69/89
(4)

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1969 / 89

The Geology of the Lake Mackay Sheet Area, Northern Territory

by

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SUMMARY

This report is the result of geological investigations undertaken in 1968 on the Lake Mackay 1:250,000 Sheet area, Northern Territory whose southern half is occupied by the western termination of the Ngalia Basin.

The basin, a narrow intracratonic depression in Precambrian igneous and metamorphic rocks, reaches a maximum width east of the Lake Mackay Sheet area of about 45 miles and has a length of just under 300 miles. The only basin sediment that crops out on the Lake Mackay Sheet area is the Proterozoic Vaughan Springs Quartzite and its included Treuer Member which is separated from Precambrian granites and isoclinally folded metasediments by a major unconformity, and hence is regarded as the base of the Ngalia Basin sequence.

Outcrops of Vaughan Springs Quartzite on the southern margin of the basin are either flat-lying or show gentle dips to the north. The largest outcrop of Vaughan Springs Quartzite on the northern margin of the basin is exposed as an easterly plunging syncline which shows upturning of the quartzite on its northern limb where it has been displaced by the Waite Creek Fault against basement granite.

Two isolated areas of sandstone cropping out some 60 miles to the north of the basin edge are of Proterozoic age, and are tentatively correlated with the Gardiner Beds which crop out at the margin of the north east Canning Basin, in Western Australia.

A large gravity low extends from eastern Lake Mackay to eastern Napperby. A local gravity minimum occurs in the north-west of the adjoining Mount Doreen Sheet area. Seismic reflection results in the area of this local feature have been interpreted as a low angle overthrust of basement rocks over about 16,000 feet of Ngalia Basin sediments. This gravity minimum extends onto the central-eastern part of the Lake Mackay Sheet area.

Regionally metamorphosed basement sediments have been tightly folded about north-east trending axes, and show an apparent increase in metamorphic grade from south-west to north-east.

No mineral deposits of economic significance are known in the area, and the age of the only exposed basin sediments precludes any possibility of hydrocarbon accumulation.

INTRODUCTION

General

This record describes the geology of the Lake Mackay 1:250,000 Sheet area, Northern Territory. The mapping of this area is part of a joint programme of geological and geophysical investigation undertaken by the Bureau of Mineral Resources in the Ngalia Basin. Three geologists, A.T. Wells, T.G. Evans and T. Nicholas mapped the sediments in the westernmost extension of the Ngalia Basin lying in the southern half of the Sheet area, and also the marginal basement complex and isolated undifferentiated Proterozoic sedimentary outliers to the north. The mapping was undertaken during the winter months of 1968.

Location and access

The area investigated extends east from the Western Australian/ Northern Territory border (Longitude 129°00') to Longitude 130°30', and between Latitude 22°00' and 23°00', covering in all an area of about 6,700 square miles and lying entirely within the Lake Mackay Aboriginal Reserve (Fig. 1a).

Prominent physiographic features within the area include Lake Mackay in the west, the McEwin Hills and Sandford Cliffs on the northern margin, and Mounts Carey and Redvers, Dry Bluff, and Mount Morris in the south.

The area is uninhabited, with the possible exception of a few nomadic aboriginals; there are no roads, and water is a rare commodity. After exceptional rains, surface water collects in clay pans but usually disappears within a few days. Native wells have been reported on Ethel Creek (Lucky Hit Waterhole) and at Sandford Cliffs (O'Grady's Well).

Access to the area from the east is by graded road which links Yuendumu Native Settlement with Mount Doreen Homestead at Vaughan Springs in the western part of the adjoining Mount Doreen 1:250,000 Sheet area. There is an aircraft landing ground at Mount Doreen Homestead with a weekly mail service to Alice Springs via Yuendumu Native Settlement. Emergency hospital facilities are available at the Native Settlement.

The nearest access to the south of the Sheet area is a graded dirt road running from Alice Springs to the Canning Stock Route, at its nearest point passing through Sandy Blight Junction on the Mount Rennie 1:250,000 Sheet area (Fig. 1a).

The party was camped on Waite Creek in the westernmost part of the Mount Doreen Sheet area (Fig. 2), some 26 miles south-south-west of Vaughan Springs by graded track. All water for camp use was obtained from the permanent Vaughan Springs at Mount Doreen Homestead.

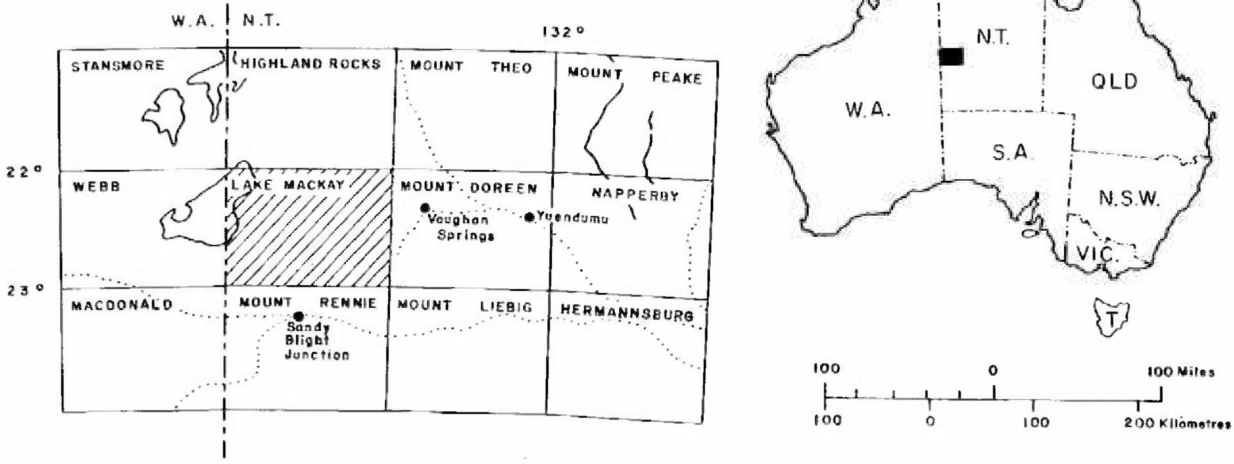
Climate

Figure 1b summarizes the meteorological data recorded from Mount Doreen Homestead, the nearest station to the area, and was made available by the Bureau of Meteorology, Darwin.

The region is arid, is subject to very irregular rainfall, and lies in the 4 to 10 inch rainfall belt. The mean daily summer maximum may reach or exceed 100°F for many weeks, temperatures being characterized by marked diurnal and seasonal fluctuations. In winter the nights are cold, with frosts common in late June and early July. The prevailing wind is from the south-east.

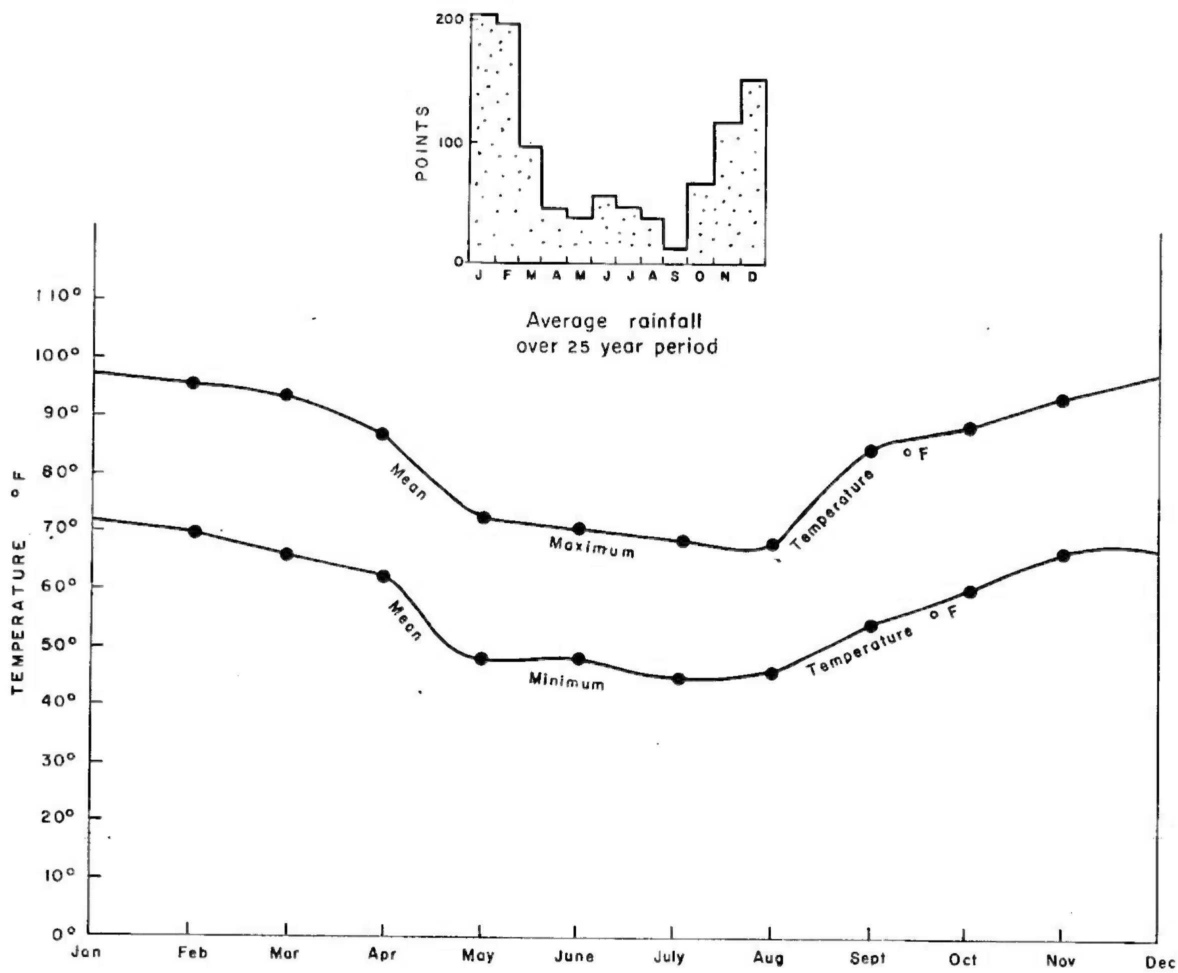
POSITION OF AREA MAPPED AND REFERENCE TO AUSTRALIAN 1:250,000 MAP SERIES

Fig. 1a



METEOROLOGICAL DATA MOUNT DOREEN SHEET AREA

Fig. 1b



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Development

Because of the nature of the country, which is semi-desert, no attempts at development have been made; the area was proclaimed as part of a native reserve in 1959.

Survey method

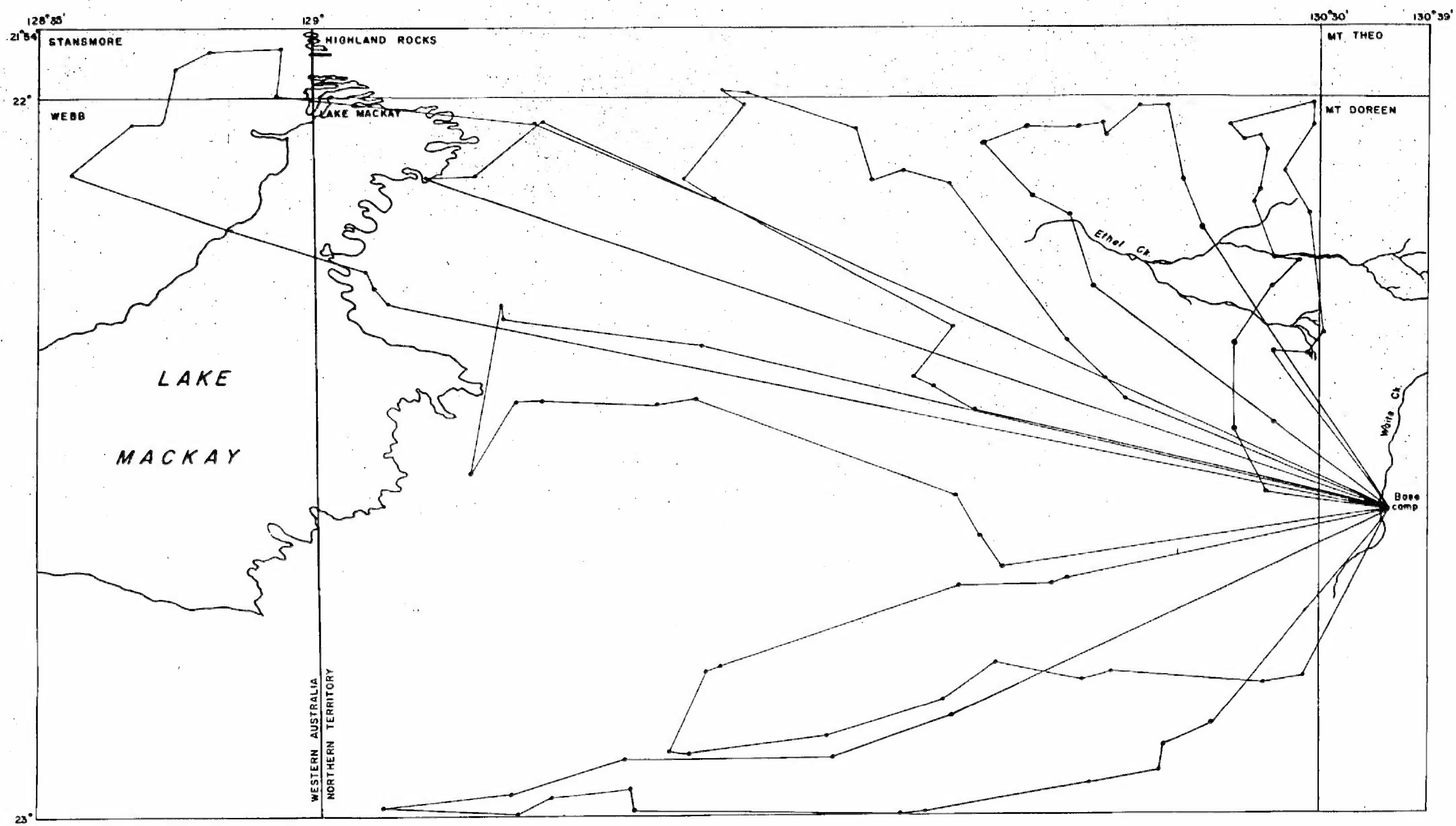
Reconnaissance traverses using 4-wheel drive vehicles were made of a few selected areas in the more accessible eastern third of the Sheet area. As outcrops are very scattered, and access and water supply posed considerable problems even for 4-wheel drive vehicles, extensive use was made of a helicopter for geological traverses.

In all, 32 hours were flown over a period of 8 days in a Bristol Sycamore Mk. IV helicopter chartered from Associated Helicopter Services Pty Ltd. Some 100 geological observation points were visited, and these as well as traverse lines are indicated in Figure 2.

A photo-geological interpretation of the western end of the Ngalia Basin and marginal areas of basement rocks was prepared in 1964 by the B.M.R. Photogeology Group (Rivereau, 1965). The remaining parts of the Sheet area were photo-interpreted by members of the B.M.R. geological party before the survey commenced. Transparent overlays with this photo-interpretation were thus available for each air photograph (scale 1:46,500) taken by the R.A.A.F. in 1950. The geology on these overlays was revised and corrected, and then transferred to controlled photoscale overlay sheets. The photoscale maps were reduced photographically to 1:250,000 scale, and the maps redrafted at this scale for the preliminary edition.

PHYSIOGRAPHY

Drainage in the area is controlled by a gentle westerly grade from elevations of about 1,850 feet on the eastern margin of the Sheet area, down to 1,200 feet at Lake Mackay itself. The only stream of any consequence in the area is Ethel Creek, which rises in granite



HELICOPTER TRAVERSE LINES AND GEOLOGICAL OBSERVATION POINTS.

Fig. 2

To accompany Record 1969/89

Scale

5 0 5 10 15 20

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country in the north-western corner of the Mount Doreen Sheet area, and which eventually floods out into the sand plains to the west.

The area has been divided into the following physiographic divisions:

A. Salinas

The main salt lake in the area, after which the sheet is named, is Lake Mackay, covering an area of approximately 1,330 square miles, of which only the eastern margin of some 250 square miles lies within the Lake Mackay 1:250,000 Sheet area.

The lake itself occupies the centre of the local system of internal drainage. Numerous small islands of sand occur in its eastern half, but because of the extreme summer temperatures and low rainfall, no surface water is seen except after flash flooding. The lake bed is devoid of vegetation.

B. Plains of travertine with sparse sand cover

This region is of low relief, the soil is shallow and typically contains large concretionary masses and smaller nodules of travertine. It supports a sparse vegetation of samphire (Arthrocnemum) and saltbush (Atriplex vesicaria), the former commonly occurring in the small channels which fringe the lake margins and in some of the smaller salt pans.

In the southern half of the area there is an east-west line of small salt pans, clay pans and travertine plains which may be the isolated remnants of a former drainage system.

C. Aeolian sand

Sand dunes and plains cover the greater part of the Lake Mackay Sheet area. The dunes reach a height of about 30 feet and a length of 30 miles; their general trend is east-west. They are longitudinal dunes formed under a bidirectional wind regime - the "south-easterly trades" which predominate in the area in the winter months and the second important wind direction from the east.

At the present time the dunes are stable, but some mobile sand is present on the dune crests. Although the dunes run parallel, convergences and divergences are common, forming at times a braided pattern. The dunes support a sparse spinifex cover with occasional shrubs and rare eucalypts.

D. Quartzite ridges and mesas

This division includes a number of low quartzite mesas and ridges in the southern part of the Sheet area from the western end of the Campbell Range to Mount Morris. Also included are two isolated hilly areas in the north-west - the Sandford Cliffs and McEwin Hills. Relief is rather low, being at its greatest about 400 feet above the level of the surrounding plain.

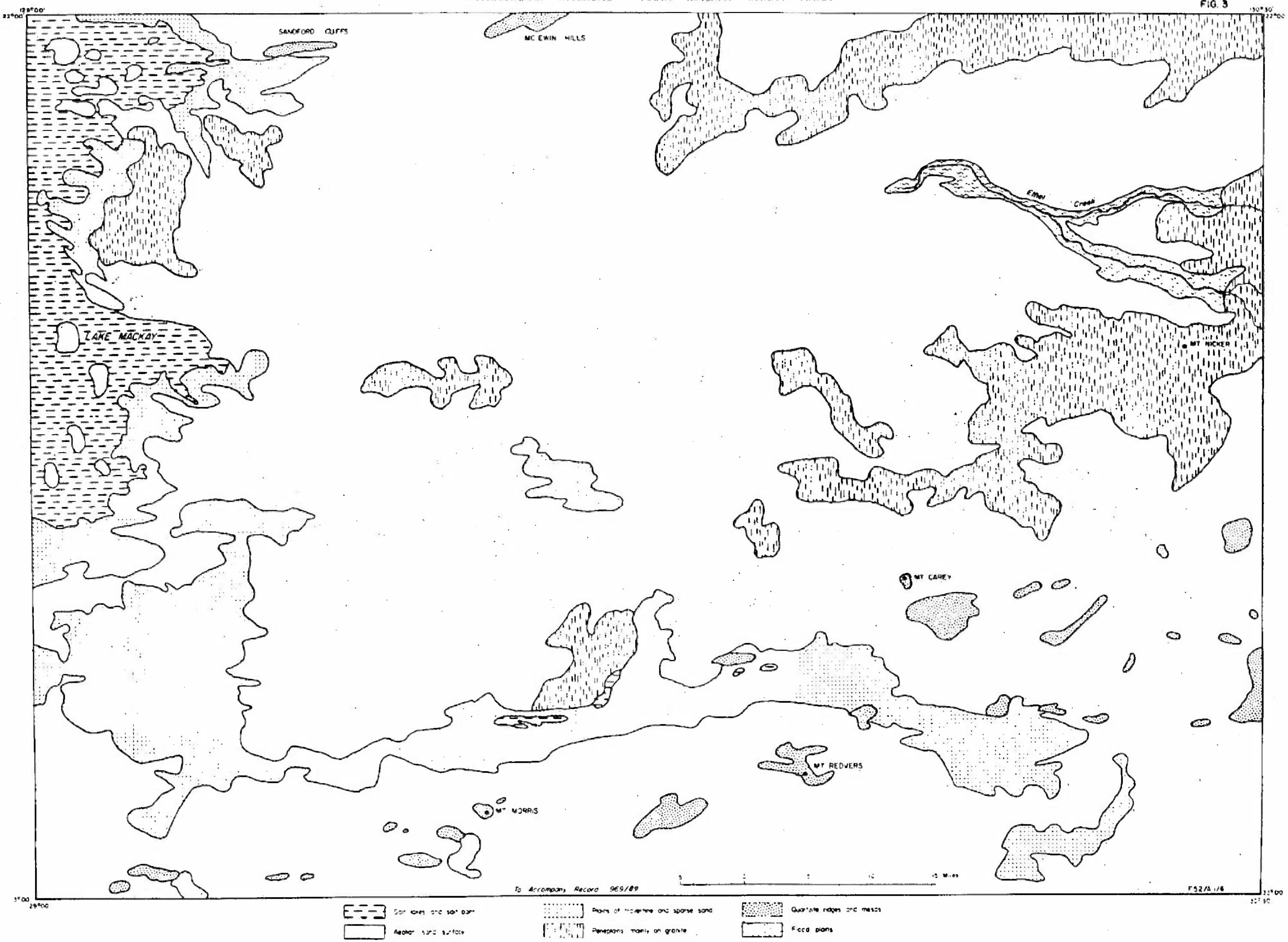
Piedmont angle on the mesas is steep, the cappings being quartzite overlying granites and schists. These basement rocks are intensely weathered in the foot-scarp zone, whilst a short distance away from the scarp these same rocks are usually much less altered. Because of this concentrated foot-scarp weathering, steep scarps are commonly developed. The scarp slopes are usually barren, although the low ridges and mesas support short grasses, acacias and rare eucalypts.

E. Lateritic plains mainly on granite

This division occurs in several places on the Sheet area, and is particularly well developed in the north where laterite forms low mottled reddish-brown mesas 30 to 40 feet high on deeply weathered granite (Fig. 9). The scarp faces on the mesas are usually cavernous, and vertical solution channels several feet in diameter are present in the lateritic profile.

PHYIOGRAPHIC DIVISIONS — LAKE MACKAY SHEET AREA

FIG. 3



Near the margin of the lake, the laterite is present as low mounds of dark brown to almost black ironstone pisolites, the relief in this area being only a few feet. Dark lateritic gravel plains are also common in the north-west sector of the Sheet area. The vegetation cover is scant short grasses and scattered low shrubs.

The division also includes gently undulating country with a thick cover of mulga, which is confined largely to the eastern and southern parts of the area. Here schists intruded by quartz dykes crop out as hogbacks with an overall north-easterly trend. The dykes support no vegetation, although the schists in places support thick grass. Low unweathered granite tors in the area are bare but are surrounded by kerosene grass plains. After rain small soaks and marshy areas may be found at the bases of these rounded tors.

PREVIOUS INVESTIGATIONS

The first explorer to enter the area was Colonel P. Egerton Warburton who in 1873 led an exploratory expedition from Alice Springs to Roebourne in northern Western Australia (Warburton, 1875). He travelled west from Annie Spring (on the Mount Doreen 1:250,000 Sheet area), crossed the Lake Mackay Sheet area, and continued a few miles into Western Australia. Lack of water forced him to backtrack to Annie Spring, where he turned north to Ethel Creek and thence to Mount Farewell on the Highland Rocks 1:250,000 Sheet area. His only geological observations were 'low granite hills' west of Annie Spring, and 'low hills of conglomerate' (McEwin Hills) on the northern margin of the area.

In 1902, Maurice and Murray crossed the continent from Fowler's Bay in South Australia to the Cambridge Gulf (Maurice and Murray, 1904). They travelled north from Mount Russell (Mount Rennie 1:250,000 Sheet area) and crossed the south-eastern corner of the Lake Mackay Sheet area where they observed 'quartzite and quartzose sandstone' (the Vaughan Springs Quartzite) and 'brown iron ore and vein quartz' on the western slopes of Mount Cockburn.

Carnegie (1898) first suspected the presence of a large lake in the area when he saw signs of it in a mirage. In 1925, Wyckham (ref. not seen) reported a large freshwater lake in the same area as Carnegie, but was discredited in the belief that he had mis-identified Lake Macdonald - much further to the south.

A number of aerial traverses over the area were made in 1930 by the Mackay Aerial Survey Expedition, and a prominent salt lake was named after the expedition leader, Donald Mackay. A reconnaissance map was later compiled by Commander Bennett, a member of the expedition (Mackay, 1934).

Terry (1934), in describing an expedition undertaken in 1932 and 1933, found Wyckham's tracks near Lake Mackay which was then dry, and substantiated Wyckham's claim. Terry sampled Lake Mackay sediments (see p. 25), and also reported 'large lateritic plains' in its vicinity. His travels also took him to Dry Bluff and Mount Carey in the south, and from McEwin Hills to Sandford Cliffs and just beyond the Western Australian border to a 'high narrow sandstone range' which he named after Alec Ross, the last survivor of the exploration parties of Giles.

In 1937 Sir Herbert Gepp and P.B. Nye (B.M.R. File A/378), whilst conducting an inspection flight of the mineral resources of northern Australia, were forced down en route from Tennant Creek to Tanami. They landed near the eastern shore of Lake Mackay at a small lake which they named Lake Rapide, and were rescued a week later by a land party which set out from The Granites.

The region was not systematically mapped until the Division of National Mapping, Department of National Development, undertook a geodetic survey of the Lake Mackay Sheet area in 1959.

In 1964, J.C. Rivereau of the Institut Française du Petrole made a photogeological study of the Lake Mackay, Mount Doreen and Napperby 1:250,000 Sheet areas in an overall study of the Ngalia Basin (Rivereau, 1965).

In 1966, the British Services Expedition spent some time in the area; geological observations were made by Squadron Leader Batstone, the party geologist. At the time of writing, the results of these investigations were not available.

A helicopter gravity survey covering the Lake Mackay Sheet area was made in 1967 by Rotorwork Pty Limited under contract to the Bureau of Mineral Resources. The results of this gravity survey are reported in Whitworth (1969, in prep.).

The first comprehensive investigation of the sediments of the Ngalia Basin was undertaken for the Bureau of Mineral Resources by Cook (1963), who mapped the Yuendumu Native Reserve and who later made reconnaissance surveys of the Mount Doreen and ~~Napperby~~ Sheet areas in 1964 (Cook and Scott, 1967). The geology and petrology of the central part of the Ngalia Basin was described by Wells, Evans and Nicholas (1968) in an unpublished record. The geology of the eastern end of the Ngalia Basin is described in Evans and Glikson (1969). Selected rock samples from the area have been described by Kelley (1968), and Whithead and Haslett (1968).

STRATIGRAPHY

General

The stratigraphy of the Lake Mackay Sheet area comprises the Precambrian basement rocks which make up the floor and margins of the Ngalia Basin, and Proterozoic basement-derived sediments that form the westernmost extension of the basin.

Only one sedimentary formation, the Vaughan Springs Quartzite and the included Treuer Member crops out on this Sheet area, and is of Proterozoic age. The Vaughan Springs Quartzite lies everywhere unconformably upon Precambrian metasediments and granite.

Exposure is generally poor; the maximum exposed thickness of the Vaughan Springs Quartzite and included Treuer Member is of the order of 9,000 feet. A seismic survey along Waite Creek on the western edge of the adjoining Mount Doreen Sheet area (Jones, 1969, in prep.) indicated a thickness of at least 16,000 feet of Proterozoic and Palaeozoic sediments in the deepest part of the basin. A cross-section indicated that the sediments appeared to be thickening to the north-west towards the Lake Mackay Sheet area.

Unnamed sandstones at two other localities in the far north of the area bear some similarities to the Vaughan Springs Quartzite and also the "Upper" Proterozoic Gardiner Beds exposed at the north-eastern margin of the Canning Basin in Western Australia.

The Precambrian crystalline basement rocks and metasediments remain unnamed; poor exposure and widely separated outcrops make it difficult to draw conclusions as to the possible spatial and temporal relationships of these older rocks. There is an apparent general decrease in metamorphic grade in these rocks from the north-east to the south-west of the area.

PRECAMBRIAN

General

Sporadic outcrops of granite, granite-gneiss, low-grade schists, and meta-quartzites occur throughout the Lake Mackay Sheet area. The most common metamorphic rocks are quartz-muscovite schists, which may contain biotite, chlorite, tourmaline and zircon. An isolated occurrence of sillimanite-garnet and cordierite-bearing gneiss has been recorded from the north-eastern part of the Lake Mackay Sheet area. The occurrence of garnet in meta-granites cropping out northwest of the centre of the Sheet area probably indicates a higher grade metamorphism here than in the south of the area. The prevalence of low-grade metamorphic rocks correlates with the decline in metamorphic grade from east to west in the adjacent Mount Doreen Sheet area. This variation, coupled with the occurrence of high-grade rocks in the north of the Lake

TABLE I - STRATIGRAPHY OF THE LAKE MACKAY SHEET AREA, NORTHERN TERRITORY

	AGE	FORMATION	MAP SYMBOL	MAXIMUM THICKNESS	TOPOGRAPHIC EXPRESSION	LITHOLOGY	REMARKS
CAINOZOIC	QUATERNARY		Qa		River bed, flood plain and flood out	Alluvium	
			Qc		Talus and detrital slopes	Colluvium	
			Qs		Sand plains and dunes	Sand	
			Qr		Plains	Red soil and alluvium	
			Ql		Low mounds, hummocky terrain	Travertine	
			Qe		Salt pan margins, drainage channels	Sand, evaporites, travertine	
			Qt		Salt lakes and salt pans	Evaporites	
			Cz		Mesas and buttes of low relief and low rounded hills	Silcrete and ferruginized rock	
PRECAMBRIAN	PROTEROZOIC	VAUGHAN SPRINGS QUARTZITE	Buv	9,000 ±	Prominent resistant cuestas and mesas; low ridges	Tough, white, pink and grey quartzite, thick bedded with small cross-beds common. Occasional local basal pebble conglomerates	
		TREUER MEMBER	But	6,000 ±	Low weathered ridges and rubble covered flats	Whitish-grey, thin bedded silicified sandstone, glauconitic in part; chocolate brown, yellow, white and purplish red siltstones and shales. Deeply weathered	Member occurs in lower half of the Vaughan Springs Quartzite
		Unnamed sandstones at Sandford Cliffs	Bu	800 ±	Low sandstone cliffs	White to pink cross-bedded medium grained thin bedded ortho-quartzite	
		McEwin Hills	Bu	1000 ±	Low hills	Reddish brown thin bedded kaolinitic micaceous cross-bedded sandstone	
				UNCONFORMITY			
PRECAMBRIAN			pЄ		Low hills and rises	Undifferentiated igneous and metamorphic rocks	
			pЄd		Small ridges, rarely greater than 2 feet in width	Virtually unaltered dolerite; uralitized and sheared dolerite	Dykes cut granites and schists
			pЄg		Low rounded tors	Porphyritic (microcline) granite: garnet-bearing meta-granite	Associated with aplitic and coarse pegmatitic dykes, quartz dykes
			pЄn		Low isolated hills	Gneiss, garnet-cordierite-sillimanite gneiss	
			pЄm		Low rounded hills and rises	Undifferentiated schist, quartzite and amphibolite	
			pЄq		Low ridges in schist	White to yellow metaquartzite, cross-bedded and ripple marked; sericite quartzite	Interbedded with mica quartz schist
			pЄs		Low rounded hills and rises	Mica-quartz schists, phyllites, hornfels	Cut by numerous large near vertical quartz dykes. Tourmaline common

Mackay Sheet area, indicates either a general decline in metamorphic grade from northeast to southwest or two suites of metamorphic rocks. This pattern is similar to that observed in the Napperby Sheet area.

The metamorphic rocks are intruded by granitic gneiss, granite, dolerite and meta-dolerite dykes. Microscopically, the igneous and metamorphic rocks of the Lake Mackay Sheet area show close similarities to the basement rock suites of the Napperby and Mount Doreen Sheet areas. Although little is known at present about the field relationships, the petrographic similarity, coupled with the geographic proximity of the basement on the Lake Mackay Sheet area to that of the Mount Doreen and Napperby Sheet areas, suggests that the basement suites of these areas can be regarded as part of one and the same orogenic system.

Quartz-muscovite schist

The commonest basement rock type by far on the Lake Mackay Sheet area is quartz-muscovite schist; phyllites have been recorded from Mount Morris. The average composition of these schists is 60-70% quartz and 20-30% muscovite. The quartz is recrystallized to give a tight mosaic of grains which in some sections tend to be fused together to form larger grains. There is usually elongation of the quartz grains in a direction parallel to the schistosity of the rock. The muscovite occurs in discrete crystals and irregular layers which may be crenulated.

The quartz-muscovite schists cropping out in the north-east contain an additional 5-15% of biotite and traces of potash feldspar. In nearly all specimens of this rock type there are minor amounts of tourmaline and rounded zircon grains of sedimentary origin.

Differences between specimens from widely scattered localities on the Lake Mackay Sheet area are very minor - overall composition is within the limits set out above. The schists are the result of low-grade regional metamorphism (greenschist facies) of pelitic and quartzose pelitic sediments of varying composition.

Hornfels

Several specimens of hornfels are recorded from the south-eastern corner of the Sheet area. They form a narrow aureole between granite and quartz-muscovite schist, and are dark, fine to very fine grained rocks with either very weak or no schistosity developed. Their composition is 15-20% quartz in discrete grains, 25-30% biotite in scattered aggregates or else partly enclosing muscovite, and muscovite or sericite which makes up the bulk of the rock. Tourmaline, zircon and apatite appear in trace quantities, and in some cases the tourmaline appears to be authigenic. The rock has been formed by the contact metamorphism of quartzose pelitic sediments.

Quartzite and feldspathic quartzite

Quartzites are commonly interbedded with the quartz-muscovite schists, usually as beds 1 to 2 inches thick, but in places up to 20 feet thick (localities LM126, LM142). Relict cross-stratification is preserved in these thicker beds, and at one locality (LM142) current ripple markings have been recorded.

Specimens from various localities differ in purity, but fall mainly into three compositional types. These are composed of 98-100% quartz; 85-95% quartz and 10-15% sericite; and feldspathic quartzite with 50-60% quartz, 5-15% feldspar with the remainder of the rock being sericite, some muscovite and clay minerals. Only one specimen examined could be described as a meta-arkose, and contained 60-70% quartz, 30-40% plagioclase, orthoclase and rare microcline together with very minor biotite and chlorite.

Generally the quartz grains are strained and show undulose extinction; pressure solution has also produced interpenetration and welding together of grains in some of the specimens. In many cases iron oxides are present at the grain boundaries. Rare well rounded grains of zircon and tourmaline are usually present in trace quantities, and in a few examples silica has been leached along grain boundaries freeing grains and rendering the rock friable. These rocks have undergone the same low-grade regional metamorphism that has affected the widespread quartz-muscovite basement schists.

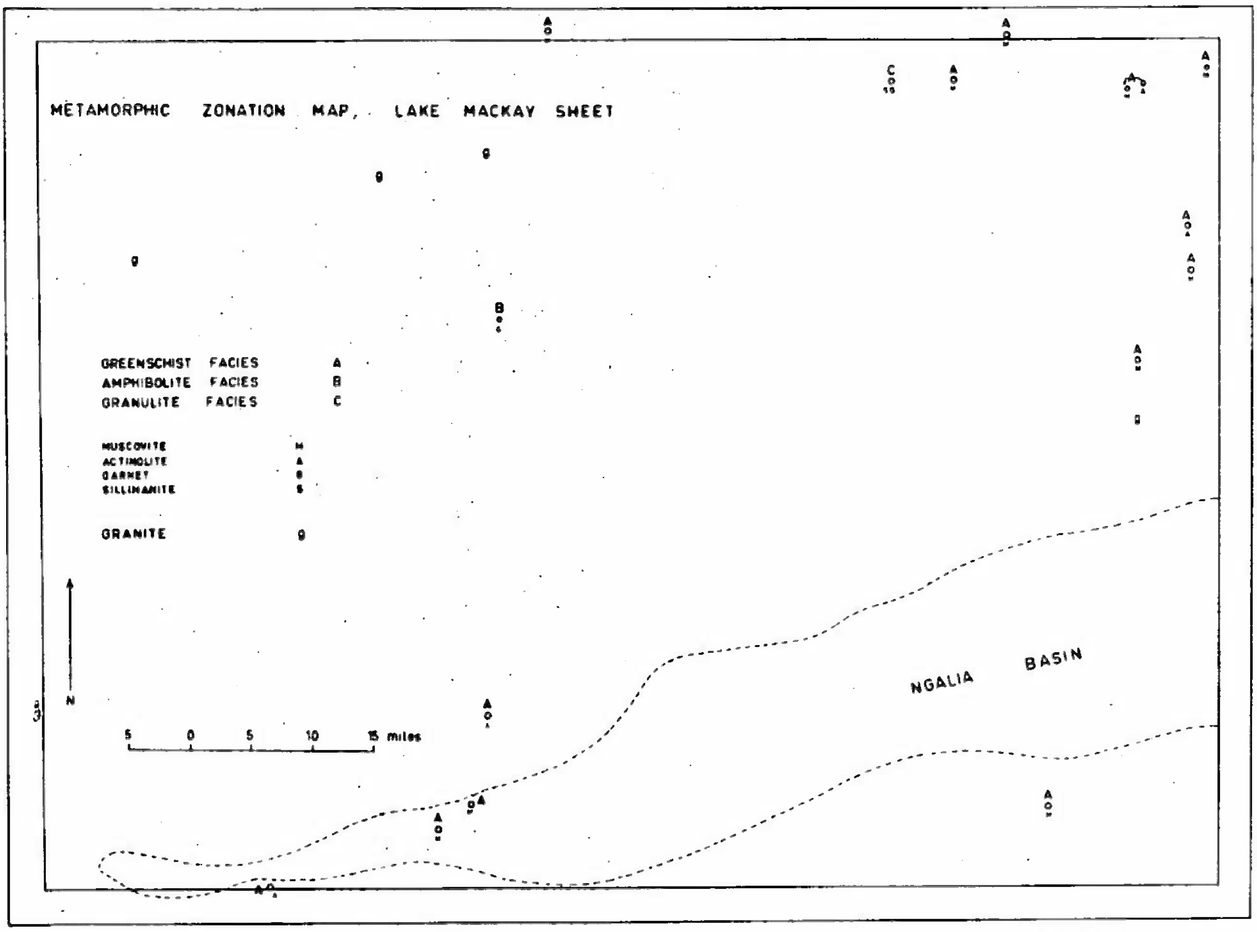


Fig 4 To accompany Record 1969/89 F52/A11/4

Granite

Distribution of granitic rock masses is illustrated in Figure 4. They are mainly porphyritic granites with large phenocrysts of microcline-perthite comprising about 40-50% of the rock. The groundmass of 20-40% quartz is intergrown with potash feldspar and rare albitic plagioclase. The 5-15% biotite in the groundmass is usually slightly deformed and contains inclusions of apatite and zircon; grains of very rare sphene and metamict allanite have been observed in some of the specimens.

Many of these granites have undergone metasomatic changes as evidenced by the presence of up to 10% of members of the epidote group (mainly zoisite and clinozoisite) replacing plagioclase. The presence of strained and sutured quartz grains and of deformed biotite in many of the granites indicates varying degrees of tectonic stress.

Many pegmatitic and aplitic dykes intrude these granites. These late stage differentiates are extremely coarse grained, with large euhedral crystals of feldspar up to 1 foot in length, well developed books of muscovite and euhedral tourmaline crystals. The fine grained aplites are largely perthitic potash feldspar and quartz.

Gneiss and meta-granite

Outcrops of gneiss of high metamorphic grade are confined to the north-eastern corner of the Lake Mackay Sheet area. The major components of this strongly foliated cordierite-garnet-sillimanite gneiss are quartz and microcline together making up to 80% of the total rock, euhedral groups of sillimanite associated with biotite and cordierite, and almandine garnet forming open clots of poikiloblastic grains elongated in the direction of the foliation. This granulite facies gneiss is thought to have probably been derived by regional metamorphism from an original granitic rock type.

Garnet-bearing meta-granites occur to the north-west of the centre of the Lake Mackay Sheet area, and to the west near the margin of Lake Mackay. This rock type has distinct foliation, the texture is granoblastic, and consists of 50% pinkish-orange microcline and about 20% oligoclase. The rock contains 20% quartz which is myrmekitically intergrown with the oligoclase. About 5% of biotite is present, and garnet of approximate composition $Pyr_{70}Al_{30}$ occurs in widely separated dark red clots. The rock is granitic in composition, and has experienced high grade metamorphism. At one locality it is sheared.

Dolerite and meta-dolerite

The emplacement of these basic intrusions, rarely greater than 2 feet in width in the Precambrian terrain, appears to be the last igneous event to take place in the basement complex before the extensive erosion and hiatus that preceeded the deposition of the blanket sands of the Proterozoic Vaughan Springs Quartzite.

Many of these dolerite dykes have undergone low-grade metamorphism, are relatively unweathered, and are dark grey-green in hand specimen. Texture is usually relict ophitic, with prismatic labradorite or andesine in random orientation surrounded by patches of hornblende and some remnants of pyroxene. Grains of ilmenite scattered throughout the rock are partly replaced by leucoxene or sphene. In some specimens the plagioclase is altered in part to sericite or epidote. It is likely that the alteration in these dolerite dykes is wholly deuteric.

Relationships, structure and metamorphism

Because of the paucity of outcrops and poor exposure of the metamorphic and igneous basement suite, it is not possible to present a complete picture of the history and structural background of the area. A tentative sequence of events based upon evidence from the Lake Mackay Sheet area and the north-west corner of the Mount Doreen Sheet area is as follows: first the deposition of a thick sequence of pelitic and quartzose-pelitic sediments with minor cross-bedded and ripple-marked orthoquartzite indicating a relatively shallow-water environment of deposition. This has been followed by folding on north-east trending axes and the emplacement of granite bodies. The area has undergone regional metamorphism, with low greenschist grade in the south-west and amphibolite grade in the centre of the area. The last igneous event before erosion and peneplanation appears to be the emplacement of numerous small dolerite dykes.

Granulite facies gneiss in the north-east may be a relict area of Archaean rocks from which the Precambrian sediments were originally derived; alternatively they may be orthogneisses whose high metamorphic grade is due only to an overall increase in metamorphic grade to the north-east and related in time to the lower grades of metamorphism in the south-west.

The overall structural pattern of the schists is relatively simple; it is dominated by a system of steeply dipping, tight, north-west trending folds. Where schist and quartzite are observed together, the foliation in the schist is parallel to the bedding of the quartzite.

Granite in the southern part of the area is for the most part unmetamorphosed, garnet-bearing meta-granite occurs near the centre of the Sheet area, and, it is thought, orthogneiss in the north-eastern sector.

Large massive quartz dykes symptomatic of regional tension also have an overall north-east trend, and intrude the schists and granite.

PROTEROZOIC

Vaughan Springs Quartzite

The Vaughan Springs Quartzite is a massive to thick bedded orthoquartzite. It is cross-stratified, ripple-marked, tough and compact, although in places it may be friable with only a thin skin of surface silicification. The quartzite is pink, yellow-grey and white; where it is friable it is reddish brown. Thin localized basal pebble conglomerates are present in places, with phenoclasts of vein quartz derived from the underlying Precambrian basement rocks.

The Vaughan Springs Quartzite was first observed on the adjoining Mount Doreen Sheet area by Tindale (1933) who referred to it as the 'Hann Range-Uldirra Hill-Crown Hill series' of quartzites and conglomerates. Cook (1963) made no attempt to name the unit but designated it as 'Unit A'; Wells et al. (1968) were the first to define and name the formation.

The type section (EX-11) is located to the west of the Vaughan Springs syncline near Mount Doreen Homestead, and here about 5,400 feet of Vaughan Springs Quartzite crops out.

In the western termination of the Ngalia Basin on the Lake Mackay Sheet area, the distribution of the Vaughan Springs Quartzite is sporadic and limited to the southern half of the Sheet area (see Plate 1). No contact is known of any of the younger units known elsewhere in the Ngalia Basin sequence with the Vaughan Springs Quartzite on the Lake Mackay Sheet area.

Strong silicification has made the formation highly resistant to weathering; the quartzite crops out as cuestas (Mount Cockburn), mesas (Mount Morris, Dry Bluff and Mount Redvers) and in very subdued topography as low rises that extend to the south-west corner of the Sheet area.

The maximum thickness of the formation on the Lake Mackay Sheet area is in an east plunging syncline 4 miles south-east of Mount Carey (Fig. 6). The total thickness here of ~~15~~ 9,000 feet has been estimated from aerial photographs, and is made up of ~~9~~ 3,000 feet of Vaughan Springs Quartzite and 6,000 feet of the included Treuer Member.

The Vaughan Springs Quartzite lies with major unconformity upon Precambrian schist and granite; the top of the formation is either eroded or obscured by Quaternary deposits.

Fig. 5

Mount Morris - Vaughan Springs Quartzite unconformably overlying Precambrian schists.

GA/731

Fig. 6

Treuer Member (light tone - top of picture, and Vaughan Springs Quartzite (lower half of picture) in syncline 4 miles south-east of Mount Carey.

GA/734

At Mount Redvers, the Vaughan Springs Quartzite unconformably overlies deeply weathered granite which is poorly exposed on the steep scree slopes. The formation consists of a medium grained, pale pinkish-buff quartzite with sub-rounded quartz grains; numerous poorly sorted pebble layers are present near the base. The phenoclasts are mainly vuggy vein quartz, with a few isolated pebbles 6 inches across. The quartzite contains 10-15% sericite and some detrital tourmaline and zircon grains. Medium-scale cross-stratification is common.

At Mount Morris (Fig. 5) the orthoquartzite is essentially flat lying and is fairly well sorted, coarse grained, and with some thin, medium-grained, well sorted interbeds. About 1-2% sericite is present; the rock has been cemented by partial interpenetration and welding of grains by pressure solution, and partially by the recrystallization of secondary quartz. Medium-angle cross-bedding is common, and a basal conglomerate composed of grey chert pebbles 2-3 inches across is present.

The age of the Vaughan Springs Quartzite is regarded as Proterozoic. Its gross lithology and stratigraphic position is similar to the Heavitree Quartzite of the Amadeus Basin which unconformably overlies Precambrian basement rocks and which is separated from fossiliferous Lower Cambrian dolomite by a number of Proterozoic formations (Wells et al. 1967).

Minor basal conglomerates and interbedded siltstones are present in the Heavitree Quartzite, e.g. Ellery Creek (Pritchard & Quinlan, 1962) apparently however the siltstone is dissimilar to the Treuer Member of the Vaughan Springs Quartzite.

On the Mount Doreen Sheet area to the west of the Vaughan Springs Syncline, the Vaughan Springs Quartzite is unconformably overlain by the Mount Doreen Formation - a glacial sequence with close similarities to the Proterozoic Olympic Member of the Pertatataka Formation of the Amadeus Basin.

The Vaughan Springs Quartzite is the oldest sedimentary formation in the Ngalia Basin; no fossils have been found.

Treuer Member

The Treuer Member occurs in the Vaughan Springs Quartzite, and is a sequence of fine grained, thin-bedded clastic rocks; it consists mainly of yellow, purplish-red and white shales and siltstones with interbedded thin, partly glauconitic, laminated sandstones.

The Treuer Member was first described by Wells et al. (1968) from the Mount Doreen Sheet area where it crops out intermittently from south of Mount Davenport to the eastern end of the Treuer Range. The type section (NX-5) lies about 12½ miles south-east of Mount Davenport where the Member is 1,700 feet thick, and occurs about 300 feet above the base of the Vaughan Springs Quartzite, which is in faulted contact with basement granite.

On the Lake Mackay Sheet area, only two exposures of the Treuer Member are known - one about 8 miles west of Waite Creek near the edge of the Sheet area, the other about 4 miles south-east of Mount Carey. In both places the Member crops out as low weathered ridges of the more resistant interbedded sandstones, and as rubble covered flats of deeply weathered shales and siltstones.

There is considerable thickening toward the west from the type section where it is 1,700 feet thick, to a locality near Mount Carey on the Lake Mackay Sheet area where a thickness of about 6,000 feet has been estimated from aerial photographs. At this locality the Vaughan Springs Quartzite occurs in an easterly plunging syncline whose northerly limb is in faulted contact with basement granite. The Treuer Member occurs about 1,500 feet above the base of the formation and has an average dip of about 30° to the north-east on the southern limb of the syncline.

Fig. 7

Intraformational breccia in Treuer Member, 4 miles south-east of Mount Carey.

GA/1588

Fig. 8

Intraformational breccia in Treuer Member, 4 miles south-east of Mount Carey.

GA/1582

At the above locality (LM32) a good example of an intraformational breccia is exposed (Figs 7, 8). This strand line feature is thought to have resulted from the shoaling and temporary withdrawal of the sea, the exposed sediments becoming dessicated with subsequent formation of mud cracks (Pettijohn, 1957). Upon the re-advance of the sea, further muddy sediment was laid down; presumably there was sufficient current action to disrupt the mud-cracked bottom sediment, but not sufficient to produce noticable shingling of the disrupted laminae. In the top right of Figure 7 several small laminae are overturned; most of the indurated laminae are slightly less than 1 inch in thickness.

At this locality the sequence is yellowish, thin-bedded sandstone overlain by purplish-red, red-brown, yellow-brown and yellow fine grained siltstones. Interbedded chert a few inches thick occurs near the base of the intraformational breccia which is in a bed about 2 feet thick of purplish-red siltstone. Scattered angular fragments of chert occur at the top of the bed. The exposure of siltstone and minor interbeds is small and about 25 feet thick.

About 2 miles further to the south-east the Treuer Member overlies friable red-brown, tough, siliceous sandstone of the Vaughan Springs Quartzite. The member is poorly exposed and crops out as a weathered, thin-bedded, creamy micaceous siltstone.

At locality LM51, about 8 miles west of Waite Creek, the northern end of the outcrop of Treuer Member is overturned, and here a thin bedded, glauconitic, highly siliceous medium grained sandstone occurs. This rock shows a very mature sedimentary texture; the once well rounded quartz grains show extensive overgrowths of authigenic quartz, and the glauconite occurs as elongated well rounded pellets. Thin bedded sandstones showing graded bedding and cross-stratification are common; they are interbedded with fine grained siltstones.

An example of arkosic sandstone from this locality contains 40-45% of well rounded, fine grained potash feldspar, much of which is weathered to clay. The remainder of the rock consists of sub-rounded to rounded quartz grains with authigenic quartz overgrowths; traces of detrital zircon and iron oxides are present.

The presence of glauconitic sandstones in the Treuer Member indicates a shallow depth of deposition and slow sedimentation; glauconite is thought to be deposited under weakly oxidizing conditions as are also red and purple-red shales and siltstones. Ripple markings and intraformational breccias are also an indication of sedimentation in shallow waters.

No fossils have been detected in the Treuer Member; its age is Proterozoic.

Unnamed sandstones at Sandford Cliffs and McEwin Hills

Two isolated sandstone outcrops lie on the northern margin of the Lake Mackay Sheet area; the Sandford Cliffs about 6 miles to the east of the margin of Lake Mackay (Fig. 10), and the McEwin Hills (Fig. 11) near the top centre of the Sheet area and overlapping onto the Highland Rocks Sheet area.

The Sandford Cliffs rise only about 100 feet above the desert floor, and the range is about 4 miles long. The sediments are at least 800 feet thick, and occur in a west-plunging, tightly folded syncline whose axis trends almost east-west. Dips of up to 75° have been measured on the flanks of the fold. No contacts between the sediments and the basement rocks have been observed.

The sandstone is poorly bedded, pale brown to red-brown, and in the main is highly silicified on the surface although it is friable and porous in places. In thin section the rock is very poorly sorted, consisting of coarse sub-angular to sub-rounded quartz grains set in a matrix of medium to very fine, almost silt grade, angular quartz fragments. Most of the quartz grains show no undulose extinction, and

Fig. 9

Laterite mesas on Precambrian metamorphic rocks, about 30 miles east of McEwin Hills.

GA/1600

Fig. 10

Unnamed Proterozoic sandstone at Sandford Cliffs.

GA/1599

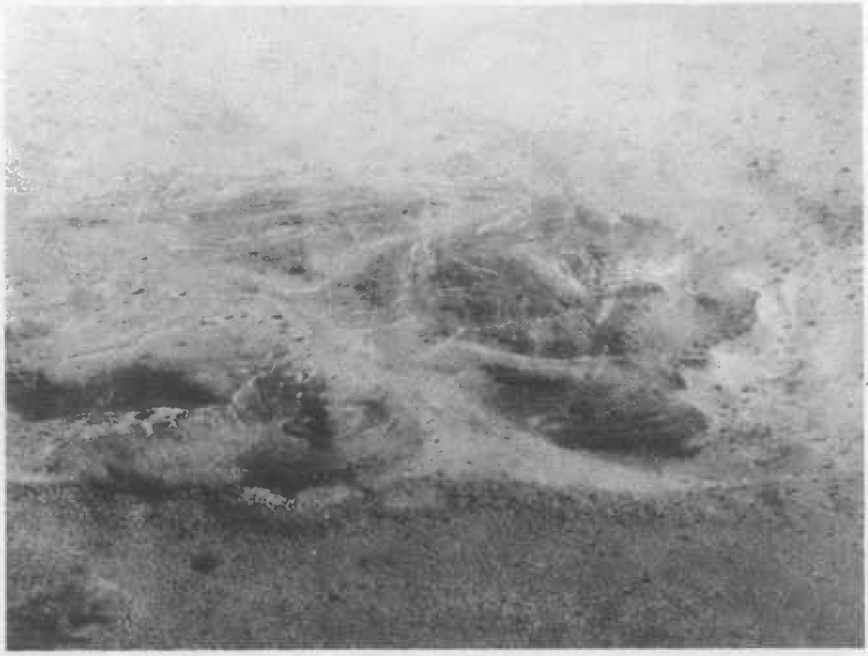


Fig. 11

McEwin Hills - Proterozoic sandstones lying unconformably on Precambrian schist.

GA/1549

Fig. 12

Cross-bedding in Proterozoic sandstone at McEwin Hills.

GA/1610

no quartz overgrowths have been observed. Many of the larger grains show abundant vacuoles, some of which contain gas bubbles. There are numerous small voids in the rock, and a few scattered patches of clayey material. From the poor degree of rounding and sorting and other evidence listed above, a better term for this rock would be a protoquartzite.

Current ripple-marking is present. Numerous small quartz stringers occur in the sandstone at the eastern end of the outcrop. No fossils have been found at the Sandford Cliffs.

The sandstone of the McEwin Hills rises to about 180 feet above the sand plain, and unconformably overlies Precambrian schists. The sediments occur in a small syncline that plunges to the south-west and are at least 400 feet and possibly as much as 1,000 feet thick.

On the eastern end of the hills, the formation is a friable, medium grained, red-brown, in part richly micaceous sandstone that dips about 15° to the north-west and contains low angle cross-bedding sets up to 4 feet thick (Fig. 12). The lowermost beds here contain fragments of schist ¼ inch across derived from the underlying basement rock.

Some beds contain clay pellets up to ¼ inch in length which have been largely replaced by limonite; much of the interstitial cement of the rock is yellow to dark-brown limonite.

In other places, the sandstone is tough, silicified, medium grained and medium to thin bedded with rare scattered quartz pebbles up to 3 inches across.

At locality LM154, the sandstone appears to be draped over the underlying schists whose surface relief before deposition of the sandstone appears to be of the order of 50 feet.

The nearest outcrops of similar rock type on the Lake Mackay Sheet area are those of the Proterozoic Vaughan Springs Quartzite some 60 miles to the south and east-south-east. However, about 30 miles to the north-west, just inside the Western Australian border, and cropping out extensively on the Stansmore and Lucas 1:250,000 Sheet areas are large outcrops of current-bedded, ripple-marked sandstone of the Gardiner Beds (Casey & Wells, 1964).

Sandstones in the Alec Ross Range on the Webb Sheet area (which adjoins the Lake Mackay Sheet area on its western side) can be correlated with the Gardiner Beds. They are lithologically similar to the Vaughan Springs Quartzite and dissimilar to the sandstones of the Sandford Cliffs and McEwin Hills though they may be of the same age.

The Gardiner Beds have a photo-interpreted thickness of 5,000 feet. They are mainly sandstones which may be either friable and porous or else hard and silicified. Most of the sandstone is well sorted, and may contain thin pebble beds, fine laminated shales and siltstones; pink sandy dolomite is present at Red Cliff Pound on the Stansmore Sheet area. The Gardiner Beds unconformably overlie the Halls Creek Metamorphics and are regarded as 'Upper' Proterozoic in age.

CAINOZOIC

Undifferentiated

Deposits of undifferentiated Cainozoic age occur mainly in the northern half of the Lake Mackay Sheet area, and crop out as horizontal to sub-horizontal duricrust cappings. The sediments are mainly of ferricrete forming deposits 30-40 feet thick, and have been developed mainly on deeply weathered granite and gneiss (Fig. 9). Solution channels in the ferricrete may reach a diameter of 3 feet. In low lying areas, black and very dark brown ironstone pisolites form a cover on low mounds near the eastern and northern margins of Lake Mackay.

Silcrete is in places developed in low lying areas to the south of the Sheet area.

These undifferentiated Cainozoic sediments are the product of a long period of post-Mesozoic erosion and deep weathering.

QUATERNARY

The Quaternary sediments on the Lake Mackay Sheet area include sand, alluvium, colluvium, red soil, evaporites and travertine.

Aeolian sand covers much of the area, forming extensive longitudinal dunes and redistributed sand fields. These dunes and sand plains are largely fossil features, and are now mainly stabilized by vegetation. The dunes are linear, commonly braided, parallel over considerable distances and are symmetrical in section with smooth crests. They are usually less than one mile apart and have a general east-west trend.

Alluvium in the area is limited to the river banks and flood-out of Ethel Creek. Red soils occur in interdune corridors in the south-eastern corner of the Sheet area, and elsewhere mainly on Cainozoic silcrete and ferricrete in the eastern part of the Sheet area. The red soils support a dense cover of mulga which forms groves that usually tend to be aligned along contours.

Colluvium is restricted to areas of sharp relief on the scarp slopes of ridges, and in many places covers the contact between Proterozoic and Precambrian basement rocks.

Quaternary evaporites occur at Lake Mackay, and at a small chain of salt pans in the centre of the southern half of the Sheet area.

Lake Mackay covers an area of approximately 1,330 square miles, although only about 1/5 of its surface lies on the Lake Mackay Sheet area. The surface crust is usually quite dry, although the underlying sediment is moist at shallow depth, and occasionally the lake, or part of it, may be filled after exceptionally heavy rain. The colour of the lake surface is subject to change depending on seasonal conditions; Terry (1934) reported that when first seen, the lake was white on the surface, but of a brownish colour on his second visit a year later. His explanation for this phenomenon is that in a dry season the contained salts are leached to the surface by ascending moisture, which upon evaporation deposits these salts as a white crust. After rain, the salts are re-dissolved and percolate down into the lake-bed sediments, leaving the surface a brownish colour.

The lake sediment is a dark grey-brown water-logged clay, with large (up to 2 inches) well formed gypsum crystals at a depth of about one foot. Halite occurs as a thin surface crust.

Analyses I and II in Table 2 are of the thin surface crust, and material from a depth of 3 inches, from locality LM194, at the north-east corner of Lake Mackay (68660580A, B). Analysis III is of the surface crust from locality LM56, 9 miles north-north-west of Mount Redvers (68660005). The fourth analysis is of material collected by Terry (1934) from an auger hole sample taken over a depth of 43 inches from the north-eastern corner of Lake Mackay.

Travertine occurs around the margins and in the drainage channels of Lake Mackay, and there are extensive developments of travertine across the whole of the southern half of the Sheet area. It is suspected that this latter area marks the site of a large pre-existing drainage channel, and a continuation of this trend of travertine in low lying areas occurs to the east on the south side of the Ngalia Basin on Mount Doreen and Napperby Sheet areas.

TABLE 2

ANALYSIS %

	I	II	III	IV
Water soluble				
Calcium	0.19	3.8	2.15	5.91
Magnesium	0.54	0.09	0.08	
Sodium	35.3	2.85	14.0	1.64
Potassium	0.59	0.16	0.32	0.49
Carbonate	None detected	None detected		
Bicarbonate	"	"		
Chlorine	53.6	3.6	0.74	2.97
Sulphate	4.35	10.7	34.1	14.17
Water insoluble residue	1.88	72.0	43.8	74.82
$CaCO_3$ *	None detected	None detected		
$CaSO_4$ *	0.48	4.5		

* As percentage of residues

The travertine has a hummocky relief, and is thought to have originated by deposition of calcium carbonate from ground water in low lying areas. In a few outcrops, tough, white, massive vuggy chalcedonic silica, about 5 feet thick, occurs in the travertine. Some of the chalcedony and limestone may be of lacustrine origin.

STRUCTURE

Ngalia Basin

The basin is a narrow intracratonic depression in Precambrian igneous and metamorphic rocks, and extends some 290 miles from west to east over the Lake Mackay, Mount Doreen, Napperby and the western edge of the Alcoota 1:250,000 Sheet areas.

The structural history of the basin is best observed on the Mount Doreen Sheet area, and it is here also that the geological history (q.v.) has been obtained. The structural outline of this area is fully discussed by Wells et al. (1968).

In summary, geophysical and geological evidence indicates that the basin is asymmetrical, the sediments of the southern margin dipping gently northwards into the basin, although in some places they have been tilted by block faulting. The northern margin on the other hand is in many places a high angle thrust fault with overturning of the sediments next to the fault line. In the northern part of the basin there is a maximum thickness of about 14,000 feet of sediment. To the north-west of the Vaughan Springs syncline, a seismic reflection survey indicates a possible low angle overthrust with a horizontal displacement of tens of miles of basement rocks over about 16,000 feet of sediment. In places the high angle thrusting has faulted out some of the older formations completely.

At least three minor periods of epeirogeny have affected the sedimentary sequence as reflected by the unconformities present in the central part of the basin. Major diastrophism in the post-Ordovician faulted the northern edge of the basin, and a second period, known as the Mount Eclipse Orogeny occurred in Carboniferous or later times and folded and thrusted the sediments in the northern edge of the basin, in some cases by renewed movement on pre-existing fault planes.

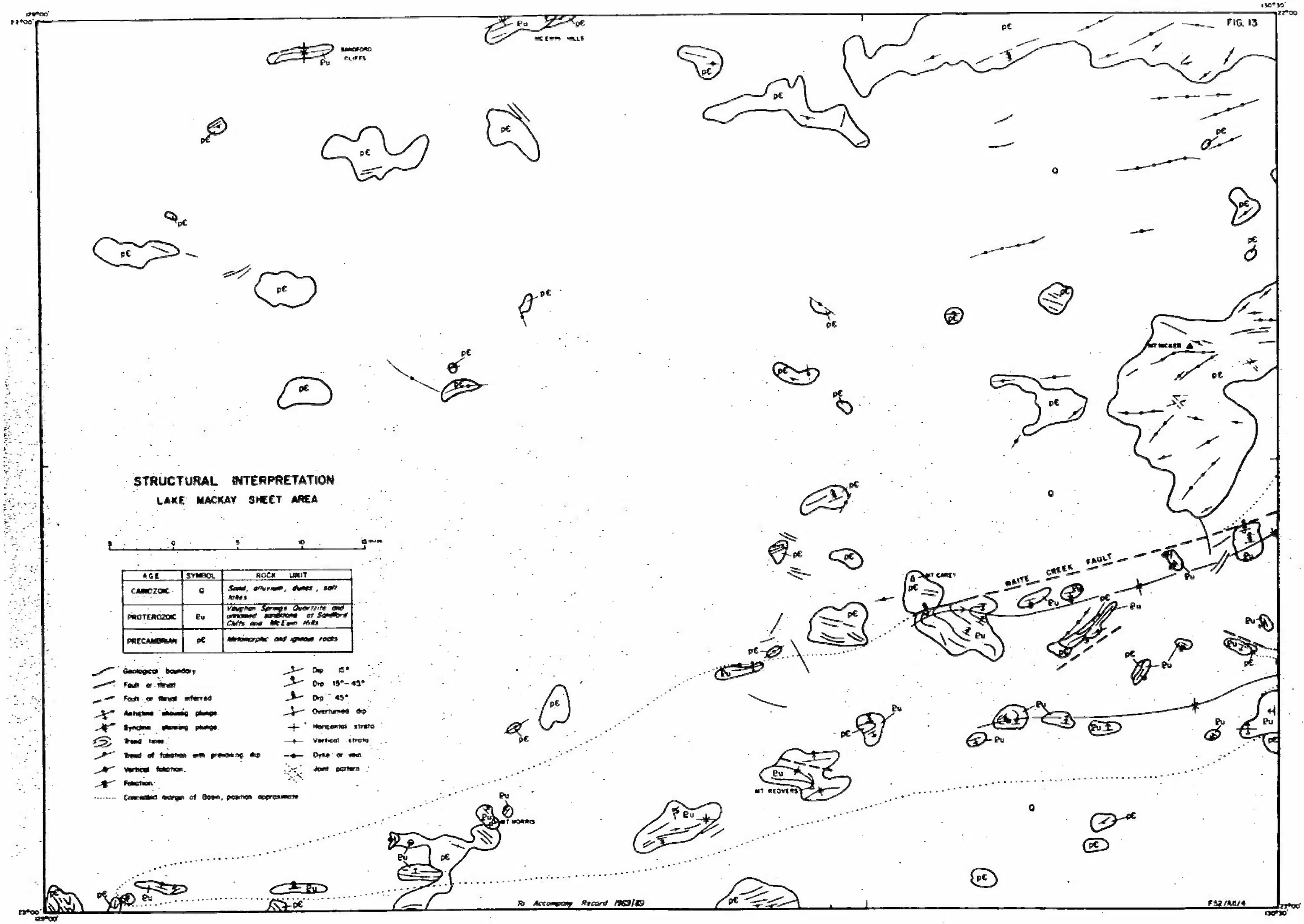


FIG. 13
STRUCTURAL INTERPRETATION
LAKE MACKAY SHEET AREA
SANDFORD CLIFFS
McEWIN HILLS
MT RICKER
MT CAREY
WAITE CREEK FAULT
MT REDVERS
MT MORRIS
5 0 5 10 15 miles
AGE
SYMBOL
ROCK UNIT
CAINOZOIC
Q
Sand, alluvium, dunes, salt lakes
PROTEROZOIC
Pu
Vaughan Springs Quartzite and unnamed sandstone of Sandford Cliffs and McEwin Hills
PRECAMBRIAN
p€
Metamorphic and igneous rocks
Geological boundary
Fault or thrust
Fault or thrust inferred
Anticline showing plunge
Syncline showing plunge
Trend lines
Trend of foliation with prevailing dip
Vertical foliation
Foliation
Concealed margin of Basin, position approximate
Dip 15°
Dip 15°–45°
Dip 45°
Overturned dip
Horizontal strata
Vertical strata
Dyke or vein
Joint pattern
To Accompany Record 1963/89
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Quaternary deposits cover most of the Lake Mackay Sheet area, and the only basinal sequence present is the Proterozoic Vaughan Springs Quartzite, the top of which has been removed by erosion.

From Figure 13, it can be seen that only two east-west synclinal axes of any importance are present. The northern-most of these is bounded by the Waite Creek Fault, and from overturning of beds along the northern synclinal limb it would appear that the basement rocks to the north are on the upthrown side of the fault. A few very minor faults sub-parallel the Waite Creek Fault. Most of the outcrops on the southern margin are flat-lying or gently dip into the basin; a few minor folds are also present.

The fact that the Proterozoic quartzite and sandstones of the Ngalia Basin (Vaughan Springs Quartzite), the Amadeus Basin (Heavitree Quartzite) and north-eastern Canning Basin (Gardiner Beds) are very similar in lithology and all lie with major unconformity on Precambrian basement rocks suggests that they are coeval and once formed part of a very extensive blanket sand laid down before the initiation of individual intracratonic basins after the close of the Proterozoic.

Basement rocks

As the mapping programme was oriented largely to the investigation of the Ngalia Basin rather than to the Precambrian basement complex, only a highly simplified account of the geology and structure of these rocks is possible.

On the Lake Mackay Sheet area basement exposures are very scattered, and all that can be said is that in the low grade metasediments the axes of the isoclinal folds trend north-east with foliation paralleling relict bedding. Massive quartz dykes present particularly in the eastern half of the area also run parallel to the fold axes.

Geophysical surveys.

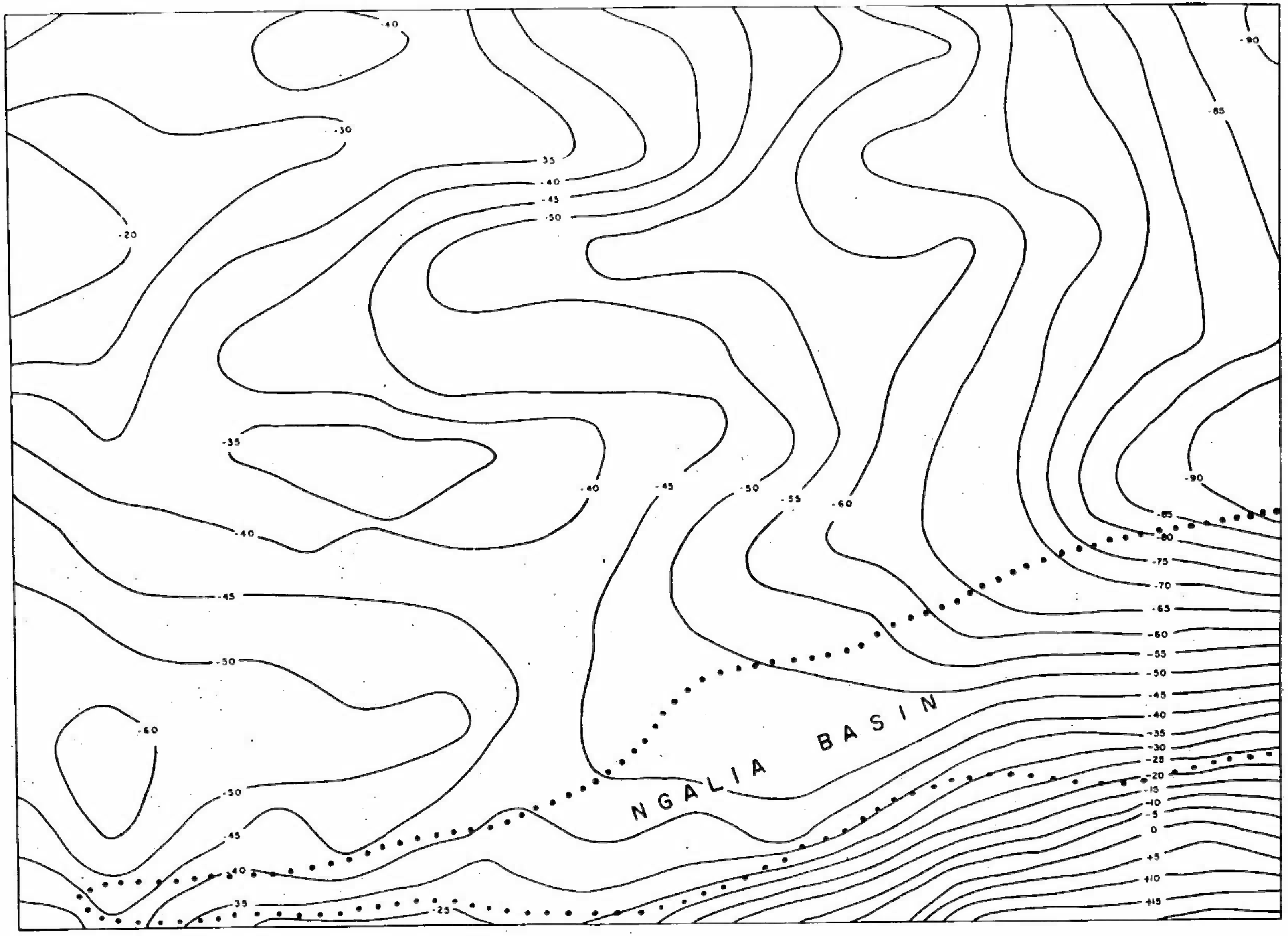
The Lake Mackay Sheet area was included in part of a regional gravity survey made under contract to the Bureau of Mineral Resources in 1967. The station density used in this survey was one station per 50 square miles.

The Ngalia Basin is dominated by three major gravity features, the Willowra Regional Gravity Ridge to the north, the Yuendumu Regional Gravity Low along the southern flank of which is found the Ngalia Basin, and the Papunya Regional Ridge to the south. The interpretation of gravity features occurring in the area has been discussed by Whitworth (1969, in prep.), Wells et al (1968) and Evans and Glikson (1969).

The Willowra Regional Gravity Ridge lies much further to the north, and is not dealt with in this report. However, it is worth noting that the two gravity ridges probably have similar origins, and both lie within the Arunta Mobile Belt (Whitworth, 1969, in prep.).

The Yuendumu Regional Gravity Low comprises two major units. The western unit called the Treuer Gravity Low, is the only one falling within the area of interest. It lies mainly in the northern sector of the adjoining Mount Doreen Sheet area and overlaps onto the Lake Mackay Sheet area. Its western edge is not yet adequately defined. A local minimum on north-west Mount Doreen corresponds approximately with the Vaughan Springs Syncline. If the whole of the Regional Gravity Low is also caused by low-density sediments, then the Ngalia Basin is the surface expression of a much larger faulted Proterozoic-Palaeozoic basin with overthrusting southwards of many miles on the northern margin (Whitworth, 1969, in prep.).

Seismic studies made by the Bureau of Mineral Resources in 1968 (Tucker, 1969) and later (Jones, pers. comm.) have indicated that up to 16,000 feet of sediment dipping gently to the north-north-west occurs at Waite Creek on the western edge of the Mount Doreen Sheet area, and appears to continue for a few miles beneath granitic basement rocks north-west of the Vaughan Springs Syncline. This evidence supports Whitworth's idea that the northern edge of the Ngalia Basin is formed by a low-angle thrust, at least in part. However, the seismic evidence indicates thrusting of only a few miles in a fairly local area. There is no direct evidence for large scale thrusting.



LAKE MACKAY BOUGUER ANOMALIES

AND GRAVITY FEATURES

SCALE

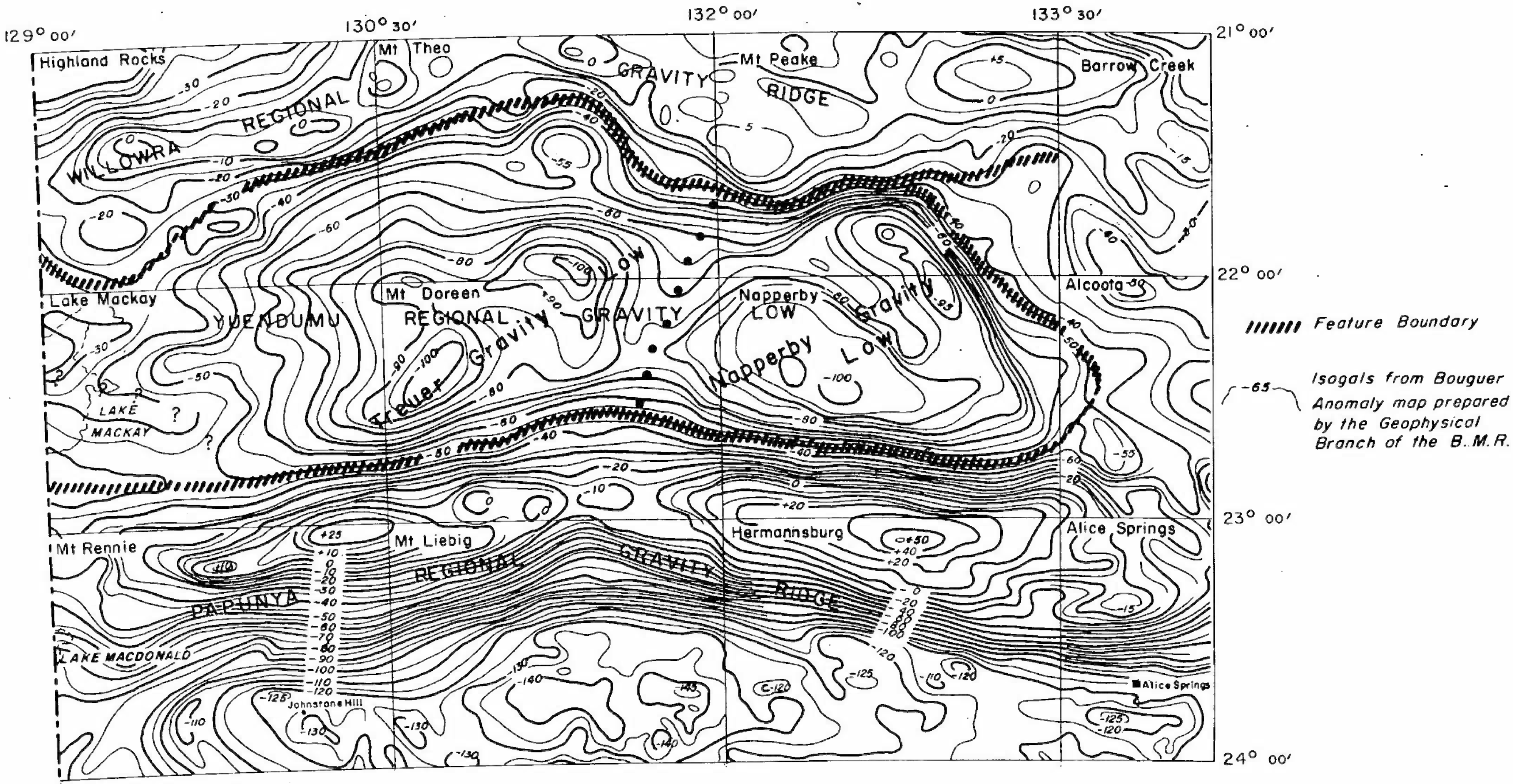
5 0 5 10 15 20miles

Fig 14

-55 *Isogals from Bouguer Anomaly map prepared by the Geophysical Branch of the B.M.R.*

To accompany Record 1969/89

F52/A11/5



BOUGUER ANOMALIES

AND GRAVITY FEATURES

Fig. 15

40 0 40 80 Miles

To accompany Record 1969/89

NT/A 192

Whitworth supported his view by stating that "there are isolated exposures of Palaeozoic and Upper Proterozoic sediments on the Mount Theo and Highland Rocks Sheet areas". Despite the geology of these two areas being virtually unknown, it is very doubtful that further investigation will provide evidence of extensive areas of Proterozoic sediments in these northern areas to support Whitworth's contention.

The south-eastern sector of the Lake Mackay Sheet area is largely occupied by the increasing gradient of the Papunya Regional Gravity Ridge, which on the Mount Rennie Sheet area reaches a maximum of +25 milligals. Although no surface geological feature is present to explain this basement density high, Wells et al (1967) have suggested that this gravity ridge may have been caused by crustal warping with subsequent elevation of the mantle close to the surface. Whitworth argues that wavelength analysis of the gravity feature indicates that the density contrast cannot be deeper than about 13 km., hence crustal warping is an unlikely cause of the feature. Langron (1962) suggests that high density ultrabasic rocks have been brought close to the surface by faulting, while Flavelle (1965) believes the origin may be in a fundamental horizontal density change within the crust. Whitworth suggests that a combination of these two interpretations may better account for the gravity anomaly, with the high density rock being derived by intense metamorphism.

GEOLOGICAL HISTORY

The Ngalia Basin initially formed part of a very much larger sedimentary basin - including the Amadeus Basin - which originated in the latter part of the Proterozoic. The Ngalia Basin lies entirely within the stable continental shield of Precambrian crystalline rocks. Quartz-mica schists and thin interbedded and cross-stratified ortho-quartzites of the basement have been intruded by granites, undergone regional metamorphism and at a late stage been intruded by dolerite dykes.

The late Proterozoic cycle of sedimentation began after uplift and a long period of erosion and peneplanation of the Precambrian basement. The Vaughan Springs Quartzite was deposited on a stable continental platform as a shallow marine blanket sand. The areal extent of the blanket sand deposits in the Ngalia and Amadeus Basins indicates mild subsidence; the high degree of textural and mineralogical maturity of the sandstone has been achieved by prolonged washing and winnowing of the material probably in a shallow marine strandline environment.

The presence in the included Treuer Member of intraformational breccia indicates shallow tidal flats which at some stage exposed sediments to the atmosphere; glauconite in this member provides additional evidence that the member accumulated where sedimentation rate was slow, the sea was shallow and a possible partially restricted marine environment prevailed.

The Vaughan Springs Quartzite and included Treuer Member is the basal formation of the Ngalia Basin and none of the remaining Proterozoic and Palaeozoic formations found further east are exposed in the Lake Mackay Sheet area. From seismic evidence obtained near the eastern edge of the area, there is little doubt that at least some of the sedimentary sequence developed elsewhere in the basin is present here at depth.

The following remarks apply to the adjoining Mount Doreen Sheet area where a more complete sequence of events can be interpreted from existing field evidence.

A number of Proterozoic and Palaeozoic formations, deposited mainly in a shallow marine environment and interrupted by minor periods of epeirogeny were laid down in the basin. A period of diastrophism, the Kerridy Movement, faulted and folded all the pre-Carboniferous sediments, and was followed by uplift and erosion after which the Carboniferous Mount Eclipse Sandstone, a thick sequence of continental sandstone with basal conglomerates was deposited.

Diastrophism in Carboniferous or later times, the Mount Eclipse Orogeny, further folded and faulted all the sediments and was probably responsible for most of the major structures present in the Ngalia Basin on the Lake Mackay Sheet area.

No further marine invasions have occurred since this time, and the only evidence for later sediments are the duricrust profiles of laterite and silcrete which developed during the Tertiary.

ECONOMIC GEOLOGY

Petroleum Prospects

The western termination of the Ngalia Basin occupies only about 1/6 of the area of the Lake Mackay Sheet area, the rest of the area being Precambrian granites and metasediments.

In the basin proper, widely scattered outcrops of only one sedimentary formation, the Proterozoic Vaughan Springs Quartzite, occur. The formation, from its very age, is non-prospective. From surface indications only, the petroleum potential of this part of the basin would appear to be negligible.

It is known from seismic evidence however, that just beyond the eastern edge of the Sheet area, to the north-west of the Vaughan Springs syncline, up to 16,000 feet of sediment dips gently to the north-north-west. The section appears to thicken to the north-west and to pass beneath basement granite. This section may, because of its thickness contain some Palaeozoic formations and possible source rocks. The thrusting probably took place during the Mount Eclipse Orogeny.

The several unconformities visible in surface exposure on Mount Doreen Sheet indicate that there was ample time during which any hydrocarbons originally present could have escaped.

The only likely source rock known elsewhere in the basin is the Cambrian Walbiri Dolomite, as other formations are unfossiliferous and the Mount Eclipse Sandstone is of continental origin. Many of the Palaeozoic formations present in the basin would act as suitable reservoir rocks, the most important being the Ordovician Djagamara Formation. Shales and siltstones suitable as cap rocks occur as interbeds in all of the formations younger than the Walbiri Dolomite.

As can be seen from Figure 15, the Treuer Gravity Low, whose suggested explanation is low angle overthrusting of basement rocks over sediments of the Ngalia Basin sequence, extends over onto the eastern part of the Lake Mackay Sheet area. If this explanation of the gravity low is correct, then the following remarks apply equally well to the buried section on the Lake Mackay Sheet area.

Taken overall, the fact that only one formation, of Cambrian age, could be a source rock, that a number of hiatuses occur in the geological column, and that unconformities exist between most of these formations, then the petroleum potential of the area can only be rated as very low.

Water supply

As a consequence of low rainfall and a high evaporation rate, surface water is very rare on the Lake Mackay Sheet area. Native wells are known at the Sandford Cliffs (O'Grady's Well) and on Ethel Creek (Lucky Hit Rockhole). Several other rock holes shown on the map were discovered during the survey. They occur mostly in areas of granite outcrops.

For a few days after heavy rain, accumulated surface water may remain in claypans and small rockholes, but most of the rain quickly returns to the atmosphere by evaporation.

Only one stream, Ethel Creek, is present on the Sheet area, and it is rapidly lost in the desert sand plain.

The local centre of internal drainage is Lake Mackay. Any temporary accumulation of water present here after heavy rains would be too saline for either human or animal consumption.

Two very shallow water bores were drilled by the Water Branch of the Northern Territory Administration in the area in 1958 at the request of the Native Welfare Department. Both wells were dry. Welfare No. 1 was drilled to a depth of 42 feet and Welfare No. 2 to a depth of 21+ feet. The locality of these bores is unknown.

Miscellaneous deposits

No mineral deposits of economic value are known from the Lake Mackay Sheet area.

Rose quartz

At locality LM172 (Grid ref. 248297), Precambrian gneiss is intruded by coarse pegmatite and quartz dykes. The pegmatite contains large euhedral crystals of feldspar and coarse veins of tourmaline. The quartz dyke consists of rose quartz, which at best is only partially translucent, and is extensively flawed. Sunlight has bleached the rose colour from the quartz to a depth of several inches. The pink tint of rose quartz is attributed to the presence of manganese, which in this case is no doubt derived from the tourmaline in the pegmatite.

Amethyst

A north-east trending quartz dyke about 3 miles long and bearing about 13 miles east-south-east of Mount Carey contains sporadic patches of amethystine quartz (Grid ref.313169) which line cracks and joints in the massive dyke rock. Crystals are small, and colour and quality is poor.

ACKNOWLEDGEMENTS

The members of the geological party are indebted to Mr and Mrs W. Braitling of Mount Doreen Homestead, and to Mr and Mrs J. Hemming of the Yuendumu Native Settlement for their help and generous hospitality during the fields season. Acknowledgement is also due to the Resident Geologist and staff at Alice Springs for their continued assistance.

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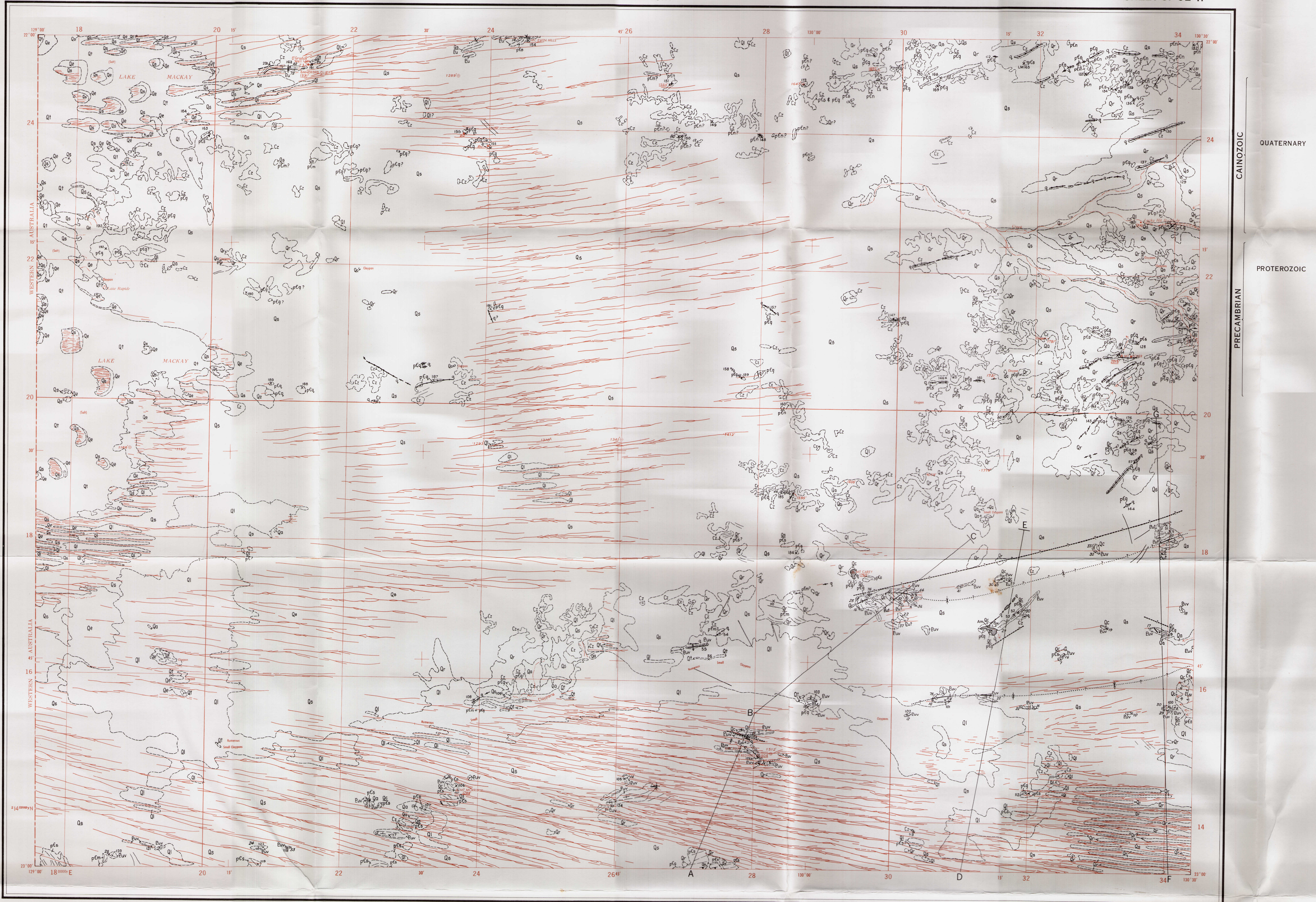
AUSTRALIA 1:250,000 GEOLOGICAL SERIES

LAKE MACKAY
NORTHERN TERRITORY

SHEET SF 52-11



Reference

CAINOZOIC

QUATERNARY
- Qa — *Alluvium*
- Qc — *Colluvium*
- Qs — *Aeolian sand*
- Qr — *Red soil, alluvium*
- Ql — *Travertine*
- Qe — *Sand, evaporites, travertine*
- Qt — *Evaporites*

Undifferentiated
- Cz — *Silcrete and ferruginized (lateritized) rock*

PRECAMBRIAN

PROTEROZOIC
- Undifferentiated — Pu — *Sandstone*
- Vaughan Springs Quartzite — Puv — *Thick bedded quartzite, interbedded pebbly sandstone and pebble conglomerate*
- Treuer Member — Put — *Thin bedded sandstone, glauconitic sandstone and siltstone. Possibly interbedded evaporites*

- p€ — *Undifferentiated igneous and metamorphic rocks*
- p€g — *Granite*
- p€d — *Dolerite*
- p€s — *Schist*
- p€m — *Undifferentiated schist, quartzite and amphibolite*
- p€q — *Quartzite*
- p€n — *Gneiss*

Geological boundary
Anticline
Syncline showing direction of plunge
Fault
Lineament

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

15 *Strike and dip of strata*
Vertical strata
Horizontal strata
76 *Strike and dip of overturned strata*
Prevailing strike and dip of overturned strata
Dip < 15°
Dip 15° – 45°
Dip > 45°
Trend lines
Joint pattern
(*air-photo interpretation*)
87 *Strike and dip of foliation*
Prevailing strike and dip of foliation
Vertical foliation

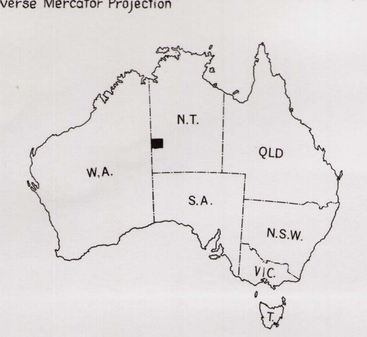
×127 *Specimen locality, text reference prefix LM*
Dyke; q – quartz, do-dolerite

•Am *Minor mineral occurrence*
Am *Amethyst*
Rq *Rose quartz*

•WH *Waterhole*
•RH *Rockhole*
Sand dunes

State boundary
Trigonometrical station
Astronomical station
•2015' *Elevation in feet, instrument levelled*
•1716' *Elevation in feet, barometric*
(*Datum: mean sea level*)
(PA) *Position approximate*

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Division of National Mapping, Department of National Development. Commonwealth aerial photography; complete vertical coverage at 1:46,500 scale
Transverse Mercator Projection



INDEX TO ADJOINING SHEETS
Showing Magnetic Declination

CORNISH SF 52-1	LUCAS SF 52-2	THE GRANITES SF 52-3	MOUNT SOLITAIRE SF 52-4	LANDER RIVER SF 53-1
HELENA SF 52-5	STANSMORE SF 52-6	HIGHLAND ROCKS SF 52-7	MOUNT THEO SF 52-8	MOUNT PEAKE SF 53-5
WILSON SF 52-9	WEBB SF 52-10	LAKE MACKAY SF 52-11	MOUNT DOREEN SF 52-12	NAPPERBY SF 53-9
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COBB SG 52-1	RAWLINSON SG 52-2	BLOODS RANGE SG 52-3	LAKE AMADEUS SG 52-4	HENBURY SG 53-1

ANNUAL CHANGE 0' 45"E

Scale 1:250,000

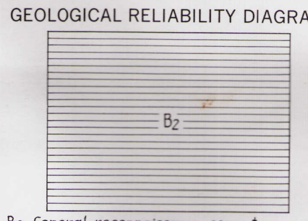
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Sections
(Cainozoic sediments omitted. Folding in part schematic)
Scale $\frac{V}{H} = 2$

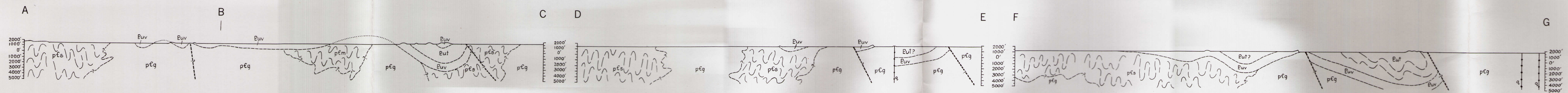
Geology, 1968, by: A.T. Wells, T.G. Evans and T. Nicholas
Compiled, 1968, by: A.T. Wells, T.G. Evans, T. Nicholas and Miss D.M. Pillinger
Cartography by: Geological Branch B.M.R.
Drawn by: Miss D.M. Pillinger

GEOLOGICAL RELIABILITY DIAGRAM



B_2 General reconnaissance, some traverses and air-photo interpretation

PRELIMINARY EDITION, 1969
SUBJECT TO AMENDMENT



LAKE MACKAY
SHEET SF 52 11

Complimentary