LAKE MACKAY
NORTHERN TERRITORY

SHEET SF/52-11 INTERNATIONAL INDEX
Explanatory Notes on the Lake Mackay Geological Sheet

Compiled by T. Nicholas

The Lake Mackay Sheet area lies on the eastern perimeter of the Great Sandy Desert, and covers the area between latitudes 22° and 23° south, and longitudes 129° (the Western Australian border) and 130°30' east. Geologically the area consists of two main parts: the western end of the Ngatia Basin — an Adelaidean to Palaeozoic intracratonic sedimentary basin — and the predominantly crystalline rocks of the Precambrian basement which occupy a larger area.

The Lake Mackay Sheet area is uninhabited and is nowhere crossed by roads or vehicular tracks. The area is almost entirely semi-desert, although sparse, low, arid woodlands occur on its eastern edge. Rainfall generally averages less than 250 mm annually; surface water is rare and can only be obtained from a few small springs or native soaks and rock holes whose sources are not permanent and cannot be relied upon. For any party entering the area it is essential to carry ample supplies of food and water. The area lies entirely within the Lake Mackay Aboriginal Reserve.

Access to the area by four-wheel-drive vehicle is from the east by way of Mount Doreen homestead at Vaughan Springs on the adjoining Mount Doreen Sheet area. The nearest access to the south is by a graded dirt road running from Alice Springs to the Canning Stock Route, which at its closest approach passes through Sandy Blight Junction on the Mount Rennie Sheet area. Access via this latter route is far more difficult because of the many east-west longitudinal sand dunes which must be traversed.

Air-photographs and maps used during the survey were: vertical air-photographs at a scale of 1:48,000, flown by the RAAF in 1957; uncontrolled photomosaics of the twelve one-mile areas within the Lake Mackay Sheet area (scale 1:63,360) prepared by the Division of National Mapping, Department of National Development; and a topographic base map at scale 1:250,000 (SF/52-11, Zone 4) prepared by the Division in 1963 from an astrofix-controlled photoscale slotted-template assembly. The accompanying geological map was compiled on the photoscale assembly and reduced to 1:250,000.

Previous investigations

No systematic geological work was carried out on the Sheet area until it was investigated by geologists of the Bureau of Mineral Resources in 1968.

The earliest exploratory investigation of the area was by Colonel P. E. Warburton (1875), who traversed the Sheet area in his east-to-west crossing of the continent from Alice Springs to the Oakover River in northern Western Australia. In 1902
Fig. 1 Structural sketch map
Maurice and Murray crossed the southeastern corner of the Sheet area on a journey from Fowler's Bay in South Australia to Cambridge Gulf (Maurice & Murray, 1904).

In 1930, the Mackay Aerial Survey Expedition carried out a number of survey flights which crossed the area; the results were incorporated in a reconnaissance topographic map (Mackay, 1934). The large lake on the western border of the Sheet area was named after Donald Mackay, the expedition leader.

Terry (1934) investigated and named many of the topographic features in the Sheet area, and sampled and analysed the lake sediments.

In 1964, J. C. Rivereau of the Institut Français du Pétrole made a photogeological study of the Lake Mackay, Mount Doreen and Napperby Sheet areas in an overall study of the Ngalia Basin (Rivereau, 1965). The British Joint Services Expedition spent some time in the area in 1967 during which geological observations were made by Squadron Leader Batstone, the party geologist.

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 was one station per 130 square kilometres (Whitworth, 1970, in press).

The geological map is the result of mapping by Bureau of Mineral Resources geologists in 1968 (Nicholas, 1969); the stratigraphic nomenclature used is derived from Bureau mapping on the adjacent Mount Doreen Sheet area in 1967 (Wells, 1971).

**PHYSIOGRAPHY**

Aeolian sand covers the greater part of the Sheet area in the form of redistributed sand plains and longitudinal sand dunes which are particularly prominent in the south and centre. The sand plain is broken in the southern half by a few low quartzite rises, cuestas, and mesas, and in the east and north by low residual hills of schist and granite.

Drainage is controlled by a gentle westerly grade from elevations of about 560 m in the east to 360 m in the extreme west. A prominent playa lake, Lake Mackay, is the local centre of internal drainage. Although the lake covers an area of approximately 3500 sq. km, only about one fifth of its surface area lies on the Lake Mackay Sheet area; the remainder lies across the border in Western Australia.

Longitudinal sand dunes, formed under a bidirectional wind regime, reach heights of 10 m, and some are 50 km long; their general trend is east-west. The dunes are linear, parallel over considerable distances, and symmetrical in section with smooth crests. Although the dunes run parallel, convergences and divergences are common and form a braided pattern; where short anastomoses are present, the acute angle of the junction points west in the direction of dune migration. The dunes are now largely fossil features whose flanks are stabilized by vegetation, although some mobile sand remains on their crests.

Most of the small hills to the north and northeast rise less than 30 m above the general level of the sand plain, whereas heights of the quartzite mesas and cuestas in
<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Map Symbol</th>
<th>Maximum Thickness (m)</th>
<th>Topographic Expression</th>
<th>Lithology</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Qa</td>
<td></td>
<td>River bed, flood plain, and flood-out</td>
<td>Alluvium</td>
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<td></td>
<td></td>
<td>Qc</td>
<td></td>
<td>Talus and detrital slopes</td>
<td>Colluvium</td>
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<tr>
<td></td>
<td></td>
<td>Qs</td>
<td></td>
<td>Sand plains and dunes</td>
<td>Sand</td>
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<td></td>
<td></td>
<td>Qr</td>
<td></td>
<td>Plains</td>
<td>Red soil and alluvium</td>
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<td></td>
<td></td>
<td>Qi</td>
<td></td>
<td>Low mounds, hummocky terrain</td>
<td>Travertine</td>
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<tr>
<td></td>
<td></td>
<td>Qe</td>
<td></td>
<td>Salt-pan margins, drainage channels</td>
<td>Sand, evaporites, travertine</td>
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<td></td>
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<td>Qt</td>
<td></td>
<td>Salt lakes and salt pans</td>
<td>Evaporites</td>
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<tr>
<td></td>
<td></td>
<td>Cx</td>
<td></td>
<td>Mesas and buttes of low relief and low rounded hills</td>
<td>Silcrete and ferricrete</td>
<td></td>
</tr>
<tr>
<td>PRECAMBRIAN</td>
<td>Vaughan Springs</td>
<td>Puv</td>
<td>2,750 ±</td>
<td>Prominent resistant cuestas and mesas, low ridges</td>
<td>Tough white, pink, and grey quartzite, thick-bedded, small cross-beds common, Local basal pebble conglomerate</td>
<td>Member occurs in lower half of the Vaughan Springs Quartzite</td>
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<tr>
<td></td>
<td>Quartzite</td>
<td></td>
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<td></td>
<td>Treuer Member</td>
<td>Put</td>
<td>1,825 ±</td>
<td>Low weathered ridges and rubble-covered flats</td>
<td>Whitish-grey thin-bedded silicified sandstone, glauconitic in part; chocolate brown, yellow, white, and purplish red siltstone and shale, Deeply weathered</td>
<td></td>
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<tr>
<td></td>
<td>Sandstone at</td>
<td>Pu</td>
<td>250 ±</td>
<td>Low sandstone cliffs</td>
<td>White to pink cross-bedded medium-grained thin-bedded orthoquartzite</td>
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<td></td>
<td>Sanford Cliffs</td>
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<tr>
<td>Sandstone at McEwin Hills</td>
<td>Pu</td>
<td>300 ±</td>
<td>Low hills</td>
<td>Reddish brown thin-bedded kaolinitic micaceous cross-bedded sandstone</td>
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<tr>
<td><strong>UNCONFORMITY</strong></td>
<td></td>
<td></td>
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<tr>
<td>pCd</td>
<td>Ridges, rarely wider than 0.7 m</td>
<td>Slightly altered dolerite; uralitized and sheared dolerite</td>
<td>Dykes cut granites and schists</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pCg</td>
<td>Low rounded tors</td>
<td>Porphyritic (microcline) granite: garnet-bearing meta-granite</td>
<td>Assumed with aplite and coarse pegmatite dykes, quartz dykes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pCn</td>
<td>Low isolated hills</td>
<td>Gneiss, garnet-cordierite-sillimanite gneiss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pCm</td>
<td>Low rounded hills and rises</td>
<td>Undifferentiated schist, quartzite, and amphibolite</td>
<td>Interbedded with mica-quartz schist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pCq</td>
<td>Low ridges in schist</td>
<td>White to yellow metaquartzite, cross-bedded and ripple-marked; actinite quartzite</td>
<td>Cut by numerous large near-vertical quartz dykes, Tourmaline common</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pCs</td>
<td>Low rounded hills and rises</td>
<td>Mica-quartz schist, phyllite, hornfels</td>
<td></td>
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</table>
the southern half of the Sheet area reach 120 m in a few localities. Piedmont angles are steep as a result of intense weathering in the scarp-foot zone.

There are no large drainage channels in the Sheet area; the only stream is Ethel Creek, which rises in granite country in the northwestern corner of the adjoining Mount Doreen Sheet area and floods out onto the desert floor to the west. For the greater part drainage is subterranean, and is responsible for Lake Mackay, and possibly for the extensive development of travertine across the southern part of the Sheet.

**STRATIGRAPHY**

The stratigraphic succession of the Sheet area comprises the Precambrian basement rocks that make up the floor and margins of the Ngalia Basin, and the basement-derived Adelaidean to Palaeozoic sediments deposited within the basin. The stratigraphy is summarized in Table 1.

**Precambrian rocks of the basement**

The main metamorphic rock types of the area are quartz-muscovite schist and minor interbedded metaquartzite. These metasediments are intruded by granite, granite gneiss, and small dolerite dykes. An isolated occurrence of sillimanite-garnet and cordierite-bearing gneiss has been recorded from the northeastern part of the area. The occurrence of garnet in metagranites cropping out northwest of the centre of the Sheet area indicates a higher grade of metamorphism here than in the southern part. The granulite facies gneiss in the northeast may be a relic of Archaean rocks from which the Precambrian sediments (as distinct from the Adelaidean sediments) were originally derived; alternatively it may be a paragneiss whose high metamorphic grade is due only to an overall increase in grade of metamorphism in the southwest.

The Precambrian basement rocks of the area remain unnamed; poor exposure and widely separated outcrops have not allowed the spatial and temporal relationships of the various rock types to be determined and isotopic age determinations are not yet available.

Numerous pegmatite and aplite dykes intrude the granites; these late stage differentiates are coarse-grained, with large euhedral feldspar crystals up to 30 cm long and subordinate euhedral tourmaline crystals. Muscovite is common, but the books are not of economic size or grade. Numerous massive quartz dykes in the eastern half of the area generally parallel the fold axes of the metasediments.

**Adelaidean sedimentary rocks of the Ngalia Basin**

Only one sedimentary formation of the Ngalia Basin, the *Vaughan Springs Quartzite* and its included *Treuer Member*, crops out on the Lake Mackay Sheet area. It is the basal formation of the Ngalia Basin succession, and lies everywhere with major unconformity upon Precambrian metasediments and crystalline basement rocks. The top of the formation is either eroded or obscured by Quaternary deposits. The formation name is taken from Vaughan Springs at Mount Doreen homestead on the adjacent Mount Doreen Sheet area to the east.
The Vaughan Springs Quartzite is a massive to thick bedded orthoquartzite. It is cross-stratified, ripple-marked, tough and compact, although in places it is friable with only a thin skin of surface silicification. Its colour varies through shades of pink, yellowish grey, and white; friable varieties are reddish brown. Thin localized basal pebble conglomerates are present in places, with phenoclasts of vein quartz derived from the underlying basement rocks. The thickest section is about 2750 m, and was measured in an east-plunging syncline about 6 km southeast of Mount Carey. Wells et al. (in prep.) have defined and named the formation.

In the western end of the Ngalia Basin, the distribution of the Vaughan Springs Quartzite is sporadic and limited to the southern half of the Sheet area. No contact of the Vaughan Springs Quartzite with any of the younger units exposed elsewhere in the basin sequence is known in the area.

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

The age of the Vaughan Springs Quartzite is regarded as Adelaidean. In gross lithology and stratigraphic position it is similar to the Heavitree Quartzite of the Amadeus Basin (Wells et al., 1967). On the Mount Doreen Sheet area to the east 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 farther to the south. No fossils have been found in the Vaughan Springs Quartzite.

The Treuer Member of the Vaughan Springs Quartzite has been named from the adjoining Mount Doreen Sheet area (Wells et al., 1970, in prep.). On the Lake Mackay Sheet area only two exposures are known, one just south of the Waite Creek Fault near the eastern edge of the Sheet area, the other about 6.5 km southeast of Mount Carey.

The Treuer Member is a sequence of fine-grained thin-bedded clastic rocks which are mainly yellow, purplish red, and white shale and siltstone with thin interbedded partly glauconitic laminated sandstone. Surface outcrop is as low weathered ridges of the more resistant interbedded sandstones, and rubble-covered flats of deeply weathered shale and siltstone. On adjoining Sheet areas to the east this shaly sequence of the Treuer Member is commonly incompetently folded and contains minor slump structures.

At the locality near Mount Carey, the Vaughan Springs Quartzite occurs in an easterly plunging syncline whose northerly limb is in fault contact with basement granite. The Treuer Member occurs about 450 m above the base of the formation and is about 1825 m thick at this locality.

Ripple markings and intraformational breccias are present in the Member, and, although no fossils have been found, its age is assumed to be Adelaidean.

Undifferentiated Adelaidean at Sandford Cliffs and McEwin Hills

Two isolated sandstone outcrops are present at the northern margin of the Lake
Mackay Sheet area. The Sandford Cliffs is a range about 6.5 km long rising to a height of about 30 m above the desert floor. The sandstone is poorly bedded, fine-grained, and well sorted; it is pale brown to reddish brown and is mostly highly silicified, although it is friable and porous in places. Current ripple-marking is present, and the rock is unfossiliferous.

The sandstone is at least 250 m thick, and occurs in a west-plunging, tightly folded syncline with an east-trending axis. No contacts between the sediments and basement rocks have been seen.

The sandstone of the McEwin Hills (55 m above the sand plain) unconformably overlies Precambrian schist, and is folded into a southwest-plunging syncline. It is at least 125 m and possibly as much as 300 m thick. The sandstone is a friable, medium-grained, reddish brown rock which is richly micaceous and cross-stratified. The lowermost beds contain schist fragments and scattered quartz pebbles derived from the underlying basement.

The sandstones of Sandford Cliffs and McEwin Hills are tentatively correlated with the Gardiner Beds of the Stansmore and Lucas 1:250,000 Sheet areas to the northwest. The Gardiner Beds unconformably overlie the Halls Creek Metamorphics and are regarded as ‘Upper’ Proterozoic in age (Casey & Wells, 1964).

Cainozoic

Deposits of undifferentiated Cainozoic age occur mainly in the northern half of the area, and crop out as horizontal to sub-horizontal duricrust cappings. The deposits in the north are of ferricrete up to 12 m thick, developed mainly on deeply weathered granite and gneiss. In low-lying areas, black to very dark brown ironstone pisoliths form a cover on low mounds near the eastern and northern margins of Lake Mackay. In the south, silcrete is developed on outcrops in areas of low relief.

Quaternary

Alluvium occurs mainly on the banks and flood-out of Ethel Creek. Red soil occurs in interdune corridors in the southeastern corner of the area, and elsewhere mainly on Cainozoic silcrete and ferricrete. Aeolian sand covers much of the area and forms extensive longitudinal sand dunes and redistributed sand fields. The dunes are usually less than 1.5 km apart and generally trend east-west. Colluvium is restricted to areas of sharp relief on the scarp slopes of ridges, and in many places covers the contact between the basin sediments and Precambrian basement rocks. Thin deposits of evaporites occur at Lake Mackay and at a small chain of salt pans in the centre of the southern half of the area. The lake sediment is a dark grey-brown waterlogged clay underlain at a depth of about 30 cm by a layer of well formed gypsum crystals. Travertine occurs around the margins and in the drainage channels of Lake Mackay, and the extensive development of travertine across the southern half of the Sheet area may mark the site of a large pre-existing drainage channel. The travertine has hummocky relief, and in a few outcrops tough, white, massive, vuggy chaledonic silica about 1.5 m thick occurs in the travertine.
STRUCTURE

The Ngalia Basin is a narrow intracratonic depression in Precambrian igneous and metamorphic rocks, and extends 465 km from west to east over the Lake Mackay, Mount Doreen, Napperby, and the western edge of the Alcoota 1:250,000 Sheet areas.

Paucity of outcrop and poor exposure of the metamorphic and igneous basement suite do not permit delineation of regional structure, but available evidence indicates that the area is dominated by a system of tight northwest-trending isoclinal folds. Where schist and metaquartzite are observed together, the plane of schistosity is approximately parallel to the original bedding.

The structure of the Ngalia Basin is best seen in adjacent areas and can be broadly applied to the Lake Mackay Sheet area. Geophysical and geological evidence farther east in the well exposed part of the basin shows it to be asymmetrical. The sediments of the southern margin dip 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 sediments overturned next to the fault. In the north of the central part of the basin there is a maximum thickness of about 4250 m of sediment. To the northwest (adjoining the Lake Mackay Sheet area) a seismic reflection survey has indicated a possible low-angle overthrust with a displacement of some 10 km of basement rocks over about 4900 m of sediment.

In the Lake Mackay Sheet area, two important east-west synclinal axes are present. The more northerly of these is bounded by the Waite Creek Fault with the basinal sediments on the southern downthrown side of the fault. The largely concealed Waite Creek Fault trends west-southwest from the eastern edge of the area to just south of Mount Carey and may be part of a much larger fault trending in the same direction from Mount Doreen homestead at Vaughan Springs on the adjoining Sheet area. The second synclinal axis parallels the first and extends from about 20 km south-southeast of Mount Carey to the eastern edge of the Sheet area. Most of the outcrops on the southern margin of the basin are flat-lying or dip gently into the basin; a few minor folds are present.

GEOLOGICAL HISTORY

Precambrian sedimentary and igneous rocks have been folded, faulted, and metamorphosed on a regional scale, but the number of orogenies that they have undergone is unknown. Paucity of outcrop precludes a more detailed account of the early geological history.

The Ngalia Basin lies entirely within the stable continental shield composed of these Precambrian rocks and its history is better known. The Adelaidean cycle of sedimentation began after the Precambrian basement had been subjected to uplift and a long period of erosion and peneplanation. The Vaughan Springs Quartzite was deposited on a stable continental platform as a shallow marine blanket sand whose considerable areal extent and textural and mineralogical maturity indicates mild subsidence probably in a shallow marine strandline environment.
The presence in the Treuer Member of intraformational breccias suggests an environment of shallow tidal flats which at some stage exposed the sediments to the atmosphere; glauconitic sandstone in this member provides additional evidence that the sediments accumulated where the sedimentation rate was slow, and the sea was shallow and partly restricted.

In adjoining areas a more complete sequence of later events is apparent: a number of Adelaideon and Palaeozoic formations, deposited mainly in a marine environment and interrupted by minor periods of epeirogeny, were laid down and are now preserved in the basin. A period of diastrophism faulted and folded all the pre-Carboniferous sediments, and was followed by uplift and erosion, after which a thick sequence of continental origin was deposited.

An orogeny in Carboniferous or later time further folded, faulted, and in places thrust sediments over the basement, and was probably responsible for most of the major structures exposed in the basin sediments of the Lake Mackay Sheet area.

No further marine incursions have occurred since this time, and the only later sediments are clays of Tertiary age which have been intersected in drill holes near the centre of the Ngalia Basin and which probably also occur on the Lake Mackay Sheet area.

**ECONOMIC GEOLOGY**

No metallic deposits of economic value were found in the basement rocks of the area. Small amounts of rose quartz occur near the northern margin of the Sheet area at locality 172, and sporadic patches of amethystine quartz line cracks and joints in a massive northeast-trending quartz dyke about 21 km east-southeast of Mount Carey.

**Water**

As a consequence of low rainfall and high evaporation rate, surface water is rare in this remote and relatively inaccessible area. For a few days after rain, accumulated surface water may remain in small rock-holes, claypans, and minor sand soaks, but most of the moisture quickly evaporates. Native wells are known at Sandford Cliffs (O’Grady’s Well) and on Ethel Creek (Lucky Hit Rockhole). Other soaks discovered during the survey were detected by noticeably thicker vegetation and the presence of numerous birds. Any temporary accumulation of water in Lake Mackay would be too saline for either animal or human consumption because of the presence when dry of a thin surface crust of halite.

**Petroleum prospects**

The petroleum potential of the area is poor. Ngalia Basin sediments occupy only about one sixth of the Lake Mackay Sheet area. Widely separated outcrops of only one formation, the Adelaideon Vaughan Springs Quartzite, occur in the Sheet area, and this formation is non-prospective. From surface indications only, the petroleum potential of this part of the basin would appear to be negligible.
Just beyond the eastern edge of the Sheet area seismic evidence shows that up to 4900 m of sedimentary rocks dip gently to the north-northwest and pass beneath basement granite. This section, overthrust by basement rocks, may, because of its thickness, contain some Palaeozoic formations including possible source rocks. Elsewhere in the basin the only formation likely to have been a source of hydrocarbons is a fossiliferous Cambrian dolomite. Many of the Palaeozoic formations present on the adjoining Mount Doreen Sheet area would act as suitable reservoir rocks, and shales and siltstones suitable as cap rocks occur as interbeds in all formations younger than the Cambrian dolomite. However, the several unconformities visible in surface exposures on the Mount Doreen Sheet indicate that there was ample time for any hydrocarbons originally present to escape.
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