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THE STRATIGRAPHY OF THE MESOZOIC AND PERMIAN SEDIMENTS OF THE DESERT BASIN, WESTERN AUSTRALIA.

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INTRODUCTION.

The Desert Basin* covers an area of approximately 140,000 square miles in the Kimberley and Eastern Divisions of Western Australia. Geological investigations have been almost entirely confined to the northern part of the area; the southern part is covered by parallel sand-dunes with a few scattered outcrops and is relatively unexplored (Fig. 1).

Previous investigations in the area have been sponsored by oil companies and reports have been prepared by Wade (1936), Kraus (1942), and Reeves (1949). Papers on palaeontology and stratigraphic correlation have been contributed by Teichert (1939, 1941, 1947).

A programme of geological mapping was initiated in the area by the Commonwealth Government in 1948. The entire area is being mapped, using aerial photographs, stratigraphic studies are made and fossils are collected for correlation purposes. The aim of the investigations is the evaluation of the petroleum prospects of the area. During the period 1948 to 1950, mapping has been carried out in Dampier Land and the area north of the Mt. Fenton Fault (Fig. 1); the information in this paper will refer mainly to the area already mapped with brief reference to the unexplored area to the south.

* The name Desert Basin was used to differentiate the area from the other artesian basins in Australia. Recent research indicates that the Desert Basin may be structurally more complex than the simple sedimentary basin postulated originally by Maitland and Montgomery (1924).

STRATIGRAPHY.

MESOZOIC (Brunnschweiler, 1951)

The horizontally-lying sedimentary sequence exposed along the coast and in the interior of Dampier Land (Fig.1) consists mainly of marine ferruginous sandstone with a few conglomeratic beds, claystone, glauconitic marl, and silicified limestone. Palaeontological analysis of the fauna has shown that it is mainly of Cretaceous age. The

sediments overlap Pre-Cambrian rocks at the northern end of King Sound and Permian sediments in the area between Derby and Grant Range.

The sequence, which was originally termed Derby Series by Wade (1938), has been sub-divided into five formations (Table 1).

Table 1 - Stratigraphic Units, Mesozoic Dampier Land.

Western Dampier Land	Thickness feet	Stages	Thickness feet	Central & Eastern Dampier Land
Cape Leveque Sandstone	0 - 20	Aptian (Albian?)		?
Unknown equivalent of Melligo Quartzite		Aptian	5 - 30	Melligo Quartzite
Jowlaenga Sandstone (upper part)	60	Neo-comian	150	Jowlaenga Sandstone
		Neo-Tithonian	?	Langey Crossing Marl
		Tithonian Port-landian?	?	Frazer River Limestone

The oldest formations known are the Frazer River Limestone and the Langey Crossing Marl. Outcrops of the limestone are isolated and unfossiliferous but probably pre-date the Langney Crossing Marl, which contains the ammonite genus Kossmatia Uhlig also recorded from the Himalayan Spiti Shales and from New Zealand. In Dampier Land, Kossmatia is found with a radially ornamentated, archaic, Buchia (Aucella), and Belemnopsis cf. gerardi Opp. The characteristic Buchia - Belemnopsis assemblage known from the Himalayas, the East Indies, North-Western Australia, and New Zealand, is therefore considered to be Kimmeridgian - Tithonian rather than Oxfordian.

The overlying formation, the Jowlaenga Sandstone, is of Neocomian age and contains the following faunal assemblage : - belemnites Hibolites subfusiformis Rasp., Belemnopsis cf. tanganensis Futt., pelecypods Meleagrinella n. sp.aff. superstes (Spitz), Iotrigonia n.sp.aff. limatula Whitehouse. Similar Neocomian assemblages are found in Eastern

Queensland and the Himalayas. Iotrigonia and the belemnites are also common in South Africa, whereas Meleagrinella is not known there.

The youngest formations of the Mesozoic sequence are the Melligo Quartzite and the Cape Leveque Sandstone. The former contains Fissilunula, Cyrenopsis, Pseudavicula, Panopaea, and is correlated with the Aptian Roma Series of the Great Artesian Basin. (The plant-bearing Cape Leveque Sandstone in which, as the only marine fossil, a new species of Inoceramus was found, is probably younger than the Melligo Quartzite, and therefore of late Aptian or Albian age.)

PERMIAN.

The stratigraphic units in the area were originally defined by Wade (1936). Later investigations have suggested minor alterations but in general Wade's original nomenclature has remained. Amendments by the writers are in accordance with the requirements of the Australian Code of Stratigraphical Nomenclature. The generalized stratigraphy of the area is tabulated in Table 2.

Table 2 - Permain Stratigraphic Units, Northern Part, Desert Basin, W.A.

System	Formation	Lithology	Thickness (feet)
LOWER PERMIAN (Kungurian, Artinskian, Sakmarian).	Liveringa Group	Greywacke, sedimentary iron ore, sandstone, siltstone. Mainly estuarine.	1200 approx.
	Noonkanbah Formation.	Sandstone, limestone, siltstone, shale and claystone. Marine and brackish water.	1200
	Poole Sandstone Nura Nura Limestone Member Erosional unconformity	Sandstone, arkosic sandstone, conglomerate. Estuarine. Limestone, sandstone, bands of conglomerate.	200 - 1200
	Grant Formation Unconformity	Sandstone, conglomerate, arkosic sandstone, tillite, siltstone, shale and limestone. Glacial and aqueo-glacial.	0 - 3500
Devonian Limestone			

PERMIAN (contd)

Grant Formation:

The formation name is derived from the Grant Range Blatchford (1927) (long. 124° 10' E, lat. 18° 00'S) and was originally applied by Woolnough (1933), who used the term Grant Range Beds for the glacial deposits. After a careful study of outcrops, and taking into consideration the logs of bores which have penetrated the formation, the writers have decided to rename the unit the Grant Formation. The formation is redefined to include all the glacial sediments deposited between the limestones of Upper Devonian age and the Poole Sandstone; the formation includes the Kungangie, Willanyie, and Grant Range Beds of Wade (1936), and probably the Hawkestone Sandstone of Kraus (1942), Findlay (1942), and Reeves (1949).

Distribution: The upper beds of the formation are exposed in the crestal portion of the Poole Range, St. George Range, Mt. Wynne, and Grant Range Domes. Outcrops are also found along the north-eastern margin of the basin (and possibly as small outliers in inaccessible parts of the King Leopold Ranges), where the formation overlaps older Palaeozoic and Pre-Cambrian rocks.

Lithology: The Grant Formation contains several types of glacial and aqueo-glacial sediments, including sandstone, conglomerate, tillite, varves, siltstone, and shale. Intra-formational contortions are a characteristic feature of the glacial sediments.

Most of the exposed rock is sandstone - typically massive, poorly bedded, white, weathering to red-brown, silty sandstone with grains generally subangular but sometimes subrounded to rounded. Pebbly lenses containing occasional boulders are present, and also cherty siltstones. A typical section, from the Poole Range, through the upper beds of the Grant Formation is given below:-

Poole Sandstone	Thickness (feet)
Sandstone, white, weathering to brown, massive, current-bedded	40
Siltstone, yellow, white, blue, grey, thinly bedded, often sandy with thin bands of clayey sandstone.	82

PERMIAN (contd)

Poole Sandstone (contd)	Thickness (feet)
Siltstone, blue-grey, finely bedded with coarse sandstone bands. Contains limestone concretions and glacial pebbles.	21
Sandstone, light grey, with scattered glacial pebbles and boulders.	4
Tillite, massive, grey, sand siltstone with lenses of coarse sandstone. Boulders distributed throughout.	70

Thickness: Although no complete section of the Grant Formation is available in the area, the No. 3 Bore, Poole Range, penetrated 3264 feet of Grant Formation. Approximately 200 feet of the formation crops out above the bore site indicating a minimum thickness of 3460 feet. Outcropping sections reach a maximum thickness of approximately 500 feet in the St. George Range.

Palaeontology: Fossils are rarely found in the formation, and are restricted to tracks of marine worms and indeterminate plant remains with some fossil wood. The precise age of the formation cannot be determined until further information is at hand. A Permian age, however, seems to be certain because of the evidence of glaciation, which in other areas in Western Australia has occurred in Permian time.

Poole Sandstone: The type area for this formation is situated in the Poole Range (long. 125° 45' E., lat. 18°50's) where it is conformably overlain by the Noonkanbah Formation, and is separated from the underlying Grant Formation by a minor erosional unconformity. The formation name replaces Pool Range Series and Lower Ferruginous Serious (Wade 1936), and Poole Range Sandstone (Reeves, 1949). The Nura Nura Limestone Member, (Wade, 1936) at the base of the formation, is exposed, near Mt. Wynne.

Distribution: Outcrops of the formation are confined to the area between Pinnacle Fault and Mt. Fenton Fault (Fig. 1), and form prominent outliers capping the Grant Formation. The formation is well exposed along the flanks of the folds such as Poole Range and Grant Range Domes.

Lithology: Most of the formation consists of well-bedded, white, weathering to light-brown, fine, micaceous sandstone with plant remains. Outcrops of low elevation are commonly highly ferruginized. Cross

PERMIAN (contd.)

bedding, ripple marks, and worm tracks are characteristic, and indicate shallow water, partly estuarine, deposition. The Nura Nura Limestone Member consists of calcareous sandstone, sandy limestone, and limestone, with bands of unsorted, coarser sediments.

The change in lithology from Poole Sandstone to the Noonkanbah Formation is gradational.

Thickness: The thickness of the formation increases in a north-westerly direction from approximately 200 feet in the Poole Range to approximately 600 feet in the western St. George Range, and at least 1200 feet in the Nerrima Bore and Grant Range.

Palaeontology: During 1950, a fossiliferous marine bed which is very likely the equivalent of the Nura Nura Limestone at Mt. Wynne was located near the base of the Poole Sandstone in the St. George Range. The bed contains mainly brachiopods, especially "Chonetes pratti", together with productids, Streptorhynchus, Spirifer and Cleiothyridina, further molluscs, such as a predominant Edmondia together with Dentalium, Bellerophon, and a doubtful ammonoid. Ostracods, Healdia and Bairidia, bryozoans, mainly Trepostomata, and Foraminifera, such as Ammodiscus sand possibly Calcitornella, are found sporadically.

Fossil plants occur throughout the formation, particularly in the upper part of the section. Glossopteris, Lepidodendron, Noeggerathiopsis, Stigmaria, and seeds, have been identified. No determinable Gangamopteris has been found and it is in fact assumed not to occur north of the 22nd degree of latitude.

Approximately 60 genera and species have been identified in the Poole Sandstone.

Noonkanbah Formation:

This formation was named by Wade (1936) at the type locality on Noonkanbah Station (long.124°50'E., lat.18°30'S). Later observers, Kraus (1942), Reeves(1949), have referred to it as the Noonkanbah Shale. As a result of detailed observations by

the writers in the eastern part of the area, it is clear that, whereas the section is composed mainly of shales in the Nerrima area, east of the Poole Range the predominant rock types are non-shaly. It has therefore been decided to refer to the unit as the Noonkanbah Formation.

The formation is conformably overlain by the Liveringa Group, and conformably underlain by the Poole Sandstone.

Distribution:

The formation covers a large portion of the area between the Pinnacle and Mt. Fenton Faults. Outcrops are poor except to the east, where non-shaly rocks predominate. The flanks of domes, such as Poole Range and Grant Range Domes, are composed of beds of the Noonkanbah Formation.

Lithology: Outcrops in the Christmas Creek area consist of alternating sandstone, limestone and siltstone. In the Nerrima Bore the main rock types are shale, claystone, limestone and siltstone.

Thickness: A surface section of 1260 feet was measured recently in the Christmas Creek area. This agrees closely with estimates made by Wade at other localities - 100 feet approx. north and south of Grant Range, 1320 feet at Jimberlurah Ridge, 1320 feet in the Duchess Ridge area, 1200 feet at Kimberley Downs. On the Nerrima Dome the Noonkanbah Formation surface section and strata penetrated by the core is 1200 feet thick. (Guppy, Cuthbert, and Lindner (1950).

Palaeontology: The Noonkanbah Formation contains the richest marine fauna in the Permian sequence - approximately 170 genera and species have been recognized. In the Christmas Creek area the lower half of the formation is poorly fossiliferous, whereas the upper 700 feet contain a rich and varied fauna of bryozons (at least 32 species) and brachiopods (productids and, Spirifer),

Strophalosia and Cleiothridina, Calceolispongia first appears at 800 feet above the base of the section in the area west of Christmas Creek. Foraminifera and corals are present together with pelecypods. The pelecypods increase in number towards the top of the section until they predominate over all other types in the Liveringa Group. No cephalopods or trilobites have been found.

The bryozoans are represented chiefly by the order Cryptostomata, which appear in numbers 750 feet above the base. Those Mollusca which are generally associated with calcareous Trepostomata and Cryptostomata are present.

Foraminifera are abundant, particularly Calcitornella, which appears at 550 feet from the base in the Christmas Creek area, and is frequently found with Dictyoclostus, both of which indicate warm, shallow-water, conditions. Calcitornella is replaced at 1250 feet above the base by the arenaceous forms Ammodiscus and Frondicularia, and finally by the arenaceous Hyperamminoides, the most common form in the Liveringa Group. The only fusulinid known is an uncertain parafusulinid from the uppermost beds of the section. In the North-West Basin Geinitzina and Calcitornella are both restricted to the Callytharra Limestone.

Worm tracks occur low in the section while Serpulites appears at 900 feet above the base and again at the base of the Liveringa Group. "Chonetes pratti", Strophalosia kimberleyensis, Streptorhynchus, and spiriferids, are common throughout the sequence.

Liveringa Group:

The group was originally termed Liveringa Series (or Upper Ferruginous) by Wade (1936), from the type locality at lower Liveringa Ridge (long.124°06'E.,lat.17°56'S.) As redefined the

Liveringa Group (contd)

group includes all sediments of Permian age younger than the Noonkanbah Formation. The Liveringa Group includes the Liveringa Iron Sandstone, Belina Shale and Erskine Sandstone of Kraus (1942) and Findlay (1942), and replaces Liveringa Beds of Reeves (1949). The Group conformably overlies the Noonkanbah Formation and is unformably overlian by Mesozoic sediments.

Distribution:

Outcrops of the Group are confined to the area between the Pinnacle and Mt. Fenton Faults (Fig. 1); sections are exposed in the folded areas between Grant Range and Nerrima Dome.

Lithology:

Outcropping beds are usually highly ferruginized giving a dark brown to almost black peaty and concretionally hard cap, which masks the original lithology of the sediments. Reconnaissance in the area indicates that the group may be divided into four formations when more detailed investigations have been completed. The basal marine beds contain alternating calcareous, sandy sediments with intra-formational pebbles and fragmental fossils; grey-green arkosic sandstone, and intercalated red-brown fine, oolitic limonite. The overlying estuarine beds consists of ferruginized, fine micaceous, sandstone and arkosic sandstone with plant remains. The estuarine beds, according to Kraus (1942) and Reeves (1949), are overlain by as much as 600 feet of shales which they named Belina Shale. Overlying the Belina Shale are sandstone beds termed Erskine Series by Wade.

Palaeontology:

The lower part of the section contains mainly brachiopods and pelecypods and the upper part, freshwater beds with plant remains. Of the foraminifera, Hyperamminoides was the only form identified, though Chapman and Parr (1937) described fusulinids from the higher marine beds. Corals and crinoids are rare, ostracods uncommon, and bryozoans are almost completely absent. Conularia first appears at the base of the sequence together with reappearing Serpulites.

"Chonetes pratti" and other productids, spiriferids, and Cleiothyridina, are the predominant brachiopods; the molluscs, which

form the largest group, include Sanguinolites, Cardiomorpha, Edmondia, and the Timor genus Atomodesma, and the gastropods include large pleurotomarids and bellerophontids.

The upper freshwater beds contain Glossopteris, stem casts and fossil wood.

AGE OF THE SEDIMENTS.

The fossil record of the area is mainly one of recurrent faunas and species ranging through more than one formation, although the assemblage in successive beds are often distinctive.

The oldest fossil evidence for a Permian age of the sediments of the Desert Basin in the occurrence of the ammonoids Thaleassoceras wadei, Metalegoceras clarkei, and Metalegoceras striatum, in the Nura Nura limestone Member of the Poole Sandstone. These fossils are younger in age than Metalegocers jacksoni of the Irwin River glacial beds of the southern part of Western Australia and are probably of early Artinskian age (Teichert, 1941).

The fusulinids Neoschwagernia and Verbeekina from the upper-most marine beds of the Liveringa Group indicate approximately the close of the Artinskian (Chapman and Parr, 1937).

The still limited information suggests that at least the Poole Sandstone, Noonkanbah Formation, and the marine Liveringa Group, were deposited during Artinskian time.

The persistent marine fauna, including well-preserved worm tracks in various horizons throughout the sequence, indicates a rapid rate of sedimentation which kept pace with the continuous subsidence of the area of deposition. This resulted in the accumulation of at least 4000 feet of sediments during Artinskian time.

STRUCTURE.

The northern part of the Desert Basin consits of three distinct physiographical divisions which are closely related to regional structure. These are -

(1) an area to the north-east of Pinnacle Fault (Fig1),

(2) a central division which is situated between the Pinnacle and Mt. Fenton Fault, and

STRUCTURE (contd)

(3) a south-western division to the south-west of Mt. Fenton Fault.

The north-eastern division comprises the rugged King Leopold Ranges, which are formed by folded Pre-Cambrian rocks, overlapped along their south-western margin by Devonian and Ordovician limestones. The Devonian limestones form a number of ranges such as Rough Range, Oscar Range and Napier Range. They are overlian by scattered remnants of Permian glacial beds of the Grant Formation.

The central division bounded by the Pinnacle and Mt. Fenton Faults consists of Permian sediments which have been folded into two and possibly three anticlinal lines of folding with a trend oblique to the main faults (Fig. 1.)

The south-west division extends from the Mt. Fenton Fault into the desert area, and consists mainly of long, approximately east-west trending sand dunes with a few scattered outcrops. Although little is known of this vast plateau area, available evidence suggests that this plateau area is covered by sediments, mainly sandstone, of Mesozoic age.

The main structural problem in the area is to determine whether the region between the Pinnacle and Mt. Fenton Faults is either a trough within which the thickest section of Palaeozoic sediments has been deposited, or a step with a thicker section of Palaeozoic sediments south-west of the Mt. Fenton Fault. It is expected that by means of further geological and geophysical field work sufficient evidence will be accumulated to establish the significance of the Mt. Fenton Fault for regional structure.

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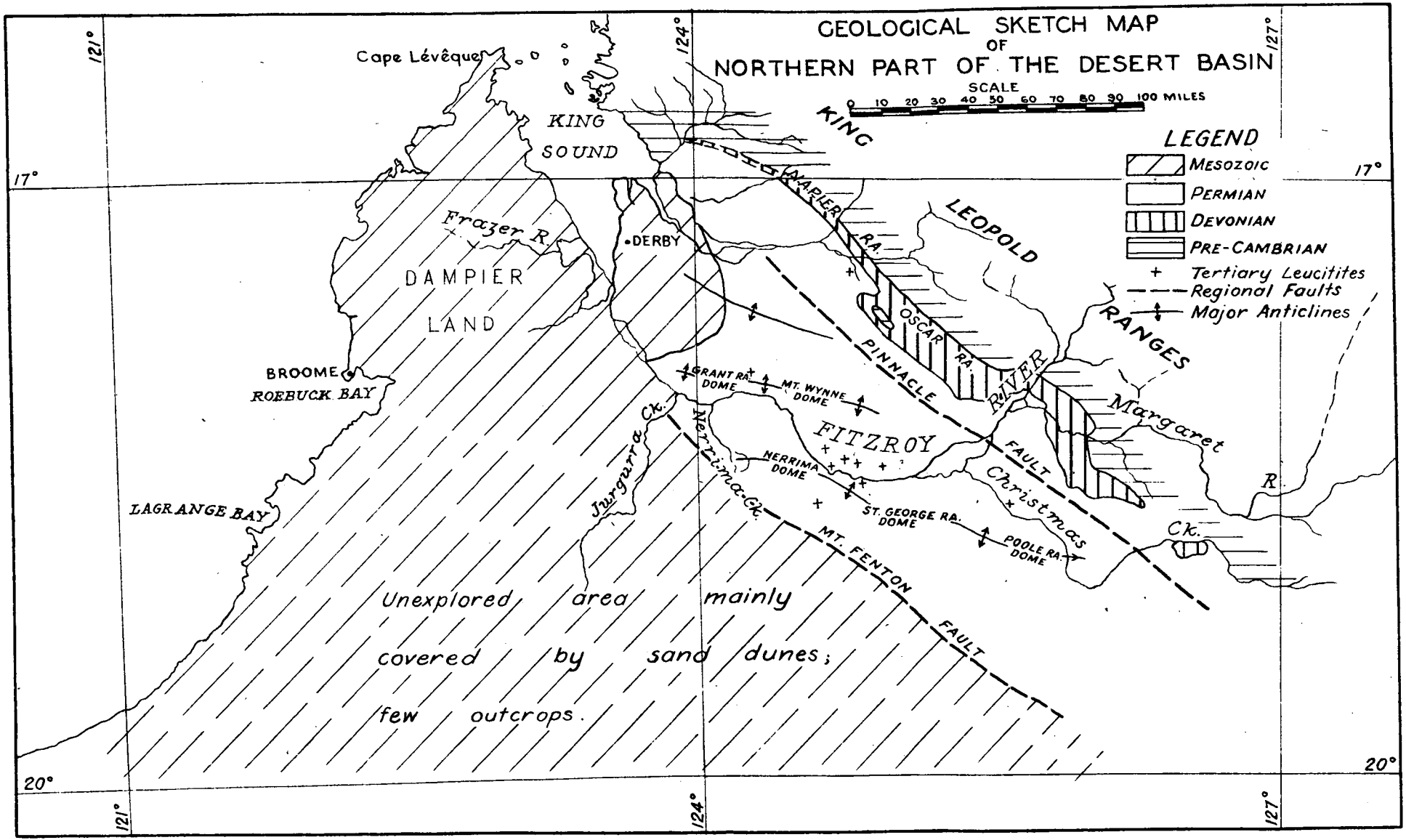
GEOLOGICAL SKETCH MAP
OF
NORTHERN PART OF THE DESERT BASIN
SCALE
0 10 20 30 40 50 60 70 80 90 100 MILES
LEGEND
Mesozoic
Permian
Devonian
Pre-Cambrian
Tertiary Leucitites
Regional Faults
Major Anticlines
121°
124°
127°
17°
20°
Cape Lévêque
KING SOUND
KING LEOPOLD RANGES
DAMPIER LAND
Fraser R.
DERBY
BROOME
ROEBUCK BAY
LAGRANGE BAY
DAMPIER RA.
OSCAR RA.
PINNACLE FAULT
GRANT RA. DOME
MT. WYNNE DOME
FITZROY
NERRIMA DOME
ST. GEORGE RA. DOME
POOLE RA. DOME
Jurgurra Ck.
Nerrima Ck.
MT. FENTON FAULT
Christmas Ck.
Margaret R.
Unexplored area mainly covered by sand dunes; few outcrops.