		800 (3004-3804)		95+(4615-4710)	70+ (5105-5175)	701+(4803-5504)
	Jay Creek Limestone						
	Hugh River Shale						
	Shannon Formation		1343 (3804-5147)				
	Giles Creek Dolomite		1471 (5147-6618)				
	Chandler Limestone		522 (6618-7140)				
	Todd River Dolomite						
	Petermann Sandstone						
	Deception Formation						
	Illara Sandstone						
	Cleland Sandstone						
	Tempe Formation						
	Eninta Sandstone						
	Arumbera Sandstone	1519+ (surf. - 1530)	378+ (7140-7518)				
	Pertatataka Formation	2200 (1530-3730)					
	Julie Member	420 (1530-1950)					
	Winnall Beds						
	Inindia Beds						
	Areyonga Formation	535 (3730-4265)					
	Bitter Springs Formation	1832 (4265-6097)					
	Loves Creek Member	1015 (4265-5280)					
	Gillen Member	817+ (5280-6097)					
		T.D. 6097 Data from G. Schmerber B.M.R.Rec. 1966/82, and B.M.R.Rec. 1967/-.	T.D. 7518 Data from A. Fehr B.M.R. Rec. 1966/5	T.D. 3983	T.D. 4710	T.D. 5175	T.D. 5504

West Mereenie No.2	East Mereenie No. 3	Mt. Charlotte No. 1	Palm Valley No. 1	Waterhouse No. 1	Johnny Creek No. 1	East Johnny Creek No.1
K.B. 2535	K.B. 2532	K.B. 1260	R.T. 1921	-	K.B. 2211	K.B. 2200
	Thicknesses corrected for deviation and dip *	42+(surf. - 56) possibly includes some Idracowra Sandstone				
	347+*(surf. - 386)		456+ (surf. - 470) 546 (470 - 1016)			
1518+ (surf.-1532)	1770 (386-2352)	464 (56-520) 500 (520-1020) 180 (1020-1200) shale equivalent to Polly Conglomerate	1744 (1016-2760)			
314 (1532-1846) 1060 (1846-2906) 830 (2906-3736) 230 (3736-3966) 1031+ (3966-4997)	293 (2352-2677) 1094 (2677-3834) 824 (3834-4668) 231 (4668-4902) 309+(4902-5215)	340 (1200-1540)	448 (2760-3208) 1112 (3208-4320) 976 (4320-5296) 338 (5296-5634) 1024+(5634-6658)		539+(surf. - 550)	149+ (surf. - 160) 187 (160-347) 926 (347-1273)
		792 (1540-2332)		2254+ (surf. - 2254)	327+ (550-877)	682 (1273-1955)
		740 (2332-3072)				
						789 (1955-2744) 550 (2744-3294) 651 (3294-3945)
				827+ (2254-3081)		740 (3945-4685) 69 (4685-4754)
		1598 (3072-4670)				
		2130 (4670-6943)* 430 (4670-5100) 1843+ (5100-6943)	*true thickness			216 (4754-4970) 1374+ (4970-6344) (Includes Loves Creek and Gillen Members?)
T.D. 4997	T.D. 5215	T.D. 6943 Data from G.Schmerber Rec. B.M.R. 1966/120	T.D. 6658	T.D. 3081 Data from G.Schmerber Rec. B.M.R. 1966/137	T.D. 877	T.D. 6344

Gosses Bluff No. 1	James Range A No. 1	Highway Anticline No.1	Erldunda No. 1	Ochre Hill No. 1	McDills No. 1		Well Name
K.B. 2453	K.B. 1600	K.B. 1616	K.B. 1343.5	K.B. 2300	K.B. 412		Datum (feet a.s.l.)
							Formation
			126.5(surf. - 140)		85 (surf. - 101)		Quaternary
					1335+ (101-1436)		Rumbalara Shale
					916 (1436-2352)		De Souza Sandstone
					1438 (2352-3790)		Crown Point Formation
						Pertnjara Group	Brewer Conglomerate
			760 (140-900)				Hermannsburg Sandstone
							Parke Siltstone
						Finke Group	Idracowra Sandstone
Not true thicknesses					280 (3790-4070)		Horseshoe Bend Shale
due to steep dips.					1730 (4070-5800)		Langra Formation
					1290 (5800-7090)		Polly Conglomerate
					1120 (7090-8210)		Mereenie Sandstone
			340 (900-1240)			Larapinta Group	Carmichael Sandstone
1032+ (surf. - 1046)							Stokes Siltstone
3489+ (1046-4535)					814 (8210-9024)		Stairway Sandstone
					(unnamed unit)		Horn Valley Siltstone
							Pacoota Sandstone
		467+ (surf.-480)*	*true thickness abt.436	414+ (surf.-428)		Pertaoorrta Group	Goyder Formation
		3290 (480-3770) *	*true thickness abt.2950				Jay Creek Limestone
	2013+(surf.-2026)						Hugh River Shale
							Shannon Formation
							Giles Creek Dolomite
							Chandler Limestone
					1491+ (9024-10515)		Todd River Dolomite
							Petermann Sandstone
							Deception Formation
							Illara Sandstone
				1762 (428-2190)			Cleland Sandstone
				447 (2190-2637)			Tempe Formation
							Eninta Sandstone
	400 (2026-2426)						Arumbera Sandstone
							Pertatataka Formation
							Julie Member
			2510 (1240-3750)				Winnall Beds
			550 (3750-4300)				Inindia Beds
	170 (2426-2596)						Areyonga Formation
	404+(2596-3000)		1163+ (4300-5463)	1124 (2637-3761)			Bitter Springs Formation
	(Probably Loves		450 (4300-4750)	(Probably Loves			Loves Creek Member
	Creek Member)		713+ (4750-5463)	Creek Member)			Gillen Member
T.D. 4535	T.D. 3000	T.D. 3770	T.D. 5463	T.D. 3761	T.D. 10,515		
		Data from G.Schmerber	Data from G.Schmerber		Modified from Well		
		B.M.R. Rec. 1966/83	B.M.R. Rec. 1966/182		Completion report		

Summary and Conclusions

The main exploration programme in the Amadeus Basin is new focussed on the northern province where intensive exploration by seismic methods is in progress. The surveys are designed primarily to locate structures beneath the continental sediments of the Pertnjara Group in the Brewer and Missionary Plains, and to outline any concealed structures in the area as far west as the Cleland Hills and the Mount Rennie Sheet area.

Areas in the central northern part of the Amadeus Basin, where a complete sequence of the Larapinta Group and Pertaoorrta Group remains, is the most favourable for further exploration (stratigraphic and structural test drilling).

The seismic surveys in the Missionary Plain area, on behalf of Magellan Petroleum (N.T.) Pty Ltd, show that closed structures occur in the potential Ordovician and Cambrian reservoir rocks in several places beneath the Pertnjara Group. These are shown in seismic structure maps prepared by Geophysical Associates Krieg and Campbell (1965). Figure P6 is a seismic structure map adapted from this report showing contours on horizon 'A' (about the base of the Mereenie Sandstone), and Figure P7 shows contours on horizon 'E' (approximately the top of the Bitter Springs Formation). The Tyler Structure north-east of Gosses Bluff, is a typical closure in an area in which the full Larapinta Group sequence is preserved.

Other prominent structures with closure beneath the Pertnjara Group occur near the western end of the Waterhouse and Ooraminna Anticlines. Orange No. 1 Well was recently drilled on a seismically defined domal structure beneath the Pertnjara Group between the Waterhouse and Ooraminna Anticlines, but a large part of the Larapinta Group has been eroded in this area. Figure P10 shows seismic contours on horizon 'B' (about 4000 feet below the top of the Pertaoorrta Group), which has (shows) about 1000 feet of (vertical) closure over an area of about 42 square miles.

One of the main problems is to outline areas where there is significant permeability in the reservoir rocks of the Larapinta Group. Outcrops of the Larapinta Group along the MacDonnell Ranges front also show intense secondary silification similar to that found in the Mereenie Wells.

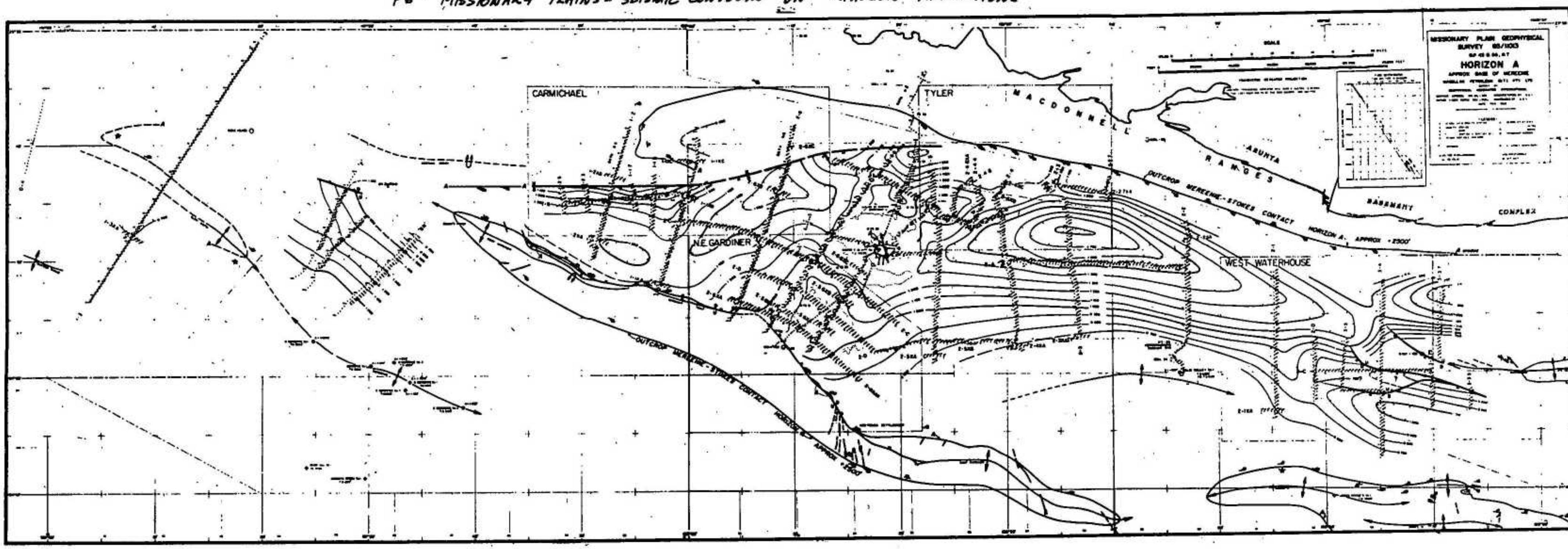
Probably one of the most important sequences in the Pertaoorrta Group is the zone of interfingering of the eastern carbonate-shale facies and the sandstone facies to the west. This transition occurs over a large area roughly encompassed by Parana Hill, Petermann Hills, and the western part of the James Ranges and Gardiner Range. Important reservoir rocks may be developed on the north-south zone on which the Illara structure is situated, and traps in this area would be favourably situated for hydrocarbons migrating from the marine carbonate rocks of the Pertaoorrta Group. The wells in the central folded belt of the Basin penetrated sections of these rocks in the transition zone (Plate 7). Although only traces of residal hydrocarbons and gas have been found in these rocks, many of the sandstones show intergranular porosity. An unfavourable aspect of the sequences is the presence of fresh water in a large proportion of the sandstones.

In addition further exploration along the Mereenie Anticlinal trend is warranted to ascertain if any reversals are present, and further wells are required at Palm Valley to delineate the gas field and ascertain if oil production is feasible.

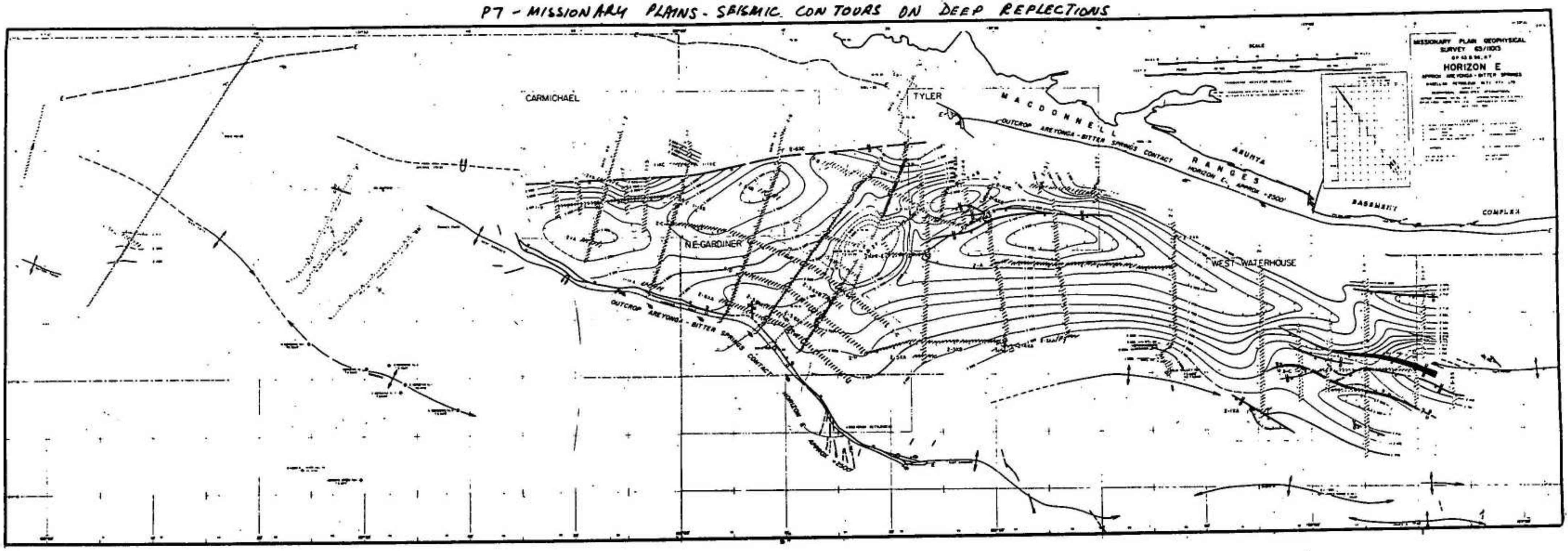
The remaining areas of the Basin can be given lower priority. A large part of the Basin where Proterozoic rocks crops out at the surface as well as the subsurface occurrences are considered to be poor prospects. These sediments are practically unmetamorphosed and contain some residual hydrocarbons and small amounts of gas, but it seems unlikely that they can be seriously considered as a source for large quantities of hydrocarbons.

The western parts of the Basin have only relatively thin marginal sequence of Ordovician rocks and the Cambrian sequence is represented by deltaic sandstones which can only be considered worthy of further prospecting if petroleum migration into the sandstone facies of the Pertaoorrta Group can be demonstrated in the central part of the Amadeus Basin. Most of the exposed anticlines are breached with Proterozoic rocks exposed in the eroded cores.

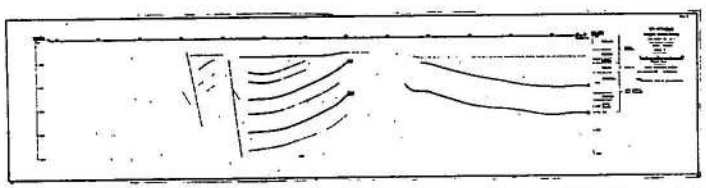
P6 - MISSIONARY PLAINS - SEISMIC CONTOURS ON SHALLOW REFLECTIONS



P7 - MISSIONARY PLAINS - SEISMIC CONTOURS ON DEEP REFLECTIONS

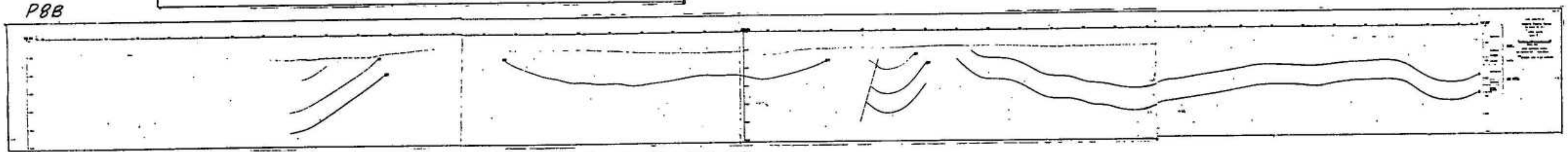


P8A



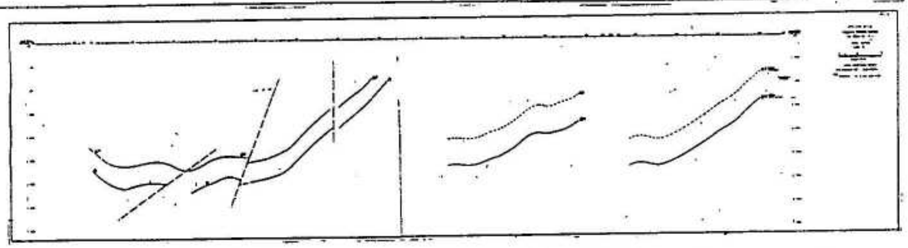
LINE 1

P8B



LINE 2

P8C.

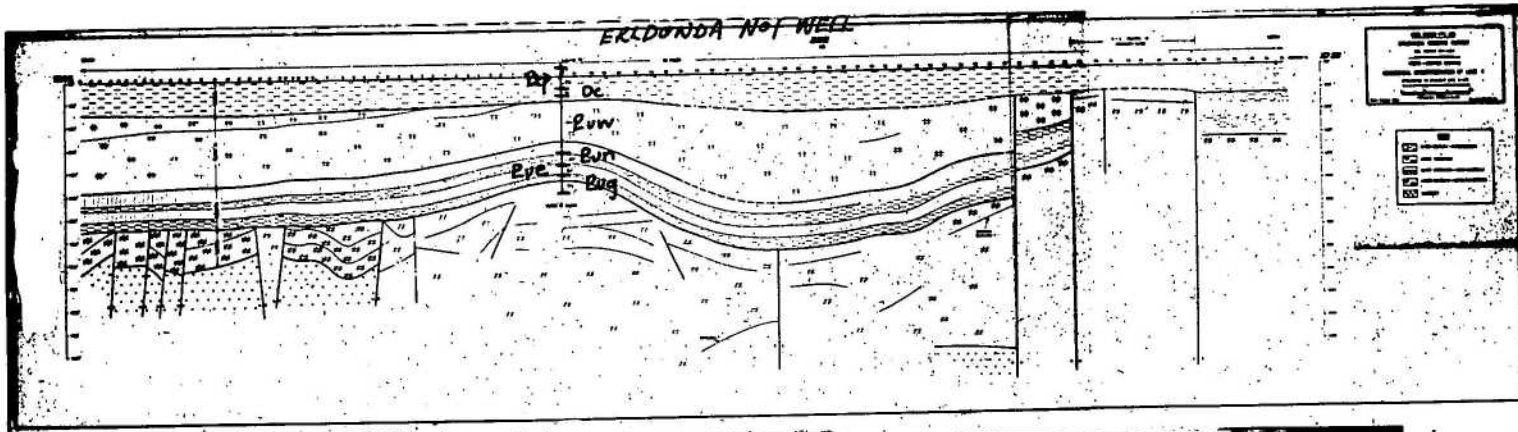


LINE 3

KULGERA SEISMIC SURVEY - INTERPRETATIVE CROSS SECTIONS OF LINES. 1, 2 and 3.

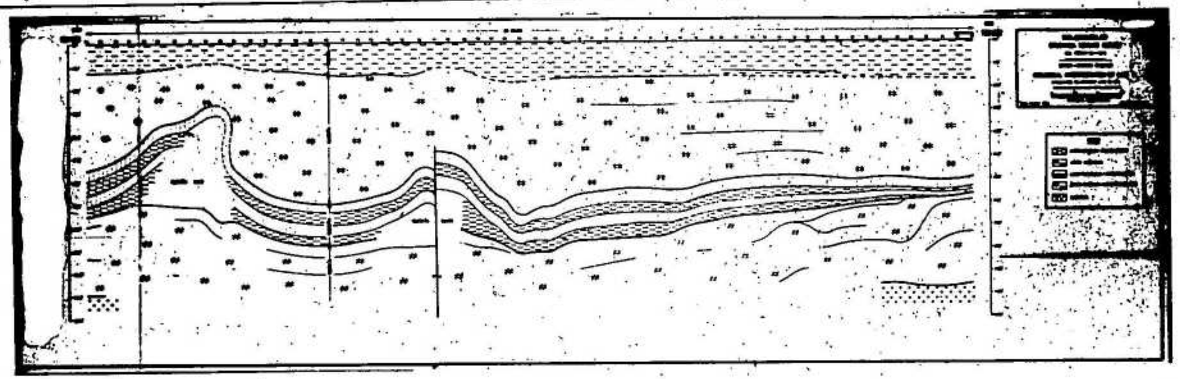
Horizon A is approximately near the base of the Winnall Beds and Horizon B is approximately the top of the Gillen Member of the Bitter Springs Formation.

P9A



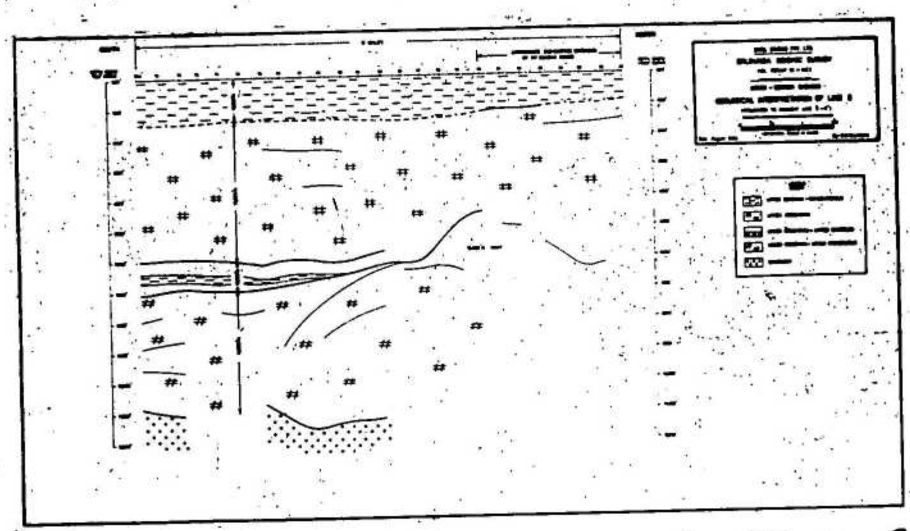
LINE (1)

P9B



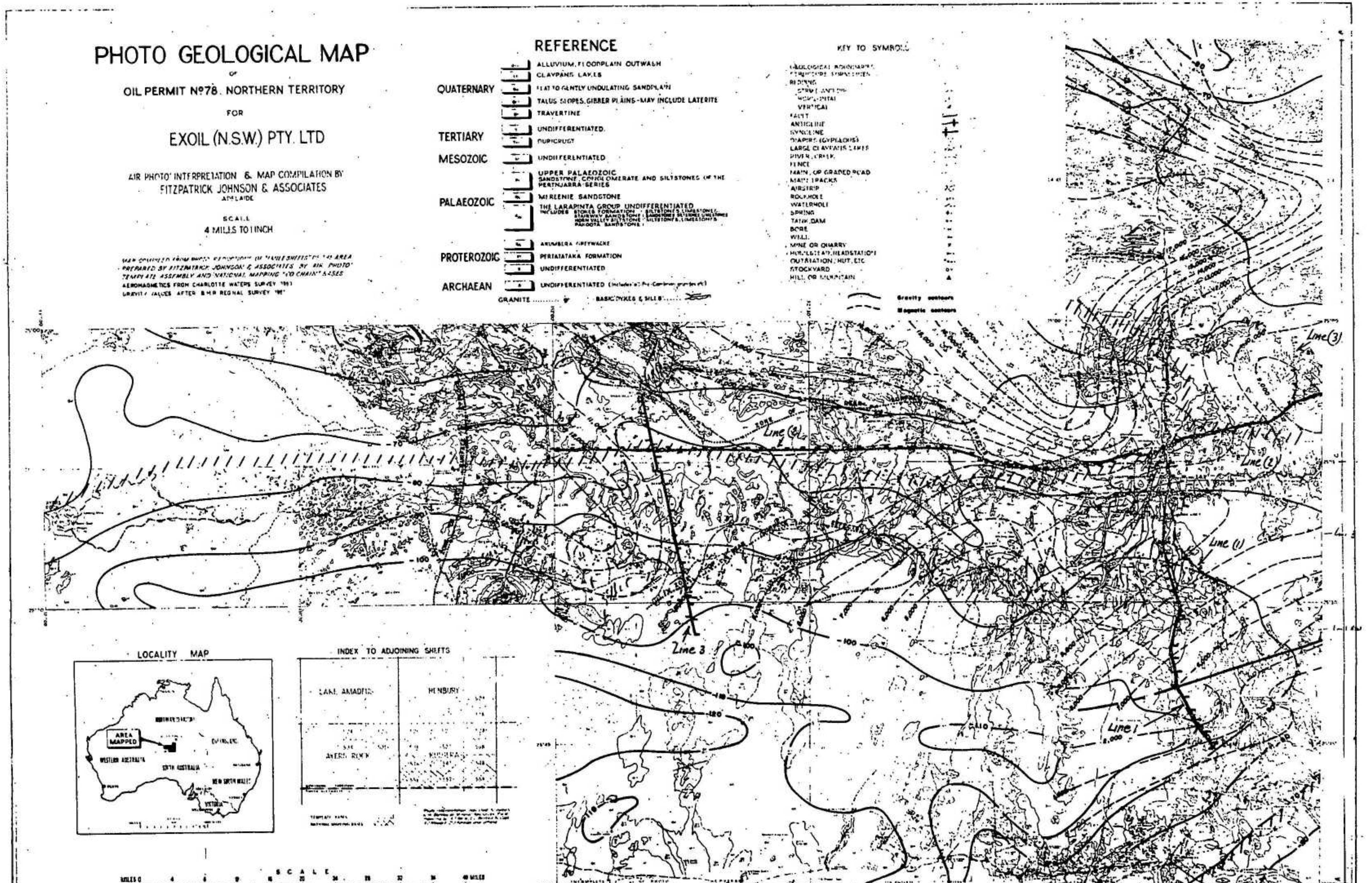
LINE (2)

P9C



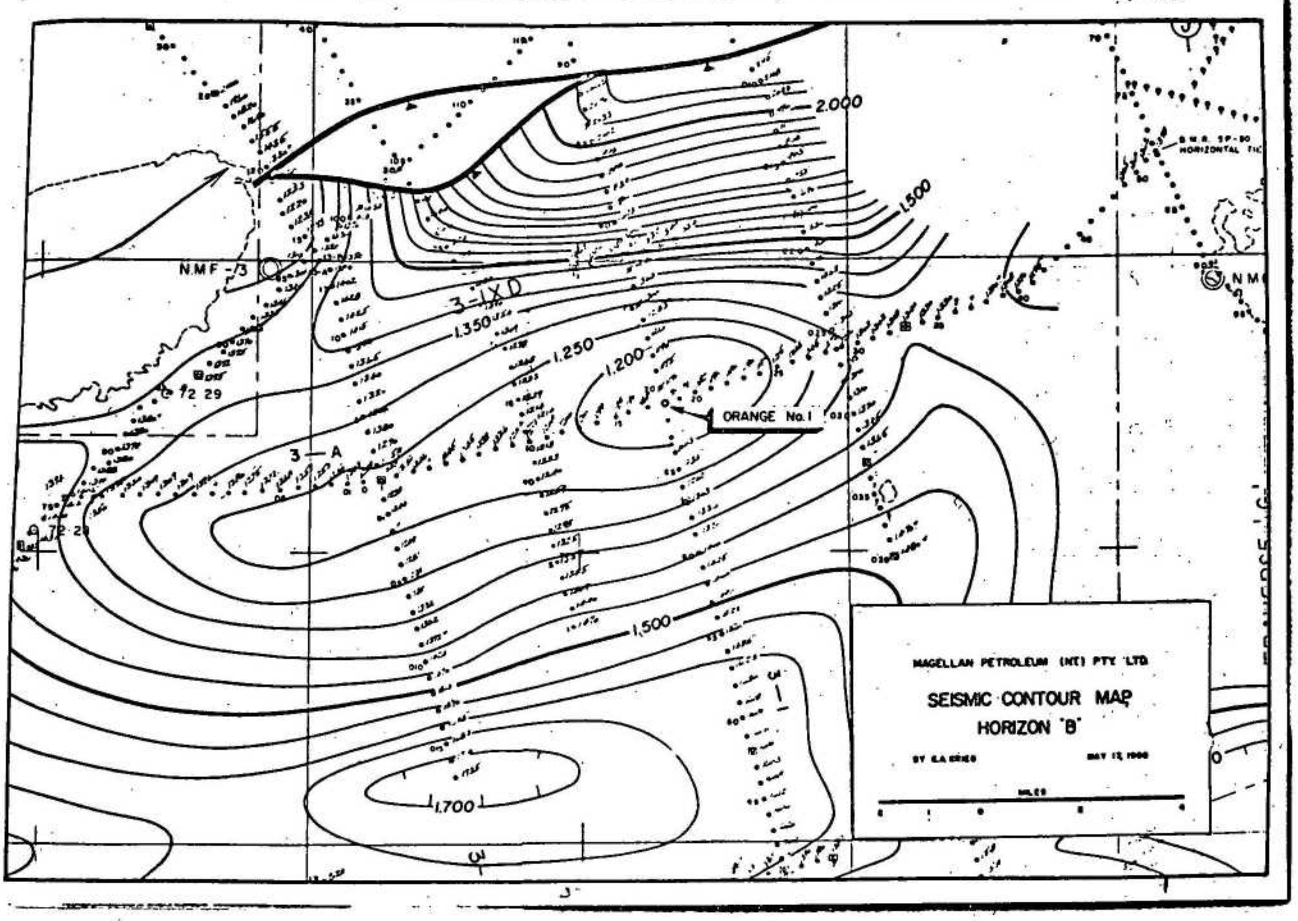
LINE (3)

ERLDUNDA SEISMIC SURVEY - INTERPRETATIVE CROSS SECTIONS OF LINES (1), (2) & (3)
Pzp - Pertnjara Group, Oc - Carmichael Sandstone, Ruw - Winnall Beds, Run - Inindia Beds,
Rve - Loves Creek Member, Rug - Gillen Member (Bitter Springs Formation)



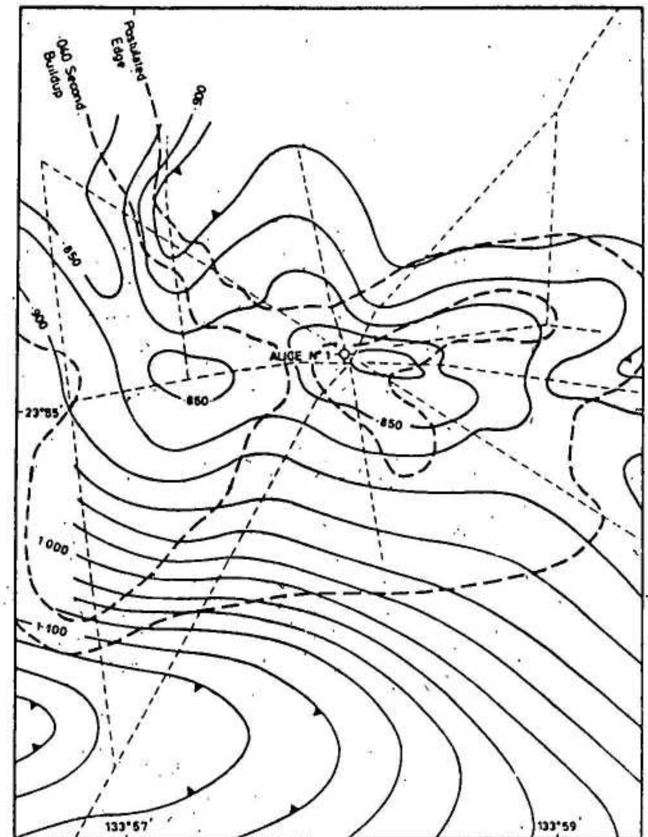
P9D - LOCATION OF SEISMIC LINES - KULGERA AND ERLDUNDA SEISMIC SURVEYS. Kulgera lines 1,2 & 3 ; Erldunda lines (1), (2) & (3)

P10



ORANGE PROSPECT - SEISMIC CONTOURS, HORIZON 'B'.

P11



EXOIL (N.T.) PTY. LTD.

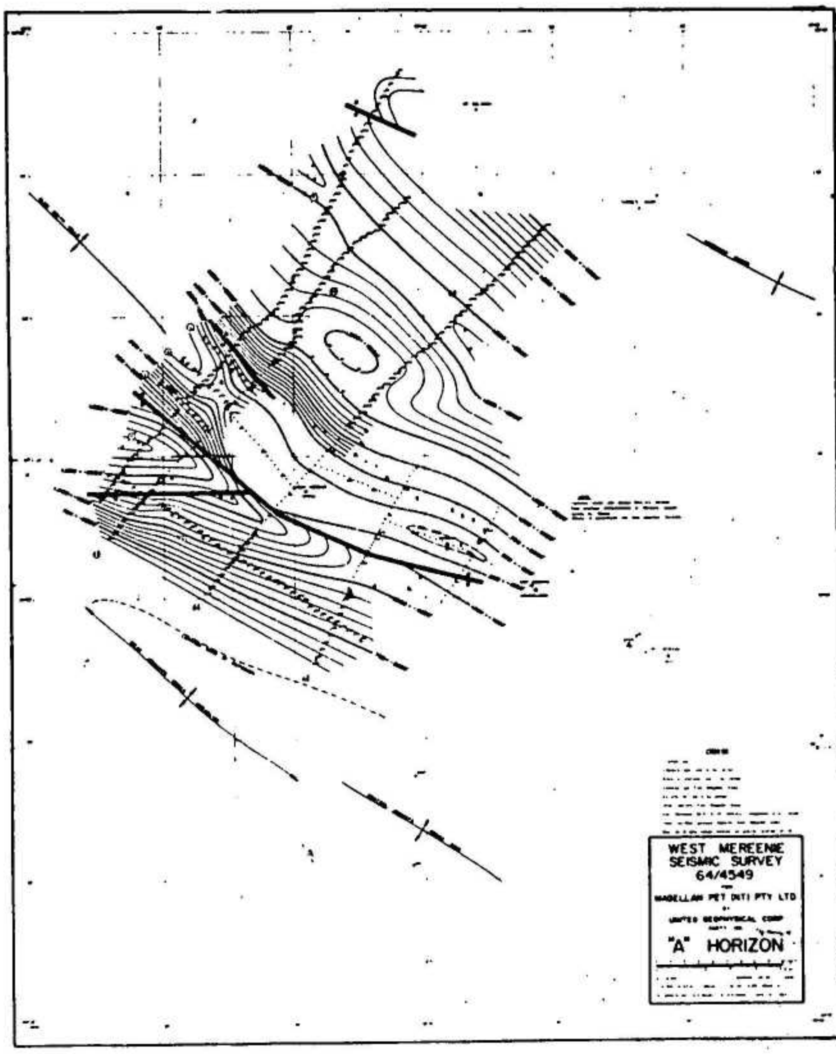
ALICE PROSPECT SEISMIC SURVEY

0 1/2 1 MILES

Seismic Lines — Contours — Cycle Divergence

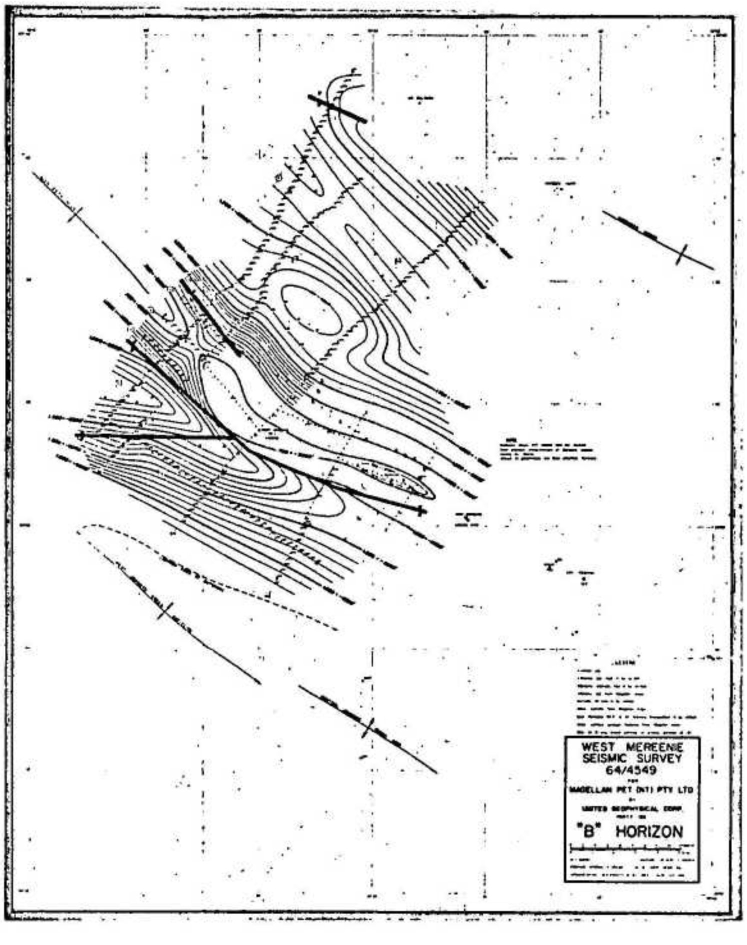
ALICE PROSPECT - SEISMIC CONTOURS APPROXIMATELY THE SHANNON FORMATION HORIZON

P12A



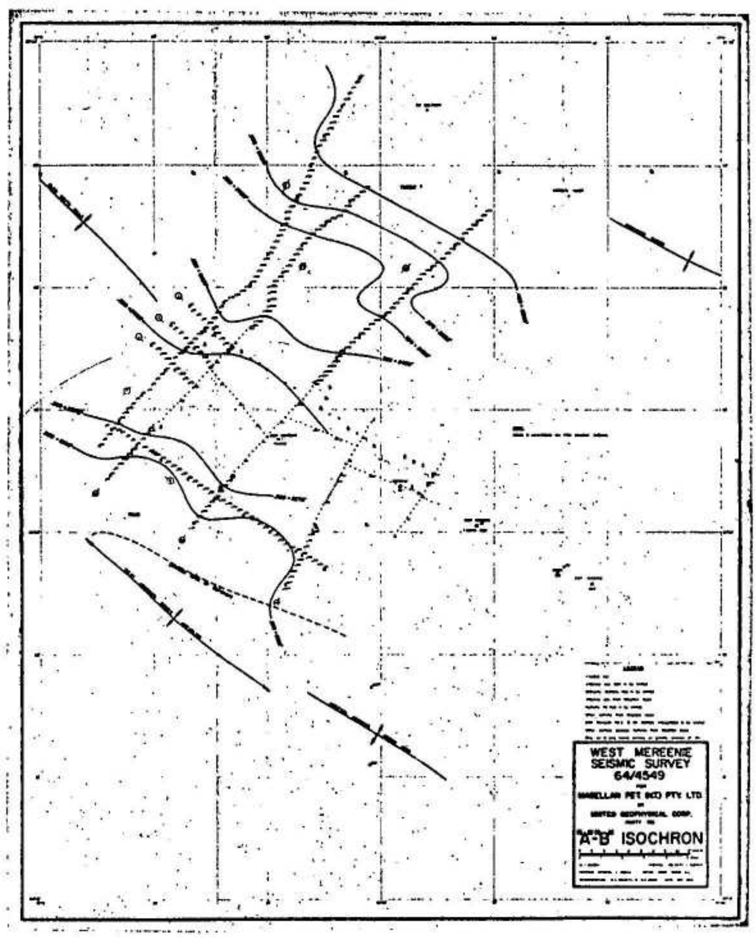
WEST MEREENIE ANTICLINE, SEISMIC CONTOURS, HORIZON 'A'.

P12B



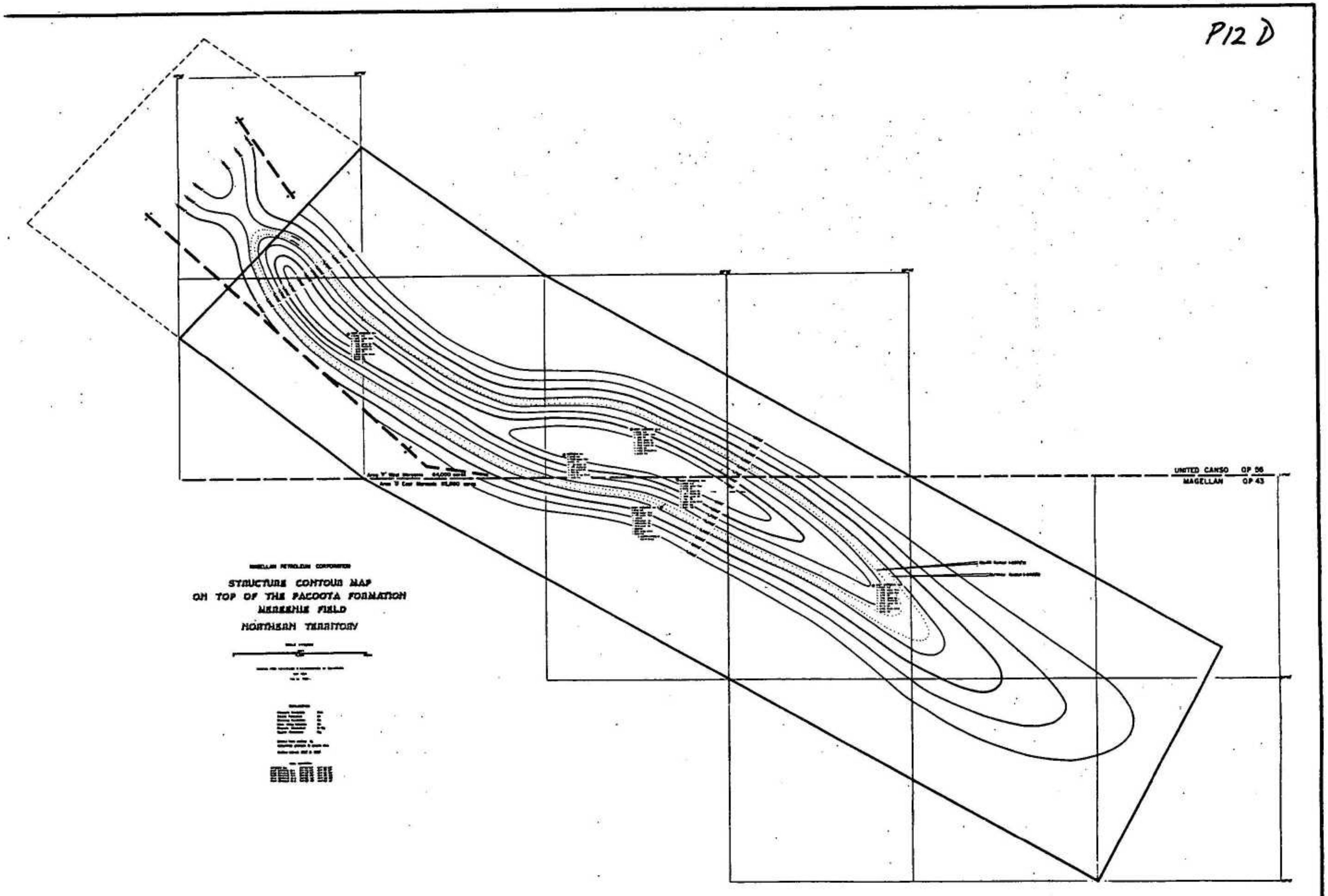
WEST MEREENIE ANTICLINE
SEISMIC CONTOURS, HORIZON 'B'.

P12C



WEST MEREENIE ANTICLINE, "A"-"B" ISOCHRON.

P12 D



STRUCTURE CONTOUR MAP ON TOP OF THE PACOOTA SANDSTONE, MEREENIE ANTICLINE.

P13

MT. CHARLOTTE No. 1

SEISMIC STRUCTURE MAP

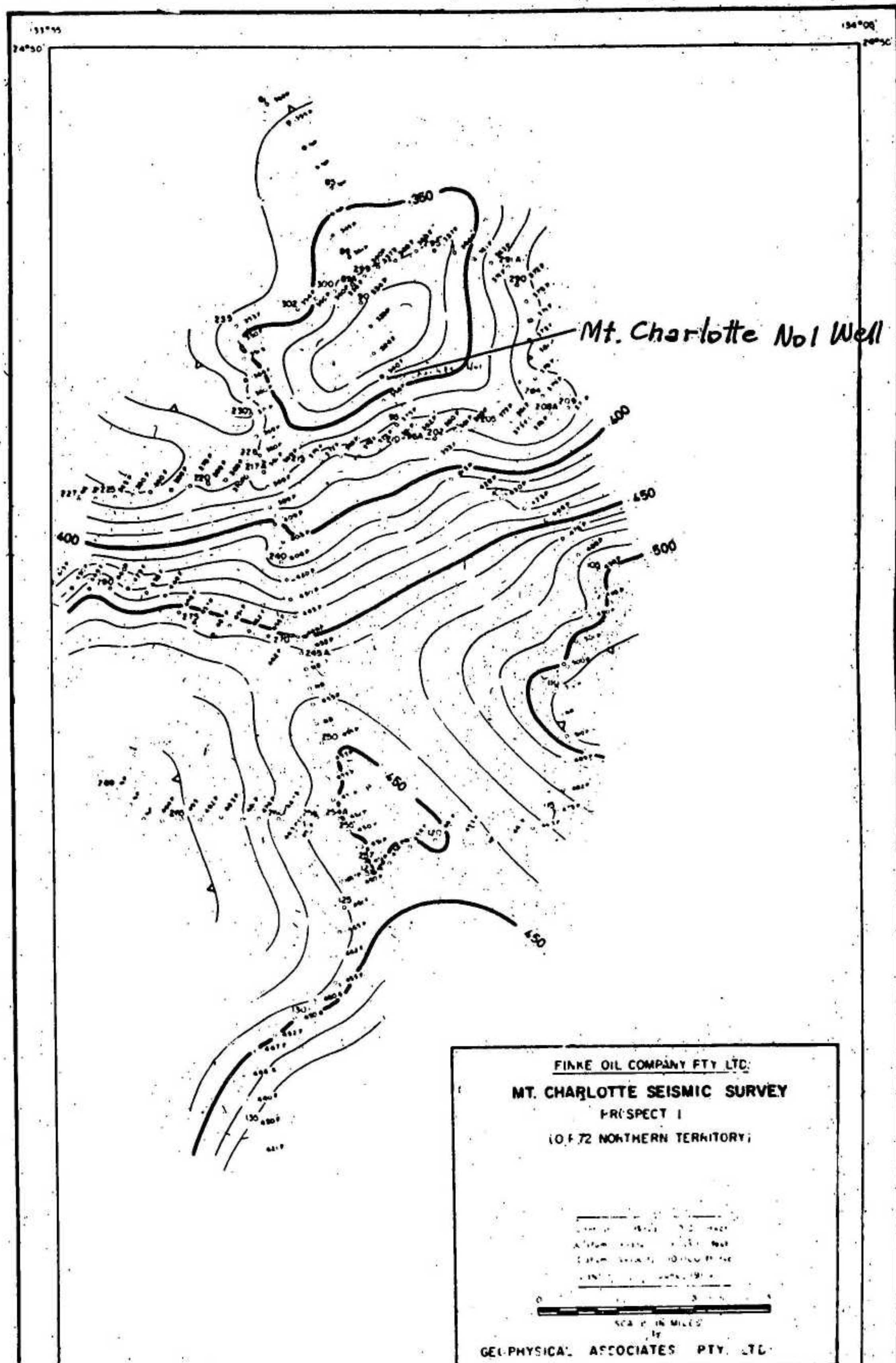
Showing

Structure Contours on

BITTER SPRINGS HORIZON

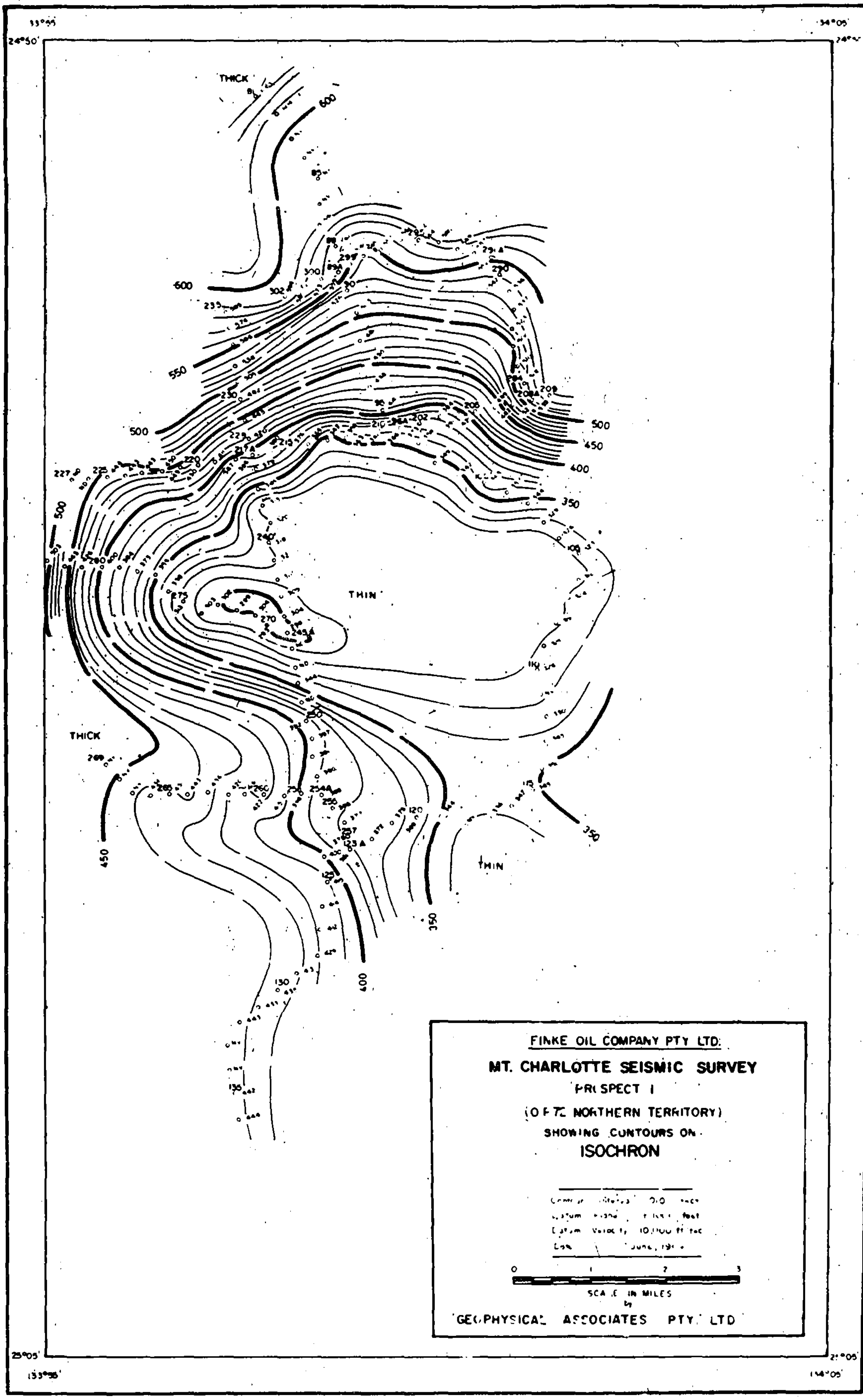
MOUNT CHARLOTTE ANTICLINE, SEISMIC CONTOURS ON BITTER SPRINGS FORMATION.

P14A



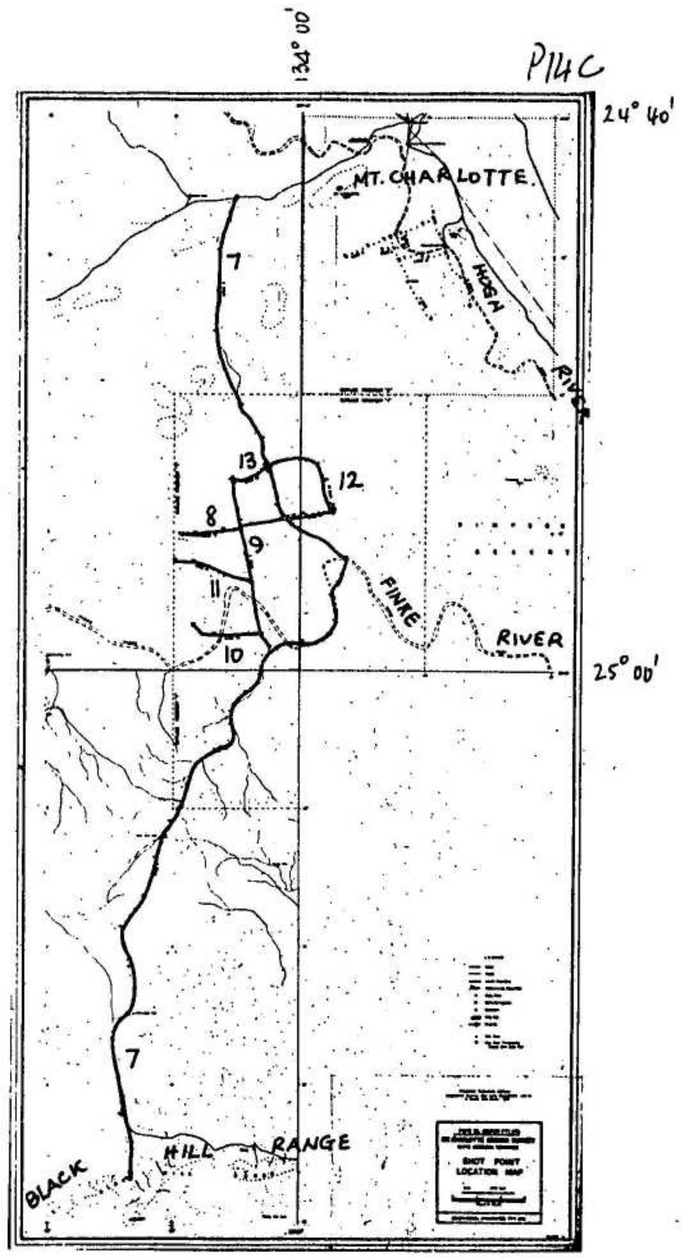
MOUNT CHARLOTTE ANTICLINE, SEISMIC CONTOURS, APPROXIMATELY TOP OF CAMBRIAN.

P14B



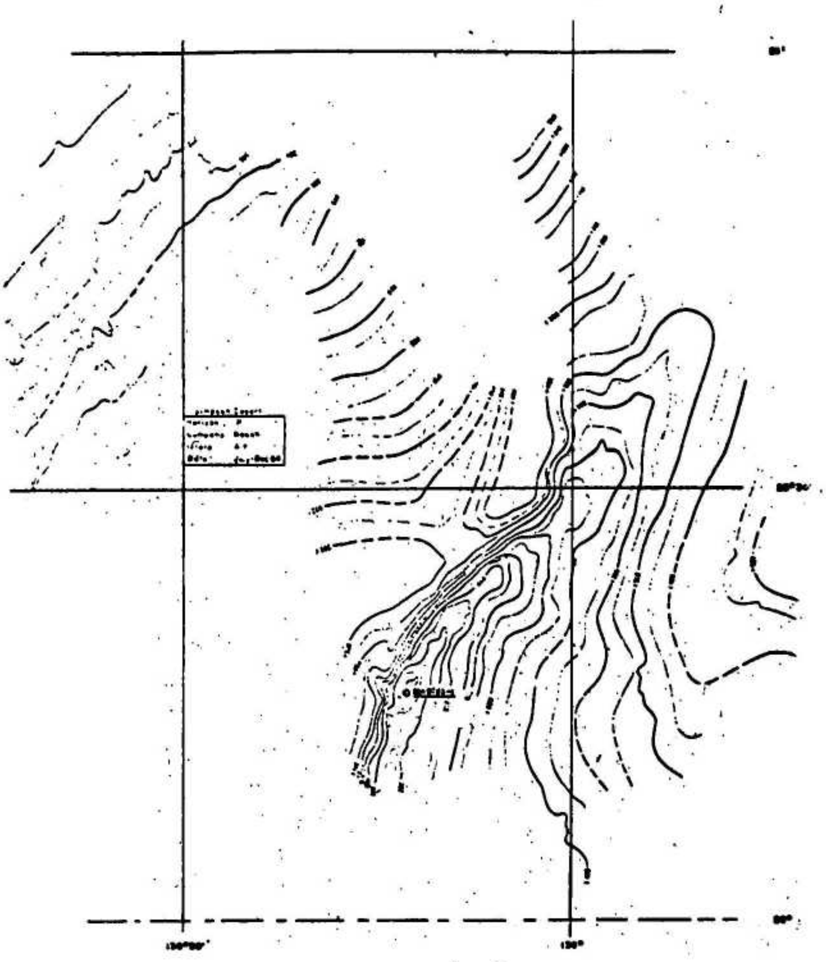
MOUNT CHARLOTTE ANTICLINE, CAMBRIAN ISOCHRON

P14C



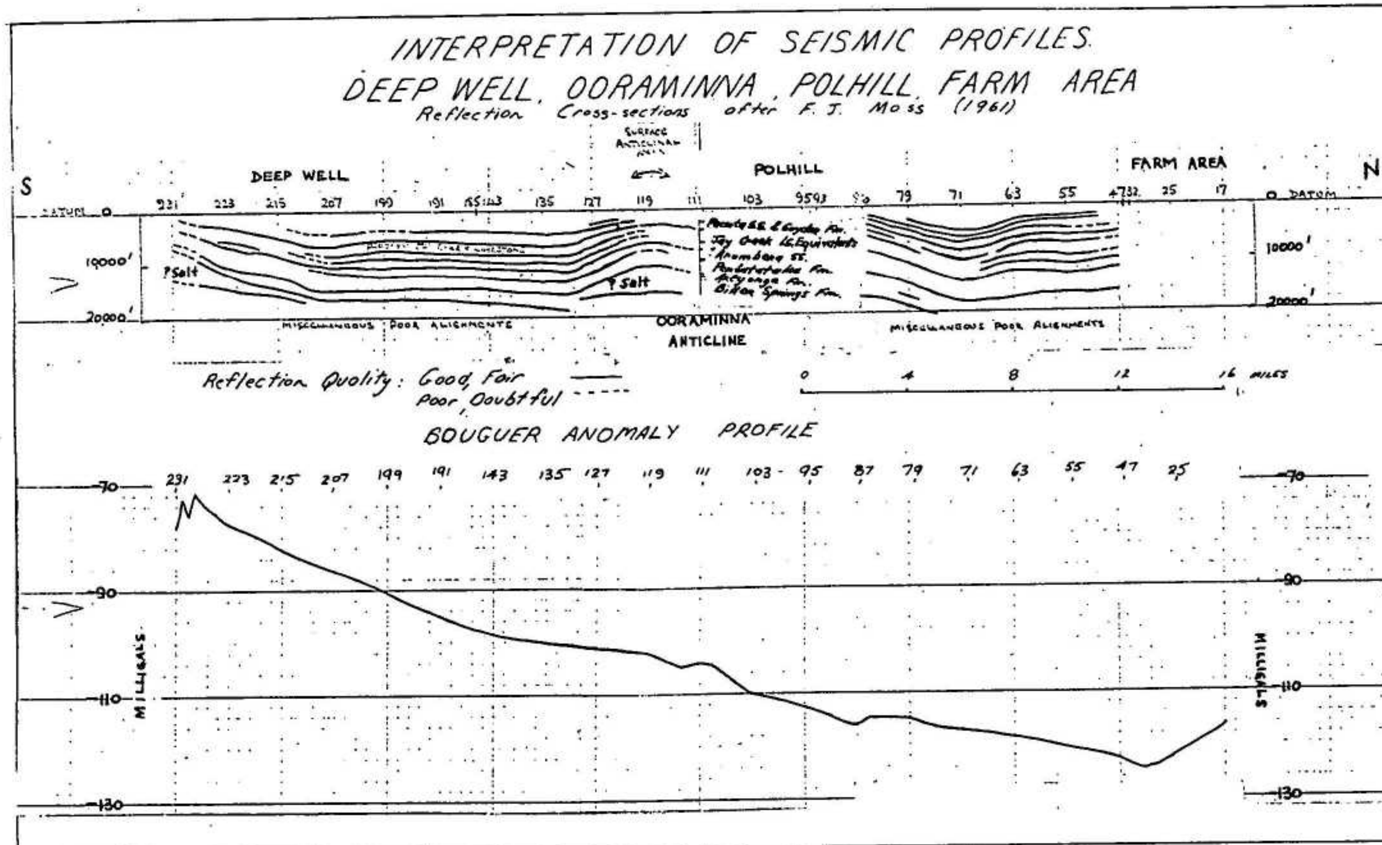
MOUNT CHARLOTTE SEISMIC SURVEY,
LOCATION OF SEISMIC LINES.

P15



REFLECTION SEISMOGRAPH SURVEY
MC DILLS ANTICLINE
by
Geosurveys of Australia Pty. Ltd.
Horizon: Permian C.I. - .05 ms.

McDILLS ANTICLINE, SEISMIC CONTOURS ON PERMIAN HORIZON.


INTERPRETATION OF SEISMIC PROFILES.
DEEP WELL, OORAMINNA, POLHILL, FARM AREA
Reflection Cross-sections after F. J. Moss (1961)
S
N
DEEP WELL
POLHILL
FARM AREA
OORAMINNA
ANTICLINE
MISCELLANEOUS POOR ALIGNMENTS
Reflection Quality: Good, Fair
Poor, Doubtful
0 4 8 12 16 MILES
BOUGUER ANOMALY PROFILE
MILLIGALS

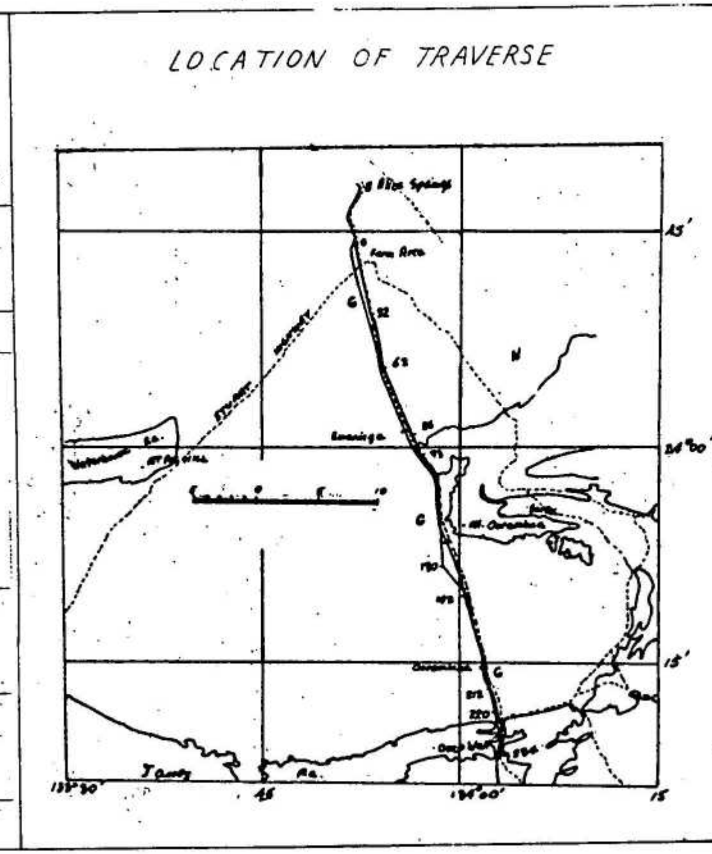
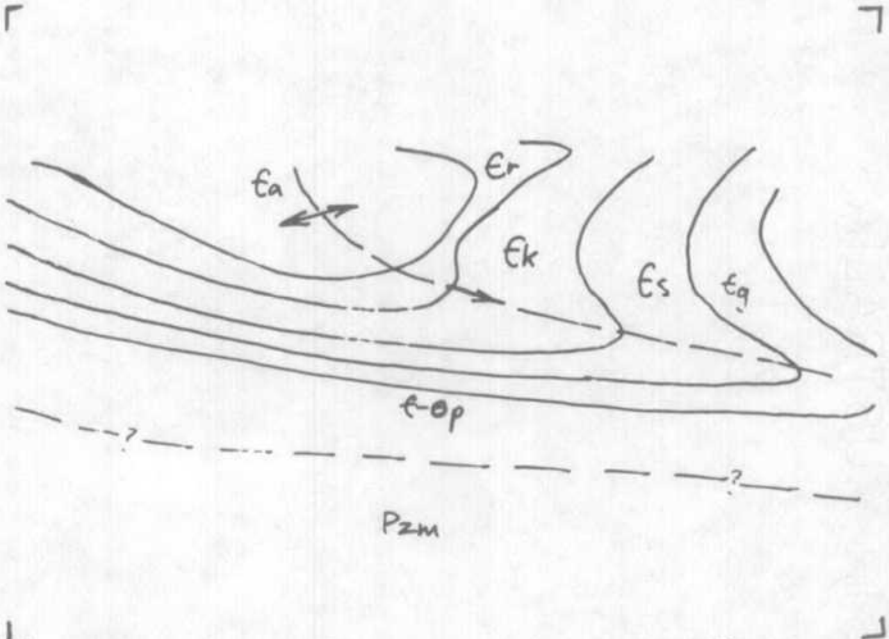

LOCATION OF TRAVERSE
Alice Springs
Farm Area
Ooraminna
Deep Well
24°00'
134°00'

Fig. P17 Western nose of the Ooraminna Anticline. Dark hills of Arumbera Sandstone in the core.
G/9137



Western nose of the Ooraminna Anticline.
Ɛa Arumbera Sandstone, Ɛr Todd River Dolomite,
Ɛk Giles Creek Dolomite, Ɛs Shannon Formation,
Ɛg Goyder Formation, Ɛ-Op Pacoota Sandstone,
Pzm Mereenie Sandstone.

Fig. P18 Overlay to photograph above.

In the eastern part of the Amadeus Basin the Ordovician Larapinta Group formations are for the most part eroded and the Cambrian sediments are generally too deeply dissected to be prospective.

In the Simpson Desert the western marginal facies of the Great Artesian Basin sediments contain potential reservoirs in the Mesozoic, Permian and Devonian-Carboniferous rocks. Possible source rocks in the area are the Lower Cambrian carbonate rocks and any marine equivalents of the Permian rocks developed basinwards. The present indications are that the Palaeozoic source rocks are for the most part eroded, and a large part of the sequence as known in the Amadeus Basin was not deposited. The problem remains to discover areas of thick Palaeozoic source beds. A large part of the sequence in this area is made up of non-prospective deltaic, fluviatile and transitional deposits of the Finke Group over 3000 feet thick, which adds considerable cost to drilling operations and involves penetrating a thick sequence to reach possible Palaeozoic source beds.

NON-METALLIC DEPOSITS

Introduction

Few of the non-metallic deposits discussed here can be regarded as having economic potential.

Principal references, in addition to regional geological reports of the Bureau of Mineral Resources include Sullivan and Opik (1951) for ochre deposits; Joklik (1955) for detailed work on the mica etc. of the Hart's Range and Strangeway's Range areas; Barrie (1964) and Cook (1966a) for phosphate deposits; and McLeod (1966) for a general account of most metallic and non-metallic deposits of the Northern Territory.

Asbestos

Anthophyllite veins occur in serpentine in the Disputed Creek area of the Hart's Range. The asbestos is of poor quality and is unlikely to be an economic prospect.

Barytes

Thin veins of barytes, up to about 6" thick, occur in the Bitter Springs Formation in the core of the Parana Hill Anticline. The small amount of material available and the remoteness make exploitation unlikely.

Beryl

Small quantitites of beryl are associated with potash feldspar in some of the mica-bearing pegmatites of the Hart's Range. The quantity found so far is too small to be of economic interest.

Building Stone

Sandstones of the Heavitree Quartzite, the Arumbera Sandstone, the Pacoota Sandstone and the Pertnjara Formation have been used as building stones on cattle stations and in Alice Springs. Limestones of the Jay Creek Limestone have also been used as a building stone at the Santa Teresa Mission.

Clays

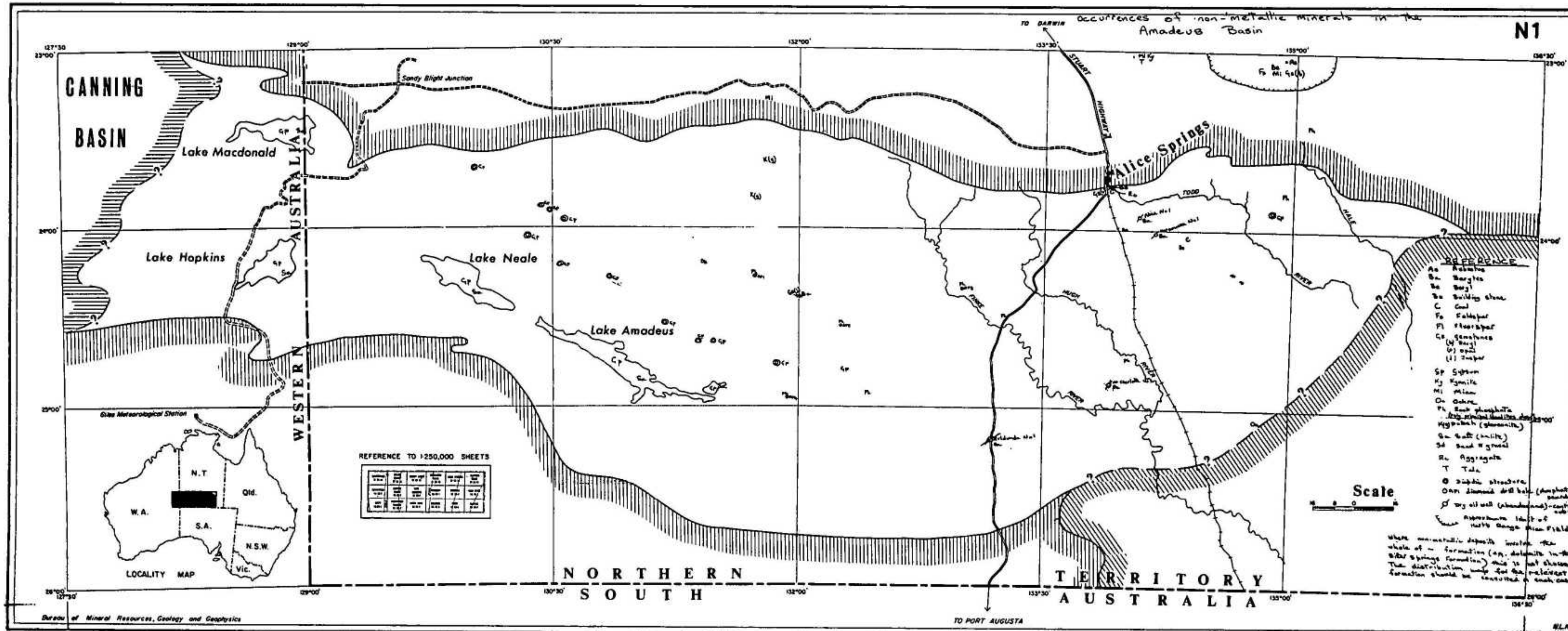
Some of the Upper Proterozoic and Palaeozoic lutites may be suitable for shale brick-making whilst Tertiary clays may be suitable as ceramic clays. However few studies have as yet been made of their suitability.

Coal

Lignite occurs sub-surface in Tertiary sediments of the Farm Area south of Alice Springs. The deposits are thin, have a high ash content, and occur at a depth of about 900 to 1,000 feet, consequently they have no economic potential. A similar occurrence has also been reported from the Tertiary of the Yam Creek area, north of the Santa Teresa Mission, from near the Palmer River and at 16 mile Bore on Burt Plain. There may be coal in some of the other Tertiary basins in the eastern MacDonnell Ranges area, e.g. near Ambalindum.

Dolomite

The Bitter Springs Formation, the Pertatataka Formation and the Pertaoorrta Group contain thick dolomite sequences; with the possible exception



Occurrences of non-metallic minerals in the Amadeus Basin
N1
TO DARWIN
STUART HIGHWAY
Sandy Blight Junction
CANNING BASIN
Lake Macdonald
Lake Hopkins
Lake Neale
Lake Amadeus
Alice Springs
TODD
HALE
RIVER
FINKE
HUGH
WESTERN AUSTRALIA
Giles Meteorological Station
REFERENCE TO 1:250,000 SHEETS
N.T.
Qld.
W.A.
S.A.
N.S.W.
Vic.
LOCALITY MAP
Scale
REFERENCE
Gp Gypsum
Ky Kyanite
Ru Aggregate
T Talc
NORTHERN TERRITORY
SOUTH AUSTRALIA
TO PORT AUGUSTA
127°30'
129°00'
130°30'
132°00'
133°30'
135°00'
136°30'
23°00'
24°00'
25°00'
26°00'
Bureau of Mineral Resources, Geology and Geophysics

of areas near Alice Springs, the remoteness of the occurrences from any potential market make their commercial exploitation unlikely in the foreseeable future. Reserves are very large.

Feldspar

Considerable quantities of feldspar occur in the Arunta Complex and the Musgrave Block. In particular feldspar (blocky microcline) occurs in thick pegmatites of the Hart's Range area. The remoteness of the area makes it most unlikely that the feldspar will be exploited commercially in the foreseeable future.

Fluorspar

Fluorspar is said to be present in the eastern MacDonnell Ranges but no other details are known.

Gemstones

Beryl occurs in the eastern MacDonnell Ranges and in the pegmatites of the Hart's Range but gem quality material is only found in small amounts. Garnet (generally almandite) is very common in the eastern MacDonnell Ranges (e.g. Ruby Gap) and some stones are considered to be of gem quality.

Opal has been reported from duricrust on the Heavitree Quartzite but the occurrences are rare and cannot be considered of economic interest. Various attractive stones are polished (by tumbling) for use in jewellery. In particular jasper, which is very common in the Areyonga Formation and Inindia Beds, is used for this purpose.

Gypsum

Gypsum is common in the salt lakes (Lake McDonald, Lake Amadeus, etc.) and one attempt has been made to exploit the gypsum of the Erldunda area for use in the local building industry. In addition gypsum, derived from the Bitter Springs Formation, occurs in the cores of many of the diapiric structures of the Lake Amadeus and Mount Rennie sheet areas (Figure N1).

The quantities of gypsum present are very large and are more than adequate to meet local demands.

Kyanite

Kyanite-biotite schists occur in the Strangeways Ranges north-east of Alice Springs. Kyanite crystals up to four inches in length also occur in the Arltunga area but the quantities in both areas is probably small.

Limestone

Thick limestone beds occur in the Bitter Springs Formation, the Pertatataka Formation and the Pertaoorrta Group. In addition, Tertiary limestones and travertine occur in many areas. Travertine has been used for the manufacture of lime in the Alice Springs area. Reserves of limestone are considerable and are more than sufficient for local needs.

Mica

Mica is financially the most important mineral in the area. It has been mined mainly in the Harts Range Mica Field situated about 100 miles north-east of Alice Springs, but small quantities (mainly phlogopite) have also been mined in the Strangeways Range, about 50 miles north-north-east of Alice Springs.

The Harts Range Mica Field has been worked sporadically since about 1890 but all activity ceased in 1961. Up to that time over $ 1,000,000 worth of mica had been mined. The mica is mainly good quality muscovite and occurs in pegmatites within the Arunta Complex. The pegmatites are common over an area of about 400 square miles and there are numerous inactive mines.

Ochre

Ochreous bands occur in various parts of the Amadeus Basin sequence. There is a native ochre mine at Ochre Hill, in the Goyder Formation. Only the Cretaceous of the Rumbalara area contains good quality ochre.

The yellow ochre occurs in a horizontal bed from one to four feet thick in several mesas east of the Rumbalara Siding. The ochre is good

N2

GEOLOGICAL FORMATIONS (& THEIR EQUIVALENTS)		ASBESTOS	BARYTES	BERYL	BUILDING STONE	CLAYS: BRICK	CLAYS: CERAMIC	COAL	DOLOMITE	FELDSPAR	FLUORSPAR	GEMSTONES: BERYL	GEMSTONES: GARNET	GEMSTONES: OPAL	GEMSTONES: JASPER	GYPSUM	KYANITE	LIMESTONE	MICA	OCHRE	PHOSPHATE	POTASH: CARNALLITE SYLVITE ETC.	POTASH: GLAUCONITE	SALT (HALITE)	SAND & GRAVEL	AGGREGATE	TALC
CAINOZOIC	QUATERNARY															+						?		✳	✳		
	TERTIARY					+	+	✓						✓				✳									
MESOZOIC	KUMBALARA SHALE & DE SOUSA FM					+	+													✳							
DEVONIAN-CARBONIF EROUS (?)	PERTNJARA FORMATION				✳	+																					
SILURIAN-DEVONIAN	MEREENIE SANDSTONE																										
LARAPINTA GROUP (CAMBRO-ORDOVICIAN)	CARMICHEAL SANDSTONE																										
	STOKES FORMATION					+															✓						
	STAIRWAY SANDSTONE					+															+		✓				
	HORN VALLEY SILTSTONE					+														✓	✓		✓				
	PACOOTA SANDSTONE				✳																✓		+				
PERTAOORRTA GROUP (CAMBRIAN)	GOYDER FORMATION																			✓							
	JAY CREEK LIMESTONE				✳				+									+									
	HUGH RIVER SHALE					+																					
	TEMPE FORMATION																	+			✓		✓				
	CHANDLER LIMESTONE																	+				?		+			
	ARUMBERA SANDSTONE				✳																		✓				
UPPER PROTEROZOIC	PERTATATAKA FORMATION					+			+									+		✓			✓			+	
	AREYONGA FORMATION														+						✓						
	BITTER SPRINGS FORMATION		✓						+							+		+				?		+		+	
	HEAVITREE QUARTZITE				✳									✓												✳	
BASEMENT	ARUNTA COMPLEX	✓		✓						+	✓	+	+				✓		✳		✓						✓
	MUSGRAVE-MANN COMPLEX			?						+	?	?	?						?		?						?

REFERENCE:

? Expected that would be present but not so far been found or not reported

✓ Present in minor quantities

\+ Present in moderate (or large) (though not necessarily commercial) quantities.

✳ Large quantities and is being or has been worked commercially

THE OCCURRENCE OF IMPORTANT NON-METALLIC MINERALS IN THE ROCK UNITS OF THE AMADEUS BASIN

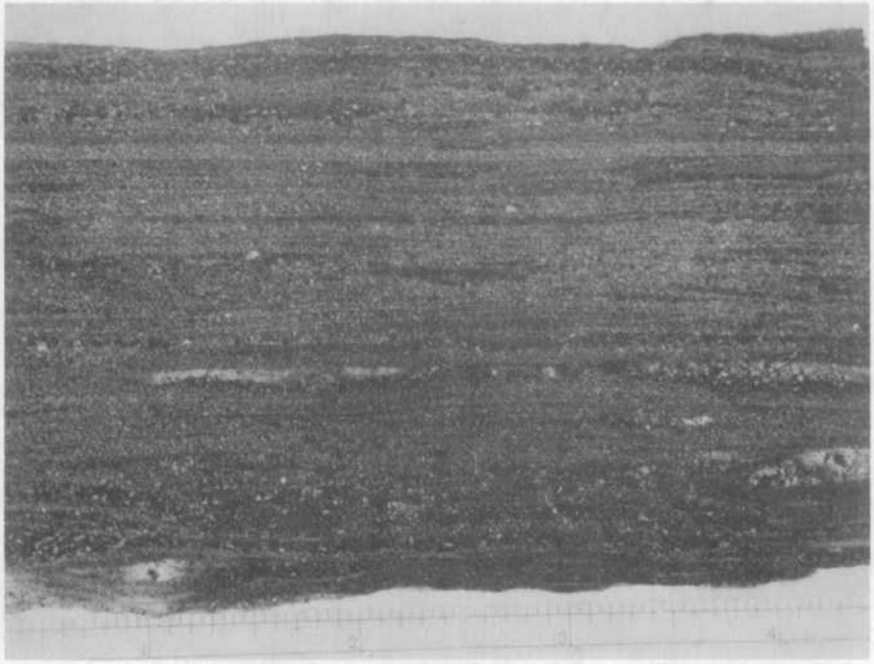


Fig. N.3 Banded phosphorite - thin bands of phosphate (apatite) and chert in the Areyonga Formation. Alice Springs Sheet area. (Photograph by C. Zawartko).
G/9074

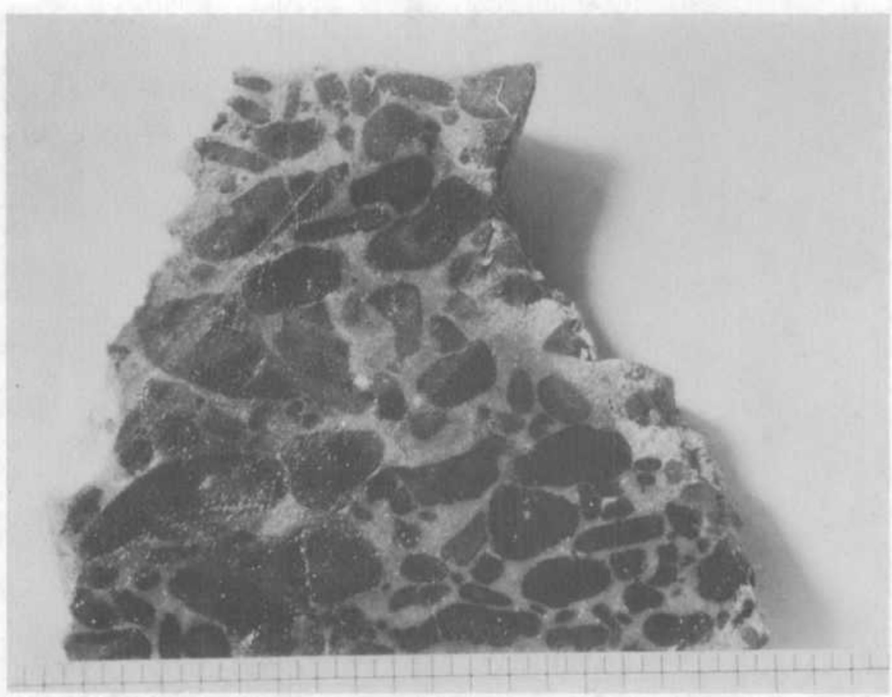


Fig. N.4 Pelletal phosphorite (dark) with a sandy matrix (light) in the Stairway Sandstone. (Photograph by C. Zawartko).
G/9072

quality, containing up to 55% ferric oxide. Prior to 1951, when the mine closed down, this deposit had supplied the bulk of Australia's needs; a total of 7,900 tons worth about $ 60,000 was extracted. Since that time artificial pigments have been widely used and it is unlikely that the mines will be reopened in the foreseeable future.

Phosphate

Pelletal phosphorites occur in the Areyonga Formation, the Tempe Formation, the Pacoota Sandstone, the Horn Valley Siltstone, the Stairway Sandstone and the Stokes Formation. As no thorough testing of other formations (such as those in the Pertaoorrta Group which in places have the "classic" black shale-chert assemblage of Sheldon (1964)), has been undertaken, it cannot be positively stated that these are the only, or even the richest, phosphate-bearing formations within the Amadeus Basin. Apatite-rich bodies also occur within the Arunta Complex.

Areyonga Formation: Thin phosphorites occur in the basal conglomerate of the Areyonga Formation, about eight miles north of Ringwood Homestead, in the north-east corner of the basin (Wells et al. 1967). The basal conglomerate, which overlies the Bitter Springs Formation, is about four feet thick and is composed of subangular pebbles, cobbles, and boulders with a poorly sorted quartz arenite matrix which is phosphatic in part. The phosphatic bands are from three inches to one foot thick, lenticular, and from five to ten feet long. The phosphatic mineral (cryptocrystalline ?apatite) is grey or black and occurs as thin stringers (see figure N3) commonly interbedded with thin chert laminae. Samples of the conglomerate contain from one to seven percent P_2O_5 and individual phosphorite bands contain up to 30% P_2O_5.

The Areyonga Formation phosphorites are of interest as, with the exception of the pre-Cambrian banded iron-apatite bodies, they are some of the oldest undoubted sedimentary phosphorites in the world (the age of the overlying Pertatataka Formation is about 730 m.y.). They formed on an unconformity surface probably whilst extremely slow deposition was taking place, thus giving phosphatic sediments time to accumulate. One puzzling aspect of this occurrence is its association with a formation regarded as predominantly ?glacigene. It has been the present authors experience that Recent glaciomarine sediments from the Antarctic shelf are markedly deficient in phosphorus. Possibly the phosphorites formed in moderately cold sub-polar waters in areas where dynamic upwelling resulted from, for instance, a steep sea-bottom topography, and phosphatic sediments were deposited as the upwelling current became saturated with phosphate. Alternatively the phosphorites may have formed during a warm interglacial period.

The limited nature of the Areyonga Formation phosphorites makes it highly unlikely that they will be exploited commercially.

Tempe Formation: Thin pelletal phosphorites occur in a few places within the Tempe Formation. They are associated with glauconitic sandy limestones which contain abundant echinddem plates and phosphatic brachiopod shells. Some of the pellets appear to be fragments of phosphatic shells which have been abraided and rounded by current action but most are primary pellets showing concentric banding about a nucleus composed of a quartz grain or calcite fragment.

The phosphatic bands are believed to be of low grade an this, coupled with their limited lateral extent and thickness, makes it highly unlikely that the formation has economic potential unless high P_2O_5 values can be obtained in the associated black shales.

Pacoota Sandstone: In general this formation is poorly phosphatic. There are however rare phosphatic pellets scattered throughout the orthoquartzite; there are also rare pelletal and nodular bands which contain up to 16% P_2O_5. The pellets and nodules contain abundant detrital quartz and are equivalent to the "sandy pellets" of the Stairway Sandstone.

It is thought that the Pacoota Sandstone phosphorites formed on a shallow shelf on which phosphate-bearing (?upwelling) currents may have impinged. However the considerable quantities of terrigenous material reaching the basin prevented the formation of high grade phosphorites.

It is most unlikely that the Pacoota Sandstone phosphorites are of economic importance.

Horn Valley Siltstone: The Horn Valley Siltstone is slightly phosphatic throughout and probably averages about 1% P_2O_5. There are also a few pelletal phosphorite bands near the top of the formation. The pellets may occur in limestones, sandstones or siltstones. The maximum P_2O_5 content recorded from the Horn Valley Siltstone is 7%. The pelletal bands are generally only about one inch thick but a phosphatic band about twelve inches thick occurs near the top of the Horn Valley Siltstone in the Mount Holder area.

The appearance of the phosphorites close to the contact with the overlying Stairway Sandstone suggests that the conditions of deposition represented a "preview" of the more phosphatic Stairway Sandstone conditions. The phosphorites formed under moderately deep marine conditions and probably were not subject to the winnowing action which concentrated the Stairway Sandstone phosphorites.

None of the Horn Valley Siltstone phosphorites are of commercial importance.

Stairway Sandstone: Phosphorites occur sporadically throughout the Stairway Sandstone but are especially common in the middle lutaceous part of the formation. The phosphatic bands are generally pelletal or nodular in form and range in thickness from less than one inch to eight inches. Because of poor exposure their lateral extent is unknown. The nodules are up to five inches in diameter. They are grey, brown, white or purple in outcrop but invariably black in the sub-surface. Pelletal bands have P_2O_5 contents of up to 22% and individual nodules contain up to 27% P_2O_5. There appear to be two main types of nodules - grey and brown. The grey pellets are irregular and have a wrinkled surface; they generally contain up to 20% P_2O_5. The brown pellets are well-rounded, sub-spherical and sandy; they contain up to 14% P_2O_5.

Cook (1966a unpubl. and 1968) has shown that there are ten distinctive modes of occurrence of the phosphatic mineral (generally cryptocrystalline apatite) which are characterised by their internal or external structure. Numerically the two most important types are the "structureless" pellets (which show no internal structure) and the "sandy" pellets (which contain a high percentage of terrigenous quartz grains). Other pelletal types show "concentric", "irregular", "composite" or "encasing" internal forms. In addition, the phosphate may form the cement of arenites, have a laminate habit, replace fossils, or may occur as secondary phosphate minerals such as corkite (a lead arsenophosphate) or ?dahllite (a hydroxy calcium phosphate).

The phosphorites occur throughout the Stairway Sandstone (there are approximately two hundred individual phosphatic bands in the Stairway Sandstone of the AP1 core) - most are however found within silty units or in thin sandy bands (see Figures N4, N5) within silty units or rarely, within limestone bands (see Figure N6).

Barrie (1964 unpubl.) and Crook (1964, unpubl.) have suggested that the phosphorites are derived but it can be demonstrated (Cook, 1966a, unpubl. and 1968) that the pellets are "lag deposits" which have been concentrated by winnowing action. In particular, the skewness values of the sediments associated with the phosphorites show a regular decrease as the P_2O_5 content increases.

Such a relationship can most logically be explained by the winnowing out of fine material whilst the coarser detrital quartz and phosphatic pellets and nodules remain.

These pellets and nodules are in general thought to have originally formed as primary phosphatic precipitates on a very shallow shelf where there was little terrigenous sedimentation and which lay in the path of phosphate-rich ?upwelling currents. It is possible that there was some replacement of fossils, fecal pellets, calcite and/or dolomite, glauconite and clay by phosphate, but this replacement phosphate formed only a small percentage of the total.

It is estimated that there is at least 1.2 x 10" tons of P_2O_5 in the Stairway Sandstone. However much of this is overlain by a considerable thickness of sediments. Approximately 8 x 10^9 tons of P_2O_5 are possibly within workable distance of the surface but most of this is probably too low grade to be workable. The only possible economic concentrations of Stairway Sandstone phosphorites are likely to be found in areas of maximum winnowing.

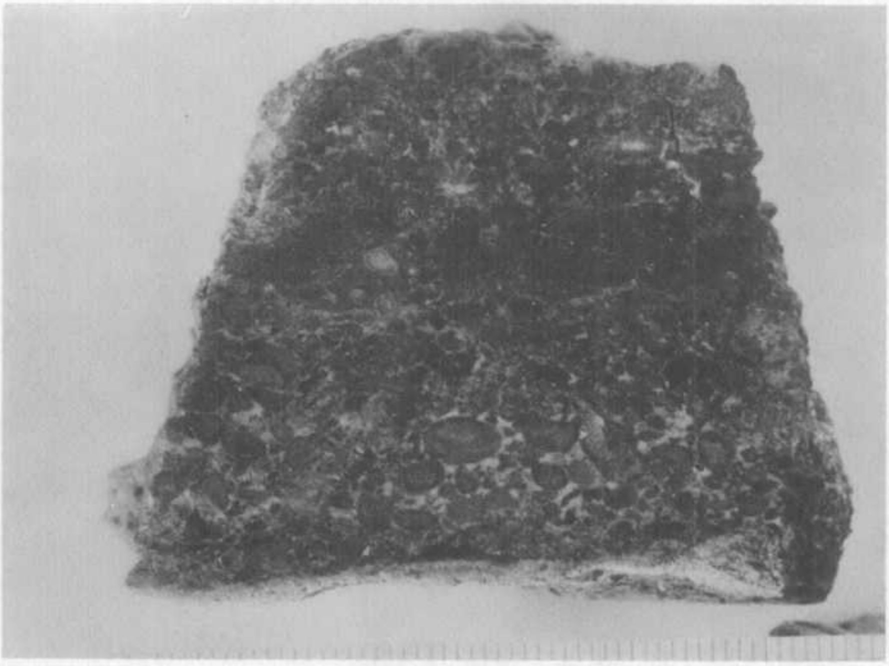


Fig. N.5 Pelletal phosphorite with some of the nodules showing concentric banding. Stairway Sandstone. (Photograph by C. Zawartko).
G/9073

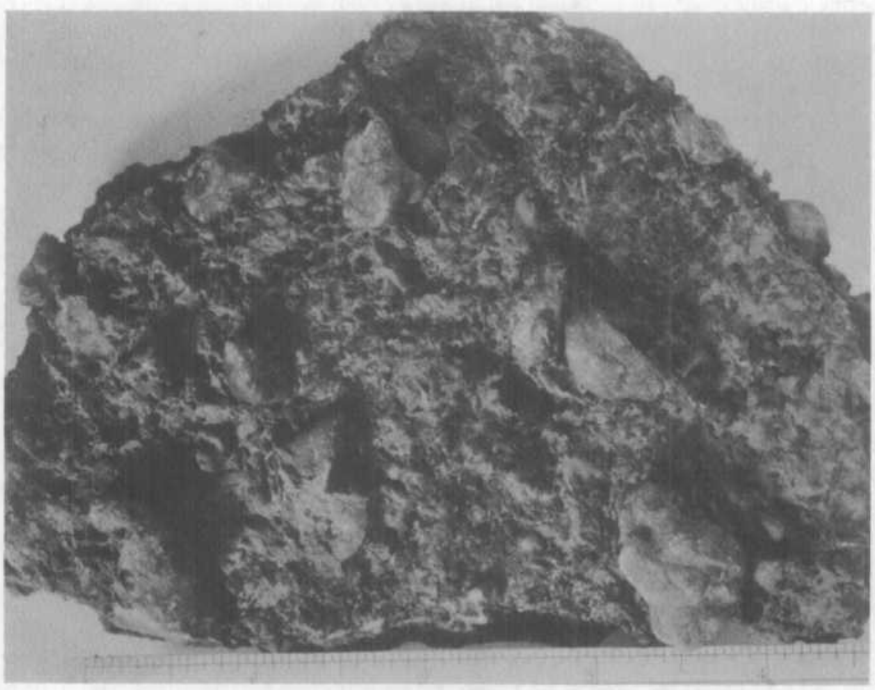


Fig. N.6 Phosphorite nodules weathering out from a limestone matrix. Stairway Sandstone at Johnny Creek. (Photograph by C. Zawartko).
G/9075

Such areas would possibly be indicated by thinning of the formation. Thinning occurs towards the southern margin of the basin; it may have occurred on topographic highs if there were any present in the seas of Stairway Sandstone time. Winnowing probably occurred in areas where it can be shown by palaeocurrent studies that there were high current velocities.

There is also a possibility that some secondary enrichments of phosphorites may have occurred - perhaps during the Tertiary weathering cycle. In addition, in the Johnny Creek area there are Quaternary gravels composed almost entirely of phosphatic pellets and nodules derived from the underlying Stairway Sandstone.

Therefore whilst the present prospects of the Stairway Sandstone are only moderate the location of a major area of concentration could provide economic deposits.

Skewness is a measure of the degree of assymmetry of a sediment (Folk and Ward, 1957).

Stokes Siltstone: Thin pelletal phosphorites occur near the base of the Stokes Formation. The maximum P_2O_5 content recorded is 13.9% in a sample from the Johnny Creek area. The phosphorites are identical with those of the Stairway Sandstone and their presence in the Stokes Siltstone is probably a reflection of the transitional nature of the boundary. The mode of formation is the same as that suggested for the Stairway Sandstone.

The Stokes Siltstone is unlikely to contain phosphorites of economic importance.

Arunta Complex: Magnetite-apatite rich bodies occur in the Arunta Complex at two localities.

McCarthy (In Forman, et al., 1967) describes a magnetite-apatite metaquartzite from the upper reaches of Illogwa Creek. It is estimated that about 15% apatite is present. The metaquartzite shows sedimentary banding and the body is probably a metamorphosed sedimentary phosphorite of pre-Cambrian age. Owen (1944) records two small magnetite-apatite rich bodies from the

Alcoota Sheet area. The bodies were thought by Owen (1944) to be pegmatitic, within a metamorphosed limestone which was probably within the Arunta Complex. However, the description of the rock is similar to that given by McCarthy (op.cit.) and the apatite may have a sedimentary origin. P_2O_5 contents of up to 38.7% have been recorded on samples from the Alcoota area but the deposit is considered to be uneconomic by Owen (1944) and to contain no more that a few tons of apatite. However Youles and Woolley (pers. comm.) consider that recent gesphysical work (Tipper, 1966) suggests that reserves may be of the order of 100,000 tons of apatite per vertical foot.

Potash

The minerals carnallite and sylvite commonly occur in evaporitic deposits and therefore it is possible that they may occur in the evaporites of the Upper Proterozoic Bitter Springs Formation, in the evaporites of some of the diapirs and salt anticlines derived from this formation, and also the Cambrian Chandler Limestone. Analyses have failed to reveal their presence in any of these evaporites or in those of the Lake Amadeus salt lake system. There have however been too few analyses for it to be stated that they are not present.

Glauconite (used as a raw material for potash) occurs in the Pertatataka Formation, the Tempe Formation, the Arumbera Sandstone, the Pacoota Sandstone, the Horn Valley Siltstone and the Stairway Sandstone. Only the Pacoota Sandstone contains a rich concentration. This occurs in a 20 foot interval about 500 below the top of the formation in the Idirriki Range and the Gardiner Range. The glauconite is estimated to form up to 50 percent of the rock in parts of this 20 foot bed. It occurs in gently dipping rocks and the reserves are probably very large.

Youles (1966b) reports the presence of potash in grey-green, red-brown, and brecciated siltstone of the Areyonga Formation from diamond drill hole samples at the Ringwood Copper prospect about 20 miles south-east of Ringwood Homestead. Several samples of grey-green siltstone above 256 feet in hole No. 1 were analysed for K_2O and gave results of 5.3 - 6%. Below 256 feet values were 3.6 - 3.8%.

Salt (Halite)

Halite is known only subsurface in the Bitter Springs Formation (intersected in the Ooraminna No. 1 Mount Charlotte No. 1 and Erldunda No. 1 wells) and the Chandler Limestone (intersected in the Alice No. 1 and Mount Charlotte No. 1 wells).

Halite commonly occurs as an incrustation (generally associated with gypsum) on the surface of Lake Amadeus, Lake Neale, Lake Hopkins and Lake McDonald. Salt has been extracted from the eastern end of Lake Amadeus for local use.

Sand and Gravel

Sand and gravel for use by the local building industry in Alice Springs is extracted from the bed of the River Todd just north of Alice Springs and from Sixteen Mile Creek. Reserves are very large. There are also unlimited supplies of fine aeolian sand in many parts of the area.

Aggregate is at present obtained by the crushing of the Heavitree Quartzite which is quarried near Alice Springs. Some of the hard massive limestones and dolomites of the Bitter Springs Formation and the Pertatataka Formation may also be suitable.

Talc

Talc schist occurs in the Strangeway's Range 40 miles north-north-east of Alice Springs. The deposit is small and low grade and isunlikely to be of economic interest.

METALLIFEROUS DEPOSITS

Copper

Occurrences of copper in the south-western margin of the Amadeus Basin were reported by Forman (1963) and Wells, Forman and Ranford (1964). None of the deposits is of economic size.

In the north-eastern margin (Forman, Milligan and McCarthy, 1967) copper has been recorded from a number of localities, principally in the gold field areas and in a north western extension of the gold mineralization belt. The copper occurs in stockworks of red copper oxide in quartz on the edges of intrusive quartz reefs, or as veins of the carbonates, malachite, azurite, atacamite. Chalcanthite has also been recorded. Arsenic is associated with the copper in the Excelsior Mine, White Range. Copper shows also occur within a five mile radius east and north of Southern Cross Bore; three miles south-south west and seven miles south of Mount Riddock Homestead, and two miles north of Ruby Gap Gorge.

A minor copper occurrence near Heasts Bluff Cattle Project is reported in Wells, Forman and Ranford (1965).

Copper has also been reported from the Pertaoorrta Group and Larapinta Group within the Amadeus Basin, Ranford et al. (1966). Copper mineralisation is known from four localities on the Henbury Sheet area (Ranford, et al., 1966) and an unpublished report on 'Amadeus Copper Deposits' by A.D.M. Bell, 1953 a & b).

1. Waterhouse Range (Owen Springs Prospect)

Copper mineralisation in the form of malachite and cuprite occurs 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 during 1954 to investigate this deposit but the results were disappointing and the project was abandoned.

2. Areyonga (Namatjira's Prospect)

Copper mineralisation in the form of malachite, azurite, chalcocite, digenite, chrysocolla and covellite occurs in a 'crush zone' or 'fault breccia' in the Eninta Sandstone of the Pertaoorrta Group about 10 miles east-south-east of the Areyonga Native 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 mineralised specimen from the fault breccia (Hy 402) was submitted for mineral identification and contains the minerals listed above plus some possible enargite and gold. The major constituent of the ore sample submitted was a fine-grained, steel grey admixture of chalcocite and digenite.

3. 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 micaceous sandstone of the Goyder Formation of the Pertaoorrta Group.

4. Boggy Hole

Malachite has been reported from a 'ferruginous oolite grit' exposed in the banks of the Finke River about 42 miles north-north-west of Henbury Homestead. Bell (1953d) reports that 'the oolite grit band is variable in character and from five to ten feet in thickness'. Unlike the other copper showings this one occurs within the Larapinta Group sediments.

5. Ringwood

The copper mineralisation in the basal part of the Areyonga Formation in outcrops about 2 miles south of Phillipson No. 6 bore have been investigated by two diamond drill holes (Youles 1966b). The green and grey siltstone intervals in the formation contain chalcopyrite and secondary copper minerals have been traced at the surface for seven miles along strike. Spectrographic analyses show up to 2500 ppm. copper and up to 120 ppm. cobalt in the mineralised intervals.

6. Undoolya Gap

The mineralized zones in the Bitter Springs Formation at Undoolya Gap extends over about 2 feet and values of 0.2% to 0.5% copper were recorded (Youles, 1966a). The sequence penetrated by the one diamond drill hole was part of the Gillen Member.

7. Pinnacles area

Patchy copper mineralization occurs in the Pinnacles area about 35 miles north-north-east of Alice Springs and diamond drill sites have been selected to test the deposits.

Miscellaneous Metals

Secondary lead minerals, galena, silver and gold were found with secondary copper minerals in vein quartz intruding the Mount Harris Basalt on the Bloods Range Sheet area (Forman, 1966). None of these minerals occurred in economic quantities and the outcrop of mineralized vein quartz was very small.

In the north-eastern margin of the Basin small lead shows, with associated silver and in one case bismuth, have been prospected at the Glankroil Mine, (Winnecke's Gold Field) at Kenny's Prospects (a few miles north of the field) and at a locality 1½ miles north of the old Arltunga Police Station. An analysis of two samples from Kenny's Prospect (unpublished A.M.D.L. report AN339-63) indicated silver contents of 30 oz. and 14 oz. per long ton.

About 900 samples of exploratory well cuttings at intervals of 10 feet, from Ooraminna No. 1, Waterhouse No. 1 and Alice No. 1. Wells have been analysed for base metals. The following results are taken from the annual summary of activities of the Alice Springs Resident Geologists Office for 1966 and are reported by Youles (1966c). Spectrographic analyses of the samples from the Ooraminna No. 1 well revealed consistent high lead and zinc values in the 450 feet of shales near the top of the Pertatataka Formation. Maximum values were: lead 2000 ppm., zinc 800 ppm. The lead apparently occurs as oxide and zinc as carbonate; no sulphides were identified. In the samples from Waterhouse No. 1, sporadic high lead values occur near the base of the Jay Creek Limestone. No associated high zinc values were recorded. In the Alice No. 1 well cuttings the whole of the Goyder Formation contains high lead (400 - 800 ppm) and zinc (up to 400 ppm.) values.

Gossans are wide spread on the Pinyinna Beds in the south-western part of the Amadeus Basin in the Petermann Ranges. Four prospects were briefly inspected at Butler Dome, Stevenson Peak, Katamala Cone, and Chirnside Creek by J. Ivanac (B.M.R.) in 1966. The following description is taken from the summary of activities of the metalliferous section for 1966. (Bureau of Mineral Resources, 1966). The prospects consist of manganiferous jasper lenses in carbonaceous and dolomitic shale and dolomite of the Pinyinna Beds.

At Butler Dome three groups of steeply dipping manganiferous and siliceous gossans and collapse breccias extent over a strike length of about 7000 feet. Each group is about 1000 feet long, and occurs in highly folded and contorted carbonaceous and dolomitic rocks of the Pinyinna Beds. The main gossan is 45 feet wide, and stands out as a prominent blue-black outcrop. A shaft about 40 feet deep has been sunk in the footwall of the gossan to prospect quartz veins which cut the gossan. The gossans are similar to those at Mount Isa, and contain boxworks and limonite derived from sulphides. The surrounding sediments have been sericitised, and contain substantial amounts of iron oxide (limonite and haematite). There is abundant evidence to suggest that the mineralization is bedded, and is possibly of syngenetic origin. Several chip samples of the gossans were collected, and these show anomalous lead, zinc, and cobalt values. The results are tabulated below.

The three other localities showed minor gossanous material, but no upstanding jasper bodies similar to those at Butler Dome. There appears to be a change from carbonaceous to dolomitic facies westwards from Butler Dome.

The gossans in the region are at present being prospected by Planet Metals.

The following results were obtained for trace element analyses on twenty samples from Butler's Done, Chernside Creek, and Stevenson Peak, Petermann Ranges, N.T. Samples were collected and submitted by J.F. Ivanac, and analysed by A.D. Haldane and J.R. Beevers (B.M.R. Laboratory Report No. 35)

Trace metals were extracted by digestion with hydrochloric/nitric acid followed by determination by atomic absorption spectrophotometry.

All results are expressed in parts per million.

	Cu	Pb	Zn	Co	Ni	Cd	Ag
Butler's Dome							
G1A	66	60	50	37	46	<1	<2
G1B	70	60	170	240	86	2	3
G1C	15	20	17	9	12	1	<2
G1D	<2	<10	1	<5	<5	<1	<2
G1E	175	20	79	25	49	<1	<2
G1F	51	25	180	140	52	1	<2
G1G	120	15	640	980	120	4	6
G1H	32	20	500	170	125	2	2
G1I	41	40	29	25	22	<1	<2
G1J	53	25	55	43	43	<1	<2
G1K	62	25	140	31	46	<1	<2
G1L	200	25	110	21	46	<1	<2
G1M	350	15	64	25	26	<1	<2
G1N	150	15	77	15	45	<1	<2
G1O	290	20	100	27	62	<1	<2
G1P	3	<10	2	<5	<5	<1	<2
G1Q	<2	<10	2	<5	<5	<1	<2
G1R	57	<10	33	10	18	<1	<2
Stevenson's Peak							
G41	28	25	470	1300	100	7	<2
Chernside Creek							
G51	3	25	25	12	14	<1	<2

All digestions were analysed for Au by solvent extraction/AAS. Au was not detected at a limit of 1 ppm for all samples.

Tin

Minor deposits of tin have been reported from two of the copper prospects in the Strangways Range.

Radioactive minerals

Betafite, samarskite, columbite and monazite are associated with some of the mica-bearing pegmatites in the Harts and Strangways Ranges, but none of these occurrences have been exploited.

Walpole (1951) reported on minor occurrences of radioactive minerals in the Mount Cavenagh area.

Gold

Deposits of gold were worked at Arltunga, Winnecke and White Range between 1897 and 1937. Since then attempts to discover new deposits have been made and a few prospectors have lived in the area but the results were discouraging.

Ferruginous deposits

Thin beds of pisolitic ironstone occur in the Horn Valley Siltstone on the western side of the Amadeus Basin.

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).

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 silica.

Small limonitic iron deposits overlying the Bitter Springs Formation have been reported in the north-eastern part of the Amadeus Basin (Wells et al. 1967).

HYDROLOGY

General

The resources of surface water and of groundwater have been developed for use by the pastoral industry and by settlements, within an area bounded by longitudes 131° 00' and 136° 00' east and latitudes 23° 00' and 26° 00' south. Only meagre and largely qualitative basic datas are available and this severely limits attempts to assess the resources. As a result development has been undertaken with a very limited understanding of these resources.

The occurrence of groundwater outside of this area can be predicted on the basis of geological extrapolation, with a degree of confidence appropriate to such procedures.

Previous Investigations

L.K. Ward (1926) compiled an inventory of the bores and wells in existence at the time of his visit to the Northern Territory. He described the occurrence of groundwater and drew attention to the potential of aquifers in the Great Artesian Basin. This inventory was expanded by the Chief Engineer of the United States Army Service of Supply for general intelligence requirements (United States Army, 1942).

Aird (1953) reported to the Commonwealth Government on the 'suitability, both in quantity and quality, of the available waters for the production of fodder on pastoral holdings' in the Alice Springs and Barkly Tableland Districts. He concluded that the significant aquifers occurred in the alluvium along the water courses and in solution cavities in limestones. He recognized that aquifers are not available at all localities, because of the complex geological structure, and that a careful selection of the site is often necessary if a bore is to intersect one. Acting on one of his recommendations the Commonwealth established the Water Resources Branch of the Northern Territory Administration, to provide for the development and the regulation of the use of the water resources of the Northern Territory.

The occurrence and hydrology of groundwater in the Alice Springs Town and Inner Farm Basins has been investigated by a number of workers. The earliest reports are those of Owen (1952 a,b and 1954), who considered aspects of salinity, recharge and groundwater movement. Jones (1957) was able to refine Owen's ideas and to prepare a more accurate bedrock contour map with the aid of additional information. He was the first to consider the Inner Farm Basin.

The Bureau of Mineral Resources carried out resistivity and seismic surveys in the two basins in 1956 (Dyson and Wiebenga, 1957). The results of their surveys were used in subsequent planning of parts of the Department of Works drilling programme. Wilson (1958) reported the results of this investigation, and examined groundwater movement, salinity distribution and groundwater storage. He also carried out pumping tests on some of the production wells and measured some flows of the Todd River.

Jephcott (1959) studied the relationship between groundwater salinity and river flow in the Town Basin, and concluded that sodium and bicarbonate are the most sensitive indicators of recharge to the basin. Forbes (1962) discussed groundwater movement and salinity in both the Town and Inner Farm Basins, and he estimated that the annual safe yield from the Town Basin is 149 million gallons. He also estimated the average annual yield of surface run-off at Heavitree Gap to be 3,180 million gallons.

Quinlan and Woolley (1962, 1966) discussed the occurrence of groundwater in the two basins, using the results of drilling to 1964. They drew attention to the decline in the volume of groundwater in storage since 1953, and made a preliminary interpretation of the results of their pumping tests. They concluded that the safe yield of the Town Basin is dependant on the length of the interval of time between successive river flows.

Woolley (1966) discussed the occurrence and use of groundwater in the Emily and Brewer Plain area, south of Alice Springs township, including the Alice Springs Outer Farm Area.

The occurrence of groundwater in the Amadeus Basin has been discussed by Rade (1957), Jones and Quinlan (1962), and Quinlan (1961). Information on the types of aquifers which are available and on the salinity of the water which they contain is shown on a map prepared by the Australian Water Resources Council (1965). Jones and Quinlan (1962) and Perry et al. (1963) drew attention to the potential for the use of groundwater for irrigation. Rochow (1965) described the occurrence of groundwater on the Finke 1:250,000 Sheet; and Woolley (1965) assessed the resources available to supply the township of Kulgera.

Legislation and assistance

Staff of the Resident Geological Section in Alice Springs have been selecting bore sites for pastoralists since 1952. In the period up to 1961 advice on suitable sites was given, at no charge, direct to any pastoralist who requested assistance. The pastoralist had complete control of drilling operations, and reference could still be made to the Geological Section as to whether drilling should continue or cease as operations progressed.

During the latter part of this period a scheme of Drought Relief drilling was undertaken, administered by the Commonwealth Department of Works, and Lands Branch of the Northern Territory Administration. In this scheme, a pastoralist had to convince a Lands Branch inspector that his property was drought stricken. The inspector would then decide if any area on the property, outside the range of existing watering points, carried sufficient feed to warrant additional bores. If such an area existed, he would nominate an area in which a bore would be useful, and the Resident Geologist would then be asked to select a site within that area. Drilling was carried out by contractors under the supervision of the Department of Works. Up to three attempts were allowed in any area, and the pastoralist was required to pay only for successful bores. Financial assistance was also available for payment for these bores.

Since 1961, assistance to pastoralists and agriculturalists has been available under the Water Supplies Development Ordinance 1960-65, administered by the Water Resource Branch. Since that date, an increasing proportion of bores drilled in the Northern Territory have been drilled under the terms of the Ordinance, until at present these bores acount for nearly 70% of all private bores drilled.

In practical terms, the Ordinance provides the means whereby the Commonwealth Government, acting through a Commissioner for Water Development, bears the cost of a certain amount of unsuccessful drilling, thereby greatly reducing the financial risk to the pastoralist in establishing groundwater withdrawal points. The Commissioner may give advice on the location and design of bores, earth tanks, pumping equipment, storage and distribution equipment, and the layout and preparation of land for irrigation. He may also provide financial assistance for any or all of these. For pastoral boresites, generally up to three attempts in an area are available, unless the first or second attempt indicates that further attempts would be unsuccessful. The pastoralist pays only for bores considered successful by the Commissioner.

The greater flexibility in selection of sites made possible by the Ordinance, and the removal of financial risk from the pastoralist have assisted the Resident Geologists considerably in establishing useable watering points in many difficult areas. Most sites drilled in central Australia under the Ordinance have been selected by the Resident Geologists, who provide a written opinion on the prospects at a proposed site for the guidance of the Commissioner.

The Administrator in Council has the power to proclaim a Declared Area, i.e. a Water Control District. Within a Water Control District the Administrator has the power to control, among other things, the construction of water bores. No Water Control District has yet been proclaimed in central Australia.

Availability of data

Data used as the basis for this report are held by three Northern Territory Administration branches, Resident Geological Section, Water Resources Branch, and Animal Industry Branch. Information has been drawn mostly from the records held in the Resident Geological Section, organised in Bore Data Files, which include some data originating with the other two branches.

One set of Bore Data Files has been prepared for each 1:250,000 map sheet area, and individual bores within each area are assigned a number consisting of two parts; first the number of the map sheet, and second, a consecutive number denoting its position in the set of files. Hence the 173 bores in the Rodinga (G53/2) sheet area are numbered G53/2-1 to G53/2-173. A Bore Data Sheet containing data on supplies, water qualities, depth, standing water level, depth of aquifers, date drilled, name of driller, and location and selection of site, is placed in the file for each known bore, and is followed immediately by sheets showing water analyses and description of strata samples. Where available an opinion written on the proposed site before drilling is also included.

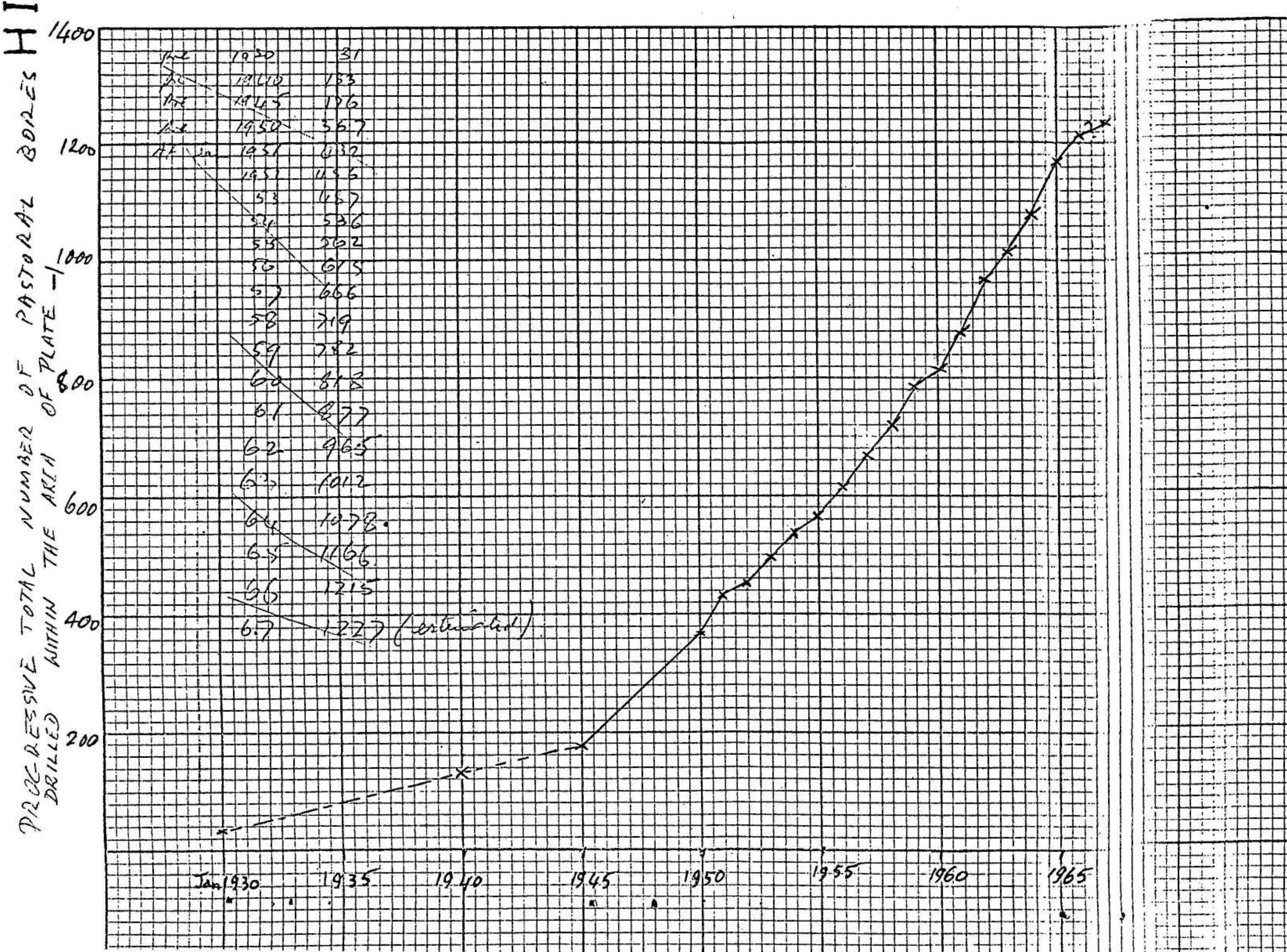
This system has been found to be readily useable, both with regard to extraction of information and addition of new data. It has also been used as the basis for a set of transparent maps, generally at 4 mile scale traced from photo mosaics, on which surface drainage and bores have been plotted. Only bores for which the location is known accurately enough to plot on air photographs at 1:50,000 (approx) scale are shown.

The Bore Data Files are supplemented by a set of edge punch cards. Most of the information from the Bore Data Files is summarised on the punch cards, which can be used as a rapid means of extracting information from the whole set of files.

Samples of cuttings from a large proportion of the water bores are also held in the Resident Geological Section. They are stored in 1oz. glass screw top bottles, arranged in groups based on the 1:250,000 map sheet areas, and are readily available for inspection.

History of Development

Data on early bores and wells are very scarce, and only since about 1950 are the available records anywhere near complete. Ward (1926) noted 19 existing wells and bores, mainly along the north-south stock route, and selected six sites which apparently were all subsequently drilled. These, together with a small number of others in different areas, constitute the 31 bores and wells known to have been drilled before 1930. This figure is the basis for the graph (Figure H1) of the progressive total of bores and wells


H I
PROGRESSIVE TOTAL NUMBER OF PASTORAL BORES DRILLED WITHIN THE AREA OF PLATE -1
1400
1200
1000
800
600
400
200
1930 31
1940 153
1945 196
1950 367
1951 432
1952 456
53 487
54 536
55 562
56 615
57 666
58 719
59 782
60 818
61 877
62 965
63 1012
64 1078
65 1166
66 1215
67 1227 (estimated)
Jan 1930
1935
1940
1945
1950
1955
1960
1965

drilled in the area. Practically no detailed information about dates of drilling is available for the period 1930-1940, but 102 bores appear to have been drilled in this time. Slightly more detail is available for the period 1940-1950 and the graph shows progressive totals at 1945 and 1950 (each plot on the graph is for January of the particular year). From 1950 onwards, it has been possible to obtain an approximate yearly figure for the number drilled. About 200 bores are known, for which it has not been possible to estimate the date of drilling and these have been omitted from the graph.

The most notable features of the graph is the increased rate of drilling from 1945 onwards. In both these years the fall-off in drilling could have been due to the poor season, but in both cases also the rate of drilling increased again, while the drought progressed, as pastoralists endeavoured to provide watering points for remaining areas of feed. The decrease in drilling in 1956-66 was apparently due to the generally depressed state of the pastoral industry as a result of the drought which has been continuous since 1958. Also many holdings are approaching a "fully developed" state and no further stock watering points are required.

The number of bores (and wells) used in preparing the graph in Figure H1, is 1227 i.e. the total number drilled including both successful and dud drilling, but excluding the 200 for which drilling dates are not available.

Of the 1427 bores recorded at April 1966, about 800 have been estimated to be successful. Where information is available, a successful bore has been regarded as having more than 450 gph of water with a salinity of less than 7000 ppm. In a large number of cases, however, no information is available except that the bore (or well) has actually been used, and in these cases a bore (or well) has been deemed successful if it has been equipped. This is a dubious assumption with many old wells and the figure of 800 includes many wells (and some bores) in which the supply was probably less than 450 gph. It also includes a small number of bores with water having more than 7000 ppm, total dissolved solids (TDS) and in a few cases it includes duplicate or replacement bores. Information is insufficient to resolve the question specifically, but it is estimated that about 700 bores meet the requirements for a successful bore given above, excluding duplicate and replacement bores. This indicated an overall success rate of one bore in two tries. Of the 650 bores for which the aquifer is known (see Table H2) 296 were successful, so this random group of bores also shows a success rate of about one in two.

Under the terms of the Water Supplies Development Ordinance, a successful bore is generally regarded as one having a supply of 500 gph or more, or water having a salinity of less than about 7000 ppm (depending on individual ionic concentrations in marginal cases). The lower limit of 450gph has been used here in order to include a few marginal cases with supplies of 450-500 gph.

Perry (1962) plotted about 490 man made watering points in the area in 1956, including an unknown number of dams. In the total area described by Perry, which is nearly double the Amadeus area, 907 man made and natural watering points enabled grazing of 64% of the useable country using a 5 mile grazing radius (or 37% of the area using a 3 mile grazing radius).

Assuming 400 of the 490 man made watering points mapped by Perry in the Amadeus area were bores, then there has been an increase of 300 in the number of man made watering points (700 bores in 1966) i.e. an increase of 60% since 1956. It is assumed that there has been equitable distribution of new bores in previously unwatered country, and that the figures for percentage of useable land being used apply also to the restricted "Amadeus area". It this is so, then all the useable land of the Amadeus area is now within grazing distance of water, using a 5 mile grazing distance. If a 3 mile grazing radius is used, then just over half of the Amadeus area's useable land is now within grazing distance of a watering point. Some of these assumptions are probably only partly valid, but the figures support the idea that much of the area is now fully developed in the sense that sufficient watering points have been established for the pastoral industry.

Availability of groundwater

The availability of groundwater within the area of Plate 1 is discussed qualitatively in relation to those rock units which are known to contain aquifers. Table H2 summarizes the results of drilling to provide water for the pastoral industry in the area.

Arunta Complex

The igneous and metamorphic rocks of the Arunta Complex are not inherently porous. Aquifers within these rocks are zones of fracturing and jointing, which were formed during periods of structural deformation, and zones of weathering, in which intergranular porosity has been developed as a result of the chemical reconstitution of the rock minerals. Both types of aquifers are of limited extent in one or more dimensions.

Fractured and jointed zones are generally narrow, of variable length, and are generally porous to depths of less than 200 feet from the surface of the ground. It is difficult to select sites for bores to intersect such zones below the piezometric surface, because they are usually steeply dipping, and only small changes in dip, or small errors in its measurement may cause the target to be missed, resulting in a dry hole. Moreover the hardness of the rock may prevent drilling at an economic rate unless expensive special equipment is available.

Recharge is derived from alluvial beds of water courses where they cross outcrop of the aquifers, and it occurs only for short periods following run-off. The narrow width of these zones limits the quantity of water which may be accepted as recharge, and hence also the safe yield of the system. Large fluctuations in the piezometric surface can then be expected under natural conditions. These bores in the Arunta Complex of the MacDonnell Ranges which failed during the recent drought are believed to have had an available drawndown less than the magnitude of such fluctuations. The rates of withdrawal of groundwater by the pastoral industry are modest, less than 1,000 gallons per hour from bore pumping for an average of less than 12 hours per day, and their failure is not considered to be an indication of regional depletion.

Zones of weathering are horizontal, tabular bodies in which minerals of the parent rocks have been reconstituted during periods of sub-areal weathering. Their thickness is variable and depends on the suscep tibility of the parent rock to weathering, and to solution by percolating groundwater. The maximum which has been intersected in water bores in Central Australia is less than 250 feet. These zones lie beneath plains which are pediments to the MacDonnell Ranges. It is difficult to predict the position of aquifers, and the convenience of the pastoralist is often a major factor in the selection of a bore site.

Recharge probably occurs by direct infiltration from the surface, which is not an efficient mechanism, and it will limit the quantity of recharge water available to these aquifers. This together with their low permeability, will adversely affect the quality of groundwater.

Only 43 of the 183 bores drilled in the igneous and metamorphic rocks and for which there are records, (Table H2), obtained adequate supplies (i.e. more than 450 gph) of groundwater, and 6 of these had water too saline for stock consumption. Approximately 50 percent of the 183 bores intersected aquifers which contained salt water. It is inferred that individual aquifers of both jointed and weathered types lack interconnection, thus preventing the regional movement of groundwater, reducing the efficiency of the processes of recharge, and increasing the opportunity for the solution of chemical ions from rock minerals.

Of the 43 bores which produced 450 gph or more, 17 were less than 100 feet deep, 21 were 100 - 200 feet deep and 5 were 200 - 300 feet deep. None was deeper than 300 feet. This is in agreement with the conclusions of Davis & Turk (1964), who consider that the optimum depth for wells in crystalline rocks is less than 150 to 250 feet.

They also concluded, from their study of 2336 bores in granite and schist in the eastern part of the United States, that in unweathered rock from 5% to 15% are failures (less than 60 gph), median yields are less than 480 gph, and 10% will have yields of 3000 gph or more. Results from this type of rock in the Amadeus Basin area are even poorer, as indicated in Table H2.

TABLE H2 SUMMARY OF THE RESULTS OF WATER BORES DRILLED FOR THE PASTORAL INDUSTRY AMADEUS BASIN

Formation	No. of Bores	Depth		No of bores with yields of			Maximum tested yield (gph)	No of bores with salinity		Salinity Range (ppm)	Availability of groundwater
		Range (ft)	Average (ft)	0	<450	>450		<7000ppm	>7000ppm		
Quaternary	85	12 - 310	75	0	19	66	3000	75	10	170-29,000	Excellent
Tertiary	76	16 - 675	190	12	24	40	6000	47	17	400-10,261	Good
Rumbelara Shale	12	50 - 420	180	0	9	3	1000	2	10	3,000-29,000	Very Poor
De Souza Sandstone	33	75 -1474	500	0	0	33	29000	33	0	417- 6,213	Excellent
Ligertwood Beds	0										
Buck Formation	0										
Crown Point Formation	22	100 - 687	445	3	7	12	1200	19	0	397- 3,854	Excellent
Finke Beds (Undiff.)	4	90 - 350	190	1	2	1	900	2	1	3,086- 7,000+	Poor to moderate
Santo Sandstone	5	70 - 570	210	0	3	2	5000	5	0	201- 550	Good
Horseshoe Bend Shale	13	40 - 700	340	0	11	2	700	9	4	2,945- 8,200	Poor
Langra Formation	13	60 - 600	300	0	7	6	1200	0	13	8,000-130,000	Very Poor
Polly Conglomerate	0										
Brewer Conglomerate, Hermannsburg Sandstone, Parke Siltstone	60	82 -1040	340	13	23	24	2500	35	25	464-10,000	Poor to moderate
Mereenie Sandstone	17	7 - 900	280	1	2	14	1460+	16	0	85-7,000	Excellent
Carmichael Sandstone	0										
Stokes Siltstone	3	272- 770	570	1		?	460	0	2	7,650-14,000	Very Poor
Stairway Sandstone	18	130 - 771	280	0	3	15	2000	12	6	1,156-20,000	Moderate
Horn Valley Siltstone	0										
Pacoota Sandstone	4	203 - 550	310	0	1	3	8000	4	0	764- 1,914	Good
Goyder Formation	3	250 - 448	330	0	1	2	1500	3	0	567- 1,184	Good
Hugh River Shale	0										
Jay Creek Limestone	6	134 - 426	240	0	1	5	1800	5	1	642-10,000	Moderate
Shannon Formation	6	100 - 165	150	0	2	4	1200	6	0	388- 2,700	Poor
Giles Creek Dolomite	3	183 - 250	210	1	1	1	1000	0	2	8,700-15,000	Poor
Chandler Limestone	2	75 - 150	110	0	0	2	-	0	2	8,600-23,000	Poor
Todd River Dolomite	1	200	-	1	0	0	-	-	-	-	Poor
Arumbera Sandstone	13	116 - 450	200	0	0	13	1500	11	2	824- 9,300	Moderate to good
Petermann Sandstone	0										
Deception Formation	0										
Tempe Formation	1	160	160	0	0	1	2000	1	0	2,000	Poor
Eninta Sandstone	0										
Quondong Conglomerate	0										

TABLE H 2 (contd)

	No. of Bores	Depth		No of bores with yields of			Maximum tested yield (gph)	No of bores with salinity		Salinity Range (ppm)	Availability of groundwater
		Range (ft)	Average (ft)	0	<450	>450		<7000ppm	>7000ppm		
Cleland Sandstone	4	25 - 100	70	4	0	0	-	-	-	-	Very Poor
Mt. Currie Conglomerate	0										
Ayers Rock Arkose	0										
Maurice Formation	0										
Sir Frederick Congl.	0										
Ellis Sandstone	0										
Carnegie Formation	0										
Inindia Beds	4	215 - 345	275	0	4	0	350	3	1	850- 9,062	Poor
Boord Formation	0										
Pinyinna Beds	0										
Dean Quartzite	0										
Winnall Beds	5	140 - 412	300	0	2	3	1000	4	1	1,440- 8,000+	Poor to moderate
Pertatataka Formation											
Limbla Member	6	10 - 300	140	2	0	4	2400	4	0	816- 5,400	Moderate
Undifferentiated	19	84 - 388	160	1	6	12	2800	17	1	718-13,000	Moderate
Areyonga Formation	5	102 - 300	240	1	1	3	1200	4	0	277- 2,400	Moderate to good
Bitter Springs Fm.	18	61 - 315	200	4	7	7	1200	12	2	809- 8,350	Poor to good
Heavitree Quartzite	3	20 - 146	80	2	0	1	700	1	0	2,400	Poor
Arunta Complex	183	20 - 485	135	43	97	43	4000	91	49	505-41,000	Poor

TABLE

YIELDS OF BORES IN BASEMENT COMPLEX

No of Bores	Yield	% of total recorded
102	0 - 100 gph	58 %
16	101 - 200	9
9	201 - 300	5
5	301 - 400	3
10	401 - 500	5½
24	501 - 1000	13½
8	1000 - 2000	4½
2	2000 - 3000	1
1	over 3000	½
177 Total		

Heavitree Quartzite

The dominant lithology of the Heavitree Quartzite is silicified, kaolinitic quartz sandstone. The mechanism for the introduction of silica into the pore spaces is not known, but it results in a general reduction in the permeability.

Three bores have been drilled in the formation; two were abandoned because of hard drilling before intersecting an aquifer and the third obtained a supply of stock quality water from joints. The formation crops out in areas of pronounced relief with little pastoral potential where there is little demand for the development of groundwater, and other aquifers which have a better potential are usually available.

Bitter Springs Formation

Rocks of the Bitter Springs Formation will yield variable quantities of groundwater to bores. The quality of the water is between 1,000 and 323,000 parts per million TDS and is related to the geological environment of individual aquifers.

Most of the limestones and dolomites are massive andwithout porosity. Vughs are present in some of the cores and cuttings from water bores and holes drilled by petroleum exploration companies, but it cannot be demonstrated that they provide permeability nor can it be demonstrated that there is a stratigraphic control for their development. The lining of drusy calcite and dolomite to some indicates that the rocks were once permeable, even if they are not so now.

Structural deformation has jointed the carbonate rocks and siltstones in many localities, and these are good aquifers if the joint systems are open below the piezometric surface. It is not possible to predict the occurrence of these aquifers. Anhydrite and gypsum fill the fractures and joints in cores cut in Ooraminna No. 1 and Mount Charlotte No. 1 wells (McTaggart et al., 1965, Planalp and Pemberton, 1963); these minerals are thought to have been deposited from solution in groundwater and to have been taken into solution from the evaporites in the formation.

Beds of black pyritic siltstone are aquifers. The pyrite occurs as very fine crystals and as large porous aggregates of very fine euhedral crystals. The porosity of the aquifer may be intergranular and associated with zones of mineralization, and or fracture porosity. The groundwater in aquifers of this type is generally saline, with more than 2,500 parts per million of total dissolved solids, but it may be of better quality in those situations where there is an opportunity for recharge. In either case it contains appreciable quantities of the sulphate radicle.

The processes of sub-areal weathering can result in an increase in the porosity and permeability of some of the rock types of the formation in the vicinity of an unconformity. One such type consists of very thick units of strongly deformed and contorted dolomitic limestone, siltstone and intraformational breccia. Many of the dolomitic limestones are cherty and contain ankerite. Vughs lined with drusy calcite are common in the intraformational breccias. The breccia and fractures provide the porosity, and if they are interconnected the permeability of this type of aquifer is very high. Large quantities of groundwater with a salinity less than 2,000 parts per million are stored in these aquifers, and much of the water contains less than 1,000 parts per million.

Areyonga Formation

Lenses of sandstones in the upper portion of the formation are porous, but their permeability is low because of the presence of kaolinitic matrix and calcareous cement. The limited areal extent and the permeability may adversely affect the quality and the quantity of the water which can be extracted.

Pertatataka Formation

Aquifers in the Pertatataka Formation are of limited areal extent and care is needed in the selection of bore sites, so that porous zones are intersected below the piezometric surface and the amount of hard drilling is kept to a minimum. Twenty five bores have been drilled to provide water for stock (Table H2), of which sixteen were successful.

The siltstone and shale of the Formation generally have law porosity and permeability, and bores drilled in these rocks will produce less than 100 gallons per hour of saline water. Weathering processes have increased the porosity and permeability of beds of steeply dipping pyritic siltstone. In areas of good local recharge, and where the base of the weathered zone is below the piezometric surface, these rocks will yield limited quantities of water containing appreciable quantities of sulphate, but which is suitable for use by stock.

The sandstone of the Formation is mainly hard, very fine to fine grained calcareous and silicified, without interstial porosity. Zones of jointing in the laminated and very thinly bedded sandstones in the vicinity of faults, and on the crests of tight folds, are aquifers. Bores which intersect them may yield up to 3,000 gallons per hour of variable quality water, with between 1,000 and 9,000 parts per million total dissolved solids. Permeable beds of sandstone in the Julie Member, and rare interbeds, between 1 and 5 feet thick, of sandstone in sequences of siltstone and impermeable sandstone in the remainder of the Formation have been used as aquifers. They will produce up to 1,000 gallons per hour of water which contains between 1,000 and 5,000 parts per million. The aquifers within the Julie Member are not always accessible as the sites at which they could be developed are in areas of pronounced relief, and of little pastoral potential.

Winnall Beds

Sandstones, with intergranular porosity, in the Winnall Beds have been used as aquifers for pastoral bores. Not all of the sandstones are permeable, and bore sites should be selected to intersect specific beds which appear to be aquifers. The groundwater which is available is usually only suitable for use by stock, and the yields which can be expected are adequate for this.

Aquifers in the Mount Kingston - Black Hill Range on the Finke Sheet area contain water with a TDS of 13,000 ppm, which is thought to have migrated from the Langra Formation.

Arumbera Sandstone

Some beds of sandstone in the formation are aquifers. The results of the porosity and permeability determinations of cores cut in Ooraminna No. 1 Well (Planalp and Pemberton, 1963) indicate that the permeable sandstones have a porosity greater than 20 percent. These aquifers may be thin beds of quartz sandstone in a sequence of very silty quartz sandstone and siltstone, or very large lenses of quartz sandstone in Units 2 and 4 (Wells et al., 1967, in press) of the formation.

Groundwater in these aquifers usually contains between 1000 and 8000 parts per million of total dissoved solids, and appreciable quantities of the sulphate radicle. The water is generally suitable for pastoral use.

The Arumbera Sandstone generally crops out in areas of strong to moderate relief which have little pastoral potential. Aquifers have been exploited in those areas where the dip of the formation is less than 45 degrees and where it is possible to select sites to intersect specific beds of sandstone which appear to be permeable on the surface.

Cleland Sandstone

Four attempts have been made on the Mount Liebig Sheet area to drill holes in the Cleland Sandstone. Each of these was abandoned because of hard drilling before an aquifer was intersected. In outcrop the sandstone appears to be impermeable, because of the amount of matrix between the sand grains. Some beds may be permeable, but these are not known in outcrop. The prospects of obtaining supplies of groundwater from the formation are poor.

Hugh River Shale, Todd River Dolomite, Chandler Limestone, Giles Creek Dolomite, Shannon Formation, Jay Creek Limestone.

These six formations of the Pertaoorrta Group have been recognized on the basis of lithology and the relative proportions of interbedded limestone, dolomite, shale, siltstone and sandstone. Two types of permeability may be recognized in this group of rocks. The first is related to the original texture of the rock and the diagenetic processes which have been effective. Some of the carbonate rocks are vughy, and if these pores are interconnected the rocks are permeable. Thin beds of permeable sandstone and sugary dolomite have been intersected in some water bores and petroleum exploration wells. The occurrence and distribution of this type of permeability in these rocks cannot be predicted.

The second type of permeability is considered to result from the processes of deformation and weathering. Groundwater for the pastoral industry and for domestic consumption is usually taken from aquifers which are less than 250 feet from the surface. Within central Australia these aquifers are generally within zones of weathering, as they have been exposed to more than one period of sub-areal weathering since Palaeozoic time. The processes of weathering together with those of structural deformation have in some instances been responsible for the development of permeability in carbonate rocks.

Interbedded limestones with siltstone and shale will act as a sequence of competent and incompetent beds during folding. In structurally favoured locations it is expected that joint systems will be developed in the competent beds, providing pathways for the entry of water from the surface into the carbonate rocks.

These concepts are not supported by a casual analysis of the results of drilling water bores in the six formations (Table H2), which would indicate that the Shannon Formation and the Jay Creek Limestone are the only important aquifers. Such an analysis is not statistically sound, and is not supported by information on the occurrence of permeability in these formations in petroleum exploration wells.

Hugh River Shale

Aquifers have been intersected in James Range A No. 1 and in Highway No. 1 wells (McTaggart and Pemberton, 1965a and b). In both cases the porosity is thought to be mainly due to fracturing and jointing on the crests of anticlines. The yield and the quality of the groundwater obtained are suitable for stock. The logs of the holes show that at these locations the formation contains appreciably more beds of limestone and dolomite than in the type section at Ellery Creek.

No water bores have yet been drilled in the formation.

Todd River Dolomite

The dolomite is crystalline and is very poorly or thickly bedded and has little or no porosity. Anhydrite and calcite fill the fractures in McDills No. 1 (Amerada Petroleum Corp. 1965) and in Alice No. 1 Well (Pemberton, Chambers, Planalp and Webb, 1963). The beds of sandstone at the base of the formation may be permeable.

Chandler Limestone

The folding and contortion of the beds of limestone and dolomite have been accompanied by recrystallization, which has largely destroyed any original porosity. The presence of beds of salt in the section has an adverse affect on the quality of the groundwater.

Giles Creek Dolomite

The formation does not contain aquifers which could be exploited by the pastoral industry (Table H2). The drill stem test of the cavernous interval from 6375 to 6382 feet in Alice No. 1 well indicated that it was permeable and contained water with a TDS of 23,000 parts per million. Two other intervals at 6520 and 6600 feet appear to be permeable on the microlaterolog.

Shannon Formation, Jay Creek Limestone

Beds of sandstone and of fractured limestone and dolomite are aquifers which will yield adequate quantities of groundwater. The quality of the water obtained from bores drilled to date is generally suitable for stock and in some cases is suitable for domestic consumption.

Goyder Formation

Sandstone beds in the Goyder Formation are aquifers, and they will yield up to 1500 or more gallons per hour of water which contains less than 1200 parts per million of total dissolved solids (Table H2). The logs of Alice No. 1 and East Johnny Creek No. 1 wells indicate that below 900 feet from the surface the permeable beds of sandstone are thin, between one and two feet thick. They occur sporadically in a sequence of interbedded calcareous sandstone, limestone, dolomite, siltstone and shale.

In outcrop, much of the sandstone is a fine to medium grained very porous quartz sandstone with an open texture, and with small amounts of silica cement at the point to point contacts of the grains. It is believed that the calcareous cement has been leached from these sandstones during three periods of weathering since pre-Permian time and that the silica cement was introduced to the upper part of the weathered zone during the same periods. The base of the weathered zone on the crest of the Johnny Creek Structure is below 600 feet (Benbow and Planalp, 1965).

In those areas where the base of the weathered zone is below the piezometric surface the sandstone will be a very permeable aquifer. Within other areas groundwater can only be obtained from the thin lenses of porous sandstone, and from joints if they are present. The permeability of such an aquifer may be low and only those bores which intersect more than one will be capable of producing an adequate supply of groundwater. The dip of the formation must be low if more than one is to be intersected within an economic depth.

Pacoota Sandstone

Aquifers in the Pacoota Sandstone are generally beds of medium grained quartz sandstone which are between five and ten feet thick in a sequence of interbedded silty quartz sandstone, siltstone and shale. The amount of silica and carbonate cement in the quartz sandstone is variable and will adversely affect the permeability. In Palm Valley No. 1 and East Mereenie No. 1 wells the formation is fractured (Magellan, 1965; Benbow et al., 1964a) and the permeability due to fracturing is much greater than the intergranular permeability of the sandstones. It is expected that fractures and joints will only be developed in structurally favourable locations.

Supplies of groundwater varying from 200 to 8000 gallons per hour have been obtained from water bores which are less than 550 feet deep. The quality of this water is suitable for stock and in some cases for domestic consumption. Only 4 holes have been drilled in the Pacoota Sandstone, because it occurs mostly in areas of considerable topographic relief which are unsuitable for pastoral use.

Stairway Sandstone

Eighteen bores have been drilled for water in the Stairway Sandstone, of which twelve produce sufficient water suitable for stock (Table A2).

Within the syncline to the south of the Mount Burrell Anticlincrium the water in the formation has a TDS of 13,650 ppm. The salinity is derived from beds of salt in the Chandler Limestone, which unconformably underlies the Stairway Sandstone. This contamination would presumably be greater if impermeable sediments of the Finke Group did not transgress the Stairway Sandstone on the southern limb of the syncline and prevent the movement of groundwater through the formation. On the northern flank of the syncline the TDS of the groundwater is less, approximately 8,000 ppm, because of the effects of local recharge through the outcrop.

The available core analyses and the logs of the petroleum exploration wells indicate that significant intergranular porosity and permeability is restricted to the basal member of the formation. In the north-west portion of the Amadeus Basin this type of porosity has been destroyed by secondary enlargement of quartz grains, but may be replaced by fracture porosity in structurally favourable situations.

Stokes Formation

The limited information available indicates that groundwater prospects are poor due to low permeability of the three bores drilled in it, one was dry, one had 400 gph at with 7650 ppm TDS and one had 150 gph with 14,000 ppm. TDS.

Carmichael Sandstone

No water bores have been drilled in the Carmichael Sandstone. The formation is permeable and has yielded 1000 gallons per hour of good quality water in petroleum exploration wells on the Mereenie Anticline.

Mereenie Sandstone

The Mereenie Sandstone consists of fine to medium grained quartz sandstone and some thin interbeds of siltstone. The sandstone has an intergranular porosity between 18 and 25 percent, and a permeability between 80 and 1500 millidarcies (Bureau of Mineral Resources unpublished data). The lithology does not change significantly and the whole of the formation can be considered an aquifer with variable permeability. Adequate supplies of water for all purposes can be obtained from suitably constructed bores. Those currently used for the Alice Springs Town Supply have specific capacities between 500 and 1400 gallons per hour per foot of drawdown.

The content of total dissolved salts of the groundwater in the formation is generally less than 1000 ppm. and it may be less than 500 ppm. It rises to 7000 ppm in the Gardner Range where saline water moves into the Mereenie Sandstone form the Bitter Springs Formation across a fault contact. The regional significance of this contamination cannot be assessed.

Parke Siltstone

The distribution of the unit is not well known. Outcrop is restricted to the area to the south-west of Alice Springs, but production bore P6 of Alice Springs intersected about 500 feet (true thickness), this is the maximum known thickness. There is no intergranular permeability in the siltstone, but in the western part of the Amadeus Basin there is locally some joint permeability. Sandy beds near the base of the siltstone are also aquifers at the Mereenie anticline, but the extent of these beds is unknown.

Hermannsburg Sandstone

Two or three thin porous sandstones near the base of the formation are aquifers, which will yield between 1000 and 3000 gallons per hour of water which contains between 750 and 3000 parts per million of total dissolved solids. The aquifers occur as large lenses in beds of siltstone and impermeable sandstone and they may not be present in all areas.

Close to the top of the formation there is commonly a zone of jointing, which is an aquifer. On the northern margin of the Krichauff Ranges the bores which intersect this aquifer will yield water under small artesian heads.

The yields of successful bores vary between 1000 and 3000 gallons per hour of water which contains between 750 and 3000 parts per million of total dissolved solids. They are useful aquifers for the pastoral industry and for small settlements. The Areyonga Native Settlement and the Hermannsburg Mission Station rely on these aquifers for domestic supplies.

Apart from these aquifers significant permeability of any type is absent, and many dud holes have been drilled at sites selected at random by diviners and others. Most of the bores shown in Table H2 as being in Pertnjara Group have been drilled in this formation.

Brewer Conglomerate

The porosity and permeability of the formation have been largely destroyed by the introduction of a calcareous cement into the sandstone and conglomerate. The majority of bores drilled in the formation were abandoned either as dry holes, or because they produced inadequate supplies of water, which was either saline or of good quality. Some holes were abandoned due to difficult drilling conditions.

Horseshoe Bend Shale

Interstitial permeability in this unit is negligible, but bedding plane joints create some permeability. Supplies are all small, the highest being 700 gph (see Table H2), and the water quality moderate to poor. The unit is not an important source of groundwater.

Langra Formation

Permeability in this unit is generally good, and supplies over 1000 gph are normal, but the salinity is always high. The upper sandstone unit (above the shale near the top of the formation), generally has water of 8000 - 9000 ppm, and this water is sometimes marginal for stock use. The lower sandstone unit has water containing over 10,000 ppm, and the highest salinity recorded is 130,000 ppm, from bore G53/6-79 (Clough's Bore). This bore is unusual in that artesian conditions occur, and the piezometric surface is three or four feet above natural surface.

Santo Sandstone

This is the only formation within the Finke Group which contains good quality water. (Table H2). Other formations in the Group may yield stock quality water in exceptional cases, where there is some local recharge diluting the main body of saline water. (see sections above)

Very few bores have been drilled into the Santo Sandstone, and it is not important in a regional sense because it only occurs below the piezometric surface in very restricted areas, most of which are a short distance south of Maryvale Homestead. Of the known bores in the unit, those with small supplies have almost certainly been stopped before reaching the base of the sandstone and hence may actually have been able to produce adequate supplies. It is a highly useful aquifer in the area between Maryvale Homestead and the Finke/ Hugh River junction, although its distribution is difficult to predict because of the Quaternary Sand cover. Useable water is stored in the Santo Sandstone in small synclines, where pockets of good water occur in a generally saline area.

There is no information on long term yields, but bore G53/2-126, a few miles south of Maryvale Homestead, has been used for about 12 months for irrigation. It has been tested at 5000 gph. Recharge to the formation is dependent on flows in the Finke and Hugh Rivers and Alice Creek.

Crown Point Formation

This unit is a particularly valuable and reliable aquifer over a large area in the south-east part of central Australia.

The most saline water known is less than 4000 ppm (Table H2) and supplies are always adequate for domestic or stock purposes, except where the base of the formation occurs above or only slightly below the piezometric surface. Except in one or two cases, the aquifer is a medium to coarse grained sandstone, often pyritic, and in places pebbly to conglomeratic.

Availability of water depends largely on the pre-Permian topography e.g.; in the area around the north-west margin of the Gt. Artesian Basin. Relief on this surface is relatively severe, and successful bores occur where there is sufficient depth below the piezometric surface. Further to the south-east in the deeper parts of the Artesian Basin, there is practically no information within the Northern Territory. In some areas, the presence of the overlying de Souza Sandstone means that no water bores are drilled as deep as the Crown Point Formation. At McDills No. 1, a major artesian flow was encountered at 2375 feet from a pyritic grey sandstone immediately above the top band of Permian coal. This aquifer is thought to be within the Crown Point Formation, or at least to be of Permian age, and may be extensive beneath the Jurassic Artesian Basin aquifers.

Very little is known about recharge to the formation, but some recharge is certainly taking place along the belt of outcrop extending east-north-east from Rumbalara Siding. Maximum yields and the effect of long term pumping are unknown.

Rumbalara Shale

Porosity occurs in two different manners in this unit. First, there is often a weathered zone below the superficial sediments, which commonly yields about 100 gph of highly saline water from small perched groundwater bodies. Secondly, there are thin sandstones in the unit, apparently mainly near the base, and these produce up to at least 1000 gph of highly saline water. In only one case (Lucky Bore, east of Erldunda Homestead) is the salinity low enough for stock use. In this case the water is 3000 ppm, but the identification of Rumbalara Shale from the driller's log is suspect, and the aquifer may actually be within one of the small Tertiary basins known in the area. Excluding Lucky Bore, salinities range from 9000 to 30,000 ppm, and the Rumbalara Shale is therefore of no use as a potential source of water for stock, irrigation or domestic use. The source of the salt (dominantly sodium chloride) is unknown, but it is most likely either present in connate water or the result of stagnant conditions.

Except in the general vicinity of Erldunda Station, the Rumbalara Shale is usually underlain by the de Souza Sandstone which is a reliable aquifer. Lack of good quality water in the Rumbalara Shale is therefore not a serious problem except in a very restricted area.

De Souza Sandstone

This is one of the main aquifers of the Artesian Basin, but only two bores drilled into it in the Northern Territory are known to have located artesian conditions (Anacoora and Dakota bores). The greatest number of bores drilled in the unit are around the north-west margin of the Artesian Basin, in the recharge areas where the piezometric surface is below ground surface. Groundwater enters the unit along the north-east trending outcrop and subcrop belt which extends laterally from about Rumbalara Siding to near Finke. The water moves south-east into the Great Artesian Basin, with a superimposed mound in the piezometric surface along the Finke River.

Quality ranges from about 600 ppm to about 3500 ppm, except in an area west of Kulgera where water of over 6000 ppm is present in aquifers tentatively assigned to the De Souza Sandstone. Tested supplies range up to 3000 gph from pumped holes, and the flow at Anacoore Bore was initially about 30,000 gph. The head at Anacoona Bore was 48 feet in 1900 and at present is estimated at less than 5 feet. The only other data on water level changes are from Charlotte Waters Bore, where there was no decline from 1900 to 1938. The present water level is not known.

Results of drilling in this formation are summarised in Table E2.

Tertiary (pre-silcrete deposits)

The older or pre-silcrete Tertiary deposits are of lacustrine origin (Pontifex 1965, Woolley 1966), and consist dominantly of white and grey clay and sandy clay with no effective permeability. Aquifers within the section are sand, with one or two possible exceptions (e.g. one possible laterite aquifer in Alice Springs Farm Area, F98). The sands are oligomict quartz sand, fine to very coarse, and often angular to very angular. The quartz is generally colourless to transluscent. There is a varying amount of white kaolinitic matrix, but size sorting is generally good. The sands are mostly less than

10 feet thick, and rarely as much as 20 feet thick. Tested supplies up to 3000 gph have been obtained from these sediments, and except in a few cases this is also the maximum yield. Water quality is generally good to moderate for stock purposes, and often of domestic quality. Woolley (1966) concluded that water from these deposits in the Alice Springs Farm Area can be utilized only for stock watering and limited domestic use. These comments can probably be extended to most of the pre-silcrete Tertiary deposits.

Tertiary (post-silcrete deposits)

The post silcrete conglomerate (Tc) is impermeable and is not known to occur below the piezometric surface. It is therefore of no importance as an aquifer.

The sequence of limestone, sandstone, siltstone and claystone, capped with chalcedony (Tl), of Wells, Ranford, Stewart, Cook and Shaw (1965) probably contains permeable zones, but they are unlikely to be extensive below the piezometric surface. There is very little information available.

Post silcrete fluvial unconsolidated sediments are known in some areas, but most of these are outside the Amadeus Basin area. The best known occurrences are at Willowra (Morton 1965), Utopia (Woolley 1965) and Alcoota (Woodburne 1967b). At Utopia and Willowra, supplies of up to 10,000 gph are being used for irrigated agriculture. Similar deposits probably occur in the Alice Springs Outer Farm Area, but are difficult to distinguish from the overlying Quaternary deposits.

Table H2 summarises results of drilling in Tertiary sediments, but does not distinguish between pre and post silicrete deposits.

[illegible]

Quaternary clastic deposits are widespread in the Amadeus Basin Area. However, they extent below the piezometric surface in only relatively small areas, mainly in long narrow zones along major river courses. There are also extensive piedmont deposits north of the MacDonnell Range which include both clastic and non clastic aquifers.

Quinlan and Woolley (1962, 1966), have discussed in some detail the alluvial deposits of the Alice Springs Town Basin. These deposits are representative of a large proportion of the Quaternary alluvial deposits in the area, and consist dominantly of grey and brown silt and clay, which include varying amounts of sand. Thin lenses of sand generally less than 10 feet thick, form a minor proportion by volume but are the only aquifers. The sands are angular, polymict, fine to coarse grained, and in places gravelly, and represent buried river bed deposits. The sandy silt and clay represent bank and flood plain deposits. Along some of the major rivers (particularly the Finke) individual sand beds can be up to 50 feet thick.

Extensive piedmont deposits along the northern flank of the MacDonnell Ranges contain up to 300 feet of Quaternary deposits; over a large part of this area they overlie a considerable thickness of older (Tertiary and Permian probably lacustrine and fluvial deposits. Because of the presence of better aquifers in these older deposits, only a few of the bores in this region obtain water from Quaternary aquifers. The most notable area is in the vicinity of Haasts Bluff Settlement, where about six bores produce good supplies of good quality water from Quaternary sands.

Of the 85 bores for which records are available and which produced water from Quaternary aquifers, 37 are less than 50 feet deep, 26 are between 50 and 100 feet deep, 12 are 100 to 150 feet deep and 10 are over 150 feet deep. The quality of water from these aquifers is generally good and is less than 2000 ppm except in a few cases. The extreme case of 29,000 ppm (Table H2) occurs where water in alluvium in the Finke River is being contaminated by highly saline water effluent from Finke Group aquifers. Other cases of relatively saline water in Quaternary clastic aquifers are associated with water effluent from the Bitter Springs Formation.

Tested supplies from Quaternary alluvial aquifers range up to 3000 gph in pastoral bores (Table H2) but these are generally not maximum supplies. Continuous pumping at rates of over 6000 gph has been maintained for several years from some bores in the Alice Springs Town Basin.

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