MOUNT DOREEN
NORTHERN TERRITORY

SHEET SF/52-12 INTERNATIONAL INDEX

COMPILED BY A. T. WELLS
Explanatory Notes on the Mount Doreen Geological Sheet

Compiled by A. T. Wells

The Mount Doreen Sheet area lies in the southwestern part of the Northern Territory between latitudes 22°00' and 23°00' south and longitudes 130°30' and 132°00' east. A graded earth road connects Alice Springs with Yuendumu Native Settlement, a distance of about 300 km, and continues to old Mount Doreen homestead and thence to the Granites and Tanami. Other graded earth roads connect with the beef road, as the main road is locally known, and ungraded tracks radiate from the homestead to bores and wells. The western part of the Sheet area is less accessible than the east.

The area is covered by vertical air-photographs at a scale of about 1: 46 500, and a photomosaic and a topographic map at 1:250 000 scale have been produced by the Division of National Mapping.

The average rainfall is less than 250 mm, but is extremely irregular. Summer maximum temperatures exceeding 40°C are common and generally temperatures are characterized by marked diurnal and seasonal fluctuations. Frosts are common in late June and July.

Beef cattle are raised over much of the area, but the central part, occupied by sand plains and dunes that support a vegetation chiefly of spinifex with small shrubs and a few groves of oaks, is at present considered to be unusable. By contrast the northern half is underlain by large stretches of alluvium which in many places supports a dense cover of mulga trees and grasses. Most of the inhabitants are aboriginals living at the Yuendumu Native Settlement. There are two cattle properties—New Haven in the central southern part of the Sheet area, and Mount Doreen with its homestead at Vaughan Springs.

Previous Investigations

All the unpublished and published previous investigations are listed in the bibliography. The most comprehensive of the few geological investigations that preceded the present survey were reconnaissance mapping by Cook & Scott (1967) and by Australian Geophysical Pty Ltd (1966, unpubl.). The main geophysical investigations are those of the BMR seismic parties in 1967, 1968, and 1969 (Jones, 1969; Tucker, 1969, both unpubl.). Other recent regional geophysical surveys are an airborne magnetometer survey for Pacific American Oil Co. by Aeroservice Ltd (Hartman, 1963, unpubl.) and a seismic survey for the same company by Geophysical Associates Pty Ltd (Hudson & Campbell, 1965, unpubl.).

Rivereau (1965, unpubl.) carried out a photogeological study of the Ngalia Basin, the major outcrop of which is included in the Mount Doreen Sheet area. These photo-interpretation maps were used as a planning basis for the geological mapping undertaken by BMR in 1967 and 1968 (Wells et al., 1968, unpubl.; Evans & Glikson, 1969, unpubl.; Nicholas, 1969, unpubl.). About 1 450 m of stratigraphic drilling was completed in 1969 (Evans & Nicholas, 1970, unpubl.) and a further 760 m was completed in 1970. A synthesis of BMR’s geological and geophysical investigations is at present in preparation (Wells et al., in prep.).
PHYSIOGRAPHY

The area can be readily divided into seven physiographic regions (Fig. 1).

Fig. 1. Physiographic subdivisions.

Acolian sand occupies about half of the land surface and in places longitudinal dunes tens of kilometres long are common. The sand plain occurs mainly in and south of the area underlain by the Ngalia Basin.

Alluvial fans and plains are confined mainly to the north near the larger mountain ranges. The larger streams are in this region and mostly drain northwards, away from the ranges; Ethel Creek, however, drains westwards into sand plains on the Lake Mackay Sheet area. Waite Creek flows southwards onto sand plains north of Mount Stanley, and a small creek drains into Kerridy Waterhole. Most streams in other parts of the Sheet area are confined to the higher ranges and hills, but are short and are quickly dissipated in the sand plain.

The remaining divisions occupy small areas. Mountain ranges are confined mainly to the north. Linear quartzite ridges occur in the sand plains in the southern
part of the Sheet area; Central Mount Wedge, which is probably the highest peak in the area, occurs on one of these ridges in the southeast. Alluvial fans are confined to small areas where the larger streams debouch on to the plain.

Plains of travertine and chalcedony are found in and around the southern ranges mainly in internal drainage areas. Salt lakes with thin crusts of evaporites are also common near them; the largest is Lake Eaton.

For further details of the development of the physiography of the area the reader is referred to Mabbutt (1962).

**STRATIGRAPHY**

The stratigraphic succession in the Mount Doreen Sheet area is shown in Tables 1 and 2, and the relationship between the rock units is shown diagrammatically on the map. There are two main groups of rocks in the Sheet area—the older Precambrian crystalline and metasedimentary rocks which have been termed basement, and the younger Precambrian and Palaeozoic sediments of the Ngalia Basin that unconformably overlie them (Fig. 2).

The older Precambrian rocks crop out in the north and south of the Sheet area; the sediments of the Ngalia Basin are preserved in a depression in the basement, the long axis of which trends easterly through the centre of the Sheet area.

The four main groups are—

1. Granites, adamellites, granodiorites and related porphyritic rocks, and acid granulites, all affected to varying degrees by dynamic metamorphism.

2. Basic intrusive igneous rocks and amphibolites.

3. Intermediate to high grade metamorphosed rocks that are considered as basic to intermediate granulites.

4. Mica-quartz schists, some bearing garnet and andalusite, and minor quartzites.

The acid granulites may have been formed by metamorphism of granite, but, because of their high alumina content, are more likely to have originated as pelites. Slight retrograde metamorphism is suggested by the presence of some low grade minerals.

There is an apparent decline in metamorphic grade from east to west in the Sheet area. Dolerite and basalt dykes, metamorphosed during a later episode, intrude rocks throughout the Sheet.

Slightly altered sedimentary rocks just north of the Ngalia Basin near the Patmungala Syncline (Fig. 2) have been named the *Patmungala Beds* (Wells et al., in prep.). They are unconformably overlain by Adelaidean sediments of the Ngalia Basin and are intruded by granite, but no similar rocks are known elsewhere in the Sheet, and their relationship to other early Precambrian metamorphic rocks is not known.
<table>
<thead>
<tr>
<th>Period</th>
<th>Formation and Map Symbol</th>
<th>Thickness in Metres (maximum)</th>
<th>Lithology</th>
<th>Topography</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adelaïdean</td>
<td>Yuendumu Sandstone (Puy)</td>
<td>705+</td>
<td>Fine, medium and some coarse sandstone, moderately sorted; medium and thin bedded, flaggy, in part cross-bedded, convoluted and micaceous, silty, reddish brown and some pale brown. Coarse arkose locally at base</td>
<td>Mostly rounded hills and small cuestas</td>
<td>Correlated with Arumbera Sandstone of Amadeus Basin</td>
</tr>
<tr>
<td></td>
<td>Mount Doreen Formation (Puy)</td>
<td>335</td>
<td>Green siltstone with subrounded striated and faceted erratics up to 4 m across. Pink laminated dolomite and red shale commonly at top, and green siltstone with dolomite lenses at the base. Lenses of dolomitic sandstone and pebbly sandstone in the sequence with erratics</td>
<td>Scree slopes with dolomite Stromatolites in dolomite. Conforming small scarps or low hills. Also in valleys or at base of scarp Amadeus Formation in base of scarps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vaughan Springs Quartzite (Puy)</td>
<td>1,645+</td>
<td>White and pink quartzite, tough, closely-jointed, thick bedded and massive, with basal coarse pebbly hemaitic sandstone and pebbly conglomerate. Small cross beds, some ripple marks. Minor interbedded blue and green shale with mud cracks and ripple marks above conglomerate in places</td>
<td>Prominent ridges and cuestas, Correlated with Heavitree rare mesas and buttes Quartzite in Amadeus Basin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treuer Member (Put)</td>
<td>550</td>
<td>White and grey laminated to thin bedded sandstone, cross bedded in places, in part micaceous and rich in small clay pellets. Thin beds of glauconitic sandstone common near base. Interbedded grey, red, and maroon siltstone in places dominant. Deeply leached, evaporite encrustations common</td>
<td>Rubble-covered flats with a few sharp low discontinuous ridges in lower half of Vaughan Springs Quartzite. May contain interbedded evaporites</td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>Formation and Map Symbol</td>
<td>Thickness (maximum)</td>
<td>Lithology</td>
<td>Topography</td>
<td>Remarks</td>
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<tr>
<td>PRE-ADLADEAN</td>
<td>Patmungala Beds (pCp)</td>
<td>1 100±</td>
<td>Silty sandstone, quartzite, siltstone, recrystallized vitrocrystalline tuff, minor interbedded stretched chert pebble conglomerate and shale. Slightly metamorphosed</td>
<td>Irregular hills and low discontinuous strike ridges with high relief</td>
<td>Intruded by coarse granite</td>
</tr>
<tr>
<td></td>
<td>pCg</td>
<td></td>
<td>Granite, adamellite, granodiorite, and related porphyritic rocks, dynamically metamorphosed</td>
<td>Rounded hills and a few prominent tors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pCa</td>
<td></td>
<td>Orthogneiss, gneissic granite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pCd</td>
<td></td>
<td>Amphibolite, mafic igneous rocks including unaltered olivine dolerite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pCs</td>
<td></td>
<td>Mica-quartz schists, some with andalusite and garnet</td>
<td>Rounded hills, a few small pinnacles and ridges</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pCq</td>
<td></td>
<td>Quartzite</td>
<td>Prominent ridges and mountains</td>
<td>Schist and quartzite interbedded at Mount Hardy and near Venerable Creek</td>
</tr>
<tr>
<td></td>
<td>pCn</td>
<td></td>
<td>Paragneiss, basic and acid mainlly rounded hills</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ages and interrelationships of the unnamed Precambrian rock units are not known and they are not necessarily in chronological order here or on the geological map.
<table>
<thead>
<tr>
<th>Period</th>
<th>Formation and Map Symbol</th>
<th>Thickness in metres (maximum)</th>
<th>Lithology</th>
<th>Topography</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUATERNARY</td>
<td>Qa</td>
<td>Alluvium</td>
<td>River bed, flood plain and floodout</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qc</td>
<td>Colluvium</td>
<td>Talus and detrital slopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qs</td>
<td>Sand</td>
<td>Plains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qt</td>
<td>Travertine</td>
<td>Low mounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAINOZOIC</td>
<td>Cz</td>
<td>Silcrete and ferruginized rock</td>
<td>Low areas and buttes, low rounded hills</td>
<td>Thick Tertiary sand and clay penetrated in bore holes</td>
<td></td>
</tr>
<tr>
<td>CARBONIFEROUS</td>
<td>Mount Eclipse Sandstone (Pzt)</td>
<td>2 000–2 500</td>
<td>Pale brown and reddish brown arkosic sandstone and subgreywacke, coarse, poorly sorted, thin-bedded to massive, cross-bedded, in part calcareous and micaceous. Cobble and boulder beds common; few red micaceous siltstone interbeds</td>
<td>Hogbacks, cuestas, a few prominent rounded hills</td>
<td>Contains a few poorly preserved plant fossils including Cardiopites polymorpha Goeppe, and Lepidodendron veltheimianum Sterngberg, of Carboniferous age. Correlated with Pertjara Group of Amadeus Basin</td>
</tr>
<tr>
<td></td>
<td>Kerridy Sandstone (Pzy)</td>
<td>700</td>
<td>Reddish brown sandstone, and subgreywacke, medium to coarse, moderately sorted, silty, in part calcareous and arkosic, thin to thick bedded and commonly cross-bedded and convoluted. Some interbedded siltstone</td>
<td>Low irregular hills with small sharp hogbacks</td>
<td>Tentatively correlated with Carmichael or Stairway Sandstone in Amadeus Basin</td>
</tr>
<tr>
<td></td>
<td>Djagamara Formation (Pze)</td>
<td>320+</td>
<td>Grey and white sandstone, laminated and thick bedded, in part glauconitic, abundant clay pellets, mostly silicified and tough</td>
<td>Prominent hills, cuestas and strike ridges</td>
<td>Minimum age of 449 m.y. (K-Ar). Lithologically similar to Stairway and Pacoota Sandstones, Invertebrate tracks(?) at Mt Djagamara</td>
</tr>
<tr>
<td></td>
<td>Bloodwood Formation (Cz)</td>
<td>200+</td>
<td>Silstone, reddish brown to purple brown and pale green, thin bedded; red sandstone. Both in part richly micaceous. Convolute beds and current ripples common in siltstone</td>
<td>Well rounded hills</td>
<td>Abundant trace fossils and rare macrofossils near middle, Pennatulaceans, Helcionellis, and Protrichites and Rustophycus; probably Lower Cambrian</td>
</tr>
<tr>
<td></td>
<td>Waltiri Dolomite (Cw)</td>
<td>165+</td>
<td>Dolomite, light and dark grey, pink, thick-bedded, fragmental in part; siltstone, green and blue, in part micaceous; thin interbeds of pink sotmatolitic and oolitic dolomite and grey, well rounded, medium and coarse sandstone. Minor glauconitic dolomite near base</td>
<td>Rounded hills and low cuestas (dolomite); low mounds beneath scree slopes and in valleys (siltstone)</td>
<td>Brachiopods, hyolithids, and trilobite fragments. Lower Cambrian or ?Lower Middle Cambrian with Bloodwood F, correlated with Pertaoorta Gp of Amadeus Basin</td>
</tr>
</tbody>
</table>
The oldest formation in the Ngulia Basin is the Adelaidean *Vaughan Springs Quartzite* (Wells et al., in prep.), a tough, mostly well sorted, pink quartzite that forms prominent cuestas and hogbacks along the margins of the basin. The formation unconformably overlies the crystalline and metasedimentary rocks of the basement. The lower part of the formation includes a sequence of interbedded siltstone and fine-grained sandstone which has been called the *Treuer Member* (Wells et al., in prep.). The member is known in outcrop only in the northwest, but occurs in several other parts of the basin outside the Sheet area. The Adelaidean age is assigned to the formation on the strength of its correlation with the Heavitree Quartzite.

In the Yuendumu area the Vaughan Springs Quartzite is unconformably overlain by the *Yuendumu Sandstone* (Wells et al., in prep.), and in the Naburula Hills (730537) and Treuer Range (690530) area by the Mount Doreen Formation and the Mount Eclipse Sandstone.

The *Mount Doreen Formation* (Wells et al., in prep.) consists of siltstone, tillite, and minor dolomite. The erratics in the tillite consist mostly of igneous and metamorphic rocks and the largest observed, of quartzite, is about 4 m across. Many are striated and faceted. The formation unconformably overlies the Vaughan Springs Quartzite, the Patungala Beds, or crystalline basement rocks, and is unconformably overlain by the Mount Eclipse Sandstone and Djalamara Formation. Outcrops are confined to the Naburula Hills (730537) and Treuer Range (690530) in the northwest. The formation is assigned to the Adelaidean by virtue of its glacial affinities.

The *Yuendumu Sandstone* (Wells et al., in prep.) is mostly a fine and medium-grained reddish brown sandstone which crops out on the north side of the Walbiri Ranges (770529) south of Yuendumu Native Settlement. The basal part is commonly coarse-grained and feldspathic; the upper beds are finely micaceous and thin-bedded. The formation lies unconformably between the Walbiri Dolomite above and the Vaughan Springs Quartzite below. The formation has no internal evidence of age, but regional correlation suggests that it may straddle the Adelaidean-Cambrian boundary.

The *Walbiri Dolomite* (Wells et al., in prep.) is a sequence of dolomite, siltstone, and minor sandstone that crops out on the north side of the Walbiri Ranges (770529), south of the Yuendumu Native Settlement. The basal siltstone is very fossiliferous, although the fossils are mostly fragmented. The massive dolomite contains a few small poorly preserved brachiopods. The interbedded sandstone contains very well rounded medium and coarse quartz grains and is commonly cross-bedded. Some of the oolitic pink dolomite near the base contains large stromatolite colonies. The Walbiri Dolomite unconformably overlies the Yuendumu Sandstone and is overlain apparently conformably by the Bloodwood Formation. The fossils in its base suggest that it is Lower Cambrian or possibly lower Middle Cambrian (J. G. Tomlinson, pers. comm.); but the overlying Bloodwood Formation contains Lower Cambrian fossils. The Walbiri Dolomite is similar lithologically to the Giles Creek Dolomite of the Amadeus Basin but could equally well be correlated with the Todd River Dolomite.
The Bloodwood Formation (Wells et al., in prep.) occupies a small area north of the Walbiri Ranges mainly west of Djuburula Peak (778531). The contact with the underlying Walbiri Dolomite, although poorly exposed, appears to be conformable; it was penetrated in diamond drill holes near Djuburula Peak (778531). The formation is unconformably overlain by the Mount Eclipse Sandstone; no contacts with the ?Ordovician sequences have been seen. Fossils have been dated as Lower Cambrian (A. A. Öpik, pers. comm.): the age of the lower part of the Pertaabarra Group in the Amadeus Basin.

The Djagamara Formation (Wells et al., in prep.), consists of grey and white sandstone, interbedded in places with thick beds of green shale. In the Naburula Hills (730537) flow casts are common. The formation crops out in the Walbiri Ranges, Naburula Hills, Treuer Range, and Vaughan Springs Syncline. It overlies the Mount Doreen Formation unconformably in the Naburula Hills and at Davis Gap, and in the east is faulted against older rocks. It is overlain by the Kerridy Sandstone, apparently conformably near White Point (780530), but unconformably farther south and west; and unconformably by Mount Eclipse Sandstone in several places. The Djagamara Formation contains no internal evidence of age, but K-Ar dating on glauconite from a single sample of the Djagamara Formation yielded a minimum age of 449 m.y. (A. W. Webb, pers. comm.) which is Middle Ordovician on the currently accepted geological time scale.

The Kerridy Sandstone (Wells et al., in prep.) consists of interbedded purple to reddish brown sandstone and siltstone. In the Naburula Hills (730537) it lies unconformably between the Mount Eclipse Sandstone and the Djagamara Formation. The formation may be Ordovician in age and equivalent to one of the younger formations of the Larapinta Group of the Amadeus Basin.

The Mount Eclipse Sandstone (Wells et al., in prep.) consists of coarse-grained arkosic sandstone and greywacke, with interbedded cobble and boulder conglomerate and red micaceous siltstone. The phenoclasts in the conglomerate are mostly quartzite, occasionally mixed, and in places entirely limestone. The formation underlies large areas along the northern part of the Ngalia Basin, particularly in the Naburula Hills, south of Davis Gap, and in the Walbiri Ranges. A few scattered poor exposures occur in the central sand plain. The Mount Eclipse Sandstone unconformably overlies the Vaughan Springs Quartzite, Mount Doreen Formation, Bloodwood Formation, Djagamara Formation, and Kerridy Sandstone in different parts of the basin. The top is eroded. The plant remains close to the top have been dated as Carboniferous; the lower part could possibly extend into the Devonian.

Quaternary sediments form a thin superficial cover over large parts of the area. They include silcrete, ferricrete, travertine, alluvium and red soil, sand and sand dunes, colluvium, and evaporites in salt lakes. The most widespread deposit is aeolian sand in plains, and in a few dunes, mostly in the south. Tertiary lacustrine deposits are probably widespread beneath the Quaternary sediments, and unconsolidated sand, clay, and silt up to 180 m thick have been intersected in several stratigraphic boreholes (Evans & Nicholas, 1970). Tertiary microfossils were discovered in a thin lignite bed penetrated in a borehole to the east on the Napperby Sheet area; they indicate a post-Eocene and pre-Pliocene age (D. Burger, pers. comm.).
Figure 2. Mount Doreen structure map.
STRUCTURE

The main structural features of the Mount Doreen Sheet area, along with interpreted depths to magnetic basement and locations of seismic traverses, are shown in Figure 2.

The relationships between the mapped Precambrian basement rock types are not known. Most of the lineaments, trend-lines, and faults in these rocks strike about east-west but tend to parallel the northern margin of the Ngalia Basin. In the northwest, for example, the trend of the northern margin of the basin changes to southwest and the quartz dykes in the basement show a similar change of direction. Most of the quartz dykes probably mark the position of faults. Because the dykes are unfolded and follow the basin trends it is suggested that they were formed at the time of the major Carboniferous? orogeny that folded and thrusted the sediments in the Ngalia Basin.

The central part of the Ngalia Basin is exposed on the Mount Doreen Sheet area. It is an east-west elongated intracratonic depression in which up to 4 900 m of sediments are preserved. In cross-section the basin is asymmetrical; the greatest thickness of sediments is preserved towards its northern margin.

Two major diastrophic periods have affected the basin sediments and were preceded by several minor epeirogenic episodes. These episodes were responsible for vertical movements in the crust which are recorded in the sedimentary column by numerous unconformities. Extensive erosion followed each period of uplift and the formations were completely removed in places. A diagram on the geological map illustrates the rock relationships that resulted. It is suggested that because there is little angular discordance at most of the unconformities, parts of the area were near the edge of sedimentary deposition. Another important structural implication is that the formations extended over a larger area than outlined by the preserved basin margins and at times areas of deposition were continuous with nearby structural basins, including the Georgina, Amadeus, and Canning Basins.

The first major diastrophism in the basin occurred after the deposition of the Kerridy Sandstone and before that of the Mount Eclipse Sandstone. The age of the movement, which has been named the Kerridy Movement by Wells et al. (in prep.), is probably Silurian. It caused uplift along what is now the northern margin of the basin. The sediments were deformed and several thousand metres were eroded before the Carboniferous continental sediments were deposited. Uplifts of the basement probably occurred to the north of the basin to become the main provenance area for the Carboniferous deposits.

The last major diastrophism that occurred in the area caused major folding, thrusting, and faulting, probably in Carboniferous time. This event has been termed the Mount Eclipse Orogeny by Wells et al. (in prep.). The basement rocks were reactivated during this movement and in several places were thrust over the sediments for as much as 8.6 km. The thrusting is evident, and the sediments most deformed, along practically the whole of the northern margin of the basin. In places the beds are steeply overturned to the north (e.g. 13 km west of Davis Gap). There are no remnants of the sediments on the basement either north or south of the basin in the Mount Doreen Sheet area.
The sediments at the southern margin for the most part dip at moderate to steep angles northward into the basin and the contact with the basement is unconformable. The sediments have had a different history from those in the north. Upwarping of the basement to the south probably occurred during the Kerridy Movement and continued during the Mount Eclipse Orogeny: the effect was to tilt the sediments mainly towards the basin and in other places disrupt them by block faulting.

The folds in the sediments trend about east-west and are mostly doubly plunging. Fold amplitude decreases and wavelength generally increases towards the southern margin of the basin. Individual structures along the northern margin of the basin are described by Wells et al. (1968).

**Gravity surveys**

A regional reconnaissance gravity survey of the Mount Doreen Sheet area by BMR in 1967 is discussed by Whitworth (in prep.). A more detailed survey over part of the Ngailia Basin was made for Pacific American (Hudson & Campbell, 1965) and isolated profiles along BMR seismic lines have been observed (D. Townsend, BMR, pers. comm.). Figure 3 is a regional map showing Bouguer anomalies and gravity features. Parts of two major gravity features are present in the area—the Yuendumu Regional Gravity Low and the Papunya Regional Gravity Ridge. It might be expected that if a basement of uniform density existed then the gravity low would coincide with the Ngailia Basin and the less dense sediments. In fact the gravity minima occur well to the north of the basin over areas of crystalline basement rocks and the thickness of sediments appears to contribute little to the outline of the gravity anomalies.

Hence it may be deduced that the main contributing factors to the gravity anomalies are density gradients within the basement rocks. To produce such density contrasts it is postulated that mantle material is relatively closer to the surface in areas of positive Bouguer Anomalies such as the Papunya Regional Gravity Ridge. It has been demonstrated recently that high grade granulite facies rocks crop out in parts of these areas. The exact mechanism whereby mantle material is brought closer to the surface is not known. The most likely explanations are crustal warping as a result of basement uplift or large scale thrusting during major orogenies.

The position of the gravity minima to the north of the Ngailia Basin may be explained as being the net effect of density variations within the Precambrian basement rocks and the crustal foreshortening.

**Aeromagnetic survey**

An aeromagnetic survey by Aero Service Ltd for Pacific American Oil Co. (Hartman, 1963) included the sedimentary basin on the Mount Doreen Sheet area. The contours on interpreted depths to basement (Fig. 2) show that the basin is divided into two parts separated by a north-south basement swell. The estimated depth to magnetic basement is about 5 300 m (17 500 ft) below sea level in the
Fig. 3. Bouguer anomalies and gravity features of the Ngalia Basin.
eastern sub-basin and about 6 100 m (20 000 ft) in the western sub-basin, whereas
the basement swell near the centre of the basin is about 850 m (2 800 ft) below
sea level. The structure of the basin margin in outcrop and the seismic results add
further evidence for shallow basement in the central zone.

The areas of intense anomalies in the southeast have been interpreted as faulted
basement blocks which have a northward plunge. An abrupt change in magnetic
pattern in the northeast has been interpreted as a fault and corresponds approxi-
mately with the position of the Yuendumu Fault at the northern margin of the basin.

Seismic surveys

The first seismic survey was carried out by Geophysical Associates for Pacific
American Oil Co. (Hudson & Campbell, 1965, unpubl.) in the eastern part of the
Mount Doreen Sheet area. Their results were presented as a depth contour map
based on a horizon tentatively identified as Lower Palaeozoic. The maximum depth
to the ‘Lower Palaeozoic’ horizon is given as about 4 000 m. Several faults trending
east-west were identified and interpreted by the authors as thrust faults with over-
thrusting from the north. They suggested that salt in the stratigraphic section may
have acted as a glide plane for the postulated overthrusting. The survey confirmed
the presence of a deep basin that had been indicated previously by an aeromagnetic
survey.

Seismic surveys by BMR (Jones, 1969; Tucker, 1969, both unpubl.) were
made in the Mount Doreen Sheet area in 1967, 1968, and 1969; the traverse lines
are shown on Figure 2. The surveys crossed the basin from north to south, with
cross-traverses in places to tie with the previous work of Hudson & Campbell
(op. cit.). The traverse lines were located in the west along Waite Creek, south
of Davis Gap to the southern margin and southwest of Mount Allan in the east.

The seismic surveys carried out by BMR confirmed the asymmetry of the basin
and showed that its major axis lies towards the northern margin. The sediments
dip gently northwards from the southern margin towards this axis. North of the axis
the structure is more complicated, with folding and several major faults, and at
least one and possibly two large overthrusts. In the west at Waite Creek the seismic
results indicate overthrusting from the north of about 9-10 km; the sediments here
are about 4 000 m thick, one of the thickest sections in the basin. A similar maximum
thickness of sediments is indicated about 18 km south of Mount Allan, and about
3 800 m of sediment is present at Davis Gap and as far as 13 km farther south.

The other area of possible major overthrusting detected by the seismic surveys
occurs just south of the Naburula Hills; this overthrust may possibly be a continu-
ation of the Yuendumu fault.

In the cross sections at Waite Creek and Davis Gap the more prominent
reflections have been correlated with three formations—the Mount Eclipse
Sandstone, Mount Doreen Formation, and Vaughan Springs Quartzite. The distribu-
tion of the seismic events in cross-section suggests that these three formations
constitute most of the sedimentary sequence.
GEOLOGICAL HISTORY

The earliest history of the area is recorded in the Precambrian metasedimentary, high grade metamorphic, and igneous basement terrain. The geochronology of these rocks is unknown, but the Paimungala Beds are probably the youngest metasediments in the basement and the youngest igneous rocks are the granites that intrude them. The schists and quartzites that trend east-west across the northern part of the Sheet area, which are also intruded by granite, are presumed to have been deposited after the formation of the high-grade gneissic rocks and granulites, but their relationship to the Paimungala Beds is unknown.

The late Precambrian and Phanerozoic geological history of the Mount Doreen Sheet area can be summarized as follows:

1. Uplift and planation of the early Precambrian basement rocks.
2. Subsidence of the area and invasion by the sea.
3. Deposition, probably in the Adelaidian, of the Vaughan Springs Quartzite in a shallow marine environment.
4. Uplift and erosion of the Vaughan Springs Quartzite mainly in the central part of the Sheet area. In the Naburula Hills area it was completely removed from large areas of the granite basement rocks.
5. Deposition of the Mount Doreen Formation in the western part of the Sheet area (Naburula Hills and farther west) in Adelaidian time. The youngest part of the formation was laid down during a glacial episode, and a large part of the formation accumulated in a shallow marine environment. The abundance of crystalline basement phenoclasts attests to the presence of nearby basement rocks at this time.
6. Deposition of the Yuendumu Sandstone in the late Adelaidian and possibly early Cambrian on eroded Vaughan Springs Quartzite eroded in the east, possibly in a marine environment. The formation was apparently not deposited in the west.
7. In the area south of Yuendumu Native Settlement the Walbiri Dolomite, Bloodwood Formation, Djagamara Formation, and Kerridy Sandstone were laid down in Cambrian and Ordovician times. The transgression of the early Cambrian sea was probably limited to the eastern part of the Sheet area. The Walbiri Dolomite was deposited unconformably on the Yuendumu Sandstone and was followed conformably by the Bloodwood Formation.
8. After early Cambrian sedimentation there was a major regression and the Sheet area was probably land in the late Cambrian and early Ordovician. Evidence of erosion and any movement in this period is lacking as the contact between the Cambrian and Ordovician rocks is faulted.
9. The succeeding Ordovician marine transgression, however, extended much farther west and probably covered the whole of the Sheet area. In the west the Djagamara Formation overlaps the Cambrian rocks and rests unconformably on
Adelaidean formations of the basin. The younger Kerridy Sandstone was probably not deposited west of the Naburula Hills and was most probably laid down in a regressive phase. The formation may have been deposited partly under terrestrial conditions.

10. The sea then retreated from the area for the last time and the area was strongly affected by diastrophic movements, the Kerridy Movement of Wells et al. (in prep.). Faulting formed the northern margin of the basin and large areas of basement rocks were uplifted to the north and south of the basin, providing a source for the Carboniferous sediments.

11. The Carboniferous Mount Eclipse Sandstone was deposited in a combination of alluvial and piedmont environments on most of the older formations in the basin. The formation was derived from sediments eroded from upfaulted blocks and from areas of basement rocks mainly to the north of the basin.

12. The final orogenic episode in the basin, the Mount Eclipse Orogeny of Wells et al. (in prep.), threw the sequence into a series of tight folds. The basement rocks were thrust over the basin sediments, at the northern margin, in places for several kilometres. The intensity of deformation of the sediments decreased from north to south. At the same time the basement to the south of the present margin of the basin was subjected to broad vertical movements causing the gentle northward tilt of the overlying sediments. Tensional forces were prevalent in this zone as opposed to thrusting and in places the sediments yielded by block faulting.

13. A prolonged period of erosion ensued and most of the folds were breached. The erosion probably produced a landscape of high relief, with the resistant quartzite ridges and some of the Precambrian rocks forming high scarps and ridges.

14. During the Tertiary Period, terrestrial clay, silt, and sand accumulated in valleys, flood plains, and lakes. The present level of some of the deposits and the existence of a superimposed drainage pattern suggest that a large part of the Palaeozoic and Precambrian rocks in the Sheet area was covered at the end of Tertiary deposition.

15. The Tertiary sediments were eroded, probably as a result of regional tilting. Drainage patterns were superimposed on the underlying Precambrian and Palaeozoic formations in places. A deep weathering profile developed on the Precambrian and Palaeozoic rocks and was later dissected in the subsequent pluvial periods.

16. Dunes and sand plains were formed in a subsequent arid phase, but the climate later ameliorated and dunes were fixed by a sparse cover of vegetation. A pattern of internal drainage was probably initiated during the regional tilting and playa lakes developed along the southern margin of the Sheet area. The major drainage divide lies along the northern margin of the basin; streams draining the basement rocks flow northwards, and the few that cross the basin flow to the south towards the playa lakes, which act as a focus of internal drainage.
17. The latest events in the geological history of the area include the deposition of alluvial red soils, alluvium, colluvium, and stream deposits, formation of travertine in the sand of low-lying areas, and the evaporite crusts of playa lakes.

ECONOMIC GEOLOGY

Petroleum

The Mount Doreen Sheet area includes the largest part of the Ngalia Basin, within which there are large thicknesses of Palaeozoic as well as Adelaidian sediments. Some Palaeozoic rocks are possible source rocks for petroleum. However, the basin is unlikely to be a large oil producer, for several reasons. First, there are few good cap rocks and reservoir beds. The many unconformities in the sequence indicate periods of uplift, accompanied by prolonged erosion. The likely source beds are Cambrian and Ordovician and statistically are less likely to contain large quantities of petroleum than much younger rocks. Lastly, the structures in the sediments were impressed during the Upper Palaeozoic, and since this time erosion has exposed the source beds or possible reservoirs in the cores of many folds. The petroleum potential of the area is therefore not rated highly.

Water supply

Subsurface water in the area is used for domestic water supplies at the Yuendumu Native Settlement, and at Mount Doreen and New Haven homesteads. A large number of bores at widely spaced localities are used by the cattle industry. Up to early 1967 over 170 water bores and wells had been completed; they are listed by Kingdom et al. (1967, unpubl.). Bore data sheets are on file in the Resident Geologist’s Office, Alice Springs.

Water bores drilled into basement rocks are rarely successful, but those in the sediments of the Ngalia Basin yield greater supplies, although the water is not always of good quality. Probably the best quality and supply of water is available from the Quaternary and Tertiary superficial sediments. Water encountered in the stratigraphic holes drilled in the Ngalia Basin area is believed to occur in Tertiary sediments. The water was usually struck at depths between 25 and 30 m.

Surface water in the area is not plentiful because of the arid climate. Native wells are found close to or in stream channels but yield little water. The known surface waters include Kerrij (783520), Odnapinna (762476), and Pulca Currinya (790477) water holes, which often retain water all the year round. Of the natural springs shown on the map, Vaughan Springs is probably the largest. It provides about 7.3 kilolitres per hour of excellent quality water.

Miscellaneous deposits

Some mineral deposits in the northern half of the Sheet area have been worked in the past, and many other, smaller, occurrences are known. Most occur in the Precambrian basement rocks, but a few are known in the sediments of the Ngalia Basin. The more common minerals in the deposits include secondary copper, wolframite, barytes, fluorite, galena, and iron oxides. Industrial minerals include building stone, dolomite and limestone, gravel, and evaporites.

The main mineral occurrences are briefly described in Table 3. Most of the deposits in the basement rocks are confined to outcrops of mica schist and quartzite,
### Table 3: MINERAL DEPOSITS—MOUNT DOREEN SHEET AREA

<table>
<thead>
<tr>
<th>Name of mine or deposit</th>
<th>Locality and grid reference</th>
<th>Main metal</th>
<th>Minerals present (major minerals italicized)</th>
<th>Country rock</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nobagalong</td>
<td>13 km NW of Yuendumu, 781544 Settlement</td>
<td>Copper</td>
<td>Malachite, cuprite</td>
<td>Other deposits to E and W</td>
<td></td>
</tr>
<tr>
<td>Silver King</td>
<td>18 km W of SW from Wolfram Hill, 725552</td>
<td>Copper</td>
<td>Azurite, malachite, chalcocite, cerussite, galena, anglesite, linarite, native silver, brochantite or antlerite, 1cuprite, manganese oxides Galena</td>
<td>Mica gneiss and quartzite gneiss</td>
<td>Two shafts sunk</td>
</tr>
<tr>
<td>Patmungala</td>
<td>22 km SSW of old Mt Lead Doreen homestead, 731541</td>
<td></td>
<td></td>
<td>Patmungala Beds—vitrice crystal tuff</td>
<td>Prospecting pits only</td>
</tr>
<tr>
<td>White Point IP Anomaly</td>
<td>1.2 km W of White Point, 779531</td>
<td></td>
<td></td>
<td>Walbiri Dolomite</td>
<td>Two diamond drill holes with negative results</td>
</tr>
<tr>
<td>Yuendumu</td>
<td>7.2 km SW of Yuendumu, Settlement, 782533</td>
<td>Copper</td>
<td>Malachite, chalcocite, azurite</td>
<td>Walbiri Dolomite</td>
<td>One pit</td>
</tr>
<tr>
<td>White Point</td>
<td>1.2 km SW of Yuendumu, Settlement, 779531</td>
<td>Barium</td>
<td>Barytes and galena</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mount Hardy Copper Mine</td>
<td>2.6 km N of Mt Hardy Copper Mine, 766557</td>
<td>Copper</td>
<td>Malachite, chalcocite</td>
<td>Quartz reef</td>
<td></td>
</tr>
<tr>
<td>Mount Hardy Copper Mine</td>
<td>27 km NW of Yuendumu, Settlement and 6.4 km ENE of Mt Hardy, 766552</td>
<td>Copper</td>
<td>Malachite, azurite, chalcocite, galena</td>
<td>Gneiss and schist. Copper in quartz veins and gneiss</td>
<td>755 tons of ore extracted by end 1967</td>
</tr>
<tr>
<td>Mt Hardy (Prospect 1)</td>
<td>Abt 6.4 km NE of Mt Copper Hardy and 1.6 km W of Mt Hardy copper mine, 765555</td>
<td>Copper</td>
<td>Malachite, azurite, chalcocite</td>
<td>Micaceous schists with quartz reefs</td>
<td></td>
</tr>
<tr>
<td>Mt Hardy (Prospect 2)</td>
<td>About 1.6 km W of Prospect No. 1, 765554</td>
<td>Copper</td>
<td>Malachite, azurite, chalcocite, bornite</td>
<td>Quartz veins in quartz schists and gneisses</td>
<td></td>
</tr>
<tr>
<td>Clark Mine No. 1</td>
<td>26.4 km W of Wolfram Hill, 711561</td>
<td>Copper</td>
<td>Malachite, azurite, cuprite</td>
<td>Quartz vein in mica schist and gneiss</td>
<td></td>
</tr>
<tr>
<td>Clark Mine No. 2</td>
<td>26.4 km W of Wolfram Hill, 711561</td>
<td>Copper</td>
<td>Malachite, azurite</td>
<td>Quartz vein in mica-quartz gneiss and chlorite-mica schist</td>
<td></td>
</tr>
<tr>
<td>Clark Mine No. 3</td>
<td>26.4 km W of Wolfram Hill, 711561</td>
<td>Copper and tungsten</td>
<td>Malachite, azurite, chalcocite, wolframite, scheelite, pyrite, tinanite, cerussite brochantite, chrysocolla, siderite, galena, wolfinite, argentite, gold</td>
<td>Quartz veins in mica-quartz gneisses</td>
<td></td>
</tr>
</tbody>
</table>

Data obtained mainly from files in Resident Geologist's Office, N.T.A., Alice Springs, N.T.
a belt of which runs from 6.5 km north of Yuendumu Native Settlement westwards through Mount Hardy, Wolfram Hill, and the Clark Mine to Venerable Creek in the northwest. The rocks in this belt contain copper, wolframite (Mount Doreen Wolfram Field), and silver and lead (Silver King Mine). The rocks are similar lithologically to those present in the Reynolds Range farther east and show a similar type of mineralization. They are probably the same age.

Apart from the mineralization in this belt the only known mineral deposits in the basement rocks occur in the Patmungala Beds on the north side of the Naburula Hills (730537) and in quartz veins in the same region. The mineralization occurs in the vitric tuffs and consists of secondary copper staining and galena.

Fluorite is common in the quartz veins just north and northwest of Dja'gamarra Peak (737538) and in a quartz vein about 1½ km south of the Yuendumu/Mount Doreen road (733529) in the Naburula Hills.

Small mineral occurrences are known in the sediments of the Ngalia Basin. Secondary copper deposits occur in several places both in brecciated dolomite and in the basal siltstone and shale of the Walbiri Dolomite southwest of Yuendumu Settlement (788536). A copper occurrence has also been recorded in the Dja'gamarra Formation near White Point (780530).

Small occurrences of barytes together with minor amounts of galena are present in the Walbiri Dolomite about 0.8 km northwest of White Point on the north side of the Walbiri Ranges (779531).

The only deposits being worked at present are the copper deposits at Mount Hardy (761554), and building stone from the Yuendumu Sandstone south of Yuendumu Settlement (788536). All other known deposits are small and at present uneconomic.

The copper deposits at Mount Hardy are being worked by Aborigines from the Yuendumu Settlement. The ore is hand-picked and then transported to the settlement, where a small treatment plant is being installed. The treatment process will involve acid leaching of the ore and precipitation of the copper from solution.

The building stone at Yuendumu Native Settlement is used extensively for paths, retaining walls, and buildings. The stone is quarried about 4.8 km south of the settlement where flat paving slabs are obtained from the upper part of the Yuendumu Sandstone. The sandstone is a finely micaceous reddish brownstone, and splits easily into slabs about 8-10 cm thick.

The Cainozoic gravels shedding from the Vaughan Springs Quartzite on the north-facing slopes just south of Yuendumu Settlement have been screened and used from time to time for road surfacing.
BIBLIOGRAPHY

Published


STUART, J. MCDONALL, 1865—Explorations in Australia; the journals of John McDouall Stuart during the years 1858-1862, etc. *London, Saunders, Oiley & Co. 2nd Ed.*

TERRY, M., 1934—Explorations near the border of Western Australia. *Geogr. J.*, 84(6), 498-510.


Unpublished

Most unpublished references can be consulted either at the Bureau of Mineral Resources, A.C.T., or at the Resident Geologist's Office, Alice Springs, N.T.


AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES, 1967—Twenty-two samples from the Ngalia Basin. Ibid., MP 827-68.

AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES, 1968a—Fifty-seven miscellaneous rocks. Ibid., MP 571-69.

AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES, 1968b—The petrography of fifty-four rock samples from the Mount Doreen and Lake Mackay Sheet areas in the Northern Territory. Ibid., MP 1080-69.

AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES, 1969—Three brief descriptions and one identification. Ibid., MP 2312-69.


PACIFIC AMERICAN, 1964—Photogeological map (1 : 250 000) of permit 81 (Ngaila Basin) by B. J. Fitzpatrick for Pacific American Oil Co.


