RECONNAISSANCE GEOLOGY AND PETROGRAPHY

NGALIA BASIN, NORTHERN TERRITORY

by

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Record 1966/73

C O N T E N T S

INTRODUCTION

This report on the geology of the Ngalia Basin stems from the reconnaissance field work of one of us (P.J.Cook) in the area. In all, seven weeks field work was undertaken; five weeks during 1962 whilst on the staff of the Resident Geologist's Office, Alice Springs, and two weeks during 1964. On the second trip Cook was accompanied by J.Perry, J.Rivereau and K.Edgeworthy.

I.F.Scott of the Australian Mineral Development Laboratories was responsible for petrographic descriptions of thin sections, with the exception of descriptions of some granitic and gneissic rocks from the Yuendumu area by W.R.Morgan of the Bureau of Mineral Resources. Where Morgan is responsible, this is indicated by the initials "W.R.M." after the description. The position of specimens is shown on the photogeological maps.

J.C.Rivereau of the Institut Francaise du Petrole prepared photogeological maps of the basin (Rivereau, 1965).

Location and access

The Ngalia Basin covers an area of about 7,000 square miles in the southern part of the Northern Territory to the north-west of Alice Springs. It lies approximately between latitudes $22^{\circ}10'$S and $22^{\circ}55'$S and between longitudes $130^{\circ}00'$ and $133^{\circ}30'$. Its western margin is uncertain due to poor outcrop. The basin is about 200 miles long and up to 50 miles wide.

The Stuart Highway passes through the eastern margin of the area. A formed earth road links Yuendumu Native Reserve with the Stuart Highway and Alice Springs; there are several station tracks on the northern and southern margins of the basin. Roads used by geophysical survey crews cross the central part of the basin south of Yuendumu. Access is very poor on the western margin of the basin.

There are permanent settlements at Yuendumu Native Reserve, Vaughan Springs Homestead, Newhaven Homestead, Mount Allan Homestead, Napperby Homestead and Aileron.

Potable water is available at the inhabited homesteads but is rare elsewhere, particularly in the western half of the basin.

Previous Investigations

The Ngalia Basin succession was probably first examined by Tindale (1933) who used the name Hann-Range-Uldiarra Hill-Crown Hill series for these rocks. The Mount Doreen Mineral Field was visited by Keik (1941).

The hydrology of the Yuendumu Native Reserve has been the subject of several unpublished reports (Ryan, 1956; Jones and Quinlan, 1958; Quinlan 1958; Wiebenga et. al., 1959).

The Ngalia Basin sediments have so far received little attention; Quinlan (1962) briefly mentions the area. Cook (1963, unpubl.) prepared a geological map of the Yuendumu Native Reserve, which is situated on the northern margin of the basin. This report has been used as a basis for later work. Rivereau (1965) prepared a photogeological map of the Ngalia Basin.

STRATIGRAPHY

A generalized geological map of the Ngalia Basin and a composite stratigraphic column are given in fig.1.

Specimen localities are marked on the photogeological maps. The numbers on the map refer to both the field number and the registered number. A number 43 would be prefixed by "NB" when used as a field number and by "65.6600" when used as a registered number. Registered numbers are used in this report. Some numbers are prefixed by the letter "R" - these numbers refer to specimens collected in 1962 when another numbering system was operative.

Information stratigraphic names are used for all rock units at the present time, as the Ngalia Basin is to be systematically mapped in the near future by the Bureau of Mineral Resources.

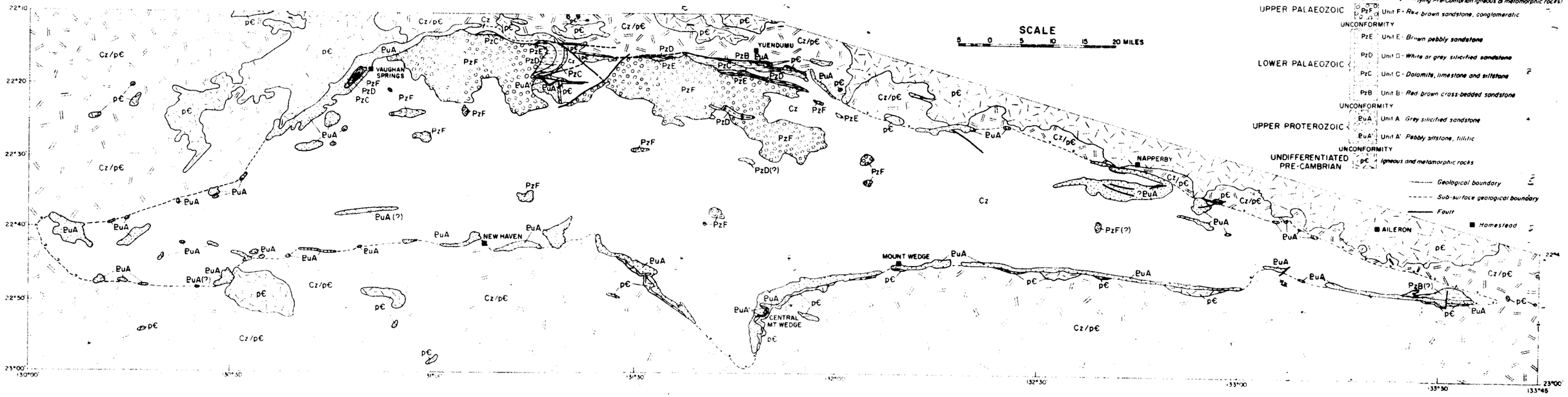
UNDIFFERENTIATED PRE-CAMBRIAN BASEMENT

The metamorphic and igneous basement rocks, which underlie the Ngalia Basin succession on the southern and northern margins, are extremely varied. They consist of schist, gneiss, migmatite, quartzite, amphibolite, gneissic granite and "granite". Pegmatites are common; there are ?dolerite dykes in some areas.

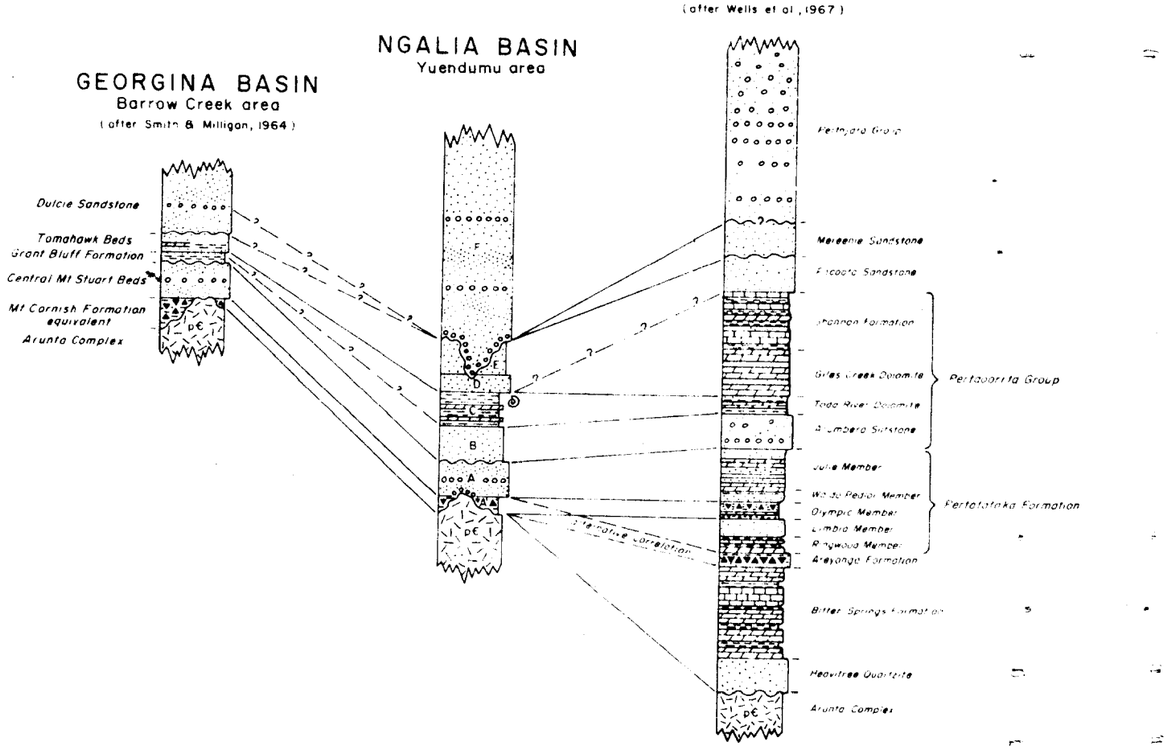
Metamorphic Rocks

Gneiss and schist are the most abundant metamorphic rocks. The schist (generally biotite schist) commonly has a well developed east-west foliation. The gneiss is predominantly a mica-quartz gneiss; it is generally coarse grained and has a moderately well developed foliation approximately parallel to the foliation in the schist.

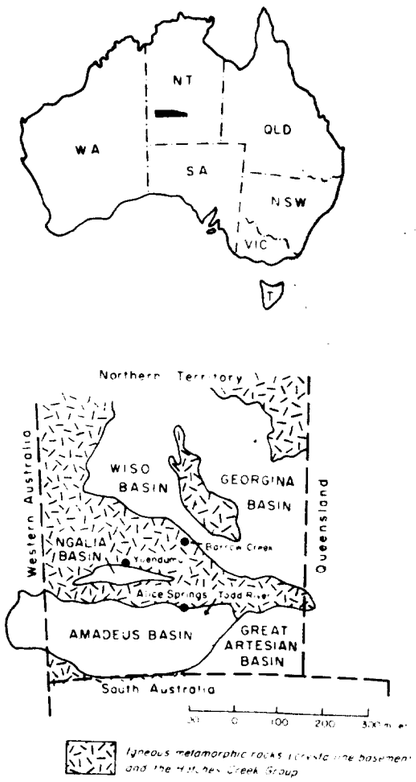
THE NGALIA BASIN, NORTHERN TERRITORY



TENTATIVE CORRELATIONS



LOCALITY MAP



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A gneiss from north-east of Yuendumu Settlement (number R11346) is described as a sillimanite-plagioclase-biotite-quartz gneiss. In thin section the rock consists of a mosaic of intergrown, unstrained quartz grains about 1.25 mm. in size, biotite-sillimanite-plagioclase segregations measuring up to 5 mm. across, and more rare single grains of plagioclase about 1 mm. in diameter; this plagioclase (andesine) is altered to sericite along its margins and cracks. The segregations consist of small brown biotite flakes, fibrous bundles and acicular crystals of sillimanite that are sometimes altered to sericite, and fine-grained plagioclase. Rarely, small sub-poikiloblastic grains of andalusite may be found in the segregations. Accessory zircon was noted. An estimate of the mineral percentages is quartz 70, biotite 15, plagioclase 10, sillimanite 5 (W.R.M.). The sillimanite may be the result of contact metamorphism.

?Phyllite occurs in some areas, such as rock specimen 65.660048 from about 20 miles west of Napperby Homestead. In hand specimen the rock fractures along joint surfaces as well as other irregular planes which correspond approximately to the orientation of sericite flakes. From thin section examination the rock is considered to be a sericitized siltstone which has numerous quartz veins and cross fractures. The latter are filled with clay and appear to follow earlier narrow veins. The rock consists of silt size quartz grains and at least 5% sericite in very fine, preferentially oriented flecks, evenly scattered through the rock. Trace amounts of fine-grained opaques are also present.

A fine grained metamorphic rock (Number 65.660049) which occurs just below the contact of basement and Ngalia Basin sediments at Mount Wedge is a sheared quartzo-feldspathic rock which has been recrystallized and partly replaced by sericite, biotite and opaques. The quartz in the rock forms an irregular, embayed, interconnected network of mosaics strongly aligned in a preferred orientation. Only remnants of the feldspar (plagioclase) remain after this severe alteration to mica and opaques. In view of the increased development of biotite in parts of this rock it is difficult to determine whether the parent rock was sedimentary (sandstone) or igneous (granite) in origin. Biotite-rich layers may reflect some bedding phenomenon.

Quartzites are common within the basement. They are generally white or pale brown in colour, very fine grained, strongly jointed and fractured and up to 500 feet thick. They are steeply dipping in most places; their strike is generally parallel to that of the schistose and gneissic country rock. The contact with the surrounding metamorphic rocks is sharp. Many of the quartzites are of considerable lateral extent and can be followed for distances of up to ten miles.

A typical specimen of quartzite (Number 65.660011), which crops out about four miles west of the Siddley Range, is described from thin section as a cataclastic quartzite. The sample is essentially quartz and a grain or two of zircon, the quartz exhibiting severe strain extinction and a marked preferential orientation of the often lensoid grains. Sutured grain boundaries are present on all the quartz grains and the interstitial material is finely recrystallized quartz. A fine-grained, irregular, cross-cutting band may be the remnants of a vein.

A specimen (Number 65.660014A) from 50 to 100 feet below the top of the metamorphic rocks at Central Mount Wedge is described from thin section examination as a very altered quartzo-feldspathic sandstone. For the most psrt sand grains are not a major constituent in this specimen. Sericite-muscovite, biotite, chlorite and clay minerals form the main part of the rock. Much of this material has replaced earlier grains of feldspar of which only a few remnants are left. However in this particular thin section there is a quartz-rich area where subrounded mosaics of quartz are set in a micaceous (mostly sericite) groundmass with associated opaques. Along the quarta rich area boundary is an accumulation, or possibly "vein", of chlorite crosscut with biotite. Minute remnants of garnet reflect the origin of the "vein" chlorite-biotite material.

Igneous Rocks

The metamorphic rocks of the basement have been intruded by a number of granitic bodies.

These "granites" are generally coarse grained, with large phenocrysts of feldspar up to 3 inches in length. Dark, round or ovate zenoliths (some up to several feet across) are present within the "granites" in places. The phenocrysts or zenoliths may show a poorly developed lineation. The granites are particularly well exposed in the northern halves of the Mount Doreen and Napperby 250,000 sheet areas. The largest outcropping granite

in the area is probably the Napperby Granite. A specimen (Number 65.660049) of this granite from Day Creek, about 11 miles east of Napperby Homestead, is described as a very coarse-grained biotite granite which has been sheared and crushed a little. These shear zones are indicated by granulated quartz and reorientation of biotite flakes. Perthitic microcline is more abundant than the sodic plagioclase which often exhibits myrmekitic rims adjacent to potash feldspar grains. Quartz is abundant forming 30% to 40% of the rock while mafic minerals form another 10 to 15%. The quartz grains frequently have sutured grain boundaries and shadowy extinction. Biotite and opaques are common associates and zircon and apatite occur as accessory minerals.

The most thorough examination of the granitic rocks to date has been made in the northern part of the Yuendumu Native Reserve, in the vicinity of Rock Hill. Cook (1963, unpubl.) considered that there were four granitic bodies in this area, the largest one being the Rock Hill Granite (Kiek, 1941) which is 2-3 miles wide and about 20 miles long. In hand specimen the Rock Hill Granite is creamish-grey mottled with black, it is coarse-grained and porphyritic; phenocrysts are up to 2 inches in length. The rock is a granulated biotite quartz-diorite (Spec.No.R.11340, from about 10 miles north of Yuendumu Settlement). In thin section the average grain-size of the groundmass is 4 mm. The texture is hypidiomorphic, modified by granulation due, presumably, to shearing. In some of the granulated portions of the rock a granoblastic texture has resulted from the recrystallization of the granulated material. Quartz (40%) forms anhedral grains with strong strain shadows, and is commonly granulated. Plagioclase (40%) is subhedral to tabular, and is micro-fractured and shows some marginal granulation. It is slightly sericitized. Biotite (15%) is pleochroic from fawn to dark brown, and forms large anhedral to tabular books; these are slightly to moderately distorted. Microcline-perthite (5%) is interstitial, and shows some granulation. Muscovite is present in minor quantities only, and is associated with biotite. Apatite, zircon, black iron ore, epidote and garnet are accessory (W.R.M.).

Xenoliths are common within the Rock Hill "Granite". A specimen of a xenolith (specimen No.R11341) from the south east corner of the "granite" is described as a biotite-plagioclase-microcline-quartz gneiss. In thin section, the groundmass has an average grain-size of 0.4 mm., and porphyroblasts range to 1.5 mm. in length. The texture is granoblastic, foliated, and porphyroblastic. The grains, including the porphyroblasts, are elongated parallel to the foliation. Quartz (50%) is granoblastic and strained; microcline-perthite (40%) is granoblastic to poikiloblastic, and also forms the porphyroblasts. Plagioclase (5%) - probable andesine - is sub-tabular to granoblastic, and is somewhat sericitized; some of the muscovite in the rock may represent completely altered plagioclase. Where the plagioclase is adjacent to microcline, myrmekitic structures have developed. Biotite (5%) is pleochroic from straw to dark brown, and is sub-poikiloblastic. Black iron ore is associated with biotite, and other accessory minerals noted were apatite and zircon (W.R.M.). The granoblastic and gneissic texture of the xenolith suggest that it is a fragment of country rock rather than a cognate xenolith. Some of the microcline may have been introduced metasomatically.

A "granite" with a uniformly fine grained texture crops out over an area of about four square miles, 13 miles west of Yuendumu Settlement. A specimen of this (No.R11344) is described as muscovite-biotite trondhjemite. In hand specimen the rock is creamish-grey and coarse-grained. In thin section the texture is xenomorphic-granular and porphyritic, the average grain-size in the groundmass is 2.5 mm., and the phenocrysts range up to 5.5 mm. in size. Marginal intergrowths of the constituent grains suggest a granoblastic texture resulting from re-crystallization. Quartz (45%) forms multi-grain aggregates; the grains have intergrowths resembling a jig-saw puzzle. Very little straining occurs in quartz, whereas in some of theplagioclase crystals micro-fracturing has taken place. This is unusual; in most rocks which have suffered movements sufficient to fracture plagioclase, quartz shows strong strain shadows and is commonly granulated to a greater or lesser extent. This suggests the quartz has recrystallized subsequent to any movements the rock may have suffered. Plagioclase (50%) oligoclase - forms sub-tabular crystals with rather irregular, intergrown margins. Biotite (2%) is pleochroic from straw to dark red-brown, and occurs as anhedral

to tabular flakes showing little or no distortion. Microcline-perthite (2%) is interstitial, and muscovite (1%) forms subhedral flakes. Accessory zircon and apatite are present (W.R.M.).

Six miles north-east of Yuendumu Settlement, a small granite crops out over an area of about 2 square miles. A specimen is described as a granulated, recrystallized and greisenized muscovite-biotite granite. In hand specimen the rock is creamish-grey speckled with black and is medium-grained and porphyritic. The feldspar phenocrysts attain a size of about 8 mm., and commonly have coarse-grained muscovite associated with them, suggesting griesenization. In thin section the rock has a grain size of about 0.4 mm., and its textural characters are rather similar to the granulated and recrystallized rock (R.11343) described below. A large area of very coarse intergrown muscovite and quartz is thought to be a greisenized feldspar phenocryst; in this area the quartz and muscovite show very little distortion, hence the greisenization must have taken place after the movements causing the granulation. The estimated mineral percentages are: microcline-perthite; 45, muscovite; 2, and accessory zircon. (W.R.M.).

A specimen (No.R.11343) from the north-west corner of what is thought to be the same granitic body is described as a sheared and recrystallized biotite adamellite. In hand specimen it is pink-cream, mottled with black, and is apparently coarse-grained. In thin section the rock is seen to be extensively granulated, and the granulated portions are commonly recrystallized to a granoblastic texture. The grain-size in the granulated zones is about 0.5 mm., and relict grains (porphyroclasts) range up to 3 mm. across. A foliation or banding in the rock has resulted from the granulation, and there is some grain elongation parallel to this banding. Quartz (35%) is strained and granulated. Microcline-perthite (40%) and plagioclase (25%) form micro-fractured porphyroclasts, and are granulated and recrystallized. Biotite (1%) is pleochroic from straw to dark brown and forms clusters of small flakes aligned parallel to the banding. Biotite has epidote and leucoxene associated with it. Accessory minerals are zircon and apatite (W.R.M.).

To the north-west of Yuendumu Settlement there are several small outcrops of hornblende biotite adamellite. A typical hand specimen (Spec.No.R.11345) is white, heavily speckled with black. It is coarse-

grained and on some surfaces has a definite gneissic foliation. In thin section the rock is hypidiomorphic-granular, and some marginal recrystallization of the grains has taken place. Mica tends to be lineated. The rock has an average grain-size of 2 mm. Quartz (35%) is interstitial to poikilitic and is somewhat strained. Plagioclase (35%) - oligoclase - is tabular, and is mostly only slightly sericitized in some crystals, core zones are strongly sericitized. Microcline-perthite (15%) is interstitial to poikilitic. Biotite (10%) forms strings of coarse, lineated flakes, and is only slightly distorted. It is pleochroic from straw to dark mud-brown, and has yellow epidote associated with it. Hornblende (5%) is pleochroic from pale green to bluish green, and forms sub-prismatic crystals that are commonly partly altered to biotite. Accessory minerals are apatite, sphene, and zircon (W.R.M.).

As a result of the petrographic work on the igneous rocks of the Yuendumu area, Morgan has made the following remarks:-

"The mica "granites" could well be members of a related series of intrusive rocks ranging from mafic-rich to leucocratic types; such intrusive series are quite common - several examples are summarized by Buddington (1959), and more recently, ideas on their genesis were reviewed by Vance (1961). The important feature of the mica "granite" specimens is that they all show signs of granulation followed by some recrystallization of the granulated material. These suggest movement followed by reheating. The movement may have been tectonic; on the other hand the movements could have resulted from intrusion of related material into almost completely solidified rock that is represented by these granulated specimens; heating of this by the newly injected magma would cause the granoblastic textures to develop. This process is described very clearly by Waters and Krauskopf (1941) in the Colville Batholith, U.S.A.

The hornblende-biotite adamellite has a foliation that is probably a primary igneous flow structure - however, this can only be confirmed in the field by plotting the foliation in relation to the adamellite margin. The other textural characters in the rocks suggest that it is of igneous rather than metamorphic origin".

Approximately half-way along the road between Yuendumu Settlement and Vaughan Springs Homestead the basal sediments overlie weathered granite. A typical specimen (No.65.660041A) is described from thin section examination as a severely sericitized biotite-bearing quartz breccia. Remnants of biotite are present in a sericite-muscovite groundmass filling the interstices between large angular quartz fragments. The biotite is usually twisted and buckled and appears to be breaking down to white mica and iron oxides (Figure 4). Pleochroism is common in the biotite, but probably due to loss of iron, these colours are not as strong as in fresh biotite.

A short distance from specimen 65.660041A the granite has been injected (possibly along a fault zone) by a tourmaline pegmatite (Spec.No.65.660041B) in which quartz and potash feldspar are the other main constituents. Traces of rutile needles and a little green mica were also observed.

The whole rock has undergone some crushing stresses which have resulted in a shadowy mosaic extinction in the major constituents.

SEDIMENTARY ROCKS

Unit A

This is thought to be the oldest unit of the Ngalia Basin succession. It occurs at the base of the succession in two places - Central Mount Wedge and near the road between Yuendumu Settlement and Vaughan Springs Homestead (about equidistant between the two) At both these localities it unconformably overlies basement and is conformably overlain by Unit A sandstones.

At Central Mount Wedge, the unit was apparently deposited on an irregular surface and ranges in thickness from 100 to 200 feet. It consists of poorly sorted conglomerate and conglomeratic siltstone with minor sandstone; the siltstone is tillitic in aspect. Boulders range up to 18 inches in diameter; they are fairly well rounded and no striae were seen. Bedding is very poorly developed. In a thin section of conglomerate from Central Mount Wedge (Number 65.660013A) the grains and rock fragments in the specimen vary considerably both in size and shape. The largest rock fragments are approximately 1 cm. in length while some of the interstitial grains are fine sand size. The various components

range from rounded to angular in shape with, perhaps, the intermediate sizes having the highest degree of rounding. The larger fragments are quartz and composite quartz mosaics with interspersed sericite and minor biotite. Other quartz mosaic composites contain euhedral secondary opaque grains. Fragments which were probably once quartz-feldspar mosaics have occasionally been almost completely replaced by sericite, biotite and minor biotite. Other quartz mosaic composites contain euhedral secondary opaque grains. Fragments which were probably once quartz-feldspar mosaics have occasionally been almost completely replaced by sericite, biotite and minor ?chlorite. The remainder of the rock is fine to coarse sandy particles of quartz (almost exclusively) set in a highly sericitic groundmass. Minor biotite and muscovite flakes are present and occasional zircon, green tourmaline and opaque grains were also observed. There is possibly some degree of sorting in that the coarse fragments are closely related and associated with these are fine grains of opaques, rutilated quartz (with biotite) and zircon.

Similar coarse poorly sorted sediments also crop out near the top of a prominent escarpment on the Yuendumu - Vaughan Springs Road. I.P.Youles (pers.comm.) has found striated pebbles near this locality. The tillitic sediments are only about 25 feet thick; the section is as follows:-

Strongly silicified sandstones of Unit A (Spec.65.660044 from this unit).

(3) Pebble and cobble conglomerate - almost a breccia, with extreme angularity. 20 feet thick (Specimen 65.660043).

(2) Red or red-brown pebbly siltstone or mudstone - 3 feet thick (Specimens 65.660042A, B).

(1) Basal Conglomerate - pebbles, cobbles and boulders (up to 2 feet in diameter) of silicified sandstone, vein quartz and metaquartzite. The clasts are generally poorly rounded 1 - 3 feet thick. Overlies strongly weathered granite (specimens 65.660041A, B).

In the thin section of a pebbly siltstone (Specimen 65.660042A) angular quartz grains reached a maximum size in the coarse sand range and graded down to the siltstone groundmass. These quartz fragments form up to 20% of the rock and are very poorly sorted (Figure 5). The siltstone groundmass consists, essentially, of quartz and muscovite with a liberal dusting of red hematitic material (some areas are opaque). Minor amounts of clay size material are present in the grain interstices but more commonly the grains are welded together or contain interstitial iron oxide.

Sample 65.660042B is a pebbly mudstone. The approximate size of the largest fragments is in the upper limits of the pebble size range. These subrounded to angular fragments are completely unsorted and range down to the silt sized groundmass (30 to 40% fragments). Minor amounts of muscovite are present in the rock but, for the most part, the groundmass consists of quartz with interstitial sericite and clay. Minor hematitic material is present but it is confined to a narrow half-inch band in this particular sample. Although layering is present in the rock there is no evidence of graded bedding. The poor sorting, angular fragments and general features of this rock and sample 65.660042A could be described as tillitic. However, due to the monomineralic (quartz) nature of the fragments, these rocks are possibly tilloids (Pettijohn, 1957).

Thin section examination of specimen 65.660043 showed the rock to be a quartz conglomerate in which fragments of quartz have a complete range of size from cobbles to silt grains. Although the sorting is very poor there are two main groups of clastics. Fragments generally larger than coarse sand are set in a matrix of medium (and finer) sand size grains which are in turn enclosed in a sericite-clay cement containing minor quantities of silt size quartz grains. Clastic fragments form 60 to 70% of the rock while sericite with occasional muscovite aggregates makes up most of the remainder. A subrounded cobble size rock fragment of quartzite was the only type of clastic, other than quartz, seen in thin section. In general rounding of the components was poor to absent.

On the southern flank of the Stuart Bluff Range near Mount Hammond the silicified sandstones of Unit A are underlain by a 1 foot bed which from thin section examination could probably be classed as a very poorly sorted clastic composite. The rock consists of large composite grains (3 mm.) of quartz, potash feldspar and muscovite, other large grains of microcline which are

frequently rounded and very highly altered, and individual subrounded quartz grains. Interstitial material consists of rounded to angular grains of quartz aand (fine to medium grained) cemented by sericite, clay and minor ?chlorite. Muscovite has developed in places from recrystallization of the sericite while some other flakes appear to be detrital (often severely altered). Occasional grains of potash feldspar are also interstitially distributed through the rock.

The larger fragments of microcline are severely altered and replaced by opaline and/or clay material.

This rock type is probably very slightly reworked granitic material; in places it is difficult to establish where the boundary is between the clastic composite and the underlying weathered granite. This unit may be the lateral equivalent of the "tillitic unit" or it may be the basal conglomerate of Unit A.

The age of the "tillitic unit" cannot be positively established but the tillitic form and its position unconformably below known Cambrian sediments strongly suggests that it is Adelaidean (Upper Proterozoic).

Unit A

Unit A comprises sandstone with minor siltstone and some conglomeratic bands. It conformably overlies the "tillitic unit" and is unconformably overlain by Unit B near Yuendumu.

Unit A crops out on both the southern and northern margins of the basin, forming prominent scarps in many places; in particular it forms Central Mount Wedge, the Siddley Range, the Stuart Bluff Range, and the Hann Range on the southern margin and some of the ridges of the Truer Range on the northern margin. It forms the capping of many of the mesas in the Lake Mackay Sheet area on the western margin of the basin; it may underlie the entire Ngalia Basin.

The unit appears to thin both to the north and the east. In the Vaughan Springs area and possibly also near Central Mount Wedge, the unit is at least 1,000 feet thick but near Yuendumu it is only 3-400 feet thick.

Unit A consists predominantly of grey or grey-brown fine to coarse grained, thin to thickly bedded, strongly silicified sandstone; cross-bedding, ripple marks, mud pellet markings and flow and slump casts are common. A few of the sandstones are white, clean and very friable but most are strongly resistant to weathering, forming prominent ridges.

Conglomeratic bands are present in places. One band occurs 150-200 feet above the base of the formation in the Stuart Bluff Range; it is 30-40 feet thick and contains well rounded cobbles (mainly metaquartzite with minor vein quartz) up to 4 inches in diameter. In many places there is a coarse, poorly sorted sub-angular conglomerate at the base of the formation. There are some minor silty interbeds in places.

The age of the unit is uncertain; its position above a probable Upper Proterozoic tillitic horizon and below Cambrian sediments, together with a marked lithological affinity with Upper Proterozoic sediments of the Amadeus and Georgina basins, suggests that the formation is of Upper Proterozoic age.

Several specimens from the Stuart Bluff Range near Mount Hammond were collected from various positions above the base of the formation.

Specimen 65.660002 from 6 inches above the base of the formation is a poorly sorted orthoquartzite (more than 95% quartz) with interstitial clayey cement where the grains are not welded together. Occasional secondary silica overgrowths are formed on quartz grains but this is a rather infrequent phenomenon. The majority of the fine to medium quartz grains exhibit shadowy extinction probably because of load strain in therock. Some of the grains (especially the larger ones) are well rounded but most are subrounded to subangular. Some degree of preferential alignment of elongate grains is evident but it is not a prominent phenomenon. Trace amounts of opaques, ?rutile and muscovite were observed. The porosity of the rock is quite low.

A second specimen (65.660003) was collected 15 feet above the base of the formation. It is a poorly sorted orthoquartzite with essentially identical features to 65.660002. Porosity may be slightly higher and in this specimen there is no preferred orientation of any of the constituents. Grains are fine to medium sand size with the latter predominating.

Specimen 65.660004 from 100 feet above the base of the unit is a poorly sorted fine to medium-grained orthoquartzite. Once again this rock has essentially the same mineralogy and texture as 65.660003 and 65.660002. There is a slight increase in the amount of clayey interstitial material (approximately 5%). The grains, although commonly well packed, are less compressed than in the other samples and consequently individual grains show less strain. A trace of zircon and amphibole was observed.

Specimen 65.660005 from 150 feet above the base of the unit is a quartzose conglomerate in which pebbles of quartz reach a maximum diameter of 2.5 to 3.0 cm. There is a complete range of sizes down to the well rounded quartz groundmass. These finer grains (medium to coarse sand size) frequently have silica overgrowths (Figure 1) and any non-siliceous interstices (approximately 10%) are infilled with clay and sericite. Pebbles in the conglomerate include relatively unstrained quartz as well as strained sutured composite quartzites (metamorphic).

Specimen 65.660006 from 170 feet above the base of the unit is a much finer grained conglomerate than 65.660006. The largest grains observed are less than 5 mm. in diameter although these do not form the major portion of the rock. Most of the grains are angular to subrounded, medium to coarse sand size particles, frequently strained although loosely packed in a matrix of clay, sericite and a little muscovite. The matrix in this rock forms 20% to 25% of the sample. Traces of tourmaline, rutile and dusty opaques are also present. The dusty opaque material is probably fine haematite which is responsible for the red colour of the rock.

At the Siddeley Range, Unit A is strongly silicified; tension fractures are common throughout the rock and in places quartz veins, up to 4 inches in thickness, cut through the silicified sandstone. A specimen from this locality (Number 65.660007) was collected from the base of the formation at the Siddeley Range. This rock is an orthoquartzite; it is composed almost entirely of quartz except for 1 to 2% sericite and muscovite. These micaceous flakes are confined to grain boundaries which are usually sutured and silicified by secondary overgrowths. The rock is fairly well sorted with only occasional larger grains in the medium-grained sandy host. The confining pressure on the rock has caused all the grains to exhibit shadowy extinction as well as sutured grain boundaries. Traces of dusty opaques are also present in the rock.

The petrography of specimens of Unit A from the northern and southern margins of the Ngalia Basin is very similar. Specimen 65.6600016A, from about 3 miles south-east of Yuendumu Settlement, is a poorly sorted, fine to coarse-grained, limonite-sericite cemented orthoquartzite. The majority of the grains are subrounded to rounded quartz and all exhibit undulose extinction. Some of the grains have been fractured and/strained to produce a mosaic pattern. Trace amounts of zircon, tourmaline and muscovite were

observed.

Specimen 65.6600016B is from the same locality and also from near the base of the unit. From thin section examination it is described as a very siliceous conglomerate in which rounded to more common angular fragments of quartz, or quartz mosaics up to 1.5 cm. in diameter, are set in a hematitic siliceous groundmass. The hematite, which gives the rock its deep red colour, is usually confined to the grain boundaries in association with the silica cement. The groundmass sand grains are medium to coarse in size and often well rounded. Occasional flakes of muscovite are also present. Rounded blebs of opaque material are not uncommon in the interstices of the larger rock fragments.

A specimen 65.6600044 from about half way along the Yuendumu-Vaughan Springs road and about 50 feet above the base of the unit is a poorly sorted pure orthoquartzite. The quartz grains range from fine to medium sand size and are nearly all rounded to well rounded and cemented by quartz overgrowths. Many of the grains show some degree of strain extinction. The rock has a low porosity.

Three specimens (65.660037A, B and C) were collected from the southern limb of the Vaughan Springs Syncline, where Unit A is well exposed. Specimen 65.660037A is a typical friable sandstone from near the base of the unit. It is a pure orthoquartzite in which most of the grains are of medium sand size. These grains are well sorted and usually have closely compacted grain boundaries. The quartz is subrounded to rounded and frequently the grains exhibit undulose extinction. The only impurities in this thin section are trace amounts of iron hydroxide or oxide.

Specimen 65.660037B is also a fairly typical sandstone from the middle of Unit A. The rock is a fine to medium grained orthoquartzite. It is composed almost entirely of quartz grains tightly packed together with sericite developed along the grain boundaries. The grains are rarely rounded and commonly exhibit undulose extinction.

Trace amount of zircon and opaques are the only accessory minerals.

Specimen 65.660037C is from a thin lutaceous interbed near the top of Unit A. It is a sericitized silty claystone. More than 90% of the rock consists of clay or clay sized particles. The sericite flakes have a definite orientation parellel to the ?bedding. A few quartz grains are sand size.

Irregular layers of almost pure clay or clay and quartz transect the rock in the approximate plane of the bedding. These layers are not parallel and may be the result of pre-consolidation movements in the rock.

Unit A also crops out in the vicinity of Napperby Homestead in a structurally complex area, with a strongly folded thrust cutting through the formation. The structure was examined about three miles west of Napperby Homestead and three specimens (Numbers 65.660048A, B and C) were collected.

Specimen 65.660048A is a typical Unit A sandstone which has been unaffected by the thrusting. It is a very porous orthoquartzite. The grains are poorly sorted and fall into the fine to medium sand size range. Most of the grains, however, are fine sand. Any degree of rounding is a rarity and the irregular grains are commonly sutured together. As a consequence of this, grain boundaries are highly indented and grains exhibit shadowy extinction. The interstices between the quartz grains are partly or completely filled with fine granulated quartz, clay and dusty opaques. Overgrowths of quartz on grains are present but not common. Traces of zircon occur in the sample.

Specimen 65.660048B is from the thrust zone and appears to be a very crushed and clayey equivalent of 65.660048A. Quartz-rich areas contain sheared out grains with sutured grain boundaries and shadowy extinction. Traces of muscovite, tourmaline and opaques are present in these quartzite areas. Other irregular patches in the rock contain a mixture of clay and quartz or mainly clay on its own. Sericite and muscovite are present in stringers through these sheared areas. Red iron oxides are quite common in the more clayey portions and these tend to make the rock mottled in colour. When the iron is deposited in the clay it frequently forms tiny spherical blebs. There is no regularity in the sheared areas with respect to the quartz-rich areas and cross-cutting both are late stage, clay filled fractures.

Specimen 65.660048C is a white silicified sandstone from 2-3 feet above the thrust zone. It is a medium-grained pure orthoquartzite which has been severely fractured and crushed. Very few of the grains still show evidence of their original nature as most have been strained or crushed. Crush zones transect the rock but only in one place was a pocket of clay with associated iron oxides observed.

Minute amounts of zircon and tourmaline were also present.

Unit B

Unit B is a sandstone sequence. It unconformably overlies Unit A and is overlain apparently conformably by Unit C. At the present time this unit is known only from the northern margin of the basin near the Yuendumu Settlement. It is absent from the Vaughan Springs Syncline. South of Yuendumu the unit forms low strike ridges. In this area it is about 1,000 feet thick. Unit B consists of pale-brown or grey sandstone, which weathers to a red-brown. It is fine to coarse grained, pebbly in places, poorly rounded, poorly sorted, thin bedded, cross-bedded in places, friable and poorly exposed. A specimen of Unit B (65.660019B) from about 2 miles south of Yuendumu Settlement is a porous, cherty sandstone with comparatively good sorting and a medium grain size. Approximately 50% of the clastic fragments are quartz grains which range from rounded to angular in shape. Other forms of silica present include numerous cherty grains as well as traces of chalcedony. Minor amounts of sericitized, fine sandstone and schist fragments, as well as occasional muscovite flakes, occur as detrital grains.

Interstitial material includes limonitic cement, clay, chlorite and a little sericite.

Traces of rutile, zircon and opaques are also present.

The age of Unit B is uncertain due to the absence of fossils. As it is overlain with apparent conformity by Unit C (which contains Cambrian fossils) and overlies a strong angular unconformity, probable Upper Proterozoic sediments, it is possibly Cambrian in age.

Unit C

Unit C is a carbonate-lutite sequence. It overlies Unit B apparently conformably and is overlain (again with apparent conformity) by Unit D. In places it is unconformably overlain by Unit F. Unit C crops out sporadically over a considerable distance. At the present time it has been recognized as far east as Yuendumu Settlement and as far west as Vaughan Springs. In both these areas the Unit is about 1,000 feet thick. It is the only formation in which fossils have so far been found.

The dolomites of Unit C are well exposed south of Yuendumu Settlement. Here they are grey, pink or yellow, weathering to dark grey; thin bedded, strongly silicified and brecciated in places; generally only moderately to poorly exposed as low rounded hills. Travertine is present as a thin veneer on the outcrop in places. Large irregular masses of barytes occur

within the dolomite at an outcrop three miles west of White Point Bore on Yuendumu Native Reserve and there are also specks of ?galena. Copper mineralization (as cuprite and malachite) also occurs within this unit south of Yuendumu Settlement and in other areas.

Specimen 65.660020, from near the middle of Unit C south of Yuendumu Settlement, is described from thin section examination as a quartz bearing dolomite. Most of the quartz crystals are subhedral because of their growth in a vein structure. Carbonate has partly replaced the quartz but the general outline of the vein is still visible. Occasional grains of partly replaced quartz also occur in the body of the rock (less than 5%). None of the grains appear detrital and the whole rock is a crystalline (fine - to medium-grained) aggregate.

Specimen 65.660033 is a very fine grained dolomite from an outcrop approximately half way between Yuendumu Settlement and Vaughan Springs. The rock is transected by numerous randomly oriented, irregular veins of quartz, recrystallized dolomite, calcite and barite. Opaques sometimes partially fill the vein structures. Barite is also associated with irregular areas of quartz mosaic which are commonly being replaced by dolomite. These quartz mosaics may be remnants of vein structures. Crosscutting veins frequently offset each other but without any particular controlling direction.

A third colomite specimen (65.660038) from Vaughan Springs Syncline is described as a very fine-grained dolomite containing micro-beds of silty and sandy detritus at comparatively regular intervals. The clastics in these lenses and beds are, for the most part, quartz, ?biotite and muscovite although both potash and plagioclase feldspar as well as trace amounts of carbonate detritus and rock fragments (?chert) are present. Probably not more than 5% of the rock is made up of non-dolomitic material. Dark-brown and opaque dentritic staining parallel to two major planes in the rock (including the bedding plane) is probably of a manganiferous origin.

Although rarely exposed, siltstone (with some silty sandstone) forms a high percentage of the thickness of Unit C. The best known exposure of Unit C lutites is about three miles west of White Point Bore, where about 300 feet of siltstone with minor sandstone is exposed. Whilst the siltstones are best developed near the top of the unit, they occur throughout it. The siltstones are purple, purple-brown, fissile, thinly bedded to laminate and richly micaceous (mainly muscovite). A specimen (65.660024A) of

siltstone from about 300 feet below the top of Unit C is described from thin section examination as a porous, micaceous, clayey siltstone with very distinct graded bedding. Only a very occasional quartz grain is of fine sand size. Muscovite flakes form more than 10% of the rock and these have nearly all been deposited approximately parallel to the bedding plane. This has resulted in the rock being quite fissile. Traces of chlorite are present and sericite is quite common in the rock. The whole rock is finely dusted with hematitic material, thus producing the reddish-brown colour in the rock.

The minor interbeds of sandstone are red-brown in colour, frequently silty, poorly sorted, thin bedded, slumped and ripple marked with some cross-bedding. Like the siltstone, it is very micaceous.

A specimen of sandstone (65.660024B) from 3 miles west of White Point Bore, about 300 feet below the top of Unit C, is a micaceous feldspathic sandstone. Quartz grains (fine - to medium-grained) are far more abundant than potash feldspar grains and cherty rock fragments. Muscovite flakes, a few biotite flakes and other micaceous flakes are almost completely replaced by opaques. Silica, hematite and minor amounts of clay and sericite are the main cementing agents. The silica is in the form of quartz overgrowths on subangular to subrounded grains of quartz. Trace amounts of tourmaline, zircon and ?glauconitic grains occur in the rock.

Unit C is the only unit in which fossils have been found. The first fossil to be found (by D.Woolley, Resident Geologist, Alice Springs) was from the upper part of Unit C, at a locality about 3 miles west of White Point Bore. The fossil was subsequently identified by A.A.Opik as a Protichnites, a track probably produced by a large trilobite such as an asaphid and probably of Lower Palaeozoic age. Fossils were also found in siltstones of Unit C by A.W.Lindner and N.W.Hamilton of American Overseas Petroleum Ltd. These were subsequently identified by A.A.Opik as a Helcionella and the fossil tracks Rusophycus and Protichnites. They are of Lower Cambrian age.

Unit D

Unit D is predominantly a sandstone sequence with a few minor siltstones. It overlies Unit C apparently conformably and is apparently conformably overlain by Unit F. At the present time Unit D is known to crop out sporadically across the entire Mount Doreen Sheet area on the northern margin of the basin (a distance of about 100 miles). It is generally well exposed, forming prominent strike ridges in places. Everywhere it is exposed the unit is about 500 feet

thick.

The sandstones of Unit D are white, grey-white or pale brown, fine grained, well sorted thinly to thickly bedded and cross-bedded in places. Mud- pellet markings are common in the outcrops near Penhalls Bore, Yuendumu Native Reserve. Most of the sandstones are strongly silicified.

A typical specimen (65.660021A) of weathered Unit D sandstone with some mud pellet markings is from just south of Penhalls Bore, described from the thin section examination as a well sorted, fine - to medium-grained ortho-quartzite. For the most part the quartz grains have been welded together by pressure solution leaving few voids. Strain extinction was evident in most grains. However minor amounts of clay are present in restricted bands through the rock. The only other non-quartz material is an occasional grain of zircon as well as a few cherty grains.

A specimen of a strongly silicified sandstone (65.660021B) from the same locality, is very similar to 65.660021A and is even closer to being mono-mineralic. It is a pure medium-grained, well sorted, orthoquartzite without chert fragments, but containing one or two tourmaline grains. Although many of the original quartz grains were well rounded, pressure solution and the cementing of the rock by quartz overgrowths has almost eliminated many of the primary grain boundaries.

Unit D is well exposed about half way along the Yuendumu-Vaughan Springs Road. Here, some of the sandstones have a high glauconite content. Such a rock (65.660034A) is described as glauconite bearing orthoquartzite. (X-ray analysis would be necessary to confirm the mineral as glauconite). For the most part the rock is cemented by qyartz overgrowths although minor amounts of clay and sericite are also present as interstitial components. A small amount of barite is also present, both as ?detrital grains and interstitial cement.

The rock is well sorted and of medium grain size. Quartz grains exhibit overgrowths on usually well rounded to subrounded hosts. The glauconite grains are often well rounded and of a similar size to the quartz grains. Accessory tourmaline, muscovite and opaques also occur in the rock.

Specimen 65.660034B from the same locality is a somewhat finer grained equivalent of 65.660034A. The mineralogy is essentially the same except for the additional presence of a few grains of zircon and potash feldspar. In the Vaughan Springs Syncline, the sandstones of Unit D are very similar

to those south of Yuendumu Settlement; no glauconite was seen. A typical specimen from this locality (65.660039A from near the base of the unit) is a fine-grained orthoquartzite which exhibits a fair degree of sorting. The rock is wholly cemented with quartz overgrowths on originally rounded to well rounded grains of quartz. Shadowy extinction in the quartz grains is quite a common phenomenon. Rounded clay aggregates of a similar size to the quartz fragments form approximately 5% of the rock. Accessory amounts of zircon, tourmaline and opaques are also present.

A second specimen from this locality (65.660039B from near the top of the unit) is mineralogically similar to 65.660039A except for the additional presence of minor amounts of limonitic ?clayey material, acting as a cementing agent, and traces of muscovite flakes. The degree of sorting is poorer than in 65.660039A although the grains are of fine sand size with one or two exceptions. Although the finer grain sizes tend to be in bands, there is no regular distribution or grading of these bands. However they are apparently sufficiently different in texture to cause fissility in the rock.

About 8 miles south-east of Yuendumu Settlement, a prominent ridge of grey, silicified sandstone is possibly composed of Unit D. The thin section of a specimen (65.660045A from near the top of the ridge) is described as follows: This rock is a poorly sorted protoquartzite in which very well rounded quartz grains varying in diameter from 0.5 mm. to 1.5 mm. (coarse sand) are present in a generally fine sand size quartz matrix (Figure 6). These finer grains are subrounded to rounded and are themselves cemented by interstitial clay and a little very fine quartz. Narrow quartz overgrowths are also present. This interstitial material forms 10 to 15% of the rock. Other than quartz, which makes up 95% of the clastics, rounded grains of quartzite and clay aggregates are also present. Tourmaline and opaques occur as accessory constituents.

There are no fossils in Unit D, but its conformable position above Cambrian sediments suggests that it is probably either Cambrian or Ordovician in age.

Unit E

Unit E is composed predominantly of sandstone. It conformably overlies Unit D and is unconformably overlain by Unit F. At the present time it is

only known to crop out on the northern margin of the Basin, in the vicinity of Yuendumu Settlement. It has a maximum thickness of about 1,000 feet.

Unit E consists of pale brown or grey (weathering to grey-brown) sandstones. The sandstones are generally moderately sorted, thin to thickly bedded, commonly cross-bedded and slumped. They are similar in appearance to those of Units B and F.

A specimen (65.660022A) from Unit E just south of Penhalls Bore on Yuendumu Native Reserve is a medium-grained protoquartzite containing quartz and chert grains as well as other rock fragments. The fragments consist of sericitized fine-grained sandstone and sericite schist. Clay occurs as detrital grains and as a cementing agent for many of the grains. However, frequently the quartz grains have undergone pressure solution and are cemented by quartz overgrowths. Many of the quartz grains originally had rounded shapes but overgrowths have eliminated most evidence of this. Traces of opaques and tourmaline are also present in the rock.

Specimen 65.660022B from the same locality is essentially a fine-grained equivalent of 65.660022A. Textural qualities are much the same and as well as trace amounts of tourmaline and opaques, a few grains of zircon are also present.

A sample (65.660027) from just below the top of Unit E at a point 6 miles south-west of Yuendumu Settlement is a very poorly sorted ortho-quartzite (more than 95% quartz). Grain sizes vary from clay to coarse sand size, the larger quartz grains being rounded while the smaller interstitial material is usually very angular and frequently has sutured grain boundaries. These interstitial fragments of quartz form the major part of the matrix and due to pressure solution act as a siliceous cement. Minor amounts of clay are also present as interstitial material. Traces of zircon, tourmaline, mustovite, sericite and opaques are also present.

A sandstone which crops out about 8 miles south-east of Yuendumu Settlement is also thought to be Unit E. A specimen of this sandstone (65.660046) is an extremely poorly sorted lithic greywacke. Quartz grains form approximately 60% of the rock and these constituents are angular to subrounded and of fine to medium sand size. The remainder of the rock contains chert, sericite schist, quartzite and muscovite flakes as well as clay aggregates. There is some degree of preferential alignment of mica flakes as seen along fracture surfaces in the hand specimen (probably

bedding). However there is no size grading of components. Clusters of quartz grains are held together by pressure solution but in general the cementing agent is red hematitic material which causes the rock to be quite friable.

No fossils have been found in Unit E. Its position above Cambrian sediments and below a major unconformity suggests that it is of Lower Palaeozoic age.

Unit F

Unit F is composed predominantly of sandstone. It unconformably overlies Units E, D and C. The top is everywhere an erosional surface. It crops out over a considerable area, particularly in the area south and south-west of Yuendumu Settlement, where it forms prominent hills and ranges. It forms several mesas in the central part of the Basin. Unit F is an extremely thick rock unit estimated from air-photographs to be in the order of 7,000 feet thick. No fossils have been found in the Unit although a few ?fossil tracks have been seen in the Unit about 4 miles west of White Point Bore. It is suspected that the Unit is Upper Palaeozoic (?Devonian - ?Carboniferous) in age.

The sandstone is pale brown or red-brown, poorly sorted, pebbly and conglomeratic in part, micaceous in part, kaolinitic, friable, thin to massively bedded and cross-bedded. Ripple marks, mud-pellet markings, mud-cracks, lump-rolls and load-casts are present in places. There are a few silty interbeds. Cross-bed current directions, measured in the central part of the basin, suggested that the main source area for the sediments lay to the south-west.

A typical specimen of a well bedded sandstone from near the base of Unit F (Number 65.660026 at a locality 3 - 4 miles west of White Point Bore, Yuendumu Native Reserve) is described from thin section examination as a protoquartzite.

Because of the very poor sorting of clastics this bedding is not obvious in thin section. The grains are restricted to the fine and medium sand sizes and when these are not held together by quartz overgrowths the cementing medium is clay, sericite or limonitic material. In general the grains are irregular in shapr and very seldom do they show well rounded features. Muscovite flakes, chert grains, sericitized fine sandstone fragments and occasional clay aggregates are also present in the rock but

form less than 10% by volume of the sample. Iron oxides and/or hydroxides occupy nearly 5% of the rock. Tourmaline and zircon grains are accessories.

A specimen (65.660028) of sandstone from near the base of the Unit 7 miles south-west of Yuendumu Settlement is a porous cherty subgreywacke. The components are relatively poorly sorted and restricted to the fine - to medium-grained sizes. Quartz grains form at least 50% of the rock while cherty fragments, clay aggregates and sericitized grains (fine-quartzite or schist) make up the remainder of the clastics. Clay cement (approximately 10 to 15% of the rock) often associated with sericite binds the rock together. Accessory amounts of rutile, muscovite and opaques are also present in this specimen.

In the field, specimen 65.660030, from an isolated outcrop about 8 miles south of Kerridy Waterhole, was suspected to be silicified Unit F. Thin section examination revealed that, although similar im mineralogy to 65.660028, this rock contains different component proportions and improved sorting. It contains at least 75% quartz and is therefore classified as a medium-grained protoquartzite. Chert fragments, clay aggregates and partly sericitized rock fragments (?schistose) form the remainder of the rock. Many of the grains were originally rounded but the rock is now silicified with overgrowths of quartz cementing the components into a tight mass with low porosity. Trace amounts of rutile, tourmaline, muscovite and minor opaques are evident in thin section.

Specimen 65.660031A was collected from an outcrop of Unit F in the middle of the basin about 30 miles south of Yuendumu Settlement. It is from near the base of the outcrop but is probably high in Unit F. The specimen is a well sorted subgreywacke which closely approaches a protoquartzite in composition. As well as the quartz grains (medium to fine-grained) fragments of chert, sericitized quartzite, clay, schist and muscovite flakes are common constituents. Clay cement is more common than in 65.660030 but silica overgrowths are less abundant. Most of the grains have been coated in a thin layer of iron oxides or hydroxides prior to cementation. Opaques now form 5 to 10% of the rock. Tourmaline and rutile occur as accessory constituents.

Specimen 65.660036, a typical sandstone, is from 500 - 1,000 feet above the base of Unit F at an outcrop about half way along (and just north of) the Yuendumu-Vaughan Springs road. It is a very poorly sorted protoquartzite. As well as strained, irregular shaped quartz grains there are also rock fragments of chert, sericitized silt and claystone, as well as aggregates of sericite and clay. The components range from fine- to medium-grained sand sizes with trace amounts of coarse grains. Together with quartz overgrowths on the quartz grains, these latter two minerals are common cementing agents in association with limonitic material. Occasional biotite and muscovite flakes as well as zircon grains are also present in the rock.

Specimen 65.660040 is also a typical Unit F sandstone. It is from about 50 feet above the base of Unit F in the core of the Vaughan Springs Syncline. The specimen is a porous cherty subgreywacke which consists of approximately 70% quartz. The remainder is mostly clay (as interstitial material as well as detrital aggregates), muscovite flakes, and minor schistose fragments. Tourmaline, opaques and zircon are accessory components. The rock is fine- to medium-grained, very poorly sorted, and contains very few grains with any significant degree of rounding. Quartz grains in contact are welded together but seldom exhibit quartz overgrowths. Clay is the only other form of cementing medium which imparts any coherence to the rock. In places there are conglomerates at the base of and within Unit F. The basal conglomerate is 2 - 3 feet thick at an outcrop four miles west of White Point Bore. It consists of well rounded clasts up to 4 inches in diameter and composed mainly of vein quartz, metaquartzite and silicifed sandstone. There are also a few fragments of the underlying siltstone of Unit C.

Conglomerates within Unit F are particularly well developed about 2 miles south of Smiths Gift Bore on the western margin of the Napperby Sheet area. Here, conglomeratic bands are up to six feet thick. They are composed of well rounded pebbles, cobbles and boulders up to 1 foot in diameter. Most of the phenoclasts consist of vein quartz, silicified sandstone and metaquartzite in a poorly sorted sandstone matrix. Sandstones also occur with the conglomerates. A specimen of the sandstone (65.660047A) is considered, from thin section examination, to be a porous protoquartzite approaching the purity of an orthoquartzite. The quartz grains are mostly of

fine sand size and usually angular to subrounded in shape. Quartz overgrowths are present but not common. The rock is tightly welded together by pressure solution. Minor amounts of chert fragments as well as tourmaline, zircon rutile and opaque grains also occur in this sample. The heavy minerals are commonly segregated in narrow bands. Minor hematitic material gives the rock a slightly reddish colour.

A typical sandstone from this locality is specimen 65.660047B, described as a very loosely packed orthoquartzite from thin section examination. Poor sorting of the quartz grains is a feature of the rock, the grains ranging from the fine to medium sand sizes. Angular to sub-rounded grain shapes are common and the rock is cemented with opal. The opal forms thin coatings on both large and small grains and never fills interstitial cavities completely (Figure 7). Consequently, the rock is quite porous although silty grains sometimes partly fill these interstices. In hand specimen the red-weathered surface is quite durable while an inch below this surface it is friable. In thin section it is seen that the opaline cement is only a surface phenomenon and is almost completely absent in the friable portion of the sample.

CORRELATION OF NGALIA BASIN SEDIMENTS WITH THOSE OF THE GEORGINA AND AMADEUS BASINS (Fig.1)

Unit A^1 The tillitic nature of this unit is similar to that of the Mount Cornish Formation (Smith, 1964) of the Georgina Basin. In the Amadeus Basin, there are two tillitic horizons, the Areyonga Formation and the Olympic Member of the Pertatataka Formation (Wells, et.al., 1967). Correlation of Unit A^1 with the younger formation (the Olympic Member) is favoured. This would also equate the unit with the Marinoan tillite horizon of the Adelaide Geosyncline rather than with the Sturtian tillite.

Unit A This unit is correlated with the Central Mount Stuart Beds of the Barrow Creek area, because of the lithological similarity of the two units and because both are underlain by a tillitic horizon (Smith, pers.comm.). On these same grounds, the Pertatataka Formation (or its arenitic equivalent, the Winnall Beds), - Ranford et.al., 1966 - is correlated either in part or wholly with Unit A.

Unit B This red-brown sandstone is similar in lithology and occupies a similar stratigraphic position to the Grants Bluff Formation of the Georgina Basin and the Arumbera Sandstone of the Amadeus Basin. A report of Helcionella sp.

by Smith and Milligan (1964) in the upper part of Grants Bluff Formation of the Barrow Creek area suggests that only the lower half of the formation in that area should be correlated with Unit B.

Unit C The known Lower Cambrian age of Unit C and its calcareous lithology supports a correlation with the Todd River Dolomite of the Amadeus Basin (Wells, et.al., 1967) and with the Mount Baldwin Formation (Smith, 1964) of the Georgina Basin. As mentioned previously, the presence of Helcionella sp. may mean that the upper part of the Grants Bluff Formation of the Barrow Creek area is the time equivalent of the Mount Baldwin Formation and also of Unit C.

Unit D Though Unit D overlies Unit C with apparent conformity, it is suspected that there may be a major time break between the two units. Unit D may be as young as Upper Cambrian or Ordovician. Unit D is correlated on lithological grounds with the Tomahawk Beds of the Barrow Creek area of the Georgina Basin (Smith & Milligan, 1964) and the Larapinta Group (possibly the Pacoota Sandstone) of the Amadeus Basin.

Unit E Unit E has uncertain affinities with units of adjacent basins. It may be equivalent to part of the Tomahawk Beds and the Larapinta Group. It is considered unlikely that this unit is correlatable with the Mereenie Sandstone of the Amadeus Basin.

Unit F On lithological grounds and because of its strongly unconformable relationship with underlying units, Unit F is correlated with the Upper Devonian-Carboniferous Pertnjara Group (Particularly the Hermannsburg Sandstone) of the Amadeus Basin (Wells et.al., 1967; Tomlinson, 1967). It is probably also equivalent to the upper part of the Dulcie Sandstone of the Georgina Basin.

STRUCTURE

The Ngalia Basin has been affected by at least three important episodes of earth movement. These are represented by the basement complex which unconformably underlies Unit A, the unconformity at the base of Unit B and the unconformity at Base of Unit F. These may correspond to three main orogenies in the Amadeus Basin referred to by Forman et.al., (1967) as the Arunta Orogeny (Upper Proterozoic), the Petermann Ranges Orogeny (late Upper Proterozoic) and the Alice Springs Orogeny (Devonian - Carboniferous).

As Unit F is also strongly folded in many parts of the basin it may be a continental, syn-orogenic formation of the Pertnjara Group type.

These movements in the Ngalia Basin produced uplift, folding and faulting of uncertain magnitude. Some of the folds visible in Unit F to the south of Yuendumu settlements are of the Jura-type (i.e. broad synclines and sharp anticlines). This may be due to the presence of an incompetent formation (possibly Unit C or perhaps some other unit not recognised at the present time). Nettleton (1965) considers that seismic work south of Yuendumu Settlement has indicated anomalies which may be due to the presence of salt. He further considers that a northward decrease of Bouguer anomaly values across the same area is caused by the northward slope of the floor of the Ngalia Basin to an axis situated near the outcropping northern margin.

Aeromagnetic data (Hartman, 1963) has indicated the presence of approximately 17,000 feet of sediments south of Yuendumu Settlement. In much the same area there also appears to be a complex horst or group of horsts. Hartman (1963) describes one feature (Anomaly 1 - 8) as possibly being due to a small igneous plug penetrating the section. This anomaly appears to correspond to outcropping basement approximately half-way along the Yuendumu-Vaughan Springs road.

Flavelle (1966) has shown by a regional gravity survey of the Napperby Sheet area that there is a large negative gravity anomaly (-100 mgals), north of Napperby Homestead, in an area of outcropping basement. Further north, in the Reynolds Range area, it appears from the air-photographs that there is a complex infolding of sediments and basement corresponding to a gravity ridge. The structure here may be similar to that of the northern margin of the Amadeus Basin.

It is suspected that on the northern margin of the Ngalia Basin in the Napperby Sheet area, there is overthrusting of basement over the sediments. At a locality three miles west of Napperby Homestead, where there is thought to be a folded thrust involving Unit A, the sediments dip beneath the granitic basement rocks. The regions where sedimentary rocks are known to crop out in the southern half of the Napperby Sheet area corresponds to a steep north-dipping gradient. There is no correlation between the limits of the Ngalia Basin indicated by outcrop and the bouguer anomaly map. This may be due to the gravity gradient being dominated by

the presence of a large body of granite or it may be due to complex overfolding or overthrusting of basement onto the Upper Proterozoic and Palaeozoic sediments of the Ngalia Basin. Either explanation is possible in the Napperby Sheet area. In the Yuendumu area the northern boundary of the basin appears to be a normal fault.

Further work is likely to show that the Ngalia Basin has had a complex structural history, possibly similar to that of the Amadeus Basin.

GEOLOGICAL HISTORY

The main events may be summarized as follows:-

1. Deposition of arenites and luties in the pre-Cambrian
2. Regional metamorphism, with metamorphism of the arenite-lutite sequence to schists, phyllites, metaquartzites etc. (Lower Proterozoic)
3. Injection of large igneous bodies such as the Rock Hill Granite and the Napperby Granite (Lower Proterozoic).
4. Area probably above sea level for considerable length of time, with erosion and peneplanation taking place during the Upper Proterozoic
5. Either marine or continental glacial sediments deposited in parts of the area (Unit A^1) during the Upper Proterozoic
6. Thick sequence of marine sandstones with some conglomerates and some lutites deposited over the entire basin, probably under shallow marine conditions (Unit A) in the Upper Proterozoic
7. Major earth movements with folding of sediments and possibly also affecting basement in the Upper Proterozoic-lower Cambrian. Area raised above sea-level and subsequently eroded.
8. Shallow-water marine conditions return to the area in the Lower Cambrian Units B, C, D and E were deposited in the Cambrian-Ordovician. Possibly some breaks in sedimentation during this time but not recognized as yet.
9. Major orogeny during the Devonian-Carboniferous with the deposition of a thick sequence of coarse continental deposits (Unit F). Strong folding and probable faulting of the sediments and possibly also affecting the basement rocks.
10. The region remained continental throughout the Mesozoic, and Cainozoic

REFERENCES

BUDDINGTON, A.F. (1959) Granite emplacement with special reference to North America. Geol.Soc.Amer.Bull., 70. 671-748

COOK, P.J., 1963 The geology of Yuendumu Native Reserve, Northern Territory. Bur.Min.Resour.Aust. Rec.1963/37 (unpubl.)

FIAVELIE, A., 1966 The 1965 helicopter gravity survey by contract Northern Territory and Queensland. Bur.Min.Resour.Aust. (unpubl.)

FORMAN, D.J., MILLIGAN, EN., & McCARTHY, W.R., 1967 The structure of the north-eastern margin of the Amadeus Basin, Northern Territory. Bur.Min.Resour.Aust. Report 103 (in press)

HARTMAN, R.F., 1963 Interpretation report of airborne magnetometer survey over portion of oil permit No.81, Ngalia Basin, N.T. Report by Aeroservices Ltd. for Pacific American Oil Company (unpubl.)

JONES, N.O., AND QUINLAN, T., 1958 "The groundwater problem, Yuendumu Native Reserve, Northern Territory". Bur.Min. Resour.Aust.Rec.1958/51 (unpubl.)

KIEK, S.N., 1941 The Mount Hardy Copper Field, Central Australia. Aerial, Geological and Geophysical Survey of Northern Australia Report 55

NETTLETON, L.L., 1965 Report on interpretation of gravity results, Napperby area. Oil Permit 81. Northern Territory of Australia (unpubl.)

PETTIJOHN, F.J., 1957 — Sedimentary Rocks, Harper, New York, p.265

QUINLAN, T., 1958 — Report on groundwater prospects, Yuendumu Native Reserve. Bur.Min. Resour.Aust.Rec. 1958/1 (unpubl.)

QUINLAN, T., 1962 — An outline of the geology of the Alice Springs area. C.S.I.R.O. Aust.Land Res.Series No.6

RANFORD, L.C., COOK, P.J., & WELLS, A.T., 1966 — The geology of the central part of the Amadeus Basin, Northern Territory. Bur.Min.Resour.Aust. Report (in press)

RIVEREAU, J., 1965 — The photogeology of the Ngalia Basin, Northern Territory. Bur. Min.Resour.Aust.Rec.1965(unpubl.)

RYAN, G.R., 1956 — Report on the copper reef at Yuendumu Native Settlement N.T. Bur.Min.Resour.Aust.Rec.1956/123 (unpubl.)

SMITH, K.G., 1964 — Progress report on the geology of the Huckitta 1:250,000 sheet, Northern Territory. Bur.Min. Resour.Aust.Report 67

SMITH, K.G., & MILLIGAN, E.N., 1964 — Explanatory notes on the Barrow Creek, 1:250,000 Geological Series Bur. Min.Resour.Aust.

TINDALE, N.B., 1933 Geological notes on the Cockatoo Creek and Mount Liebig country, central Australia. Trans.Roy.Soc.S.Aust. 57, 206-217

TOMLINSON, J.G., 1967 A new occurrence of Bothriolepis in Central Australia. Bur.Min.Resour. Aust.Bull. (in prep.)

VANCE, J.A., 1961 Zoned granitic intrusions, an alternative hypothesis of origin. Geol.Soc.Amer. Bull., 72, 1723-1728

WATERS, A.C., AND KRAUSKOPF, K., (1941) Protoclastic border of the Colville Batholyth. Geol.Soc.Amer.Bull., 52, 1355-1418

WELLS, A.T., FORMAN, D.J., RANFORD, L.C., & COOK, P.J., 1967a. The geology of the Amadeus Basin. Bur.Min.Resour. Aust.Bull. (in press)

WELLS, A.T., RANFORD, L.C., STEWART, A.J., COOK, P.J., AND SHAW., R.D., 1967(b). The geology of the north-eastern part of the Amadeus Basin, Northern Territory. Bur.Min.Resour. Aust.Report (in press).

WIEBENGA, W.A., GOODCHILD, R.J., & BAMBER, B., 1959 Preliminary report on a geophysical investigation of groundwater at Yuendumu, Northern Territory. Bur. Min.Resour.Aust. Rec.1959/7

FIGURE 1

Quartz overgrowths on rounded quartz grains.
TS 65.66.0005 XN, x40

FIGURE 2

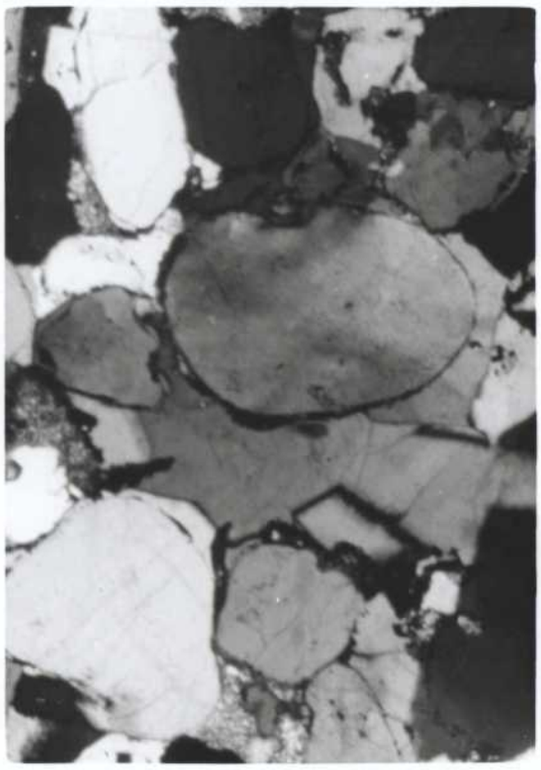
Cataclastic quartzite
TS 65.66.0011 XN, x40

FIGURE 3

Sericite biotite and opaques replacing plagioclase feldspar.
TS 65.66.0015 XN, x100

FIGURE 4

Twisted biotite altering to white mica and iron oxides.
TS 65.66.0041A XN, x25



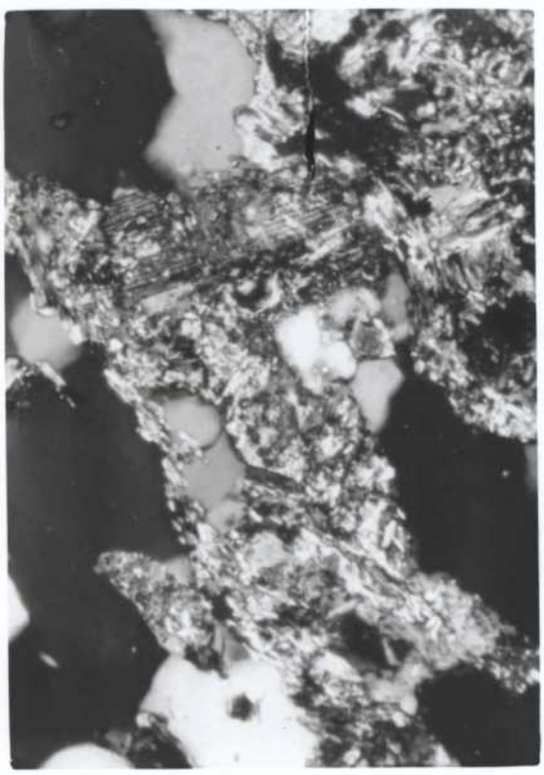


FIGURE 5

Poorly sorted pebbly siltstone with a "tilloid" texture.
TS 65.66.0042A XN, x25

FIGURE 6

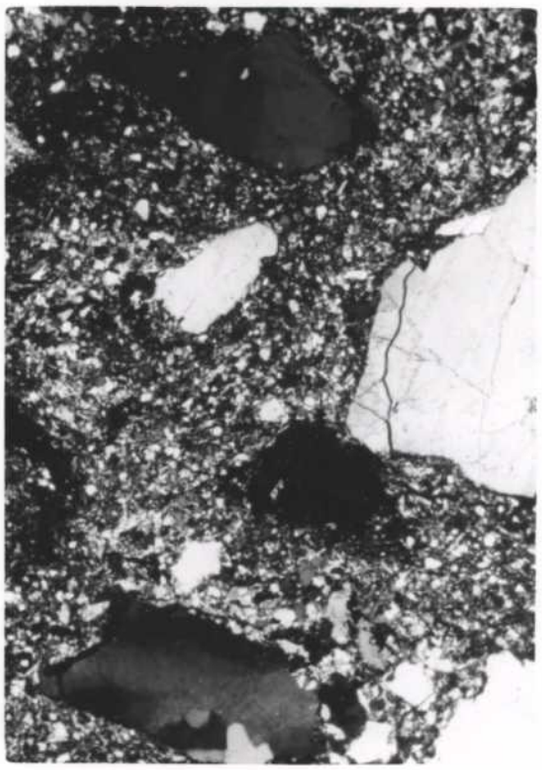
Poorly sorted, well rounded quartz grains in a proto-quartzite.
TS 65.66.0045A XN, x25

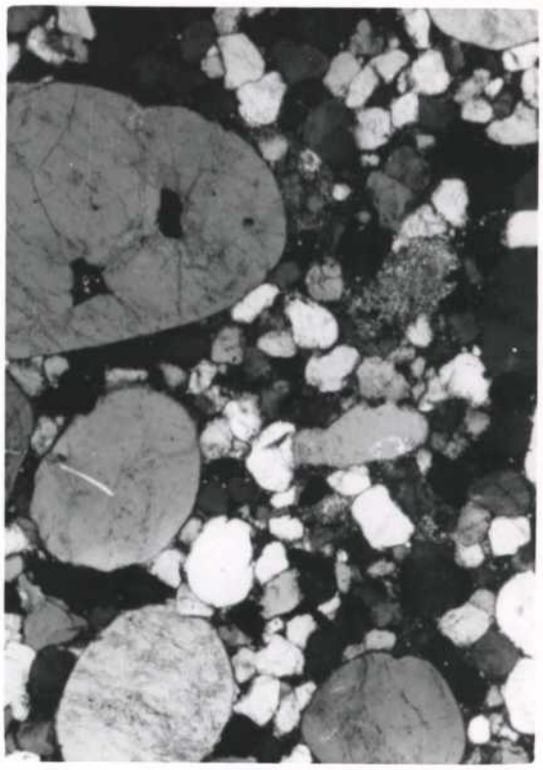
FIGURE 7

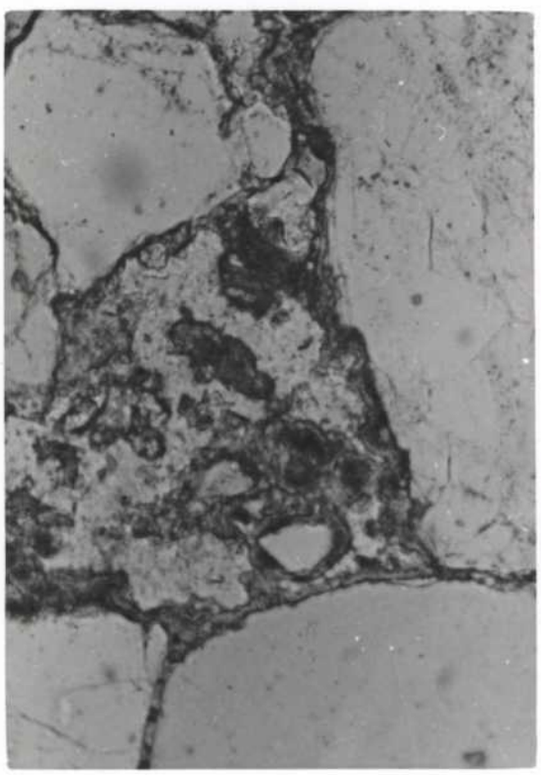
Opal cement forming thin coatings on quartz grains.
TS 65.66.0047B PPL, x100

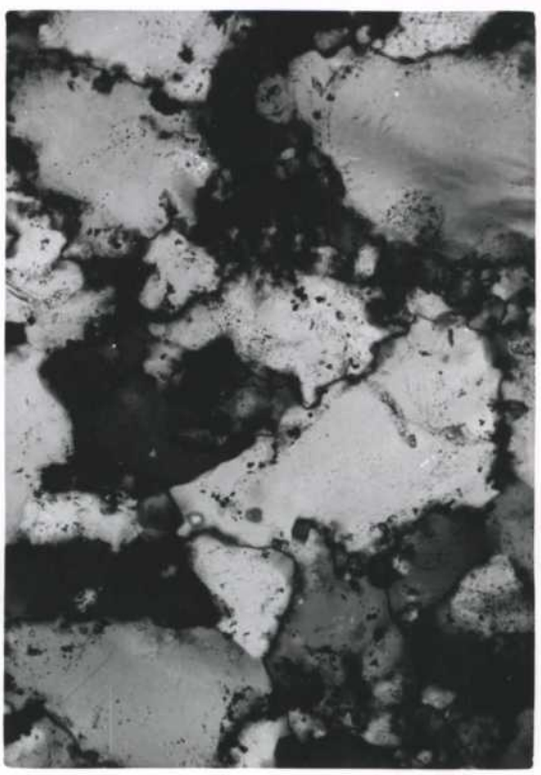
FIGURE 8

Irregular shaped quartz grains sutured together.
TS 65.66.0048A XN x100







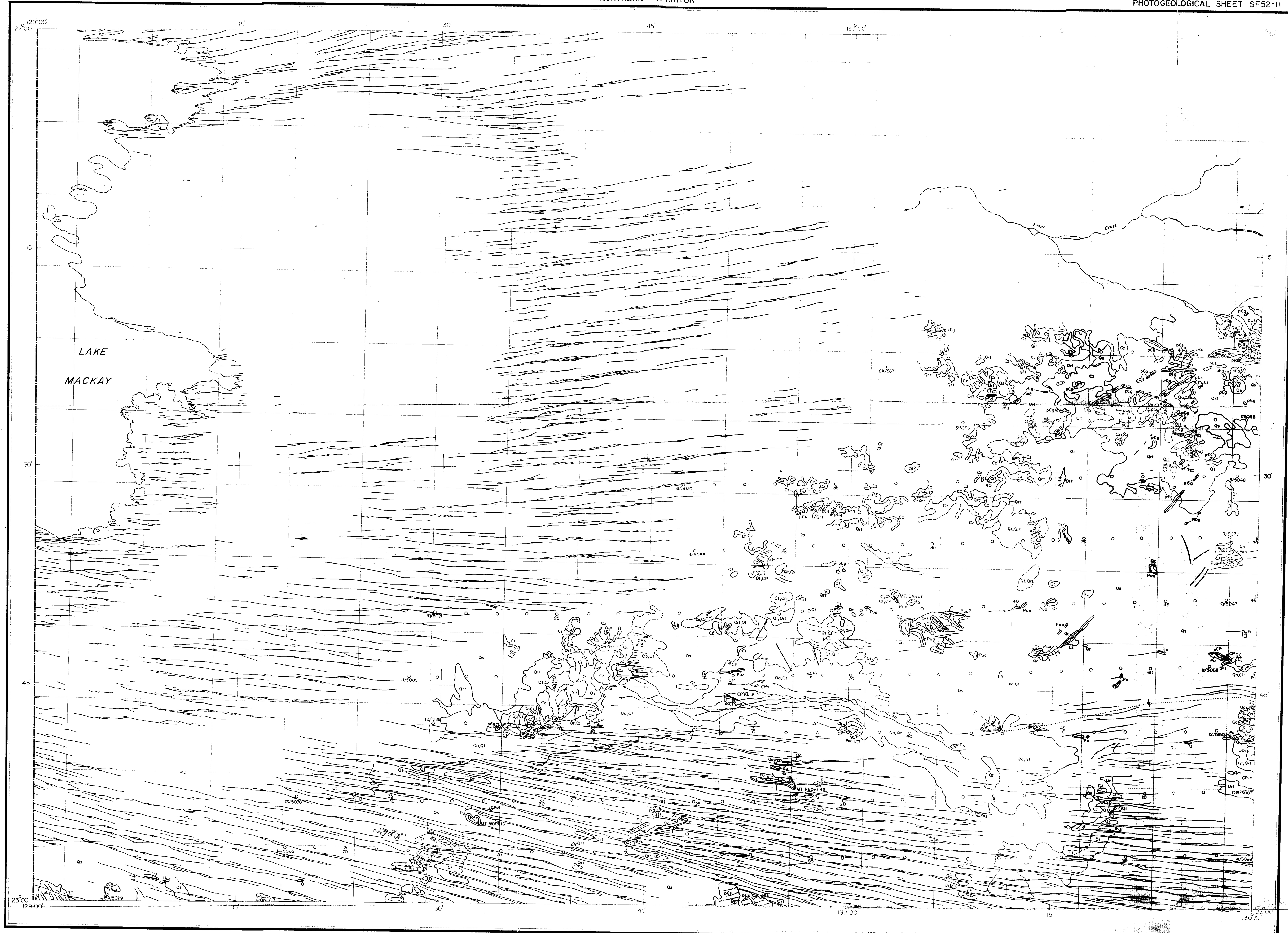


BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

LAKE MACKAY

NORTHERN TERRITORY

AUSTRALIA 1:250,000
PHOTOGEOLOGICAL SHEET SF52-11



REFERENCE

Photogeological Character	Symbol	Possible Geological Equivalent			
	Qa	Alluvium, floodplain, floodout	QUATERNARY		CAINOZOIC
	Qc	Colluvium, detrital slope			
	Qs	Sand plain			
	Qrt	Plain with timber cover			
	CP	Clay or saltpan			
Grey to light toned, with white spots	Qt	Travertine			
Dark toned, mesa-form, small scarp	Cz	Laterite; continental formation	UNDIFFERENTIATED		
Unconformity					
Light grey to white toned, hard appearance	Pua	Sandstone, mainly silicified, conglomerate, arkose	UPPER PROTEROZOIC TO LOWER PALAEOZOIC		?
Light grey toned, jointed, hard appearance	Pu	Undifferentiated, (Southern ridge), sandstone, silicified sandstone, conglomerate			
Unconformity					
Grey toned with white patches, very thin bedded, steeply dipping, low outcrop	p€s	Quartz-sericite schist, quartz amphibolite	UNDIFFERENTIATED		PRECAMBRIAN
Massive and well jointed outcrop intruded by many dykes	p€g	Gneissic granite, granite (may include quartzite ridges)			
	U	Undetermined			

- Lithological boundary
- Probable lithological boundary
- Anticlinal axis
- Synclinal axis
- Fault
- Probable fault
- Edge of bed
- Probable edge of bed
- Edge of bed expressed as scarp

Estimated dips

- Horizontal
- Very low
- Low
- Medium
- Steep
- Vertical

- Trend line
- Joint pattern
- Topographic scarp
- Laterite (L), Terrace (T), Scree (S)
- Quartz dyke or vein

- Principal road
- Minor roads and tracks
- Railway line (Siding, Station)
- Telephone line
- Fence
- State boundary
- Mine
- Homestead
- Yard
- Windpump
- Airport or Airfield, Landing ground
- B Bore
- T Tank
- W Well
- S Spring
- WH Waterhole
- D Dam
- Photo-centre points
- Photo-centre points-adjoining sheet
- Sand dunes

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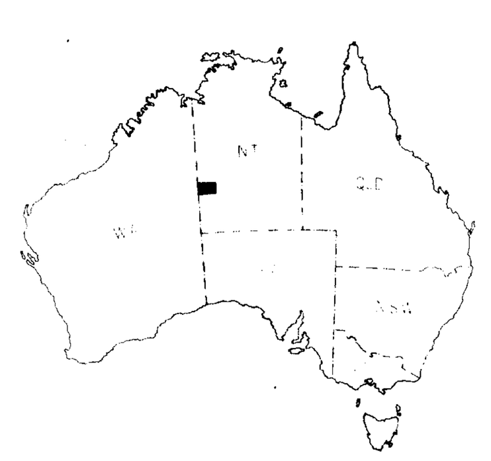
Detail adjusted to photoscale compilation prepared by the Division of National Mapping, Department of National Development
Aerial photography by Royal Australian Air Force; complete vertical coverage at 1:46,000 scale
Transverse Mercator Projection



SCALE 1:250,000

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5 0 5 10 15 20 25 KILOMETRES

INDEX TO ADJOINING SHEETS

STANSMORE	HIGHLAND ROCKS	MT THEO
WEBB	LAKE MACKAY	MT DOREEN
MACDONALD	MT RENNIE	MT LIEBIG

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F52/A11/1

BUREAU OF MINERAL RESOURCES,
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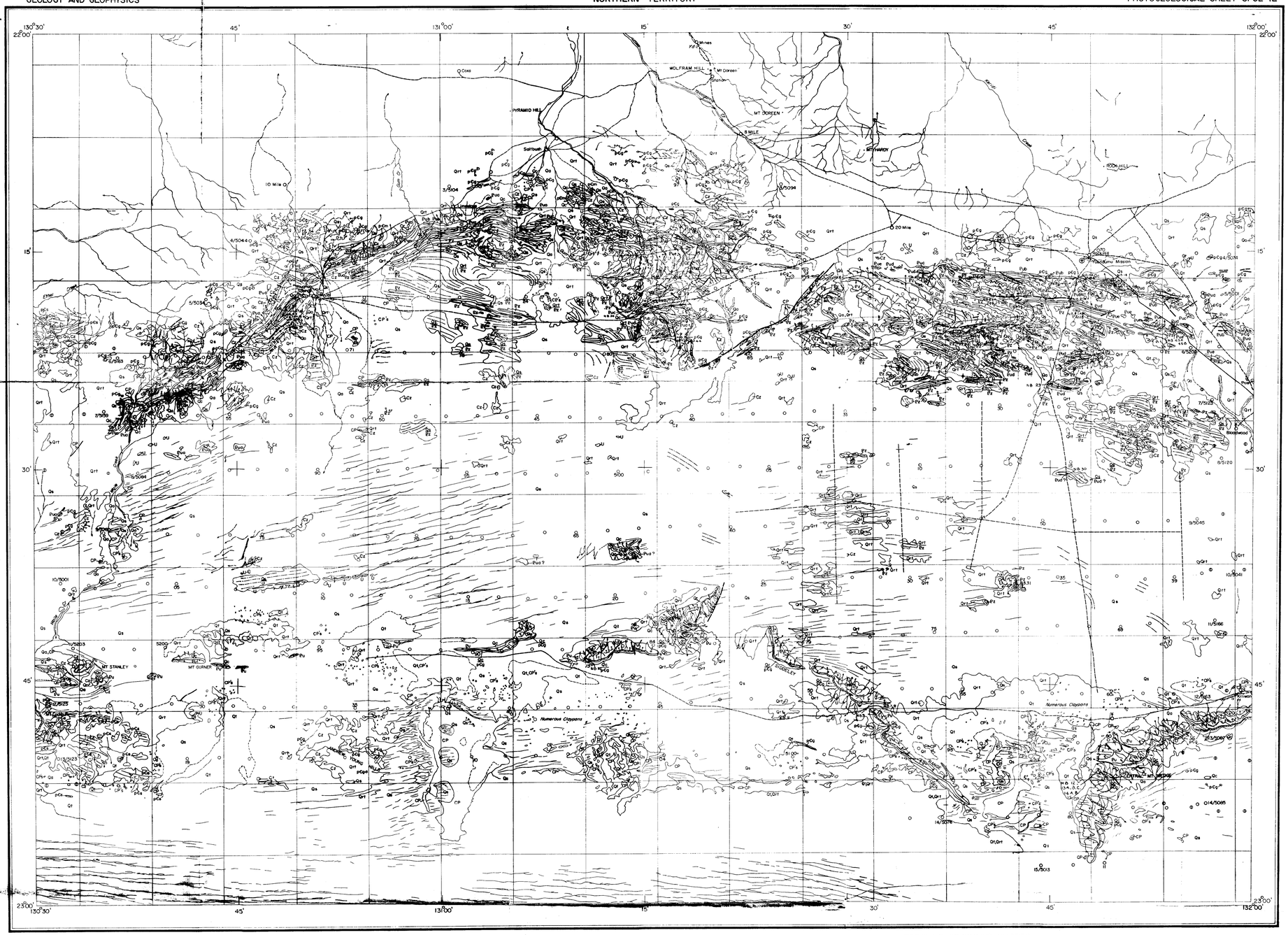
MOUNT DOREEN

NORTHERN TERRITORY

AUSTRALIA 1:250,000
PHOTOGEOLOGICAL SHEET SF52-12



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Transverse Mercator Projection

SCALE 1:250,000

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5 0 5 10 15 20 25 KILOMETRES

INDEX TO ADJOINING SHEETS

HIGHLAND ROCKS	MT THEO	MT PEAKE
LAKE MACKAY	MT DOREEN	NAPPERBY
MT RENNIE	MT LIEBIG	HERMANNS-BURG

Photo-interpretation by the Photogeological Group, Bureau of Mineral Resources, Geology and Geophysics 1965
Interpreted by: J.C.Rivereau, Institut Français du Petrole

REFERENCE

Photogeological Character		Possible Geological Equivalent		
	Qa	Alluvium, floodplain, floodout	QUATERNARY	CAINOZOIC
	Qc	Colluvium, detrital slope		
	Qs	Sand plain		
	Qrt	Plain with timber cover		
	CP	Clay- or salt pan		
Grey to light toned, with white spots	Qt	Travertine		
Dark toned, meso-form, small scarp	Cz	Laterite, continental formation	UNDIFFERENTIATED	
Dark toned, thin bedding well developed	Pz	Red brown sandstone, conglomerate	? UPPER PALAEOZOIC	
Unconformity				
Dark toned, thin bedded	Pue	Red brown sandstone	UPPER PROTEROZOIC TO LOWER PALAEOZOIC	PRECAMBRIAN ?
Grey and light toned	Pud	Sandstone silicified in part		
Unconformity ?				
Medium grey toned, soft appearance	Pud_1	Sandstone, siltstone		
Dark grey toned, rounded outcrop	Puc	Dolomite		
Unconformity ?				
Dark toned	Pub	Red brown sandstone		
Unconformity				
Light grey to white toned, hard appearance	Puo	Sandstone, mainly silicified, conglomerate, arkose		
Light grey toned, jointed, hard appearance	Pu	Undifferentiated, (Southern ridge), sandstone, silicified sandstone, conglomerate		
Unconformity				
Grey toned with white patches, very thin bedded, steeply dipping, low outcrop	pCs	Quartz-sericite schist, quartz amphibolite	UNDIFFERENTIATED	
Dark toned, hard appearance, high relief, roughly bedded, intruded by many dykes	pCm	Quartzite, gneiss, migmatite, amphibolite		
Massive and well jointed outcrop intruded by many dykes	pCg	Gneissic granite, granite (may include quartzite ridges)		
	U	Undetermined		

- Lithological boundary
- Probable lithological boundary
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- Probable edge of bed
- Edge of bed expressed as scarp
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- Overturned strata
- Estimated dips
- Horizontal
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- Low
- Medium
- Steep
- Vertical
- Trend line
- Joint pattern
- Topographic scarp
- Laterite (L), Terrace (T), Scree (S)
- Quartz dyke or vein
- Principal road
- Minor roads and tracks
- Railway line
- Telephone line
- Fence
- State boundary
- Mine
- Homestead
- Yd Yard
- Windpump
- Airport or Airfield, Landing ground
- Bore
- T Tank
- Well
- Spring
- Wtr Waterhole
- Dam
- Photo-centre points
- Photo-centre points-adjoining sheet
- Sand dunes
- NB 12 x Specimen locality

Replace sample prefix N.B by prefix 65-6600 to conform to B.M.R. Data Retrieval System.

F52/A12/4

BUREAU OF MINERAL RESOURCES,
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NAPPERBY
NORTHERN TERRITORY

AUSTRALIA 1:250,000
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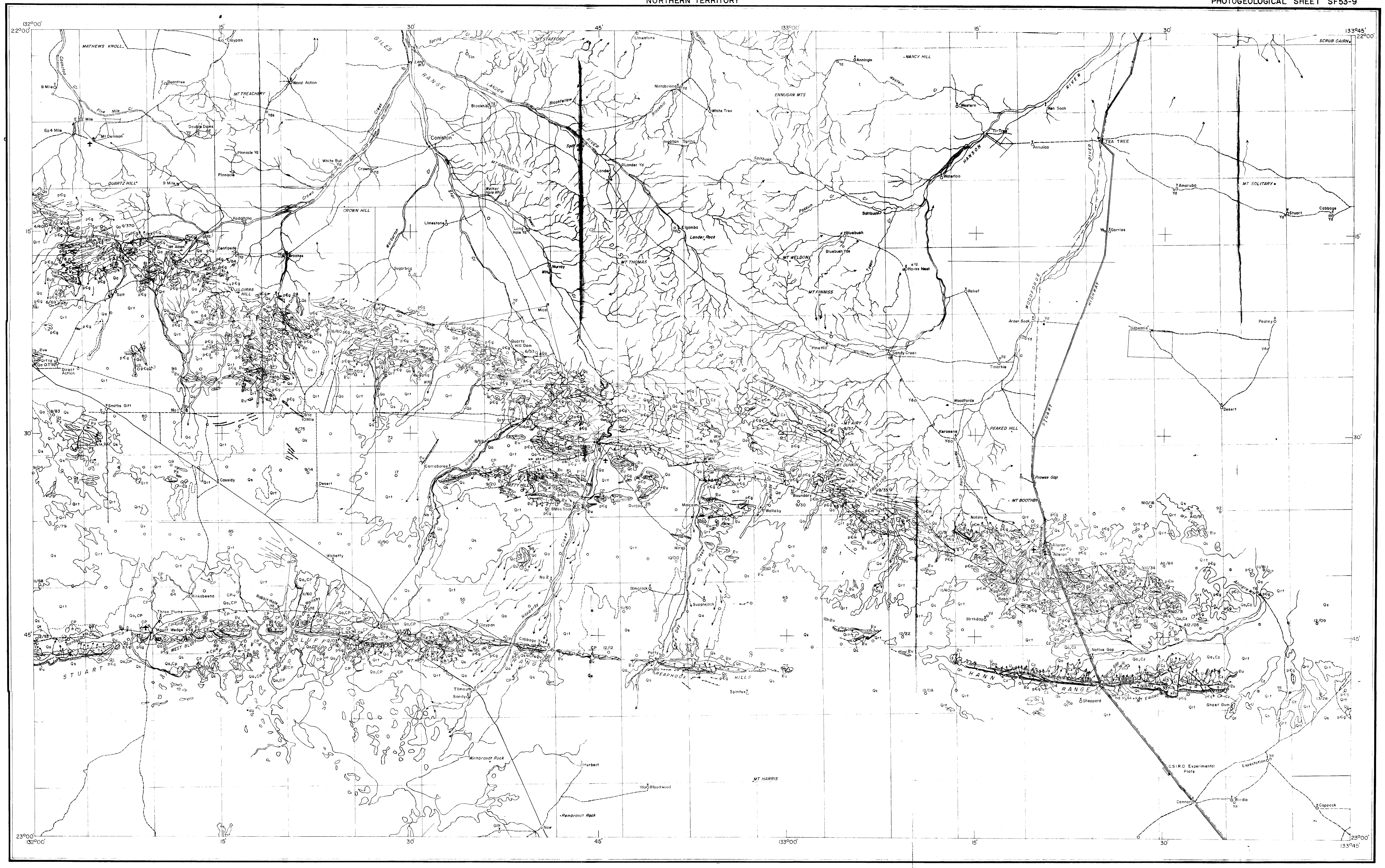

REFERENCE

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	Qc	Colluvium, detrital slope		
	Qs	Sand plain		
	Qrt	Plain with timber cover		
	CP	Clay-or salt pan		
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Dark toned, mesa-form, small scarp	Cz	Laterite, continental formation	UNDIFFERENTIATED	
Dark toned, thin bedding well developed	Pz	Red brown sandstone, conglomerate	? UPPER PALAEOZOIC	
		Unconformity		
Dark toned, thin bedded	Ɛue	Red brown sandstone	UPPER PROTEROZOIC TO LOWER PALAEOZOIC	PRECAMBRIAN
		Unconformity ?		
Dark toned	Ɛub	Red brown sandstone		
		Unconformity		
Light grey toned, jointed, hard appearance	Ɛu	Undifferentiated; (Southern ridge), sandstone, silicified sandstone, conglomerate		
		Unconformity		
Dark toned, hard appearance, high relief, roughly bedded, intruded by many dykes	p€m	Quartzite, gneiss, migmatite, amphibolite	UNDIFFERENTIATED	
Massive and well jointed outcrop intruded by many dykes	p€g	Gneissic granite, granite (may include quartzite ridges)		
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- Railway line
- Telephone line
- Fence
- State boundary
- Mine
- Homestead
- Yard
- Windpump
- Airport or Airfield, Landing ground
- Bore
- Tank
- Well
- Spring
- WH Waterhole
- Dam
- E Earth tank or dam
- Photo-centre points
- Photo-centre points - adjoining sheet
- NB51 Specimen locality

Replace sample prefix N.B by prefix 65-66-00 to conform to B.M.R. Data Retrieval System.

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Detail adjusted to photoscale compilation prepared by the Division of National Mapping, Department of National Development.
Aerial photography by Royal Australian Air Force, complete vertical coverage at 1:46,500 scale.
Transverse Mercator Projection.

SCALE 1:250,000

5 0 5 10 15 Miles

5 0 5 10 15 20 25 Kilometres

INDEX TO ADJOINING SHEETS

MT THEO	MT PEAKE	BARROW CREEK
MT DOREEN	NAPPERBY	ALCOOTA
MT LIEBIG	HERMANNS-BURG	ALICE SPRINGS

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F53/A9/1