HENBURY
NORTHERN TERRITORY
COMMONWEALTH OF AUSTRALIA

1 : 250,000 GEOLOGICAL SERIES—EXPLANATORY NOTES

Henbury, N.T.

SHEET SG/53—1 INTERNATIONAL INDEX

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Minister for National Development

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
CANBERRA 1968
Explanatory Notes on the Henbury
Geological Sheet

The Henbury 1 : 250,000 Sheet area covers about 6500 square miles in the
southern part of the Northern Territory. It is situated in the central part of
the Amadeus Basin, a basin containing Proterozoic and Palaeozoic sedi-
ments, with some superficial Tertiary and Quaternary deposits.

Alice Springs, the town nearest the Sheet area, is about 140 miles from
Tempe Downs homestead and about 80 miles from Henbury homestead.
Access from Alice Springs is by graded highway, which runs through
the east side of the Sheet area. Numerous graded tracks run from the
highway to the homesteads and bores. There are four occupied station hom-
esteads, tourist camps at Wallera Ranch and Palm Valley, and a settlement
and mission station for aborigines at Areyonga. Rain falls mostly in summer
storms and is most unreliable; the average annual rainfall is about 10 inches.
Temperatures are high in summer, frequently exceeding 100°F, but
moderate in winter, with a maximum normally of about 70-80°F and
with frequent frosts at night.

Maps and air-photographs covering the Henbury Sheet area are available
from the Division of National Mapping, Department of National Develop-
ment, Canberra. They are: Photomosaic at a scale of 4 miles to 1 inch;
planimetric map, at a scale of 4 miles to 1 inch; dyeline maps at a scale of
approximately 1 : 46,000 (air-photograph scale), controlled by a slotted-
templet assembly, with principal points, wing points, topography and
drainage; air-photographs, flown at 25,000 feet by the R.A.A.F. at a scale
of approximately 1 : 46,000.

Previous Geological Investigations

The Henbury Sheet area was first explored in 1860 by John McDouall
Stuart (Stuart, 1861), but it was not visited by a geologist until 1886, when
Chewings investigated the source of the Finke River. Chewings later referred
to the Henbury area in a number of papers (Chewings, 1891, 1894, 1914,
1928, 1931, 1935). Brown, who first visited the area in 1889, also made
reference to it in several papers (Brown, 1890, 1891, 1892, 1895). The
first fossils to be found in the Amadeus Basin were discovered in the Tempe
Downs area by Brown, who published Etheridge's identifications in several
of his papers. The Horn Expedition of 1892 (Tate, 1896) spent several
weeks in the vicinity of Tempe Downs and made extensive fossil collections
from the Larapinta (Larapintine of Tate) Group.
In 1916 a government surveying party travelled through the Sheet area and Day (1916) recorded the presence of sandstone ridges and scarps in the Angas Downs area. Ward (1925), Mawson (Mawson & Madigan, 1930), and Madigan (1931, 1932) all briefly mention the Henbury Sheet area, but their interests were mainly in the MacDonnell Ranges to the north. Joklik (1952) made a few geological observations in the Angas Downs area.

In 1953 the National Lead Company carried out a geochemical and drilling programme in the Waterhouse Range in the search for copper.

The Bureau of Mineral Resources undertook its first programme of geological mapping in the Amadeus Basin in 1956, when Prichard & Quinlan (1962) mapped the southern part of the Hermannsburg Sheet area. This work has formed the basis for much of the later geological work. In 1957, Quinlan reconnoitred much of the Amadeus Basin, including the Henbury Sheet area (Perry et al., 1962). Brunnschweiler made a short visit to the area in 1959 (Brunnschweiler, 1959, unpubl., 1961) and made general geological observations. Gillespie and Leslie of Frome-Broken Hill Pty Ltd undertook reconnaissance geological mapping of the area (Leslie, 1960, unpubl.) and made extensive palaeontological collections (Taylor, 1959, unpubl.). Frome-Broken Hill Pty Ltd later relinquished their oil permits in the area. The permits were granted to Magellan Petroleum Corporation, who have since been mapping their oil permit leases (Stelck & Hopkins, 1962; McNaughton, 1962, unpubl.; Haines, 1963, unpubl.; Rannef, 1963; Williams et al., 1965).

The area was photo-interpreted in 1960 by the Institut Français du Pétrole for the Bureau of Mineral Resources as part of a programme covering the whole basin (Scanvic, 1961, unpubl.). From 1960 to 1964 the Bureau of Mineral Resources carried out a programme of reconnaissance geological mapping of the entire Amadeus Basin. The reports on the various areas are listed in the bibliography. As part of this programme, the Henbury Sheet was mapped in 1963, with Ranford and Cook mapping the northern three quarters and Wells and Stewart the southern quarter (Ranford et al., 1966). The geology of the whole basin is discussed by Wells et al. (1967, in press).

The Bureau of Mineral Resources began geophysical work in the Henbury Sheet area in 1960 (Goodeve, 1961, unpubl.), when two aeromagnetic traverse lines were flown across the area. An aeromagnetic and radiometric survey was flown by the Bureau of Mineral Resources in 1965 (Young & Shelley, 1966, unpubl.). A helicopter gravity survey was carried out in 1962 (Lonsdale & Flavelle, 1963, unpubl.). Seismic work in the Sheet area includes a short traverse over Palm Valley Anticline in 1961, a detailed survey in the vicinity of Exill Highway No. 1 in the James Ranges, and a traverse along the main road south of Palmer Valley homestead.

The first well to be drilled in the search for oil was Palm Valley No. 1, which was drilled during 1965 by Magellan and partners. Two wells were also drilled in 1965 by Exoil and partners—James Range ‘A’ No. 1 and Highway No. 1.

The Henbury meteorite craters have attracted a large number of visitors since they were first described by Alderman (1932) (see Appendix 1).

**PHYSIOGRAPHY**

The areas of greatest relief are areas of gently folded Palaeozoic sediments. The distribution of the six main physiographic divisions in the Sheet area is shown in Figure 1.

The various physiographic divisions are discussed briefly below.

*High mountain ranges and hills:* the ranges and hills rise from 200 to 1000 feet above the general level of the sand plain. The three areas comprise the Waterhouse Range, the James, Gardiner, and Levi Ranges, and the Chandlers Range. These ranges are generally underlain by Pernjara Group and Merene Sandstone, and a small area of Larapinta Group. Many of the ranges have steep marginal escarpments. Drainage follows strike valleys and joint and fault patterns in the Merene Sandstone, or is dendritic over the Pernjara Group.

*Low ranges and hills with intervening sand dunes and sand plain:* hills in this division rise 50-200 feet above the surrounding plain and are generally composed of steeply dipping Larapinta Group sandstones or Winnall Beds.

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Fig. 1. Physiographic divisions. A—high ranges and hills; B—low ranges and hills with dunes and sand plain; C—sand plain with dunes and sand outcrops; D—sand plain with dunes; F—gibber or alluvial plain with mesas; G—alluvial flood plains.
Drainage tends to follow strike valleys locally, but the overall drainage pattern is either south towards the Lake Amadeus salt lake system or east towards the River Finke.

Sand plain with many sand dunes and some low outcrops: this division covers only a small part of the Sheet area. Within it, sandstones are only poorly defined, and outcrops rise only about 10 feet above the sand plain. The drainage pattern is poorly developed, with only a few small watercourses.

Sand plain with dunes: outcrops are very rare or completely absent in most areas. The sand dunes, which are of the braided type, are up to 50 feet high; their overall trend is to the south-west. Although the Finke and Palmer Rivers flow through areas of the division, there is no well developed local drainage pattern.

Gibber or alluvial plain with mesas and low hills: the mesas and hills rise to 100 feet above the general level of the plain. The geology of this division is somewhat variable, but in most places the controlling geological feature appears to be the presence of a thin veneer of Tertiary sediments or of silcrete (formed in the Tertiary weathering profile) which forms the hard capping of the mesas. Drainage is locally controlled by hills, but in general is directed towards the Finke or Hugh Rivers.

Alluvial flood plains with some clay pans: this is a low, monotonous area with no defined drainage pattern. There are few outcrops. The area is probably underlain by Tertiary sediments.

STRATIGRAPHY

Rock units are named according to the Australian Code of Stratigraphical Nomenclature. All formation and group names have been approved by the Territories Committee on Stratigraphical Nomenclature. The stratigraphy and palaeontology are summarized in Table 1.

Two formations have their type localities in the Henbury Sheet area—the Quandong Conglomerate and the Chandler Limestone. They have been defined by Ranford et al. (1966). All other formations were originally defined outside the Henbury Sheet area, by Prichard & Quinlan (1962), Wells et al. (1965b, 1967, in press), or Ranford et al. (1966).

Most of the ages of units have been obtained from palaeontological data supplied by Miss J. G. Tomlinson (BMR, pers. comm.). Some sediments from other areas have been dated isotopically. The oldest unit of the Amadeus Basin sequence, the Heavitree Quartzite, is not exposed in the Henbury Sheet area, nor is there any exposure of crystalline basement.

GEOPHYSICS

Gravity (see Fig. 2)
The bouguer anomaly map shows a gradient across the Sheet, with isogal values ranging from −60 mgals on the southern margin of the Sheet area to −120 mgals on the northern margin. Parts of two gravity features recognized
<table>
<thead>
<tr>
<th>Period</th>
<th>Rock unit</th>
<th>Lithology</th>
<th>Thickness (metres)</th>
<th>Stratigraphic relationship</th>
<th>Palaeoecology</th>
<th>Water supply</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allervium (Qa)</td>
<td>Silts, sands, gravels.</td>
<td></td>
<td>100+</td>
<td>Unconformable or discordant on older sediments.</td>
<td></td>
<td>Good potential for high quality water.</td>
<td>Mainly associated with percolation drainage. Present mainly in southern part of the area. Commonly over limestone and dolomite. Commonly round salt lakes. Probably from weathering of Tertiary conglomerates.</td>
</tr>
<tr>
<td>Sand (Qa)</td>
<td>Fine-grained arenite sand.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Travertine (Qf)</td>
<td>Grey &amp; white, vein, calcite.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Gympum (Qg)</td>
<td>Grey &amp; white, soft, friable.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Conglomerate (Qc)</td>
<td>Well-rounded unconsolidated conglomerate.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Limestone (T)</td>
<td>Grey &amp; white limestones &amp; cherts.</td>
<td>unded limestones &amp; sandstones.</td>
<td>100</td>
<td>Unconformable or discordant on older sediments.</td>
<td></td>
<td>Fresh water.</td>
<td></td>
</tr>
<tr>
<td>Conglomerate (Ti)</td>
<td>Rounded pebbles, cobbles, and boulders in poorly sorted sandstone matrix.</td>
<td>50+</td>
<td>Unconformable or discordant on older sediments.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silcrete (Th)</td>
<td>Grey, white, pale brown hard silcrete.</td>
<td></td>
<td>10</td>
<td>No fossils.</td>
<td></td>
<td>Marine fossils.</td>
<td></td>
</tr>
<tr>
<td>Laterite (Ta)</td>
<td>Dark brown, limonitic limestone &amp; sandstone.</td>
<td></td>
<td>20+</td>
<td>No fossils.</td>
<td></td>
<td>Some fossils, but generally salty.</td>
<td></td>
</tr>
<tr>
<td>Sandstone (Ts)</td>
<td>White kaolinitic sandstone &amp; sandy silcrete.</td>
<td></td>
<td>60+</td>
<td>Wood fragments.</td>
<td></td>
<td>Very poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Hemmenburg Sandstone (Pcr)</td>
<td>Red-brown fine to coarse sandstone &amp; thickly bedded silcrete, including carbonate limestones and silcretes.</td>
<td>1500+</td>
<td>Unconformable on Menonie Sandstone &amp; possibly on Park Silite. Conformable on Menonie Sandstone &amp; unionable in south.</td>
<td></td>
<td>Plant remains (sphagnum) &amp; a fish spine.</td>
<td>Potential for some local supply of moderate quality water. No potential.</td>
<td></td>
</tr>
<tr>
<td>Park Silite (Pcr)</td>
<td>Red-brown micaceous limestone, silcrete, interbeds of calcareous silcrete, limstone &amp; sandy silcrete.</td>
<td>1800</td>
<td>Unconformable on Menonie Sandstone &amp; unionable in south.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Menonie Sandstone (Pm)</td>
<td>White thinly bedded fine to medium cross-beded framboidal sandstone.</td>
<td>200</td>
<td>Unconformable on Conicalus Sandstone, locally unconformable on older formations.</td>
<td></td>
<td>Worn trilobes &amp; common marine fossils.</td>
<td>Large yield of high quality water. Some aeolian influences apparent.</td>
<td></td>
</tr>
<tr>
<td>Conicalus Sandstone (Pm)</td>
<td>Red-brown fine to medium poorly sorted kaolinitic sandstones, some thin silcrete interbeds.</td>
<td>460</td>
<td>Gradational from Stokes Silite.</td>
<td></td>
<td>Coastal and estuarine sediments.</td>
<td>Moderate yield of good quality water. Some pseudomorphs after halite.</td>
<td></td>
</tr>
<tr>
<td>Stokes Silite (Os)</td>
<td>Grey &amp; green silcrete with thin interbeds of pink &amp; yellow limonites, grey fine-grained sandstone, rare phosphatic nodules.</td>
<td>1500</td>
<td>Gradational from Stairway Sandite.</td>
<td></td>
<td>Marine fossils.</td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Stairway Sandite (Os)</td>
<td>White fine to coarse well sorted sandstone with interbedded green silcrete &amp; thin phosphatic &amp; limestone bands.</td>
<td>180</td>
<td>Conformable on Horst Valley Sandite.</td>
<td></td>
<td>Marine fossils.</td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Horst Valley Limestone (Os)</td>
<td>Grey-green, thick-bedded sandstone &amp; silcrete with interbedded grey limestone.</td>
<td>350</td>
<td>Conformable on Horst Valley Sandite.</td>
<td></td>
<td>Marine fossils.</td>
<td>Poor prospects.</td>
<td></td>
</tr>
<tr>
<td>Pacifica Sandite (E-Gp)</td>
<td>Grey &amp; white fine to coarse well sorted and sorted to thinly bedded sandstone with thin silcrete interbeds.</td>
<td>2050</td>
<td>Conformable on Pacifica Sandite.</td>
<td></td>
<td>Fossiliferous: numerous tracks and trails.</td>
<td>Likely to provide much good quality water.</td>
<td></td>
</tr>
<tr>
<td>Geyer Formation (Cf)</td>
<td>Yellow &amp; brown fine to medium sandstone &amp; calcareous sandstone, brown silcrete, lenses of grey-brown dolomite.</td>
<td>180</td>
<td>Conformable on Priorizer Sandite.</td>
<td></td>
<td>Algic in place.</td>
<td>Other fossils rare.</td>
<td></td>
</tr>
<tr>
<td>Priorizer Sandstone (Cf)</td>
<td>Red-brown fine to medium micaceous sandstone with thin interbeds of brown silcrete &amp; lenses of sandy limonite.</td>
<td>60</td>
<td>Conformable on Deception Form. in east.</td>
<td></td>
<td>Non-diagnostic fragments.</td>
<td>Other fossils rare.</td>
<td></td>
</tr>
<tr>
<td>Deception Formation (Cf)</td>
<td>Red-brown, laminitic micaceous sandstone &amp; calcareous in part.</td>
<td>240</td>
<td>Conformable on Deception Form.</td>
<td></td>
<td>Non-diagnostic fragments.</td>
<td>Other fossils rare.</td>
<td></td>
</tr>
<tr>
<td>Eros Sandite (Cf)</td>
<td>Brown fine to medium thin-bedded sandstone &amp; silcrete sandstone.</td>
<td>240</td>
<td>Conformable on Eros Sandite.</td>
<td></td>
<td>No fossils.</td>
<td>No fossils.</td>
<td></td>
</tr>
<tr>
<td>Elk Creek Limestone (Cf)</td>
<td>Brown fine to medium thin-bedded sandstone &amp; silcrete sandstone.</td>
<td>900+</td>
<td>Conformable on Elk Creek Limestone.</td>
<td></td>
<td>Probably conformable on Elkhorn Creek Limestone.</td>
<td>Only recognized in north-west corner.</td>
<td></td>
</tr>
<tr>
<td>Elkhorn Creek Limestone (Cf)</td>
<td>Pale grey limestone, dolomite, and orange limonite with grey, brown, and green silcrete.</td>
<td>900+</td>
<td>Conformable on Eros Sandite.</td>
<td></td>
<td>Probably some supply from cleaner sandstones.</td>
<td>Only present in north-west corner.</td>
<td></td>
</tr>
<tr>
<td>Tempe Formation (Cf)</td>
<td>Brown &amp; green limonite &amp; shale with interbedded grey limestone &amp; dolomite &amp; Oolitic sandstone.</td>
<td>50</td>
<td>Conformable on Tempe Formation.</td>
<td></td>
<td>No fossils.</td>
<td>No fossils.</td>
<td></td>
</tr>
<tr>
<td>Chandler Limestone (Cf)</td>
<td>Brown &amp; green limonite &amp; dolomite.</td>
<td>300</td>
<td>Conformable on Chandler Limestone.</td>
<td></td>
<td>Gritstone, terebentites, algic.</td>
<td>Other fossils rare.</td>
<td></td>
</tr>
<tr>
<td>Ennis Sandite (Ca)</td>
<td>Brown poorly sorted thin-bedded sandstone with conglomeratic bands, silty sandstone, &amp; silcrete.</td>
<td>310</td>
<td>Conformable on Chandler Limestone.</td>
<td></td>
<td>Tilted beds, gypsophiles, black shales.</td>
<td>Other fossils rare.</td>
<td></td>
</tr>
<tr>
<td>Quadracon Conglomerate (Ca)</td>
<td>Conglomerate with boulders up to 12&quot; &amp; lenses of conglomeratic sandstone &amp; pale brown cross-bedded sandstone.</td>
<td>500</td>
<td>Unconformable on Pacifica Sandite.</td>
<td></td>
<td>No fossils.</td>
<td>Prospects poor.</td>
<td></td>
</tr>
<tr>
<td>Wannell Beds (Pw)</td>
<td>Silts, sands at base; then massive cross-bedded sandstone; silty conglomerate; top a brown medium-bedded sandstone.</td>
<td>350+</td>
<td>Unconformable on Pacifica Sandite. (7 and Invidia Beds.)</td>
<td></td>
<td>Indeterminate tracks and trails.</td>
<td>Good supply in places but water highly saline.</td>
<td></td>
</tr>
</tbody>
</table>

*Note: the table provides a detailed stratigraphy of the Hinchinbury Shale Area, including rock units, their thicknesses, stratigraphic relationships, palaeoecology, water supply, and remarks about their geological significance.*
by Lonsdale & Flavelle (1963, unpubl.) occur in the Sheet area: the Angas Downs Gravity Ridge in the south-west corner and the Amadeus Gravity Depression in the north. A further feature known as the Henbury/Lake Eyre Gravity Trough (Cook, 1966b, unpubl.) crosses the south-east corner. This trough is related to the Illamurta structural zone, a zone of diapiric growth. It forms a very distinct break between the Angas Downs Gravity Ridge to the west and the Rodinga Gravity High to the east.

A characteristic feature of the Bouguer anomaly map of the Sheet area (and of many other parts of the Amadeus Basin) is that antinodes do not appear as gravity maxima. This suggests that basement is not involved in the folding and that there is probably a major décollement between basement and the sediments. The main incompetent unit is the Bitter Springs Formation, which commonly forms the cores of anticlines and may be associated with gravity minima.

Aeromagnetic (see Fig. 2)

The depth to magnetic basement ranges from 32,000 feet in the north-west corner of the Sheet area to 12,000 feet in south-east. In general the total thickness of non-magnetic rocks (Proterozoic and Palaeozoic sediments) is very much greater in the northern half of the Sheet area.

A strong north-north-west zone of magnetic anomalies crosses the Sheet area: it corresponds to the trend of the Henbury/Lake Eyre Gravity Trough. Cook (1966b, unpubl.) has suggested that this trend on the Henbury Sheet area is part of an important structural zone which crosses the Amadeus Basin and may be considerably more extensive.
Fig. 3. Radiometric contours.

Radiometric (see Fig. 3)
The radiometric contour map shows no clear relation between radiometric trends and geology. In general the radiometric minima correspond to areas of Quaternary aeolian sands, Mereenie Sandstone, and the sandstone unit of the Pernjara Group. Radiometric maxima commonly occur over anticlines in whose cores Lower Palaeozoic or Proterozoic sediments are exposed. The reason for this is uncertain: some of the maxima may correlate with areas of outcrop of Stairway Sandstone (which contains phosphorites and should therefore have a higher than average radioactivity), but this cannot be definitely established. The radiometric values range from 12.5 counts per second or less to about 90 counts per second. Values are generally higher in the northern half of the Sheet area than in the south.

STRUCTURE

Folding (see Fig. 4)
The Petermann Ranges Orogeny (Forman, 1966) of late Proterozoic or Lower Cambrian age was the first orogeny to affect Amadeus Basin sediments. Its effects are particularly evident in the south-western part of the Sheet area, where Proterozoic sediments (particularly the Winnall Beds) have been folded into tight westerly or west-north-westerly folds. The synclinal axes are especially prominent in the Liddle Hills area, where the Winnall Beds underlie prominent hills.

Fairly important epeirogenic movement occurred in the ?Silurian in the eastern half of the Sheet area. This Rodingan Movement (Wells et al., 1967 in press) may have involved some minor folding, but the second major folding episode was during the Alice Springs Orogeny (Forman et al., 1966),
of Devonian-Carboniferous age. Folding occurred throughout the Sheet area, but was particularly well developed in the northern half. Here, large westerly or west-north-westerly folds (parallel to the folding of the earlier orogeny) developed—for example, the Gardiner Range Anticline, the James Ranges anticlines, the Waterhouse Range Anticline. Some folding may have developed as a result of the movement into anticlines or diapiric structures of salt of the Bitter Springs Formation and to a lesser extent the Chandler Limestone. The Illamurta structure (see Cook, 1966a) may be a diapiric structure (of the Goyder Pass type) with associated folding of overlying strata and possibly also some gravity sliding on the flanks of the structure.

Faulting
The two main types of faults are large longitudinal thrust faults and small transverse faults.

The Gardiner Range longitudinal thrust fault has a lateral extent of about 50 miles along a north-west trend, and a displacement of about 14,000 feet (Bitter Springs Formation is faulted against Pernjara Group). The Chandler Range thrust fault has a more westerly trend; it is about 20 miles long and has an apparent displacement of about 5000 feet. Along much of this fault incompetent Chandler Limestone has been intruded along the fault plane. Strong thrusting has also been associated with the development of the Illamurta Structure, with Areyonga Formation thrust over Mereenie Sandstone; and the thrust plane may have been folded. Other thrust faults are also present in the Bacon Range and at the western end of the Seymour Range.

Fig. 4. Structural sketch map.
There are a large number of longitudinal transverse faults in the Sheet area, but their displacement is generally small. Their trend is approximately north-south. Such faults are commonly found to branch off from the much longer longitudinal thrust faults.

**GEOLOGICAL HISTORY**

The oldest unit exposed on the Henbury Sheet area is the Proterozoic Bitter Springs Formation, which is predominantly a carbonate-lutite sequence with abundant algal stromatolites and evaporites; it was probably laid down on a shelf in fairly warm shallow water. Conditions gradually became cooler and marine glacial sediments were deposited in the Areyonga Formation and Inindia Beds. The temperature was variable, however, for beds of algal limestone occur sporadically throughout the Areyonga Formation. The Inindia Beds possibly represent a deeper-water facies to the south, where the sedimentation was predominantly lutaceous and little gravel or sand was ice-rafted into the area. At the close of Inindia Beds/Areyonga Formation sedimentation some epeiric movement took place and possibly influenced sedimentation: lutites and carbonates of the Pertatataka Formation were deposited in the northern half of the Sheet area and massive cross-bedded sandstones with some interbedded lutites (the Winnall Beds) in the south. This facies distribution probably indicates that the main source area was to the south. In the late Proterozoic or early Cambrian the Petermann Ranges Orogeny profoundly affected the form of the basin, and the southern half of the Sheet area was raised above sea-level. In this same area the Upper Proterozoic strata were also severely folded and probably faulted. As a result, for much of the Cambrian and Ordovician the area remained above sea-level; though there are some conglomerates of uncertain (but probably Cambrian) age. To the north, a marine shelf covered a wide area; Pertaoorrra Group sedimentation began with the deposition of the Quandong Conglomerate and the Eninta Sandstone, both coarse-grained sediments which may be equivalent to the conglomerates to the south. They may be synorogenic conglomerates, developed contemporaneously with the Petermann Ranges Orogeny. The Chandler Limestone and lower Tempe Formation (? Lower Cambrian) were laid down in very saline water, but the upper Tempe Formation (lower Middle Cambrian) probably heralded the main marine incursion in the north-western quadrant: fossiliferous glauconitic limestone, dolomite, and siltstone were deposited while to the east more massive dolomite and limestone with interbedded siltstone and claystone of the Jay Creek Limestone were being deposited. Jay Creek sedimentation continued in the east until the Upper Cambrian, but in the west terrigenous sedimentation (represented by the Illara Sandstone, the Deception Formation, and the Petermann Sandstone) prevailed. By the time the Goyder Formation, the youngest of the Pertaoorrra Group, was laid down, the environment of deposition was the same through the whole of the north. Throughout Pertaoorrra Group time the connexion with the open sea lay to the east.

Conditions probably did not change much during the early part of Larapinta Group sedimentation: more sandy terrigenous sediments flowed in from the west, and the water was more disturbed during the deposition of
the Pacoota Sandstone. The main link with the open sea still lay to the east. The water was probably shallow, but deepened considerably during deposition of the Horn Valley Siltstone, so that the bottom was below wave base, the circulation fairly restricted, and a prolific pelagic fauna thrived. Consequently a strongly reducing environment developed in the bottom waters. The environment became rather more oxidizing with the incoming of the lower unit of the Stairway Sandstone; conditions were similar to those of Pacoota Sandstone time, with an agitated shallow sea. The main source area now lay to the east and the open sea to the west. The environment once again became more reducing during the deposition of the middle unit of the Sairway Sandstone; black carbonaceous shales and phosphorites were deposited over most of the area, but a little limestone developed in the Seymour Range area, and some red-beds on the eastern margin. At the opening of upper Stairway Sandstone sedimentation the sea flooded south over the entire Sheet area. In such a shallow sea salinity gradually increased until the Stokes Siltstone was laid down in a very shallow, very saline sea. Larapinta Group sedimentation closed with the deposition of the Carmichael Sandstone, possibly a deltaic or estuarine deposit.

After the deposition of the Carmichael Sandstone, major uplift, possibly with some folding, occurred (the Rodingan Movement); this was accompanied or followed by the erosion of several thousand feet of sediments in the north-east corner of the Sheet area. The area was reduced to a land surface with low relief, and the sea gradually transgressed from the west until the Merenie Sandstone was deposited over most of the Sheet area. Conditions during this time are rather uncertain: possibly shallow marine, lacustrine, and aeolian deposits are all represented in the Merenie Sandstone. Wells et al. (1965b) and other authors have suggested that the Merenie Sandstone is overlain unconformably by the Pertnjara Group. The unconformity in fact probably occurs above the basal Parke Siltstone of the Pertnjara Group; it is most unlikely that a siltstone overlies an unconformity whereas pebbly sandstone of the Hermannsburg Sandstone lies conformably on it. This possible unconformity within the Pertnjara Group resulted from the Alice Springs Orogeny. During the orogeny major folding and faulting affected the whole Sheet area, but especially the northern half, and the continental sediments of the Pertnjara Group were deposited. Since that time the area has been stable, and has never been submerged. During the Tertiary the climate was relatively wet, and lakes formed in several areas; fluvial sediments (conglomerate and sand) were also deposited. The Tertiary was followed by a more arid phase in the Quaternary during which dunes formed and moved across much of the area. In most recent times, the dunes became fixed, possibly by a sparse cover of vegetation growing in response to a slight alleviation of the climate.

**ECONOMIC GEOLOGY**

*Surface water*

Numerous waterholes and rockholes contain permanent water in the northern half of the Sheet area and particularly along the Finke River. All accessible surface water is now used for the watering of stock. Semipermanent waterholes occur throughout the area, and dams are frequently used for the storage of surface water.
Underground water

The water potential of all rock units is summarized in Table 1. Underground water is widely used for the watering of stock and for domestic use. About 100 bores have been drilled in the search for water, the deepest (Hugh River Stockroute No. 3 Bore) to a depth of 500 feet. The standing water level varies from about 100 feet in the north to 2-300 feet in the south. Salinities also appear to increase to the south; the maximum recorded salinity is 20,285 parts per million. The Quaternary alluvium, some of the Tertiary gravels, and the Mereenie Sandstone are regarded as the best potential aquifers.

Petroleum

The northern half of the Sheet area is considered to be the area of greatest petroleum potential, for this is the area with the greatest thickness of favourable section together with a number of anticlinal structures. To date, three wells have been drilled in the search for oil; the results are summarized in Table 2. Pertaoorta Group sediments have been tested in Waterhouse Range No. 1 Well (sited just to the east of the Sheet area) and in the Highway No. 1 Well, but results were not encouraging. Proterozoic sediments were tested in Earlunda No. 1 Well, just south of the Sheet area, and also in the James Range 'A', No. 1 Well; but again results were not encouraging. At the present time, only the Larapinta Group appears to have any appreciable hydrocarbon potential. The only surface structure with closure in the Larapinta Group is the Palm Valley Anticline; there may be subsurface anticlines with closure in the Larapinta Group in the area between the Waterhouse and James Ranges.

### TABLE 2. DRILLING OPERATIONS
(to April 1966)

<table>
<thead>
<tr>
<th>Well</th>
<th>Date drilled</th>
<th>Total depth (feet)</th>
<th>Bottomed in</th>
<th>Status</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway Anticline No. 1</td>
<td>May-June 1965</td>
<td>3770</td>
<td>Bitter Springs Formation(^1) or Pertaoorta Group(^2) carbonate rocks</td>
<td>Dry</td>
<td>Stratigraphy of well uncertain</td>
</tr>
<tr>
<td>James Range 'A' No. 1</td>
<td>April-May 1965</td>
<td>3000</td>
<td>Bitter Springs Formation</td>
<td>Dry</td>
<td></td>
</tr>
<tr>
<td>Palm Valley No. 1</td>
<td>Jan.–May 1965</td>
<td>6658</td>
<td>Pacoota Sandstone</td>
<td>Gas producer</td>
<td>Large quantities of gas and some condensate</td>
</tr>
<tr>
<td>Waterhouse Anticline No. 1</td>
<td>Jan.–May 1965</td>
<td>3081</td>
<td>Arumbeena Sandstone</td>
<td>Dry</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) interpretation by Exoil et al. \(^2\) interpretation by author

Phosphate

Five formations contain pelletal phosphorites—the Stokes Siltstone, Stairway Sandstone, Horn Valley Siltstone, Pacoota Sandstone, and Tempe Formation; of these only the Stairway Sandstone is regarded as containing possible economic deposits.
The Stairway Sandstone phosphorites are pelletal, with pellets up to 2 inches or more in diameter. The pellet beds range from 1 to 12 inches in thickness and have a P_2O_5 content of up to 19 percent. These phosphatic beds are sparsely distributed throughout the Stairway Sandstone: the greatest concentration is in the middle part of the formation and also towards the southern part of the Sheet area, where the formation is thinnest. Cook (1963) records that the Stairway Sandstone contains abnormal concentrations of some trace elements such as lead and vanadium in samples from the Lake Amadeus Sheet area. The Bureau of Mineral Resources drilled the Stairway Sandstone in the Levi Range (AP2) and near Mount Holder (AP3). Neither hole located any phosphorite horizon of commercial importance (Barrie, 1964, unpubl.).

**Barites**

Thin veins of barytes occur in the Bitter Springs Formation in the core of Parauna Hill Anticline, but are too small to have any economic potential.

**Evaporites**

Halite and gypsum occur in the Bitter Springs Formation and the Chandler Limestone and perhaps also in the Quaternary of the Lake Amadeus salt lake system. Both these minerals have been worked commercially in Lake Amadeus.

**Potash**

Potash has not so far been found with any of the evaporite deposits. The greatest chance of finding potash is probably in the Lake Amadeus salt lake system. Glaucolite (from which potash may also be extracted) is present in thin beds in the Tempe Formation, Horn Valley Siltstone, and the Stairway Sandstone, and in thick beds, containing up to 50 percent glauconite in places, in the Pacoota Sandstone.

**Limestone**

Limestone suitable for burning for lime is present in sediments ranging from Proterozoic to Tertiary in age and occurs throughout the Sheet area.

**Jasper**

Jasper is common in the Areyonga Formation and in the Inindia Beds and when polished makes an attractive stone for use in jewellery.

**Building Stone**

Several of the Palaeozoic sandstones would probably make excellent building stones.

**Road metal**

Limestone and dolomite would probably make a useful crushed road metal. At present Tertiary gravels are used for this purpose.
Copper

Four copper occurrences are recorded. The most important is the Owen Springs Prospect in the Waterhouse Range. The deposit was extensively drilled in 1953-54, but results were disappointing. The copper occurs in the Goyder Formation, mainly in the form of malachite and cuprite, and is thought to be syngentic. The exploration programme was abandoned when it was found that the copper did not extend to any great depth. A second prospect, known as Namatjiras Prospect, occurs near Areystonga in a fault breccia within the Eninta Sandstone. The copper occurs as malachite, azurite, chalcocite, and several other forms. Minute quantities of gold (?) are also recorded at this locality by Ranford et al. (1966). Copper has been recorded from the Goyder Formation of the Alalgara Yard area (Lalgra Prospect), as pellets of malachite in a micaceous sandstone. The only copper prospect recorded in the Larapinta Group is about 42 miles NNW of Henbury homestead from near Boggy Hole in the Finke River and occurs as malachite within an oolite grit band . . . from 5 to 10 feet thick' (Bell, 1953, unpubl.).

Iron

The only deposits of economic potential are those of the Tertiary laterites or ferricretes which form an extensive capping (covering about 20 square miles) on the Mereneie Sandstone, on the southern margin of the James Ranges. A specimen from near Illamurta Yard contained 43.5 percent of iron, and a selected specimen from the Goyder Formation of the Levi Range contained 84 percent Fe₂O₃.

Manganese

Beds and lenses of manganese-rich rock occur irregularly in the upper part of the Goyder Formation. In a selected sample from the Lake Amadeus Sheet area, Ranford et al. (1966) record 56 percent manganese. The manganese is thought to be present only as a thin encrustation.
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APPENDIX

THE HENBURY METEORITE CRATERS

The Henbury Meteorite craters are of considerable interest to visitors to the Henbury Sheet area. Their existence has been known since at least 1922, though they were first described in detail by Alderman (1932). He mapped a total of 13 craters (Fig. 5) but later workers (Taylor & Kolbe, 1965) have suggested that the existence of crater 9 is doubtful. The area around the craters originally contained a considerable amount of meteoric iron (octohedrite) and impact glass (fused country rock), but most of the material has now been removed. Rayner (1939) carried out a geophysical survey of the craters, but failed to find indications of a large body of iron in any.

The largest crater (No. 7), which is 600 feet in diameter and 40-50 feet deep, was mapped in some detail in 1963 by Milton & Michel (1965). They found that much of the crater rim is composed of overturned flaps of what were previously underlying sediments. Two of the craters (Nos 3 and 4, Fig. 5) display rays and ray loops of ejecta similar in pattern to those around craters on the moon (Milton & Michel, 1965); this is the only terrestrial locality known to show such features.

The age of the craters is uncertain; Alderman (1932) suggests that they are thousands of years old, but Milton (pers. comm.) has suggested that they may only be hundreds of years old.
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